Natural solutions versus technical solutions

How ecosystem benefits can make a difference in public decisions

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Abstract

'Building with Nature' solutions seem like a logical alternative to technical solutions. Working with nature instead of against it might save civil engineering costs. But will it also generate additional civil engineering benefits? Typical engineering benefits are related to flood prevention, transportation and sand mining. Both technical and natural solutions can produce these benefits. Natural solutions, however, may produce additional ecosystem benefits. These are rarely accounted for in investment decisions about engineering projects.

This is not surprising as there are no rules stating that and how these benefits should be calculated. The Netherlands is the first country in Europe to install a national guideline for monetising ecosystem benefits within cost-benefit analyses in the public sector. This article shows how this guideline provides a systematic approach to prevent both over- and under-estimations of ecosystem benefits. The key to this approach is to make a distinction between goods and services that directly generate welfare while linking those to conditional functions that indirectly generate welfare.

This approach is applied to flood defence in the Scheldt estuary in Belgium. It resulted in benefit estimates that were large enough to compensate for the extra cost of natural solutions. Taking ecosystem benefits into account influenced the flood protection decision of the national government: the natural 'inundation areas'-solution was preferred to the technical solution of 'dyke heightening'.

KEYWORDS

ecosystem valuation, national guideline, cost benefit analysis, goods and services, inundation area, estuary, functions of nature

1. Introduction

In civil engineering, natural solutions are gaining popularity as an alternative to technical solutions. When natural solutions save costs, they are -of course- welcomed. For example, making use of water currents to reduce the cost of dredging. When a natural solution turns out to be more costly than its technical compeer, the technical solution is usually favoured. For example, creating natural inundation areas is more expensive than dyke heightening, because the creation of inundation areas requires giving up valuable agricultural land.

But is it fair to compare two types of solutions merely on the basis of cost, when they might also differ in terms of benefits? If designed for a specific purpose (e.g. flood protection) both natural and technical solutions have similar key benefits (e.g. prevented flood damage) for society. The natural solution may, however, have ecosystem benefits, that the technical solution does not, such as recreational or carbon fixation benefits.

The key to promoting natural solutions thus lies in scientists' ability to determine ecosystem benefits. Both ecologists and economists have carried out studies to calculate ecosystem benefits in monetary terms. Once a price tag is put on ecosystems benefits, they can be included in the cost-benefit analyses that investment decisions are based on (Pearce and Turner, 1990; Layard and Glaister, 1994; Hanley and Spash, 1993).

The extent to which ecosystem benefits are accounted for in cost benefit analyses differs per country. In Belgium and in the Netherlands, the values of ecosystems were not included in cost-benefit analyses for actual political decisions until the year 2004. In that year, a national guideline for determining ecosystems' benefits was endorsed by the Dutch government (Ruijgrok et.al., 2004).

An interesting feature of this guideline is the way in which it tries to prevent possible over and under estimation of ecosystem benefits. The few valuation studies that had been conducted in the past seemed to produce results that either completely overruled the costs of the appraised project or were absolutely negligible compared to the project costs. On the one hand, policy makers felt that studies concluding that ecosystems are much more valuable than any economic activity, could not be right and were not helpful to make decisions on planned economic activities or civil engineering projects. On the other hand, they felt that studies concluding that ecosystems' values are negligible were not really helpful either.

It thus seemed that the results of valuation studies were perceived as either too high or too low to play a role in the costbenefit analysis for concrete investment decisions on civil engineering projects[1]. In this chapter, it is shown how the Dutch guideline helps to prevent over and under estimations of ecosystem benefits on the basis of a case study in Belgium: flood protection in the Scheldt estuary.

2. The methodology of ecosystem valuation

Definitions

In order to understand the way in which the ecosystem benefits of the Scheldt estuary are determined in this chapter, it is important to note how the term benefit is defined and used. The socioeconomic benefits are defined as the amount of both material and immaterial forms of welfare that nature generates for society. This means that socioeconomic benefits are larger than the cash flows derived from nature. These cash flows, which can be rather limited for unexploited, pristine natural areas, form the financial benefits. The broad welfare definition means that the socioeconomic benefits are purely anthropocentric: they pertain strictly to human welfare. Socioeconomic benefits do not encompass the intrinsic value of nature, as the welfare of other organisms, plants and animals is not included[2]. Figure 1 shows the economic, the financial and the intrinsic benefits of ecosystems.

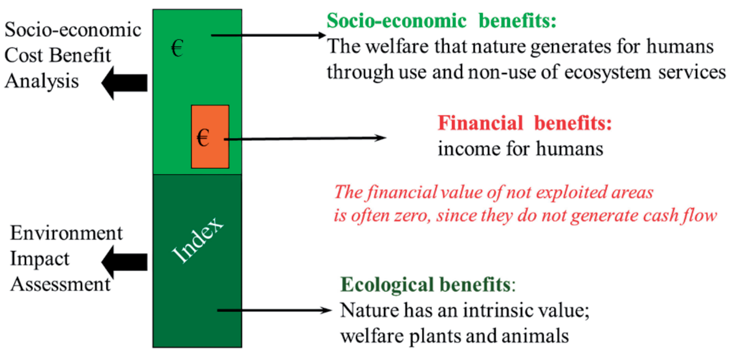

Figure 1. The three benefits of nature

1 Another reason why the results of ecosystem valuation studies are not used in political decision making, is that these studies do not always measure change. E.g. Costanza et.al. (1997) estimate the values the of current natural capital stock to awaken politicians. Of course, this value cannot help a policy makers to decide whether they should give up a part of a nature reserve to build a parking lot. For that decision they need to know the value of the change to the reserve and compare it with the benefits of the parking lot.

2 If humans obtain welfare from the well being of other organisms, this is included in the form of a nonuse value.

Unlike intrinsic benefits (mostly referred to as intrinsic value[3]), the economic benefits of ecosystems can be expressed in monetary terms by means of several economic valuation techniques (Taylor, 2001; Ward and Beal, 2000; Mitchell and Carson, 1989). Expressed in monetary terms, the benefits can be included in socioeconomic cost-benefit analyses which are also in monetary terms. In order to do that with the ecosystem benefits of the Scheldt estuary, the various ways in which these ecosystems generate welfare flows were investigated.

It is noted here that the intrinsic benefits of ecosystems, which are not included in cost-benefit analyses, are usually reported in environmental impact assessments in terms of a score or index. In those assessments, the impacts of civil engineering projects are determined from the perspective of the welfare of species.

Methodology

Ecosystems generate human welfare because they produce goods and services that humans can use and/or simply enjoy without using it- the so-called nonuse function (see e.g. Bateman et.al. (2002), Hanley and Spash (1993), Pearce and Moran (1994)). The use of goods and services can be direct or indirect through the use of other goods or services[4].

Examples of direct forms of use pertain to goods such as wood, clean water, and fish or to services such as recreational opportunities, protection against flooding or climate change. Examples of indirect forms of use are 'nutrient recycling' and 'fish nurseries' which respectively result in 'clean water' and 'fish production'. By using the clean water or the fish, we indirectly use the nutrient recycling service and the nursery service. In other words, the ecosystem´s nutrient recycling and the nursery function are conditional to the production of clean water and fish.

To capture all benefits of an ecosystem, it is important not to omit any goods and services that the ecosystem produces, because that causes an underestimation of the nature value. At the same time, it is also important not to value indirect forms of use in addition to direct forms of use, as this causes overestimations. A way to solve the problem of potential under- and overestimations is to make a distinction between conditional functions that indirectly generate welfare and goods and services that people can directly use or

3 A benefit is comprised of a quantity times a value, e.g. flood protection benefits are the number of houses protected times the avoided damage per house or recreational benefits are the number of recreational visits times the value (i.e. willingness to pay) per visit. Similarly, intrinsic benefits can be expressed in terms of the number of hectares of nature types times the number of (rare) species per hectare.

4 Sometimes the categories 'direct-' and 'indirect-use' are interpreted as respectively tangible and intangible goods and services.

enjoy without using (the socalled nonuse) and to systematically link conditional functions to goods and services. To understand this solution, we shall take one step back and look at the original functions of the nature approach.

The functions of nature approach, which distinguishes production, information, regulation and carrier functions, was originally developed by ecologists to identify the substance and energy flows between the ecosystem and the economic system (e.g. van der Maarel and Dauvellier, 1978). The approach was immediately applied by both ecologists and economist[5] to determine the economic value of ecosystems (van Holst et.al, 1978; Gren et.al, 1994, Barbier, 1993; de Groot, 1992; Costanza et.al, 1997), even though this approach was not developed for this purpose. Later, the approach was further developed by the Millennium Ecosystem Assessment panel, that distinguishes supporting services, i.e. conditional functions and other goods and services (i.e. the other functions[6] (Millennium Ecosystem Assessment, 2005). Figure 2 shows how the different types of functions form a link between the ecosystem and the economic system.

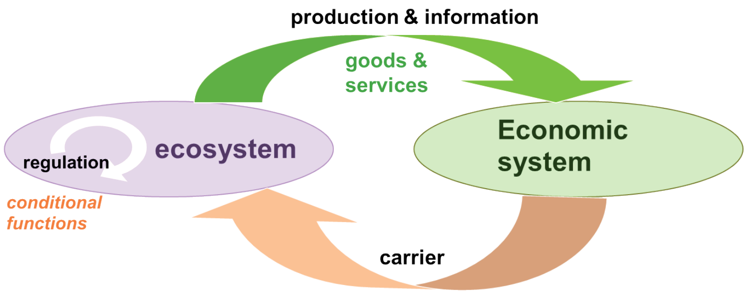

Figure 2. The functions that ecosystems fulfil for the economic system

In figure 2, the different categories of functions are represented by arrows pointing in different directions. The production and information functions reflect a flow from the ecosystem to the economic system. They form the supply of goods (production) and services (information) from which humans directly derive welfare when using or not using it. These are the welfare flows that we are searching for when trying to determine the economic benefits of ecosystems. Carrier functions represent an opposite flow from the economic system to the ecosystems. Humans put houses, waste, roads etc. into

5 It may be noticed here that in studies done by economists, the total economic value concept usually plays a central role, whereas in studies by ecologists, the functions of nature approach is the central focus.

6 This panel uses the terms provisional, regulation and cultural functions. The socalled carrier functions are no longer distinguished.

the ecosystem. Carrier functions should not be included in ecosystem benefit calculations, because they lead to overestimations. In the end, the space that ecosystems provide carries all human activities, rendering the ecosystems´ benefits equal to the benefits of all human activities. In situations where we would like to compare the benefits of ecosystems with the benefits of economic activities, this is not very helpful. For example, suppose we need to decide whether or not to build a road through a natural area. We would like to compare the benefits of the road with the costs of losing the ecosystem in that area. If the benefits of carrying a road are attributed to the natural area, than the costs of losing the ecosystem will always be exactly equal to the benefits of the road, leaving the matter undecided.

Regulation functions are flows inside the ecosystem and are represented by an arrow inside the ecosystem. They are the processes and characteristics that make the carrying of activities and the production of goods and services possible. Originally, they were also called conditional functions (Harms, 1973). Including these conditional functions in addition to goods and services (i.e. production and information functions) is the major cause of overestimates in valuation studies. Conditional functions such as pollination, nutrient recycling, nurseries, carbon sequestration etc. only indirectly generate welfare since they lead to food production, clean water, fish production and protection against the effects of climate change. This means that if both pollination and the food production, or both the nursery and the fish are being calculated and added up to determine the total ecosystem benefits, one and the same welfare flow is counted twice. This is comparable with valuing both the ice cream machine and the ice cream and adding the two values up to determine the socioeconomic benefits of ice cream production.

For the sake of not omitting any important ecosystem benefits, it is useful to identify conditional functions. At the same time, they can be the cause of overestimations, when overlapping with other goods and services (see Box 1). By linking conditional functions to goods and services that directly generate welfare, it becomes easier to carry out an ecosystem benefit study without omissions and without overlap. Table 1 presents a list of wetland ecosystems functions and links the goods and services to conditional functions.

Table 1 shows that nurseries lead to fish production and nutrient recycling to clean water. Since each time there is only one welfare flow, this means that one should either value the nursery or the fish, and either the nutrient recycling or the clean water in order to correctly determine ecosystem benefits[7]. From literature on economic valuation methods, we know that conditional functions such as nutrient recycling cannot be valued in a reliable way with methods that measure people’s willingness to pay, such as CVM

7 When there are two or more conditions to one good, one should choose between the good and the most limiting condition.

and TCM, whereas commodity-like goods and services, such as ´clean water´ and ´recreational visits´, can (Freeman, 1986). These conditional functions can, however, be valued quite easily by means of cost-based methods such as abatement cost avoided. Such cost-based estimates are, however, proxy´s of the actual economic value, since it may cost much to abate (e.g. nutrient emissions) although the welfare derived from less nutrients may be smaller than the abatement costs.

Condition	Goods and Services
Nursery; Migration routes; Aeration (oxygen)	Fish
Nutrient availability; Ground water fluctuation; Pollination; Soil formation; Erosion control; Biological control	Food and other harvestable products
Erosion control (waterways); Sedimentation control	Transportation possibilities
Nutrient recycling (e.g. denitrification); Carbon sinking (organic matter); Metal binding; Silicium production; Salinity control	Clean Water
Water absorption of soil (sponge function)	Protection against floods
Carbon sequestration	Protection against climate change
Fish nursery, natural succession, biological control etc.	Recreational opportunities
Several functions that lead to biodiversity, such as natural succession and biological control	Existence and bequest of biodiversity (non-use)

Table 1. Linking conditional functions to goods and services

From the above, one can conclude that linking conditions to goods and services, does not only help us to prevent omissions and overlap in valuation studies, but it also explicates a choice in valuation methods. By means of a case study on the Scheldt estuary in Belgium, we shall show that the choice between valuing conditional functions on the basis of avoided costs or final goods and services on the basis of willingness to pay or market prices, can be made on the basis of information availability[8].

3. Case study: the Scheldt estuary in Belgium

The Belgium government is faced with the problem of protecting the population against floods in the Sea Scheldt Estuary. The existing flood protection plan for the Scheldt, which is called Sigma Plan, stems from 1977 and needs to be updated with an eye on the possible effects of climate change. Eight alternatives have been developed to update the protection plan (see table 2). They vary from higher dykes, storm flood barriers, connecting rivers,

8 When it concerns small amounts of changes in e.g. nutrient recycling, so small that actual water quality improvements are not yet noticeable to the people, one can only value this on the basis of abatement costs.

to creating inundation areas. In order to determine which alternative is the best way to protect society against floods, the alternatives are compared by means of socioeconomic cost-benefit analysis (= CBA)[9].

Five of the eight alternatives involve the rehabilitation of inundation areas, which, in fact, represent new ecosystems and thus generate ecosystem benefits. Five types of inundation areas are distinguished:

1. Agricultural inundation areas: these are created by constructing a ring dyke behind the existing river dyke. The land between the dykes remains in agricultural use but is flooded in case of storm floods to protect the hinterland.
2. Wetlands: these are constructed in the same way as agricultural inundation areas. The difference between the two is that here the area between the dykes is turned into a wetland.
3. Reduced Tidal Areas: these are also created by adding a ring dyke, but now the area between dykes will be flooded twice a day by a flood gate.
4. River expansions: these are made by creating a ring dyke and by allowing the river dyke to disappear under water. This means that land is returned to the river.
5. Wet River Valley restorations: in river valleys the river dykes are removed, allowing the river to flow freely over the grass lands.

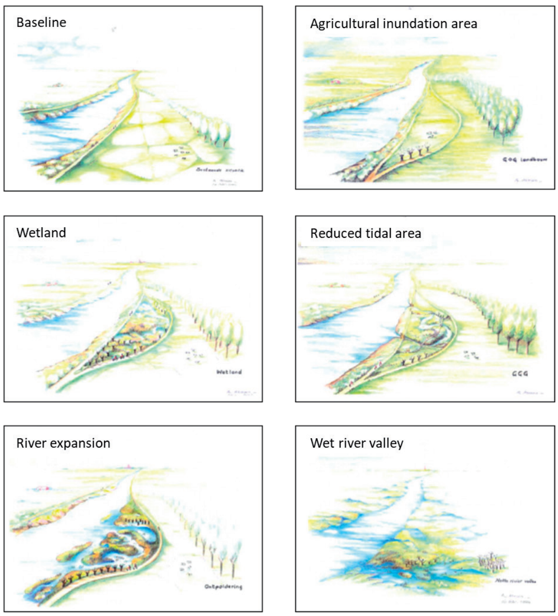

Figure 3. Artist impressions of the natural solution for the Scheldt estuary.

9 And an environmental impact assessment. In this article we focus on the CBA, as that involves ecosystem valuation.

Figure 3 shows artists impressions of these five types of natural solutions in comparison to the baseline situation. It may be noted that in the baseline the rivers have dykes on both sides. The alternative protection plans consist of different combinations of inundation areas. Table 2 gives a brief overview of the composition of the alternative plans.

Alternative	**Composition**
Storm flood barrier	No inundation areas
Higher dykes	No inundation areas
Inundation areas up to a safety level of 1 flood per 4000 years:	a) only Agricultural Inundation Areas and Wetlands; (b) Agricultural Inundation Areas and Reduced Tidal Areas; (c) Agricultural Inundation Areas, Wetlands and River Expansions
Inundation areas up to a safety level of 1 flood per 2500 years	Several Agricultural Inundation Areas and Wetlands
Inundation areas up to a safety level of 1 flood per 1000 years combined with higher dykes protecting Antwerp	Several Agricultural Inundation Areas and Wetlands
Connection between West and East Scheldt	No inundation areas
Connection between West and East Scheldt combined with inundation areas	Several Agricultural Inundation Areas and Wetlands
Restoration of upstream river valleys	(a) Several Agricultural Inundation Areas, Wetlands and Wet River Valleys, (b) Few Agricultural Inundation Areas, Wetland and Wet River Valleys (small storm flood barrier)

Table 2. Composition of flood protection alternatives.

In the CBA, both the benefits of protection against floods and the ecosystems´ benefits[10] of the five types of inundation areas are determined as well as the construction costs. In order to be able to determine the ecosystem benefits by means of the new functions of nature approach, the inundation ecosystems need to be defined in a more detailed way. Table 3 gives an overview of the ecotope composition of the five inundation ecosystems. This composition is influenced by nature management such as mowing and grazing. Since the Scheldt estuary is characterised by a transition from brackish to fresh water, a distinction is made between brackish and fresh water Reduced Tidal Areas and River Expansions[11]. In CBA it is necessary to indicate when benefits occur therefore the development time of ecotopes is also given[12].

10 Although the benefits of flood protection are also ecosystem benefits, they are treated separately in the CBA for the alternative protection plans. This is because technical solutions, such as storm flood barriers, also generate flood protection benefits.

11 For Agricultural Inundation Areas, Wetlands and Wet River Valley, this distinction is not relevant. Agricultural Areas are only flooded in case of emergency and do not change into brackish systems, though they can suffer from salt damage. Wetlands and Wet River Valleys only occur in the freshwater regions.

12 Some ecosystem benefits such as recreational opportunities will only occur after some years when the vegetation is developed. Other benefits, such water purification will occur immediately.

Characteristics	Agricultural Inundation Area	Wetland	Reduced Tidal Area	River Expansion	Wet River Valley
Ecotope composition in climax stage	100 % meadow, cornfield or production forest	Unmanaged: 100 % willow forest Managed: 50 % reed land and 50 % 5 willow forest	Fresh and unmanaged: 100 % willow forest. Fresh and managed: 20 % water vegetation, 40 % reedland and 40 % willow forest. Brackish unmanaged and managed: 20 % water vegetation, 40 % mud flat and sandbank and 40 % salt marsh.	Fresh and unmanaged: 100 % willow forest. Fresh and managed: 33 % water vegetation, 33 % reedland and 33 % willow forest. Brackish unmanaged and managed: 33 % water vegetation, 33 % mud flat and sandbank and 33 % salt marsh.	50 % swampy grasslands and 50 % structure rich grasslands
Development time	none	5 years	5 years	5 years	5 years
Salinity	fresh and brackish	fresh	fresh and brackish	fresh and brackish	fresh
Flood frequency	1 to 10 times per year	1 to 10 times per year	700 times per year, but less in climax stage	700 times per year, but less in climax stage	50 to 150 days per year
Tidal movement	no	no	yes	yes	no

Table 3. Ecotope composition and other characteristics of inundation areas.

4. Benefit calculation of the inundation areas

In order to calculate the economic benefits generated by the five types of inundation areas, an inventory was made of the welfare functions they perform. It was found that the inundation ecosystems fulfil several functions that lead to changes in human welfare.

Table 4 breaks these functions down into eleven goods and services and the conditional functions behind those goods and services. For each row in table 4 a choice was made between valuing the good or service or valuing the most limiting conditional function as a proxy for the value of the good or service. The choice that was made is underlined. The motivations behind each choice are practical. For example, it was decided to value the aeration function that Reduced Tidal Areas and River Expansions fulfil instead of the increased fish production, because there were no data available to predict the increased fish production, whereas it was possible to estimate the addition of oxygen from flooding. For clean water, a similar argumentation was used. There was no data on people´s appreciation for cleaner surface water, but it was possible to calculate the ecosystems contribution to nutrient reduction and the resulting saved cost of waste water treatment.

Goods and Services	Conditional functions	Quantification	Monetarization	Inundation area
Fish production	Aeration (most limiting) Nursery	Model prediction	Water treatment costs	RTA, RE
Wood production	Nutrient absorption etc.	Existing data on yields	Market prices	RTA, RE, W
Reed production	Idem	Existing data on yields	Market prices	RTA, RE, W
Shipping possibilities	Prevention soil erosion	Rough estimates on the basis of interpolation of existing data	Dredging costs	W, RTA
	Sedimentation control			W, RTA, RE
Clean surface water:				
- nutrient poor and algae free water	Nutrient purification (N, P)	Model prediction	Water treatment costs	W, RTA, RE
- oxygen rich water	Carbon sinking (C)	Model prediction		RTA, RE
- heavy metals free water	Metal binding (Cd, Cu, Zn, Cr, Pb, As, Ni, Hg)	Numbers from literature		W, RTA, RE
Protection against climate change	Carbon storage (CO2)	Numbers from literature	Internationally authorised value	W, RTA, RE
Recreational opportunities	Several, no specific condition was identified as being the limiting factor	Data from ferries and field counts	Empirical measurement of willingness to pay per visit	AIA, W, RTA, RE, WRV
Fish recreation	See Fish production	Existing data on fish club memberships	Cost per year of a club membership	W, RTA, RE
Housing amenities	idem	Rough estimate of affected houses from Environmental Impact Assessment	Hedonic price transferred from Dutch study in % of the average house price	AIA, W, RTA, RE, WRV
Non-use (i.e. welfare derived from the sheer existence of nature regardles of use possibilities)	Several conditions to biodiversity, no specific condition was identified as being the limiting factor	Number of households in Flanders	Empirical measurement of willingness to pay per household	W, RTA, RE, WRV

Acronyms:
AIA = Agricultural Inundation Area, W = Wetland, RTA = Reduced Tidal Area, RE = River Expansion, WRV = Wet River Valley.

Table 4. Goods and services linked to conditional functions, quantification and monetarisation

Table 4 does not only show which welfare generating functions the five types of inundation areas fulfil, but it also shows how these were quantified and monetised.

Quantification of functions

The quantification method differs per function. For some functions, such as wood production, soil erosion, housing amenities, and fish recreation, existing data sources were used. For other functions, such as the binding of heavy metals, a literature review was done for studies conducted on comparable ecosystems (Cox et.al, 2004). For the functions, aeration, nutrient purification, and carbon sinkage, the quantification was done by means of model predictions. A special substance flow model for the Scheldt estuary of the University of Antwerp was used for this purpose.

Monetisation of functions

The different functions were monetised by means of different valuation methods. Goods and services, such as wood and reed production, were valued on the basis of market prices. All conditional functions, such as erosion control and nutrient purification, were valued in terms of abatement costs, such as dredging costs and water treatment costs.

Two services, recreation and nonuse, were valued by means of an empirical Contingent Valuation Study. In this study, 1.704 inhabitants of Flanders were asked to state their willingness to pay for recreational visits and for nonuse (i.e. conservation without using). The CV-questionnaire was set up according to the prescriptions of the NOAA Guideline (Arrow et.al, 1993). Since the CVM comprised of two different values and five different ecosystems it was quite complex.

An extra complicating factor was that each type of inundation ecosystem will be realised at several locations which have not been identified yet. Fifty percent of the interviews were held among recreationists in the Sea Scheldt Area and fifty percent were held outside this area. This was done to guarantee that the sample included both recreationist and nonusers. For representativity, interviews were spread across 33 different locations and during different days of the week over a period of three months. To prevent seasonal bias, respondents who were not recreating at the moment of interview, were asked if they visit the Sea Scheldt Area at other moments in time. If so, they were regarded as recreationists. Table 5 shows the results of the CVM-study.

Statistical tests on the difference in willingness to pay for the different types of inundation areas showed that only the differences in willingness to pay for the Wet River Valley and the other types were significant. Both the recreational value and the nonuse value of the Wet River Valley were significantly lower than the values of the other types.

Ecosystem	average willingness to pay for recreation in Euro per visit (st.dev)	n	average willingness to pay for non-use in Euro per household per year (st.dev)	n
Overall value	1.68 (3.80)	1.328	15.50 (24.73)	1.439
Agricultural Inundation Area	1.76 (4.67)	158	n.a.	0
Wetland	1.61 (3.19)	284	16.10 (10.24)	335
Reduced Tidal Area	1.77 (4.76)	288	16.33 (24.88)	371
River Expansion	1.92 (3.55)	290	15.62 (23.86)	366
Wet River Valley	1.40 (2.93)	308	13.99 (25.63)	367
Acronyms: st.dev = standard deviation, n= number of measurements, n.a. = not available.				

Table 5. CVM-results: willingness to pay for recreation and non-use

5. Results per ecosystem

After the quantification and the monetisation of the different functions of the five types of inundation areas, a spread sheet model was built to calculate the present value of the ecosystem benefits. Present values were calculated taking into account the ecotope composition[13], the development time and saturation[14], the difference between fresh and brackish water[15] and the impact of nature management[16]. The latter was modelled as a variable for the sake of conducting a sensitivity analyses afterwards. Table 6 presents the results of these calculations, assuming that all nature is managed. For the details of the calculation of each benefit in table 6, the reader is referred to Ruijgrok and Lorenz (2004).

Table 6 shows that the fresh water Reduced Tidal Areas produces the largest economic benefits. The Wet River Valley and the Agricultural Inundation Area generate the smallest benefits. This is because there is hardly any nature development in these two areas compared to the baseline situation. For both the Reduced Tidal Area and the River Expansion, the fresh water areas produce greater benefits than the brackish water areas. This can almost entirely be ascribed to the difference in nutrient purification (plant absorption). From table 6 one can also conclude that after the nonuse benefits (which is not per hectare), metal binding forms the largest benefit category, followed by sedimentation and nutrient purification.

13 This determines the quantification of the wood and reed production and of nutrient absorption by the vegetation.

14 Saturation occurs for functions such as the binding of heavy metals and the sedimentation control. When a mud flat or salt marsh is mature, the input and output of heavy metals and sediment will be in balance, resulting in zero net catchments. Here, saturation was assumed to occur after 20 years.

15 This influences the quantification of ´nutrient absorption by the vegetation´ and of ´carbon storage´.

16 This has an impact on the quantification of ´nutrient absorption´ and ´wood and reed production´.

	Agricultural inundation area	Wetland	Reduced Tidal Area	Reduced Tidal Area	River Expansion	River Expansion	Wet River Vally	Unit
Ecosystem functions**:	fresh	fresh	fresh	brackish	fresh	brackish	fresh	
Aeration	0	0	87	38	87	38	0	€/ha
Wood	0	8,630	6,904	0	5,696	0	0	€/ha
Reed	0	6,421	5,137	0	4,238	0	0	€/ha
Erosion	0	260	260	260	0	0	0	€/ha
Sedimentation	0	292	20,426	20,426	20,426	20,426	0	€/ha
Nutrient purification	0	14,990	25,022	15,304	23,572	14,864	0	€/ha
rinse out (N, P)***	0	1,929	1,929	1,929	1,929	1,929	0	
denitrification (N)	0	5,846	10,084	6,138	10,084	6,138	0	
plant absorption (N, P)	0	7,215	5,772	0	4,762	0	0	
burial (N, P)	0	0	7,237	7,237	6,797	6,797	0	
C sinking	0	0	3,242	3,242	3,242	3,242	0	€/ha
Metal binding	0	507	35,501	35,501	35,501	35,501	0	€/ha
Carbon storage	0	3,421	2,737	2,808	2,257	2,808	0	€/ha
Recreational opportunities	1,381	1,381	1,243	1,243	2,037	2,037	374	€/ha
Subtotal per ha	1,381	35,903	100,561	78,823	97,057	78,917	374	€/ha
Fish recreation	-32,500	-32,500	-32,500	-32,500	-32,500	-32,500	-32,500	€/pound fish
Housing Amenity	-50,400	-50,400	-50,400	-50,400	-50,400	-50,400	-50,400	€/2 homes
Non-use	0.0	796.2	796.2	796.2	796.2	796.2	718.6	M€ if total area is this type

* The present values are computed over an infinite time span, except for benefits that physically stop after a certain number of years (e.g. metal binding stops after 20 years).

** The functions aeration, erosion, sedimentation, nutrient purification, C sinking, metal binding and carbon storage were all valued by multiplying the modelled number of mmol O2, m3 of sediment, kg of N and P, tons of C, kg of metals per hectare per year respectively the energy cost per mmol O2, the dredging cost per m3 sediment, the water treatment cost per kg N and P and metal etc. for the Scheldt estuary.

*** These are the benefits of reduced nutrient input into the environment as agricultural land is transformed into nature.

**** These are the negative benefits if one detached and one attached house, with an average value of resp. € 320.000 and € 100.000 lose their view on the river.

Table 6. Benefits per ecosystem type (present values at 4 % interest*)

6. Cost Benefit Analysis on alternative protection plans

As explained before, the Belgian government intends to choose between several flood protection plans, which are composed of different combinations of the five types of inundation areas. This means that the ecosystem benefits of a protection plan can be calculated on the basis of the benefits per type of inundation area. Table 7 presents the results assuming that all nature is managed. Only alternative protection plans that involve the creation of new nature areas are presented. Although the alternative plans do not cover exactly the same amount of land, this leads to minor differences in benefits (accounted for in table 7) and to slight differences in costs.

Table 7 shows that alternative 3b, which involves the creation of Reduced Tidal Area´s, wherever possible, to realise a safety level of 1 flood per 4000 years, generates the largest ecosystem benefits, followed by alternative 3c and 8a.

Alternative flood protection plans*	Agricultural inundation areal	Wetland	Reduced Tidal Area	River Expansion	River Expansion	Wet River Vally
3. Inundation areas up to a safety level of 1 flood per 4000 years:						
(a) Only Agricultural Inundation Areas and Wetlands	-0.21	282.24	0.00	0.00	0.00	282.03
(b) Agricultural Inundation Areas and Reduced Tidal Areas	0.09	0.00	984.69	0.00	0.00	984.79
(c) Agricultural Inundation Areas, Wetlands and River Expansions	-0.19	114.58	0.00	769.82	0.00	884.22
4. Inundation areas up to a safety level of 1 flood per 2500 years: Agricultural Inundation Areas and Wetlands	-0.52	245.49	0.00	0.00	0.00	244.97
5. Inundation areas up to a safety level of 1 flood per 1000 years combined with higher dykes protecting Antwerp: Agricultural Inundation Areas and Wetlands	0.17	184.13	0.00	0.00	0.00	184.29
6. Connection between West and East Scheldt combined with inundation areas: Agricultural Inundation Areas and Wetlands	0.15	142.97	0.00	0.00	0.00	143.12
7. Restoration of upstream river valleys:						
(a) Several Agricultural Inundation Areas, Wetlands and Wet River Valleys	-0.78	162.48	0.00	0.00	453.18	614.88
(b) Few Agricultural Inundation Areas, Wetlands and Wet River Valleys & small storm flood barrier	-0.57	57.57	0.00	0.00	610.10	667.11

* See also table 2.

Table 7. Ecosystem benefits per protection plan (present values in million Euro´s at 4 % interest)

Although the investment costs vary per alternative, they are estimated at approximately 500 million Euro. This means that the ecosystem benefits of alternative 3b, 3c, 8a and 8b surpass the costs[17]. This allows for the conclusion that investments in the development of new ecosystems within the flood protection plan are a sound investment from a societal perspective. It also leads to the conclusion that natural flood protection can compete with traditional technical solutions such as dyke heightening and storm flood bar-

17 This does not, however, mean that the other alternatives have a negative net result. Besides ecosystem benefits, each alternative also generates safety benefits in the form of avoided flood damage costs.

riers, thanks to the ecosystem benefits. Though not shown in table 7, it was found that natural solutions could compete with all the technical ones (plan 1 storm flood barrier, plan 2 dyke heightening and plan 6 connecting rivers). The ecosystem benefits more than compensate the cost difference between the natural and technical solutions.

Comparison of the Guideline with other approaches

The presented results may raise the question whether we would have had different results, had we not applied the approach of the Dutch guideline. Table 8 presents rough estimates in case: (a) just cash flows, such as wood and reed yields, had been taken into account; (b) the conditional functions behind clean water, transportation possibilities and fish production had been added up to the direct values of these goods and services; and, (c) only the easily measurable benefits of recreation and nonuse had been accounted for.

Alternative flood protection plans	Presented estimate of this study	Estimate based on only cash flows **	Estimate based on values of conditional functions in addition to values of goods and services ***	Estimate based on only recreation and non-use values
Alternative 3a*	282.03	13.28	786.25	255.63
Alternative 3b	984.79	19.40	2,547.48	755.83
Alternative 3c	884.22	20.23	2,263.36	669.36
Alternative 4	244.97	9.84	691.65	226.31
Alternative 5	184.29	5.79	526.01	173.18
Alternative 7	143.12	3.91	411.10	136.00
Alternative 8a	614.88	10.30	1,828.56	609.47
Alternative 8b	667.11	2.47	2,020.22	677.74

* See table 7 for a description.

** Only the functions that generate direct cash flow (wood production, reed production, recreation, and housing) were included here.

*** All final goods and services plus the conditional functions mentioned in table 4 are included here.

Table 8. Comparing the estimated ecosystem benefits with other approaches (present values in million Euro)

Table 8 shows that if we had estimated the ecosystem benefits of the alternative flood protection plans solely on the basis of cash flows, the benefits of all alternatives would be much smaller than the costs of ca. 500 million Euro. This would lead to the conclusion that ecosystems are a bad investment. If the values of all ecosystems´ functions had been included without eliminating overlap, the benefits of all but alternative 7 would greatly surpass the costs. Since the costs of alternative 7 are actually smaller than 500 million Euro, this would lead to the conclusion that they are all good investments.

Such a conclusion is usually not very helpful in political decisionmaking processes for two reasons[18]. Firstly, policy makers and politicians need discriminating results, that reveal different consequences of choices. And secondly, they usually feel that benefits, which are of the different order of magnitude as costs, are incomparable.

Finally, if we only include easily identifiable ecosystem values in the calculations, such as recreation and nonuse benefits, the results become more discriminating and more in line with the magnitude of investment costs again. This approach is, however, completely dependent upon CVM results. On the European mainland, this dependency is usually considered a problem, since this method is still very prone to criticism and therefore rarely applied to support actual political decisions. If the CVM results are not accepted, the ecosystems benefit will become zero, which brings us back to the original problem of ecosystems having little weight in political decisions.

7. Conclusion

This study leads to the conclusion that the natural solution of inundation areas is a serious alternative to technical flood protection solutions, such as storm flood barriers or dyke heightening due to the ecosystem benefits that they produce. Judged against the magnitude of ecosystem benefits, one may also conclude that the estimated ecosystem benefits in this study are discriminating between alternatives. They do not completely overrule the costs, which would render them useless for political decisionmaking. At the same time, the ecosystem benefits are large enough to support the necessary investments in nature development. The case study showed that the approach of the Dutch guideline, resulted in a realistic value estimate that was quite different from the results we would have had using other approaches. Moreover, this estimate was actually used in a concrete national political decision and it influenced that decision as the Belgian government opted for inundation areas where possible.

8. Discussion

In international literature on ecosystem valuation, the functions of a nature approach is widely used by both ecologists and economists (e.g. Seidl and Moraes, 2000; Wetten et.al., 1999; Costanza et.al., 1997; Perman et.al., 1996; Sorg and Loomis, 1986; Pearce and Turner, 1990; Kirkland, 1988;). These two groups use a different definition for the term 'function' (Brouwer, 2003).

18 This does not reduce the fact that from a scientific perspective such a conclusion should be helpful.

Ecologists use this term for ecological processes, servicing the maintenance of the ecosystem. As a consequence, ecologists, engaged in economic valuation studies, focus on valuing ecological processes, such as nutrient recycling, waste absorption, carbon sequestration and erosion control. These processes do not always lead to welfare (e.g. denitrification does not lead to welfare at locations where there is no eutrophication problem). Sometimes several processes lead to one and the same welfare effect (e.g. denitrification and silicium production both lead to clear water). Since functions may overlap, valuing them all separately may cause serious overestimates of the ecosystem's value (see Box 1).

Regulation functions	Production functions	Carrier functions	Information functions
Storage and recycling of nutrients	fuel wood	recreation	education
Storage and recycling of waste	medicines	habitat and nursery	research
Groundwater recharge and discharge	(clean) water	human habitation	cultural heritage
Flood control	raw materials	energy production	
Erosion control	genetic resources	agricultural crops	
Salinity control	food	grazing (life stock)	
Water treatment		transportation	
Climatic stabilisation			
Carbon sequestration			
Nurseries/ migration routes etc.			

This checklist contains potential overlap between functions. E.g.: Doesn´t ´erosion control´ lead to more ´agricultural crops´ and isn´t that ´food´? Doesn´t ´water treatment´ result in ´clean water´? Do ´climatic stabilization´ and ´carbon sequestration´ not both lead the protection against the negative effects of climate change? Don´t ´nurseries´ and ´fish migration routes´ lead to more ´food´ in the form of fish?

Box 1. Overlap of functions leading to overestimated values

Economists use the word 'function' for processes that service human needs. They focus on easy-to-perceive goods and services, such as timber and recreational opportunities. They do not systematically investigate which processes are going on in the ecosystem that might possibly generate welfare. Therefore, they run the risk of omitting things, leading to underestimates of ecosystem values. By linking the goods and services that directly generate human welfare to conditional functions that indirectly produce welfare, the economists´ and the ecologists´ approaches are combined, resulting in less extreme estimates and hopefully resulting in a more frequent inclusion of ecosystem values in actual political decisions.

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