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ECOSYSTEM SERVICES OF FRESHWATER ECOSYSTEMS

« ECOFRESH »

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ECOSYSTEM SERVICES OF FRESHWATER ECOSYSTEMS "ECOFRESH"

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SUMMARY

A. ECOFRESH: SCIENTIFIC AND POLICY CONTEXT

Integrating economic and ecological sciences into operational decision support systems is a key step for global conservation and sustainability. The perspective of ecosystem services (ES) - the services humans derive from nature - is a way to achieve this. Couching ES research within economic theory allows us to move to a more structured engagement between biophysical science, social science research and policy.

Over the past decade ES research has become an important area of investigation. The number of papers addressing ecosystems services is rising exponentially, reaching a total of more than 500 by 2010. While on the international and European level many ecosystem service initiatives have started, at the national and regional scale only few attempts to evaluate ES had been conducted at the start of the ECOFRESH project in 2010. Pilot research in Flanders however indicated that a very significant reduction in delivery of ES by the freshwater parts of the Scheldt estuary and Nete catchment had occurred, leading to major problems such as flooding, erosion, reduced fisheries etc. Similar problems are likely to prevail in most freshwater systems in Belgium. A detailed study of the services and their value provided by these systems is an urgent scientific and policy challenge.

Application of the ES concept on the institutional level requires thorough insight into the natural processes and complex structures that support ecosystem service delivery. Policy makers however need transparent and user-friendly tools that allow rapid and periodic assessment of ES and their value, in order to incorporate them into their planning policies.

B. ECOFRESH REALIZATIONS

The ECOFRESH project provides an integrated methodology which can contribute to scientific-based ecosystem service assessment in Belgium as part of an overall policy of sustainable development, focusing on freshwater ecosystems.

Two case studies were selected for thorough analysis and methodology development, comprising a river system (Grote Nete) and a stagnant water system (pond complex Midden-Limburg). The case study areas cover several different types of freshwater ecosystems, and are representative for a wide variety of freshwater ES.

ECOFRESH has three key realizations:

1) ECOFRESH provided insight into the processes and structures that support ecosystem service delivery

Based on an extensive literature survey, conceptual models were constructed which summarize the nature and relative strength of the important mechanisms that generate or affect ecosystem service delivery. Relationships between structures, functions and ES were identified. The biophysical characteristics responsible for potential ecosystem service delivery were determined and linked to land use and/or biotic factors defining the actual level of service delivery. Maps of ES in terms of potential ecosystem service delivery (supporting system & biophysical conditions) and actual delivery were created.

2) ECOFRESH quantified the value of several freshwater ES

In order to plan and manage ES, instant insight in the impact of environmental variables and/or management options on the delivery of multiple services is needed. However, existing numerical models cannot be extrapolated to describe all services in detail and in an integrative manner. Bayesian belief networks, based on the developed conceptual models, allow to describe in a (semi) quantitative way possible changes in service delivery and their socio-economic consequences. Quantitative data available on the freshwater ecosystem processes and services was included in these models, while missing links, data gaps and uncertainties were captured. Economic value was calculated for several services using the best available valuation techniques. Moreover, a stated preference valuation study was carried out for the amenity value of ponds to further fine-tune valuation functions using a distance decay function for willingness-to-pay. Integrative Bayesian belief networks have proven important tools in exploring opportunities, constraints and strategies to develop and optimize ES.

3) ECOFRESH explored social and policy processes behind the management of freshwater ecosystems

To determine whether and how the concept of ES can contribute to integrated water management, discourses of present policies for management of freshwater ecosystems and their associated services were analyzed. Literature, policy documents, and interviews with stakeholders were used. The analysis identified opportunities as well as constraints of ES as a concept to contribute to integrated water management. Recommendations for possible instruments (or adaptions to instruments) were formulated to operationalize ES in integrated water management.

C. CONCLUSIONS AND POLICY RECOMMENDATIONS

In highly fragmentized areas with agricultural and urban pressures, like Belgium, there is a strong need to understand the value of ES delivered by different types of freshwater ecosystems. Human influences increase the ecosystems' complexity and the need for tools that allow a better understanding of the functioning of the ecosystem and the delivery of ES. The primary aim of ecosystem valuation is to be able to make better (more efficient or more cost-effective) decisions regarding the sustainable use and management of ES (More-Jones et al. 2010). **The ECOFRESH project contributed to a policy-relevant strategy for ES in Belgium as part of the overall policy of sustainable development, focusing on freshwater ecosystems**. ECOFRESH is one of the first attempts in Belgium to evaluate ES in monetary and other terms. The results focus on the importance and the functioning of ES in river systems and stagnant water systems in Belgium, and constitute the first steps towards an integrated evaluation of ES. ECOFRESH delineated the opportunities as well as the support available for integration of the ecosystem service concept on the institutional level.

Determination of the ecological status of investigated ecosystems and integrative modeling of multiple ES is essential in identifying the driving factors that define the associated levels of service provision. For decision-makers, these driving factors have to serve as a guideline for selecting the key ecosystem properties that need to be monitored together with a set of efficient measures for ecosystem management.

For economic as well as non-economic ecosystem service valuation, integrative models provide insight in trade-offs or synergies between services and the related benefits for society. This makes them indispensable tools for conducting cost-efficiency analyses of restoration or conservation investments and for facilitating decision-support towards rational and knowledge-based policy on natural resource use. ECOFRESH clearly illustrates the importance of knowledge on functional trade-offs when comparing different management options, and to clearly map the beneficiaries of certain management scenarios.

The development of Bayesian belief networks for two case studies demonstrated that **Bayesian belief networks allow to capture this complexity in the production chain of ES while remaining highly flexible tools which combine several multi-disciplinary data sources and data types**. Their ability to work under data scarce conditions make Bayesian networks particularly suitable for the typically innovative ecosystem service research. The models can be applied to create management scenarios which optimize service delivery or to evaluate effects of environmental stressors or management decisions on service production. Additional assets of Bayesian networks are their transparent structure and their capacity to incorporate various expert and stakeholder opinions, which make them useful tools in discussion-support and decision-making.

The case-studies show that **an ES framework can support both practical conservation and economic development**.

Whereas “win–win” projects that achieve both conservation and economic gains are a commendable goal, they are not easy to attain. The model types developed in ECOFRESH allow policy makers to assess the combined effects of different management scenarios and strategies on several ecological, social and economic benefits. It also allows determination of the major ecosystem service trade-offs that arise from management choices, and the impact on magnitude and composition of service bundles provided by freshwater ecosystems.

The developed Bayesian models are **pilots which should be further fine-tuned to operate on the institutional level**. Main recommendations for model improvement are upscaling of the models to larger temporal and spatial scales and extensive model validation. **Upscaling** of the model output has to be conducted with care. Simple inferences to predict ecosystem service delivery and service values over different spatial and temporal scales cannot easily be made as ES are not provided linearly and many systems/functions show thresholds, tipping points and limiting functions. Moreover, many services are delivered by a complex set of interacting processes, and cannot be measured directly. **Validation** by measurement of single proxies will therefore reveal discrepancies but these do not indicate whether the model or the proxy is ‘right’. As actual or potential service provision levels are often hard or impossible to measure, directly and high-quality empirical data for model validation is scarce. It is therefore recommended to apply alternative uncertainty analyses such as stakeholder based validation, sensitivity analysis or comparison with historic data. Both the pond and the river model are applicable on **other ponds and river catchments**, provided adjustments of the variables according to local conditions and desired scenarios.

The valuation part of the project demonstrated that **by estimating the value of ES we are able to assess economic trade-offs**. This information can be used to highlight the importance of ES and to make more cost-effective decisions regarding the effective use and management of ES. The distance decay analysis shows that the population over which individual willingness-to-pay values can be aggregated to calculate the total willingness-to-pay for policy scenarios will not always be equal to an administrative unit. **Distance decay estimates are dependent on the physical context including the availability of substitutes**. Further research will implement the cross-effects of substitutes on the value people attach to river improvements as the alternatives in this study were limited to two rivers. It is also important to note that **simple inferences to predict ES delivery and ES values over different spatial**

and temporal scales cannot easily be made as ES are not always provided linearly and many systems/functions are non-linear, show thresholds or limiting functions.

The results of the social assessment of the ecosystem service concept suggest that **an ecosystem service approach will strengthen integrated water management in several respects.**

First, there is **the organizational potential**. The integrated water management approach applies an ecosystem vision to river basins as integral units, whereas an ES approach provides the linkage of ecosystems with ecosystem service providers and beneficiaries. By departing from the idea of services, common ground can be sought on a wide range of issues and on the approach that will be taken to achieve the objectives of integrated water management. Coordination and synchronization of actions by different partners are important aspects here.

Second, **ES is a concept with strong communicative potential**. It is currently used as a ‘common language’, and seen by many to be a move away from traditional sectoral thinking. A focus on communicating the benefits of ecosystem conservation or restoration projects – in particular, the added value through win-win situations - may bring these projects under greater attention, and eventually lessen the extent to which they are viewed as negative.

Third, it is recognized that **ES have potential to be operationalized into policy and practice solutions**. Today, the idea of blue-green services is already translated into certain agro-environmental measures. **However, in relation to water systems only few management agreements are available**, although, a larger number of ES could be addressed in existing water management plans.

1. INTRODUCTION TO ECOFRESH

1.1 WHAT ARE ECOSYSTEM SERVICES?

The water system provides direct or indirectly numerous goods and services, known as ecosystem services (ES). Since long time these goods and services are used to support our society in various ways. We can distinguish visible and fast renewable resources as fish, crops, timber and drinking water that distinctively can be linked to the water system. A combination of growing needs and a technological ability has resulted in an increased control and manipulation of the water system. These developments have finally led to a serious degeneration of the system's carrying capacity. The past and present large scale exploitation of marketable ES (infrastructure, agriculture, forestry) has led to such a degenerated environmental quality that there is a severe impact on society (flooding, water shortage, desiccation, pollution, land-erosion, pests…and biodiversity losses). These problems are usually solved by technical solutions such as water retention basins, sewage infrastructure, treatment plants, canalization and normalization, dredging, dams, pumping, drainage, irrigation wells, embankments, etc.…The implementation often brings about secondary effects (further disturbance of hydrological cycle and nutrient cycles leads to further loss of ecosystem functioning). This pathology of command and control is still relevant today and there is a profound pressure on policy makers to solve environmental problems by quick and visible solutions.

Belgium is a typical example of a region facing ecosystem degradation, loss of ES and replacement of these services by costly technical measures and infrastructure. Belgium, and especially the Flemish region, faces enormous challenges to improve the environmental quality in order to comply with EU environmental standards and conserve the natural capital to guarantee health and quality of life of its inhabitants.

Integrating economic and ecological sciences into an operational decision support system is a key step for global ecosystem conservation and sustainability (Millennium Ecosystem Assessment 2005). The concept of ES is key to achieve this. The ES approach has a huge potential to effectuate a sustainable management of landscapes, based on rational criteria of cost-effectiveness. Couching ES research within economic theory allows us to move to a more structured engagement between biophysical science, social science research, and policy (Fischer et al. 2008). Since the publication of the Millennium Ecosystem Assessment (2005), many initiatives were taken, both at international and national level, to further develop these concepts and make them operational. Europe's contribution to the first MEA was very limited. For the second, more comprehensive "Millennium Ecosystem Assessment" which is expected for 2015, Europe wants to become a major contributor on both assessment and methodological issues. The EU is heavily involved in several major initiatives, among others: EURECA (EURopean ECosystem Assessment), TEEB (The Economics of Ecosystems & Biodiversity), IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services) and finances several research projects such as RUBICODE (Rationalising Biodiversity Conservation in Dynamic Ecosystems). Also several national initiatives were taken. In the UK, a national ecosystem assessment was carried out (2011), and many studies on the economic valuation of ES initiated. In Belgium, however, very few attempts to evaluate ES had been conducted at the start of the project in 2010. Considering the importance of ES to the Belgian economy and to human well-being, it is logical to introduce these services in economic, social and political considerations (Staes et al. 2010).

1.2 SCIENTIFIC CONTEXT OF THE PROJECT

Although it is widely accepted that wetlands and water bodies have a strong influence on the hydrological cycle (Bullock and Arceman 2003) and it is proven that they are important for the delivery of several ES (Russi et al. 2012; Maltby 2009; Fisher and Acreman 2004), their precise functional role and the extent to which they deliver ES is very variable and can even be adverse (Bullock and Acreman 2003). Peatlands, for example, act as important carbon storage areas (Russi et al. 2012) but the emission of greenhouse gasses may potentially offset the overall sum of the benefits they deliver (Blackwell and Pilgrim 2011). Rouquette et al. (2011) show that wetlands can reduce floods but that their flood mitigation potential depends on hydrological conditions, and that they can increase flood peaks under certain circumstances. While Bullock and Acreman (2003) demonstrate that especially headwater wetlands can increase peak flows, Staes et al. (2009) prove the contrary. Verhoeven et al. (2006) concluded that freshwater ecosystems are capable of improving water quality by removing excessive nutrients from through-flowing water but that the denitrification process responsible for N-removal can become a source of the greenhouse gas N_2O under certain conditions. Given the variability and uncertainty on the functioning of several of the regulating services, it can be stated that a better understanding of how hydrological changes increase the vulnerability of freshwater ecosystems and ES (Arthington et al. 2010) and how biodiversity affects ES delivery (Bastian 2013) is needed.

While many research efforts have been done to better understand the functional role of freshwater ecosystems, much of it focused on large-scale wetlands and small wetlands have frequently been overlooked (Merot et al. 2006). However, small-scale freshwater ecosystems often provide relatively more ES than larger systems

(Blackwell and Pilgrim 2011). Especially in highly fragmentized areas with strong competition for space, such as Belgium, there is a strong need to understand the value of ES delivered by different types of freshwater ecosystems.

Many studies attempt to find standardized values of ES delivery for certain ecosystems. Often, these are based on land use and landscape characteristics or other proxies (e.g. Maes et al. 2011; Burkhard et al. 2009; Kienast et al. 2009; Naidoo et al. 2008), disregarding the functional assessment of that ecosystem. For some ES there is a quite clear correlation between land use and service delivery, this may especially be the case for provisioning services. For regulating services – services that are generally of high importance in wetlands – however, this is much more difficult as their functioning depends on several other factors such as their location in the landscape and interaction with the hydrological cycle (Blackwell and Pilgrim 2011). Understanding and quantifying the local hydro-topological placement and the site-specific biophysical characteristics of freshwater ecosystems, as well as their socio-economic value, is of great importance for successful implementation of an ES approach (Brauman et al. 2007). One of the aims of the ECOFRESH project is to increase our knowledge of ES delivered by freshwater ecosystems in Belgium. Because the role of freshwater ecosystems is site and context specific and cannot be defined by general statements based on literature review, the ECOFRESH research was carried out in a selection of case studies for which the functioning of the ecosystem and the delivery of ES was studied in detail.

In recent years, much effort was done to quantify ES but many studies focus on one or a few services e. g. pollination (Klein et al. 2007; Kremen, 2007), carbon storage (Balvanera et al., 2005) and specific hydrological services (Brauman et al., 2007). Other studies then focus only on individual and specific sites (Meire 2007). Methodologies for the valuation of ES have been developed by, among others, Pearce and Turner (1990), Freeman (1993), and Hensher (2007), whereas the value of the services of a particular ecosystem has been assessed by a large number of studies. Most of these studies however value a single ES or a single habitat. Aggregation of the different ES without double-counting (MEA, 2005) and upscaling them to a larger region (benefit transfer) remain important challenges (Bateman et al. 2006; Brouwer et al. 2009).

A key challenge lies in understanding interactions amongst ES and managing ecosystems for multiple purposes (Arthington et al. 2010; Bennett et al. 2009; Raudsepp-Hearne et al. 2009). As explained in 1.4, wetlands are known to be at the “nexus” between water and food provision (Russi et al. 2012; Power 2010; Posthumus et al. 2010). To be able to take into account all biophysical and socio-economic processes causing interactions between ES, integrated models are needed that describe how ES change under changing conditions (Haines-Young 2011; Brauman et al. 2007; Arthington et al. 2010). Detailed process-based models exist that allow to make accurate estimates of ES delivery under varying scenarios. These can be useful to calculate some ES such as water retention, floodings etc. but when moving to biogeochemical and ecological processes, the usefulness of numerical models quickly decreases, especially at small scales (Goethals et al. 2003). Their applicability in ES research becomes limited given the complexity of integrated models, high data requirements and limited decision support capacity. Recent introduction of Bayesian belief networks in ES modelling has led to an intermediate approach between detailed quantitative models and qualitative ES assessments (Landuyt et al., 2013; Haines-Young 2011). The development of such models however is still at an early stage (Haines-Young 2011). Within the ECOFRESH project the use of Bayesian belief networks to evaluate the effects of disturbances on the provision of multiple ES in a qualitative, quantitative and monetary way was explored.

1.3 ECOSYSTEM SERVICES OF FRESHWATER ECOSYSTEMS IN BELGIUM

ECOFRESH focused on freshwater ecosystems as they are one of the most threatened ecosystems in the world, despite their unique biodiversity and the important ES they deliver. Their importance for human survival and wellbeing is demonstrated by the services they deliver (Table I).

- Many wetlands occur within agricultural settings and thus deliver the ecosystem service of *agricultural production* (p. 42, 50). A distinction can be made according to man-made changes in hydrological conditions. Wetlands can be used for extensive grazing or hay production, leaving hydrological conditions virtually unspoiled. On the other hand, the high fertility of wetland soils has led to the conversion of large amounts of wetlands into intensive agricultural land by drainage, but at the cost of several regulating ES, such as carbon storage, nutrient retention, water retention, biodiversity, … With an estimated 65 % of wetland that has been drained for intensive agriculture (OECD 1996), it is considered the main cause of wetland loss and degradation in Europe.
- Another important provisioning service delivered by freshwater ecosystems is *fish production* (p. 24). On a Belgian level, this service is commercially delivered only by aquaculture in ponds and lakes, often located in ecologically vulnerable areas. A clear trade-off exists between fish production and biodiversity as ponds with commercial fish breeding are typically characterized by low species richness.
- Freshwater ecosystems also provide *potable water* through the processes of water retention (p. 32) and water purification by nutrient retention (p.23, 36)

and denitrification (p. 40), the latter being especially important in riparian zones and soils of small rivers and streams, shallow lakes and in wetlands. The Campine region in the north of Belgium, for example, is known as the 'water factory' of Flanders. Water infiltrating through the Campine plateau accumulates at the foot of the plateau in the valley of the Grote Nete, giving rise to groundwater dominated wetlands with particular ecosystems. Several companies depend on these wetlands for the extraction of potable water. Water extraction however can lead to changes in hydrological conditions, causing again costs in regulating ES such as nutrient retention and denitrification. Moreover, drinking water companies sometimes infiltrate water from nearby channels to make use of the natural filtrating capacity of wetlands. However, due to the different chemical composition of surface water and the presence of contaminants this leads to the degradation of specific ecosystems and related ES. In 1995, the European Environmental Agency estimated that around 25% of the wetlands in Europe were threatened by groundwater overexploitation (EC Environment DG, 2007).

- Wetlands also *deliver materials* such as reed, timber (p. 42) and other wood products such as willow branches, although on a Belgian level they are of limited or no commercial importance. All rivers and streams are potentially important for the delivery of hydro-power, either by the construction of a water mill like in historic times, a weir or a power dam. The creation of an artificial reservoir behind power dams, however, has a major impact on upstream ecosystems. Moreover, mills and weirs have ecological drawbacks such as impeding fish migration. However, most of the water mills in Belgium have become cultural relicts, increasing the amenity value of the landscape (p. 49). Estuaries and other tidal dominated rivers may be important for the delivery of tidal energy, although the production of electricity from tidal energy is still non-existent on the Belgian level.
- All types of freshwater ecosystems contribute to *air quality regulation* by sequestration of nutrients from atmospheric deposition in organic sediments. In particular vegetated wetlands can play a role in air quality regulation by adsorption of particulates and aerosols onto their leaves, stems and branches, absorption of gasses through stomata and/or burial in the waterlogged soil (p. 41, 49). Their layered structure (canopy, shrub, herb, grass, water) makes vegetated wetlands particularly suitable for air quality regulation. Especially freshwater ecosystems close to urban and industrial environments or main roads play a substantial role in air quality regulation.
- Freshwater ecosystems are generally part of a larger hydrological system and thus have an influence on the water cycle in many different ways. Although the role of wetlands in the hydrological cycle varies strongly, it is generally accepted that lakes and wetlands help *protect adjacent and downstream areas against flooding* by temporarily acting as upstream water reservoirs during periods of intense rainfall (p. 26, 31, 50, 53). In former times, many of the wetlands in the upstream part of catchments were converted into agricultural

land by drainage. This has led to accelerated discharge rates and increased flooding risks downstream. Wetlands and lakes upstream of urban areas are particularly valuable for flood protection. Within a dense built-up region such as the northern part of Belgium, this service is of very high importance.

- During long periods of drought, lakes and wetlands act as sponges that slowly release their water and so *maintain a certain base flow* (p. 32). Several natural methods exist to increase water retention capacity upstream, such as meandering, reducing the depth of the stream bed, macrophyte growth, …. Ponds and wetlands are well known for their ability to trap sediments, nutrients and other contaminants from runoff and surface water, functions that have led to the widespread application of ponds and wetlands for *wastewater treatment*. Inundations of sufficient duration allow biochemical processes to remove nutrients from water and soils, either by burial during sedimentation (p. 23, 36, 49, 53), by plant uptake or by transformation processes such as denitrification (p. 23, 40). Especially systems with abundant vegetation like wetlands, riparian zones, macrophyte patches in streams, act as real water filters. This is related to the ability of plants to slow down stream velocity, enhance sedimentation and increase residence time of the water, but also to oxygenate the upper water layers and sediments, a key component of biochemical transformation processes. The removal of nutrients and sediments from ground- and surface waters has multiple essential benefits: provision of clean water to support life, provision of potable water but also navigability (sedimentation). The ecosystem services *sedimentation and nutrient removal* are especially important close to agricultural land, because of high erosion rates on agricultural fields and because of increased N and P input from manure practices.
- Freshwater ecosystems play an essential role in *global climate regulation* by storing carbon in vegetation and anaerobic soils and thus reducing the amount of greenhouse gasses in the atmosphere. The ES carbon storage (p. 24, 33, 49, 53) refers to the maintenance of the existing stocks and prevention of carbon emissions, as well as the additional accumulation of carbon. The accumulation of organic material and nutrients in wetland soils also enhances soil fertility and soil structure. This reveals the earlier mentioned trade-off between agriculture and C sequestration: the fertile wetland soils are very suitable for agriculture provided that they are drained, but drainage causes loss of accumulated carbon stocks and hence greenhouse gas emission. Nevertheless, a long term synergy could arise between the ecological succession of wetlands and agriculture. As wetlands build up organic material they eventually become elevated above the groundwater table and evolve into a terrestrial forest. These very fertile soils could temporarily be exploited for organic crop production (no manure), until mineralization of the stored organic material leads to soil subsidence and the area is "given back" to the river.
- Estuaries and large rivers and lakes act as *regulators of the local climate* by controlling air temperature and humidity through evaporation and convection.

Extended pond complexes such as De Wijers clearly impact the local climate. Benefits include increase of habitat diversity and increase of agricultural production by mitigation of extreme temperatures. Large rivers, like the Scheldt, provide a source of cooling water for industrial purposes.

- Freshwater ecosystems incorporate *a very high diversity of habitats and species* among which several are endangered on the European level (p. 25, 36). Water pollution, nutrient loading, changing hydrological conditions, fish production, … are important stress factors causing large scale habitat loss and degradation. Many species rely on this diversity of habitats for different phases of their life cycle, from reproduction, nursery, juveniles to adults. Hence, species diversity of freshwater ecosystems is among the most threatened of all ecosystems and accordingly the ES derived from these systems are strongly reduced.
- Wetlands, river banks and shallow lakes provide *pollination and pest control* if they are located near agricultural areas. Typical freshwater plants attracting a lot of insects include Angelica, Valerian and Marsh woundwort. In the Wijers, a synergy between biological pest control and fish farming occurs: fish can be used as a management technique to improve water quality by suppressing excessive vegetation or controlling algal blooms.
- Habitat and species diversity is known to improve the *aesthetic quality* of the landscape and to attract recreants, tourists, schools, artists, researchers,…. (p. 49, 53). Unmanaged wetlands, rivers and lakes are symbols of wilderness and naturalness. Freshwater ecosystems are also home to several iconic and target species such as the beaver, otter and cormorant; or the burbot, brook lamprey, …. Wetlands, rivers and lakes also have important *historic values*. Historical water mills, weirs and sluices along rivers increase the heritage value of the landscape. At last, many *recreation* activities are bound to lakes and large rivers, amongst which wind surfing, sailing, , ….

Although no comprehensive work on the ES of freshwater ecosystems in Belgium exists, Meire et al. (2007) demonstrated a very significant reduction in the delivery of ES in the fresh water parts of the Scheldt estuary and the Nete catchment leading to major problems such as flooding, erosion, reduced fisheries etc. This is similar for most freshwater ecosystems in Belgium. A detailed study of the services provided by these systems, and their valuation has become an ever more urgent scientific and policy matter.

1.4 READERS GUIDE THROUGH THE ECOFRESH RESULTS

The pond complex De Wijers and the valley of the Grote Nete are the described case-studies. They represent a broad range of freshwater ecosystems in Belgium: stagnant waters, running waters and wetlands. For the pond case, focus is laid on the ponds in 'pond complex Midden-Limburg' situated in the larger eco-hydrological unit

De Wijers. For the river case, three study areas that cover the variety of ecosystems along a hydrological gradient of the catchment are studied in detail.

1. First, the most important ES are identified and **described** in terms of underlying attributes and processes (Ch. 2.1). Conceptual models are developed to help understand interactions between processes and amongst services. The extent to which the services are delivered is **quantified** for as much as possible services, based on available empirical data and model results.
2. Second, the ES for which quantitative data is available are expressed in monetary terms based on existing **valuation** methods (De Wijers, De Vennen and SIGMA; Ch. 2.2.2). For the entire pond complex Midden-Limburg and the entire Nete catchment a stated preference study is performed, measuring the willingness to pay of people for the creation of new nature (Ch. 2.2.3). The conceptual models and the quantitative data from the first task, together with the economic results are used to construct **Bayesian belief networks** that allow to study the impact of changes in environmental conditions on service delivery (Ch. 2.3).
3. Finally, for the pond complex Midden-Limburg, an analysis of the potential use of the ES concept on the **management** level is carried out (Ch. 2.4).

Results are presented per task and per case-study, each time describing methodology, results and discussion. This is followed by an overall conclusive section on the value of the results as policy support for sustainable development.

Table I – General overview of freshwater ecosystems (cfr. Water Framework Directive) and ecosystem services in Belgium

Theme	Service Class	Service Group	Nr.	Service Type°	Benefit°	Most important freshwater habitat	ECOFRESH case - description	ECOFRESH case - valuation
Provisioning	Nutrition	animal	1	Cropping	Food	All wetlands	river (SIGMA)	river (SIGMA)
			2	Animal production	Food	All wetlands	river (SIGMA)	river (SIGMA)
		Freshwater plant and animal	3	Aquaculture	Food	All lakes	pond (Wijers); river (Vennen)	pond (Wijers)
		Potable water	4	Water retention (spring, well, river, lake,...)	Potable water	All	river (Vennen)	
			5	Water purification	Potable water	Rk, Bg, BgK, Bk, BkK, Pz, Pb, Mlz, Ad, Ai, Ami-om, Ami-e, All transition waters, Czb, Cb, CFe, Zs, Zm, Bzl, All wetlands	pond (Wijers); river (Vennen, Malesbroek)	
	Materials	Biotic materials	6	Non-food plant fibres (reed, timber)	Building material	All wetlands	river (SIGMA)	
	Energy	Renewable abiotic energy	7	Hydro	Energy	All rivers		
			8	Tidal	Energy	All transition waters, Mlz		
Regulation and Maintenance	Regulation of wastes	Dilution and sequestration	9	Filtration of particulates and aerosols	Clean air	All wetlands	river (Malesbroek)	river (Vennen, SIGMA)
			10	Sequestration of nutrients in organic sediments	Clean air	All		
	Flow regulation	Water flow regulation	11	Attenuation of runoff and discharge rates (water storage)	Flood prevention	All lakes, all wetlands	pond (Wijers); river (Vennen)	pond (Wijers); river (SIGMA)
			12	Water retention	Drought prevention	All lakes, all wetlands	river (Vennen)	
			13	Sedimentation	Navigability + clean water	All lakes, all wetlands		
			14	Attenuation of wave energy	Flood prevention	All transition waters		
	Regulation of physical environment	Atmospheric regulation	15	Global cimate regulation (C-sequestration)	Climate change mitigation	Ad, Ai, Ami-om, Ami-e, Czb, Cb, CFe, Zs, Zm, Bzl, All wetlands	pond (Wijers); river (Vennen)	pond (Wijers); river (Vennen, SIGMA)
			16	Local climate regulation (temp, humidity, ...)	Local climate maintenance	Rzg, Rg, All transition waters, All lakes		
		Water quality regulation	17	Water purification (nutrient retention + denitrification)	Clean water	Rk, Bg, BgK,Bk, BkK, Pz, Pb, Ad, Ai,Ami-om, Ami-e, Czb, Cb, CFe, Zs, Zm, Bzl, All transition waters, All wetlands	pond (Wijers); river (Vennen, Malesbroek)	pond (Wijers); river (Vennen, SIGMA)
			18	Cooling water	Industrial products	Rzg, Rg, All transition waters		
		Pedogenesis and soil quality regulation	19	Maintenance of soil fertility	Agricultural productivity	All wetlands		
			20	Maintenance of soil structure	Agricultural productivity	All wetlands		
	Regulation of biotic environment	Lifecycle maintenance and habitat protection	21	Pollination	Agricultural productivity	Rk, Bg, BgK, Bk, BkK, Pz, Pb, Mlz, Ad, Ai, Ami-om, Ami-e, Czb, Cb, CFe, Zs, Zm, Bzl, All wetlands		
			22	Habitat and biodiversity support	Support of other services	All	pond (Wijers); river (Vennen)	
		Pest and disease control	23	Biological control mechanisms	Agricultural and fish productivity	All		
		Gene pool protection	24	Maintaining nursery populations	Biodiversity support	All		
Cultural	Symbolic	Aesthetic, Heritage	25	Landscape character	Wellbeing	All	river (Malesbroek)	pond (Wijers); river (Vennen, SIGMA)
		Spiritual	26	Wilderness, naturalness	Wellbeing	All		
	Intellectual and Experiential	Recreation and community activities	27	Charismatic or iconic wildlife or habitats	Wellbeing	All		
			28	Prey for hunting or collecting (angling)	Wellbeing	All rivers, Ai, Ami-om, Ami-e, Aw-om, Aw-e, Czb, Cb, Cfe, All transition waters	pond	pond (Wijers)
		Information and knowledge	29	Scientific	Wellbeing	All		
			30	Educational	Wellbeing	All		

2. METHODOLOGY AND RESULTS

2.1 ECOSYSTEM ATTRIBUTES, PROCESSES AND SERVICES

2.1.1 Methodology

Based on own data and literature review, the most relevant services were selected for each of the case studies and classified according to the Common International Classification of Ecosystem Services, CICES, 2011 update (EEA 2011), Table I. This classification system is currently being reviewed conceptually and tested empirically in order to make it a standardized which can be used in different applications and which will be included in several projects on the national level (e.g. BEES). For each ES, underlying attributes and processes that drive service delivery were described. Conceptual models were used to help understand interactions between processes and amongst services. These models also served as a basis for the creation of service maps, for scenario analysis and for the construction of the Bayesian models in Chapter 2.3.

2.1.1.1 Conceptual models

An extensive literature review provided insight in the potential relationships and feedback mechanisms between freshwater ecosystem attributes, ecosystem processes and ES. In this first chapter, the different services are described in terms of their supporting systems defined by abiotic attributes (morphometrics, hydrodynamics, hydrological and physical characteristics), and biotic elements (population size and traits of keystone populations, community composition, biodiversity, land use) that can be expected to play an important role in the support, regulation or generation of ES (Luck et al. 2003; Kremen 2005; Luck et al. 2009). Based on this review, conceptual models were constructed that schematically summarize the nature and relative strength of the important mechanisms that generate or affect ES. These qualitative models are not only essential in the process of obtaining a more detailed and integrated insight into the processes that generate ES (Prato 2008), but they also constitute a guideline for ES mapping and they form the basis for the development of predictive Bayesian models.

2.1.1.2 Mapping service delivery

Recent advances in ES modeling focus on linking ES provision, their associated values and trade-offs across services. Common examples are InVEST (Tallis and Polasky 2009) and ARIES (Villa et al. 2009). However, none of these models map ES in terms of their supporting systems and the physical preconditions for the delivery of services. Mapping ES in terms of their supporting systems allows to identify locations that are most suitable for the optimization of individual ES, and to identify areas that

can provide multiple services (so called ‘hotspots’). The concept of hydrogeomorphological units (HGMU’s, Maltby 2009) characterizes the landscape by its function based on abiotic attributes (morphometrics, hydrodynamics, hydrological, physical and chemical characteristics). The assumption of hydrogeomorphology as a fixed condition is yet problematic for application on long-term landscape-scale planning for ES. Throughout the historical European rural landscape, man has changed and adapted hydrology and morphology to enhance ES delivery. This questions the hydrogeomorphology as only boundary condition for landscape functioning. We take the concept of HGMU’s a step further by using hydrogeomorphic characteristics for every pixel (5x5m) to describe *potential* landscape functioning. The actual function of the landscape depends on land use choices, vegetation or functional groups of species. The combined information of the supporting system and the service providing land use type allows to make maps where which ES is actually delivered. Comparison with the maps of potential delivery gives an idea of how well land use is fitted to the physical system. Maps of potential service delivery can be used as a guidance for decision makers to identify the most appropriate use(s) for an area, or the most suitable area for a specific land use demand (Bastian et al. 2011), thus optimizing land use scenarios. The potential approach is of advantage as an intermediate step in decision making (Bastian et al. 2011).
Mapping of ES was only carried out for the freshwater habitats in the Grote Nete catchment as geographic input data for the stagnant waters of the pond complex Midden-Limburg is unavailable.

2.1.2 Results – Pond complex Midden-Limburg

Description of the study area

For the case study of the “stagnant water systems”, we selected the ponds in ‘Vijvergebied Midden-Limburg’ (Hasselt; Figure 1). This pond complex contains more than 200 shallow lakes and ponds, which are directly or indirectly connected with a stream (Roosterbeek), and it is situated in the larger eco-hydrological unit ‘De Wijers’ (ca 25000 ha and 1175 ponds). Given its significance for wildlife conservation, the area is protected through both national and international legislation. The area is also important for its commercial fisheries (e.g. ornamental, consumption and sports fisheries), passive recreation and the maintenance of water quality. Although it is one of the largest of its kind in Belgium, the area can be considered as highly representative for many similar ponds and shallow lake systems in the country. The site was created by the exploitation of moorlands for fish breeding and the extraction of peat and iron ore. Once these exploitation activities ended, the ponds were abandoned. From 1865, fish breeding became a professional activity. Subsequently, new pools were created by digging up grassland areas. The substantial surface area of the pond complex, as well as the diversity of the associated biotopes, has contributed to the site’s outstanding biological value. Since 1970, this value has been threatened by deteriorating ecological conditions (low water quality, intensive use of pesticides) and the modernization of fish farming practices. Currently, most ponds in the central part of the pond complex are protected and under control of ANB (Agentschap voor Natuur & Bos), but restricted fish farming practices on a number of fish ponds is still allowed.

Figure 1 – Aerial picture of the fish pond complex Midden-Limburg

Future scenarios

Many pond complexes in Europe are strongly deteriorated and a sustainable and efficient management is essential to conserve their key functions and ecological value (Zedler and Kercher, 2005). Nature conservation organizations, however, are often not able to maintain large number of ponds due to economic or logistic reasons. On the other hand, a policy of ‘doing nothing’ with systems that are prone to eutrophication will not deliver the desired nature value and may impede a number of ES in the long term. This is mainly due to the accumulation of nutrients in the mud layer and to internal nutrient loading (Søndergaard et al., 2003). The accumulation of an anoxic mud layer in productive ponds will also negatively affect the development of water plants (Jeppesen et al., 1998). Such ponds are often characterized by a decline in the piscivorous fish stock, an increase of bethivorous and planktivorous fish populations and an extensive proliferation of exotic species (Declerck et al., 2002). Moreover, a policy of ‘doing nothing’ will, on the long term, lead to silting up of the pond and consequently disappearance of the freshwater ecosystem. As in many European pond complexes, also in the pond complex Midden-Limburg there is a conflict of interests between the sector of nature conservation and those of commercial fish-breeding. Nevertheless, there are a number of positive aspects which could be linked to the management of commercial fish ponds. Commercial fish ponds are, for example, regularly drained in order to harvest fish. This may enhance water quality through increased sedimentation, sediment compaction, decomposition of organic material and enhanced macrophyte development (Woltemade, 1997).

A multi pond system like the pond complex Midden-Limburg (Zonhoven) can store a large amount of water. All ponds in the central part receive their water via a network of ditches from the stream Roosterbeek. Ponds which are located at the beginning of a chain can act as buffer and reduce the discharge of nutrients and pollution to downstream lakes and ponds (Yin et al., 1993; Shan et al., 2002). Some ponds in the complex are continuously in contact with the stream and these are often used for fish culturing. Other ponds are emptied and re-filled on a regularly (yearly) basis and the inflow is completely closed after refilling. These management strategies (draining or not) can have serious implications for biodiversity of many organism groups (e.g. Van de Meutter et al., 2006) but also for the nutrient dynamics and the release of CO_2 and CH_4 from the soil. The ponds in the pond complex have an average surface area and depth of respectively 2 ha and 1 m. In those shallow and small systems, fish can play a key role in determining the trophic dynamics and biodiversity. A large scale survey of the ponds was done to assess the effect of different fish management strategies on the biodiversity of different components in the ponds (phytoplankton, zooplankton, macroinvertebrates and macrophytes) (TWOL study Lemmens et al., 2012). In this study five categories of fish management types were *a priori* distinguished: 1) commercial fish ponds with mainly high carp densities, 2) commercial fish ponds for breeding juvenile fish, 3) non-managed fish communities, 4) ponds that are stocked with planktivorous fish and 5) ponds that are actively kept fishless. With exception of phytoplankton, highest species richness was found in the fishless ponds type and lowest in the ponds used for commercial carp breeding. The other management types had intermediate and comparable levels of species richness. The water of the commercial carp ponds was also more turbid and contained higher concentrations of nutrients than the other pond types. Fishless ponds had highest levels of vegetation cover. Commercial ponds that were used to breed juvenile fish had relatively high diversity and this may create a possibility to reconcile/combine fish farming practices and nature conservation goals. The TWOL-study focused mainly on the link between biodiversity support and fish production. In the current study we want to obtain more insight via a detailed model into the processes that do not only support biodiversity, but generate a broad spectrum of ES. Five relevant management scenarios were considered in the scenario analysis: intensive breeding (with additional feeding), extensive breeding (without additional feeding) and 3 variants of nature-oriented management (ranging from low to no initial fish stocking).

Ecosystem services

Based on an extensive literature survey we listed a number of key ES of stagnant water bodies. These were used as input for the construction of a conceptual model.

1. Water quality improvement: denitrification and nutrient retention

Ponds & lakes are well known for their ability to remove sediments, nutrients, and other contaminants from water, functions that have led to the widespread application of ponds for wastewater treatment (Vymazal et al., 2006). Shallow ponds are effective in removing nitrates from through flowing water, because denitrification is a coupled process wherein nitrates (present in aerated water) are reduced by anaerobic bacteria (found in anoxic soil) to nitrogen gas. Phosphorus (P) tends to attach to soil particles, so the best strategy for removing phosphorus is to trap sediment-rich water and hold it long enough for soil particles to settle out. According to Hansson et al. (2005) and Verhoeven et al. (2006) a trade-off is expected between biodiversity support and nutrient removal. Shallow depth, large surface area and high shoreline complexity are likely to provide a high biodiversity of birds, benthic invertebrates and macrophytes and to have high nitrogen retention, whereas a small, deep lake is likely to be more efficient in phosphorus retention, but less valuable in terms of biodiversity. Verhoeven et al. (2006) also indicate that the combination of water quality improvement with wetland biodiversity requires loading rates below critical thresholds. However, in many agricultural catchments these limits have been surpassed and sometimes even beyond which the wetland ecosystem no longer performs its retention function properly but releases nutrients or emits the greenhouse gas N2O (Verhoeven et al. 2006). In such catchments, the only feasible measure is to decrease fertilizer levels.

Strongly linked with the aspect of nutrients is the problem of cyanobacterial blooms, mass developments of cyanobacteria floating at the surface of waterbodies, which have become a recurrent and increasingly important phenomenon in freshwaters worldwide over recent decades. The formation of such blooms in surface waters is closely linked to water eutrophication. These nuisance blooms represent major potential hazards to human and animal health, and interfere in various negative ways with the sustainable use of surface waters for e.g. drinking water treatment, recreation, irrigation and fisheries. Between 25 and 70% of the blooms are toxic. Many approaches have been used to mitigate the effects of eutrophication and cyanobacterial blooms in ponds and lakes. A substantial reduction of nutrient loading is recommended; particularly in cases when nutrients come from point sources. It might, however, not produce the desired effect in cases of accumulation of phosphorus in the sediment or diffuse external nutrient sources (Søndergaard et al., 2007). A substantial reduction in fish densities (biomanipulation) can shift ponds or lakes from phytoplankton to submerged vegetation dominance, thus improving the water quality and reducing the risk of cyanobacterial blooms.

2. Fish production

An important ES of ponds and lakes is the production of fish. At this moment, fish are generally valued for their qualities as goods, selected by human preferences, in the form of food protein, fishmeal, fish oil, game fish, and for aquaculture production. Apart from these, Holmlund & Hammer (1999) also list a number of other ES provided by fish itself, which are often undervalued (e.g. regulating nutrients and carbon fluxes, linkage within and between aquatic systems). Despite the abundance and variation of fish, most western fisheries focus on a few target species. Fish production is maximized by means of high initial stocking densities, using mixed fish cultures, providing supplementary food and keeping a maximum and fixed water level, often impeding high levels of biodiversity. On the other hand, fish can also be used as a management tool for improving the water quality in nutrient rich lakes (biomanipulation). This type of management is based on the idea of top-down food web control, by removing benthivorous and planktivorous fish and stocking piscivorous fish in order to suppress algal blooms (Benndorf et al., 1988; Kasprzak et al. 2007) or by stocking herbivorous fish, like grass carp, to suppress vegetation. In Flanders 31 companies are involved in fish trading. Only 14 of them actually culture fish themselves. Like in Midden-Limburg, many aquaculture companies have ponds located in ecologically vulnerable areas.

3. Carbon storage

Understanding the role of ponds and lakes as climate regulators is growing and their role in sequestering carbon (C) is becoming appreciated (Dean & Gorham, 1998). Carbon sequestration rates have been measured in various ecosystems, and lakes and ponds are known to store vast quantities of C, especially in their soils. Downing et al. (2008) even indicated that ponds and lakes may bury in total more carbon than the oceans, despite the fact that the total area of ponds and lakes only constitute 2% of the world ocean’s surface area. They also showed that small ponds had greater deposition and accumulation rates per unit area than larger ponds or lakes. Therefore, these small ponds can be very important carbon sinks, especially in agricultural areas where landscapes are disturbed and nutrients abundant. The estimated average annual carbon burial rate for aquaculture ponds, however, was lower than that of large, river impoundments and small, agriculturally-eutrophic impoundments, but higher than that of inland seas and natural lakes. This is because aquaculture pond management (cf. yearly draining) typically minimizes organic matter accumulation (Boyd et al., 2010). Although lakes and ponds store vast quantities of C in vegetation and especially in their anaerobic soils, under some conditions they can act as significant source of CO_2 (Cole et al., 1994) and contribute more than 10% of the annual global emissions of the greenhouse gas CH_4 (Mitra et al., 2005). Whether ponds function as net sink or source of greenhouse gases depend mainly on interactions involving physical conditions of the soil, microbial processes and vegetation characteristics. Even so, Mitra et al. (2005) claim that destroying pristine wetlands would cause more carbon emission than several thousand years of net greenhouse gas emissions of those wetlands. It is less clear, however, what role created or restored ponds and lakes will play in managing C. For example, Glatzel et al. (2004) found that the rate of C-sequestration can differ between natural and recently restored peatlands. The high decomposability of new peat in restored peatland resulted in very slow C sequestration and net emissions of both CO_2 and CH_4. In addition, the time span in which carbon sequestration is taking place can differ strongly among water body types. Organic matter in bogs, for instance, may remain undisturbed for many years, but C rich sediments of very shallow and vegetation poor floodplain ponds may be quickly removed by frequent flood flows.

4. Biodiversity support

In a comparative study, Williams et al. (2003) showed that ponds and lakes can contribute more to regional richness than other waterbody types, like rivers, streams and ditches, and harbor more uncommon or rare species. This is largely because of their high beta diversity (compositional dissimilarity among sites). Isolated ponds are physically heterogeneous habitats. These waterbodies often have small catchment areas (Davies et al., 2008) and can, as a result, have highly individual physico-chemical characteristics that vary considerably between ponds depending on local geology and land use (e.g. entirely wooded, heavily grazed, draining acid- or base-rich strata). Rivers and large streams, in contrast, usually have extensive catchments and this, combined with the homogenizing action of flowing water, will usually ensure that they are characterized by less variable physico-chemical conditions than small lentic waters. Environmental factors that are often correlated with species number and rarity in ponds are area, isolation, pH (and the related chemical measures alkalinity, calcium, conductivity), abundance of vegetation and phosphorus concentration (Biggs et al., 2005; Declerck et al., 2005). Important to note is that not all organism groups always respond similarly to the same environmental gradients or stressors (Declerck et al., 2005, but see Declerck et al., in prep.). A habitat rich in birds is thus not necessarily rich in zooplankton and vice-versa. This also means that certain conservation efforts, that are ideal for one organism group, are not always ideal for another organism group. Although ponds can be an important biodiversity resource, studies have also shown that ponds outside nature reserves are often significantly degraded. Lakes and ponds are threatened by a number of human activities, of which the most important include nutrient loading, contamination, altered water regimes, habitat loss (reduction of connectivity), exotic species, and acid rain (Brönmark and Hansson, 2002). Human activities have frequently switched pristine and clear shallow lakes into a turbid state lacking plants and with reduced diversity (Scheffer et al., 1993) and there has been considerable effort in Europe in recent decades to restore these systems (Jeppesen et al., 2005).

5. Peak flow attenuation through water storage

Economic costs associated with flood damage have risen considerable over the past 100 years, owing in large part to increased agricultural and urban expansion into floodplains. Within watersheds, ponds and lakes are becoming appreciated for their role in storing and slowing the flow of floodwaters. Mitsch and Gosselink (2000) pointed out that the location, the number and the size of ponds within the landscape can strongly determine its function and value to man. Ponds located near a river probably have a greater functional role in improving stream water quality and in mitigating downstream flooding than if they are isolated from a river. Also, ponds located near the upper part of a stream will have different functions from those located more downstream near the stream’s mouth. But it is still a point of discussion whether it is better to have several small wetlands in the upper reaches of a watershed in mitigating flood events or only a few large ones in the lower reaches (Mitsch & Gosselink, 2000). Apart from the spatial position, ponds can vary strongly in their hydrological connectivity: on the one end of the gradient, ponds are not connected in a temporary or permanent way to other water bodies and form isolated basins that are ground- or rainwater fed. As their role in mitigating floods is not always apparent, their value for this service is often not taken into account or neglected. On the other end of the gradient, ponds are part of a riparian system (e.g. flow-through systems) and continuously process large amounts of water. In this case, the water inflow approximately equals the outflow. In a more intermediate position, ponds are occasionally fed during flood events of a river and water is gradually released to the river after the flood passes.

6. Recreational value (angling/passive recreation)

During this century, sport fishing of wild and stocked game fishes in lakes and rivers has become a popular recreational activity internationally. In Flanders, however, the number of angling license holders has significantly decreased (almost halved) from 1980 until 2006. During the last years the popularity of angling is rising again (Natuurindicatoren, 2008). Intimate contact with nature while fishing is claimed to be one of the major incentives for sport fishing (Schramm and Mudrak, 1994). The increasing demand for game fish and suitable fishing- and swimming-areas, is often in conflict with the decreasing water quality owing to other human activities. But in some cases, also the increasing demand itself can cause a decrease in water quality and overall biodiversity due to overstocking with harmful fish species, like carp (*Cyprinus carpio*). In our region, fish ponds that are considered ideal for angling, support seldom high biodiversity. Passive recreation mainly depends on the size and/or number of the ponds and on its location in the landscape. A pond in an urban environment can have a much higher recreational value than one in a nature reserve.

Conceptual model

In this part we summarize the main mechanisms that generate or affect ES. We briefly describe the freshwater ecosystem attributes and ecosystem processes that are crucial for the functioning of the ecosystem and for the ES (Table II). As the conceptual model was used as a basis for the development of the Bayesian model we refer to Figure 11.

Table II – attributes and processes that drive ES delivery

Biological components	
Phytoplankton	*Are grazed on by zooplankton, decreases water transparency*
Cyanobacteria	*Are difficult to graze on by zooplankton, may produce toxins, can enhance nitrogen fixation*
Large zooplankton	*Can control phytoplankton*
Piscivorous fish	*Can control planktivorous fish and to a lesser extent bethivorous fish*
Planktivorous fish	*Can control large zooplankton biomass*
Benthivorous fish	*Strongly increase water turbulence*
Macrophytes (submerged)	*Is a crucial component of structural diversity in the water column, often associated with high levels of biodiversity of different groups of organisms. Often has a high aesthetic and recreational value. Fixate nutrients and abate eutrophication. Diminish the growth of phytoplankton. Decrease water turbulence and velocity and increases sedimentation rate.*
Piscivorous birds	*Especially cormorants decrease fish production*
Morphological and structural characteristics	
Depth	*Affects water retention, may also affect water turbulence*
Surface	*Affects water retention, small surfaces may impede fish production*
Sedimentation rate	*Affects carbon sequestration*
Water velocity	*Affects sedimentation rates*
Retention time	*Affects sedimentation rates, carbon sequestration and denitrification*
Drainage regime	*This is the number of times a pond is completely emptied in order to harvest fish. This strongly affects carbon sequestration.*
Shoreline complexity	*Affects biodiversity and recreational value. Is strongly affected by the way how ponds are managed.*
Physico-chemical characteristics	
Water turbulence	*Affects water transparency*
Water transparency	*Is crucial for macrophyte development*

Nutrient concentration	*Nitrogen (N) and especially phosphorus (P) determine the primary production. High nutrient supply may cause symptoms of eutrophication, like phytoplankton blooms, decreased water transparency and a decline in the macrophyte stand. These symptoms are more prominent if the fish stock is dominated by benthivorous fish.*
Management related components	
Additional feeding	*Increases fish production and the nutrient concentration in the water*
Purification	*Application of nutrient removal techniques*
Nets	*Diminish fish predation by cormorants*
Accessibility	*This influences the recreational value*

2.1.3 Results – Grote Nete

The Grote Nete catchment in the North of Belgium is a typical lowland landscape with little relief and numerous brooks and small rivers with low flow velocity. The soil type varies from sand with sandy loam and loamy sand in the floodplains to loamy and clayey soils in the southernmost part. Land use mainly consists of agriculture (22% pasture and 15% cropland), paved area (28%), forest (17%) and wetland (4%).

Almost the entire length of the valley of the Grote Nete till the city of Heist-op-den-Berg makes part of a Natura2000 Special Protection Zone. Freshwater habitat types occurring here include:

- Rbbsf: wetland forest with broad leaved willow
- 91E0: alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*
- Rbbsm: *Myrica* gale shrub
- Rbbhf: *Filipendula ulmaria* herb communities with grassland characteristics
- 6430: hydrophilous tall herb fringe communities
- Rbbhc: *Caltha palustris* dominated grassland
- 6510: lowland hay meadow
- Rbbmr: reedland and other *Phragmition* vegetations
- Rbbmc: *Magnocaricion* (grote zegge) communities
- Rbbms: *Parvocaricetea* communities (kleine zegge) not included in type 7140
- 7140: transition mires and quacking bogs

Further downstream (SIGMA study area), the Grote Nete becomes tidal influenced and the habitattype 1130 'estuary' occurs. The associated ES for each habitat type are listed in Table II.

Table III – Overview of ES in the different Natura2000 habitattypes occurring in the Grote Nete valley

Nr.	Service Type	Benefit	rbbsf/ 91E0	rbbsm	rbbhc/ rbbmc/ rbbms	rbbmr	6510	6430	7140/ 7210/ 7230	1130	3130/ 3140/ 3150/ 3160	WFD_ rivers
			forest	shrub	grassland	reed	meadow	herb	fen	estuary	pond	river
1	Crop	Food	✓	✓	✓	✓	✓					
2	Animal prod.	Food		✓	✓	✓	✓					
4	Water retention	Potable water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	Water purification	Potable water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	Non-food plant	Building material	✓	✓	✓	✓						
7	Hydro	Energy		✓	✓	✓				✓		✓
8	Tidal	Energy		✓	✓	✓				✓		
9	Air filtration	Clean air	✓	✓	✓	✓	✓	✓	✓			
10	Nutr. seq.	Clean air	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	Water storage	Flood prevention	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12	Water retention	Drought prevention	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13	Sedimentation	Navigability + clean water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
14	Attenuation of wave energy	Flood prevention		✓	✓	✓				✓		
15	C-sequestration	Climate change mitigation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	Water purification	Clean water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
19	Soil fertility	Agricultural productivity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20	Soil structure	Agricultural productivity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
21	Pollination	Agricultural productivity	✓	✓	✓		✓	✓	✓			
22	Hab. + biodiv. support	Support of other services	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
24	Nursery populations	Biodiversity support	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
25	Landscape character	Wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
26	Naturalness	Wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
27	Iconic wildlife	Wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
29	Scientific	Wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
30	Educational	Wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

A selection is made of three case studies based on representativeness for freshwater ecosystems along a hydrological gradient (Figure 2 left), availability of datasets and existing research results, as well as the presence of past or planned infrastructure changes which affect ES provision so as to allow for scenario analysis. For as much as possible ES, (potential) delivery was expressed in quantitative terms. These data were used as input for the economic valuation and summarized in Chapter 2.2.2. Due to size restrictions of the report and to avoid repetition, for each case-study only a showcase of the identification and quantification results is provided. Maps are available for the majority of the ES on the scale of the entire Grote Nete catchment.

2.1.3.1 Case De Vennen

<u>Description of the study area</u>

De Vennen is located in the upstream part of the Grote Nete, near the confluence of several lowland brooks and ditches. The area incorporates numerous typical seepage dominated valley bottom wetlands. The main stream running through the area, Grote Nete, originates on the Campine plateau (Figure 2 left) and has a naturally meandering course which is typical for lowland rivers in sandy soils. The other streams are artificial ditches from historic times which have been dug to drain the wetlands and make the area more suitable for agriculture. Some of these ditches are located lower in the landscape compared to the Grote Nete and drain the area more than the Grote Nete itself (Figure 2 right).

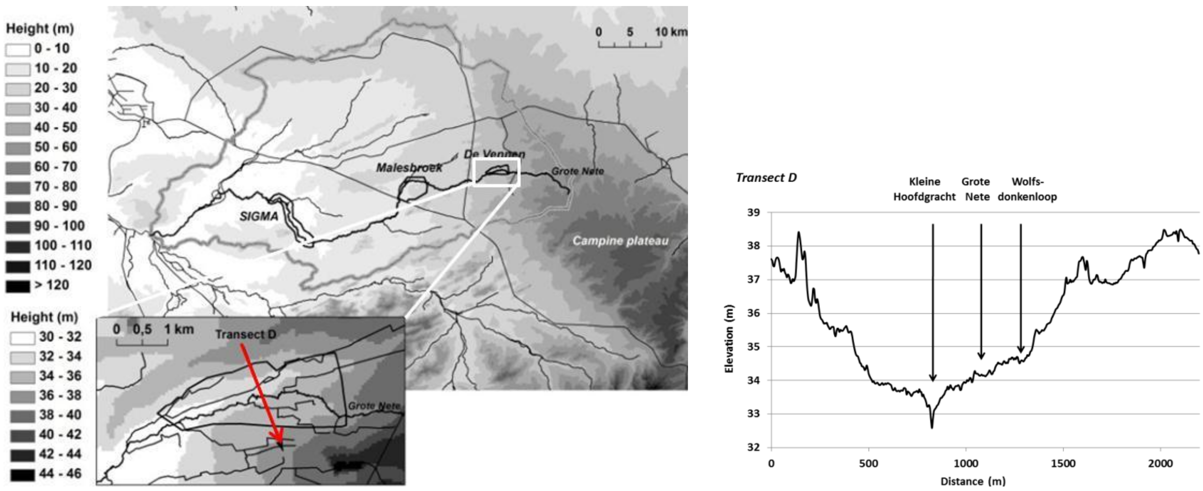


Figure 2 – location of the study areas within Grote Nete catchment (left); topographical location of the streams (right)

The area consists of light sandy loam to sandy soils and is bordered by a land dune parallel to the water courses in the north. Large parts of the area are permanently wet, especially near the confluence of streams. The area is located on the transition between the swampy soils along the Kleine Hoofdgracht and the Grote Hoofdgracht and the dry soils of the land dune in the north making it a very diverse landscape. The area consists of a patchwork of different landscape units hosting biologically valuable elements, amongst which willow shrub, alder brooks, humid *Calthion* grassland, *Filipendulion* bush etc. Protected European and regionally important habitattypes within De Vennen include: rbbsf, rbbhc, rbbmr, 6430, 91E0 and 7140 (cfr. p. 28). The upstream part of the Grote Nete has a very good water quality and is home to several protected species such as *Cobitis taenia*, *Cottus gobio* and *Lampetra planeri* (ANB 2011).

Future scenarios

Since the early nineties, a lot of effort has been done to increase the natural value of the area by restoring wetlands. Many of the drainage ditches have lost their function due to the disappearance of intensive agriculture (ANB 2011). It is the aim of the nature organizations and the province of Antwerp (European LIFE project Grote Nete + Provincial Action Plan Mol-Balen 2010-2015) to continue restoring the natural river dynamics and the historic landscape in order to:

1) Increase upstream water retention capacity to reduce flood risks downstream and to guarantee water availability during dry periods
2) Stimulate spontaneous nature development in certain areas and maintain or increase biodiversity in specific hotspots by means of pattern management

Several measures will be taken in order to achieve these goals: reduce the slope of the embankments and create concave embankments, increase the degree of meandering, reduce the depth of water courses, create shallow riparian zones as breeding site for fish and top soil removal to allow plants to reach the groundwater with their roots and store extra water. The effects of the scenarios in terms of ES are hypothetically derived from the description of the future scenario of De Vennen within the Provincial Action Plan 2010-2015, the Conservation Goals and the application report for recognition of the nature reserve De Vennen (Natuurpunt 2009).

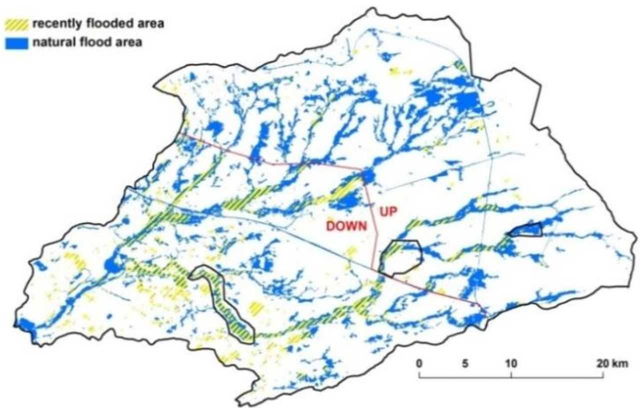
Ecosystem services

While water retention, peak flow attenuation and biodiversity are the main targeted goals, other ES, such as climate regulation by carbon sequestration and nutrient retention, also benefit from the restoration measures.

1. Peak flow attenuation through water storage

The majority of studies on water quantity functions of wetlands conclude that wetlands reduce average annual river flow and that this is related to increased evaporation (Bullock and Acreman 2003). The effective function of a wetland however strongly depends on its position in the catchment and its hydrological typology (groundwater or river stage influenced) (Staes et al. 2009). A wetland can only be efficient for the ES water storage if it is connected with the river network (Merot et al. 2006). These so called surface water wetlands are either directly influenced by flooding or indirect by in stream water tables that influence the valley groundwater table. Especially small-scale upstream valley bottom wetlands can be very effective in reducing peak discharge and runoff volume downstream. Decreases in peak discharge up to 40% were reported after installing a water retention zone in small catchments in the Belgian loam belt (Evrard et al. 2007). The effectiveness of a wetland in reducing downstream peak flows also depends on its topographic configuration which determines how much and how long water can be stored within the landscape.

Analysis of the map with recently flooded areas and natural flood areas (Figure 3) reveals that the majority of the recently flooded areas are found in the downstream part of the Grote Nete (84%) despite the fact that an equal part of natural flood areas is found upstream (48%) and downstream (52%). 85% of the natural flood areas in the upstream part have not been flooded recently, while 32% of the recently flooded areas downstream are outside of natural flood areas. This can be explained by numerous drainage measures upstream causing accelerated run-off and thus increased peak discharges downstream. Increased surface water retention in wetlands upstream can play an important role in peak flow attenuation: wetlands are able to accumulate rainfall until they are filled up and thus increase the time lag between rainfall event and resulting flow from the surface and subsurface, reducing peak discharge downstream.



	upstream (km²)	downstream (km²)
Natural flood areas	129,45	140,41
Recently flooded areas	28,62	150,18
Natural flood areas, recently flooded	20,07	102,33
Natural flood areas, not flooded recently	109,39	38,08
Recently flooded outside natural flood areas	8,55	47,85

Figure 3 – Recently flooded areas (VMM 2011) and natural flood areas (VMM 2010a) (left); upstream-downstream analysis of recent and natural flood areas (right)

2. Water retention

The water retention capacity of an area is a function of the residence time of water and depends on the presence of drainage systems, meandering degree of the stream (increases residence time), river drop (decreases residence time), the amount of impervious area, retention capacity of the soil and slope. Especially groundwater rather than surface water dependent wetlands fulfill the function of water retention

Within the study area, the relation between the water courses and the valley is very intense: the river discharge strongly depends on fluctuations of the groundwater table. During heavy rainfall these streams are characterized by relatively high peak discharges, while during periods of drought small brooks are easily under risk of desiccation. The wetlands within the study area play an important role to preserve base flow conditions: during periods of heavy rain they store excessive precipitation flowing from the Kempen plateau (Merot et al. 2006) which they release during dryer periods. Transformation of wetlands into dry agricultural fields in the past has led to an accelerated runoff increasing the risk of drought during dry periods and the risk of downstream flooding. Water retention in wetlands thus is an important ES as they can mitigate the severity of low flow periods, decrease flood risks downstream and guarantee the continuous supply of (potable) water.

To make an estimation of the potential amount of water retention, a reference map for the mean highest groundwater level in the absence of any drainage system was developed. Within the study area (Figure 4), an additional volume of 1.068.280m³ water could be stored in the absence of any artificial drainage. The parcels with largest retention capacity are found near the confluence of Kleine Hoofdgracht with Ongelbergseloop and in the valley of Kleine Hoofdgracht. The relatively lower location of these ditches in the landscape compared to the Grote Nete itself (Figure 4) explains why the streams of lower category drain the area.

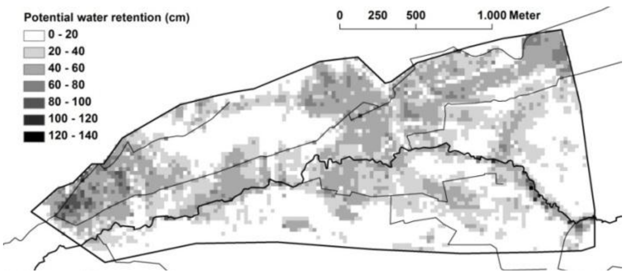


Figure 4 – Potential water retention in De Vennen

3. Carbon storage

One of the most important ES of wetlands may be the regulation of climate change through sequestration of greenhouse gasses such as carbon in the soil (MEA 2005). The most important factors for soil organic carbon (SOC) storage are wetness, clay content and land use (Meersmans et al. 2008). Soils in natural and semi-natural ecosystems (forest, permanent grassland, …) are capable of storing more C than regularly disturbed soils such as agricultural fields or temporary grasslands. The more biomass remains within the system, the more C can be stored in the soil. Wetness and clay content increase the capacity of SOC storage as biodegradation is slower in wet, clayey soils due to oxygen depletion. Rewetting thus increases C storage capacity of soils whereas drainage decreases SOC. The best ways to improve C sequestration is by increasing the area of land cover types with high sequestrating capacity (ex. forest) and by protecting existing landforms with large C stocks.

Carbon sequestration rates in wetlands strongly depends on the evolution phase of the wetland and thus on the related height above the water table and plant species. At the beginning, marshes are able to sequester large amount of carbon each year. They are characterized by a high species richness, high litter production rates and high litter quality. They are frequently or continually inundated with water, creating ideal conditions to accumulate dead organic material in oxygen poor conditions. As marshes accumulate dead organic material, they gradually build-up, eventually leading to the development of a terrestrial ecosystem (decomposition) or a bog which is separated from groundwater influence (large C stocks).

Fens are peat-accumulating groundwater-fed wetlands. They are characterized by a rich vegetation consisting mainly of grasses, reeds and tree communities such as willows, birches and alders. The formation of bog constitutes the end phase of marsh development and is characterized by a very slow evolution and thus very low carbon sequestration rates. Raised bogs eventually develop when peat builds up and separates the fen from its groundwater supply, the bog becomes mainly rain-fed and acid, creating poor decomposition conditions. Raised bog is generally dominated by Sphagnum moss with low litter quality (low decomposition). Carbon sequestration rates are lowest in raised bogs. In these areas it is especially important to safeguard the historic carbon stocks. In Belgium, as in the rest of Europe, raised bog is very rare. It is mainly found in the natural area High Fens.

Lettens et al. (2005) showed that the sandy soils in the north of Belgium contain large SOC stocks and that the highest SOC losses between 1990 and 2000 occurred in these sandy soil associations. Especially poorly drained agricultural soils have shown a strong SOC decline which is probably caused by artificial drainage (Meersmans et al. 2011). The study area thus deserves particular attention as the potential for release of C to the atmosphere after changes in land use is greatest.

The potential SOC stocks are calculated based on the results from Meersmans et al. (2008). They estimated the maximum potential SOC for Flanders for 4 land use categories (grassland, forest, heath and cropland) for each combination of soil texture and soil moisture. Data on soil texture is derived from the soil map (GIS-Vlaanderen 2001). Data on soil moisture is derived from the soil moisture map created within the frame of this project (see 2. Water retention). For the category "forest" a further subdivision was made into "forest" and "marsh forest". Quantification data for the latter is based on Liekens et al. (2009) who estimated a SOC stock in well-developed marshes of at least 350 ton C/ha, based on Altor and Mitsch (2008). An additional land use category "open water" was added to take into account elevated potential SOC stocks in still standing open water. An average of 350 ton C/ha was considered for this class. Also, an estimation of 427 ton C/ha in bogs was derived from Meersmans et al. (2008) and Altor and Mitsch (2008). Information on the soil type “dune” per land type category could not be derived from Meersmans’ study and was therefore treated as sand in this project. Information on the actual vegetation is derived from the second version of the Biological Valuation Map (INBO 2010).

The scenario for rewetting consists of an increase of the local groundwater levels with 50cm on the parcels that are suitable for water retention (Figure 4). This scenario represents a pronounced effect of the measures described in the provincial action plan and is entirely hypothetic. A vegetation scenario was developed based on the description in the report for recognition of the nature reserve De Vennen (Natuurpunt 2009). However, the developed scenario is more extreme and supposes that the combination of rewetting and spontaneous nature development on the valley bottoms will lead to the development of a vast alluvial forest. The existing ponds and lakes will gradually silt up and develop into fens and peat bogs. The dryer areas in the north and the south are assumed to develop into heath.

As marshes are prone to store large amounts of carbon in the early stages of their development (Altor and Mitsch 2008), the study area is exceptionally suitable for climate regulation. In historic times, De Vennen mainly consisted of wetlands. During the 18^{th} and 19^{th} century, large parts of the valley of the Grote Nete, amongst which De Vennen, were drained by means of artificial ditches and converted into pasture and cropland. Like in many parts of Flanders, these historic land-use conversions have most probably contributed to a decrease in actual SOC stocks (Mestdagh et al. 2009). Since the nineties, many of the former wetlands within the study area are being restored. These wetlands are now at the beginning phase of marsh development and it is expected that with the development of a vast alluvial forest in the valley of the Grote Nete SOC stocks will increase significantly: the natural succession of wet grassland into alluvial forest may potentially lead to almost 25% more SOC storage within the study area (111.368 ton) compared to the actual maximum SOC storage potential of 86.239 ton (Figure 6).

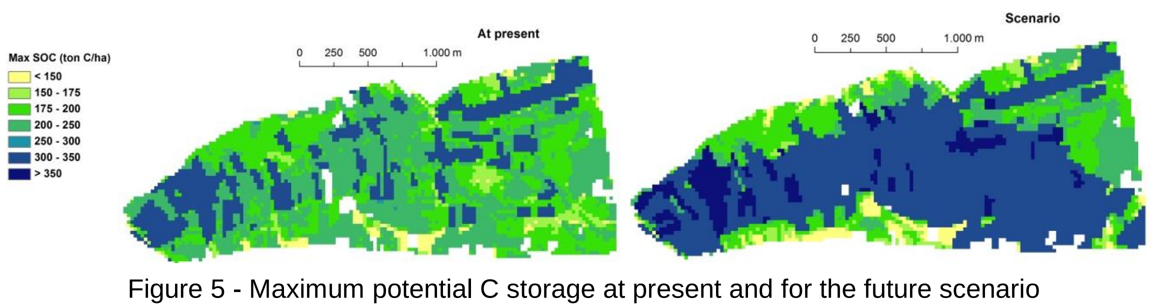


Figure 5 - Maximum potential C storage at present and for the future scenario

It needs to be mentioned that methane flux rates may increase with time as water logged soils become anaerobic. Establishing a pulsing hydrological regime with intermittent lower water tables during the growing season may help to minimize methane fluxes as a wetland ages (Altor and Mitsch 2008).

4. Nutrient storage

The main source of nitrate N and phosphate P in natural soils is dead organic material which accumulates in the upper humus layer. Without biochemical transformations, these nutrients are unavailable for uptake by plants and accumulate within the soil. If too much nutrients accumulate, the excessive amount of nutrients leaks to groundwater and surface water reserves. Nutrient storage in soils is considered an ES if it prevents leakage to water reserves and thus improves water quality.

N is stored in soils by burial of dead organic material under anoxic conditions in the absence of mineralization. Soils with high clay content, permanent high water tables or an undisturbed top layer are thus most suitable for N as decomposition rates are low. P fixation, however, not only depends on soil water content but changes in soil hydrology also play an important role in P mobilization. Drying of wet ecosystems as well as rewetting of dry ecosystems both result in a release of phosphate. In wet systems, drying will result in a release of fixed P due to mineralization of organic material. In more aerated circumstances, Fe, Al and Ca play an important role in P fixation in soils. Rewetting of dry systems, on the other hand, causes dissolving of iron oxide and consequently mobilization of P.

The amount of N and P which can be stored in soils increases with the amount of organic carbon. An increase in potential SOC due to rewetting (Figure 5) will thus increase the nutrient retention capacity of the soils in De Vennen. Especially groundwater fed wetlands with iron rich seepage are important for P fixation.

5. Biodiversity support

In this context, biodiversity is seen in terms of plant and animal diversity and rareness. The role of freshwater ecosystems herein is the provision of habitat for biodiversity conservation (Blackwell and Pilgrim 2011). Wetlands all over the world incorporate unique habitats often hosting rare and endangered species. Certain species are particularly adapted to fluctuating hydrological regimes typical for headwater wetlands. The total area of a wetland is not a reference for its biological value (Blackwell and Pilgrim 2011) or species richness. Figure 6 shows that the most species rich parcels do not coincide with the largest parcels and vice versa. Headwater wetlands as found in De Vennen may be very well suited for biodiversity despite their small size.

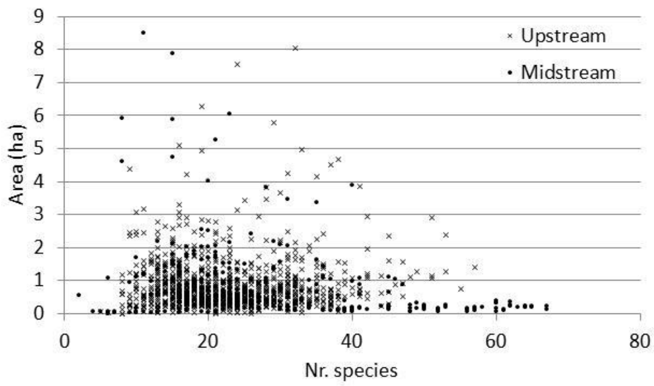


Figure 6 - number of species per parcel vs. parcel area (based on data from Backx et al. 2002)

De Vennen is a biological valuable area thanks to its location on the transition from swampy soils in the valleys to dry oak-birch forest and heath relicts on the valley edges. The majority of the swampy valley bottoms is covered with grassland. The parcels with highest species diversity coincide with wet grasslands hosting typical wetland species such as *Calthion*, *Filipendulion*. Some very species rich areas are found in well-developed willow and alder brooks.

The location of De Vennen within a Natura 2000 area and a VEN protected area further underlines the biological importance of the area. As mentioned, it also made part of the European LIFE programme 2005-2010 for environmental and nature conservation and large parts of the area are property of nature organizations. The area is very suitable for the further development of typical European protected wetland habitats such as species-rich *Nardus* grassland, *Juncus* meadows, wet hydrophyllous tall herb fringe communities, *Alnus* and *Frexinus* alluvial forests and transition mires (ANB 2011). Restoration of the natural hydrology since 2011 will allow these habitats to expand.

2.1.3.2 Case Malesbroek

<u>Description of the study area</u>

The study area is located along the valley of the Grote Nete at about 25 kilometers downstream from its source (Figure 7). It is a typical midstream valley bottom area consisting of wetlands and historic mire depositions. The relief is dominated by the south-west oriented valley of the Grote Nete and a series of parabolic land dunes parallel to the valley (Figure 7). Heights vary between 17 and 32m TAW. The study area is surrounded by embranchments of the Kempen plateau from which it intercepts runoff. The wetlands are groundwater as well as surface water fed.

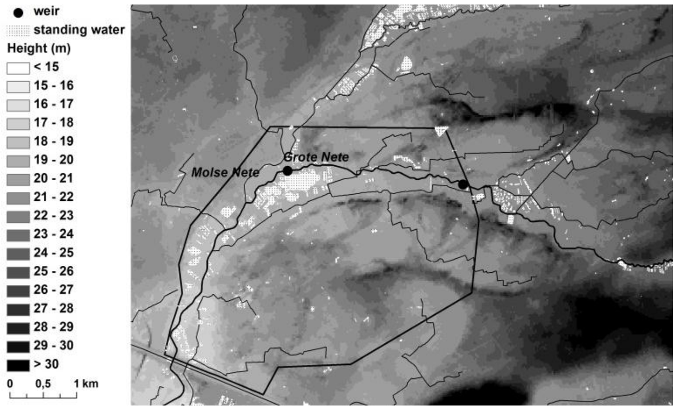


Figure 7 - Elevation within the study area Malesbroek (OC-GIS 2011)

Hydrology within the area is dominated by the confluence of two major rivers, Grote Nete and Molse Nete, an extensive drainage system with larger ditches parallel to the Grote Nete also discharging within the study area and some smaller non-classified ditches. The drainage network within the study area is particularly well developed. The connection of the artificial ditches with the Grote Nete has systematically been relocated more downstream in order to increase drainage of the wet valley. This has led to an inverse topography with water levels in the ditches up to 1m lower than the water level of Grote Nete. Several ponds, amongst which Malesbroek, are found on the alluvial plains of the Grote Nete and Molse Nete. They constitute the relicts of peat extraction since the 19th century. The water level in the study area is regulated by two weirs along the Grote Nete (Figure 7). Straightening and embanking of the Grote Nete have led to increased drainage, interruption of the natural flood regime and partial loss of its natural meandering structure.

The area, which covers a nature reserve and a protected landscape, makes part of a habitat directive and a VEN area. Several protected European and regionally important habitattypes are found in Malesbroek: rbbsf, rbbhc, rbbmr, rbbsm, 6430, 91E0, 7140, 3130 and 3150 (cfr. p. 28). The area hosts some rare species, such as *Lampetra planeri, Cobitis taenia, Triturus cristatus and Luronium natans* (Haskoning 2006). The most valuable parcels are found closest to the Grote Nete: valley bog, mesophyll meadow land, reed and *Filipendula* communities, willow shrub and sometimes alder brooks. The dryer parts on the valley edges are covered with cropland or pasture, and pine forest on the land dunes. Malesbroek hosts a highly diverse avifauna including 70 breeding bird species.

Future scenarios

Like De Vennen, Malesbroek is subject of the European Life+ project which aims to protect existing natural value and to restore specific valuable habitat for which the area is particularly suitable. As habitat development in freshwater ecosystems is driven by hydrological dynamics, measures to restore natural characteristics of the valley are expected to support these goals of nature development. The scenario for restoration of ecohydrology within the study area consists of meandering of Grote Nete, removal of artificial weirs and connecting Grote Nete with Malesbroek to create a flow-through wetland. Besides nature development, restoration measures are expected to benefit water quality regulation by denitrification, air quality regulation and recreation potential.

Ecosystem services

1. Recreational value

Freshwater is known to be an important attracting factor for recreational activities to human beings. Especially still standing water bodies and rivers can be very suitable for the development of aquatic recreation, such as active water sports or fishing. Not only the water itself but also water-bound nature constitutes an attraction pole to recreants. The more attraction values are found in an environment, the more likely recreation will develop.

A better accessibility of nature to recreants, facilities for visitors, information folders and yearly activities are expected to increase societal support for nature development. The creation of vast natural areas allows to direct recreation development into restricted areas so that vulnerable habitats and species can better be protected (ANB 2011) and attraction values sustained.

A method was developed to map the physical suitability of an area for the delivery of the ES recreation, based on the landscapes’ natural potentials. For each factor that can potentially attract recreants a polygon map was created containing water related elements of interest: (1) the map with still-standing water bodies is a selection of the NGI 2010 layer “Watersurface” (NGI 2011) where the attribute is at least 7ha; (2) the map with rivers is based on the Flemish Hydrological Atlas (VMM 2010b) where the river category is 0 or 1; (3) the map with water-bound nature is derived from the map with protected landscapes (AGIV 2010). For each of the three polygon layers a raster map was created with for every pixel the distance to the nearest element within the layer. The three raster maps were reclassified into suitability maps with a score based on the calculated distances: 4 - very suitable, <500m; 3 – suitable, 500-1000m; 2 - average suitable, 1000-1500m; 1 - poorly suitable, 1500-2000m and 0 - not suitable, >2000m. Finally, an overall suitability map was created by making the sum of the three suitability scores in each pixel (Figure 8). As can be seen from Figure 8, there is a good match between the resulting map and the map of effective recreation or sports facilities (Van Esch et al. 2011). The same analysis on the scale of the entire Nete catchment revealed that 92% of the areas that are indicated as very suitable for recreation actually have a recreation or sports facility at less than 100 m distance, indicating that the occurrence of recreational and sports facilities is related to the presence of freshwater. This can be explained by the several larger streams, ponds and a protected nature reserve that are found in an area of a few square kilometers. The map also identifies zones with high potential for recreation development.

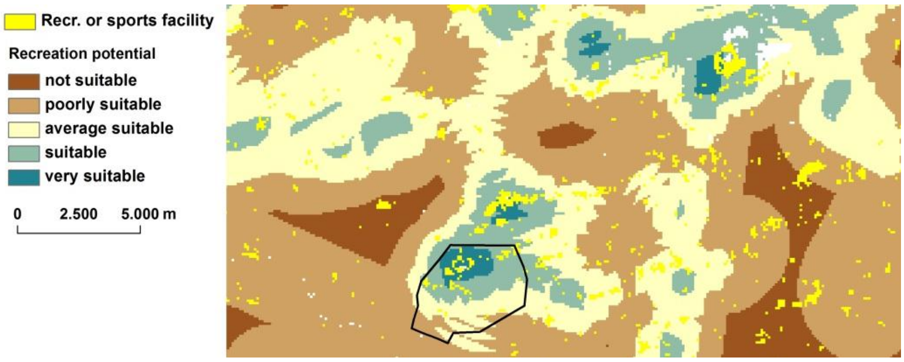


Figure 8 - Effective vs. potential recreational development near Malesbroek

The area harbors an extensive cycling network and the development of a walking trail network is expected to further increase the recreational value of the area.

Many of the former peat extraction ponds are now used for fishing. Connecting some of the ponds with Grote Nete and Molse Nete offers the opportunity for certain species, such as Rhodeus sericeus amarus, to extent their habitat and colonize new ponds. Fish stocks in the Grote Nete are expected to increase as a result of the removal of the two weirs which act as fish migration bottlenecks. Restoration of the natural river structure creates habitat for fish spawning and nursery and thus benefits fish stocks. Increasing the water quality and restoring the natural structure of the embankments (soft slopes + removal of levees) offers new opportunities for fishing and water-bound recreation. The area also attracts a lot of bird watchers as it is home to more than 70 breeding bird species. The presence of many weekend cottages underlines the importance of the study area for recreation.

2. Water quality improvement by denitrification

Water quality regulation by denitrification is considered an ES if it prevents leakage of nutrients to groundwater. Denitrification is the process in which bacterias convert nitrate into nitrogen under poor oxygen conditions. Denitrification can only occur if it is preceded by nitrification, a process in which bacterias convert ammonia into nitrite and nitrate under oxic conditions, and if the water stays long enough in the sediments or in the basin. Microsites of freshwater ecosystems with a pronounced oxygen gradient, such as riparian zones, limnic sediments and intertidal zones, are very suitable for water purification through denitrification. Factors that influence denitrification rates in terrestrial soils are water content, soil texture, N supply, temperature, C supply, vegetation and structural variation. Highest denitrification rates are found in wet soils with a water saturation of 80% where both anoxic and oxidized conditions exist. Denitrification rates are highest in soils with 80% clay/loam (Pinay et al. 2007). Plants roots and bioturbation further increase potential denitrification as a result of an increase in surface area with an oxygen gradient. A higher degree of meandering leads to (1) a longer residence time of the water within the area, and (2) an increase in riparian zone, both of these effects increasing denitrification potential. The total amount of N removed by denitrification in shallow lakes, wetlands and riparian zones can be estimated with the formula of Seitzinger et al. (2006):

$$\%\, removal = 23{,}4 \times residence\ time\ (in\ months)^{0{,}204}$$

$$residence\ time = \frac{volume}{discharge}$$

The Grote Nete within the study area is about 6m wide, has a total length of 3665m before meandering and 5365m after meandering, an average depth of 1m and an average daily discharge of 2,68m³/s. With an estimated N supply of 0,607 mgN/l, the amount of N the Grote Nete can remove is calculated 0,96 kgN before meandering and 1,52 kgN after meandering (Table IV).

Connecting Malesbroek pond with Grote Nete will lead to gradual silting up of the pond allowing vegetation to establish in shallow zones and develop into a flow-through wetland. This will significantly increase denitrification potential as N-loaded water from the Grote Nete is continuously being supplied. With a surface area of Malesbroek pond of 13,04ha and an average depth of 1m, the total amount of N removal is 8,17 kgN compared to 0,02 kgN if the course of the Grote Nete remains unchanged (Table IV).

Table IV - N removal by denitrification by scenarios of meandering and flow-through wetland creation

	At present (kgN)	Scenario (kgN)
Riparian	0,96	1,52
Flow-through wetland	16,15	0,02

3. Air quality regulation

The efficiency of air quality regulation by vegetation depends on the degree of tree cover, diversity of species composition and biomass structure, and sound green space management in the urban environment (Jim and Chen, 2008). The higher the degree of tree cover, the more vegetative surface (leaves, branches and trunks) is available onto which fine dust particles can be adsorbed. Part of the precipitated dust falls on the ground during rain showers and can be re-adsorbed onto leaves of lower vegetation layers (shrub, herb, grass or humus layer). The presence of multiple vegetation layers instead of bare soil underneath trees thus improves air regulation by dry fine dust capitation (Vaes et al. 2005). Coniferous trees are slightly more suitable for the adsorption of fine dust than deciduous trees. However, leaf trees with a complex branch structure and rough, hairy and sticky leaves are also apt to remove fine dust from the air (Tonneijck and Kuypers 2005).

Besides physical deposition of fine dust particles, vegetation can also remove gases which act as precursors of secondary fine dust and volatile organic components such as PCB's, furans and dioxins. Trees with broad and thin leaves, such as leaf trees, are most suitable for the removal of gases by absorption through their stomata. Trees with a thick cuticula, such as coniferous trees, are more prone to adsorb volatile components onto the thin wax layer on their leaves or needles (Hiemstra et al. 2008). A good mixture between tree types thus guarantees a most optimal removal of air pollution.

As the role of forests and trees for the removal of harmful air particles strongly depends on the demand for this service, Malesbroek can be relatively important for this ES taking into account its location at about 1km from the city of Geel and 1km from the highway E313. Allowing nature to develop spontaneously in a multi-layered structure increases the potential for removal of harmful air particles.

2.1.3.3 Case SIGMA

Description of the study area

The SIGMA study area is a typical downstream valley bottom wetland area. It is located at more than 100km from the source of the Grote Nete (Figure 2). The alluvial plains within the area are very pronounced and they are susceptible to flooding. The soils are dominantly clayey and sand-loamy, and become loamy sand away from the river. Agriculture is very important within the area as it constitutes 51% of the total surface, from which 29% is cropland and 22% production grassland. Forestry, taking up 17% of the surface, is also an important production service within the area. Several protected European and regionally important habitattypes are found in the SIGMA study area: rbbsf, rbbhc, rbbmc, rbbms, 6430, 91E0, 6510 and 1130 (cfr. p. 28).

Future scenario

In 2005, the Flemish government approved the SIGMA plan for the valley of the Grote Nete in which protection against floods and naturalness are the principal goals. Cost-benefit analysis (De Nocker et al. 2004) revealed that the area is potentially very important for the service climate regulation through carbon sequestration. Measures to restore natural inundation areas are expected to increase SOC stocks with 1.966 tonC/y, which is mainly a result of rewetting and wetland development (Chapter 2.1.3.1). Rewetting of the area, however, comes in direct competition with agricultural and wood production. Specifically in this area, the challenge is to optimize the main targeted services with the least possible impact on agricultural production. This chapter therefore focuses on ES trade-offs.

<u>Ecosystem service trade-offs - Provisioning services vs. climate regulation</u>

Trade-offs occur when the provision of one ES is reduced as a consequence of increased use of another service. One of the most common trade-offs arises between intensive agriculture and climate regulation through carbon sequestration since hydrological conditions for both of these services are contrary while man has succeeded to adapt hydrology through technical measures.

Freshwater ecosystems often contain high amounts of organic content due to inhibition of mineralization in poor oxygen conditions. By draining these naturally wet soils, man has succeeded to exploit the very fertile soils for agricultural purposes. Furthermore, soils of freshwater ecosystems along rivers are often composed of alluvial deposits with high loam or clay content. As soil fertility is related to organic content, clayey and loamy soils are more fertile than sandy soils because minerals can more easily be adsorbed onto clay or loam particles while in sandy soils they are easily flushed out by precipitation. Soils of freshwater ecosystems however, are waterlogged and need to be drained in order to be exploited, a practice that has commonly been applied in the Nete catchment and has led to great losses of wetlands.

Due to the high agricultural value of the area, the SIGMA restoration plan needs to give special attention to the trade-offs between the provision service agriculture on the one hand and regulating and habitat services such as water retention, carbon sequestration, nutrient retention and biodiversity on the other hand. However, sound land use planning can create possibilities for synergies. Streams in agricultural catchments usually remain in good condition if the extent of agriculture is less than 30-50% (Allan 2004). Pastures are generally less restricted to abiotic soil conditions allowing for synergies between agricultural production and regulating and habitat services. Extensive grazing of wetlands, for example, is an increasing practice across northwestern Europe (Blackwell and Pilgrim 2011).

As mentioned in Chapter 2.1.3.1, drainage of naturally wet soils decreases C storage capacity and results in losses of historic C stocks. Meersmans et al. (2011)

concluded that an overall strong SOC decline in poorly drained agricultural soils in Belgium is probably caused by artificial drainage. Soils in natural and semi-natural ecosystems such as wetland and natural grassland are capable of storing more C than regularly disturbed soils (Post and Kwon 2000) such as agricultural fields or pasture, thus creating a clear trade-off. This can be explained by several factors. Intensive grazing increases mineralization rates by oxygenation of the soil (Mestdagh et al. 2009), while harvesting reduces the amount of biomass that remains within the system and that can be transferred to the soil. Wood harvesting on the other hand is more likely to result in long term SOC loss due to profound soil disturbances rather than biomass removal (Jandl et al. 2007). The Bayesian belief network developed in this project are a first step towards the development of a decision supportive tool to optimize land use for the delivery of bundles of ES (Chapter 2.3.5).

2.1.3.4 Conceptual model

Based on the description of the ES, a conceptual model was constructed of the links between ES for a typical wetland ecosystem in the valley of the Grote Nete (Figure 9). It does not aim to be exhaustive in the sense of ecosystem processes and attributes, but rather focuses on the relationships between ES, allowing to better understand potential trade-offs and synergies between services.

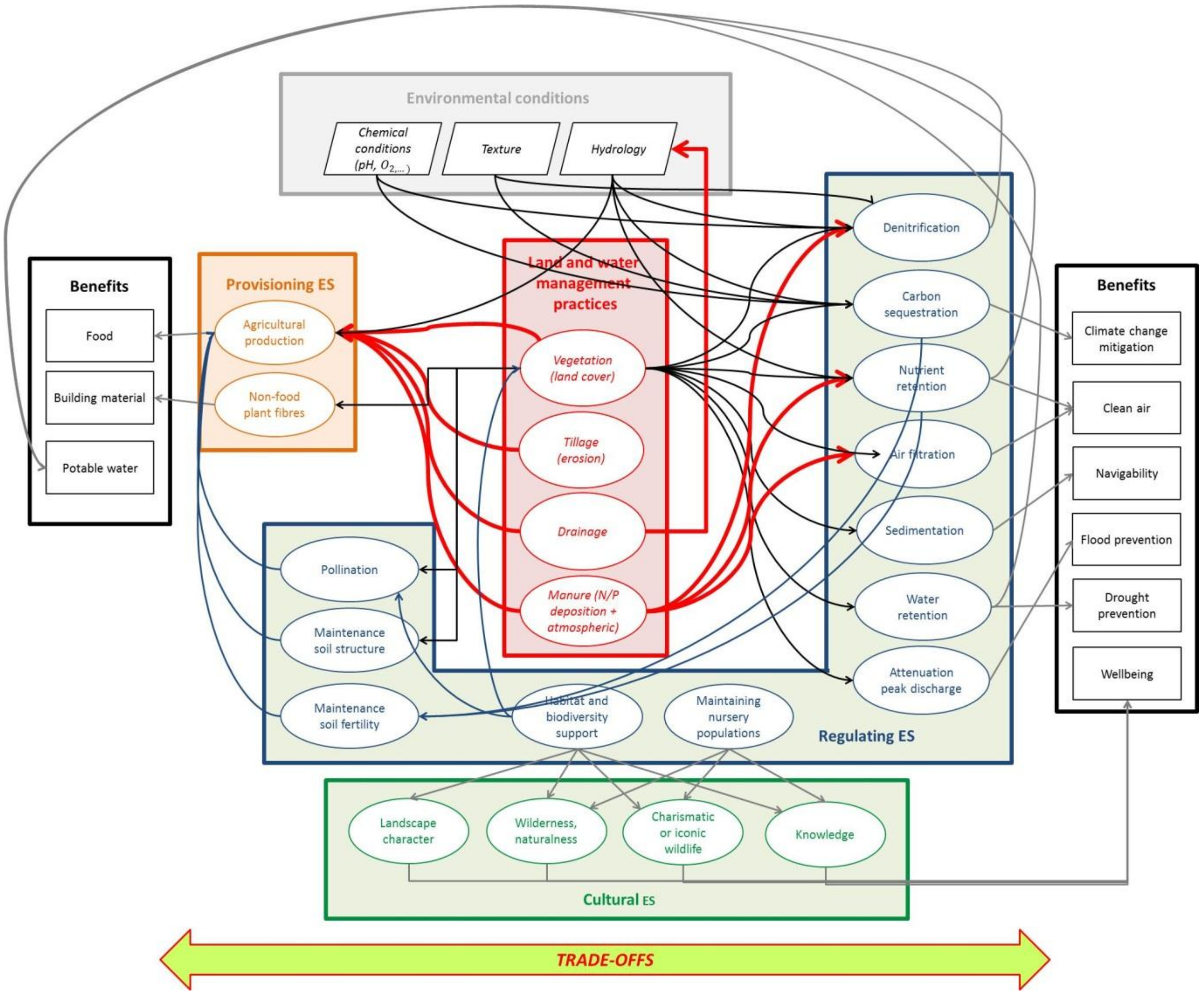


Figure 9 – Conceptual model of ES delivered in a typical wetland in the valley of the Grote Nete

2.1.4 Discussion

Especially in highly fragmentized areas with agricultural and urban pressures, link Belgium, there is a strong need to understand the value of ES delivered by different types of freshwater ecosystems. Human influences increase the ecosystems' complexity and the need for tools that allow a better understanding of the functioning of the ecosystem and the delivery of ES. Conceptual models are useful tools to visualize the complex structure of ecosystems and the link with ES. They allow to gain insight into the links - trade-offs and synergies - between services. Within the frame of this project they also served as a guideline for the mapping and data gathering. Although conceptual models can integrate the complexity of the ecosystem, they are not suitable to assess the behavior of the system, for example for scenario analysis. Hence, the conceptual models were translated into statistical Bayesian belief networks. The conceptual models thus served as a supportive tool for the development of the Bayesian networks.

2.2 SOCIO-ECONOMIC IMPORTANCE OF ECOSYSTEM SERVICES

2.2.1 Main research questions

The economic valuation of ES is a complex process that is reliant on the availability of relevant and accurate biophysical data on ecosystem processes and functions but also on the appropriate applications of economic valuation (Morse-Jones et al. 2010). This chapter provides clarification on important considerations in ES valuation and review how the literature has dealt with this issues to date: spatial explicitness, marginality, the double-counting trap and the challenges of dealing with non-linearities in benefits, and threshold effects. This is largely based on the work done by (Morse-Jones et al. 2010) and own work for the Flemish government (Liekens I. et al. 2009).

The review makes clear that the value of ES may be very different from one site to another, due to specific geo-physical and socio-economic characteristics of the region. Primary data collection is desirable for every case, but when this is not feasible due to budget and time constraints, or when expected payoffs to original research are small, benefit transfer has become an increasingly practical way to inform decisions. Benefit transfer involves the adaptation of existing valuation information to new policy contexts where valuation data are absent or limited (Environmental Protection Agency 2000, in Troy and Wilson 2006). Errors arising from the transfer of study site values to the policy site are inevitable. So-called generalisation errors occurs when values for study sites are transferred to policy sites that are different without fully accounting for those differences. Such differences may be in terms of population characteristics (income, culture, demographics, education etc.) or environmental/physical characteristics (soil characteristics, quantity and/or quality of the good or service, availability of substitutes, accessibility etc.).

2.2.1.1 Spatial explicitness

The approach of developing spatially explicit valuation functions including the relevant characteristics for each ES, may be a promising method that allows to estimate the value of ES of an ecosystem within a certain region (Bateman et al. 2011), because they capture the fact that ES values vary across space, but do not require primary data collection for each project. In developing these valuation functions spatial explicitness plays an important role. The largest aggregation error at larger spatial scales is in most cases not due to errors on the values themselves but are caused by the way these values are multiplied with the quantity or number of stakeholders. Information is needed on (a) influences of multiple habitats on the total quantity of a service, (b) the number of stakeholders that benefit from this service, and (c) the economic scale on which the ES occurs.

This chapter tackles issues concerning (b) and (c) for the cultural services. To reveal how stakeholders' willingness to pay for ES varies with scale and distribution, a distance function approach as applied by, amongst others, Ferraro (2004), Bateman et al. (2006) and Bateman et al. (2011) provides a suitable entry point. In addition, the distance function approach needs also to take into account some other socio-demographic and spatial indicators, such as income and substitutes (e.g. other green recreation areas). VITO recently developed a distance function for nature development (Liekens et al. 2013).

The influence of site-specific characteristics is also illustrated by Naidoo and Ricketts (2006) in a cost benefit analysis of three potential conservation corridors. The three were potentially equivalent, however one corridor generated three times more benefits. This was due to spatial factors such as slope and soil type. Liekens et al. (2009) also illustrated the importance of spatial factors such as soil type, ground water levels, surrounding land use,… in estimating the value of ES of nature areas in Flanders.

Luisetti et al. (2008) illustrate the importance of spatial context in aggregating benefits of new wetland creation on the east coast of England. They found that the distance attribute in their choice experiment was significant and negatively signed, indicating that utility declines as distance from the site increases – the so called distance decay effect. Also Liekens et al. (2013) concluded this for the creation of different types of natural areas. This means that assuming a constant unit value across populations for a specified change in ES provision would have led to biased estimates.

The above examples illustrate that if we fail to take into account spatial variability in ecosystem supply and demand, we risk over– or underestimating ecosystem values. Valuation studies ideally encompass all these spatial variables when eliciting public preferences and WTP values. However, the number of studies that provide information on the effect of this set of spatial characteristics on WTP is limited (Bateman et al. 2011). In fact, despite the vast body of literature on the economic value of ecosystem goods and services provided by natural areas, existing valuation studies pay limited attention to important spatial characteristics in the valuation of landscape, open space and fragmentation.

2.2.1.2 Double counting

A second issue is aggregating the separate services without double-counting certain services. Taking into account trade-offs between services remains an important challenge. A potential approach to tackle these challenges is to identify the specific physical processes involved in the ecosystem under study, which are often dependent on site-specific characteristics, and apply these to the beneficiaries related to the "site". For certain ES (e.g. carbon sequestration, non-use benefits) these beneficiaries could be at a large distance from the site.

2.2.1.3 Relevance

To be most useful for policy makers, ES must be assessed within their appropriate spatial context and economic valuation should provide marginal estimates of value (avoiding double-counting) that can feed into decisions at the appropriate scale. Economic estimates should recognize possible non-linearity's and should be well within the bounds of the "safe minimum standards", which guarantees that changes to the ES do not lead to the surpassing of a threshold at which an ecosystem may change abruptly into an alternative steady state (Morse-Jones et al. 2010).

Solving these issues is crucial to tackle the integration of multiple services at multiple scales. Defining a methodology for the integration and up scaling of demand maps for ES will thus be of key importance. Indeed, most work performed on valuing freshwater ES, has focused on a single service or a single habitat. More work is needed on integrating multiple services at regional scales (Chan et al. 2009).

Within ECOFRESH steps have been taken to improve the economic valuation, that takes into account spatial explicitness into the valuation function (specific for cultural services) as Liekens et al. (2009) already developed it for some regulating services and try to integrate multiple services by coupling economic values to the physical processes into the Bayesian belief network (Chapter 2.3).

Following steps were performed:

- Quick scan of some cases to have an idea of the available information and applicability of data for benefit transfer
- Original research to answer the research questions
- Integration results with outcomes of the Bayesian belief network for the case Pond complex Midden-Limburg (Chapter 2.3.4) to recalculate economic value of some policy scenarios

2.2.2 Quickscan value of case studies

The different ES can be valued through various methods. Economists have a toolbox to value goods and services that ecosystems can deliver, and the appropriate tools depend on the characteristics of the goods or services (see Freeman (1994); (Brouwer 2000); and reviews made in e.g. Markandya et al. (2008); Hanley and Barbier (2009); Champ et al. (2003); Young (2005)). A combination of valuation techniques is required to comprehensively value freshwater ES.

Although in the beginning of the project, we identified some research needs concerning the valuation of freshwater ecosystem services, we performed a quick scan in order to see how the existing information on quantification and valuation methods could be used in the case studies and how the existing methodologies could be improved. In addition, it also clarified what were the main information gaps on specific freshwater ecosystems. The identification and first quantification results from Chapter 2.1 were used as a basis for economic valuation. This valuation was based on our valuation tool “nature value explorer”, which offers a range of quantification and valuation functions based on a mixture of valuation methods to value changes in ecosystem services (Liekens et al., 2009) and literature review. The benefits delivered in the cases De Vennen, Sigma Grote Nete and pond complex Midden-Limburg were estimated and are reported below.

2.2.2.1 Case De Vennen

Regulating services

SOC storage

Making use of the quantitative estimates of Chapter 2.1.3.1 and using “Natuurwaardeverkenner” (Broekx et al. 2012) the implementation of the foreseen measures in the area are estimated to increase SOC sequestration with 980 ton C/year, resulting in a yearly benefit of 180 k€ for climate regulation. For the quantification the multiple regression approach of Meersmans et al. (2008) was used. To assess the monetary value of carbon sequestration by ecosystems, three different methods can be used: market prices, marginal damage costs and avoided abatement costs. As impacts are global, the selected data are based on studies at the global level. Based on these range of values in literature, we have taken the value of 50 €/ton $C0_2$-eq. (183 €/ton C), in line with a study on economic aspects of climate change for the Flemish Environmental Agency (MIRA, 2008).

Nutrient removal

Through denitrification and nitrogen (N) and phosphorus (P) retention in the soil, 57 ton N and 3 ton P was prevented entering surface waters, resulting in a yearly benefit of 4.200 k€ (maximum value of N- and P-sequestration). The nitrogen (N) and phosphorus (P) content of soils is derived from the carbon content (Koerselman en Meuleman, 1996). Denitrification rates were based on estimates from Seitzinger et al. (2006) and Pinay et al (2007). The avoided abatement cost method is used to value nutrient removal, as costly abatement measures to obtain environmental goals can be avoided due to the natural nutrient removal that an ecosystem delivers. The specific value of an additional kg N or P removed by an ecosystem is derived from the marginal cost curve of N and P removal, which was calculated for the Flemish river basin management plan to reach a good water status according to the European Water Framework Directive (Cools et al., 2011).

Air quality

As explained in Chapter 2.1.3.2, green areas can capture fine particles and air pollutants. For this relatively small case the scenario changes hardly the quantities being captured (only 35 kg PM10).

Cultural services

The biodiversity in the area and the accessibility for walking and biking will increase, which has a positive impact on the preferences of recreants and households. VITO, together with IVM, VUAmsterdam performed a stated preference study (choice experiment) measuring the willingness to pay of people for the creation of new nature depending on the nature type, size of the area, accessibility of the area, biodiversity level and distance to their home. More details on this study may be found in Liekens et al. (2013). Based on the estimated valuation function, the amenity and non-use values range between 1.500 – 4.000 k€ per year.

Estimated total economic value

In Table V an overview is given of all the estimated benefits of the case study De Vennen. They could be aggregated without double-counting. The total value of the selected ES is estimated at +/- 6 million €/year. Most important values are related to water quality improvements and amenity/non-use values.

Table V - Quantity and value of ES for “De Vennen”

Service	Quantitative change		Monetary value
	ton/year	kg/year	k€/year
Climate regulation (SOC)	985,360		180
Water quality : N-sequestration soil (N)		45.719,57	3.383
Water quality: P-sequestration soil (P)		3.047,97	2.438
Water quality: Denitrification (N)		11.005,99	814
Air quality (PM10)		35,44	1
Amenity and non-use			1.503- 4.157

2.2.2.2 Case SIGMA Grote Nete

Provisioning services

In the optimal scenario for the Sigmaplan (Chapter 2.1.3.3), the loss for agriculture was calculated starting from the fact that the land is already flooding in the present scenario. Depending on the flooding regime in the present scenario (yearly or 4-yearly), losses in the project scenario were estimated between less than 1 mio € and 4,4 mio€. This number is based on the lost agriculture production due to the rate of flooding of the inundation area. For more details see Broekx et al. (2011). As there was no information available on the area of production forest under pressure in the project scenario, it was not possible to estimate the economic value of this loss. The economic loss is expected to be relatively small as only a very small part of the totally forested area disappears in the SIGMA scenario.

Regulating services

To calculate the benefits from flood water detention, the avoided damage costs are considered, using a risk based approach. Through hydrological modeling, flooding maps were generated based on different storm return periods. The damage was calculated with damage functions. This was done for this particular area in a cost benefit analysis for the optimization of the Sigmaplan (Broekx et al. 2011). The value for protection against flooding was estimated to be 2.400.000€/year.
Making use of the findings of Meersmans et al. (2008) and "Natuurwaardeverkenner" (Broekx et al. 2012), C-sequestration in the soil would increase with approximately 2.200 ton/year, resulting in a yearly benefit of 410.000 €/year.
Through denitrification an N-P-retention in the soil, an extra 165 ton of N and 7 ton P is prevented entering surface waters in the project scenario, resulting in a yearly benefit of 12.000.000€. Quantification and valuation were performed using literature and the Environmental Cost Model "Water" (Coolset al. 2011).
The alteration in land use from agriculture to specific natural land use increases the precipitation of fine particles out of the atmosphere (Oosterbaan and Vries 2006). This increase was estimated at 1 ton/year, resulting in a yearly benefit of 36.000€. Again the monetary value was estimated on the basis of avoided damage costs (health).

Cultural services

The estimated valuation function (see Ch. 2.2.2.1 and Liekens et al. 2013) shows a different preference for certain habitats. Forests are preferred higher than heathland and wetlands than natural grasslands and marshes. There is a positive preference in going from agricultural land to nature area. In some parts of the case study area, the land use will change in a positive way (e.g. preference for existing cropland is lower than for the change into wetland, wet grasslands..), in other parts in a negative way (e.g. preference for existing forest is higher than for the change into wet nature areas) related to the preferences of the Flemish population in the valuation study. The biodiversity in the area will increase, and recreation will be still possible, having a positive impact on the willingness to pay of the respondents. Based on this study, the amenity and non-use values were estimated to range between 4.200.000€ and 6.500.000€ extra per year.

Estimated total economic value

Table VI gives an overview of all the estimated benefits of changes in the case study Sigmaplan Grote Nete. Most of them could be aggregated without double-counting. There is offcourse a trade-off between the provisioning services in the present scenario and the improvement of the regulating services. That is why the effect on provisioning services is negative.

Table VI - estimated economic value for changes in case Sigmaplan Grote Nete

Service	Quantitative change		Monetary value
	ton/year	kg/year	k€/jaar
Agricultural products			-1.000 to -4.400
Timber products			?
Protection against flooding			2.400
Climate regulation (SOC)	2.239,66		410
Water quality: N-retention (N)		110.360,25	8.167
Water quality: P-retention (P)		7.357,35	5.886
Water quality: denitrification (N)		53.196,47	3.937
Air quality (PM10)		1.209,73	36
Amenity and non-use			4.217 - 6.500

The quantifiable economic value of the change in ES provided by the measures taken in the project scenario ranges between 17 and 18million €/year.

2.2.2.3 Case River Nete

In the European project Aquamoney (Guidelines for assessing the benefits of the Water Framework Directive) a value function to calculate the willingness to pay of households for an improvement of the good ecological status of the river Dender was developed. This function was used for benefit transfer to the River Nete case. For the benefit transfer we assumed that 20% was recreational value what we distributed over the Flemish rivers based on the population density and distances from the river (based on the distance decay function of the Dender). 80% was assumed to be non-use value and this was equally distributed over the rivers in Flanders. Using this practical approach, restoration of the natural stream, improvement of the water quality and biodiversity of the Nete-catchment would lead approximately to an economic value of 239.000€/km stream, including use and non-use values. For the entire Nete-catchment this will lead to 71 million€/year.

In using the above mentioned approach questions arise concerning the availability of substitute rivers and the way this affects the value of the river under study. Also whether or not changes in large and smaller rivers could be valued in the same way.

2.2.2.4 Case pond complex Midden-Limburg

At the moment of the quick scan hardly any quantitative information was available for the pond system of Midden-Limburg. Original research was performed in the next step to solve this lack of data.

2.2.2.5 Conclusions of the quick scan

The lack of quantitative data for many services, especially regulating and cultural services, may impede valuation of ecosystem services. This was especially the case for the pond complex Midden-Limburg. The question on how size/number of ponds would affect the value people attach to the ponds (spatial explicitness, upscaling) could therefore not be solved through the quick scan valuation.

In order to analyse this issue, an original valuation study was performed in which data on amenity and non-use values was gathered, in addition to the information gathered in this chapter and Chapter 2.1 about the regulating services of ponds.
As mentioned in Chapter 2.2.2.3 some questions were raised in trying to transfer the results of the Dender Case study to other rivers in Flanders. These questions concern mainly how substitutes and scope (brook, small river, large river, pond) influence the preferences of people (spatial explicitness, substitutes). Again an original valuation study needed to be performed trying to answer this.

When estimating the total economic value all the different ES values need to be summed. It was not always clear how different ES influence each other. Some are compatible while others are competitive. Questions on the trade-offs remain in order to aggregate the different services e.g. between provisioning services and regulating services, between regulating and cultural services... (issue of double-counting). For several cases this was partly solved by implementing different services into a Bayesian belief network (Chapter 2.3.4). In the case of pond complex Midden-Limburg this model was also linked to the economic values calculated in Chapter 2.2.4.

2.2.3 Spatial explicitness in valuing cultural services

2.2.3.1 Methodology

In the surveys launched for ECOFRESH, the value people attach to improvements in the ecological status of freshwater bodies for recreational use, amenity value and non-use were investigated.

Hanley et al. (2006) show that water bodies may provide a wide variety of use and non-use values. As the area is highly urbanized and the waterway network is very dense, substitution possibilities are large. So far, it is unclear how water bodies are being used and to what extent recreation behavior and nature appreciation will change when quality improvements occur under the implementation of the Water Framework Directive (WFD). Distance decay of attached values is expected to be large, which is one of the main foci of the European study Aquamoney (www.aquamoney.org) . After this study some questions concerning influence of substitute rivers and size of waterbodies popped up to properly implement the results.

Which people attach which value to which water body will be a very difficult, yet important question to answer, as this determines the boundaries of the market area over which individual Willingness To Pay can be aggregated in order to determine the benefits of implementing the WFD at the case study site at a population level. Therefore two substitute rivers, Nete and Demer, were included in the survey in order to clarify further the influence each river has on the value people attach to this rivers.
Although different economic valuation methods exist, the only method to value the non-use value is the stated preference valuation.

The two principal techniques for stated preference valuation that are consistent with welfare economics are Contingent Valuation (CV) and Choice Experiments (CE). Both techniques are well established in the academic literature and in policy applications, and have been successfully employed to value national water quality improvements (Mitchell and Carson, 1984, and Huber and Viscusi, 2006) as well as hundreds of other non-market benefits. Both approaches have as their objective the estimation of maximum willingness-to-pay for improved policy alternatives relative to some baseline. The maximum that people are willing to pay for a good is an economic measure of its value.

The CV technique is focused on valuing one scenario so is suited primarily to situations where estimates of total benefits of an environmental program are needed. By contrast, CE questions value marginal changes, as well as valuing whole environmental programs, and so are useful for valuing elements of policies and programs. Adopting both techniques provides the ability to cross-validate the total value estimates, though differences are expected.

The key elements of CE and CV questionnaires are similar. Both require the specification and presentation of baseline and improvement scenarios, and the selection of a payment vehicle, e.g. taxes or water bills. Both require the selection of an elicitation format and an experimental design.

In order to estimate site-specific values and analyze the substitution patterns underlying the willingness to pay (WTP) for changes in environmental service provision in different sites, a labeled site-selection CE was developed. Respondents were asked to choose the site they prefer to be improved depending on ecological quality improvement scenarios (see attributes). In the case of the pond complex it was not a difference in site but a choice between the number of ponds being improved (1 or 50).

We selected attributes and visual materials in light of the three objectives of the WFD: water quality, hydromorpholgy and biological quality of the water bodies. Previous research has shown that bio-physical water quality indicators may be hard to understand for the general public and result in insignificant parameter estimates (Hanley et al., 2006). They found that virtually everyone in the test public felt unable to judge the water status except at some superficial level by how it looks and smells, and unable to value fine differences in status or the reasons why status had changed. On the basis of this evidence, it was decided that a very simple metric of ecological status was needed although it needs to be linked to scientific measures of this ecological status. We based ourselves on the classes used by the Flemish Environmental Agency (VMM) on water quality and biological index and divided these in simple three-level classes: mean, good and very good.

The different classes were explained by using text, pictures and illustrations. The use of the illustration was proposed as a way of helping respondents construct a value for an unfamiliar and complex good. An alternative that was considered at an early stage, and rejected, was to use photographs of water bodies at different status levels. Certain important aspects were not visible in photographs, while other things appear in photos that lead to a biased interpretation, e.g. the nature of the weather in the photos. A large part of the illustrations were tested on coherence with other materials and for their overall usefulness. The descriptions were also successively improved in terms of their scientific accuracy through several iterations with the Flemish administrations.

The unit adopted to measure the "quantity" of each status level is river stretch expressed in kilometres of river for rivers, and hectares of surface water area for the ponds. For the latter also the number of ponds was indicated. Maps indicating the location of the rivers and the location of the pond system under consideration in the surveys were included in the surveys.

It is critical that the payment vehicle be something respondents think they would actually have to pay and could not avoid. This is so that they give answers which reveal their true valuations. At the same time, the payment vehicle must be realistic in the sense that respondents will see that the valued goods could lead to costs being recovered through the payment vehicle suggested. Also, the payment vehicle needs to allow that other groups will also (if true) be paying, so that household respondents do not give answers based on fairness concerns instead of their own benefit values. The payment vehicle adopted for the CE is the water bill taxes. Adopting water bill taxes was considered due to its desirable properties of universal coverage and clear necessity of payment.

Respondents are asked to choose between two alternative scenarios which are described using 5 attributes. The 5 attributes for the pond case are the measure improving the sides/banks of the ponds, water quality improvement, species richness, presence of walking/biking trails and a cost attribute. The simplified levels of these attributes are found in table 1. The cost attribute is a raise in the water tax going from 10€/household.year to 200€/household.year divided in 6 levels. The 5 attributes for the river case are the measure improving the natural running of the river, water quality, species richness, length and location of the improvement and a cost attribute. The simplified levels are found in table 2. The cost attribute is a raise in the water tax going from 10€/household.year to 200€/household.year divided in 6 levels.

In the pond case respondents could choose between quality improvements in one pond or in 50 ponds to be able to aggregate changes in different ponds and to see if this is linear or not. In the river case we let the respondents chose between quality improvements in the Nete or in the Demer, to be able to investigate how substitute rivers influence the value people attach to quality improvements in one river.

Table VII - Attributes and levels of Pond complex Midden-Limburg

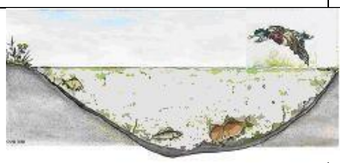
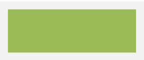
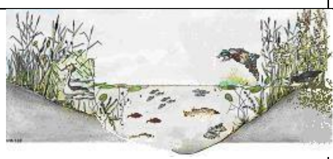
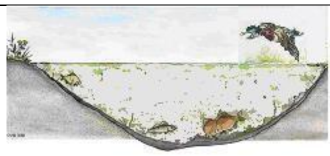
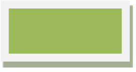
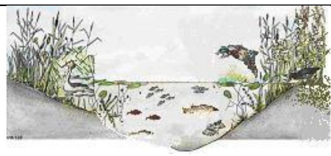
Attribute name	Natural look	Water quality	Species richness	Recreation
				No trails
				Limited access via walking trails
				Good access via walking and biking trails

Table VIII - Attributes and levels river Grote Nete/Demer

Attribute name	Natural look	Water quality	Species richness	Location/length
				Demer: Werchter Aarschot (15 km) Nete: Herenthout-Westerlo (20 km)
				Demer: Aarschot-Diest (20 km) Nete: Westerlo-Geel (15 km)
				Demer: Werchter-Diest (35 km) Nete: Herenthout-Geel (35 km)
				

2.2.3.2 Results

Case Pond complex Midden-Limburg

The survey was send out through a panel of survey company IVOX. It was send out to ad random households in a 50-km range of the case study location. The representativeness of the socio-demographics was guarded by the company. In total and after data-cleaning 533 respondents were kept in the analysis. The respondents are relatively representative for the Flemish population as table VIII shows. A majority of the respondents visits open water for recreation (Table IX). 77% of the respondents never visited the study site.

Table IX - socio-demographic information respondents pond case (missing % are caused by non-replied questions)

		Survey	Flanders
Gender	Man:	51%	49%
	female:	48%	51%
Age	18 tot 29	14%	22%
	30 to 64	69%	57%
	>= 65	15%	21%
Household size	1:	17%	12%
	≥ 2:	82%	88%
Education	Primary school	7%	39%
	Secundary school	50%	33%

	Higher education (bachelor/master) (bachelor/master)	43%	27%
Household income	<€750	2%	19%
(monthly net income)	€750-1500	23%	32%
	€1500-€2500	30%	21%
	€2500-€3000	12%	10%
	€3000-€4000	22%	7%
	>4000	11%	10%
Job status	Active	58%	66%
	Non active	42%	34%

Analysis of the results was done with LIMDEP, NLOGIT 4.0, using the nominal logit model with error components. All parameters were significant in the 1% and 5% level. Based on the parameters of the utility model the willingness to pay can be estimated. Table X presents the results of the final model, which leads to two important findings. First, the results show a willingness to pay for improvements in the ponds: water quality was valued highest, followed by accessibility and species richness. Strangely, respondents preferred intermediate accessibility (meaning few walking trails) over maximum accessibility (walking and biking trails). Second, the results suggest that the number of ponds is not that important (not significant). Meaning that the same improvement in 50 ponds is not 50 times more valuable than the improvement in one pond. People with higher incomes want more for their income and would invest in more improved ponds. We also find a strong distance decay meaning that respondents living further away from the ponds are willing to pay less than people living close by.

Table X - final logitmodel and marginal WTP case Pond complex Midden-Limburg

	parameter	standard error	marginale BTB
raise in watertax	-0,01241	0,000549	
semi-natural banks	0,130756	0,069664	10,54 €
natural banks	0,127817	0,073386	10,30 €
Average accessibility	0,310595	0,072162	25,03 €
good accessibility	0,24193	0,076583	19,50 €
average speciesrichness	0,228804	0,06757	18,44 €
good speciesrichness	0,301804	0,081745	24,32 €
good water quality	0,635002	0,073593	51,18 €
very good water quality	0,720065	0,078676	58,03 €
income	0,000214	0,335524E-04	0,02 €
Member of a nature organisation	0,848632	0,125448	68,39 €
income linked with size	5,10E-06	0,681458E-06	0,00041 €
log of the distance between home and ponds	-0,15035	0,029006	- 12,12 €

gender	0,148913	0,084595	12,00 €

Case Nete/Demer

768 complete surveys were collected (Table XI). These were quite representative for the Flemish population.

Table XI - socio-demographic information respondents Nete-case

		Survey	Flanders
Gender	Man:	52%	49%
	Female:	47%	51%
Age	18 tot 29	13%	22%
	30 to 64	70%	57%
	>= 65	12%	21%
Household size	1:	17%	12%
	≥ 2:	79%	88%
Education	Primary school	5%	39%
	Secundary school	47%	33%
	Higher education (bachelor/master) (bachelor/master)	47%	27%
Household income	<€750	2%	19%
(monthly net income)	€750-1500	19%	32%
	€1500-€2500	37%	21%
	€2500-€3000	14%	10%
	€3000-€4000	17%	7%
	>4000	10%	10%
Job status	Active	66%	66%
	Non active	34%	34%
Member nature organisation		19%	8,1%

Only 10% of the respondents always chooses the status quo meaning that a large group has an interest in the suggested scenarios within the proposed price range. Even for small changes in comparison with the status quo more than 50% of the respondents were willing to pay for the proposed scenarios.

62% of the respondents chose for a scenario that costs 75€ or more. 92% of the respondents did not have a specific preference for one river above the other river. This means that they were seen as good substitutes for each other.

A logitmodel was used to estimate the marginal willingness to pay for the attributes in the scenarios (Table XII).

Table XII - logitmodel and marginal willingness to pay
(log likelihood: -4158,229; number of obsservations: 4608)

	parameter	standard error	marginale BTB (in € per household per year)
raise in watertax	-0,01257849	0,00043996	
change from average to good water quality	0,35172148	0,09745731	27,96
change from average to very good waterquality	0,97745426	0,17093047	77,71
SIZE of the riverstretch	0,00577549	0,00219419	0,46
change from bad to average speciesrichness	0,80950417	0,15520418	64,36
change from bad to good speciesrichness	1,40492937	0,14920488	111,69
shortest distance from home to the river	-0,02746895	0,00275892	-2,18
distance to the nearest substitute river	0,02806371	0,00277151	2,23
age linked with waterquality	-0,00701736	0,00291366	-0,56
age linked with size	1,83E-05	7,84759E-06	0,00146
income linked with good waterquality	0,00014084	3,62051E-05	0,0112
income linked with very good waterquality	0,00013845	3,8173E-05	0,0110
age linked with average speciesrichness1	-0,00801204	0,00309855	-0,64
age linked with good species richniess	-0,01578085	0,00301094	-1,25
member of nature organisation minked with green banks	0,80417964	0,13514334	63,93
member linked with medium restauartion of the riverflow	0,99953851	0,1335374	79,46
member linked with « room for river »scenario	1,31555425	0,13211064	104,59

We observe spatially explicit information as people who live further away from the river are willing to pay less for improvements than people who live nearby (KMKORT). Also the substitution effect plays: the further away people live from a substitute river the more they prefer the changes in one of the rivers in the choice

experiment, but both Nete and Demer have also an influence on each other as they were perceived as good substitutes for each other (SUBS).
The respondents have a high preference for species richness (SPMED and SPECG) and water quality (QG and QVG) but don’t really have a preference in how these quality improvements are reached. Members of a nature organization, however, do take into account the measure to reach the quality improvements. They prefer the space to the river-scenario (MEMNAT) above the greening of banks (MEMBAN) or the reconnection of old meanders (MEMOG). Respondents with a high income are putting more weight on the water quality improvements. Older people are already pleased with a good quality and prefer a very good quality less than younger people. They also value species richness less than younger people.

2.2.4 Aggregation of the different services: double-counting issue

The conceptual models developed in Chapter 2.1 show the interactions between different ecosystem processes and different services (biophysical relations). The models allow ES to be accounted for without double-counting. The valuation results for the pond case are linked with the ecosystem processes and delivery of services in the developed Bayesian Belief network (Chapter 2.3.4). We were therefore able to again look into the value of different scenarios for the pond complex and link the valuation results and calculations of the Environmental Cost Model “water” specific for the pond complex (Table XIII).

Provisioning services

The possibility of fish production in the ponds could have a large benefit of 68,2 to 3.470 €/ha.year depending on which management regime is followed.

Regulating services

As the ponds interact with a stream, they are able to remove nitrogen out of the water and thus regulate water quality in the stream. The N-removal ranges between 3,89 kg to 229 kg N/ha.year depending on management scenario and catchment land use. The value of the N-removal in the region is calculated with the Environmental Cost Model “water” and is estimated to be 5€/kg N. This is quite low because the water quality in the catchment is already good and not so many measures need to be taken to improve it further to reach the water quality goals for N.

Amenity value/cultural value

The maximum amenity value of the ponds needs to be calculated with the value function above. It is very dependent on the factors of shore line complexity, accessibility, water quality and biodiversity level and the distance decay. On average it ranges from 76.100€ to 4.150.000€/ha.year

If we should just add up all the monetised services taking into account the potential flow of ES without accounting for the trade-offs between different ES, a total value of approximately 4.155.000€ was calculated. However, the provisioning function will decrease when N-removal and biodiversity rate increase. In the Bayesian belief network the trade-offs are accounted what leads to the following values for different scenarios:

Table XIII – Valuation results for the different management scenarios of the pond complex Midden-Limburg

Management	Total economic value (in €/ha.year)
intensive breeding	78.420
extensive breeding	3.260.518
natuur mgt 1 (low stocking of fish)	3.970.740
natuurmgt 3 (no stocking)	4.340.218

This clearly shows that not accounting for the trade-offs would over- or underestimate the total economic value in certain scenarios.

2.2.5 Conclusions

By estimating the economic value of ES in monetary terms we have a common, comparable unit with which to assess trade-offs. This information can then be used to demonstrate the importance of ES: to evaluate different policy interventions, to examine the costs and benefits and how they are distributed across society and so on. In short the primary aim of ecosystem valuation is to be able to make better (more efficient or more cost-effective) decisions regarding the sustainable use and management of ES (More-Jones et al. 2010)

Although spatial explicitness is very important, only few valuation studies accounted for this. The results of the valuation studies provide insight in the spatial distribution of WTP values for environmental quality changes under the Water Framework Directive. It shows that policy makers should be careful in the unconditional use of values from a single-site study as quality improvements could be site-specific and depend on changes at other water bodies nearby.

Also the distance decay analysis shows that the population over which individual WTP can be aggregated to calculate the total WTP for policy scenarios will not always be equal to an administrative unit. The distance decay estimates are dependent on the physical context including the availability of substitutes.

The results also show that one should be very cautious in using average units/ha, as the cases show that this will not be necessary linear for some ES. e.g. The amenity value of the pond complex Midden-Limburg shows that the WTP for 50 ponds is not 50 times higher than the WTP for one pond. This is also found in the case of the

Nete: as the stretch of river becomes larger, the WTP will increase. The effect is very small. If we compare improvements in a stretch of 15km with improvements in a stretch of 35 km and combine this with the distance decay we see that although the length of river that improves more than doubles, the total value only increases with 17%.

The case of the pond complex Midden-Limburg clearly illustrates the importance of knowledge on the trade-offs between different ES when making an analysis of different management options. Off course these values are not the only aspect taken under consideration by policy makers. One should also clearly map the beneficiaries of the different ES in order to know who gains and who loses in certain management scenarios.

2.3 BAYESIAN NETWORK MODELS

2.3.1 Basics and applicability of Bayesian modeling

Quantitative and qualitative research on ES is an emerging topic in scientific research. This has led to the development of a range of ES models varying from basic qualitative models to complex mechanistic models which enable quantification of ES (Haines-Young, 2011; Kareiva et al., 2011; Kremen, 2005). Recent introduction of Bayesian belief networks (BBNs) in ES modeling has led to an intermediate approach between both methods. Their applicability in ES research is promising because of their high transparency, their implicit treatment of uncertainties, their suitability for participatory model development and the possibilities they offer for integrating multi-disciplinary, quantitative and qualitative data and knowledge (Bashari et al., 2008).

Few examples applying Bayesian belief networks in ES modeling exist (Ames et al. 2005; Molina et al. 2009; Bagstad et al. 2011; Haines-Young 2011). The majority concern ES that can be measured easily. The inability to measure services blocks the possibility to train or validate the model with data thus reduces validation possibilities for example to only expert evaluation and sensitivity analysis. Also, modeling of multiple ES and visualization of trade-offs is still rare in current BBN applications. In the next chapter, we will illustrate Bayesian model development, application and results as conducted in case studies from the ECOFRESH-project and evaluate its applicability in ecosystem service modeling through a SWOT analysis. For a detailed analysis of the general applicability of BBN in ES research we refer to the review of Landuyt et al. (2013) which has been written during the project and submitted to the journal ‘Environmental Modelling and Software’.

2.3.2 Methodologies for model development

The applicability of BBNs in modeling the provision of multiple ES on different spatial scales was explored based on the two cases “pond complex Midden-Limburg” (scale of the single pond) and “Grote Nete” (catchment scale). The pond-case focusses on how management interactions can optimize the services it provides. For the river-case the scale is enlarged from system level to landscape level and service provision is maximized through land use optimization taking into account the local provisioning potential. When required, specificities of the two case studies will be addressed separately below.

In general, model development was based on Marcot et al. (2006) and Smith et al. (2007). Firstly, an influence diagram was constructed. Secondly, the developed causal network was converted into a Bayesian network in Netica (Norsys 1998).

2.3.2.1 Influence Diagram

Pond complex Midden-Limburg

For the pond complex Midden-Limburg, an influence diagram describing service provision of a single pond was composed (Figure 10a). First, a causal network of the system functioning was constructed based on expert knowledge from KUL including manageable or precondition variables (V1 to V3), variables of system functioning and ecological processes (V4 to V9) and a number of services (ES1 to ES3) (Marcot et al., 2001; Bashari et al., 2008). Six services were included in the final diagram: carbon sequestration, N-removal, nutrient retention, recreation, water retention and fish production. The spatial and temporal scales considered were respectively 1 ha (approximately the size of one pond) and 1 year. Then a management scenario variable (M1) was added influencing the manageable variables in the scheme and enabling a scenario analysis of the system. Finally, monetary valuation was used to deduct comparable values for evaluating provision of the ES and for combining these into a single ecosystem service bundle index (EBI) value. The final BBN can consequently allow for a comparison of the total monetary value of the system under the three scenarios and could allow a management optimization for the pond.

Grote Nete

The influence diagram for the Nete basin schematizes delivery of a bundle of services taking into account biophysical potential of the ecosystem and actual land use (Figure 10b). Soil and hydrological characteristics were used as biophysical variables (BV1 to BV3) and known feasibility models were used to evaluate ES provision potential: the expert based evaluation of agricultural suitability for the province of Antwerp (Provincie Antwerpen 1998), the soil suitability for trees (‘BOBO’ BOdemgeschiktheid voor BOsbomen, Devos 2000) and the modeled SOC estimates by Meersmans et al. (2008). Combination of these service potential indicators (P1 to

P3) with land use variables (LU) allowed to generate actual service delivery indicators (ES1 to ES3). The three services modeled in the BBN are food production, wood production and climate regulation, considered as long-term storage of organic carbon in the soil (SOC). Consequently, suboptimal service provision can be attributed both to suboptimal biophysical potential or suboptimal land use. At the end all separate service delivery indicators are combined into a single ES bundle index (EBI) to allow an integrated evaluation of multiple service delivery. Attribute values of geographical data layers will be used as inputs to the operational model (Smith et al., 2007).

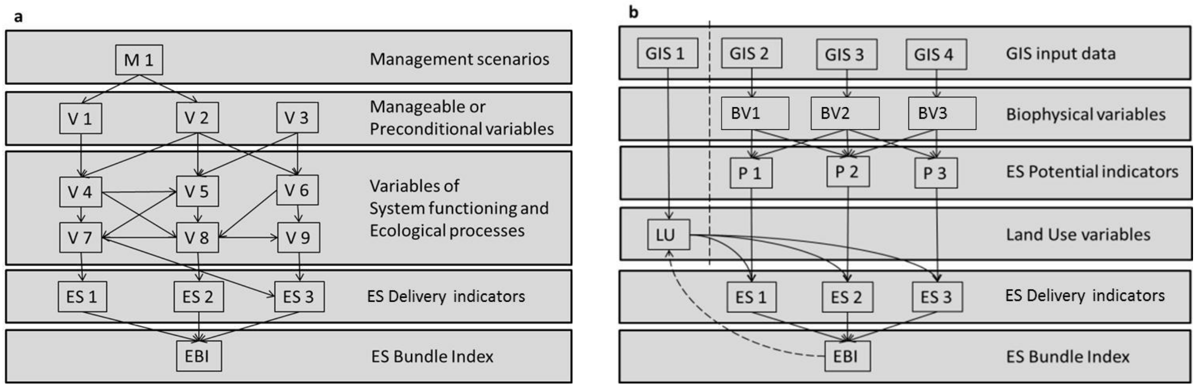


Figure 10 - Schematical influence diagrams for the provision of multiple ES for a single pond from the case study the pond complex Midden-Limburg (a) and on landscape scale from the case study the Nete basin (b). The full lines indicate how the actual ES bundle (EBI) provision value is determined based on the selection of a management scenario (a) or based on geographical data of the input variables (b). The dashed lines illustrate how the optimal land uses are selected based on the maximal attainable SB value under certain biophysical conditions,

2.3.2.2 Operational model

For converting the conceptual model into an operational BBN, variables and their states were defined and conditional probability tables (CPT) of non-input variables were populated with knowledge rules. In order to avoid too strong dependence on expert judgment for populating CPTs, quantitative and qualitative data sources from literature were applied to operationalize submodels when available.

<u>Pond complex Midden-Limburg</u>

Equations selected from literature or deducted from KUL data from the Pond complex Midden-Limburg were used to populate the CPTs in the Pond complex Midden-Limburg' influence diagram for the submodels fish production (Lemmens et al. 2012) and nitrogen removal (Ramseyer 2002), see Table XIV; Figure 11. The CPTs of remaining variables were populated based on expert judgment from the partners from KUL, VITO and UGent.

The submodel for yearly fish production (FP) in the pond uses fish stocking (FS), the availability of additional feeding (AF) and the likelihood of cormorant predation (C) as determining variables. Assigning numerical values to the variables' states allows for applying these in further calculations such as the net gain in total fish mass (FP_G). Fish stockings were assumed to increase ten-fold for all functional fish groups with additional feeding and to double without. Local fish breeders estimate that the presence of cormorants causes a reduction in fish production of 80% for planktivores and 15% for benthivores and piscivores (Table XIV).

The actual N concentration (NC) in the pond is determined by the N concentration in the inflow (NCO), purification of the incoming water (P) as well as additional feeding (AF) as a N source and is based on expert judgment of KUL (Table XIV). Nitrogen removal in the system is modeled through the Seitzinger formula for denitrification (Deni) used in the natuurwaardeverkenner (VITO), taking into account pond depth (PD) and the retention time (RT) in the pond, which results in the outflow N concentration (NCO). Also N removal through assimilation in the fish biomass is included, assuming a whole-fish N content of 2,6% (Ramseyer, 2002).

Five relevant management scenarios were considered in the scenario analysis: intensive breeding, extensive breeding and 3 variants of nature-oriented management. According to these management scenarios it is determined what is the level of shoreline complexity (SC) around the pond, the initial stocking of benthivorous (FS_b), planktivorous (FS_pl) and piscivorous (FS_pi) fish and whether or not additional feeding (AF) is provided to the fish (Figure 11).

Table XIV - The variables and their relationships, states and units applied in the fish production and nitrogen removal submodels.

Variable (Title)	Parents or Formula	Unit	States [values]			
Submodel Fish production						
Management Scenario (MSc)	-	-	Intensive Breeding, Extensive Breeding, Nature Management 1, Nature Management 2, Nature Management 3			
Fish Stocking Benthivores (FS_b)	MSc	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-30]	Moderate [30-80]	High [80-100]
Fish Stocking Planktivores (FS_pl)	MSc	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-30]	Moderate [30-80]	High [80-100]
Fish Stocking Piscivores (FS_pi)	MSc	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-20]	High [20-40]	
Additional feeding (AF)	MSc	-	Yes [1]	No [0]		
Cormorants (C)	N, FS_B, FS_pl, FS_pi	-	Yes [1]	No [1]		
Nets (N)	-	-	Yes	No		
Fish Produced Benthivores (FP_b)	FP_b = (1-0.15*C)*(2*FS_b + 8*AF*FS_b)	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-200]	Moderate [200-500]	High [500-1000]
Fish Produced Planktivores (FP_pl)	FP_pl = (1-0.8*C)*(2*FS_pl + 8*AF*FS_pl)	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-200]	Moderate [200-500]	High [500-1000]
Fish Produced Piscivores (FP_pi)	FP_pi = (1-0.15*C)*(2*FS_pi + 8*AF*FS_pi)	$kg.ha^{-1}.y^{-1}$	No [0]	Low [0-100]	Moderate [100-400]	
Fish Produced Net Gain (FP_G)	FP_G = FP_b - FS_b + FP_pl - FS_pl + FP_pi - FS_pi	$kg.ha^{-1}.y^{-1}$				
Value Produced Fish (FP_V)	FP_V = 3.5*(FP_b - FS_b) + 4*(FP_pl - FS_pl) + 1*(FP_pi - FS_pi)	$€.ha^{-1}.y^{-1}$				
Cost Additional Feeding (AF_C)	AF_C = -0.75*AF*1.4*FP_G	$€.ha^{-1}.y^{-2}$				
Submodel Nitrogen removal						
Catchment LandUse (LU)	-	-	Intensive	Extensive	Pristine	
Purification (P)	-	-	Yes	No		
Nitrogen Concentration IN (NCI)	LU	$mg.l^{-1}$	Low [0.001-0.5]	Intermediate [0.5-2]	High [2-15]	
Nitrogen Concentration (NC)	NCI, P, AF	$mg.l^{-1}$	Low [0.001-0.5]	Intermediate [0.5-2]	High [2-15]	
Pond Depth (PD)	-	m	Shallow [0.4-1.2]	Deep [1.2-1.8]		
Retention Time (RT)	-	y	Short [0.02-0.35]	Moderate [0.35-0.67]	Long [0.67-1]	
Denitrification (Deni)	Deni = 88*(PD/RT)^(-0.368)	%				
Nitrogen concentration OUT (NCO)	NCO = NC*(100-Deni)/100	$mg.l^{-1}$	Low [0.001-0.5]	Intermediate [0.5-2]	High [2-15]	
N Change (N_ch)	N_ch = PD*10*(NCO - NCI)/RT - FP_G*0.026	$kgN.y^{-1}$				
Value N Change (V_N_Ch)	V_N_ch = -5* N_ch	$€.ha^{-1}.y^{-1}$				

Subsequently, costs and benefits were included in the model by monetary valuation of the fish production, nitrogen removal and recreation as well as identification of management costs. This enabled a cost-benefit analysis of the 5 management scenarios.

The net production of benthivorous, planktivorous and piscivorous fish was considered to yield respectively €3,5 .kg-1, €4 .kg.-1 and €1 .kg-1 and a value or cost of €5 per removed respectively added kg N.ha-1.y-1 was applied (KUL, VITO). We included costs for the placement of nets against cormorants (€100) and general maintenance costs for the different management scenarios. The costs for additional feeding assumed a net gain of 1 kg fish mass per 1,4 kg food at a price of €0,75 .kg-1 (Table XIV).

Recreation is more difficult to quantify as it is mostly a qualitative appreciation of various characteristics of the pond. One of the main advantages of BBNs is their straightforward way of handling this qualitative evaluation. The pond’s recreational value was expressed as a willingness to pay (WTP) for recreation based on a survey conducted by VITO (Chapter 2.2.3). This survey used biodiversity (BD), water quality (WQ), shoreline complexity (SC) and accessibility (a) of the pond as the main determining factors for recreation and resulted in a weighed WTP-formula which was included in the model:

WTP = €1,302,195*SC[intermediate] + €1,272,544*SC[high] + €3,092,406*A[intermediate] + €2,409,186*A[high] + €3,004,687*BD[high] + €2,278,225*BD[intermediate] + €7,169,490*WQ[high] + €6,323,186*WQ[intermediate] - €7,615,194

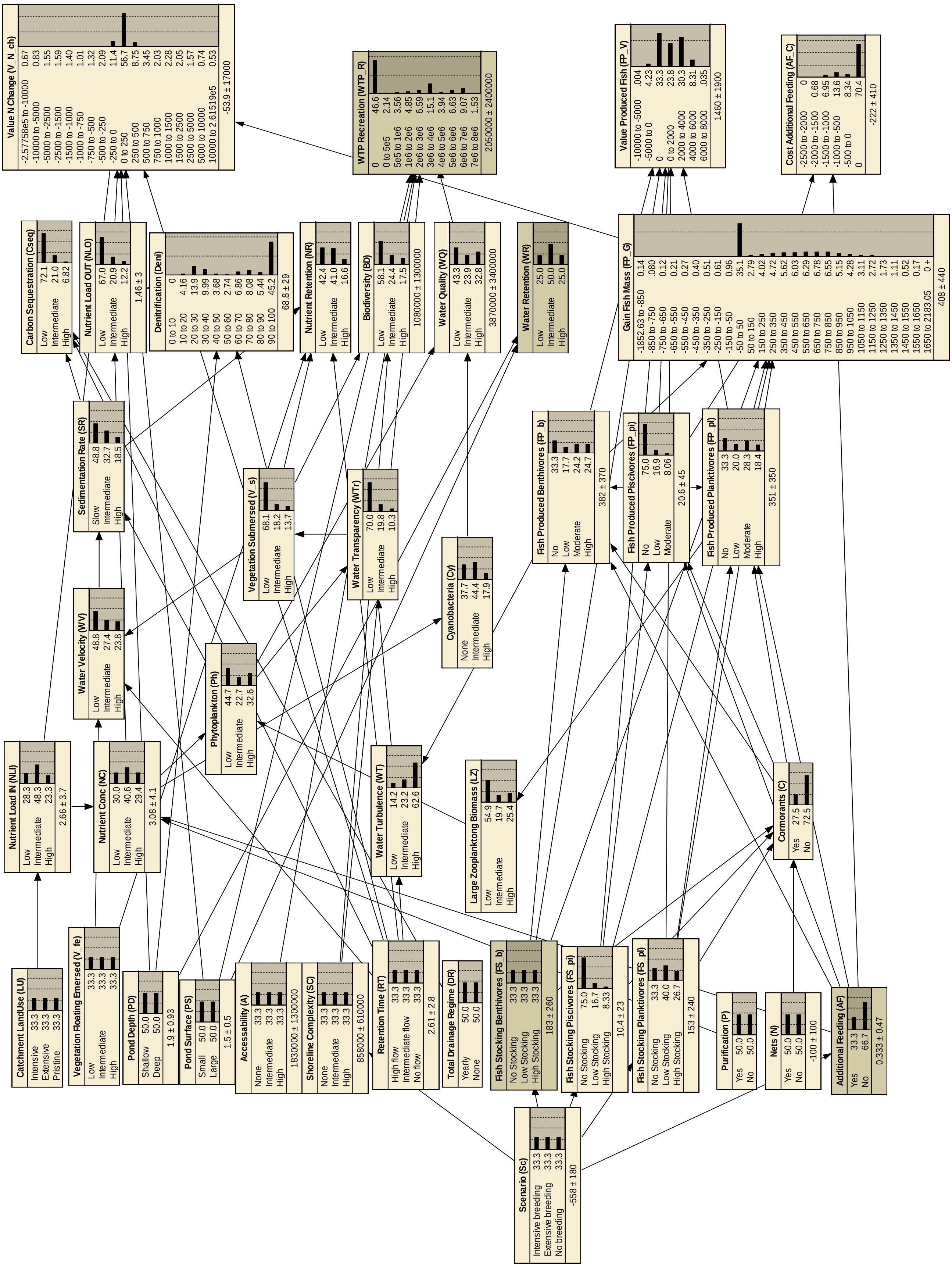


Figure 11 - Bayesian net for the valuation of ecosystem services provision by a pond system in the pond complex Midden-Limburg.

Grote Nete

Four input variables run the service provision model of the Nete basin: soil texture (ST), drainage class (DC), soil profile development (PD) and land use class (LU). Each of these variables was represented in a GIS layer derived from the Belgian national soil classification system (ST and PD) (GIS-Vlaanderen 2001), from the digital elevation model (DC) (MVG 2011) or from the classification system as proposed by Van Esch et al. (2011) (LU). For each of the modeled ecosystem services, a reclassification of the 37 land use classes of Van Esch et al. (2011) was carried out so that each class corresponds to a certain degree of service delivery (Figure 12). As all input variables and derived services were considered spatially independent relationships between adjacent pixels were omitted.
Submodels for biophysical potential of food and wood production provide 17 levels of agricultural potential (P_a (Provincie Antwerpen 1998)) and 5 levels of forest potential (P_f (De Vos 2000)). The submodel that quantifies the amount of organic carbon stored in the soil (SOC) is derived from a large-scale study conducted by Meersmans et al. (2008) and complemented with data from Post et al. (1982) and Adhikari et al. (2009) for the land use class ‘wetland’ which was not considered a separate class in Meersmans’ research. It does not strictly follow the model structure proposed in Figure 10 as SOC storage potential and land use were both internalized into their analysis. The results were divided into 6 classes from 0 (no storage) to 5 (very high storage). Knowledge rules for populating the CPTs for the nodes food production and wood production were based on expert judgment (see Annex 1) and scaled from 0 (no production) to 5 (very high production). All relationships in the BBN are deterministic, so no uncertainty is included in the CPTs of the model

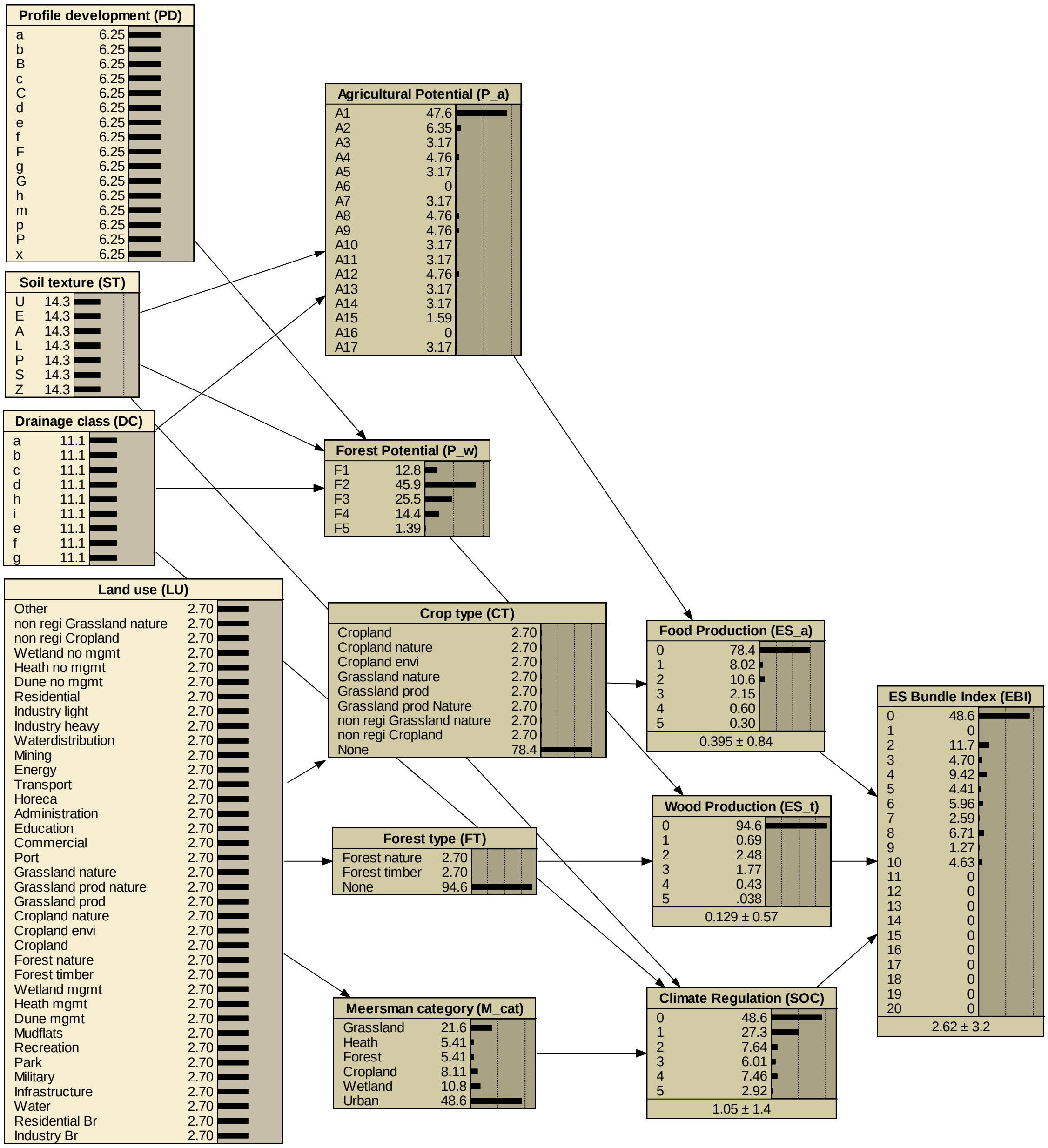


Figure 12 - Bayesian net for the provision of three ES and the ES Bundle in the Nete basin

The ES Bundle indicator (EBI) was calculated from the scores of food production (ES_a), wood production (ES_w) and climate regulation (SOC) using the equation:

$$EBI = F1 * ES\_a + F2 * ES\_w + F3 * SOC \qquad (1)$$

The factors Fx in equation 1 allow for weighing the relative importance of the three services in the service bundle indicator. For this theoretical pilot case, weighing was performed so that a proportional distribution of land use types was achieved, without considering societal demand factors or stakeholder involvement. Therefore, a double weight needed to be assigned to carbon storage (F1 = F2 = 1; F3 = 2).

This network combined GIS data-layers of attributes (bio-physical as well as land use) responsible for the delivery of ecosystem services in an indicator score for each ecosystem service. All causal relations concerning biophysical potential of the ecosystem services and effective carbon storage were extracted from existing models. Final CPTs combining land use and potential for food and wood production were based on expert judgment (Annex 1 - Tables A.6, A.7).

This model was then spatially applied on a 100m pixel basis. The attribute values of each pixel were thus used as cases to set the probability distributions of the input nodes of the model. For each pixel, the ecosystem service score was calculated through Bayesian inference. Finally, subsequent mapping of the model output enabled a visual validation of the models performance. Criteria used are appearance of gradients versus randomly scattered values, presence of illogical predictions such as wetland on dry sandy dunes. In a stepwise procedure, the model was improved to represent the reality on the field.

2.3.3 Methodologies for model applications

2.3.3.1 Pond complex Midden-Limburg

The main objective of pond complex model is to enable an integrated analysis of the five management scenarios for the pond system based on their levels of provision of the three services. The realized land use in this case is unchangeable so only certain manageable conditions or external influences on the system can be altered. First a sensitivity analysis was conducted on the operational model using the Netica software and according the method described in Bashari et al. (2008). The results of the sensitivity analysis were then presented to the study area experts from KUL and illogical dependencies in the model were revised. Subsequently, the model predictions of service provision for each management scenario were listed together with related costs and a cost-benefit analysis was performed.

2.3.3.2 Grote Nete

The Grote Nete model operates on a larger spatial scale and enables analysis of service provision of the landscape under the realized land use or land use optimization exercises to maximize the levels of service provision. In this model the local biophysical potential to deliver a certain service is of key importance.

The operational model was first applied to analyze trade-offs in provision of the three services. Therefore, a case file was simulated in Netica listing all possible state combinations of the four input variables (37.296 cases). Processing the case file and generating for each case the mean expected value of the three ecosystem service delivery indicators (food production, wood production and climate regulation) resulted in an output file containing all co-occurring levels of provision of the three services. Selecting only the combinations actually occurring in the study area allowed visualization of trade-offs between the three considered ecosystem services.

Secondly, for all state combinations of the three input variables for biophysical conditions the maximum achievable level of service provision was deducted together with a set of optimal land uses, yielding 1.008 state combinations of the four variables. Based on the GIS input data of biophysical conditions as well as actual land use of the study area, the actual, possibly sub-optimal, ecosystem service bundle index (EBI_{act}) was calculated for each pixel. Also the potential ecosystem service bundle index (EBI_{pot}) was calculated for each pixel based solely on the biophysical data and assuming an optimal land use class (Figure 10). The difference between actual and optimal EBI can then be calculated:

$$EBI_{diff} = EBI_{pot} - EBI_{act} \quad (2)$$

Mapping EBI_{diff} values for the whole study site highlighted areas with a strong discrepancy between actual and potential service bundle provision and thus opportunities for service delivery improvement. Optimal land use options were derived from the earlier developed optimal land use set.

2.3.4 Results – Pond complex Midden-Limburg

2.3.4.1 Cost-benefit analysis

For each of the three ecosystem services valuated in the BBN an exemplary result of the cost-benefit analysis for the five management scenarios is given below. The effect of a second input variable on the level of service provision was also elaborated in the examples. This second variable was selected either as the input variable having the strongest influence on the service as observed in the sensitivity analysis or as the input variable with a cost related to it.

In the submodel for fish production net gain in fish mass is considered a measure for the level of service provision (Figure 11). A monetary valuation of this service results in the value of fish produced minus the cost of fish stocking (Table XIV). Related costs are the cost of additional feeding and the cost for installing nets against cormorants in the pond. The intensive breeding scenario clearly offers the highest gain in fish mass and the highest profit (Table XV). Additional feeding is always provided under this scenario but the costs therefore are easily recovered, just as the small additional cost for installing nets. As cormorant predation only plays an important role at high levels of fish stocking, nets do not influence the provision levels for the extensive breeding or nature management scenarios. Increased predation at higher stockings also explains the lower net fish production under the extensive breeding scenario than under the nature management 1 scenario (Table XV). A list of fish stocking related to the different management scenario is available in Annex 1, Tables A.2 to A.4.

For the submodel for nitrogen (N) removal in the pond the effects of the management scenarios as well as the effect of the surrounding land use on the amount of N removed or added to the water flow are investigated (Table XVI). For ponds surrounded by intensely managed land the N inflow is relatively high (Figure 11) and all management scenarios result in a removal of N from the system. This removal however is smaller under intensive breeding, due to N being added to the system via additional feeding (Table XVI, Annex 1 - Table A.5). For extensive or pristine catchment land use additional N inflow via feeding outweighs N removal from the pond and intensive breeding results in added N in the water flow (Table XVI). As N removal through fish biomass is included in the model as a removal mechanism next to denitrification (Table XIV), the extensive and nature management 1 scenarios cause a stronger reduction of nitrogen from the system than the scenarios with very little fish production nature management 2 and 3 (Table XVI).

Table XV - Cost-benefit analysis of the input variables 'management scenario' and '(installment of) nets' (both depicted in grey) on the gain in produced fish mass, the value of produced fish and the cost of additional feeding of a pond system in Midden-Limburg. For continuous variables 'expval' is the expected mean score (a mean value weighed on the probabilities of the different states) and 'mostprob' is the state with the highest predicted probability (% depicted between brackets).

Management Scenario	Nets	Fish Produced Net gain ($kg.ha^{-1}.y^{-1}$)		Value Fish Produced (€$.ha^{-1}.y^{-1}$)		Cost Additional Feeding (€$.ha^{-1}.y^{-1}$)	
		expval	mostprob	expval	mostprob	expval	mostprob
Intensive breeding	Yes (-100 €$.ha^{-1}.y^{-1}$)	1320	1200 to 1600 (61.8%)	4960	4000 to 5000 (40.4%)	-1390	-1500 to -1000 (52.8%)
Intensive breeding	No (0 €$.ha^{-1}.y^{-1}$)	738	600 to 800 (36.7%)	2520	2000 to 3000 (53.4%)	-792	-1000 to -500 (64.7%)
Extensive breeding	-	128	100 to 200 (40.2%)	360	0 to 500 (51.3%)	0	0 (100%)
Nature management 1	-	163	100 to 200 (43.2%)	579	500 to 1000 (44.7%)	0	0 (100%)
Nature management 2	-	89.2	100 to 200 (32.2%)	332	0 to 500 (41.5%)	0	0 (100%)
Nature management 3	-	17.6	0 (82.5%)	68.2	0 (81.0%)	0	0 (100%)

Table XVI - Cost-benefit analysis of the input variables 'management scenario' and 'catchment land use' (both depicted in grey) on the change of nitrogen (N) amount and the related cost or value of a pond system in Midden-Limburg. For continuous variables 'expval' is the expected mean score (a mean value weighed on the probabilities of the different states) and 'mostprob' is the state with the highest predicted probability (% depicted between brackets)

Catchment Land Use	Management Scenario	N change (kgN/ha.y)		Value N change (€/ha.y)	
		expval	mostprob	expval	mostprob
Intensive	Intensive breeding	-64.6	-80 to -40 (14.6%)	323	200 to 400 (14.6%)
"	Extensive breeding	-230	-40 to 0 (26.5%)	1150	0 to 200 (26.5%)
"	Nature management 1	-231	-40 to 0 (26.2%)	1150	0 to 200 (26.2%)
"	Nature management 2	-229	-40 to 0 (26.7%)	1140	0 to 200 (26.7%)
"	Nature management 3	-225	-40 to 0 (27.1%)	1130	0 to 200 (27.1%)
Extensive	Intensive breeding	231	-40 to 0 (32.2%)	-1150	0 to 200 (32.2%)
"	Extensive breeding	-31.5	-40 to 0 (68.7%)	158	0 to 200 (68.7%)
"	Nature management 1	-32.1	-40 to 0 (68.5%)	161	0 to 200 (68.5%)
"	Nature management 2	-30.9	-40 to 0 (68.8%)	154	0 to 200 (68.8%)
"	Nature management 3	-30	-40 to 0 (69.0%)	150	0 to 200 (69.0%)
Pristine	Intensive breeding	191	-40 to 0 (46.2%)	-953	0 to 200 (46.2%)
"	Extensive breeding	-10.4	-40 to 0 (68.4%)	51.9	0 to 200 (68.4%)
"	Nature management 1	-11.9	-40 to 0 (71.8%)	59.7	0 to 200 (71.8%)
"	Nature management 2	-8.25	-40 to 0 (63.5%)	41.2	0 to 200 (63.5%)
"	Nature management 3	-3.89	-40 to 0 (53.3%)	19.4	0 to 200 (53.3%)

Table XVII - Cost-benefit analysis of the input variables 'management scenario' and 'accessibility' (both depicted in grey) on the willingness to pay (WTP) for recreation and the variables influencing this WTP 'shoreline complexity', 'biodiversity' and 'water quality'. For continuous variables 'expval' is the expected mean score (a mean value weighed on the probabilities of the different states) and 'mostprob' is the state with the highest predicted probability (% depicted between brackets).

Management Scenario	Shoreline Complexity mostprob	Biodiversity mostprob	Water Quality mostprob	Accessability	WTP for Recreation (€.ha^{-1}.y^{-1}) expval	WTP for Recreation mostprob
Intensive breeding	None (80%)	Low (86.5%)	Low (75.4%)	None	76,100	0 (93.7%)
"	"	"	"	Intermediate	602,000	0 (75.2%)
"	"	"	"	High	509,000	0 (75.2%)
Extensive breeding	Intermediate (70%)	Low (58.8%)	High (46.0%)	None	1,160,000	0 (36.3%)
"	"	"	"	Intermediate	3,260,000	3e^6 to 4e^6 (32.6%)
"	"	"	"	High	2,870,000	0 (27.8%)
Nature management 1	High (80%)	Intermediate (41.4%)	High (46.4%)	None	1,740,000	3e^6 to 4e^6 (34.2%)
"	"	"	"	Intermediate	3,970,000	6e^6 to 7e^6 (41.1%)
"	"	"	"	High	3,530,000	0 (27.3%)
Nature management 2	High (80%)	Intermediate (39.6%)	High (48.1%)	None	1,840,000	3e^6 to 4e^6 (36.4%)
"	"	"	"	Intermediate	4,150,000	6e^6 to 7e^6 (44.5%)
"	"	"	"	High	3,700,000	5e^6 to 6e^6 (25.9%)
Nature management 3	High (80%)	High (37.7%)	High (49.8%)	None	1,940,000	3e^6 to 4e^6 (38.7%)
"	"	"	"	Intermediate	4,340,000	6e^6 to 7e^6 (48.0%)
"	"	"	"	High	3,890,000	5e^6 to 6e^6 (26.8%)

Shoreline complexity is a manageable factor and is thus directly influenced by the management scenarios (Annex 1, Table A.1). Water quality is low at intensely managed ponds but high in the other scenarios, (Table XVII). Biodiversity is only high under the nature management 3 scenario. Although the nature management 1 scenario yields more fish than an extensively managed pond (Table XV), it also sustains a higher level of biodiversity (Table XVI). The highest WTP for recreation is obtained for the three nature-oriented management types with intermediate accessibility.

2.3.4.2 Scale dependency

The constructed Bayesian model is predicting ES of a single pond in a single year for a set of different possible scenarios. This model is a first essential step and can serve as a basis for making predictions on a larger temporal (multiple years) and spatial scale (whole multi pond system). Here, it is important to note that one cannot always make simple inferences based on the single-pond system as ES are not always provided linearly and many systems/functions are nonlinear, show thresholds or limiting functions (Koch et al. 2009). For example, for some ES critical thresholds exist defining the minimum ecologically acceptable amount of ponds in a given region. If wetlands are too small, functions as the support of certain mammals and birds, adequate storage of floodwater against flood events or attracting people for recreational purposes no longer exist. Functions may also level off, for instance the recreational value of a pond complex containing 100 ponds may be almost equal with that of a pond complex containing 200 or more ponds. In this study, the recreational value of a single pond was evaluated based on a survey (Chapter 2.2.3). This survey focused mainly on aspects of biodiversity, water quality, shoreline complexity and accessibility of the pond. Differences in pond densities, however, were only partially (only number of ponds, no aspects of diversity) included and hardly affected the recreational value. Furthermore, the total biodiversity of a pond complex (gamma diversity) does not only depend on the local diversity (alpha diversity) of the ponds, but also on the differentiation between the pond systems (beta diversity). A combination of pond management strategies in a pond complex may thus have a higher total biodiversity compared to a pond complex with only one management strategy. To assess the contribution of betadiversity to the total regional diversity one should not only include taxon richness data, but also taxa identity data.

2.3.4.3 Conclusion

Most ponds are often relatively small, shallow and easy to manipulate. This makes them highly vulnerable for external disturbances (land use changes, management choices) (De Bie et al., 2010). Unlike large lakes and rivers, there is little possibility of dilution or buffering. On the other hand, because of their small size and catchment area, it requires relatively little effort to protect ponds from land derived pollutants and to manage them in a sustainable way.

The results of the case study in Midden-Limburg show that pond management has a strong influence on multiple ES and that the three different nature management scenarios are more cost-beneficial than the scenarios of intensive and extensive breeding. The value of the ES recreation and N reduction is significantly higher in the three nature-oriented management scenarios than in the intensive breeding scenario. Fish production is much higher in the intensive breeding scenario than in all of the other scenarios but the costs of feeding make it a less cost-beneficial alternative compared to the natural scenarios.

2.3.5 Results – Grote Nete

2.3.5.1 Trade-offs in service delivery

Generally we discern three different levels of trade-offs between ecosystem services. First level trade-offs are generated by the biophysical potential of the ecosystem to deliver the different services. Knowledge about first-level trade-offs is essential to avoid unrealistic optimization scenarios (e.g. wetland on dry sandy soils, agricultural land in permanently wet areas,…). Second-level trade-offs refer to the actual delivery within the study area, capturing biophysical potential trade-offs as well as land use based trade-offs. Third-level trade-offs, which concern the final provision to society, depend on demand, accessibility, ecosystem service flow and generation of benefits. For example, a third level trade-off between wood production and climate regulation through SOC sequestration only exists if there is a demand for wood and if it is being extracted. If there is no demand, an optimization of the ES climate regulation would not lead to a decrease in wood production. For the Nete basin case study, the model allows to calculate first and second level trade-offs based on spatially explicit data.

First-level trade-offs

The trade-off between provisioning services food and wood production is described here as an example of first-level trade-offs: as food and wood production potential benefit from similar soil and hydrological processes, they are strongly correlated and demonstrate a first-level synergy in biophysical suitability (Figure 13). Biophysical potential indicates which services would benefit the Land use choices for either forestry or agriculture are governed by societal processes such as judicial status (e.g. nature reserves), local demand (e.g. horse-keeping vs. grassland demand), and traditions rather than biophysical (un)suitability for forestry or agriculture. However, when generalizing this method over larger areas, when including factors such as steep slopes, erosion sensitivity and when including additional services, these first-level service trade-offs are an essential source of information.

Second level trade-offs

Only second-level trade-offs between provisioning and regulating services are considered since land use for provisioning services (agriculture vs. forestry) makes them mutually exclusive in current practices within the study area.
Food production vs. climate regulation
As zero food production represents all land uses other than agriculture, climate regulation logically varies from lowest to highest ranges (Figure 14 left). At very low to low levels of food production, mean values of climate regulation are highest but with a large variation. At medium, high and very high food production levels, climate regulation through SOC sequestration drops invariably to very low values.
Wood production vs. climate regulation
Zero wood production level refers to all non-forest land uses, which again generates a high variability of climate regulation (Figure 14 right). Forests with very low wood production invariably deliver the highest climate regulation. From low towards medium and high wood production levels, mean climate regulation decreases, as well as variability. Note that mean values as well as maximal values remain relatively high compared to food production.

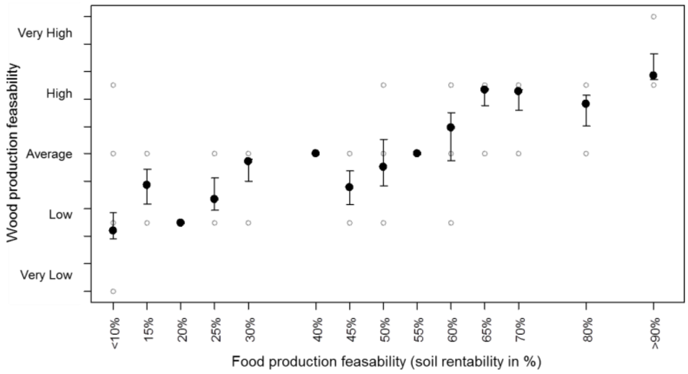


Figure 13 – First-level trade-off between food production potential (% profitability, Provincie Antwerpen (1998)) and wood production potential De Vos (2000) in the Nete basin case study. Grey dots represent feasibility values occurring within the study area (one for each pixel, of which many superposed on each other by model outcomes). Black dots represent mean values, error bars represent asymmetric standard deviations distributed according to the relative position of the mean.

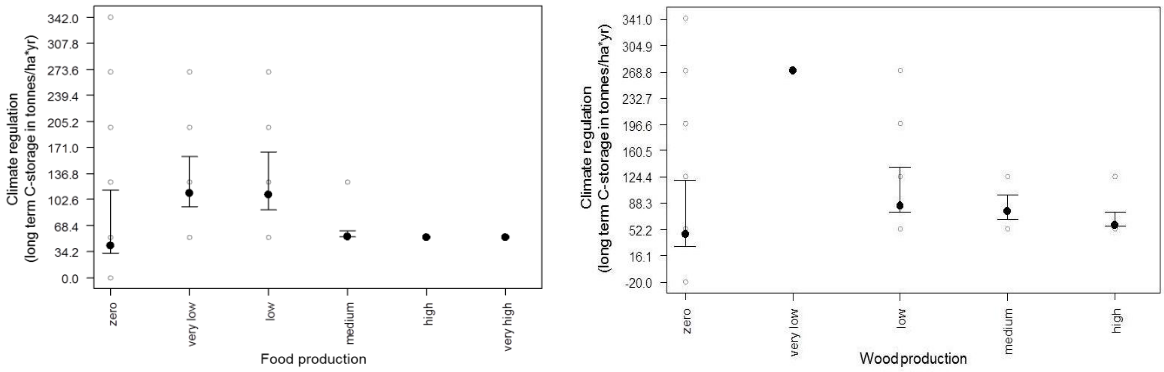


Figure 14 - Second level trade-off between food production and climate regulation (left) and wood production and climate regulation (right) in the Nete basin case study. Grey dots represent feasibility values occurring within the study area (one for each pixel, of which many superposed on each other by model outcomes). Black dots represent mean values, error bars represent asymmetric standard deviations distributed according to relative position of the mean.

2.3.5.2 The Ecosystem Service Bundle Index

Calculating the difference between actual and optimal EBI ($EBI_{diff,}$ Eq. 2) allows to identify opportunities for optimizing ES delivery in a spatially explicit way (Figure 15). When EBI_{diff} score is 0, the current land use is optimal. This is the case on 45% of the Nete basin’s non-urbanized surface. In areas with positive EBI_{diff} scores, a shift towards the optimal land use as predicted by the model may improve service delivery. Maximum EBI_{diff} scores are found in the valleys, although opportunities for improving service delivery also occur on higher grounds.

2.3.5.3 Developing optimal scenarios

Every pixel has, attached to its EBI_{opt}, one or several optimal land uses to attain the maximum service bundle delivery. Land use planning requires representation of the optimal location of different land use types (Figure 15). There are zones where several land use scenarios can generate the maximum score, since only three ES were taken into account. Wetlands are logically the most suggested land use in the valleys along the rivers and in local depressions outside of the valleys (Figure 16a). On the other hand, intensive cropland is an optimal land use option on well-drained ridges, with clustered blocks towards the southernmost parts where loamy and clayey soils prevail (Figure 16b). Production forests are proposed in a similar way by the model, but the central and northern parts of the Nete basin where sandy soils dominate are more represented (Figure 16c) as these are less suitable for cropland. Grasslands, as the optimal combination of food production and carbon storage, are the suggested land use in the wetter and sandy parts of the Nete basin (Figure 16d).

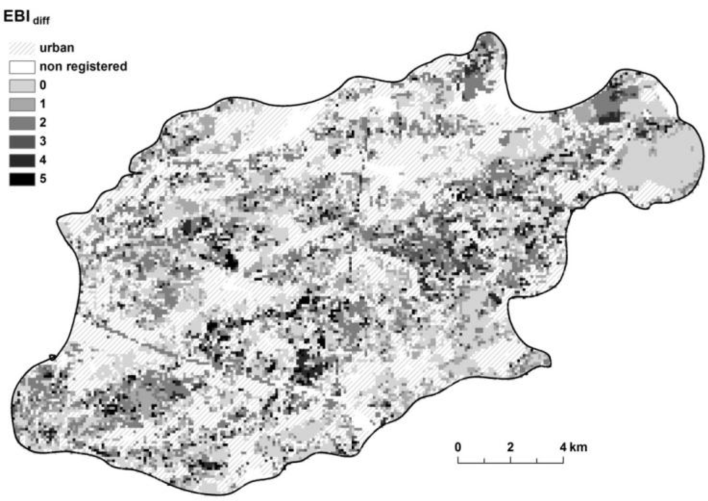


Figure 15 - EBI_{diff} as the difference between potential (EBI_{pot}) and actual (EBI_{act}) ES bundle delivery, throughout the Nete basin. Note that built-up surfaces (hatched areas) are not included in the calculations

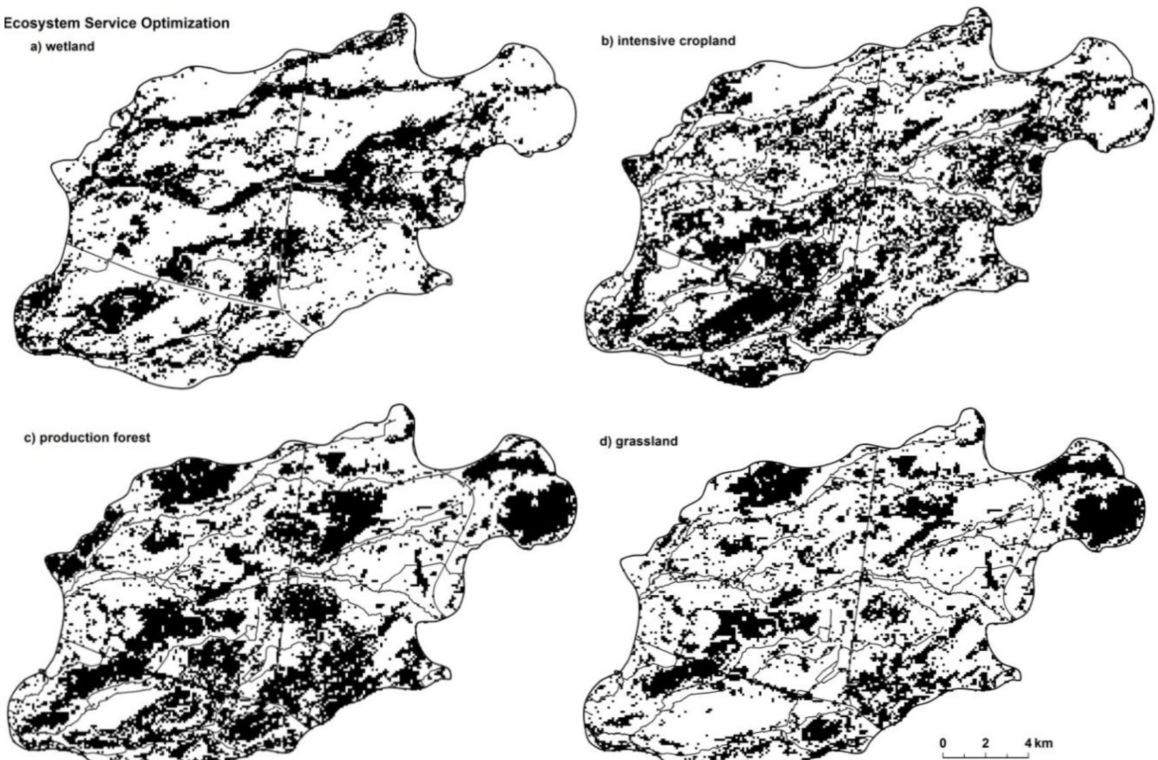


Figure 16 - Optimized land use to be wetland (a), intensive cropland (b), production forest (c) and grassland (d) in the Nete basin.

2.3.6 Discussion

Here we recapitulate the main points of a SWOT analysis on the general applicability of BBNs in ES modeling and we refer to some specific examples from the two case studies. A comprehensive discussion on these topics can be found in Landuyt et al. (2013) and Van der Biest et al. (2013).

2.3.6.1 Strengths

A first strength of BBN models is the possibility to capture complexity in ecosystem service delivery and the multidisciplinary nature of the processes that lead to service provision. Ecosystem service provision can be broken down to a production chain in which the relevant sub-processes are considered. These sub-processes are often related to different scientific disciplines and can be easily coupled in BBNs. Ecological production functions (Haines-Young, 2011) and ecosystem service valuation functions (Kragt et al. 2011) are two steps in the production chain that can be modeled using BBNs. Other examples of coupling multiple submodels in one BBN are developed by Dorner et al. (2007), Marcot et al. (2001) and Rieman et al. (2001). Although the simplest model generating valid results is always preferable (Ockham's razor), complexity could for example by added to the model of the Nete basin case study by including distance or surface rules to enhance the optimization procedure.

A second major strength of Bayesian modeling is the explicit treatment of different types of uncertainties. Uncertainties on the realized states of the input variables are reflected in the probability distributions of the variables and are automatically propagated through the model, assigning uncertainty to the models' predictions (Jensen, 2001; Marcot et al, 2006). This enables for example the calculation of risks on disservices, unexpected trade-offs and links between ecosystem services instead of depending on the mean value as a single output, ignoring the chance for deviations (Uusitalo, 2007; Gret-Regamey and Straub, 2006; McCann et al., 2006). Uncertainties in geographical input data can furthermore be addressed by checking conformity between attribute values in GIS data layers and field measurements, as conducted by Smith et al. (2007). A second type of uncertainties occurs in the causal relationships between parent and child nodes stored in the CPTs. These relationships can be probabilistic, what strongly simplifies the inclusion of several experts' opinions in the knowledge rules (Haines-Young, 2011; Uusitalo, 2007). These different uncertainty measures allow for assigning a level of confidence to the predictions, which is essential for honest decision support.

A third major strength highly relevant for ecosystem service research is the possibility to use both expert knowledge and empirical data. The combined application of expert knowledge, expected data and sampled data to develop a Bayesian belief network is an essential advantage in case of limited data availability due to small dataset or missing data or when model guidance towards the most important issues is necessary in case of sufficient data availability (Aguilera et al., 2011; Haapasaari and Karjalainen, 2010; Wang et al., 2009; Cain et al., 2003). Data availability is especially problematic for ecosystem service modeling. Updating newly gained knowledge into BBNs is furthermore straightforward because all probabilities in the CPTs are independent (Castelletti and Soncini-Sessa, 2007).

Offering discussion-support is another major advantage of Bayesian modeling. One can easily model the optimal combination of management strategies to maximize the bundle of ES or assess the effect of certain realistic scenarios (how many commercial activity can we include without jeopardizing ES apart from fish production).

Bayesian modeling also facilitates stakeholder and expert engagement in the model development, application and scenario evaluation process. This may enhance the validity and acceptance of a model and its outcomes (Marcot et al. 2006; Smith et al. 2007). Moreover, the models' transparency and easy visualization of model output scenarios through mapping offers opportunities in the context of participatory modeling which Fish (2011) denoted as essential in ES assessment (Castelleti and Soncini-Sessa 2007). Further developments of the case study models could include participative processes such as expert discussions and deliberative consensus techniques.

2.3.6.2 Weaknesses

Next to these advantages, BBN models face a couple of weaknesses which have to be addressed in future research. Typical weaknesses are related to the absence of feedback loops, obligatory discretization of both data and probability distributions of nodes and difficulties in model validation.

Absence of feedback loops is a critical restriction of BBNs (McCann et al. 2006; Nyberg et al. 2006; Castelleti and Soncini-Sessa 2007). This is especially true for modeling complex processes involved in ES provision, monetary valuations, links between supply and demand and complex spatial relations between input variables, delivered and consumed ES (McCann et al. 2006). This may for example cause problems when modeling degrading systems that loose ES. In the pond complex of Midden-Limburg, this may especially be the case for non-managed pond systems which accumulate a lot of mud. The possibility of BBNs to combine various specific complex submodels to a synoptic whole, thus realizing reliable quantitative model output, is an option to tackle this weakness.

The use of discrete data is compulsory in BBN modeling. This discretization often causes information loss of sampled data (Aguilera et al., 2010; Jensen, 2001). The use of numerous states in each node would tackle this problem of information loss. This will however lead to a small amount of data per interval, and bulky conditional probability tables which reduces model performance given equal data availability (Uusitalo, 2007; Myllymaki et al., 2002).

Due to limited availability of empirical data, model validation in ecosystem service modeling is often challenging (Kareiva et al. 2011). The problem is that many services in se cannot be measured directly while commonly used statistical methods like K-fold cross validation almost always rely on empirical data. Model validation however is strongly encouraged: the few studies that have put ecosystem service maps to the test immediately pointed out major biases (Villa et al. 2009; Eigenbrod et al. 2010). Alternative validation methods often used in Bayesian modeling, such as sensitivity analysis and visual network structure appraisal, mainly rely on expert judgment. Nevertheless, assembling objective expert opinions to verify accuracy and robustness of these models is often difficult.

Also upscaling remains partly untackled in the developed models. For the Nete basin model upscaling is no problem. As all inputs are pixel data, the Nete model can be applied on both a local or regional scale. For the Pond complex Midden-Limburg model, however, upscaling is more problematic. Currently, the Pond complex Midden-Limburg model has been developed on the level of one pond. Upscaling this to the whole pond complex is straightforward for certain ecosystem services, for example fish production, when the provision levels of several ponds can simply be summed up for the pond complex. For services related to biodiversity and habitat provision, summing up provision levels of separate ponds is not possible. The level of habitat provision will not simply double when the area is doubled and also clustering and distance effects need to be taken into account.

2.3.6.3 Opportunities

Many policy makers, decision makers and stakeholder groups have looked for ways to generate awareness for our dependency on natural systems and to stimulate incorporation of ecosystem services in decision making. Qualitative maps and illustrative monetary quantifications have been very convincing and powerful arguments. However, at least in Flanders, there is a very strong demand for concrete and applied planning for ecosystem services in the local political realities. Therefore, the risks of taking decisions with adverse effects must be minimized, remaining uncertainty must be acknowledged, scientific credibility and public acceptance must be guaranteed. The presented management scenario analyses and optimization exercises using BBNs are a first step to foresee in such an integrated approach.

While there are still important limitations related to the use of Bayesian networks in ecological modeling, recent growing scientific interest will probably lead to model improvements towards the future (Aguilera et al. 2011). Some shortcomings of Bayesian networks in regard to ecological modeling, like the absence of feedback loops, are for example currently dealt with by the use of time dependent nodes

(Bashari et al. 2008) or time sliced models (Kjaerulff 1995 Cain 2001). Further technical advances will similarly increase the feasibility of Bayesian models to take into account a broader set of ecosystem services and to expand towards spatially explicit applications.

2.3.6.4 Threats

Limited data availability is a common threat for every modeling technique. Both during model development and training and during model validation, empirical data is indispensable. In ecosystem service modeling and valuation, this empirical data is often unavailable. Limited measurability of ecosystem service quantities and their social-economic importance is a major reason for this lack of data (Kareiva et al., 2011). Data dependency of BBNs is reduced by the possibility to partly rely on expert knowledge (Uusitalo, 2007; Marcot et al., 2001). However, excessive use of expert knowledge, leading to unscientific and subjective models, is a serious threat for BBNs.

A more general threat related to all ecosystem service models is model credibility, which is closely related to policy acceptance. Next to compatibility with actual policies, visions and economy, policy credibility strongly depends on scientific background or in this case the scientific model. Because of high complexity of the modeled system, credibility of ecosystem service models is often low (McCann et al., 2006; Noon and Murphy, 1994). Model transparency of BBNs can enhance model acceptance due to high public understanding. However, transparency and limited complexity can also be a serious threat by decreasing model acceptance due to untrustworthy simplifications of the modeled system.

2.4 SOCIAL ASSESSMENT AND MAINSTREAMING OF FRESHWATER ECOSYSTEM SERVICES

2.4.1 Methodology and results

2.4.1.1 Introduction

Since the 1970s the vision on water management in Flanders has strongly evolved. An essentially protective approach in which water had to be "tamed" slowly made way for a more integrated perspective that trickled down from European level to the member states. The European Water Framework Directive (2000/60/EC) gave green light to the realization of this integrated vision. The Directive was new in two ways: the integration of ecological definitions of water and the notion of public participation for policy implementation (Steyaert and Ollivier 2007). Since then, a significant progress has been made towards increased stakeholder involvement, including the establishment of new organizational structures of cooperation and consultation. However, the organizational aspects of integrated management planning are far from easy. For example, one of the greatest challenges of the integrated catchment plan in Flanders was bringing together the administrations of environmental and spatial planning around a shared, balanced vision of multifunctional use (Schneiders and Verheyen 1998). Yet, in periods of transition – such as the move towards integrated water management - there is a need for new problem definitions, new concepts and visions so as to shift the discourses and practices of the "mainstream".

Focusing on the benefits derived from the use of water in a river system (rather than on the physical water itself) is a way to broaden the perspective of basin planners (Sadoff and Grey 2002). Ecosystem services is a powerful concept with increasing relevance to water management (Brauman et al. 2007). Since the Millennium Ecosystem Assessment (2005), the concept of ES has steadily entered both academic and political arenas. As a unifying language it attempts to find a convergence between economic interests and environmental imperatives (Brauman et al. 2007, Daily et al. 2009).

From a study in Flanders, Jacobs et al. (2010) conclude that the current evolution towards integrated water management provides a great congruence with an ES approach. This is because river basin management seeks *to work with* natural upstream and downstream ecosystem processes instead of counteracting them. Integrated water management links an ecosystem vision to a river basin approach (i.e. river basins are seen as integral units), whereas the core of the ES concept is the linkage of ecosystems with their - actual and potential future - supplies of services. What is also important here is that the explicit inclusion of beneficiaries of ES can shed a new light on the positioning of stakeholders, including their respective roles and inputs.

2.4.1.2 Study objectives

The overall aim of this study is to find out whether and how the concept of ES can contribute towards integrated water management. The focus is on the Nete and Demer catchment areas. The following questions are addressed:

- What could be the potential of ES as a concept to contribute to (a greater integration in) integrated water management?
- What are main obstacles to the implementation of integrated river basin management? What could be opportunities, (possible) "points of connection" for ES application in integrated river basin management plans?
- How can opportunities for specific ES be taken up in river basin plans? What are possible instruments (or adaptions to instruments) to operationalize ES in integrated water management?

2.4.1.3 Methodological framework

In this study, a discourse analytical framework is chosen. Following Hajer's (1995: 44) much cited definition discourse is "… a specific ensemble of ideas, concepts and categorizations that are produced, reproduced, and transformed in a particular set of

practices and through which meaning is given to physical and social realities”. As discourses are embedded in social practices they will vary between different disciplines of practice (Van Herzele, 2006). As in the domain of integrated river basin planning, stakeholders of various backgrounds, professions and disciplines act together, different discourses are likely to coexist and compete with one another. Concurrently, different stakeholders may come to support a same discourse – often for very different reasons – thus form a discourse coalition (Thalingii 2000).
Infrastructure, regulation and other realizations in water management can be seen as an expression of the very ideas or policy discourses that guide their development (Huitema and Meijerink, 2010). As such, discourses can be seen as driving forces behind every policy or plan. Policy change requires an alternative idea for managing water, i.e. a new frame or discourse (Huitema and Meijerink, 2010). Discourse coalitions that pick up on an idea can be institutional vehicles for change (Kemp and Rotmans, 2009). An issue to consider in this study is how ES discourse can give new meaning and policy content to integrated water management.

2.4.1.4 Methods and materials

Document analysis: Policy documents regarding integrated water management in both the Nete- and Demer catchment were scrutinized, including river basin management plans, “water notes”, reports, information leaflets, popularizing brochures. Documents were selected either on their relevance for integrated water management, or the relevance that was attributed to them by stakeholders.
Participant observation: Two rounds of stakeholder consultations within the context of the so-called “Masterplan De Wijers” (organized by VLM Limburg) of which the pond complex Midden-Limburg makes part, were attended in June and September 2011. It was the goal to develop a vision for future development of the region, following an ES framework using stakeholders’ preferences on how to reconcile various elements in the area (Herberg, 2011). The focus was on: 1) regulating and provisioning services in De Wijers, and 2) water-related ES of two local streams (Roosterbeek and Stiemerbeek). Participants included regional organizations (mainly governmental agencies), as well as local fish farmers, members of nature conservation and environmental action groups, an environmental officer of the municipality of Zonhoven and a local forestry official. Witnessing interactions between stakeholders, while participating in the workshops, has allowed to closely observe the reconciliatory function of ES that came into effect when searching for win-win opportunities between natural and economic systems in the area. Additional open-ended interviews and informal conversations with relevant stakeholders as well as field-notes based on observations (e.g. during a field visit to De Wijers) were used.
Semi-structured interviews: 18 semi-structured interviews were conducted from March till July 2011. Participants were recruited by non-probability, purposive sampling (Tongco, 2007). Eligibility criteria included being professionally involved in

the (broad) water sector, either at central (Flemish or regional) policy level, or local (often management) level in either the Nete - or Demer catchment. All respondents were chosen for their general broad knowledge of integrated water management and/or policy-making processes. At the end of the interview, participants were asked to refer to other persons that might also be interested in participating (i.e. snowball method). In total, 41 people were invited for an individual interview, primarily via email (secondly by telephone). 18 people agreed on doing an interview. These people belonged to the following broad sectors: agriculture (Boerenbond, ADLO, Buitendienst L&V), nature conservation (Natuurpunt), regional land-use planning (VLM, Regionale Landschappen), water management (Polders & Wateringen, Provincie Antwerpen Dienst Waterbeleid, Waterschappen Netebekken), environmental administrations (VMM, ANB), central level integrated water policy (CIW), mobility and public works (Waterbouwkundig Labo), waste water treatment companies (Aquafin) and drinking water companies (PIDPA). Five out of 41 referred to a colleague, while four could not participate at the time of the research. A total of 14 people did not respond at all. Prior informed consent was obtained before each interview. Participants were guaranteed to remain anonymous.

An interview guide was developed (Annex 2) and pilot tested with four key actors (including a discourse analyst, a water manager in each catchment and a water policy maker working at a central level). These actors were selected because they have an overview of the field from different positions. The goal of the interviews was twofold. First, a general overview of current issues in integrated water policy and management in both catchments was sought for. Additionally, the importance of ES as a concept for integrated water policies was explored. Correspondingly, the interview guide covered four themes: 1) integrated water policy and management, 2) the concept of ES; 3) overlap and connection points between both and 4) operationalization through instruments. The first part was developed to find out more about the interviewee’s background, general knowledge on integrated water policy, current bottlenecks and possible improvements. The second part aimed at finding out the interviewee’s acquaintance with ES, and the potential added value of this approach for the existing integrated water policy. Thirdly, the interviewee was asked whether and how an ES approach could improve current policies, and where potential pitfalls should be located. In the fourth part an integration of the concept into policy instruments (ranging from social-communicative over economic to legal instruments) was discussed covering all pro’s and con’s, along with a question covering the general topic of PES (payments for environmental services). Each interview ended with a question regarding a non-technical publication, an invitation to participate in the focus groups. Interviews lasted between one and two hours. All interviews were tape-recorded.

Focus groups: Two focus groups were organized at INBO in November 2011. All people that were individually interviewed were invited. One person did not reply, two had changed jobs in the meantime - one of them sent his successor- and three people said they had other commitments. The majority (13) agreed to participate, with a final dropout of four persons, one of whom sent a deputy. One focus group (four participants) was attended by local water managers and policy-makers (with a dominance of people from the Demer catchment). In the other (six participants), people from both catchments were equally distributed, with a balance of members of the nature conservation, water, agriculture, and wastewater treatment sectors.

The focus groups were organized as planned discussions in an interactive group setting. A focus group guide was developed, based on the results of the individual interviews and following standard methodological literature (Bloor et al., 2002). The goal of the focus groups was twofold: 1) to obtain feedback of the participants on the preliminary research results that focused on the main issues in integrated water management and the potential of the ES concept for IWP; 2) to explore the opportunities and conditions for ES application in a specific micro-case i.e. ‘space for water’ (i.e. the ES of flood protection). The morning session focused exclusively on stakeholder feedback (and hence aimed at triangulation of data obtained from the semi-structured interviews). The afternoon session consisted of a creative brainstorm session where participants were invited to provide new ideas and workable solutions for existing problems on the implementation of water related ES, along with other relevant policy recommendations. Both focus groups were tape-recorded and detailed notes were taken.

Data analysis: The audio-recordings of the interviews and focus groups were transcribed. A shortened version of the transcription conventions proposed by Silverman (2001) was adopted. Subsequently, these transcripts were imported into QSR NVivo9, a computer-assisted data analysis package. Initially, transcripts were scrutinized for recurring themes (e.g., “bottlenecks”, “opportunities”), that were attributed a code (or ‘node’ in NVivo). In addition, and following a methodological checklist developed by Hajer (2006), three dimensions or layers in a discourse were distinguished: 1) the terms of a policy discourse (in itself consisting of three layers: a) different discursive elements such as storylines, metaphors, myths, b) policy vocabularies (or concepts) and c) epistemic figures (or structuring rules of formation)), 2) discourse coalitions and 3) practices. All these elements were discerned and attributed a code in NVivo. In the end, a total of 31 codes were developed, covering themes ranging from “lose issues” such as climate change to answers to a specific research question (e.g., “obstacles experienced in the implementation of river catchment plans”).

2.4.1.5 Results

Policy background

The overall aim of the European Water Framework Directive (2000/60/EC) is to establish a framework for the integrated implementation of sustainable water management strategies for long-term protection of water resources that combines ecological, societal and economic demands. Unlike before, the European Water Framework Directive frames the organization of water management at the river basin level. The directive sets out strategic and well-defined objectives for water bodies: a) to prevent further deterioration of aquatic ecosystems and b) to achieve a 'good ecological status' of both surface- and groundwater by 2015. Hence, in the integrated view, ground- and surface water are no longer seen as separate issues. Besides reaching ecological targets and safeguarding water supplies, another pivotal principle in integrated water policy is an increased participation and stakeholder involvement (see also Pahl-Wostl et al. 2008).

In Flanders, the Flemish Decree on Integrated Water Policy - officially approved in 2003 - constitutes the general framework for integrated water policy. It is the juridical implementation of the European Water Framework Directive and the Floods Directive in Flemish Law. For the organization and planning of integrated water management**,** the decree on Integrated Water Policy distinguishes 4 levels in Flanders:

1. River Basin District (Scheldt and Meuse basins)
2. Flemish region (river basins Scheldt, Meuse, IJzer, Polders of Bruges)
3. Sub-basin (11 "bekkens")
4. Sub-sub-basin (103 "deelbekkens")

The Directive requires the production of a number of key documents over six year planning cycles (see Table XVIII for an overview of these structures and the corresponding plans).

Table XVIII - The translation of the European Water Framework Directive in Flanders.

Scale	**Policy-planning documents**	**Preparation of planning**	**Advise on planning**	**Decision**
Flemish region	Water Policy Note (2005)	Coordination Committee on Integrated Water Policy (CIW)	SERV and MINA-council	Flemish Government
Sub basin	River catchment management plans (2007)	River basin secretary	River basin council	River basin management
Sub-sub-basin	Sub-river catchment management plans (2007)	Catchment Committee	Local environmental councils	District water board

The Coordination Committee on Integrated Water Policy (CIW) is responsible for the coordination of the integrated water policy on the level of the Flemish Region and between the different hydrographical levels. At sub-basin level, the basin secretary ('bekkensecretariaat') develops a river catchment management plan that has to be approved by the river basin management, a political consultation between the Flemish region, the provinces and the municipalities. In addition, a social consultation with stakeholders is organized in the form of a river basin council. At the local level, the catchment committee is responsible for designing sub-river catchment management plans. Table XIX gives an overview of the stakeholders involved at different levels per sector and/or administrative scales.

Table XIX - Stakeholders in the water sector.

Scale	**Stakeholders**
Flemish level (policy domains + agencies)	• Policy area Environment, Nature and Energy (Flemish government agencies: VLM, VMM, ANB) • Policy area Agriculture and Fisheries (ADLO) • Policy area Mobility and Public Works (De Scheepvaart, Waterwegen en Zeekanaal nv) • Policy area Spatial Planning: Town and Country Planning, Housing Policy and Immovable Heritage • Policy area Economy: Economy, Science and Innovation
Regional and local water managers	• Provinces • Cities and municipalities • Polders and drainage authorities • Water district boards
Water companies (inter-communal)	• Drinking water companies (e.g. PIDPA) • Waste water treatment companies (i.e. Aquafin)
Other local actors (agriculture and nature conservation)	• Syndicate Agriculture Union (Boerenbond) • Regionale Landschappen • Natuurpunt • …

<u>The integrated water management discourse</u>

The integrated water management discourse drew on the sustainable development discourse (Arts and Buizer, 2009). Sustainable development is built on the idea that ecology and economics can be integrated, a point that it has in common with the ES discourse. The integrated water management discourse in Flanders (for a full review, see Crabbé 2008) is based on several principles. For the first time, rivers were seen as entire (eco)systems that should be managed accordingly. This idea got institutionalized in the creation of new organizational structures on catchment level that crossed administrative borders. Secondly, water was no longer seen as an enemy, but as an alley -following the adage of "working with water" instead of "against" water. Hence, more space should be provided to the river, in order to flow as naturally as possible. This principle was translated in the three stage strategy for management - (1) retaining water in the soil and ditches before (2) storing and only as a last resort (3) draining. Moreover, the concept of hydro-solidarity or the idea that water problems should no longer be shifted to downstream "neighbors" nor to future generations also gained importance. Finally, the principle of participation in the development of plans and a higher degree of institutional integration through collaboration instigated public consultation rounds, as well as several new structures for collaboration and consultation.

Crabbé (2008) discerns different discourse coalitions in the formation period of integrated water management in Flanders. Adepts of the integrated water management idea managed to get the system approach and the ecology discourse anchored in the Flemish Decree Integrated Water Management. Opponents of the idea belonged to the agricultural and industrial sector and policy domains that are traditionally considered to be "grey" (Crabbé 2008). These opposing coalitions reflect contrasting interests of that period. The "grey sector" criticized integrated water management for defending no other interests than those of environmental protection and nature conservation, while the agricultural and industrial sector criticized the bureaucratic and administrative aspects of environmental policy. The new rules and organizational structures that were created with the institutionalization of water policy were thus heavily contested.

<u>The potential of the ecosystem services concept for integrated water management</u>

The ES concept is employed in different ways across various actors in the Flemish water sector. Hence, the emerging discourse coalition around ES can be divided into different fractions.

Firstly, the concept of ES has been actively taken up by a small group of policy makers and water managers in the Demer catchment. Today, water managers are confronted with countless claims on the water system. While some of these claims can be easily combined, others appear to be mutually exclusive. Attempts to reach consensus have been made using ES as a framework of action. In the on-going strategic projects of De Wijers and Herk en Mombeek, the ES concept is applied as a framework to achieve an improved collaboration between different local stakeholders when implementing actions that are part of the (sub-) river catchment management plans in line with the objectives of integrated water policy (in this case tackling a combination of several local issues on fish migration, water quality, erosion and water quantity). In Herk en Mombeek it is the intension to bring all authorities in the area together. The aim is to unite all administrations in charge of water in a sort of steering group, so that problems can be signalized and tackled collectively (whereas before issues were usually addressed more bilaterally). The lead organization, Regionaal Landschap Haspengouw en Voeren (together with the Demer secretary), has outlined several themes that they will work on, i.e. water quality, water quantity, erosion, blue green services (in which farmers are involved in reaching 'green' targets). In the case of De Wijers ES is used as a framework for participatory workshops with local stakeholders, which ultimately should lead to novel ideas for a regional master plan (developed by the provincial department of VLM).

In both strategic projects, the concept is used for its organizational potential as a "common language" that is also believed to neutralize traditional sectorial thinking. Departing from the idea of "services", it can be illustrated who is benefitting from services, who is delivering services, thereby communicating different roles. When participants explained why they choose to work with the ES concept, it became clear that important elements of the ES concept overlap to a certain extent with the principles of integrated water management, i.e. focus on the water (eco)system, integral-holistic vision, aim at multifunctional land use, creation of win-win situations, and sustainable development as guiding principle. Since both projects are still in progress, it is not possible to determine the actual impact of using ES as a frame for action.

Secondly, there were several participants that recognize the rhetoric value of the ES concept as a useful communication tool to substantiate on-going projects in which several goals of integrated water policy and planning are combined. While none of these advocates actually used the term ES as such, their argumentation was rooted in the basic idea of "services delivered to humans by the ecosystem", and these services are achieved through a certain management decision or action. A recurrent term overheard during interviews was the creation of "added value" (for society as a whole) through win-win situations, referring to the multiple services that can be achieved through implementing a project. As such, certain management choices could be motivated. Projects for implementing integrated water management plans are often (still) quite unilateral and directed at solutions that are not integrated in principle. Hence, unlike the first group, the second fraction of the discerned discourse coalition does not depart from the idea of ES to set up a project. They rather motivated their management choices for implementing integrated projects retrospectively. While the ES concept can promote their projects, they can become promoters of ES alike. This fraction thus adds to current social support for research on ES.

A remarkable difference between management approaches in both catchments was observed. While managers in the Demer catchment emphasized collaborative projects (without necessarily buying land), in the Nete catchment managers seemed to prefer the strategy of buying land and implementing projects focused on combining multiple objectives (sometimes outsourcing management to other organizations like Natuurpunt).

Thirdly, representatives of the agricultural sector also tended to use the ES concept to underline the added value of those agricultural practices that assist in reaching the ecological targets of integrated water management. They employ a definition of ES that focuses on the services delivered by the farmer ('to the ecosystem'). In their view, ES are similar to blue-green services. Remarkably, often one specific ES (e.g. water quality) was selected for underlining the importance of their actions. This contrasts with the groups discussed above, who emphasized the inclusive, integrative value of the ES framework (hence in line with the integrated water management thought).

Finally, the integrative property of the ES framework was seen by part of the interviewees as having potential to guide policy change in the form of an organizational restructuration of the water sector. They consider organizational fragmentation the main bottleneck in the (lack of) implementation of integral water policies. The organizational reform they envisage includes the abandonment of the so-called 'Polders and Drainages' or district waters, which, according to the former do not work in an integral way and only pay attention to the stakes of landowners - often farmers - along the stream that belongs to their territory. Obviously, people working in the more local water boards, or traditionally benefitting from their management, had a more positive attitude towards these so-called fragmented structures. They much more emphasized the benefits of their individual action for nature. Importantly, however, these widely differing opinions and stakes nonetheless easily converged in the usage of the ES concept that lends itself for nuances and slightly different interpretations that fit all.

Although the potential of the concept was widely recognized, some major concerns were brought up during interviews. Several participants uttered their concerns about the immature status of the concept as it is applied today. A lack of scientific data was a clear reason for concern. Secondly, participants expressed concern about a present lack of ways to operationalize the concept. Interviews also confirmed that in general, the concept is considered to be difficult, complex and too academic and conceptual. Participants also complained about a lack of (vulgarizing) communication between science and policy. Moreover, intermediary evaluations of the processes in De Wijers show that ES is perhaps a concept that is too holistic and therefore also difficult to grasp in order to be used as a framework for participatory processes. In addition, several interviewees warned for the ivory tower effect that the use of the concept might have, especially on local water managers. Finally, not everyone agreed that monetization of services is the only way forward. Many warned for a reckless application of the monetary value of services in policy choices and assessing trade-offs. Non-monetary values were as important for most participants.

Ecosystem services and the implementation of integrated water management

A frequently overheard comment of interviewees was that ES as an idea is "old wine in new bottles". Several services are already tackled by existing water policy, they are just not named as such. Below a list is provided of all water related services currently addressed in water management plans. For the categorization of services, a combination was made of the classifications used in Brauman et al. (2007), Harrison et al. (2010) and Jacobs et al. (2010).

Provisioning services:

- Water (quantity and quality) for consumptive use (domestic, agricultural, industrial use).
- Water for non-consumptive use (power, transport, navigation)
- Aquatic organisms (for food, medicine)

Regulating services:

- Maintenance of water quality
- Erosion control (e.g., mitigation of mud slides)
- Regulation of water flows
- Flood (peak discharge) control and or mitigation

Cultural services:

- Recreation and tourism (hiking, fishing as a sport, kayaking, pleasure boating, swimming)
- Aesthetic value: value of the landscape, river viewing

Supporting services:

- Biodiversity (create habitat for aquatic organisms, provision of water for plant growth).

The water framework directive was created originally to obtain a better water quality. For many participants water quality is the starting point, the service, so to say, that supports all other services.

Some regulating services discussed in the other ECOFRESH chapters are currently not addressed in existing plans, i.e. carbon sequestration, tidal flood control, N-retention, P-retention and pest regulation (cyanobacterial blooms). The supporting services nutrient cycling (role in maintenance of floodplain fertility) is not directly tackled in the plans either. Some might however be positively influenced by current measures and actions that are not directly addressing these services.

Based on a discourse analysis of the interviews (and subsequent focus groups), five recurring obstacles to the implementation of integrated water policy and plans could be identified.

Lack of funds: According to VMM (MIRA 2010) water and riverbeds is still the largest expenditure of the Flemish environmental government. In 2009 more than half the budget or 56,1% was dedicated to water, while only 11,1% went to biodiversity and 6,1% was spent on energy. While all interviewees mentioned limited funds as a major obstacle to action, it was nonetheless nuanced by some, stating that with proper management and good policy choices the current budget should suffice.

Institutional and legal fragmentation: Since integrated water management departs from the water system, administrative boundaries are often a hindrance (e.g., the installation of buffer strips). The current administrative breakdown of watercourses in categories – and corresponding water managers - hinders integrated management "from source to estuary". Such fragmentation is also noticeable in the water management plans. For most interviewees the solution lies in a shift to a more central level. They also criticized the lack of agreement of accommodating policy or coordination between different laws and regulations that of ten apply to one area.

Slow processes: It was felt that administrative procedures for planning, authorizations and decision-making processes are too time-consuming. In particular, the consultation rounds necessary to obtain permits slow processes down. Several participants believed such long consultation rounds only necessary for projects in which different actors need to collaborate and their actions synchronized.

Lack of public support: For several actions there is a lack of social support (e.g. wadis, open ditches, retention basins). It was thought that this could be due to the still prevailing public perception that open water is dangerous (especially in residential areas with many children).

Lack of space for water: Most actions have to be implemented upstream to avoid problems downstream. Water managers of 2nd and 3th category are often blamed for not looking beyond their own borders. All too often water is simply drained as fast as possible.

As Tuvendal and Elmqvist (2011) observed the distribution of ES in the landscape, who the beneficiaries are and what benefits are derived from them, is in many cases unknown, at least until problems in delivery of those services occur. This goes especially for flood protection, in which case the delivery of the service is often situated upstream, with (often unknown) beneficiaries downstream. The focus group exercise departed from the idea that the ES approach is a potentially useful framework to make such links more visible by identifying and connecting stakeholders in the landscape, and as such can support problem solving and proactive management. The brainstorm session yielded two alternatives for the services of flood protection: developing a special agri-environmental scheme for flood areas and finding market mechanism to compensate for damage. Apart from that, several more encompassing alternative solutions were discussed, all based on the idea of ES. In what follows, recommendations are proposed towards possible approaches and instruments, based on the contributions of the participants in interviews and focus groups.

Communicative instruments: Communication to create public support was found most important among policy makers and water managers. It was recognized that communicating the benefits of projects in terms of services and beneficiaries could be powerful. Beneficiaries are often unaware of the benefits they receive from certain ecosystem functions. Campaigns to raise such awareness could help increasing public support for integrated water management projects. Furthermore, making water a hot topic, could make the industrial sector come on board faster as well. Today, low carbon and energy efficiency are used to boost the image of companies and brands. Can water become the next theme?

Management agreements for flood areas: When developing a flood area, it was seen as a better option to take the entire valley into account, rather than constructing a basin here and there. This would provoke less opposition, as everyone will lose a bit, though nobody will lose a lot. Alternative agreements could be made with private landowners and the industrial sector. The construction of wadis on industrial areas, parking lots, etc. might open new perspectives. Public space is sometimes already used (e.g. city parks) as emergency flood area. Participants agreed that the need is so high that all options need to be explored and combined. Depending on the desirable development, expropriation (current measure) can also be considered.

Catalogue of blue services: It was envisioned that, along the lines of the Dutch example, a catalogue of freshwater services could be developed. Through creating the option of multiple services, more win-win situations and surplus value could be created (e.g., buffer strips combined with natural river banks). Based on their effect on water quality and the combination of services, projects could be attributed "water stars". Agri-environment measures ought to be more flexible: for instance, depending on the type of mowing management a farmer gets water stars per buffer strip. Other examples include natural purification areas (e.g. reed beds), flood areas, fish migration bottlenecks and re-meandering. Private land owners could be compensated financially for contributing to a natural development of the stream, for instance, through not mowing water plants over a larger area.

A fund for water ES. A Rubiconfonds was established after the large flooding in 2002 to assist local authorities in the construction of flooding areas. From 2007 until 2009 the Flemish Government reserved 2,5 million euros yearly to subsidize such projects. A similar fund could be established to subsidize the provision of water ES. Such a fund could be filled with private capital. Alternatively, a fund could be more explicitly addressed at flooding problems, in which urban taxing mechanisms could be used to subsidize services delivered in rural areas.

Legal policy instruments: One suggestion was to install land servitude (erfdienstbaarheid) on parcels that are frequently inundated. Furthermore, it was questioned whether besides a general Watertouch (Watertoets), there could be a similar instrument specifically for rainfall.

2.4.2 Discussion

The findings from the study indicate that the ES concept has entered the arena of integrated water policies and management in Flanders. Results reveal that among the stakeholders in fact a new - multilevel and cross-sectorial - coalition is forming around the ES concept, thereby creating new opportunities for organizational integration and cooperation between sectors. However, so far it has not created the sort of institutional restructuring that is necessary for policy reform.

Most obviously, the ES concept was embraced for being a communicative device to support collaborations and integrated projects. As such, the concept was used as a kind of metaphor or storyline to get ideas across and to motivate integrated water management plans and actions. Metaphors make use of a "tangible" story or image to explain an intangible idea. ES is a generative metaphor, because it instigates discursive integration. Such metaphors and storylines have an important potential for creating discursive affinity between actors that have different opinions and stakes (Hajer 1995, Van Herzele 2006). An interesting, but still uncommon application is the use of ES as an organizing principle in pioneering strategic projects (De Wijers, Herk en Mombeek). Here, ES is being used as a framework or reconciliatory device for structuring complex collaborations.

Whereas all participants in the study embraced the ES concept, different interpretations emerged, with differing and selective emphasis on particular elements that substantiated their own point of view. For example, while water managers employ the standard definition of "services provided by nature", members of the agricultural sector speak of "services delivered to nature". Whereas different definitions of ES often revealed opposing views and positions, the focus groups made clear that this does not necessarily create insurmountable differences, as the general term or storyline of ES covers underlying differences. As long as these differences are still compatible with the common project, then differences are harmless. However, it has been seen in the past that the effects of such engaging catchall concepts is not always unanimously positive. The interpretation of sustainable development for example, facilitated a favorable approach to environmental politics, created consensus, and put a stop to previous conflicts (Fischer and Hajer, 1999). However, the price of that consensus was that it bracketed the essence of the discourse. Likewise, if not substantiated enough, the ES concept might not be able to achieve much more than covering up underlying contrasting views and objectives that are not reconcilable through a discursive tour de force. Furthermore, black-boxing or discursive closure whereby definitions are produced, which then prevent consideration of alternatives should be avoided. The fact that the concept is far from clear to many interviewees could be a potential pitfall in future projects as it might lead to obvious misinterpretations, miscommunications and false expectations.

Furthermore, the idea of ES has potential besides its application as a concept. As this study demonstrates, key actors in the Flemish water sector see potential practical applications of ES within the confinements of the current policy and financial context. These should be seen as ideas that could inspire the further development of policy instruments.

Whereas the ES concept has a clear potential to strengthen integrated water management, new policy ideas and discourse do not simply replace old ones. They are rather placed alongside an existing idea and integrated with them. There are several important points of overlap between the concepts of integrated water management and ES. In order for the idea of ES to be further embraced by the water sector, further support is required. Participants underlined that the success rate of projects often depends on individuals. Hence, policy entrepreneurs should therefore be supported. The discourse coalitions of interviewed stakeholders that supported the idea of ES might be the first institutional actors for change.

3. CONCLUSIONS AND POLICY SUPPORT

The ECOFRESH project aims to contribute to a policy-relevant strategy for ES in Belgium as part of the overall policy of sustainable development, focusing on freshwater ecosystems. It is one of the first attempts in Belgium to evaluate ES in monetary and other terms. The results provide insight into the importance and the functioning of ES in river systems and stagnant water systems in Belgium, allow evaluation in monetary terms and delineate the opportunities and the support available for integration of the ES concept on the institutional level.

As ES research is a complex research field involving different disciplines (ecological as well as socio-economic) with multiple interactions, **there is a strong need for tools that allow transparent and user friendly assessment of bundles of ES on different levels**. Integrative modeling of multiple ES is crucial in identifying the factors that determine the ecological status of investigated ecosystems and the associated levels of service provision. For decision-makers, these determining factors serve as a guideline for selecting the key ecosystem properties that need to be monitored together with a set of efficient measures for ecosystem restoration.

When comprising economic or qualitative ES valuation, integrative models help provide insight in trade-offs or synergies between services and the related benefits for society. This makes them valuable tools for conducting cost-benefit analyses of restoration or conservation investments and for facilitating decision-support towards ‘smart’ policy-making. From the project results it became clear that **Bayesian belief networks allow to capture complexity in the production chain of ES while they remain highly flexible and transparent tools that can combine several, multi-disciplinary data sources and data types**. Their ability to work under data scarce conditions make Bayesian networks particularly suitable for ES research. The developed models can be applied to create management scenarios to optimize ES delivery or to evaluate the effects of environmental stressors like climate change or management decisions on ES production. An additional asset of Bayesian network models in this regard is their capacity to incorporate various expert and stakeholder opinions, which make them useful tools in discussion-support and decision-making.

The case-studies show that **an ecosystem services framework can support both practical conservation and economic development**. Whereas “win–win” projects that achieve both conservation and economic gains are a commendable goal, they are not easy to attain. The BBN model allows policy makers, like ANB and VLM, to clearly demonstrate the effects of different management scenarios and strategies on ecological, social and economic benefits. It also allows policy makers to allocate the major ES trade-offs that arise from management choices, which can change the magnitude and relative mix of services provided by ponds and rivers.

Considering the time frame of the ECOFRESH project, however, **the developed BBNs must be regarded as explorative pilot models that can and should be**

further improved to make them operable on the institutional level. The pond model is predicting ES of a single pond in a single year for a set of different possible scenarios. The model serves as a first essential step towards the construction of a network that allows making predictions on a larger temporal (multiple years) and spatial scale (whole multi pond system). It is important to note that the constructed model is not only valid for the **pond complex Midden-Limburg**, but it is also applicable on other ponds or pond complexes in Europe. By altering the manageable or precondition variables, one is able to adjust the model according to the local conditions or desired scenarios. The **Grote Nete river model** constitutes the basis for ES assessment on a catchment scale but should be extended to incorporate all relevant provision, regulating and cultural services as well as quantitative and economic data. Since the model has been developed on a landscape scale with varying biophysical conditions, the tool could easily be applied on larger spatial scales, provided the suggested model improvements.

It is recommended that upscaling of the model outputs is conducted with great care. **Simple inferences to predict ES delivery and ES values over different spatial and temporal scales cannot easily be made** as ES are not always provided linearly and many systems/functions are non-linear, show thresholds or limiting functions. For certain services, generally provisioning services, increases in scale or area are straightforwardly reflected in provision levels. For other services such as habitat provision or recreational value, distance rules and clustering need to be taken into account and this should be given special attention in model development. It should also be mentioned that **alternative validation techniques, such as expert judgment, should frequently be applied** as actual or potential services provision levels are often hard or impossible to measure directly and high-quality empirical data for model validation is scarce.

The valuation part of the project demonstrated that **by estimating the economic value of ES in monetary terms we have a common, comparable unit with which to assess trade-offs**. This information can be used to highlight the importance of ES and to make more cost-effective decisions regarding the sustainable use and management of ES.

The distance decay analysis shows that the population over which individual willingness-to-pay values can be aggregated to calculate the total willingness-to-pay for policy scenarios will not always be equal to an administrative unit. **Distance decay estimates are dependent on the physical context including the availability of substitutes**.

Furthermore, **the results of the valuation studies can be implemented in the webbased calculation tool ‘Natuurwaardeverkenner’ which will bring this tool to an extended use**. The tool itself is used in policy processes to evaluate the costs and benefits of nature deterioration or creation, and to underpin the societal value of investments in nature conservation on regional, local and national projects. The valuation results of the case study of the Nete-Demer can be used within a broader framework for **calculating the benefits of the Water Framework Directive in Belgium** and as such scientifically underpinning the value of improving the good ecological status of our rivers. Some extended research is needed to implement the cross-effects of substitutes on the value people attach to river improvements as the alternatives in this study were limited (only 2 rivers).

The results of the social assessment of the ES concept suggest that **in several respects an ES approach will strengthen integrated water management.** First, there is the **organizational potential**. The integrated water management approach applies an ecosystem vision to river basins as integral units, whereas an ecosystem services approach provides the linkage of ecosystems with ecosystem service providers and beneficiaries. By departing from the idea of services, common ground can be sought on a wide range of issues and on the approach that will be taken to achieve the objectives of integrated water management. In this respect, attempts have already been made using ecosystem services as an integrative framework. Such initiatives aim to facilitate the cooperation between local stakeholders and administrations in charge of water when implementing actions that are part of the river catchment management plans (e.g., identifying and tackling a combination of local issues on fish migration, water quality, erosion and water quantity). Coordination and synchronisation of actions by different partners are important aspects here. Since the projects under study are still in progress, it is not possible to determine the actual impact of using ecosystem services as a framework for joint action.

Second, **ES is a concept with strong communicative potential**. It is currently used as a 'common language', and seen by many to be a move away from traditional sectoral thinking. Furthermore, ES can be employed as a communicative device for either informing the public or for motivating certain policy decisions. Lack of both public and policy support are often mentioned bottlenecks. A focus on communicating the benefits of certain projects – in particular, the added value through win-win situations - may bring these projects under greater attention, and eventually lessen the extent to which they are viewed as negative. **While the concept of ES can promote the water managers' projects, these managers can become promoters of ES alike.**

Third, it is recognized that **ES have potential to be operationalized into policy and practice solutions**. Today the idea of blue-green services is already translated into certain agri-environmental measures. **However, in relation to water systems only few management agreements are available**. Many participants in the study envisioned that, along the lines of the Dutch example, a catalogue of freshwater services could be prepared. Through creating the option of multiple services, more win-win situations could be created. Furthermore, a larger number of ES could be addressed in existing water management plans, for instance, regulating services (carbon sequestration, tidal flood control, N-retention, P-retention, Si-buffering and pest regulation) and the supporting service nutrient cycling. Finally, if all services and costs for society are considered it will enable to identify more budget friendly solutions (e.g., natural flood areas versus dams and dykes). In this respect, more research is needed on ecologically friendly alternatives to inform financially sound policy choices.

4. DISSEMINATION AND VALORISATION

4.1 PARTICIPATION IN CONFERENCES AND WORKSHOPS

4.1.1 Oral presentations – conferences

- D'Hondt Rob, Landuyt Dries, Van der Biest Katrien, Jacobs Sander. *Determination of trade-offs in ecosystem service delivery using Bayesian belief networks.* Benelearn International Conference (24-25/05/2012, Gent)
- De Bie T., De Meester L. *The biology of Ecosystem services.* TEEBelgium D0 conference. Prospects for an efficient, sustainable and equitable economy. (27/04/2012, Brussels).
- Jacobs S., Van der Biest K., D'Hondt R., Landuyt D., Vrebos D., Beauchard O., Staes, J. & Meire P. *Measuring Ecosystem Services: Science or Pragmatism?* TEEBelgium D0 conference (27/04/2012, Brussels).
- Jacobs Sander, Van der Biest Katrien. *Landscape-scale mapping of potential versus actual ecosystem services in freshwater ecosystems.* 4th Ecosystem Services Partnership International Conference (4-7/10/2011, Wageningen)
- Lemmens P. De Bie T., Mergeay J., Van Wichelen J., De Meester L. and Declerck S.A.J. *The Netherlands. Management as tool for biodiversity conservation in shallow lakes and pools*. NAEM meeting (7-8/02/2012, Lunteren, Netherlands).
- Lemmens P. De Bie T., Mergeay J., Van Wichelen J., De Meester L. and Declerck S.A.J. *The importance of management as tool for biodiversity conservation in shallow lakes and ponds.* European Pond Conservation Network 2012 (4-8/06/2012, Luxembourg).
- Lemmens P., De Bie T., Mergaey J., Van Wichelen J., De Meester L., Declerck S.A.J. *Effect of fish culture management on the composition and diversity of aquatic biota in ponds.* Shallow Lakes (24-28/04/2011, Wuxi, China).
- Lemmens P., De Bie T., Mergeay J., Van Wichelen J., De Meester L. and Declerck S.A.J. *The role of fish community composition on biodiversity and ecosystem structure*. Center for wetland Ecology (Eutrophication) (22/06/2011, Nijmegen, The Netherlands).
- Lemmens P., L. De Meester and S.A.J. Declerck. *The efficiency of artificial fish refuges against predation by cormorants*. Shallow Lakes, (24-28/04/2011, Wuxi, China).
- Liekens Inge, De Nocker Leo. *Counting the benefits of Biodiversity: opportunities and challenges.* TEEBelgium D0 conference (27/04/2012, Brussels).

- Van der Biest Katrien, Staes Jan. *Wat biedt de Nete aan ecosysteemdiensten en kunnen we die beheren?* Keynote presentatie ANKONA-dag (12/02/2011, Antwerpen)

4.1.2 Oral presentations – workshops

- De Bie T., Lemmens P., Declerck S., De Meester L. *Scale effects within ecosystems: case study pond complex Midden-Limburg.* BEES workshop II: Ecosystem services: methodologies, spatial & temporal scales (23/032011, Leuven).
- De Meester L. *Ecological mechanisms underlying the link between biodiversity and ecosystem services.* BEES workshop III: Ecosystem services and Biodiversity (24/03/2011, Leuven).
- Liekens Inge. *Spatial scales in economics.* BEES workshop II, The scaling problem: spatial and temporal effects and interactions in ecosystem service research (23/03/2011, Leuven)
- Liekens Inge. *Biodiversity and economic valuation.* BEES workshop III: Ecosystem services and Biodiversity (24/03/2011, Leuven).
- Liekens Inge. Presentation at the workshop on results of valuation studies in VITO project value based mapping (31/05/2012, Brussels)
- Liekens Inge. *WFD Benefit assessment in Flanders, Belgium*. European Workshop: How can we estimate the costs and benefits of the WFD implementation (03/05/2012, Brussels)
- Van der Biest Katrien, Jacobs Sander, Staes Jan, Vrebos Dirk, Meire Patrick. *Scale effects of ecosystem services within catchments.* BEES workshop II, The scaling problem: spatial and temporal effects and interactions in ecosystem service research (23/03/2011, Leuven)

4.1.3 Poster presentations

- Ceuterick Melissa. *At our service? The potential of the ecosystem services concept for integrated water policy discourse.* ALTER-net summer school 'Biodiversity and Ecosystem Services: An interdisciplinary Perspective' (7-16/09/2011, Peyresq, France)
- Jacobs Sander, Van der Biest Katrien, Staes Jan, Meire Patrick. *ECOFRESH – Ecosystem services of freshwater ecosystems.* General presentation of the ECOFRESH project. 4th Ecosystem Services Partnership International Conference (4-7/10/2011, Wageningen, The Netherlands)
- Jacobs Sander, Van der Biest Katrien, Staes Jan, Meire Patrick. ECOFRESH – Ecosystem services of freshwater ecosystems. General presentation of the ECOFRESH project. TEEBelgium D0 Conference (27/04/2012, Brussels)
- Lemmens P., De Bie T., Mergeay J., Van Wichelen J., De Meester L., Declerck S. *Management as tool for biodiversity conservation in shallow lakes*

and ponds. Ecology, Evolution and Biodiversity Conservation - Launch Event (06/02/2012, Leuven).

- Van der Biest Katrien, Goethals Peter, Jacobs Sander, Staes Jan, Meire Patrick. *Predicting ecosystem service delivery with bayesian belief networks.* 7th International Conference on Ecological Informatics (13-16/12/2010, Gent)

4.1.4 Organized workshops

- Closed pre-conference workshop Biodiversity Post 2010: biodiversity in a changing world. *Planning for ecosystem services: what do we need to know?* Meire Patrick, De Nocker Leo, Liekens Inge, Cliquet An, Eigenbrod Felix, De Groot Dolf, De Meester Luc, Maltby Edward, Brown Claire, Van der Biest Katrien, Jacobs Sander, Vandevenne Floor, Vrebos Dirk (07/09/2010, Antwerp)
- Lunchtalks on the valuation of ecosystem services at VITO (05/06 and 07/06/2012, Mol)

4.2 EDUCATION

- Katrien Van der Biest started a PhD in the frame of ECOFRESH at the University of Antwerp (ECOBE) in April 2010. Promotor Prof. Patrick Meire, copromotor: Dr. Sander Jacobs. Her work is focused on mapping and quantifying ecosystem services of freshwater ecosystems in Flanders. The research is mainly carried out in the Nete catchment. The Ecosystem Service Bundle Index developed in the frame of the ECOFRESH project will be further elaborated in her PhD.
- Jeremy De Valck started a PhD in the frame of ECOFRESH at VITO and KUL in March 2011. *Value based Mapping of ecosystem services*. Promotor Prof. Liesbet Vranken (KUL) and copromotor Joris Aertsens (VITO)
- Rob D'Hondt started a PhD in the frame of ECOFRESH at the University of Ghent in June 2011. Promotor Prof. Peter Goethals. *Modelling ecosystem services of wetlands.*
- Dries Landuyt started a PhD in the frame of ECOFRESH at the University of Ghent and VITO in October 2012. *Modeling ecosystem services with Bayesian Belief Networks*. Promotor Prof. Peter Goethals, copromotor Steven Broekx
- Pieter Lemmens started a PhD in the frame of ECOFRESH at the Catholic University of Leuven in 2012. Promotor Prof. Luc De Meester
- Pieter Spoelders. Master thesis Milieuwetenschap UA - *Analyse van historische, huidige en potentiële ecosysteemdiensten van het Malesbroek*. June 2011. Promotor: Prof. Patrick Meire. Copromotors: Katrien Van der Biest, Jan Staes
- Eline Van Hastel. Master thesis Milieuwetenschap UA - *Ecologisch functioneren, successie en beheer van moerasecosystemen.* June 2011. Promotor: Prof. Patrick Meire. Copromotors: Katrien Van der Biest, Jan Staes, Floor Vandevenne

5. PUBLICATIONS

5.1 PAPERS AND ARTICLES

- Landuyt Dries, D'Hondt Rob, Engelen Guy., Broekx Steven, Goethals Peter. *Exploring the potentials of Bayesian belief networks in ecosystem service modeling*. Environmental Modeling and Software (2013)
- Van der Biest Katrien, D'Hondt Rob, Jacobs Sander, Landuyt Dries, Staes Jan, Meire Patrick, Goethals Peter. *EBI: An index for delivery of ecosystem service bundles*. Ecological Indicators, Special Issue Quantifying Ecosystem Services and Indicators for Science, Policy and Practice (2013)
- Broekx Steven, Liekens Inge, Van Peel Wim, De Nocker Leo*. A manual and web based tool to support the valuation of ecosystem services in Flanders, Belgium*. Special Issue Environmental Impact Assessment Review (2012)
- Ceuterick M., Van Herzele A. *The potential of the ecosystem services concept for integrated water management in Flanders* (in preparation)
- D'Hondt Rob, Lemmens Pieter, De Bie Tom, Liekens Inge, Goethals Peter. *Modeling service trade-offs of a freshwater pond in Midden-Limburg (Belgium) under varying management scenarios.* Environmental Modeling and Software (in preparation)
- Lemmens P. De Bie T., Mergeay J., Van Wichelen J., De Meester L. and Declerck S.A.J. *Management as tool for biodiversity conservation in shallow lakes and ponds* (in preparation)
- Liekens I. *The impact of substitution effects on the willingness to pay for reaching good water status in fresh water ecosystems* (in preparation)

5.2 REPORTS

- Jacobs S., Staes J. et al. (2010). *Ecosysteemdiensten in Vlaanderen - Een verkennende inventarisatie van ecosysteemdiensten en potentiële ecosysteemwinsten*. University of Antwerp, Ecosystem Management Research Group, ECOBE 010-R127. In opdracht van het Agentschap voor Natuur en Bos.
- Lemmens P., De Bie T., Mergeay J., Mathijs E., Ercken D., Vanhove T., Vanderstukken M., De Meester L., Declerck S. (2012). *Onderzoek naar de mogelijkheden voor een duurzame integratie van visteelt en ontwikkeling van natuurwaarden in ruimtelijk kwetsbare gebieden*. Eindrapport TWOL studie (LIM/AMINAL/AN/LIM/2004/10). In opdracht van het Agentschap voor Natuur en Bos.

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8. APPENDICES

8.1 ANNEX 1: BBN - CONDITIONAL PROBABILITY TABLES

<u>**Case pond complex Midden-Limburg**</u>

Table A.1: Conditional Probability Table for assigning levels of shoreline complexity (SC) based on the management scenario (MSc). This CPT was populated on expert judgment.

Management Scenario (MSc)	Shoreline Complexity (SC)		
	None	Intermediate	High
Intensive Breeding	80	15	5
Extensive Breeding	15	70	15
Nature Management 1	5	15	80
Nature Management 2	5	15	80
Nature Management 3	5	15	80

Table A.2: Conditional Probability Table for assigning levels of fish stocking of benthivores (FS_b) based on the management scenario (MSc). This CPT was populated on expert judgment.

Management Scenario (MSc)	Fish Stocking Benthivores (FS_b)			
	No Stocking	Low Stocking	Moderate Stocking	High Stocking
Intensive Breeding	0	0	0	100
Extensive Breeding	0	0	100	0
Nature Management 1	10	90	0	0
Nature Management 2	50	50	0	0
Nature Management 3	90	10	0	0

Table A.3: Conditional Probability Table for assigning levels of fish stocking of piscivores (FS_pi) based on the management scenario (MSc). This CPT was populated on expert judgment.

Management Scenario (MSc)	Fish Stocking Piscivores (FS_pi)		
	No Stocking	Low Stocking	High Stocking
Intensive Breeding	100	0	0
Extensive Breeding	25	50	25
Nature Management 1	10	90	0
Nature Management 2	50	50	0
Nature Management 3	90	10	0

Table A.4: Conditional Probability Table for assigning levels of fish stocking of planktivores (FS_pl) based on the management scenario (MSc). This CPT was populated on expert judgment.

Management Scenario (MSc)	Fish Stocking Planktivores (FS_pl)			
	No Stocking	Low Stocking	Moderate Stocking	High Stocking
Intensive Breeding	0	0	0	100
Extensive Breeding	0	0	100	0
Nature Management 1	10	90	0	0
Nature Management 2	50	50	0	0
Nature Management 3	90	10	0	0

Table A.5: Conditional Probability Table for assigning occurrence of additional feeding (AF) based on the management scenario (MSc). This CPT was populated on expert judgment.

Management Scenario (MSc)	Additional feeding (AF)	
	Yes	No
Intensive Breeding	100	0
Extensive Breeding	0	100
Nature Management 1	0	100
Nature Management 2	0	100
Nature Management 3	0	100

Case Nete catchment

Table A.6: Expert judgment on levels of food production (ES_a) ranging from zero (0, white) to very high (5, dark grey) for every combination of states of agricultural production potential (P_a) and crop type (CT). This table can be converted to a similar, deterministic CPT as for wood production (Table 2) by assigning a 100% probability to the selected production level for every combination of input states.

Food Production (ES_a)																	
Crop type (CT)	Agricultural Potential (P_a)																
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
Cropland	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	5	5
Cropland envi	1	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	4
Cropland nature	1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3
Grassland prod	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
Grassland prod nature	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Grassland nature	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
non regi Grassland nature	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
non regi Cropland	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.7: Conditional Probability Table for assigning levels of wood production (ES_f) based on forest production potential (P_f) and forest type (FT). This CPT was populated on expert judgment and is deterministic.

Forest type (FT)	Forest Potential (P_f)	Wood Production (ES_f)					
		Zero (0)	Very Low (1)	Low (2)	Average (3)	High (4)	Very High (5)
Nature Management	F1	0	100	0	0	0	0
Nature Management	F2	0	0	100	0	0	0
Nature Management	F3	0	0	0	100	0	0
Nature Management	F4	0	0	0	100	0	0
Nature Management	F5	0	0	0	0	100	0
Timber Management	F1	0	100	0	0	0	0
Timber Management	F2	0	0	100	0	0	0
Timber Management	F3	0	0	0	100	0	0
Timber Management	F4	0	0	0	0	100	0
Timber Management	F5	0	0	0	0	0	100
None	F1	100	0	0	0	0	0
None	F2	100	0	0	0	0	0
None	F3	100	0	0	0	0	0
None	F4	100	0	0	0	0	0
None	F5	100	0	0	0	0	0

8.2 ANNEX 2: SOCIAL ASSESSMENT - INTERVIEW GUIDE (IN DUTCH)

Deel 1 Integraal waterbeleid

1. Kan u eerst kort omschrijven wat u belangrijkste taken zijn die verband houden met (integraal) waterbeleid?
   - Hoe kom jij in jouw functie in contact met integraal waterbeleid?
   - Heb je zelf meegewerkt aan de totstandkoming van integraal waterbeleid? Vanuit welke functie? (tot stand komen bekkenbeheerplannen?) Hoe?
   - Waar liggen u prioriteiten? Meest urgente knelpunten in huidig waterbeleid?
2. Wat is er volgens u ten goeie veranderd sinds de invoering van de integrale aanpak binnen het waterbeleid?

3. Wat kan verbeterd worden aan het huidige integraal waterbeleid? Hoe kan dat volgens u gerealiseerd worden?
4. Wat zijn de obstakels waar je op botst bij de uitvoering van de plannen (afstand tussen planning en uitvoering waterbeleid).

Deel 2 Het begrip ecosysteemdiensten

5. Er wordt vaak gesteld dat ecosysteemdiensten een containerbegrip is dat vele ladingen dekt. Wat begrijpt uzelf onder ecosysteemdiensten?
6. Hoe ben je voor het eerst in aanraking gekomen met dit begrip?
7. Is dit een thema dat aan bod komt binnen het veld? Is dit iets dat besproken wordt binnen… bv. CIW (*afhankelijk van de geïnterviewde*?)
8. Bent u binnen uw werkveld al met een ecosysteemdiensten benadering in aanraking gekomen (*afhankelijk van de invulling die eraan wordt gegeven in het antwoord op de vorige vraag*) en kunt u daarvan voorbeelden geven?
9. Vanuit uw ervaring, wat kunnen volgens u de mogelijkheden zijn van een ecosysteemdienstenbenadering?
10. Zijn er barrières waardoor een toepassing van het ecosysteemdienstenkader (momenteel) niet bruikbaar is? Welke?
11. Ziet u mogelijke bedreigingen of risico's in een ecosysteemdienstenbenadering? Welke?
12. Bestaan hierover verschillende opinies in het veld? Welke andere visies?

Deel 3 Aanknopingspunten met integraal waterbeleid

13. Kan een ecosysteemdienstenbenadering bijdragen aan (de verbetering van) integraal waterbeleid? Of aan de veranderingen die u wilt realiseren binnen het huidig waterbeleid? Zo ja, hoe?
14. Welke rol ziet u zichzelf daarin spelen?
15. Ziet u aanknopingspunten tussen integraal waterbeheer en ecosysteemdienstenbenadering?/ Ziet u aanknopingspunten in de bekkenbeheerplannen (5 krachtlijnen) Welke diensten zijn er momenteel al opgenomen? Welke moet meer aandacht gegeven worden?

Deel 4 Operationalisering: naar instrumenten?

Verschillende types instrumenten zijn:

a) Sociale/ communicatieve instrumenten:
    - sensibilisatie
    - informatie
    - overleg
b) Economische:
    - heffingen
    - subsidies
    - fiscale maatregelen
    - investeringen
c) Juridische:
    - wetgeving
    - vergunningen
    - passende beoordeling
    - handhaving

16. Worden er nu al expliciet financiële vergoedingen voor geleverde ecosysteemdiensten (PES) in voorzien? Zo ja, welke? Welke effecten hebben die op de toestand van watersystemen? Welke effecten hebben die voor de economische positie van de betrokkenen?
17. Waar ziet u zelf verder mogelijkheden?

Deel 5: ECOFRESH

18. Eén van de doelstellingen van dit project is een niet-technische publicatie voor een breed publiek rond ecosysteemdiensten in waterbeleid.
    - Denkt u dat hier vraag voor bestaat?
    - Hoe zou dit concreet kunnen ingevuld worden?
    - Welke zaken mogen we hierbij niet vergeten?
    - We zouden eventueel werken met een brochure waarin een aantal 'best practices' worden voorgesteld? Kunnen eventueel de voorbeelden waarnaar gepeild wordt in vraag 7 meegenomen worden?
19. Bent u geïnteresseerd de resultaten mee op te volgen? Bent u bereid deel te nemen aan een focusgroep rond de resultaten van dit onderzoek?

8.3 ANNEX 3: WATER TYPES ACCORDING TO THE WATER FRAMEWORK DIRECTIVE

Table A.8: abbreviations water types for the Water Framework Directive. For more information on the water typologies we refer to Jochems et al. (2002); Vandenbussche et al. (2002) and Denys (2009)

Category	Code	Type
Rivers	Rzg	Very large river
	Rg	Large river
	Rk	Small river
	Bg	Large stream
	BgK	Large stream, Kempen
	Bk	Small stream
	BkK	Small stream, Kempen
	Pz	Polder watercourse - freshwater
	Pb	Polder watercourse - brackish
	Mlz	Macrotidal freshwater
Lakes	Ad	Alkaline dune pools
	Ai	Alkaline, shallow water with high mineral content
	Ami-om	Alkaline, shallow, oligo-mesotrophic water with moderate mineral content
	Ami-e	Alkaline, shallow, eutrophic water with moderate mineral content
	Aw-om	Alkaline, deep, oligo-mesotrophic water
	Aw-e	Alkaline, deep, eutrophic water
	Czb	Circumneutral, weakly buffered water
	Cb	Circumneutral, well-buffered water
	CFe	Circumneutral, iron-rich water
	Zs	Strongly acid water
	Zm	Weakly acid water
	Bzl	Slightly brackish water
Transition waters	O1	Macrotidal lowland estuary
	O2	Mesotidal lowland estuary
Wetlands	W1	Eutrophe wetlands and transitional communities
	W2	Mesotrophic/oligotrophic wetlands with Carex humilis (incl. fens)