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QUANTIFICATION OF THE POTENTIAL IMPACT OF NATURE CONSERVATION ON ECOSYTEM SERVICES SUPPLY IN THE FLEMISH REGION: A CASCADE MODELLING APPROACH

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Abstract: Ecological networks of protected areas are critical elements to protect biodiversity. To achieve a minimal performance of such networks, measures and investments are necessary for nature restoration and management. The concept of ecosystem service (ES) can provide additional arguments for investments in ecological networks. However, ES delivery processes are embedded in a complex array of ecological processes and there is a need to cope with this complexity in a pragmatic manner. As many assessment studies have already been criticized for using oversimplified indicators, too much pragmatism may foreclose credibility and acceptance of ES assessments. Therefore, a cascade ES modelling approach was developed that incorporated ecological processes, multiple off-site effects, feedbacks and trade-off mechanisms through shared variables. The assessment focused on which services the existing network delivers and how these services are influenced after realization of site specific conservation objectives.

Keywords: ecosystem services; land use change; modelling; ecological network; NATURA 2000

INTRODUCTION

Rapid urbanization, industrialization, and successive agricultural revolutions cause changes to the Earths land surface with a pace, magnitude and spatial reach that are unprecedented (Foley et al., 2005). These land-use changes result, next to other factors, in continuously rising rates of habitat destruction and species loss (Foley et al., 2005; Lambin et al., 2001). Consequently, conserving biodiversity has become imperative during the last decades, and the need for conservation action is increasingly recognized worldwide (Pullin, Knight, Stone, & Charman, 2004). Nevertheless, the main conclusion of the Global Biodiversity Outlook 3 report (Secretariat of the CBD) in 2010 was that the target agreed by the world's Governments in 2002, "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth", has not been met [*sic*]".

Within the European Union the Habitat and Bird Directives are the main policy instruments for biodiversity conservation (EC 1979; EC 1992). The European Habitats and Birds Directives require the Member States of the European Union to establish a network of protected areas to ensure the long-term survival of species and habitats that are threatened on a European scale (Evans, 2012). In 2015, there were 25 717 protected areas forming the NATURA 2000 network, covering 767 995 km² or about 18% of the EU-27 land territory (Kati et al., 2015). Nonetheless, the implementation of appropriate management for NATURA 2000 sites remains a big challenge (Kati et al., 2015). In the Flemish Region (Belgium), negative trends in the conservation status of several species and habitats were observed (RBINS, 2014) and additional measures need to be taken to counter this trend.

For each NATURA 2000 area in the Flemish Region, nature conservation objectives (NCO's) are defined for the habitats and species of European importance (Louette, Adriaens et al. 2015). To achieve the NCOs, measures and investments for nature restoration and management will be necessary. This includes land-acquisition, rewetting, top-soil removal, mowing, forest conversion, etc. The high costs that are associated with the NCOs became a subject of debate in the Flemish Region. On the other hand, the realization of the NCOs could also generate additional ecosystem services (ES).

Inspired by international initiatives such as the Millennium Ecosystem Assessment (2005) and the Economics of Ecosystems and Biodiversity (TEEB, 2010), the ES concept has also been put at the heart of the EU biodiversity strategy (EC, 2012). Target 2 of this strategy states the following:”by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems”. The concept of ecosystem services may thus help to explain the benefits that the NATURA 2000 network delivers to society; and this information may further increase public support for nature restoration.

In recent years a large variety of methods and models have been developed that may help with performing ES-assessments. These methods range from simple proxy-based indicator methods (Burkhard, Kroll, Müller, & Windhorst, 2009) and tools (e.g. Peh, Balmford et al. 2013) to complex models that can incorporate geophysical processes and integrate economical, ecological and social values (e.g. Boumans, Roman et al. 2015; Villa et al., 2014; Nelson et al., 2009; Tallis & Polasky, 2009;). Also, to evaluate the impact of Natura 2000 Sites on ecosystem services, some generic guidelines (McCarthy and Morling, 2014; Arcadis et al., 2011) and benefit estimations (Kettunen et al., 2009) were produced. These NATURA 2000 methods build largely on simplified proxy-based indicator methods and benefits transfer but do not take into account the influence of local circumstances (demand, biophysical characteristics) in assessing the delivery of ecosystem services, which limits the suitability on a more local scale.

According to Boerema and Rebelo (2016), ES often remain oversimplified and poorly quantified in many studies. Furthermore, there are still few studies that quantify a broad scope of ES; although, there is an increasing trend towards integrated assessments (ibid.). But integrated studies and tools, which address many services, tend to use expert judgment approaches over biophysical methods (ibid). Many ES assessments today still make use of the land-cover based proxy method (Burkhard et al., 2009; Burkhard, Kroll, Nedkov, & Muller, 2012). It provides a low-effort and straightforward approach to assess current conditions and analyze land-use change scenarios by use of expert scoring (Jacobs, Burkhard, Van Daele, Staes, & Schneiders, 2015; Kroll, Müller, Haase, & Fohrer, 2012; Koschke, Furst et al. 2012; Lautenbach, Kugel, Lausch, & Seppelt, 2011). The need for spatially explicit multi-ecosystem service models (not a set of independent ES models) was already expressed by Nelson and Daily in 2010. The complex processes and mechanisms by which ES support the societal wellbeing are diverse and their importance are still often overlooked (Fu, Wang, Su, & Forsius, 2013). Previous studies already demonstrated that there are limitations to the use of so-called land-use based proxies (Eigenbrod et al., 2010; Geijzendorffer & Roche, 2013; Lautenbach et al., 2011). This is not surprising since ES delivery is not only determined by land-use, but also by soil characteristics, groundwater levels (incl. drainage and abstraction infrastructure), infiltration-seepage patterns, fertilizer application, atmospheric nitrogen deposition, population density, etc.

There has been an increase in the availability of tools that incorporate more complex biophysical processes in their quantification methods. The most commonly used tools that do use a biophysical approach rely on SWAT “Soil Water Assessment Tool”, e.g. (Vigerstol and Aukema 2011; Logsdon and Chaubey 2013; Francesconi, Srinivasan et al. 2016) or INVEST “Integrated Valuation of Ecosystem Services and Trade-offs” (Sharp 2015). Since SWAT is basically a hydrological model, it works at catchment level, has high data requirements, and is mainly restricted to hydrological services such as water quantity, sediment regulation, water quality and flood regulation (Francesconi, Srinivasan et al. 2016). The InVest model allows for assessment of a broader scope of services, but when the marine and coastal ES are excluded, only 7 ES remain (carbon sequestration, pollination, recreation, scenic quality, sediment retention, water purification and water yield). The review by Bagstad, Semmens et. al. (2013) provides an overview that includes other tools, but does not address the biophysical and socio-economic complexity as an evaluative criterion. Vorstius and Spray (2015) compared InVest to other tools, such as SENCE “Spatial Evidence for Natural Capital Evaluation” and EcoServ-GIS. However, they, too remain unclear in their conclusion, since their conclusion is that performance of any model depends on the match between modelling assumptions and data quality (spatial, thematic and temporal resolution). Assessing and mapping methods are characterised by compromises between what is needed, desirable, practicable, and possible (Schroter, Remme et al. 2015; Vorstius and Spray 2015). In data-rich regions - which often coincides with high landscape complexity - the ‘possible’ and ‘needed’ is higher than what is offered by generic methods. A higher spatial resolution becomes especially necessary when including ES that are supplied at a very local scale (Grêt-Regamey, Weibel et al. 2015). Recent tools, such as LUCI “Land Utilisation and Capability Indicator” (Jackson, Pagella et al. 2013; Emmett, Cooper et al. 2016) can capture and deal with these spatially complex interactions, although LUCI currently only models 7 ES (production, carbon, erosion, sediment delivery, water quality and habitat) in an integrated manner. There is also a growing effort to incorporate the spatial interactions between supply and demand in ES assessments. The ES cascade, originally developed by Haines-Young & Potschin (2010), provides a useful conceptual framework for structuring the various aspects that determine ecosystem services. Boerema and Rebelo (2016) concluded that most studies capture only one side of the ES cascade (either the ecological or socio-economic side). Quantitative studies that assess and map the relationship between the supply and social demand of ecosystem services are scarce (Castro, Verburg et al. 2014), whilst the interaction between supply and demand is crux to the notion of ecosystem services. Recent publications demonstrate an increased awareness to incorporate spatial interactions of supply and demand (Qiu and Turner 2013; Baro, Palomo et al. 2016; Rabe, Koellner et al. 2016; Verhagen, Van Teeffelen et al. 2016).

So far, there have been only a few studies that encompass a broad range of services in a comprehensive, quantitative and spatially explicit manner. According to the review of Seppelt et. al. (2011), there are four facets that characterise the holistic ideal of ecosystem services research: (i) biophysical realism of ecosystem data and models; (ii) consideration of local trade-offs; (iii) recognition of off-site effects; and (iv) comprehensive, but critical, involvement of stakeholders within assessment studies.

The main research objective of this study was to develop assessment methods that address these four facets and would have sufficient scientific credibility to stakeholders in a region with high land-pressure and critical appraisal towards nature restoration. The application objective was to assess how benefits from NATURA 2000 sites would evolve after implementation of the NCOs. Such information could be used to develop alternative financing mechanisms that enable a (partial) reflow of the value that the NATURA 2000 network delivers to society. It also raises awareness on the socio-economic return of the NATURA 2000 network and strengthens public support for nature conservation measures.

This study provides a comprehensive, large scale, spatially explicit quantification and valuation of ES delivered by the NATURA 2000 network in the Flemish Region. First, we provide background information on the NATURA 2000 network in the Flemish Region, including more details on the NCO's and associated land-use changes. Next, we present the cascade ES modelling approach, which was developed in close collaboration with institutional stakeholders and governmental research institutes. We used this modelling approach to assess which services the existing network delivers and how these services are influenced after realization of site-specific conservation objectives. We elaborate on the interpretation of the quantitative and monetary results in the discussion. To argue the added value of advanced ES quantification methods, we analyze how the cascade modelling affects correlations between land-use change and change in ES supply. These correlations provide a measure for the complexity of the modelling approach. Standard expert based ES scoring methods by default result in strong relationships to land-use. We demonstrate that advanced modelling will weaken these correlations in general and allow for atypical responses to land-use change, driven by off-site effects and feedback mechanisms.

METHODOLOGY

THE NATURA 2000 NETWORK IN FLANDERS

The Flemish Region (Flanders) is one of the three regions of Belgium; it occupies the northern part of Belgium (13 522 km², 44 % of the Belgian territory), has a high population density (445 inhabitants/km²) and one of the densest traffic networks in the world (Lammar & Hens, 2005). Urban sprawl consumes about 25 % of the Flemish territory and irrevocably continues to threaten the remaining open space (Poelmans and Van Rompaey 2009; De Decker 2011). The rural matrix is spatially heterogeneous, but dominated by agriculture (46 %), forests (11 %) and protected nature (7 %). Consequently, this rural matrix is under pressure and faces increasing competition for land (Kerselaers, Rogge et al. 2013).

Flanders has a NATURA 2000 network of 166 187 ha, or about 12.3 % of its territory, protecting 109 species and 47 habitats in 62 NATURA 2000 sites (Figure 1). It encompasses both sites designated under the Bird Directive (Special Protection Areas, or SPAs) and sites designated under the Habitat Directive (Special Areas of Conservation, or SACs). Both types can be spatially overlapping. Size of the sites range between 86 ha and 13125 ha, with a mean size of 2760 ha. At present, the NATURA 2000 sites are only partly managed as nature reserves (Louette, Adriaens et al. 2015). They also encompass urbanized zones (4 %) and agricultural land (21 %). We look at each NATURA 2000 site as a service providing unit, including other land-uses (beside nature) that occur within their perimeter (see supplementary materials part C for site-specific land-use).

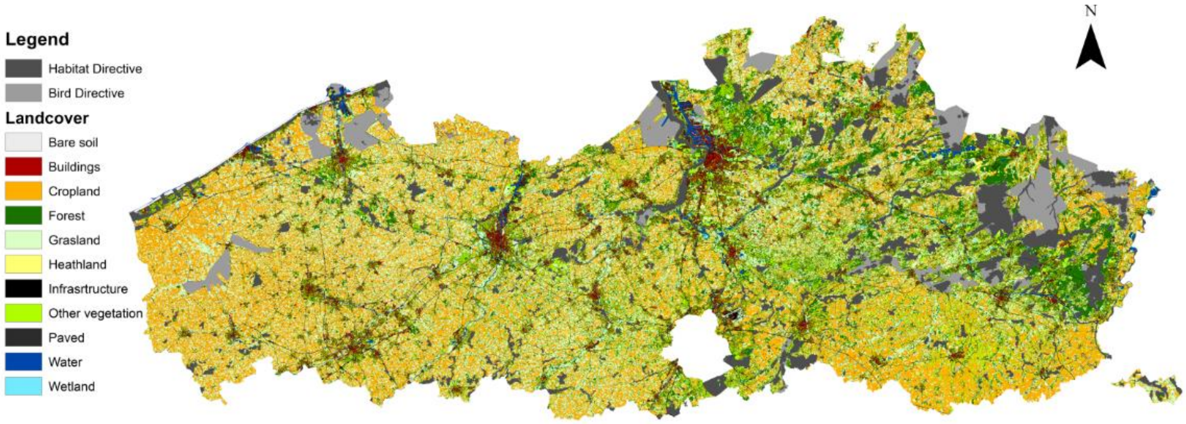


Figure 1: Map of the Flemish region with location of the Special Areas of Conservation (Habitat Directive) and Special Protection Areas (Bird Directive).

The designation of the nature conservation objectives (NCO's) has been established stepwise (Louette, Adriaens et al. 2015). Together with societal interest groups, conservation objectives were first set at the regional level by formulating targets for each habitat type without spatial allocation. In a second phase, these objectives were translated to specific targets for individual sites. The spatial allocation of the site-specific NCO's was facilitated by a land-use allocation model (Engelen, 2006) that enabled the incorporation of hard (e.g. current presence of N2000 habitats, reserve perimeters etc.) and soft conditions (abiotic suitability, agricultural production value). ES were not explicitly considered during the scenario negotiations, which were coordinated by civil servants of the Flemish Agency for Nature and Forest.

Table 1: Changes in Annex 1 habitats within NATURA 2000 network before and after realization of the Nature Conservation Objectives.

Habitat type category *	**Present situation**		**Future situation**		**Difference**	
	ha	%	Ha		ha	%
Heath and inland dunes	8 930	19.0%	12 236	17.3%	3 306	37.0%
Forests and shrubs	23 588	50.3%	40 245	56.8%	16 657	70.6%
Species rich grasslands & tall herbs	4 564	9.7%	6 541	9.2%	1 977	43.3%
Rivers and stagnant waters	1 003	2.1%	1 409	2.0%	406	40.5%
Wetlands	1 347	2.9%	1 666	2.3%	319	23.7%
Coastal and estuarine habitats	7 485	16.0%	8 806	12.4%	1 321	17.6%
Total	46 917	100.0%	70 903	100.0%	23 986	51.1%

* Classification: Heath and inland dunes (2310, 2330, 4010, 5130, 7150, 4030), Forests and shrubs (9110, 9150, 9120, 9190, 9130, 9160, 91E0, 91F0), Species rich grassland and tall herbs (6120, 6210, 6220, 6410, 6430, 6510), Rivers and stagnant waters (3110, 3130, 3140, 3150, 3160, 3260, 3270), Wetlands (7110, 7210, 7220, 7230, 7140), Coastal and estuarine habitats (1130, 1140, 1310, 1320, 1330, 2110, 2120, 2130, 2150, 2160, 2170, 2180, 2190). Habitat codes according to Habitats Directive (for more information on habitat types and their occurrence http://eunis.eea.europa.eu/).

The land-use implications of the NCOs were provided by the Flemish Agency for Nature and Forest. To provide a general picture of land-use distribution before and after realization of the NCOs, land-uses were grouped in 9 classes. In the final land-use balance only 6 846 ha switched from one land-use class to another, after application of the NCOs (Table).

Table 2: Net changes in general land-use classes within the entire NATURA 2000 network before and after realization of the nature conservation objectives.

Land-use category	Present situation		Future situation		Difference	
	Ha	%	Ha	%	ha	%
1. Urban and military buildings	12 525	7.6%	12 372	7.5%	-153	-1.2%
2. Agricultural land	55 306	33.4%	50 044	30.2%	-5 262	-9.5%
3. Heath and inland dunes	9 464	5.7%	12 494	7.5%	3 030	32.0%
4. Forests and shrubs	54 356	32.8%	56 984	34.4%	2 628	4.8%
5. Species rich grasslands & tall herbs	14 589	8.8%	14 300	8.6%	-289	-2.0%
6. Rivers and stagnant waters	5 327	3.2%	5 388	3.3%	61	1.1%
7. Wetlands	2 448	1.5%	2 298	1.4%	-150	-6.1%
8. Coastal and estuarine habitats	7 916	4.8%	9 044	5.5%	1 128	14.2%
9. Other	3 640	2.2%	2 648	1.6%	-992	-27.3%
Total	165 571	100.0%	165 572	100.0%		

The increase in Annex 1 habitat types (+ 23 986 ha) in Table 1 is almost four times higher than the net changes in land-use classes of Table (+ 6 846 ha). This indicates that, to a large extent, the NCOs are realized by conversions to Annex 1 Habitat types within the general land-use classes. Net changes for the entire NATURA 2000 network (Table 2) may be deceptive, since changes for individual sites may cancel each other out (e.g. forest creation in site A and forest removal in site B). Site-specific changes can be consulted in the supplementary materials part C. On the level of the entire NATURA 2000 network, only 6 846 ha (classes 1, 2, 7 and 9 from Table 2) can be considered as net creation of new nature on, for instance, former agricultural land. There is thus a discrepancy between observed changes of general land-use classes and the changes in specific habitat types. For instance, although "species rich grassland" declines slightly in Table , there is a large increase when we only consider the Annex 1 habitats (Table 1).

ECOSYSTEM SERVICE MODELS

For the classification of ES, version 4.3 of the CICES list was used (Haines-Young & Potschin, 2013). Given that CICES focusses on the "final services", which provide direct benefits to society and are the final stage of the ES cascade, this classification system is especially useful for ES valuations, so as to avoid double counting (Morse-Jones, Luisetti, Turner, & Fisher, 2011). An overview of the ecosystem services and functions that have been addressed in this study is given in Table 3.

Table 3: Ecosystem services and functions: [1] Included in the final aggregation of benefits for both the current and future state (realization of the Nature Conservation Objectives) of the NATURA 2000 network in the Flemish Region; [2] Quantified, but not valued; [3] Quantified (and valued) for individual NATURA 2000 sites, but not for all NATURA 2000 sites; [4] Included in the final aggregation of benefits for the current state, but not included in the assessment of the future state.

Seq.	Ecosystem service/function	Final benefit	CICES (class)
1	[3] Erosion prevention	Avoided dredging costs	Buffering and attenuation of mass flows
2	[2] Infiltration	Supporting function	Hydrological cycle and water flow maintenance
3	[1] Avoided nitrate leaching	Avoided treatment costs surface water quality	Filtration/sequestration/storage/accumulation by ecosystems
4	[2] Water retention	Supporting function	Hydrological cycle and water flow maintenance
5	[1] Nutrient removal by denitrification	Avoided treatment costs surface water quality	Filtration/sequestration/storage/accumulation by ecosystems
6	[1] Water provisioning	Avoided treatment costs drinking water, Avoided drinking water import	Ground water for drinking
7	[2] Nutrient storage in soils	Supporting function	Decomposition and fixing processes
8	[1] Carbon sequestration in soils	Climate mitigation	Global climate regulation by reduction of greenhouse gas concentrations
9	[1] Carbon sequestration in biomass	Climate mitigation	Global climate regulation by reduction of greenhouse gas concentrations
10	[2,3] Flood storage	Flood risk reduction	Flood protection
11	[3] Pollination	Supporting function	Pollination and seed dispersal
12	[1] Agricultural production	Agricultural production	Cultivated crops
13	[1] Wood production	Wood production	Fibers and other materials from plants, algae and animals for direct use or processing
14	[1] Air Quality improvement – capture of fine dust particles	Avoided health risk	Filtration/sequestration/storage/accumulation by ecosystems
15	[1] Noise reduction	Impact on real estate value	Mediation of smell/noise/visual impacts
16	[4] Health effects of green spaces (physical exercise, mental health)	Avoided health risk	Physical use of land-/seascapes in different environmental settings
17	[4] Quality of the environment and estate value	Real estate values	Aesthetic
18	[1] Recreation and tourism	Number of visitors, Willingness to pay	Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes

We used a step-by step approach to identify, quantify and monetize the ES, using the best available methods and data for the Flemish Region. The cascade modelling puts regulating and supporting functions at the top of the cascade. The output of these models is then used as input variables to model various providing services. The ES models are interdependent through their input-output relationships and shared variables (Figure 2 and 3).

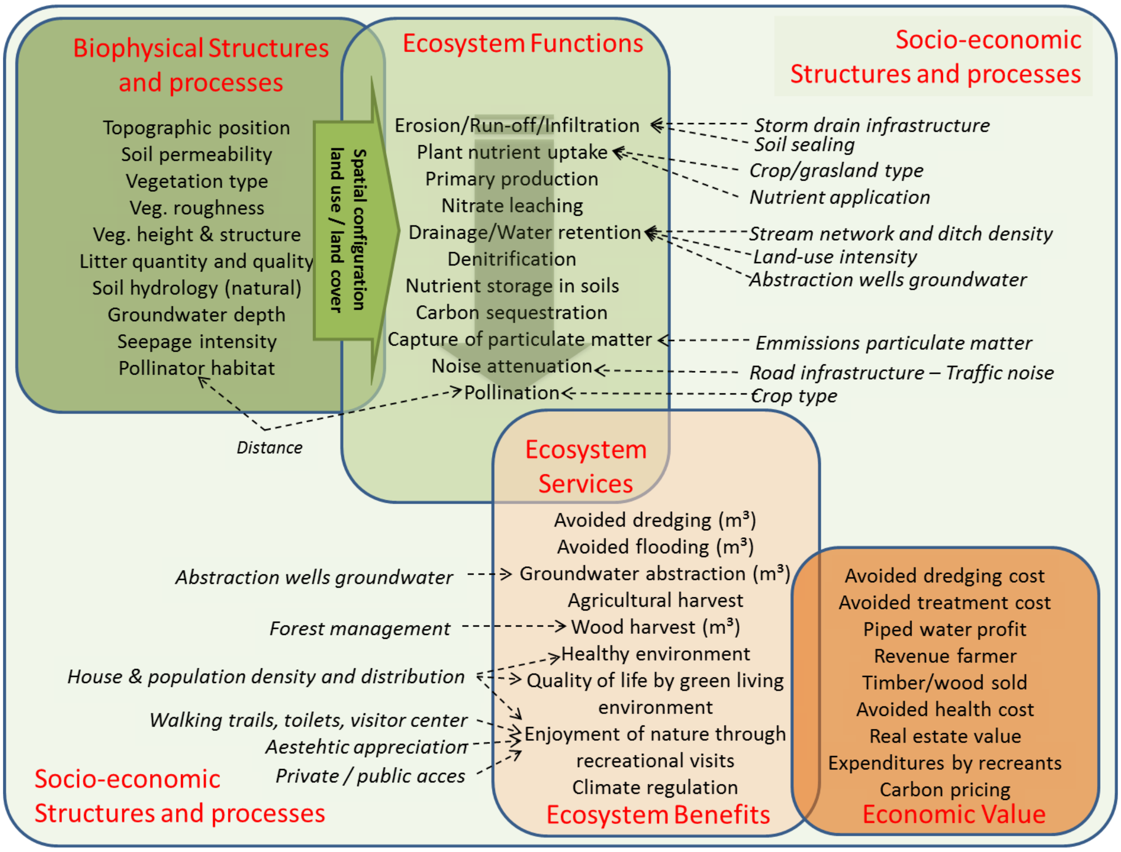


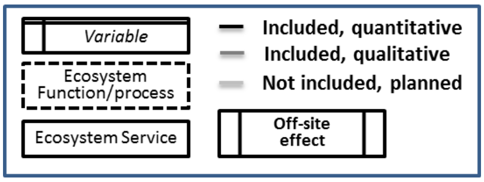
Figure 2: Allocation of model parameters (variables), modelled ecosystem functions, service delivery (quantification) and monetarization to the ES cascade (Haines-Young and Potschin 2010).

The dependencies between the various processes are visually represented in Figure 3. We distinguished variables (states), ecosystem functions (processes), off-site effects and (final) ecosystem services. Off-site effects refer to calculations where the status of the service at the pixel level is determined by spatial relationships at larger scales. These spatial dependencies have been incorporated in various stages of the modelling by defining topographical relationships (e.g. flow direction of water and sediments), distance and density factors (e.g. drainage ditch density, distance to green infrastructure) or by moving window statistics (e.g. available green infrastructure per inhabitant at different spatial scales). In this way, we were able to incorporate key mechanisms that determine trade-offs and synergies between ES.

The methods for quantification and valuation have been developed in collaboration with public institutions and have been presented to stakeholder groups. We have incorporated the most important parameters in the models, while finding the right balance between complexity and transparency. Special attention was given to the rationale of the modelling approach, which should be intuitive and comprehendible to moderately educated people.

Not all known variables and processes were included in a quantitative manner. For some ES and EF, there is an incomplete understanding of the underlying biophysical and/or socio-economic mechanisms. Therefore, results were not used for the final quantitative assessment (pollination, flood regulation and erosion prevention), as complex spatial-temporal processes, technical challenges and lacking data would have impeded a credible quantification of these ES at the site level. A spatially explicit quantification was done for 18 services, of which 14 were monetized and of which only 11 final services were accounted for in the final benefit assessment of the NCO's.

Valuation methods were based on the most suitable methods and data available. The valuation is partly based on market values (agriculture, wood production, replacement costs, avoided health costs), revealed preference methods (travel cost method for recreation and tourism), and – to a lesser extent – on stated preference methods (valuation of health effects). For most services, different quantification and valuation methods have been reported, applied and compared. This open approach was needed to avoid disputes over the methods, which could foreclose the credibility of the study. Overestimations, biased assumptions and double counting were avoided throughout the study. When considering that many services have not been included in the final valuation (e.g. erosion and flood control), we can state that these final results express a range of minimum benefits that can be attributed to the NATURA 2000 network. More information on the methods and principles behind the identification, quantification and valuation of the ES can be found in supplementary materials part A.



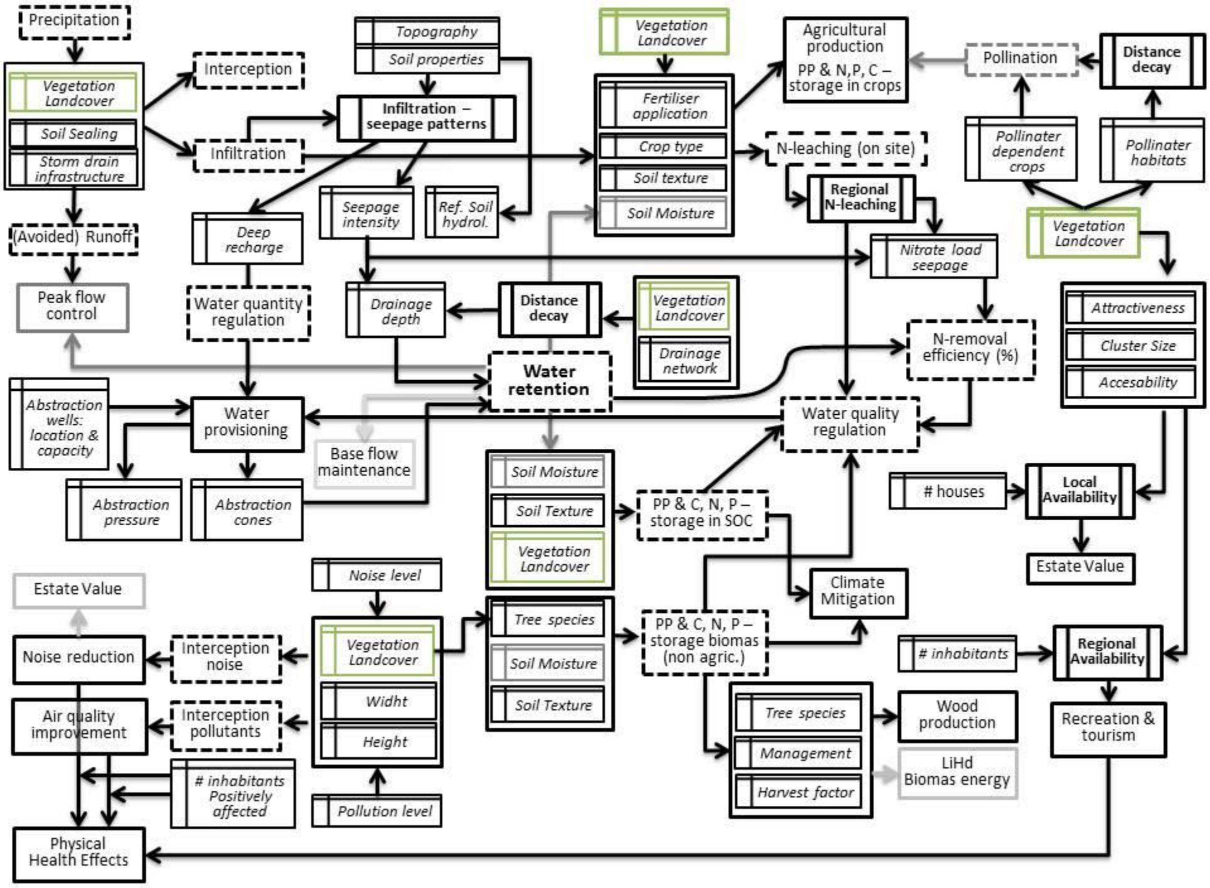


Figure 3: Relational scheme of variables, ecosystem functions (processes) and final services.

The ES models were used to evaluate both the current situation as well as the scenario after the NCO's implementation. The conventional spatial resolution for modelling was 25 by 25 meter. Spatially distributed quantitative and monetary results were aggregated to the level of individual NATURA 2000 sites.

DATA PROCESSING AND ANALYSES

The applied cascade modelling approach allows one to incorporate shared variables, off-site effects and interdependencies that determine trade-offs and synergies between ES. By analyzing the relationship between changes in land-use and changes in ES supply at the site level, we have a measure for the impact of added complexity. We present an approach for site-selection, land-use reclassification and data-analysis.

SITE SELECTION FOR EVALUATION

To prepare the data analysis, we needed to make a selection from the 63 NATURA 2000 sites. Firstly, we chose to focus on the special areas of conservation (SACs) for the further interpretation and analysis of the results. The Special protection areas (SPAs), as defined by the Bird Directive (Directive 2009/147/EC), are partly overlapping with the SAC's, as designated under the Habitat Directive (Directive 92/43/EEC). This means only the non-overlapping parts of the SPAs are excluded. These non-overlapping parts of SPAs and SACs are, to a large extent, in agricultural use and also include urban zones. The non-overlapping parts of the 24 SPAs, cover 37 % (60,756 ha) of the entire NATURA 2000 network, yet there are only marginal changes in habitat creation (2500 ha). The 38 SACs represent 63 % (105,000 ha) of the entire NATURA 2000 network in the Flemish Region. The NCO's are largely focused on the SACs, since 21,500 ha of the 23,986 ha habitat creation (Table) will take place in the SACs. The SACs (BE2300006; BE2500001 and BE2500002) were removed from the dataset. These 3 sites cover mainly estuarine habitats. Each of the SAC's can be identified through the official site-code which is used by the European Environment Agency. Details on the sites (e.g. specific species and conservation status) can be viewed in a web browser: http://natura2000.eea.europa.eu/#.

LAND-USE RECLASSIFICATION FOR DATA ANALYSIS

The original input of land-use for the ES modelling included 79 land-use classes (including the Annex 1 habitats). These 79 classes were reclassified to 8 general land-use classes for data analysis: 1. Broadleaf forest, 2. Heathland & Inland Dunes, 3. Intensive agriculture, 4. Mixed forest, 5. Species rich grasslands, 6. Other, 7. Wetland, and 8. Built-up. The reclassification details can be found in supplementary materials part B. For each of the 35 SACs, the total change in land-use (Diff) and relative changes in land-use (Rel.) were calculated. For further analyses, the class "Built-up" was removed because of the small values and limited relevance to the data analysis. Site-specific details on land-use changes can be found in supplementary materials part C.

CORRELATION ANALYSES AND MULTIVARIATE EXPLORATION

Prior to analysis, surface effect was removed by dividing land-use and ES data tables by total site surface area. This procedure was applied to T0 and Diff contexts. In Diff context, changes were computed as follows:

$$\frac{T_1 - T_0}{abs(S)_0}$$

T1 = total supply of ES at site level (respective total surface area per land-use category) after implementation of the NCO's; T0 = total supply of ES at site level (respective total surface area per land-use category) before implementation of the NCO's and S = the total site surface area.

Land-use and ES were related and tested by Pearson's correlations. In order to cope with the problem of multiple testing and associated increase in Type I error, a correction of the null hypothesis rejection level α was provided according to the procedure of Benjamini and Yekutieli (2001), based on the control of the false discovery rate, which is the expected proportion of erroneous rejections (errors committed by falsely rejecting the null hypothesis) among all rejections (i.e. significant relationships). This is a sequential Bonferroni procedure preferred in exploratory analysis (Benjamini and Hochberg, 1995). This operation was done in R with the *"p.adjust"* command from the *"stats"* package.

Multivariate ordinations were used to derive the main gradients driving the complexity common to land-use and ES. Co-inertia analyses (Dolédec & Chessel, 1994) were applied to land-use and ES delivery data. It constructs a system of axes maximizing the common information between two multidimensional structures (land-use and ES here); axes express covariances between land-use and ES, and permits highlighting trade-off. Log-transformed data were arranged in site × variable tables; land-use table was centred, and ES delivery table was standardized. The relationship between both multidimensional structures was assessed by Rv coefficient (Escoufier, 1973) and tested by a randomization test base on 9999 random permutations of the table lines (Heo & Gabriel, 1999). Computations and graphical representations were performed using R software (R Development Core Team, 2009); co-inertia analyses were performed with the "ade4" package (Chessel, Dufour, & Thioulouse, 2004).

RESULTS

INTRODUCTION TO THE RESULT SECTION

We will first present the aggregated results for the entire NATURA 2000 network. This is followed by an overview table of the changes that the implementation of the NCO's would bring about. In the second section, we analyze the extent of which (changes in) land-use can explain the observed (changes in) ES delivery.

RESULTS FOR THE ENTIRE NATURA 2000 NETWORK

ECOSYSTEM SERVICES DELIVERED BY THE NATURA 2000 NETWORK

Quantification and valuation results for the current and future situation of the Flemish NATURA 2000 network are presented in Table 2. Services specifically related to health cover a large part of the total value (air quality, recreation, physical and mental health effects of direct contact with nature). Carbon sequestration in soils, agricultural production and nutrient removal are also substantial, with respect to the total value. Wood production, carbon sequestration in biomass, noise reduction and water provisioning are important in the valuation. The total annual value is minimal in the range of € 0.8 to 1.4 billion per year, which is equivalent to € 130-230 per capita per year. Expressed as value per spatial unit, this minimum value is between € 4725 and € 8454 per hectare per year.

Table 2: Quantification and valuation of the current and future state (realization of the Nature Conservation Objectives) of the NATURA 2000 network in the Flemish Region. The quantitative and monetary valuation of changes in ecosystem services delivery generated by the realization of the Nature Conservation Objectives are indicated between brackets. NA = Not Assessed for the future state.

	Quantification per year			**Valuation (k€/year)**	
Ecosystem services	**Low**	**High**	**Units**	**Low**	**High**
Agricultural production	89 087 (-7 238)		k€ added value production	89 087 (-7 238)	
Wood production	161 722 (+167)		m³ harvested wood	5 422 (+213)	
Air quality improvement	3 981 (-78)	7 975 (-150)	ton captured particulate matter	214 953 (-4 250)	430 658 (-8 096)
Carbon sequestration in biomass	154 349 (+5 024)		ton C sequestration/year	33 957 (+1 105)	
Carbon sequestration in soils	28 474 560 (+1 758 763)		ton C stock in soils	156 610 (+9 673)	
Noise reduction	321 (NA)		houses positively affected	7 (NA)	51 (NA)
Infiltration	302 745 (+4 692)		1000 m³ infiltration	Supporting function	
Water retention	227 468 (+9 240)		1000 m³ waterretention	Supporting function	
Water provisioning	15 869 (+2 163)		1000 m³ water provisioning from NATURA 2000 sites	1 190 (+162)	3 174 (+433)
Nutrient removal	1 094 088 (+420 915)		kg N removal	5 470 (+2 105)	80 963 (+31 148)
Nitrogen storage in SOM	1 735 758 (+101 830)		ton N stock in soils	Supporting function	
Phosporus storage in SOM	115 717 (+6 789)		ton P stock in soils	Supporting function	
Pollination	216 (-4)		ha pollinator dependent crops serviced by NATURA 2000 sites	Supporting function	
Recreation and tourism	25 757 (+4 491)	42 928 (+7 485)	1000 visits per year	77 270 (+13 473)	386 350 (+67 365)
Effect on estate value	81 37 (NA)		1000 houses within 100m	14 849 (NA)	29 922 (NA)
Health effects (physical – mental)	1 801 (NA)		1000 inhabitants within 1km	183 479 (NA)	
Total				***782 296 (+15 288)***	***1 399 673 (+94 602)***
Total in € per ha				***4 725 (+92)***	***8 454 (+571)***

EFFECTS OF THE REALISATION OF THE CONSERVATION OBJECTIVES ON THE DELIVERY OF ECOSYSTEM SERVICES BY THE NATURA 2000 NETWORK

Economic valuation works best when so-called “marginal” environmental changes are being assessed (Morse-Jones et al., 2011). If we compare the quantity and value of the ES after implementation of the NCOs with the current situation (Table 4), we clearly observe a negative effect on agricultural production. This is the consequence of the loss of surface for agricultural activities. Wood production remains equal, although significant changes occur, both in terms of location of forests as well as in species composition. Pine forests are cut and transformed to heathland in many places, whilst agricultural land is transformed to broadleaved forest. Removal of fine dust particles (air quality improvement) declines, since pine forests are able to capture fine dust the entire year round and with greater efficiency than other vegetation types. Rewetting of formerly drained land improves carbon sequestration in soils, as well as nutrient retention in soils and nutrient removal by denitrification. These services are all strongly affected by water retention. Recreational benefits will rise through the increased attractiveness of publicly accessible nature. Due to the creation of larger areas, especially, more people are attracted to NATURA 2000 areas. The quantity and quality of groundwater recharge will be positively affected in the surroundings of major water production areas. Recharge quantity will be improved through conversion of pine plantations to broadleaf forest, grassland and heathland. The quality of the infiltrated water will improve through abandonment of intensive agriculture on soils that are highly sensitive to nitrate leaching. The net benefits of the realization of the NCOs are estimated at € 15 to 94 million per year. This estimation is conservative, since not all ES have been included in the valuation (e.g. health effects and impact on real estate values). For these services there was no objective proof that the realization of the NCOs would increase the benefits, although there are reasons to believe that some of these effects do occur.

We can express the net change in benefits resulting from the NCO's as an average added value per hectare. If we project this change onto the entire NATURA 2000 network (165 000 ha), this would result in an added value of 92 - 571 €/ha (Table 4). The relative change in benefits for the entire network ranges between 2 % and 7 %. But, this relatively modest change in benefit needs to be put into perspective, considering the efforts undertaken to realise the NCO's. For at least 85 % of the NATURA 2000 area, no change in land-use occurs. Adding up land-use changes for the nature categories (Table 2, classes 3-8) increases newly developed nature by 6,400 ha, but this number does not take into account the fact that site-specific changes may cancel each other out. From Table 1, we can see that there is a net increase of 23 986 hectares of high quality habitats. This is the result of both the creation of new nature and the conversion of low quality nature to high quality nature (e.g. conversion of forest plantations to mixed or broadleaved forest). If we project the change in benefits to the net change in nature quality, the added value per area unit of change would rise to a range of 637 - 3 944 €/ha. When using this projection, the relative change in benefits per area unit is much higher (12 - 32 %).

LAND-USE AND ES DELIVERY RELATIONSHIPS

It is clear that ES delivery per area unit cannot be interpreted independently from the average land-use per area unit (%). Therefore, data analyses are necessary to identify relative contributions of land-use to ES delivery. As specified in the material and methods section, the quantitative results per site were rendered surface independent by dividing them by site area before data analysis. The same was done for the (change in) ES delivery, following the implementation of the NCOs. The site-specific net land-use changes can be found in supplementary materials part C and the actual delivery of ES and ES delivery changes are displayed in supplementary materials part D. We correlate changes in land-use to the changes in the ES delivery (Table 5), followed by a co-inertia analysis between land-use and ES delivery (Figure 4).

INTERRELATIONS BETWEEN CHANGES IN ES DELIVERY AND CHANGES IN LAND-USE

Table 5: Pearson's correlations between change in land-uses and change in ES for NCO's. Rejection levels: *, < 0.05; "", 0.01; "***", 0.001. See supplementary materials for land-use reclassification details. Land-use categories: Leaf F.= leaf forest; Heath= heathland; Agric.= Agriculture; Mixed F.= mixed forests; Nat. Gras.= high biodiversity grassland; Other = other; Wetl.= wetlands. Ecosystem services categories: AgrPr= agricultural production (revenue); Timber= high quality timber; AirQ= Air quality regulation; BOC= organic carbon stored in biomass; SOC= organic carbon stored in soils; Infil= infiltration; GWRet= water retention in soils; WPQuant= total recharge (m^3) of groundwater abstraction sites; WPQual= recharge (m^3) of groundwater abstraction sites under nature management (clean water); N rem = Nitrate removal (avoided nitrate leaching & denitrification); Poll = pollination; Recr = recreation.**

	AgrPr	Timber	AirQ	BOC	SOC	Infil	GWRet	WPQuant	WPQual	N rem	Poll	Recr
Leaf F.	-0.4	0.52 *	0.63 **	0.58 **	-0.02	-0.25	0.11	-0.29	-0.35	-0.05	-0.04	0.50 *
Heath	0.44	-0.51 *	-0.58 **	-0.54 **	-0.64 ***	0.33	-0.32	0.19	0.06	-0.27	0.16	-0.22
Agric	0.75 ***	-0.39	-0.43	-0.38	-0.07	0.39	0.13	0.39	0.50 *	-0.11	-0.54 **	-0.54 **
Mixed F.	-0.37	0.36	0.23	0.32	0.21	-0.40	-0.10	-0.33	0.10	0.13	0.03	-0.20
Nat. Gras	-0.21	-0.15	-0.16	-0.18	-0.07	-0.04	-0.31	-0.05	-0.30	0.06	0.32	0.17
Other	-0.15	0.06	0.02	0.05	0.20	-0.07	0.13	0.17	0.25	0.10	-0.11	-0.09
Wetl.	-0.12	-0.03	0.01	-0.05	0.60 **	-0.02	0.31	0.11	0.13	0.30	0.15	-0.02

From the 84 correlations, 2 were highly significant, 7 correlations with moderate significance and 4 with a low significance. As expected, change in agricultural production (AgrPr.) was strongly correlated with change in agricultural land-use. Although not significant, there is a positive correlation with heathland creation. This may have been a (very weak) consequence of a reduction in agriculture on the most infertile soils, which would have increased the average yield per surface area for agriculture. The same mechanisms could be deduced for agricultural land-use, which is negatively correlated with forest creation. Forest (eg. types 9110, 9130 and 9160) creation on relatively fertile agricultural land does take place on several sites (e.g. 2200038, 2300007, 23000444, 2500003 and 2500004). Many forests will be converted from pine to broadleaved forest, grassland and heathland. Change in timber production (Timber) was positively correlated with broadleaf forests creation by increasing yield and harvest. Negative correlations were expected with all non-forest land-uses. Heathland creation occurs on the most infertile soils, often at the expense of mixed forests, which could explain the negative correlation with heathland creation. Change in <u>air quality improvement</u> (AirQ.) was correlated with broadleaf forest creation. It was negatively correlated with air quality as heathland creation occurs, to a large extent, at the expense of mixed forests. Similarly, sites with a low decrease in agricultural land will have a low creation of broadleaf forests and a low increase in air quality improvement. Change in <u>carbon sequestration in biomass</u> (BOC) shows very similar correlations with timber production and was strongly correlated with broadleaf forest. Again, heathland creation was strongly correlated, because of the very particular land-use transformation. Change in <u>carbon sequestration in soil organic carbon</u> (SOC) was strongly correlated with wetlands and its negative correlation with forest-to-heathland conversion was clearly observed. There are no significant correlations between changes in infiltration (Infil.) and changes in land-use. The effect of mixed forest to heathland conversion is weakly present. These mixed forests have a relatively high interception, due, especially, to a high prevalence of pine forest on mostly dry and infertile soils. Forest creation – at the expense of agriculture – has negative effects on infiltration. This effect is certainly preferable from a groundwater quality viewpoint. Although this effect is strong for some sites with dry sandy soils, the correlation appears non-significant. Change in <u>groundwater retention</u> (GWRet.) was not significantly correlated with land-use changes although a significant correlation with wetland creation was expected. Change in <u>water production quantity</u> (WpQuant) was weakly increased under a lesser agricultural land-use. Patterns were comparable to those for the change in infiltration, although water production was only relevant for a subset of the sites. A significant relationship with mixed forest-to-heathland conversion was expected, but the correlation was non-significant when considering all sites. The correlation of <u>water production quality</u> (WPQual.) to changes in agricultural land is evident. A decrease in agricultural land increases quality of infiltrated water. This ES is expressed in 100 m^3 of water abstracted from infiltration processes under extensive land-use. The response is nonetheless dependent on the presence of water abstraction in, or near, the sites and can explain the weak significance. The ES <u>nitrate removal</u> (N rem.) is very complex and depends on both (local) supply of nitrate (from agricultural land) and presence of wetlands for denitrification. Although correlation signs were coherent, relationships were not significant. Changes in <u>pollination</u> (Poll.) were observed only for 2 sites (BE2200038 and BE2400012) and these sites were responsible for a decrease in agricultural land; orchards will disappear for the creation of nature so that the relationship is consequential to a decreasing demand for pollinators, rather than a decrease in supply of pollinators. Recreation (Recr.) was positively correlated with broadleaf forests creation on agricultural land. Recreants prefer large connected areas over smaller areas and forests over other land-use types for recreational purposes. The sensitivity of recreational visits to changes in land-use can differ as this also depends on population density and availability of concurrent green space.

COINTERTIA ANALYSIS RESULTS

The relationship with change data was significant ($Rv = 0.43$; $p < 0.001$) and data were organized along three main axes, encompassing 97 and 89 % of the variances of land-use and ES delivery respectively (Fig. 4).

Figure 4B displays the land-use trade-offs. First, there is a land-use trade-off between agricultural land (Agric.) and broadleaf forest (Leaf F.). Also, heathland creation (Heath.) and wetland creation (Wetl.) are strongly represented. For all sites, agricultural land (Agric.) and mixed forest (Mixed F.) are converted to other land uses. Natural grasslands (Nat. Gras) also decrease in most sites (30 out of 35 sites). Transformations to broadleaf forests (Leaf F.) were associated with higher recreation and air quality. Creation of wetlands (Wetl.) covaried with an increase in N-removal and carbon sequestration in soils (SOC) (Fig. 4B and 4C). Remarkably, there is not a very strong relation between the reduction in agricultural land (Agric) and agricultural production (AgrPr). New nature was, to a large extent, created on marginal, low productive land (very dry or wet conditions). Furthermore this change in agricultural land (Agric.) and heathland creation (Heath) are both slightly associated with improvement of water quantity and quality improvement (WPQual & WPQuant). A reduction of mixed forest covaries with the increase in timber production (Timber) and carbon in biomass (BOC), since these mixed forests are mostly compensated (at site level) with the creation of broadleaf forest (Leaf F.) that have longer stand rotations, produce high quality timber and are attractive for recreational activities.

The second axis (Figure 4E & 4F) gives comparable information regarding land-use changes. Creation of broadleaf forests was associated with a bundle of ES, related to forest creation (Air quality, Timber production, recreation, carbon storage in biomass). Creation of heathland (and agricultural land) was accompanied by increase in infiltration and improvement of water provisioning, both for the quantitative as well as qualitative aspect. The increase of the pollination service (Poll.) was related to natural grasslands creation (Nat. Gras).

In general, the first axis (Figure 4B and 4C) highlighted a forest coverage trend from left (agriculture and heath land uses) to right (mixed and broadleafed forests). Independently, the second axis represented a gradient of moisture from bottom (dry, heath and broadleaf forest) to top (wet, mainly wetland associated to N removal and SOC). The third axis (Figure 4E and 4F) evidenced a complementary gradient of pollination from top to bottom (high delivery by natural grasslands and wetland to a lesser extent).

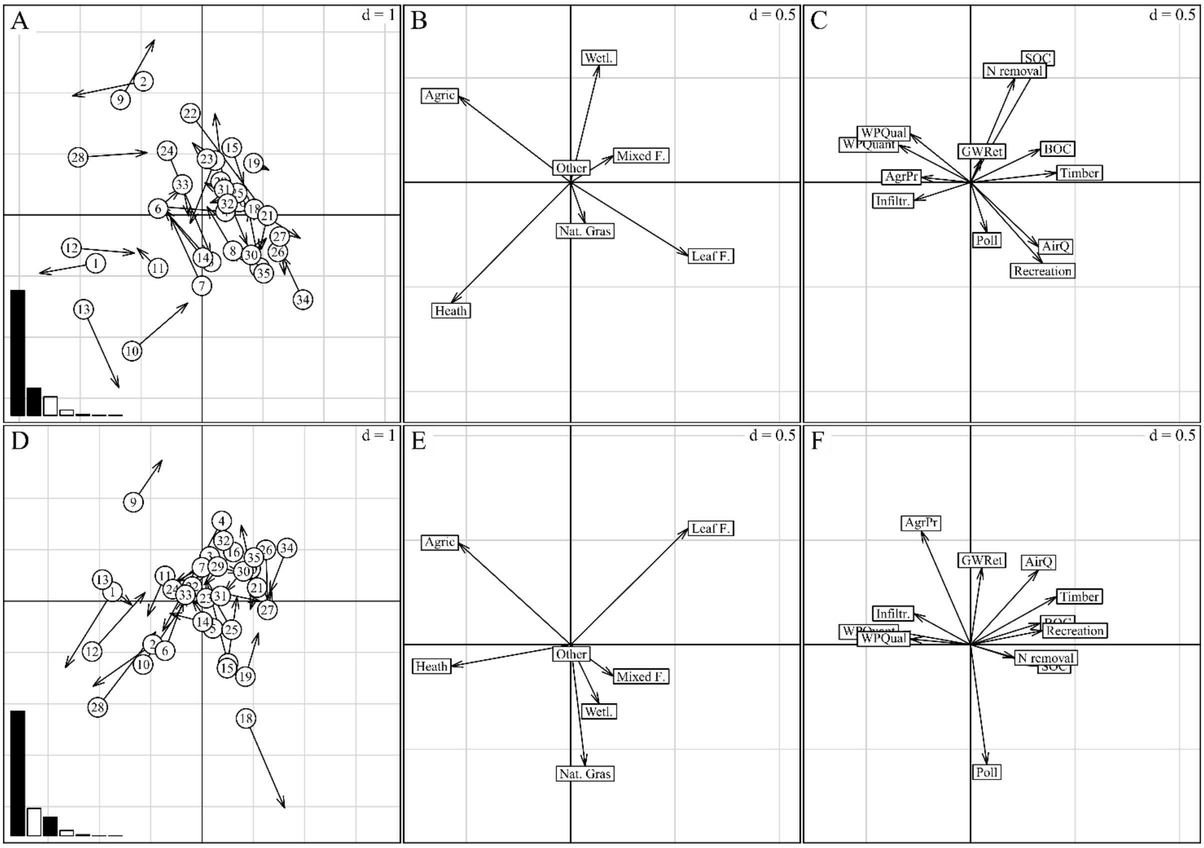


Figure 4. Co-inertia analysis between land-use changes and changes in ES delivery. A to C: axis 1 (horizontal; 70 %) and axis 2 (vertical; 15 %); D to F: axis 1 and axis 3 (vertical; 10 %); eigenvalue diagrams are inserted in A and D. A and D: co-structure between land-use (circles) and ES delivery (arrow tip) patterns (both resulting from the projections of the lines of land-use and ES delivery data tables); each arrow represents a site; arrow length indicates the lack of fitting. Numbers within circles correspond to site codes in supplementary materials part C. Supplementary materials part C and D provide details on land-use change and change in ES delivery. Pearson's correlation coefficients between the coordinates (circles versus arrow tips) on the first axis: $r = 0.78$, $p < 0.001$. On the second axis: $r = 0.71$, $p < 0.001$. On the third axis: $r = 0.57$, $p < 0.001$. "d" indicates the grid scale.

DISCUSSION

We first discuss the quantification and valuation results for the entire NATURA 2000 network and the potential policy implications. In the second part, we discuss the added value of investing in an advanced cascade modelling approach.

INTERPRETATION OF THE VALUATION RESULTS: A MIRROR FOR POLICY PROGRAMS?

The total annual value of services currently delivered by the NATURA 2000 network is in the range of € 0.8 to 1.4 billion per year. These numbers clearly point out that these sites are important to society. But quantification and valuation of the total value of the NATURA 2000 network for a static situation poses several methodological problems (Fisher et al., 2008; Toman, 1998). Such a value merely represents the hypothetical value of replacing the current state of the NATURA 2000 network with “nothing”, which is, realistically, an implausible scenario. In addition, such a drastic scenario would certainly affect the valuation methods, which are only valid for marginal changes in ES supply. However, it may be useful to demonstrate which services and values the NATURA 2000 network represents. Quantification and valuation units are expressed per year and not by total value, by which we already compromise on some of the issues.

The study only explores the impact of the NCO’s on the current situation. We ignore the fact that land-use outside NATURA 2000 network may change over time. Evidently one can expect a further increase in population and associated urbanisation (Poelmans and Van Rompaey 2009; De Decker 2011). On the other hand, certain environmental pressures may decrease due to technological innovations and stricter standards.

The scenario results give us a better understanding of the implications of the NCO’s. It is important to notice that not all services are included in the scenario assessment. Flood prevention, through peak flow control, could not be modelled accurately enough to be included, although this is recognized as an important ES. Also for health effects and property values, we were unable to differentiate the impacts of specific land-use types. Although we intuitively understand that quality and typology of open space matters, this information could not be drawn from the available data at the time of this study.

Besides being incomplete, the numbers in Table 4 are also aggregated values for the entire network and cannot be used as standard values in cost-benefit studies. Site-specific data tables for each NATURA 2000 site have been made publicly available (the excel dataset has been uploaded – a screenshot illustration can be found in annex part F). Table 6 summarizes some aspects associated with the total (change in) ES value, expressed per unit of land-use change and habitat creation. Both in terms of land-use change (Table 6 - c, d) and changes in ES value (Table 6 - e, f), there are considerable discrepancies.

Table 6: Distributions of the magnitude in land-use change and ES value per hectare at site level.

a: ES value per hectare for current situation

b: ES value per hectare for future situation

n=38	Low Estimate (€/ha)	High Estimate (€/ha)
Min	3 277	7 253
P25	4 766	10 443
P50	5 455	13 076
P75	6 197	16 153
Max	11 614	34 082

n=38	Low Estimate (€/ha)	High Estimate (€/ha)
Min	3 151	7 393
P25	4 900	11 085
P50	5 646	14 347
P75	6 357	17 401
Max	11 624	34 030

c: Land-use and habitat change (absolute)

n=38	Change in LU	Change in Habitat Area
Min	6	10
P25	102	184
P50	193	360
P75	439	660
Max	1 327	2 408

d: Land-use and habitat change (relative)

n=38	Rel change in LU	Rel. change in Habitat Area
Min	2%	1%
P25	6%	12%
P50	9%	19%
P75	16%	29%
Max	33%	40%

e: Change in ES value per hectare of land-use change

n=38	Low Estimate (€/ha)	High Estimate (€/ha)
Min	-1 233	-2 329
P25	-380	878
P50	627	2 913
P75	1 851	8 695
Max	3 598	29 515

f: Change in ES value per hectare of habitat change

n=38	Low Estimate (€/ha)	High Estimate (€/ha)
Min	-2 635	-3 925
P25	-661	2 055
P50	1 345	6 090
P75	2 908	15 270
Max	6 236	32 042

It is clear that the NCO's have a differentiated impact at the site level. Changes in land-use vary between 2% and 33%, with a central value of 9 % (Table 6 d). The change in habitat area is equally variable and has a central value of 19 % increase (Table 6 d). The creation of habitat area is often higher than land-use change and can occur through changes that remain within the main land-use class, e.g. by converting poplar plantations to wetland forest. The change in ES value that changes in land-use and/or habitat creation exert shows us that not all changes have positive effects. For 30 of the 38 sites, these effects are positive, but 8 sites have negative values associated with habitat creation (mean of high and low estimate). The negative mean values range from € -792 to € -3 280, but are not as distinct as the positive mean values that range from € 1 183 to € 17 960 per ha. The extremes in the valuation are mainly associated with changes in Air Quality Regulation, Water Quality Regulation and Recreation Benefits. Therefore, we have often provided a high and low estimate for the valuation. Since there is no scientific basis, weighted or mean numbers have not been provided.

The valuation of ecosystem services is undoubtedly controversial for many ecologists and there is a comprehensive range of literature on the matter (Jax et al., 2013; Schröter et al., 2014; Spangenberg & Settele, 2010). For policy makers, too, these valuation exercises can be challenging. The valuation of ES points to societal demands (e.g. limited publicly accessible green space) and legal standards that are currently not met (e.g. air quality, water quality). Delivery of ES like air quality and water quality improvement can be valued as marginal benefits (saved expenses of marginal costs of existing measures and investment programs). But, this relatively high valuation, points rather to the inadequacy of the current policy measures to meet the (local) demand. This can indicate a high sense of urgency in the short term, but may not be a driver for ES based planning, since more efficient measure programs can substantially decrease these marginal benefits. The issue of poor air quality in the Flemish Region (Amann et al., 2011; Buekers, Stassen, Panis, Hendrickx, & Torfs, 2011) can, for instance, not be solved by planting trees.

It is clear that there are large benefits associated with restoration and/or conservation of ecosystems. Whether their (potential) ES supply and associated monetary value should be a leitmotiv in land-use planning remains disputable. Investments in conservation, restoration and sustainable ecosystems can often result in "win-win situations", which generate substantial ecological, social and economic benefits (de Groot, Alkemade, Braat, Hein, & Willemen, 2010). In the case of the Flemish NATURA 2000 network, the scenario was primarily inspired by ecological objectives. Nevertheless, the added value of the restoration measures ranges between € 15 and 95 million per year and if this value is projected on the net increase of high quality habitat area (+ 23 986 ha), the added value per area unit of change is substantial (+637 - 3 944 €/ha).

Aristotle's quote "The whole is greater than the sum of its parts" has particular relevance to the NCO's. The predicted changes in ES supply depend on the full execution of the actions and measures to achieve them. Imagine a scenario where two existing private forest complexes will become publicly accessible and will be connected by a newly developed forest corridor. The corridor by itself would not attract extra visitors if the site is not publicly accessible. Making the two separate forest sites publicly accessible (without corridor) would also not result in the same impact, since we know that larger sites attract more visitors. It's the sum of actions to achieve the NCO's that makes up the result, not the individual elements.

ADDED VALUE OF COMPLEXITY: THE CASCADE MODELLING

One of the biggest challenges of the ES concept is to have impact on real-life decision making (Ruckelshaus et al.). In addition to the 6 lessons stated in the paper by Ruckelshaus et. al. (2015), we would like to emphasize that credibility of the methods is also an important factor in achieving impact. Ecosystem service research should be geared towards implementation; and scientists should assist this process by responding to institutional needs from the outset, and by becoming involved in collaborating with and empowering institutional stakeholders in strategy development and implementation (Cowling et al. 2008). Therefore, it is important to design and parameterize models that are able to incorporate the complexity of the natural environment and its variation across space and time (Bateman et al., 2013). The quantification and valuation methods that have been used in this paper are the result of many interactions between the developers and a mix of organisations involved in policy preparation, policy execution, policy evaluation and civil society organisations involved in the management of the open space in Flanders (recreation, agriculture, nature, and water). These consultations and interactions were already initiated with the development of the Nature Value Explorer (Broekx, Liekens, et al., 2013) and were continued for this study. The methods presented in this paper reflect an actual – and policy-relevant – approach to ecosystem services for the Flemish Region, rooted within principles and classifications of international ES literature, but based on local environmental, social and economic datasets. While the principles behind the quantification and valuation methods can be transferred to other regions with comparable data availability, it is highly unlikely that parameter values can be transferred. As is the case with other modelling platforms (e.g. InVest, ARIES), it is a demanding but indispensable task to derive correct parameter values from local studies and datasets.

The biggest innovation is that we developed one large meta-model that incorporated interactions and trade-offs between the various ecosystem functions and services. We were able to develop and apply a cascade modelling methodology, where shared variables and input-output relations between ES modules have been implemented. Concomitant to the conceptual ES cascade, as initially presented in CICES (Haines-Young & Potschin, 2013), it places supporting ecosystem functions at the top of the cascade. In contrast, most studies neglect the role of these supporting ecosystem functions throughout the modelling approach (Seppelt et al., 2011). Many regulating ES have final benefits but also affect other ecosystem services. The regulating services, especially, affect multiple final services and, therefore, need to be accounted for. For example, erosion prevention has direct benefits to avoiding dredging costs, but equally affects infiltration (groundwater recharge) and flood risk control (reduced peak flows). Therefore, the sequence by which the ES needs to be calculated is of importance (as indicated in the first column of Table 3, and by the data flow chart in Figure 3).

Demonstrating the added value or accuracy of advanced ES quantification methods is difficult when no independent ES monitoring data is available (Schulp, Burkhard, Maes, Van Vliet, & Verburg, 2014). Studies that evaluate the quality and accuracy of ES mapping and modelling are scarce. Comparison of alternative mapping methods (Schulp et al., 2014), can give insight on the congruence of modelling results, but cannot provide conclusions on the ranking of their quality.

The review by Seppelt et. al. (2011) demonstrated that the inclusion of off-site effects and feedbacks are important criteria for integrated ES assessments. When these relationships are not incorporated adequately, an important aspect of the ES concept is neglected. In contrast to studies that compare alternative methods (e.g. Vigerstol and Aukema 2011; Bagstad, Semmens et al. 2013; Nemec and Raudsepp-Hearne 2013; Malinga, Gordon et al. 2015; Vorstius and Spray 2015), we chose to analyse the strength of LU-ES correlations as an indicator for the quality of the modelling approach. The LU-ES correlations thus provide ex-post information on how important it is to consider off-site effects, feedbacks and contextual information for quantification.

For example, the number of recreational visits to a site depends on surrounding population density (off-site variable), attractiveness of the site's land-use (on-site), the presence of substitution alternatives at multiple scales (off-site variable) and the aggregated connected area of accessible green space within the site (off-site variable). Feedbacks are considered implicitly, since potential visitors (based on population parameters) are redistributed by the model. By changing the attractiveness or size of a recreation site, other sites will receive fewer visits.

It was a deliberate choice not to perform a pixel-by-pixel LU-ES comparison, as performed by Van der Biest et al. (2015), but to rather look at responses of ES supply at the site level. The results show that NATURA 2000 sites have very different responses to land-use changes and this information would otherwise be obscured. The ES delivery and land-use have been made area independent. Without doing this, the results of the correlations would be dominated by scale effects (large sites). This would not provide any information on the relative performance of the sites or the effects of the NCO's. On the other hand, it may obscure the relevance of the transformations in respect to the total ES delivery by the NATURA 2000 network.

Our method also has some limitations. The land-use variables were reduced from 79 to 8 classes, which is a severe reduction of complexity, but necessary in order to perform a statistical analysis. By reclassifying to 8 classes, we are unable to account for some transformations that remain within the general land-use classes (e.g. conversion from unmanaged wetland to habitat type 91EO). We assume that these subtler transformations have a limited effect on the analysis.

Due to ES being assessed at the site level, the relative proportion of agricultural land-use, for example, negatively affects the prevalence of other land-use types, such as broadleaf forest. This means that we can also expect less obvious correlations between certain land-use types and ES (trade-off effects). These effects are a consequence of the methodology and should not be interpreted as universal mechanisms affecting ES supply. On the other hand, such correlations also show that the NCO measures display some logic of efficiency, where possible. For sites BE2200029, BE2100026 and BE2200030 there will be 633, 402 and 332 ha of heathland restoration, respectively, through direct or indirect conversion of agricultural land. Although the quantity of the service "agricultural production" declines, the quality of the service delivery on the remainder is improved with 20 %, 11% and 19 %, respectively. This implicit optimization, by abandoning marginal agricultural land for heathland restoration, only occurs in a few sites. However, it may still pervade through by the remarkable, but not significant, positive correlation (0.44) between agricultural production and heathland creation.

CONCLUSION

The cascade modelling approach, which was used to quantify the impact of the nature conservation objectives, (NCO's) successfully incorporated multiple off-site effects, feedbacks and trade-off mechanisms. The methods provide a level of complexity that allows incorporating basic system functioning, whilst remaining intuitive and transparent enough to stakeholders. An ex-post data analysis was used to demonstrate the impact of the cascade modelling. Only a few direct correlations between land-use change and ES supply could be observed. This confirmed our hypothesis that the system is complex and has to be analytically considered in a multivariate context. Especially in the context of regulating and cultural services, actual ES supply is clearly dependent on processes that include spatial dependencies (off-site effects) and biophysical processes (e.g. soil hydrology).

Co-inertia analysis did reveal strongly concordant co-structures between the two patterns. Axes 'relationships' and 'global co-structure' bear witness of common patterns, even if we cannot always provide a precise mechanistic explanation that fits for all of the sites. This can be perfectly expected as many non-significant univariate relationships between land-use and ecosystem services nonetheless show some trends. The fact that some relationships were not significant in the bivariate correlation analysis does not mean that involved variables do not play any significant role in the system. In this respect, the co-inertia did reveal much more. Significant correlations of variables with co-inertia axes are certainly more numerous. In a system, in general, most of variables are co-linear (direct and/or indirect relations), and the significance of their roles mostly take place in the multivariate context.

This proves that advanced assessments, which include additional biophysical and socioeconomic variables, significantly impact quantification and valuation results. We advise against applying land-use based expert scoring methods at regional scales or a collection of sites, given that the needed contextual information cannot be realistically incorporated in a scoring matrix (Van der Biest et al., 2015). Expert based land-use scoring methods may be well suited and applicable at the site level, since local experts and stakeholders would implicitly take the needed contextual knowledge into account.

The results of the study show that the realization of the nature conservation objectives has positive effects on the total value of ES delivery by the Flemish NATURA 2000 network. The net benefits associated with the NCO's are in the range of € 15 - 94 million for the entire NATURA 2000 network. At least 24 000 hectares are affected by land-use transformations associated with the NCO's.

For this study, the impact of the NCO's on the monetary valuation is generally positive, but for some sites we observe rather low and even negative values. Our results point out that forest conversion to grassland, especially, and heathland negatively affects the valuation results. Forests are associated with high ES supply: they sequester carbon, regulate air quality and are attractive for outdoor recreation. It can be acknowledged that some high biodiversity habitats, such as heathland, are less effective in delivering specific ES than other habitat types.

Additionally, not all methodologies are suited to truly grasp all the differences between habitat types on aspects such as the impact of landscape diversity on recreation. Policy makers need to be aware of methodological issues and safeguard that biodiversity remains the key-priority for the restoration of NATURA 2000 sites and protected sites in general.

The results of this study were communicated and discussed with a broad range of stakeholders, with little direct effect on the NCO issue. Ongoing debates between stakeholders are still focused mainly on achieving NCOs while minimizing – as much as possible – harmful effects to stakeholders, such as agriculture and business to a maximum extent, which – in some cases – prevents the identification of potential win-wins and multi-functional solutions. Whereas the direct impact at the time was low, an added value of the ecosystem services concept for public policy was recognized. The interest from policy and societal actors on this subject has been steadily growing at different policy levels. Whether or not this interest was triggered by this study (being one of the very first to be conducted in a policy-decision context in Flanders) is up for debate.

However, plenty of work is still needed to mainstream the concept in general policy. Furthermore, whether or not triggered by this study, practical examples demonstrating the difference these types of assessments can make were, and are, being set up by various actors.

Progress on developing alternative financing mechanisms is slow. One of the insights the study provides is the potential of the NATURA 2000 network to mitigate climate change through carbon sequestration. This potential could be used to set up domestic offset schemes, whereby carbon sequestration, as a direct result of nature restoration, is financially compensated by organizations and individuals that want to off-set carbon emissions produced elsewhere. This idea is currently being explored by the Agency for Nature and Forests.

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SUPPLEMENTARY MATERIALS

PART A: QUANTIFICATION AND VALUATION METHODS

The methods that were used for the quantification and valuation are to a large extent based on the methods that are used in the Nature Value Explorer (Broekx, Liekens et al. 2013, Liekens, Schaafsma et al. 2013). For the assessment of the NCOs, the methods and principles of the NVE have been transformed to systematic spatial explicit identification, quantification and valuation procedures. Additional procedures were developed for a set of hydrology mediated ES, which were not covered by the NVE. This approach allowed implementing and assessing the spatial explicit NCOs. Information on the methods and principles behind the identification, quantification and valuation of the ES are described in a concise manner. Extensive information can be found in the report for the Agency for Nature and Forest (Broekx, De Nocker, et al., 2013).

Most maps (models) were processed on a 25 meter pixel resolution. Most models (Seq 1-13, Table 3) have been developed using ArcGIS 10.0 Model builder and Spatial Analyst, including an overarching meta-model that manages the input-output relationships by invoking the sub-models in the correct sequence. Health effects and cultural ES models (seq. 14-18, Table 3) were developed in low level programming languages (C++). The latter depend less on supporting and regulating services.

WATER RETENTION

Quantification: Water retention occurs at sites that are at least temporarily waterlogged. Many of these waterlogged sites have been drained for agriculture, housing etc… We quantify the retention as the mean level of water saturation in the topsoil (% waterlogged up to 1 meter depth). In combination with the soil porosity, we can express this as a retention volume (m^3) per area unit. Potential water retention is derived from a) Mean historical high water levels, interpolated from soil data (indication of the depth of oxidation- reduction fronts); b) information on infiltration-seepage patterns at multiple scales, which is derived from a multi-scale topographic position index on a high resolution DEM (Jenness 2006 , De Reu, Bourgeois et al. 2013). Actual retention is limited by drainage intensity, which is derived from land-use intensity (desired drainage depth) and drainage network density (distance decay principle). Also groundwater abstraction cones are taken into account as a limiting factor for water retention.

Valuation: This regulating service has not been valued, but affects other final services which can be valued (Figure 3). The effect of water retention on, for example nutrient removal (denitrification), has been quantified and valued. Effects on other services, like flood risk reduction, have not been quantified.

INFILTRATION

Quantification: Water infiltration is the movement of water from the soil surface into the soil profile (l/m^2). Potential infiltration is limited by soil texture and groundwater depth (Batelaan and De Smedt 2007). The groundwater depth has a limited effect and is an intermediate result of the water retention calculation method. More important variables are interception by vegetation and runoff from paved surface to storm drain infrastructure. Both parameters were mapped at high resolution (5 m pixels), using detailed data on vegetation (INBO 2012), paved surface (NGI 2007) and sewage infrastructure (Dirckx, Bixio et al. 2009, Vrebos, Vansteenkiste et al. 2013).

Valuation: This regulating ecosystem service has not been valued, but affects other final services which can be valued (Figure 3). The effect of infiltration on, for example water provisioning, has been quantified and valued. Effects on other services, like flood risk reduction, have not been quantified.

EROSION PREVENTION

Quantification: This ES is only quantified and valued for site BE2300007, which is a collection of forest relics in an agriculture dominated landscape. The ES erosion prevention has both on-site (the loss of fertile soil) and off site effects (the deposit of sediments elsewhere). Erosion is quantified using the RUSLE formula (Revised Universal Soil Loss Equation) by Renard, Foster et al. (1997). By calculating slope on different DEM resolutions the slope length factor was included. For this study we were interested in calculating the actual erosion prevention by comparing the current situation with a scenario where all forests are converted to cropland (C-factor = 0.3). For forests and other natural vegetation, erosion is negligible (C-factor = 0.01). We used a mean annual precipitation factor (R = 880 MJ mm/ha/y). Based on estimates from empirical data, we assume that 10 % of the on-site eroded sediments end up in the larger streams and eventually need to be dredged.

Valuation: Erosion prevention can be valued using the method of avoided dredging costs. Based on the Flemish Environmental Costing Model (http://emis.vito.be/environmental-costing-model), the dredging of non-polluted sediments has a cost of 5 to 15 €/ton. This is a low estimate, since many of the sediments would end-up at sites with polluted sediments, which could increase the processing costs up to 100 €/ton.

POLLINATION

Quantification: Pollination is a regulating service that is crucial to sustain certain types of agricultural production. The demand for pollinators was scored (0-1) for the crops of the agricultural inventory (VLM, 2011). Score 0.5 would mean that 50 % of the yield depends on pollinators. 21 crop types were found to have at least 20 % of their yield, dependent on pollination. The potential of vegetation types to provide habitat to pollinators was scored by experts (0-10). For each cell of pollinator dependent agricultural land, we evaluate the surface and quality of pollinator habitat within a certain radius and up to 1 km distance. The surface of high quality pollinator habitat (score 10) accounts for 100 % of the surface, while low quality pollinator habitat (e.g. score 5) would only be accounted for 50 % of the surface. The relative surface of pollinator habitat is a measure for the pollination probability by wild pollinators for a particular cell. This is then multiplied by the pollinator dependency factor of the crop type. This procedure takes into account that a crop can be serviced by pollinators from geographically different habitats. The service is expressed in yield that can be attributed to the surrounding pollinator habitats. For example: Consider a parcel of 5 ha with a crop type for which the yield depends for 25 % on pollination. This site is surrounded by several hectare of pollinator habitat of varying quality. From the calculations is revealed that average pollination probability is 35 %. This would mean that we can attribute 0.44 ha of yield for that particular crop-type to the pollinator habitats.

AGRICULTURAL PRODUCTION

Quantification: Because of the nature of the primary data, quantification is done directly in €/ha*yr. Typical agricultural net revenues per crop type are derived from sample data on profits and loss accounts at the farm level. These values are then used in combination with the parcel level crop registration data of 2010 and crop specific soil suitability maps to account for spatial variations in crop specific productivity.

The profits and loss accounts reflect the state of revenues and costs for particular agricultural sectors. The net revenue is the difference between the total revenue from agricultural production (excluding subsidies) minus the operational costs. For the year 2010 this was derived from detailed data from a random check of 749 particular farms (Van Broekhoven E. 2010). Because of the variability between years we used data from 2008, 2009 and 2010 to estimate the values per crop type. For fodder crop types, an alternative method is used by the agricultural administration (D'Hooghe 2012). In general, fodder crops are not sold on the market, but are used as fodder within the agricultural production chain. The net revenues from dairy and meat production are therefore distributed among the fodder production parcels at the farm level to estimate a revenue factor for fodder crops. Based on this data, a P25, P50 and P75 revenue value (per ha) was derived for the most important crop types (e.g. for corn P25=€ 1.245, P50=€1.580, P75=€1.818).

The soil suitability maps for agriculture and horticulture are based on the digital soil map of Belgium (Dudal, Deckers et al. 2005). A suitability class groups the soil types that can provide a comparable production for several crop types when uniform cultivation and fertilization practices are applied. For each crop type, a 5 class ranking is provided, where class 1 is very suitable and class 5 is unsuitable (Bollen 2012). The classes 1-2 are associated with the P75 values of the crop revenue values, the classes 3-4 are associated with the P50 values and class 5 is associated with the P25 values.

FLOOD PREVENTION

Quantification: This ES is realized by allowing temporal water storage on flood tolerant sites to avoid flooding of more vulnerable sites elsewhere. Flood prevention is a complex ES which requires catchment modeling for its quantification. A normalized quantification and valuation of this service for all NATURA 2000 sites was too complex to perform in this analysis. Several NATURA 2000 sites along the Scheldt provide a known and significant flood prevention service to flood prone city districts (Broekx, Smets et al. 2011). The role of many small distributed flood retention zones in upstream NATURA 2000 sites remains largely overlooked. Therefore a semi-quantitative method was used to identify the flood storage potential within NATURA 2000 sites. A theoretical (potential) flood storage capacity was calculated by use of the ArcView extension "buffer by elevation change" (Holzer 2005). This conceptual method is especially interesting for upstream catchments, where no spatial explicit hydrological modeling is available. The maximal flood plain extent was constrained by the presence of historical alluvial deposits (Dudal, Deckers et al. 2005) or the presence of recent floods (data from the Flemish Environment Agency). This methodology has been applied more rigorously on site BE2100040.

WOOD PRODUCTION

Quantification: Wood production depends on soil characteristics and applied harvest regime. Species specific potential produced wood volumes can be found in table A.1, where differentiation is made according to the soil suitability.

Table A1: Overview of the relationships between soil suitability and the maximal mean growth of stemwood (m^3/ha*yr).

Soil suitability	Tree species							
	Fagus sylvatica	Quercus (Robur, Rubra)	Populus	Larix decidua	Pinus sylvestris	Pinus Nigra	Picea abies	Pseudotsuga menziesii
4	4,0	3,0	9,0	6,0	4,0	6,0	6,0	8,0
3	6,7	5,0	11,0	8,7	6,0	9,3	9,0	10,7
2	9,3	7,0	13,0	11,3	8,0	12,7	13,0	13,3
1	12,0	9,0	15,0	14,0	10,0	16,0	16	16,0

Depending on management and ownership structure (private, public) a harvest factor is applied that estimates the proportion of the annual maximal mean growth that is harvested annually. The harvested volumes are available from recent data (2009-2012) on timber selling from public (state owned) forests and from forest owner cooperatives (privately owned, but the management is state coordinated). This data base has about

80.000 records of sold volumes per tree species and circumferences. For state owned forests, the harvest factor is 0.54. Privately owned forests are often unmanaged and have a lower (0.15) harvest factor. For private forests, there is an unknown fraction of harvest for private use and informal markets (especially for fire wood). For each of the NATURA 2000 sites, the proportion of privately owned and state owned forests is known. This information allows calculating harvested volumes of specific tree species.

Valuation: Valuation of wood production has been done on the basis of annual m³ harvest per year and per tree species. The value for each species was based on the database of actual selling prices in the state-owned forests for the years 2009-2012. Although the records refer to tree species, volumes and associated circumferences, the selling prices often refer to a combination of several records sold as one single lot (in average 18 records/lot). Statistical analysis (SPSS 20.0) was used to reveal a selling price (€/m³) per species and circumference class (Table A.2). The average weighted selling price for all species and circumferences was estimated at 32,43 €/m³. Trees are sold as standing timber and prices are therefore considered as net added value of timber production.

Table A2: Overview of timber values (€ per m³) sold as standing timber per circumference class for most important commercial tree species.

Circumference (cm)	Tree species Fagus sylvatica	Quercus Robur/petrea	Quercus Rubra	Populus	Larix decidua	Pinus sylvestris	Pinus Nigra	Picea abies	Pseudotsuga menziesii
100–119	30,6	27,0	27,1	27,1	25,6	26,9	28,7	24.3	28,5
120-149	33,7	30,7	30,6	30,6	29,4	27,7	29,1	24,9	31,7
150-179	39,9	41,4	36,7	36,7	33,7	29,4	30,2	26,0	33,3
180-199	43,6	45,8	38,4	38,4	37,0	27,4	33,6	28,8	34,9
200–219	48,1	48,3	39,1	39,1	41,6	32,3	32,0	25,4	37,8
220-249	48,8	50,2	43,0	43,0	45,6	-	33,5	-	35,1
>250	50,4	52,8	43,1	43,1	- $	-	-	-	32,4
Average £	39,47	35,99	33,64	36,42	29,95	27,55	29,54	24,97	31,95

$: n<10 unrealiable parameter estimation;
£: weighted mean, based on number of observations per circumference

AIR QUALITY IMPROVEMENT –PM10

The removal of fine dust by vegetation depends on the vegetation type and structure (height and specific leaf area). More leaf area effectuates a higher capture. We build on land cover based parameters from a local study (Oosterbaan and Kiers 2011). The range of these values have been confirmed by studies from the U.S.A. (e.g.(Nowak, Crane et al. 2006, Nowak 2010) and from the UK (Tiwary, Sinnett et al. 2009). These studies confirm that large scale reforestation has effects on air quality in the wide surroundings. Parks and nature areas improve air quality and these effects can be regarded as avoided emissions for the estimation of effects on public health. Table A3 provides the minimal and maximal estimations for the capture of fine particulate matter (PM10) for land cover classes.

Table A3: parameter values for capture of fine particular matter by land use /land cover classes.

Land cover / Land use	Min (kg/ha*yr)	Max. (kg/ha*yr)
Coastal habitats without vegetation	0	0
Coastal habitats with low vegetation	18	36
Coastal habitats with forest vegetation	36	73
Species rich grasland and tall herbs	18	36
Broadleaf forests without undergrowht	36	73
Broadleaf forests with undergrowht	44	88
Coniferous forest	63	127
Heathland	18	36
Phragmites	22	50
water	0	0

Wetlands	18	36
Rivers and standing water	0	0
Pastures	18	36
Cropland	6,4	12
Hedgerows, shrubs	12	24
Treerows, wooded banks, orchards	36	54
Coppiced woodland	25	50
Urban	0	0

Valuation: Air quality is in general problematic in Flanders and has serious impact on public health (Amann, Bertok et al. 2011, Buekers, Stassen et al. 2011, Dhondt, Beckx et al. 2012, Flemish Environment Agency 2012). Avoided health cost are determined for rural areas in a study for the Flemish Environment Agency at 54 €/ kg fine dust, (De Nocker, Michiels et al. 2010).

NOISE REDUCTION

Quantification: Traffic noise is the most common source of noise nuisance. The Flemish region has one of the most dense traffic networks of the world (Lammar and Hens 2005). Recent research revealed that 27 % of the population is disturbed by noise pollution. Over 10 % is severely disturbed, with significant health impacts (Stassen, Collier et al. 2008). Approximately 30 % of building facades have a noise exposure over 65dBA during daytime (Van Renterghem, Botteldooren et al. 2012). Noise exposure maps from major traffic roads are available from the Flemish Agency for Roads and Traffic. These maps express a weighted noise exposure (L_{den}: Level day-evening-night). Night and evening exposure are weighted stronger, which accounts for the impact of noise disturbance on life quality. The exposure maps are modeled and are based on the type and density of the traffic, speed limits, type of road surface as well as geometry of the surroundings. The models include the dampening effect of soils, but do not consider vegetation as a noise buffer. Noise reduction is only considered when forests or tall shrubs are situated in between important motorways and residential area. Vegetation composition and structure are important factors, but data is not always available. Noise absorption per 100 m of vegetation ranges from 7 to 12 dB for the frequency of traffic noise (500-1500 Hz).

Valuation: Noise levels affect real estate values (decline up to 1.1 %). Negative effects of noise on house values start at levels of 55 dB and increase up to 1.1 % when there is at least 70 dB noise exposure. Further increase does not seem to affect house prices. As a starting position for the valuation, we assume the average house value in Flanders, which is 192.179 €/house or 8.946 €/year*house. The low and high estimate procures from the low and high estimate in noise reduction (respectively 7 and 12 dB/100 m).

CARBON SEQUESTRATION IN BIOMASS

Quantification: The quantification of carbon sequestration in living biomass is based on the maximal annual growth of stem wood (table A4, cfr timber production). The growth of branches and roots is added to the stem wood production to estimate the total annual carbon sequestration. For this purpose we use Biomass Expansion Factors (BEF). As a final step we translate the total growth of biomass (m^3/ha*yr) to carbon sequestration values. Therefore we use the species specific carbon density (kg /m^3), as indicated in table A4. Carbon densities typically account for half of the weight. Annual carbon-sequestration (kg C per ha per year) can be calculated as follows: $C_{ha*year} = I_V * BEF * \text{carbon density}$.

Table A4: Biomass density (kg/m³) and carbon density (kg C/m³) of most common commercial tree species (Vande Walle, Van Camp et al. 2005).

Variable	Tree species							
	Fagus sylvatica	Quercus Robur/petrea	Quercus Rubra	Populus	Larix decidua	Pinus sylvestris	Pinus Nigra	Picea abies	Pseudotsuga menziesii

BEF	1,67	1,5	1,5	1,5	1,75	1,5	1,5	1,75	1,71
Density (kg/m³)	560	600	600	410	470	480	480	380	450
Carbon density (kg C/m³)	274	300	300	205	235	240	240	190	225

Valuation: Parameter values for external costs of air quality and climate change have been identified for the Flemish Environment Agency (De Nocker, Michiels et al. 2010). These values are based on avoided reduction costs. Carbon sequestration in e.g. forests and soils allows avoiding emission reduction costs (measures) elsewhere; while still achieving policy targets. Marginal costs of measures that are needed to maintain the 2° C global warming target, increase gradually over time (20 €/ton C in 2010 up to 220 €/ton C in 2050). A standard value of 220 €/ton CO2-eq. for the year 2020 is chosen. This is consistent with the values of the Flemish reference manual for societal cost benefit assessments of large infrastructure works (Mint en Rebel 2013).

CARBON SEQUESTRATION IN SOILS

Quantification: Soils under unmanaged, natural vegetation types typically have larger carbon stocks than managed vegetation types. Also soil hydrology plays a crucial role in the creation of soil organic carbon (SOC) stocks. Soil organic carbon is especially high for forests and/or hydric soils. The potential equilibrium state for soil organic carbon stocks can be calculated using the regression formula by Meersmans et. al. (2008), which includes parameters like water retention, soil texture and vegetation type. Changes in land-use typically affect both vegetation and/or drainage (ES water retention), which leads to a new potential equilibrium state for SOC stocks. Recent research by Dr. De Vos (2009) has revealed that this function systematically underestimated SOC-stocks in forest soils with 32 %. This correction factor to the regression formula of Meersmans is applied to all forests. Peatlands, wetlands and freshwater ecosystems can sequester higher carbon stocks than terrestrial ecosystems. Potential (maximal) stocks are very much dependent on hydrological regimes and how mature these ecosystems are. Depending on the hydrological regime, newly created wetlands sequester 2.5-3.5 ton C/ha*yr in the first 100 years. Older wetland systems often do not sequester much additional carbon, especially when they are not under permanent hydric conditions. On the other hand, pulsed hydrological conditions emit less methane.

Valuation: Stocks are difficult to consider in valuation exercises. Here we calculated a virtual scenario of changes in carbon stocks due to changes in land use (habitat types) and associated changes in water retention. The difference in SOC stocks would be gradually built or released at a rate of 2.5 % loss per year. The valuation method is identical to the valuation of carbon sequestration in biomass.

WATER PROVISIONING

Quantification: Water provisioning is derived from the ES infiltration and only covers water provisioning from groundwater abstractions. The Flemish region has licensed 22.600 permits for groundwater abstractions for an annual maximal abstraction of 420 million m³ per year (DOV, 2012). About 282 million m³ is licensed for abstractions from phreatic layers. It is estimated that about 60 % of the permitted volumes are effectively abstracted. There are also many thousands of unlicensed abstractions. First the point data on abstracted volumes was distributed to virtual infiltration equivalent buffers, and then the average abstraction ratio was calculated within a radius of 12.5 km. This was assumed to be an appropriate spatial (and temporal) scale to assess the sustainability of the groundwater abstractions (to compare these values to average annual infiltration at the same spatial scale). By combining both spatial supply (infiltration) and spatial demand (abstraction), we can estimate the quality and quantity of the infiltration, of which a certain fraction is abstracted. From a sustainability viewpoint, we make the assumption that the current infiltration quantity and quality should be able to sustain the current water provisioning on the long term.

In the first place we quantified the proportion of the average annual infiltration that was abstracted (based on the abstraction ratio * actual infiltration). In the north-east the relative abstraction ratio ranges up to 15 % of the total annual infiltration at the catchment level (Nete Catchment – approx.).

Secondly, we made a distinction between abstracted volumes of “clean” and “dirty” infiltration. There is no quantitative difference in infiltration when there is conversion from production grassland to nutrient poor grasslands, but it surely secures groundwater quality. Therefore the quality of infiltration needs to be quantified. All pixels that were not under agricultural and urban land-use, were classified as clean infiltration without leaching of pesticides and nutrients to the groundwater. This allowed assessing the impact of the NCO’s on the quality of infiltration.

Thirdly we quantified the impact of abstractions on groundwater levels. A relatively high proportion of drinking water production (piped water) originates from abstraction wells within or near NATURA 2000 sites. For drinking water production sites, the modeled abstraction cones were provided by the drinking water companies. But there were also thousands of smaller abstraction cones, which we modeled in a simplistic way. Typical volumes of the modeled abstraction cones are 2-4 times the annual abstracted volume. On the basis of this assumption we calculated radial depression cones for each abstraction well ($Depth=\left(AbstrVol_{ann} \div (\pi * r^2)\right)$). Volumes of declined groundwater were calculated and reported for each NATURA 2000 site, but these figures were not used further for valuation of the ES water provisioning.

Valuation: Valuation of water provisioning quantity by supply through infiltration was explored from two viewpoints. The first is the substitution cost: In times of scarcity, water is purchased in the Walloon region. A recent benchmark study of the drinking water companies revealed the average additional costs of purchasing treated water versus own production at the level of the Flemish Region. This difference in costs is approximately 0.2 €/m³. The second method used is based on the groundwater water abstraction tax. This tax is 0.075 €/m³ and can be seen as a compensation for the environmental and resource costs as formulated within the Water Framework Directive. This is the existing effective contribution from water companies and should be regarded as the absolute bottom threshold.

AVOIDED NITRATE LEACHING

Quantification: It can be debated if the cessation of fertilizer use can be categorized as an ES. It is imperative to include this since landscape level nutrient leaching is an important parameter for the ES “nutrient removal by denitrification”. Infiltration on fertilized agricultural land results in nitrate leaching to ground and surface water. Important variables are the specific combinations of soil texture, crop type, agricultural fertilizer application (kg N/ha) and atmospheric N-deposition (kg N/ha). Long-term data on autumn and spring nitrate residues in agricultural soils were available from the Flemish Land Agency (Geypens, Mertens et al. 2005). The difference between fall and spring residue is assumed to be leached out by winter precipitation. Atmospheric nitrogen deposition data were provided by the Flemish Environment Agency (FEA 2011). We assumed that nutrient leaching also occurs on non-agricultural land with high deposition rates. Although declining, these values are still relatively high (Staelens, Wuyts et al. 2012). From the data on nutrient leaching from agricultural land we know these values range between 7 % and 33 % of the nitrate application. We applied the same range of values (7 - 33 %) on non-agricultural land with N-deposition and varied the range of values accordingly to the natural sensitivity for nitrate leaching (soil texture).

Table A5: parameter values for maximal fertilizer application, fall nitrate residues in soils and winter nitrate leaching in function of cultivation and soil texture.

Cultivation	Texture	Max. N-application kg N/ha	N-residue fall	Relative residue (%)	N-leaching	Relative leaching (%)
pasture	sand	350	60	17%	32	9%
pasture	loam	370	67	18%	26	7%
pasture	clay	380	73	19%	23	6%
beet (fodder)	sand	305	49	16%	30	10%
beet (fodder)	loam	330	55	17%	24	7%
beet (fodder)	clay	330	60	18%	21	6%
maize	sand	205	86	42%	57	28%
maize	loam	220	96	44%	40	18%
maize	clay	220	105	48%	41	19%
barley and other cereals	sand	200	69	35%	42	21%
barley and other cereals	loam	215	77	36%	33	15%
barley and other cereals	clay	215	84	39%	30	14%
wheat and tricitale	sand	250	80	32%	42	17%
wheat and tricitale	loam	264	89	34%	33	13%
wheat and tricitale	clay	265	98	37%	29	11%
crops with low N-demand	sand	165	69	42%	42	25%
crops with low N-demand	loam	175	76	44%	33	19%
crops with low N-demand	clay	175	84	48%	29	17%
other	sand	50	9	18%	5	10%
other	loam	50	10	20%	4	8%
other	clay	50	11	22%	4	8%
Vegetables Group II	sand	180	86	48%	53	29%
Vegetables Group II	loam	180	96	53%	41	23%
Vegetables Group II	clay	180	105	58%	37	21%
potatoes	sand	280	111	40%	68	24%
potatoes	loam	280	124	44%	53	19%
potatoes	clay	280	136	49%	48	17%
Sugar beet	sand	205	54	26%	33	16%
Sugar beet	loam	220	60	27%	26	12%
Sugar beet	clay	220	66	30%	23	10%
Vegetables Group III	sand	125	66	53%	40	32%
Vegetables Group III	loam	125	74	59%	32	26%
Vegetables Group III	clay	125	81	65%	28	22%
Vegetables Group I	sand	250	114	45%	69	28%
Vegetables Group I	loam	250	126	50%	54	22%
Vegetables Group I	clay	250	139	56%	49	20%
crops	sand	200	90	45%	55	28%
crops	loam	215	100	46%	43	20%
crops	clay	215	110	51%	38	18%
legumes (other than peas and beans)	sand	120	39	32%	24	20%
legumes (other than peas and beans)	loam	125	43	35%	19	15%
legumes (other than peas and beans)	clay	125	48	38%	17	14%

Valuation: see below section on nutrient removal by denitrification.

NUTRIENT REMOVAL BY DENITRIFICATION

Quantification: Under conditions of (temporal) waterlogging, bacterial processes enable to remove nitrogen from ground and surface water. The most important variables are the soil moisture, supply of nitrate and soil organic carbon. As a proxy for nitrate removal efficiency, we transform combinations of the mean highest (MHG) and mean lowest groundwater (MLG) levels to an estimated nitrate removal efficiency (% of available nitrate removed).

Tabel A6: Estimated removal efficiency (%) for combinations of mean highest and mean lowest groundwater levels (in cm below soil surface).

	MLG	>50	45	40	35	30	25	20	15	10	5-0
MHG											
>50		10	13	17	20	23	27	30	33	37	40
45			20	23	27	30	33	37	40	43	47
40				30	33	37	40	43	47	50	53
35					40	43	47	50	53	57	60
30						50	53	57	60	63	67
25							60	63	67	70	73
20								70	73	77	80
15									80	83	87
10										90	93
0-5											100

Nitrogen has many and complex pathways by which it is dispersed in the environment. For this study, we focus on the issue of excess nitrogen in groundwater and surface water. Nutrient leaching from agricultural land is one of the major pathways. Reduction of nitrate leaching has already been described in previous sections, but is an important variable for denitrification. For the current situation, the avoided nitrate leaching is zero. But the NCO's include both cessation of fertilizer application and cessation of drainage. Cessation of nitrate leaching implies a decrease of nitrate supply to the denitrification zones, which in their turn may have increased nitrate removal efficiency due to rewetting. The supply of nitrogen occurs through patterns of (local) infiltration (nitrate leaching) and seepage. Infiltration and seepage patterns are the result of processes that occur on a range of spatial scales. A topographic position index (TPI) is used to identify these patterns at multiple scales (Jenness 2006). This method has also been used in other studies for the Flemish Region and has proven its applicability (De Reu, Bourgeois et al. 2013). We calculated the TPI at a range of spatial scales (radius: 250m – 2000m) to indicate these local infiltration-seepage patterns. The multi-scale TPI is then corrected for soil permeability to result in a seepage intensity map, indicating the water supply to a particular pixel (mm/day). The nitrate concentration of the supplied seepage water is calculated at the landscape level (2 km radius) by multiplying the annual nitrate leaching (kg N/ha) with the annual infiltration (m^3/ha). This allows us to calculate denitrification by multiplying the removal efficiency with the annual nitrate load for each pixel.

Valuation: The valuation is based on the marginal reduction cost for nitrate removal. The Environmental Costing Model for Flanders compares different (technical) measures on cost-efficiency (€/kg reduction) and the applicability of those measures. The cost of the most expensive measure, considered in policy approved measure programs, can be seen as the cost the society is willing to pay for a further reduction of nitrate levels in ground and surface water. For nitrate, the marginal reduction cost is 74 €/kg N. As a low estimate we apply 5 €/kg N, based on a literature review (Liekens, Schaafsma et al. 2013).

NUTRIENT STORAGE IN SOILS

Quantification: Changes in soil organic carbon also affect soil nutrient stocks. It is known that soil organic matter contains a certain percentage of nitrogen and phosphorus. Land-use change and especially drainage of historically water logged soils can increase mineralization of the SOC and result in additional supply of nitrogen and phosphorus to the environment. The release of N and P by mineralization of soils is not yet accounted for in the setting of maximal fertilizer application standards. The phenomenon of unexpected high nitrogen residues in some agricultural soils has been documented by the Flemish land Agency and can be explained by this mechanism. The C/N ratio in stocks of SOC depends on the vegetation and land-use. Higher C/N ratios in the SOC can be explained by litter production that is more difficult to decompose (high C/N, high lignin concentration). Parameter values for the C/N ratio in SOC can be found in table A7.

Table A7: C/N ratio of SOC for several vegetation types

Vegetation type/ land-use	Upper and lower estimates	Central value
Cropland and production grassland	8-12	10
Floristic and species rich grasslands	10-14	12
Broad leaf forest	15-25	20
Mixed forest	20-25	22
Coniferous forest	25-30	27
Heathland	25-35	30
Phragmites wetlands	25-35	30
Wetlands (sedges and tall herbs)	15-25	20
Eutrophic alluvial forests	15-20	17
Mesotrophic wetland forest	20-25	22
Oligotrophic wetland forest	25-30	27
Peat bogs	25-35	30

A decrease of the SOC and C/N ratio due to land-use and/or drainage can be regarded as an additional release of nutrients, comparable to fertilizer application. This mechanism was not accounted for in the calculation of the (avoided) nitrate leaching because of controversy, but could be included in the future when this mechanism is accepted.

The reverse mechanism, an increase of SOC and nutrient stocks due to land-use change and rewetting, can be categorized as the process of soil formation and maintenance. Linking this process to the improvement of water quality is highly debatable. Non-fertilized ecosystems tend to have negligible losses of nitrate to the groundwater. Ecosystems naturally tend to accumulate nutrients in SOC and biomass throughout their ecological succession if these nutrients are not removed (denitrification, grazing, harvesting, wildfires, leaching). But it is questionable whether they actively withdraw nutrients from ground and surface water. Most nitrogen is supplied from atmospheric N-deposition and the ability of some vegetation types to fixate N from the air.

Valuation: The positive and negative changes in N and P stocks in SOC are quantified, but are not valued since there are risks of double counting. Negative changes (nutrient release) could be added to the nitrate leaching calculations and be valued through ES denitrification (increased nitrate loads to the denitrification zones) and ES water production (avoided treatment costs). This is currently not included in the calculations, but will be in future calculations. Positive changes in N and P stocks in SOC cannot directly be attributed to ES that can be monetized.

RECREATION AND TOURISM

Quantification: The most common quantification unit is the number of recreational visits per year. Because there is no covering data set on the number of visitors, we need to estimate these visits based on other studies. The NATURA 2000 sites have a huge variability in terms of size, land-use, vegetation types, facilities, accessibility, distance to residential zones, etc… The number of visits can equally be very variable and depends to a large extent on these parameters. In line with several international studies (De Vries, Jellema et al. 2004 , Colson 2009, Sen, Darnell et al. 2011), we attribute visits to green space on the basis of multiple indicators.

In a first step we estimate the number of visits people make. The demand depends on the population density at several scales (locally to regional) and the relative presence of “green open space” within these scales (green open space per capita at several scales). This demand estimate is based on information (large scale enquiries) about the number of visits people make and which distances they travel for these visits. The total demand (number of visits) is calculated per municipality, based on the number of inhabitants, the availability of local green space and data on tourism and daytrips. In a second step, this “demand” is allocated to existing green spaces (both NATURA 2000 and other sites). This allocation is based on parameters from literature that determine the probability for visits to a certain site. Main parameters are distance, size, availability of other sites (alternatives) and site characteristics such as general nature type, accessibility, facilities, walking trails, etc. This balancing of demand and supply was done on three spatial scales, which can also be associated with three types of visits. Local recreation is allocated within the municipalities (308). Daytrip recreation and local tourism is allocated to the 18 touristic regions. Touristic recreational visits of more than one day are allocated at the provincial level (5). Visitors are now allocated to large clusters for three types of visits. Based on the spatial overlap of NATURA 2000 sites with these large clusters, we are able to estimate the specific number of visits to NATURA 2000 sites. The estimate was compared to observations and more detailed studies for 8 touristic clusters in which important NATURA 2000 sites are nested. For larger sites (> 100 ha), the difference between estimate and observation was limited to 25%. For smaller sites (< 100 ha), the differences were higher.

Valuation: For valuation of recreational visits, the approach of the UK National Ecosystem Assessment was used (Bateman Ian J, David Abson et al. 2011). Based on this approach, the average value was estimated at 4.4 €/visit, with slight variations that depend on the nature type (e.g. forest 4.5 €/visit; agroscapes 3.4 €/visit). Adaptations were made according to the relative preferences for certain nature types from choice experiments (Liekens, de Nocker et al. 2009a, Liekens, Schaafsma et al. 2013). From the high and low estimates found in literature (Bateman and Jones 2003, Scarpa 2003, Moons, Saveyn et al. 2008, Colson 2009, Eftec 2010), an average low (3 €/visit) and high (9€/visit) estimate was derived. More information on the valuation function can be found in the publication by Liekens et. al. (2013). The valuation of recreational visits is included in the final benefit assessment.

QUALITY OF THE ENVIRONMENT AND ESTATE VALUE

Quantification: Residential buildings with view and/or proximity to green open spaces offer a higher environmental quality and this is reflected in property values. The added value for a NATURA 2000 site depends on the number of houses within a distance of 100 meter. Property values are positively affected up to 1 km distance, but these effects overlap with recreation.

Valuation: Literature has demonstrated that the presence of green open space has effect on property values (Kroll and A.F 2010). For the valuation we use the method by Brander (2007), which was adapted to the following procedure. The number of inhabitants within buffers of 100, 300, 600 and 1000 meter of the NATURA 2000 sites are calculated. The number of houses is estimated from the average number of inhabitants in the Flemish Region (2.3 inhabitants/house). The effects are calculated, using three different distance decay functions (Less rural = 1100 inh./km² - max effect +4.5%, null effect at 800m. ; Rural = 600 inh./km² - max effect +4%, null effect at 600m; very rural = 100 inh./km² - max effect +2.75%, null effect at 250 m.). Depending on the average number of inhabitants surrounding the NATURA 2000 site, one of these three functions is attributed. As a starting position for the valuation, we assume the average house value in Flanders, which is 192.179 €/house or 8.946 €/year*house. As a low estimate only houses within a buffer of 100 m are considered. For the high estimate all houses within a buffer of 1 km are considered. The valuation is not included in the final benefit assessment since there is overlap with recreational visits.

HEALTH EFFECTS

Quantification: The presence of green open space in the direct surroundings of people has a positive effect on the physical and mental health. The effects are related to the number of inhabitants within 1 km of the NATURA 2000 sites. For health effects, there is also a certain overlap with "recreation and tourism" and "effects on estate values". However the effects on physical and mental health are of a fundamental different nature than the benefits visitors to these sites generate for the local economy (e.g. catering, rental, hotel sector). Although the motive of "recharging the batteries" (physical and mental health) can be partly overlapping, there is no indication in literature on the amount of overlap. The authors found that for these reasons it would be desirable to include these benefits, but assume a 50 % overlap with the other services for the final valuation ("recreation and tourism" and "effects on estate values"). The method used to calculate the effects, is based on the concept of DALYs (disability adjusted life years), which is an indicator to compare different health effects. For the Netherlands, there are 180 DALYs per 1000 inhabitants. For 40 % of the major diseases that result in the loss of healthy years (e.g. coronary diseases, depression…), green open space has relatively high positive effects (Dutch National Institute for Public Health and the Environment 2007). The study by Maas (2008) concludes that 10 % of additional green open space results in 2.46 healthy life years per 1000 capita.

Valuation: This effect can be valued at 87.000 € per DALY (Stassen, Collier et al. 2004). Taking into account there are 1.801.000 inhabitants within 1 km of NATURA 2000 sites, the positive effect of 2.46 DALY per 1000 capita and the assumed 50 % overlap with recreation and tourism, we calculate this benefit at 192.725 € in total.

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PART B: LAND USE RECLASSIFICATION FOR DATA ANALYSES

Table B1: Land use reclassification for data analyses

ID1	ID2	legend English	T00 (ha)	T20 (ha)
1	6	other	485	326
2	5	non registered grassland (ecologically valuable)	1675	1501
3	3	non registered agricultural land	2150	1196
4	7	Wetland (no management)	497	317
5	2	Heathland (no management)	118	70
6	2	Coastal dune (no management)	0	0
7	5	Grassland (nature management)	4268	2404
8	1	Forest (nature management)	13475	5812
9	4	Forest (forest management)	8853	5275
10	7	Wetland (nature management)	418	178
11	2	Heathland (nature management)	362	140
12	2	Coastal Dunes (nature management)	0	0
13	7	Tidal marshland	1	1
14	4	Undefined (nature management)	1063	389
15	3	cropland	5942	4760
16	3	permanent grassland	5945	4270
17	3	temporary grassland	3074	2538
18	3	Orhards	189	117
19	3	Agricultural use	270	143
20	4	Military	221	114
21	5	Grasland (Cynosurus cristatus) (habitat of regional importance)	50	49
22	7	Wetland forest (Salicion albae, Cardamino amarae-Salicetum albae) *	597	399
23	5	Shrubs (Cytisus scoparius-[Calluno-Ulicetea/Nardetea]) *	11	9
24	7	Wetland schrubs (Myrica gale-[Oxycocco-Sphagnetea]) *	118	46
25	7	wetland forest (Salicion cinereae) *	207	198
26	5	Shrubs (Lonicero-Rubion sylvatici en Pruno-Rubion radulae) *	65	65
27	5	Grasland (Lolio-Potentillion) *	19	11
28	7	Wetland grassland (Calthion palustris) *	575	554
29	7	Wetland grassland (Caricion gracilis) *	184	181
30	7	Wetland (Phragmition australis) *	653	609
31	7	Wetland (Caricion nigrae; caricion davallianae; Caricion lasiocarpae) *	40	32
32	7	6430 - Hydrophilous tall herb fringe communities of plains **	1555	1604
33	2	2310 - Dry sand heaths with Calluna and Genista **	2843	4236
34	7	4010 - Northern Atlantic wet heaths with Erica tetralix **	1975	2749
35	2	4030 - European dry heaths **	3900	4995
36	5	6210 - Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites) **	8	19
37	5	6230 - Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe) **	384	892
38	7	6410 - Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) **	42	180
39	7	6510 - Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis) **	584	1727
40	1	9120 - Atlantic acidophilous beech forests with Ilex and sometimes also Taxus in the shrublayer (Quercion robori-petraeae or Ilici-Fagenion) **	11443	20508
41	1	9130 - Asperulo-Fagetum beech forests **	2073	3279
42	1	9160 - Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli **	1839	2554
43	7	91E0 - Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) **	5063	8117
44	7	7140 - Transition mires and quaking bogs **	239	586
45-56	0	Estuarine habitats	0	0
57	7	3110 - Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae) **	8	21
58	7	3130 - Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea **	522	721
59	7	3140 - Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. **	42	44
60	7	3150 - Natural eutrophic lakes with Magnopotamion or Hydrocharition — type vegetation **	290	409
61	7	3160 - Natural dystrophic lakes and ponds **	50	111
62	7	3260 - Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation **	2	2
63	7	3270 - Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation **	14	18
64	2	5130 - Juniperus communis formations on heaths or calcareous grasslands **	14	22
65	5	6120 - Xeric sand calcareous grasslands **	62	96
66	7	7110 - Active raised bogs **	2	4

67	7	7210 - Calcareous fens with Cladium mariscus and species of the Caricion davallianae **	6	7
68	7	7230 - Alkaline fens **	8	18
69	1	9110 - Luzulo-Fagetum beech forests **	306	409
70	1	9150 - Medio-European limestone beech forests of the Cephalanthero-Fagion **	4	9
71	7	91F0 - Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris) **	8	58
72	2	2150 - Atlantic decalcified fixed dunes (Calluno-Ulicetea) **	0	0
73	7	7220 - Petrifying springs with tufa formation (Cratoneurion) **	1	1
74	8	Residential	1240	1239
75	8	Industrial	44	44
76	8	Commercial buildings	85	85
77	6	parks and recreational facilities	1687	1681
78	8	Infrastructure	131	131
79	7	water	2195	1915
***** habitat of regional importance ****** Annex 1 habitatEUR		**ID2**: (1. Broadleaf forest, 2.Built-up, 3.Heathland & Dunes, 4. Intensive agriculture, 5.Mixed forest, 6. Species rich grasslands, 7.Other, 8. Wetland)		

ID1 refers to the original classes (column 3) and ID2 refers to the general land use classes). The columns T00 and T20 respectively refer to the surface (in hectares) of the detailed land use category before (T00) and after implementation of the NCOs (T20).

PART C: SITE-SPECIFIC LAND-USE CHANGES

The actual land use and the changes associated with the NCO's (between brackets) are summarized for 35 SACs. The SACs (BE2300006; BE2500001 and BE2500002) were removed from the dataset, are not included in table C1 and do not appear in Table D1. These 3 sites cover mainly estuarine habitats. Classes 44-56 (Annex 1 habitat types 1130, 1140, 1310, 1320, 2110, 2120, 2130, 2160, 2170, 2180, 2190) are also clustered in table B1 (supplementary materials part B) since these classes do not occur in the remaining sites. For each of the remaining 35 SACs, details can be found on the total site surface (Area.), the total change in land use (Diff) and the relative change in land use (Rel.). Columns LU1 to LU8 provide the current surface for each of the 8 general land use classes, including the impact of the NCO's on (between brackets). Each of the sites can be found through the official site-code which is used by the European Environment Agency. Details on the sites (e.g. specific species and conservation status) can be found through the web viewer: http://natura2000.eea.europa.eu/#

Table C1: land use and land use change (NCO's) for the SACs (ID2: 1. Broadleaf forest, 2.Heathland & Dunes, 3. Intensive agriculture, 4.Mixed forest, 5. Species rich grasslands, 6.Other, 7. Wetland, 8.Built-up).

Id	site code	Area (ha)	Diff (ha)	Rel. %	LU 1	LU 2	LU 3	LU 4	LU 5	LU 6	LU 7	LU 8
1	BE2100015	2058	215	10%	572 (-17)	383 (134)	120 (-19)	334 (-146)	80 (-33)	22 (0)	538 (81)	9 (0)
2	BE2100016	2290	57	2%	787 (-28)	465 (0)	157 (0)	49 (-18)	161 (-11)	15 (0)	647 (57)	9 (0)
3	BE2100017	5248	669	13%	1888 (342)	100 (116)	877 (-198)	923 (-344)	395 (-114)	186 (-13)	786 (211)	93 (0)
4	BE2100019	697	57	8%	142 (34)	23 (0)	72 (-8)	130 (-26)	46 (-22)	12 (-1)	243 (23)	29 (0)
5	BE2100020	673	89	13%	231 (-3)	25 (9)	148 (-40)	158 (-18)	47 (-28)	9 (0)	43 (80)	12 (0)
6	BE2100024	3618	177	5%	715 (-50)	130 (71)	1119 (-76)	489 (-8)	513 (-43)	103 (0)	516 (106)	33 (0)
7	BE2100026	4870	1095	22%	982 (525)	183 (289)	1208 (-377)	790 (-589)	275 (-103)	245 (-26)	1036 (281)	151 (0)
8	BE2100040	4313	586	14%	401 (58)	72 (83)	1396 (-372)	566 (-203)	474 (140)	383 (-10)	836 (305)	185 (-1)
9	BE2100045	366	7	2%	73 (-1)	0 (0)	9 (4)	20 (-1)	31 (-5)	85 (0)	83 (3)	65 (0)
10	BE2200028	537	66	12%	44 (-12)	54 (55)	112 (-41)	46 (-13)	50 (5)	9 (0)	207 (6)	15 (0)
11	BE2200029	8305	1091	13%	1707 (173)	2695 (566)	1112 (-329)	458 (-238)	971 (-414)	339 (-110)	957 (352)	66 (0)
12	BE2200030	3765	359	10%	1273(-191)	1113 (258)	311 (-68)	205 (-49)	252 (-51)	31 (0)	562 (101)	18 (0)
13	BE2200031	3621	238	7%	658 (-13)	620 (203)	208 (-35)	501 (-111)	320 (-67)	119 (-12)	1133 (35)	62 (0)
14	BE2200032	1987	236,5	12%	498 (48)	87 (66)	647 (-116)	253 (-118)	94 (1)	21 (-2)	369 (122)	18 (0)
15	BE2200033	2515	191	8%	390 (-28)	6 (0)	978 (-105)	118 (-39)	223 (-19)	37 (0)	732 (191)	31 (0)
16	BE2200034	1864	146	8%	398 (67)	7 (3)	705 (-47)	154 (-38)	231 (-61)	9 (0)	343 (76)	17 (0)
17	BE2200035	3725	117	3%	1713 (-12)	880 (88)	83 (-47)	540 (-57)	151 (17)	26 (-1)	283 (12)	49 (0)
18	BE2200036	126	26	21%	26 (-5)	0 (0)	63 (-20)	8 (-1)	19 (9)	3 (0)	6 (17)	1 (0)
19	BE2200037	649	119	18%	10 (-9)	0 (0)	188 (-81)	24 (-19)	124 (-10)	1 (0)	298 (119)	4 (0)
20	BE2200038	2603	392	15%	856 (267)	1 (3)	715 (-181)	369 (-201)	146 (-8)	61 (-2)	432 (122)	23 (0)
21	BE2200039	1595	310	19%	740 (137)	15 (2)	468 (-166)	91 (-40)	141 (-91)	19 (-12)	103 (171)	18 (-1)
22	BE2200041	628	86	14%	71 (-2)	0 (0)	95 (-10)	75 (-35)	66 (-37)	14 (-2)	296 (86)	11 (0)
23	BE2200042	695	69	10%	279 (7)	15 (3)	70 (-19)	93 (-31)	48 (-19)	15 (0)	170 (59)	5 (0)
24	BE2200043	577	110	19%	102 (-4)	95 (17)	19 (-13)	58 (-50)	76 (-41)	10 (-2)	207 (93)	10 (0)
25	BE2300005	3375	567	17%	1421 (77)	50 (44)	693 (-304)	309 (-157)	255 (-94)	49 (-12)	561 (446)	37 (0)
26	BE2300007	5519	1176	21%	1612 (822)	2 (9)	2115 (-613)	224 (-102)	660 (-442)	63 (-19)	687 (345)	156 (0)
27	BE2300044	1796	405	23%	525 (188)	3 (0)	583 (-262)	132 (-93)	99 (-44)	89 (-6)	288 (217)	77 (0)
28	BE2400008	2764	47	2%	2602 (-39)	0 (13)	5 (-2)	21 (-6)	48 (12)	45 (0)	34 (22)	9 (0)
29	BE2400009	1839	164	9%	852 (52)	7 (4)	344 (-41)	132 (-66)	138 (-56)	17 (-1)	313 (108)	36 (0)
30	BE2400010	1436	132	9%	500 (82)	0 (0)	195 (-54)	184 (-75)	61 (0)	51 (-3)	423 (49)	22 (1)
31	BE2400011	4070	138	3%	2653 (28)	20 (13)	328 (-55)	155 (-35)	160 (-44)	113 (-4)	589 (97)	52 (0)

32	BE2400012	2245	190	8%	785 (97)	17 (0)	226 (-37)	297 (-84)	143 (-63)	46 (-6)	697 (93)	34 (0)
33	BE2400014	4904	876	18%	1296 (63)	148 (165)	709 (-216)	791 (-400)	648 (-252)	70 (-8)	1182 (648)	60 (0)
34	BE2500003	1869	408	22%	859 (369)	0 (0)	612 (-267)	30 (-22)	207 (-116)	26 (-3)	89 (39)	46 (0)
35	BE2500004	3052	559	18%	1479 (409)	21 (12)	691 (-259)	315 (-217)	252 (-66)	50 (-17)	207 (138)	37 (0)
	Total	90194	10562	12%	29140 (3432)	7237 (2229)	17381 (-4470)	9042 (-3645)	7605 (-2164)	2393 (-265)	15896 (4919)	1500 (1)

PART D: ES DELIVERY FOR THE CURRENT SITUATION AND CHANGES IN ES DELIVERY (BETWEEN BRACKETS) FOR THE 35 NATURA 2000 SITES DESIGNATED UNDER THE HABITAT DIRECTIVE

For each of the 35 SACs, details can be found on the total site surface (Area.), the actual ES delivery and the change in ES delivery (between brackets).

Table D1: ES delivery for the current situation and changes in ES delivery (between brackets) for the 37 NATURA 2000 sites designated under the Habitat Directive

site code	Area (ha)	Change (ha)	T0 Agric	T0 timber	T0 PM	T0 C-biomass	T0 SOC	T0 Infil	T0 GWRet	T0 WprovQuant	T0 WprovQual	T0 N-removal	T0 Pollin	T0 Recreation
units	ha	ha	1000	m³	ton PM	ton C	ton C	1000 m³	1000 m³	1000 m³	1000 m³	ton N	ha serviced	# 1000 visits
BE2100015	2058	215	208 (-37)	5843 (-1141)	106 (-17)	2177 (-356)	316 (-3)	5520 (231)	2615 (32)	879 (38)	793 (61)	31 (1,2)	0,2 (0,0)	373 (15)
BE2100016	2290	57	8 (0)	1393 (-176)	103 (-6)	548 (-43)	438 (-1)	5546 (60)	3816 (9)	1268 (14)	1141 (39)	49 (4,3)	0,7 (0,0)	711 (-8)
BE2100017	5248	669	1256 (-301)	19395 (-1072)	301 (-14)	7389 (-175)	1232 (21)	8819 (432)	8846 (255)	1996 (101)	1455 (279)	31 (21,5)	2,8 (0,0)	1388 (203)
BE2100019	697	57	106 (-22)	1071 (-75)	24 (-1)	421 (-11)	180 (-2)	1729 (14)	1508 (6)	330 (3)	192 (33)	3 (3,7)	0,9 (0,0)	172 (-2)
BE2100020	673	89	240 (-63)	3387 (-2)	38 (-1)	1335 (29)	128 (12)	1293 (35)	848 (53)	221 (6)	184 (10)	0 (1,2)	3,1 (0,3)	170 (28)
BE2100024	3618	177	2099 (-147)	9485 (-63)	146 (-3)	3588 (-26)	726 (-2)	7966 (29)	4834 (97)	1200 (5)	630 (153)	27 (10,9)	2,2 (0,0)	810 (23)
BE2100026	4870	1095	1824 (-429)	11362 (-899)	216 (-16)	4192 (-36)	1145 (20)	7233 (541)	7981 (633)	1229 (91)	803 (225)	53 (25,3)	4,9 (0,2)	849 (264)
BE2100040	4313	586	1754 (-240)	9016 (1166)	165 (1)	3328 (456)	1064 (66)	5102 (81)	8009 (318)	980 (16)	457 (95)	42 (13,3)	1,5 (0,1)	823 (145)
BE2100045	366	7	9 (0)	108 (0)	10 (0)	41 (0)	87 (2)	795 (1)	484 (6)	53 (0)	20 (5)	3 (0,3)	1,5 (-0,2)	217 (-5)
BE2200028	537	66	89 (-22)	654 (-15)	17 (-2)	247 (-6)	154 (-1)	762 (2)	1272 (35)	13 (0)	8 (3)	6 (-0,2)	0,1 (0,0)	197 (1)
BE2200029	8305	1091	1427 (-218)	16622 (-4499)	361 (-45)	6160 (-1335)	1713 (20)	17856 (515)	11807 (348)	1269 (32)	1081 (128)	24 (11,4)	1,5 (0,0)	1033 (175)
BE2200030	3765	359	244 (-17)	6652 (-483)	168 (-13)	2480 (-151)	688 (-27)	9556 (142)	3125 (94)	921 (32)	776 (118)	15 (4,3)	1,1 (0,1)	528 (4)
BE2200031	3621	238	325 (-68)	9622 (-778)	154 (-12)	3676 (-238)	930 (-26)	7102 (124)	6327 (46)	129 (3)	102 (17)	33 (3,0)	0,1 (0,0)	675 (101)
BE2200032	1987	236,5	978 (-119)	8124 (-912)	91 (-7)	2884 (-243)	447 (18)	2567 (62)	2564 (135)	265 (7)	186 (14)	30 (8,9)	0,3 (0,0)	403 (33)
BE2200033	2515	191	1603 (-121)	4010 (290)	96 (3)	1485 (113)	672 (33)	3139 (1)	4454 (154)	318 (0)	156 (20)	48 (8,8)	1,8 (0,0)	331 (12)
BE2200034	1864	146	1197 (-81)	5509 (56)	72 (3)	2047 (102)	416 (15)	2538 (15)	2953 (114)	469 (3)	255 (23)	16 (6,3)	1,1 (0,1)	316 (1)
BE2200035	3725	117	132 (-21)	18750 (-1854)	229 (-13)	6976 (-535)	505 (-6)	8585 (389)	1908 (7)	2162 (102)	1921 (239)	13 (2,6)	0,1 (0,0)	655 (-1)
BE2200036	126	26	131 (-39)	230 (-27)	3 (0)	103 (-12)	15 (8)	319 (1)	138 (2)	0 (0)	0 (0)	9 (5,0)	0,2 (0,0)	58 (15)
BE2200037	649	119	349 (-149)	554 (272)	17 (3)	210 (106)	140 (44)	1095 (0)	997 (54)	270 (0)	124 (47)	45 (9,2)	4,0 (0,1)	119 (55)
BE2200038	2603	392	1173 (-289)	11860 (622)	110 (7)	4526 (461)	511 (48)	3972 (16)	4094 (238)	89 (1)	52 (7)	26 (12,4)	81,8 (-6,8)	651 (238)
BE2200039	1595	310	699 (-232)	8767 (1292)	73 (6)	3864 (642)	333 (68)	5304 (47)	4202 (70)	0 (0)	0 (0)	8 (4,9)	14,8 (0,6)	187 (11)
BE2200041	628	86	143 (-41)	2171 (42)	24 (-1)	749 (29)	183 (29)	344 (0)	1412 (127)	2 (0)	2 (0)	6 (1,9)	3,7 (0,1)	246 (24)
BE2200042	695	69	109 (-47)	2931 (-210)	34 (-1)	1147 (-43)	143 (19)	813 (24)	889 (46)	43 (3)	29 (9)	21 (14,3)	0,8 (-0,1)	114 (23)
BE2200043	577	110	26 (-21)	1542 (518)	27 (2)	585 (160)	138 (17)	791 (25)	448 (31)	90 (4)	64 (22)	4 (0,3)	0,3 (0,1)	71 (60)
BE2300005	3375	567	991 (-395)	12841 (364)	177 (-1)	5066 (331)	674 (90)	6859 (204)	3452 (343)	360 (10)	267 (50)	21 (19,7)	1,9 (0,3)	1644 (149)
BE2300007	5519	1176	3498 (-1293)	22976 (8804)	221 (42)	9690 (3987)	937 (120)	10288 (21)	6726 (477)	96 (1)	57 (17)	5 (21,1)	9,5 (1,3)	2374 (593)
BE2300044	1796	405	832 (-362)	6645 (1487)	75 (9)	2725 (671)	399 (64)	2262 (2)	3029 (265)	48 (1)	26 (7)	3 (6,0)	1,6 (0,0)	756 (460)
BE2400008	2764	47	3 (0)	24654 (-113)	182 (-3)	11041 (-19)	405 (6)	6003 (19)	3209 (14)	215 (1)	205 (5)	1 (1,5)	1,2 (0,1)	813 (-19)
BE2400009	1839	164	525 (-94)	11813 (400)	95 (0)	4953 (286)	344 (39)	3042 (98)	2308 (131)	26 (2)	22 (3)	14 (4,7)	1,9 (0,1)	787 (157)
BE2400010	1436	132	258 (-51)	8099 (135)	73 (3)	3064 (131)	379 (15)	1249 (1)	3092 (92)	102 (0)	72 (6)	42 (6,7)	3,1 (-0,1)	534 (131)
BE2400011	4070	138	484 (-51)	26152 (186)	230 (1)	11206 (165)	744 (29)	8422 (35)	5637 (59)	813 (4)	707 (25)	135 (46,4)	2,6 (0,1)	1435 (-4)
BE2400012	2245	190	354 (-101)	11848 (302)	113 (4)	4596 (205)	591 (27)	2870 (4)	4573 (155)	190 (0)	149 (12)	48 (9,4)	17,3 (-1,5)	374 (78)
BE2400014	4904	876	1002 (-384)	15876 (-431)	232 (-9)	5892 (18)	1213 (119)	7716 (294)	9422 (644)	1084 (54)	884 (115)	17 (15,2)	3,4 (0,2)	923 (341)
BE2500003	1869	408	981 (-427)	5983 (3118)	83 (16)	2620 (1443)	244 (24)	4931 (23)	1552 (177)	28 (1)	18 (5)	24 (17,9)	2,8 (0,6)	767 (290)
BE2500004	3052	559	1176 (-455)	11538 (0)	160 (3)	4737 (340)	556 (30)	5970 (307)	3535 (180)	150 (0)	109 (23)	1 (11,0)	1,5 (0,1)	1390 (119)
total	90194	10562	27233 (-6337)	317485 (6304)	4230 (-62)	125745 (6445)	18791 (934)	168358 (3794)	132067 (5444)	17307 (535)	12951 (1815)	856 (334,3)	176,0 (-4,4)	22895 (3712)

T0 Agric: Agricultural production net revenue (in units of € 1000 per annum); T0 Timber: Wood production for use in building and carpentry (in cubic meters per annum); T0 PM: capture of airborne fine particulate matter (PM10) by vegetation (in ton particulate matter per annum); T0 C-biomass: Biomass organic carbon stock (in ton carbon); T0 SOC: Soil organic carbon stock (in ton carbon); T0 Infil: Average annual infiltration (in units of 1000 m³ per annum); T0 GWRET: Groundwater stock in shallow groundwater above the maximum drainage depth (in units of 1000 m³ per annum); T0 WprovQuant: Volume of locally abstracted water which is annually recharged by the site through infiltration (in units of 1000 m³ per annnum); T0 WprovQual: Volume of locally abstracted water which is annually recharged by the site through infiltration in zones with conservation management (in units of 1000 m³ per annum); T0 N-removal: avoided pollution of surface and groundwater through decreased nitrate leaching and denitrification (in Ton $N\text{-}NO_3$ per annum); T0 Pollin: Area of pollination dependent crops which are pollinated by wild pollinators (in hectare per annum); T0 recreation: number of visitors attracted to the site for recreation (in units of 1000 visitors per annum).

PART E: MONETARY VALUATION RESULTS FOR 38 SPECIAL AREAS OF CONSERVATION (HABITAT DIRECTIVE) – FOR THE CURRENT SITUATION.

Site CODE	Agric	Agric	Timber	Timber	AirQ	AirQ	BOC	BOC	SOC	SOC	WatProv	WatProv	WatQual	WatQual	Recr.	Recr.	Prop. Val.	Prop. Val.	Health Eff.	Health Eff.	SUM (k€)	SUM(k€)	area	ValuePerHa	ValuePerHa
	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	Ha	low	high
BE2100020	240	240	36	36	1360	2736	294	294	612	612	17	44	1	18	383	1913	24	48	330	989	3296	6931	673	4897	10299
BE2100024	2099	2099	126	126	5242	10521	789	789	3204	3204	90	240	137	2027	1822	9110	111	223	2640	7920	16260	36258	3618	4494	10022
BE2100015	208	208	73	73	3816	7680	479	479	1586	1586	66	176	154	2276	839	4197	65	131	1365	4094	8651	20900	2058	4204	10156
BE2100016	8	8	23	23	3693	7429	121	121	1679	1679	95	254	246	3647	1601	8004	52	105	1748	5243	9265	26513	2290	4046	11578
BE2500001	445	445	0	0	3637	7303	0	0	3371	3371	8	20	16	238	3857	19287	1332	2685	10237	30712	22904	64061	3786	6050	16921
BE2300006	2026	2026	122	122	5678	11398	775	775	14232	14232	34	91	81	1203	6832	34161	1136	2290	22485	67454	53402	133754	8978	5948	14898
BE2500002	1415	1415	0	0	1552	3100	3	3	2229	2229	1	4	437	6460	1435	7177	121	244	3876	11627	11070	32260	1843	6006	17504
BE2100045	9	9	1	1	357	717	9	9	370	370	4	11	15	224	487	2436	299	602	2698	8094	4251	12474	366	11614	34082
BE2100019	106	106	13	13	871	1753	93	93	922	922	25	66	16	239	388	1938	72	145	645	1936	3151	7212	697	4521	10348
BE2100026	1824	1824	134	134	7757	15586	922	922	5444	5444	92	246	263	3891	1910	9551	290	584	4258	12773	22894	50955	4884	4687	10433
BE2200032	978	978	113	113	3271	6569	634	634	2024	2024	20	53	151	2229	907	4537	54	109	2692	8075	10843	25320	1987	5457	12743
BE2100017	1256	1256	243	243	10819	21739	1626	1626	6001	6001	150	399	155	2288	3123	15613	162	327	5053	15160	28587	64652	5248	5447	12319
BE2300005	991	991	184	184	6364	12776	1115	1115	3394	3394	27	72	105	1553	3700	18498	140	281	2383	7149	18402	46013	3375	5453	13633
BE2500004	1176	1176	163	163	5765	11567	1042	1042	2763	2763	11	30	7	97	3128	15641	197	398	2968	8903	17220	41781	3052	5642	13690
BE2200033	1603	1603	65	65	3453	6906	327	327	3449	3449	24	64	238	3518	744	3721	104	210	3720	11160	13727	31023	2515	5458	12335
BE2100040	1754	1754	116	116	5933	11896	732	732	5101	5101	73	196	212	3143	1853	9263	291	586	4609	13827	20675	46613	4313	4794	10808
BE2200029	1427	1427	241	241	12973	26053	1355	1355	6147	6147	95	254	121	1797	2325	11624	304	612	7767	23301	32755	72811	8305	3944	8767
BE2200037	349	349	8	8	629	1257	46	46	730	730	20	54	224	3322	268	1338	44	89	992	2975	3311	10169	649	5102	15669
BE2200034	1197	1197	82	82	2596	5202	450	450	2052	2052	35	94	81	1203	710	3552	99	199	1814	5441	9117	19473	1864	4891	10447
BE2200043	26	26	24	24	973	1955	129	129	693	693	7	18	19	287	160	801	85	171	1093	3280	3209	7383	577	5561	12796
BE2200030	244	244	103	103	6044	12153	546	546	1999	1999	69	184	77	1144	1189	5943	84	168	1985	5956	12339	28441	3765	3277	7554
BE2400014	1002	1002	221	221	8321	16727	1296	1296	6249	6249	81	217	87	1280	2076	10378	359	724	9133	27399	28825	65494	4904	5878	13355
BE2200035	132	132	257	257	8210	16534	1535	1535	2603	2603	162	432	65	961	1475	7374	94	189	1583	4749	16115	34766	3725	4326	9333
BE2200031	325	325	117	117	5516	11088	809	809	4545	4545	10	26	164	2432	1520	7598	244	493	5347	16040	18597	43473	3621	5136	12006
BE2300044	832	832	81	81	2692	5388	599	599	2149	2149	4	10	16	243	1701	8504	286	576	3665	10994	12025	29376	1796	6695	16357
BE2200028	89	89	9	9	618	1241	54	54	730	730	1	3	30	446	444	2219	91	183	1345	4035	3411	9009	537	6351	16777
BE2400010	258	258	98	98	2620	5256	674	674	2086	2086	8	20	210	3112	1201	6004	364	733	2612	7837	10131	26078	1436	7055	18160
BE2400012	354	354	171	171	4055	8127	1011	1011	3225	3225	14	38	241	3562	841	4204	357	720	2972	8916	13241	30328	2245	5898	13509
BE2300007	3498	3498	343	343	7974	15943	2132	2132	5315	5315	7	19	23	344	5341	26706	769	1549	8516	25548	33918	81398	5519	6146	14749
BE2200042	109	109	45	45	1236	2485	252	252	720	720	3	9	106	1571	256	1282	43	87	961	2882	3732	9442	695	5369	13585
BE2200041	143	143	32	32	855	1717	165	165	997	997	0	0	31	456	555	2773	74	148	1414	4241	4264	10672	628	6789	16993
BE2200038	1173	1173	139	139	3941	7894	996	996	2868	2868	7	18	128	1897	1466	7328	205	414	2420	7259	13341	29984	2603	5125	11519
BE2500003	981	981	97	97	2985	5972	576	576	1429	1429	2	6	118	1747	1726	8630	122	246	920	2759	8957	22444	1869	4792	12008
BE2400011	484	484	434	434	8286	16602	2465	2465	4156	4156	61	163	675	9996	3228	16139	373	751	5929	17788	26092	68979	4070	6411	16948
BE2400009	525	525	174	174	3417	6850	1090	1090	1828	1828	2	5	71	1054	1770	8851	297	598	2868	8604	12043	29580	1839	6549	16085
BE2200036	131	131	3	3	108	214	23	23	79	79	0	0	45	659	130	651	84	169	253	759	855	2687	126	6784	21328
BE2400008	3	3	469	469	6547	13104	2429	2429	2314	2314	16	43	6	89	1828	9142	131	264	3835	11504	17577	39360	2764	6359	14240
BE2200039	699	699	145	145	2619	5248	850	850	796	796	0	0	40	586	420	2100	55	110	345	1035	5967	11568	1595	3741	7253

PART F: EXCEL DATA FILE THAT SUMMARIZES INFORMATION AT THE LEVEL OF INDIVIDUAL SITES (ACTUAL AND AFTER REALIZATION OF THE NCO'S)

Bossen en heiden van zandig Vlaanderen: oostelijk deel mplete list of NATURA 2000 sites, including site code

Land-use totals details on land-use classification

Land-use category (general)	Actual (2010)		After realisation NCO's		Difference	
	ha	%	ha	%	ha	% increase
Built-up	73	2,2%	73	2,2%	0	0,0%
Cropland an d production grassland	699	20,7%	395	11,7%	-304	-43,5%
Heathalnd and inland dunes	67	2,0%	129	3,8%	62	92,5%
Forests and shrubs	2.077	61,5%	2.296	68,0%	219	10,5%
Flower and species rich grasslands and thicket	285	8,4%	387	11,5%	102	35,8%
Rivers and standing waters	58	1,7%	59	1,7%	1	1,7%
Wetlands	56	1,7%	26	0,8%	-30	-53,6%
Coastal and estuarine	0	0,0%	0	0,0%	0	0,0%
Other	60	1,8%	10	0,3%	-50	-83,3%
Total	3.375	100,0%	3.375	100,0%	0	0,0%
Total "Nature"	2.603	77,1%	2.907	86,1%	304	11,7%

Habitat types

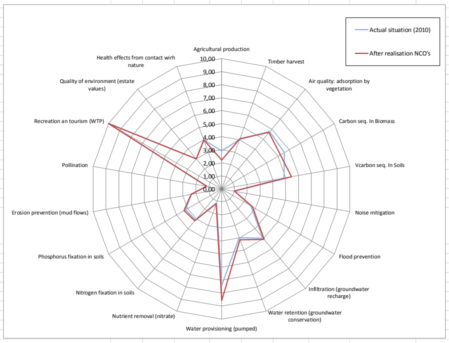
Land-use category	Actual (2010)		After realisation NCO's		Difference	
	ha	%	ha	%	ha	% increase
Heathland and inland dunes	57	4,3%	129	5,0%	72	126,3%
Forests	1.146	87,3%	2.085	81,6%	939	81,9%
Species rich grasslands	85	6,5%	313	12,2%	228	268,2%
Rivers and standing waters	21	1,6%	26	1,0%	5	23,8%
Wetlands	3	0,2%	3	0,1%	0	0,0%
Estuarine and coastal habitat	0	0,0%	0	0,0%	0	#DIV/0!
Total	1.312	100,0%	2.556	100,0%	1.244	94,8%

Forest types

Forest Types	Actual (2010)		After realisation NCO's		Difference	
	ha	%	ha	%	ha	% increase
Coniferous	505	22,5%	148	6,6%	-357	-28,7%
Decidious	1.492	66,5%	2.226	99,2%	734	59,0%
Mixed	247	11,0%	99	4,4%	-147	-11,9%
Totals	2.244	100,0%	2.473	110,2%	229	18,4%

Benefits realisation NCO's 104.737 3103,3%

	Quantification per year			Valuation (k€/yr)		Score	%change	%change
Ecosystem services	Low	High	Units (per year)	Low	High	(score 1 - 10)	benefit	score
Agricultural production		-395	k€ added value of production		-395	-0,71	-40%	-24%
Timber harvest		154	m³ harvested timber		16	0,06	9%	2%
Air quality: adsorption by vegetation	-0,27	-1,14	tonnes adsorbed fine particulate matter	-15	-61	-0,07	0%	-1%
Carbon seq. In Biomass		331	tonnes C stock biomass		73	-0,34	7%	-6%
Carbon seq. In Soils		126.850	tonnes C stock soil		698	0,58	21%	12%
Noise mitigation			number of houses with mitigation	0	0	0,00	#DIV/0!	0%
Flood prevention	Qualitative					0,20		
Infiltration (groundwater recharge)		204	1000 m³ infiltrated water	supporting		0,11		
Water retention (groundwater conservation)		343	1000 m³ retained water	supporting		0,18		
Water provisioning (pumped)		50	1000 m³ abstracted	4	10	1,15	19%	16%
Nutrient removal (nitrate)		19.651	kg Nitrate removal	98	1.454	0,06	94%	6%
Nitrogen fixation in soils		7.024	tonnes N stock soil	supporting		0,10		
Phosphorus fixation in soils		468	tonnes P stock soil	supporting		0,12		
Erosion prevention (mud flows)	Qualitative					0,00		
Pollination		0	Hectares pollination dependent agriculture within buffer of 1 km surrounding sites, serviced by wild pollinators	not valued		0,03		
Recreation an tourism (WTP)	111,84	186,40	1000 visitors per year	336	1.678	0,00	9%	0%
Quality of environment (estate values)			1000 houses within 100m	0	0	0,00	0%	0%
Health effects from contact wirh nature			1000 inhabitants within 1 km		0	0,00	0%	0%
Totals				***814***	***3.471***		4%	8%
Relative change to total benefits				***4%***	***8%***	2.701		



Actual situation (2010)

	Quantification per year			Valuation (k€/yr)		Score	%change	%change	
Ecosystem services	Low	High	Units (per year)	Low	High	(score 1 - 10)	benefit	score	
Agricultural production		991	k€ added value of production		991	2,90	1.417	1.417	only cropland and production grasslands
Timber harvest		5.438	m³ harvested timber		184	4,03	89	89	only forests
Air quality: adsorption by vegetation	118	237	tonnes adsorbed fine particulate matter	6.364	12.776	5,74	1.886	3.785	total area
Carbon seq. In Biomass		5.066	tonnes C stock biomass		1.115	5,55	537	537	only forests
Vcarbon seq. In Soils		617.100	tonnes C stock soil		3.394	4,86	1.006	1.006	total area
Noise mitigation		0	number of houses with mitigation	0	0	1,00	0	0	total area
Flood prevention	Qualitative					2,57			
Infiltration (groundwater recharge)		6.859	1000 m³ infiltrated water	supporting		4,95			
Water retention (groundwater conservation)		3.452	1000 m³ retained water	supporting		3,99			
Water provisioning (pumped)		267	1000 m³ abstracted	20	53	7,41	6	16	total area
Nutrient removal (nitrate)		20.984	kg Nitrate removal	105	1.553	1,16	31	460	total area
Nitrogen fixation in soils		33.106	tonnes N stock soil	supporting		3,10			
Phosphorus fixation in soils		2.207	tonnes P stock soil	supporting		3,20			
Erosion prevention (mud flows)	Qualitative					2,35			
Pollination		2	Hectares pollination dependent agriculture within buffer of 1 km surrounding sites, serviced by wild pollinators	not valued		1,13			
Recreation an tourism (WTP)	1.233	2.055	1000 visitors per year	3.700	18.498	10,00	1.096	5.481	total area
Quality of environment (estate values)		0,73	1000 houses within 100m	140	281	3,00	41	83	total area
Health effects from contact wirh nature		35	1000 inhabitants within 1 km		2.383	4,00	706	0	total area
Totaal				***18.395***	***41.229***	***70,93***	5.450	12.216	
Totaal in € per ha				***5.450***	***12.216***				

After realisation NCO's

	Quantification per year			Valuation (k€/yr)		Score	%change	%change	
Ecosystem services	Low	High	Units (per year)	Low	High	(score 1 - 10)	benefit	score	
Agricultural production		595	k€ added value of production		595	2,20	1.507	1.507	only cropland and production grasslands
Timber harvest		5.592	m³ harvested timber		200	4,09	87	87	only forests
Air quality: adsorption by vegetation	118	235	tonnes adsorbed fine particulate matter	6.350	12.715	5,67	1.881	3.767	total area
Carbon seq. In Biomass		5.397	tonnes C stock biomass		1.187	5,22	517	517	only forests
Vcarbon seq. In Soils		743.950	tonnes C stock soil		4.092	5,44	1.212	0	total area
Noise mitigation		0	number of houses with mitigation	0	0	1,00	0	0	total area
Flood prevention	Qualitative					2,77			
Infiltration (groundwater recharge)		7.063	1000 m³ infiltrated water	supporting		5,06			
Water retention (groundwater conservation)		3.795	1000 m³ retained water	supporting		4,17			
Water provisioning (pumped)		317	1000 m³ abstracted	24	63	8,57	7	19	total area
Nutrient removal (nitrate)		40.636	kg Nitrate removal	203	3.007	1,22	60	891	total area
Nitrogen fixation in soils		40.130	tonnes N stock soil	supporting		3,20			
Phosphorus fixation in soils		2.675	tonnes P stock soil	supporting		3,31			
Erosion prevention (mud flows)	Qualitative					2,35	0	0	
Pollination		2	Hectares pollination dependent agriculture within buffer of 1 km surrounding sites, serviced by wild pollinators	not valued		1,16			
Recreation an tourism (WTP)	1.345	2.242	1000 visitors per year	4.035	20.176	10,00	1.196	5.978	total area
Quality of environment (estate values)		0,73	1000 houses within 100m	140	281	3,00	41	83	total area
Health effects from contact wirh nature		35	1000 inhabitants within 1 km		2.383	4,00	706	0	total area
Totaal				***19.209***	***44.700***		5.692	13.244	