CHAPTER 2.8 The ecosystem services valuation tool and its future developments

Authors: Liekens Inge[1], Broekx Steven[1], Smeets Nele[1], Staes Jan[2], Van der Biest Katrien[2], Schaafsma Marije[3], De Nocker Leo [1], Meire Patrick[2], Cerulus Tanya[4].

[1] VITO, Boeretang 200, B-2400 Mol, Belgium

[2] University of Antwerp, Department of Biology, Ecosystem management research group, Universiteitsplein 1-c, B-2610 Wilrijk, Belgium

[3] University of East Anglia, Centre for Social and Economic Research on the Global Environment, Norwich NR4 7TJ, Norfolk, England, United King

[4] Flemish environment administration: LNE, Koning Albert II-laan 20 box 8, 1000 Brussels, Belgium

Abstract
Though methodologies for classification, quantification and valuation of ecosystem services are improving drastically, applications of the ecosystem services concept in day-to-day decision-making processes remain limited, especially at the planning level. Nevertheless, spatial planning decisions would benefit from systematic considerations of their effects on ecosystem services. Assessing the impacts of policy on a wide range of ecosystem services contributes to more cost-effective policy implementation, establishing win-win situations across different environmental domains. The "nature value explorer" (natuurwaardeverkenner in Dutch) is a web application developed to explore the quantity and value of ecosystem services in Flanders Belgium as part of environmental impact assessments. The tool estimates the impact of land use and land cover change on regulating and cultural ecosystem services. The web application is successful in drawing the interest of policy makers and is used in several cases to support decisions in infrastructural projects as well as nature restoration projects.

Key-words
Ecosystem services; monetary valuation; cost–benefit analysis; web application; scenario analysis

1. Introduction
Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems, collectively referred to as ecosystem services and goods (1). Degradation of the world's ecosystems during the past fifty years due to urban expansion, agricultural intensification and industrialization has led to a serious decline in ecosystem service delivery (2). The key challenge of policy making today is to prevent or reduce this incessant degradation of ecosystems and their services while meeting the increasing demands of society.

Flanders is an example of a region facing ecosystem degradation and the loss of ecosystem services and replacement of these services by costly technical measures and infrastructure in aspects as flood prevention, drought management, climate change policy and health care (3). The Flemish Region is encountering enormous challenges to improve the environmental quality in order to comply with EU environmental standards and conserve the natural capital to guarantee health and quality of life of its inhabitants. Current measures and actions are not adequate to reach these standards and already generate very high costs for environmental management. The efforts that are needed to maintain environmental quality and maintain the different functions are pushing the limits of acceptable cost-efficiency and societal support.

Since the Millennium Ecosystem Assessment (2) the services natural ecosystems deliver are being more and more recognized (e.g. 4,5). This is supported by a rapidly growing amount of literature and models on ecosystem service classification, quantification and valuation.
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Though methodologies for classification, quantification and valuation are improving, applications of the ecosystem services concept stay mainly restricted to illustrating the importance of preserving or restoring ecosystems in regional to global ecosystem service mapping or ecosystem services accounting. Important examples of large scale ecosystem service assessments include the National Ecosystem Assessment in the UK (6), the Natural Capital/INVEST project (7), and the "Valuing the Arc" initiative (8). Its use in day-to-day decision-making processes remains limited however, especially at the planning level (9).

Both limited interest among geographers and excessive complexity of currently available models are depicted in the literature as major reasons for this lack (4,5,10). Frequent occurring mismatches between the spatial scale of research and the spatial scale of applications can be another reason for limited applicability of current research in spatial planning (11). Nevertheless, spatial planning decisions would benefit from systematic considerations of their effects on ecosystem services (12). Estimating the impacts of policy on a wide range of ecosystem services can also serve as an element in the development of more cost-effective policy implementation, establishing win-win situations across different environmental domains as water, air and climate change. To date, most tools for environmental impact assessment (e.g. Cost Benefit Analysis, Strategic Environmental Assessment, Life Cycle Analysis) do not include impacts on ecosystems (alterations in vegetation and biodiversity). In this chapter, we present the "nature value explorer" (natuurwaardeverkenner in Dutch), a web application specifically built to explore the quantity and value of ecosystem services in day-to-day decision making in Flanders Belgium, as part of a e.g. a cost-benefit analysis (CBA). The Nature Value Explorer combines spatially sensitive and site-specific inputs with generic quantification and valuation functions, allowing effective and straightforward identification of service providing areas to support spatial planning in Flanders. The application is developed to estimate the impact of land use and land cover change on ecosystem services. It does not address degradation of habitat quality.

As the end-user perspective is a crucial first step in the design of practical tools, we start from an inventory of user requirements for quantification and valuation of ecosystem services in Flemish policy making in Section 2. These requirements are used to define the design characteristics of the web application, described in section 3. Section 3 also describes the applied methodology for quantification and valuation. The use and an example are found in section 4. The conclusion in section 5.

2. User requirements

User requirements and potential policy applications were derived from 26 individual end-user consultations. The involved end-users are a mix of organizations involved in policy preparation, policy execution, policy evaluation and civil society organizations. The list covers all actors with a prominent role in the management of the open space in Flanders (recreation, agriculture, nature, water management).

An important conclusion that can be drawn from all consultations is that the general interest from potential end-users in Flanders in the ecosystem services concept is very large. Not only typical nature conservation administrations or civil society organizations express an interest but also end-users focussed towards spatial planning, agriculture, land and water management consider a more in-depth knowledge of ecosystem services as added value for policy making.

The expected advantages to apply ecosystem service based approaches confirm typical advantages listed in (13). Demonstrating the importance of nature and biodiversity and arguing for the protection of existing nature or for additional nature development was often mentioned. A clear common need exists in an operational decision support tool/instrument both for balancing different land use types, development of specific nature areas as for global cost-efficiency of measures over different policy domains. For use in cost-benefit analysis (CBA) and other decision support tools, different end-users were eager to have easy to calculate indicator data or supply and demand maps as for quantifying as well as for monetizing ecosystem services taking into account spatial aspects.

Important requirements listed specifically for the tool were user-friendliness, transparency, flexibility and scientific reliability. User-friendliness is especially important for non-specialist users. The tool needs to be made clear what a specific service exactly means, how this service can be quantified and valued and where required input data can be found. Unfortunately, these properties do not match easily and trade-offs between accuracy and applicability are unavoidable.

3. Methodology

An ecosystem goods and services approach was followed to develop the tool. First a list was made identifying the important ecosystems in Flanders. Second the international classification of ecosystem services (CICES) was used to list all possible ecosystem service (4). Then quantification and value functions were developed based on different methods and studies for use within value transfer exercises. For the provisioning services crop production and wood production were considered. For cultural services we consider the recreation, amenity and non-use value. Regulating services include nutrient retention and climate regulation (sequestration in soils and biomass), air quality regulation and noise mitigation.

Table 1 gives an overview of the ecosystem goods and services included in the tool.

TABLE 19-1 Quantified and Valued Ecosystem Services in the Tool

Service		Quantification Method / Important Variables	Valuation Method
Cultural services	Recreation, amenity, and nonuse value	Choice experiment with attributes such as size, accessibility, nature type, surrounding environment	
Provisioning services	Crop production	Standard gross margin	
	Wood production	Potentially produced volume and harvest factor	
Regulating services	Water quality regulation: Denitrification	Seitzinger: residence time Pinay: soil moisture and texture	Avoided cost method for N
	Climate change: C sequestration in soils	Meersman: soil drainage, vegetation type and soil texture	Avoided cost method for C
	Water quality regulation: N, P sequestration in soils	C/N/P ratios	Avoided cost method for N and P
	Climate change: C-sequestration in forest biomass	Wood increment and species-specific carbon sensity	Avoided cost method C
	Air quality: removal of PM_{10}	Removal factors in Oosterbaan et al. 2006	Avoided damage costs
	Noise mitigation	Huisman 1990: noise level, width forest	Hedonic pricing

The web application does not allow for detailed spatially explicit ecosystem service quantification and grid based computations. Instead, a flexible system of service providing units (SPU) for which end-users can define specific properties (e.g. soil characteristics, vegetation type) and thus the potential to vary the spatial detail was advocated. If budgets are more extensive and the availability of data is not an issue, users can decide to define for each scenario a large amount of SPUs on a relatively small scale (up to 1 ha).

The tool can be consulted on the internet via http://www.natuurwaardeverkenner.be. End-users are able to create and save scenarios, share scenarios with other registered users and consult public scenarios. Interactive discussions are stimulated through a discussion forum. User-friendliness is increased by adding information boxes explaining each service and its required input data, a section with frequently asked questions and an information page containing background documents and publications related to the nature value explorer.

2.1. Cultural services

Cultural services include use values related to recreation, amenity and education and non-use values related to bequest values and existance values. For all of these individual services, specific quantification methods and valuation techniques can be used or stated preference techniques that are able to capture all cultural services in single willingness to pay estimates. A stated preference study (choice experiment) surveying peoples willingness to pay for nature restoration, was performed to capture all cultural services in a single value function. This experiment was described in detail in (14). The idea behind the development was that the value of a nature area is not captured by one characteristic but depends on a number of characteristics of the area studied, on the characteristics of the beneficiaries, i.e. the people that attach a value to this area and on spatial characteristics such as size and distance (15). In a choice experiment, respondents are presented with a number of alternatives from which they are asked to choose. The alternatives can be a good or service, characterized in terms of different ‘attributes’, but also policy alternatives or land use change scenarios (16). Each alternative is defined in terms of the same attributes, including a price, but with different values (attribute levels). Examples include varying levels in biodiversity (high-low), accessibility (accessible or not) and size of the area (between 1 and 200 ha).

Usually respondents are shown two or three alternatives on a choice card and an option which allows them to choose none of the two, also referred to as the ‘opt-out’. In the case of land use changes, this ‘opt-out’ can also represent the current situation or no land use change. As respondents express their preferences by making choices between different alternatives, they trade off the different attributes and levels. A statistical function can then be estimated that links choice probabilities to the characteristics of the alternatives. The trade off between price and other attributes is especially relevant, as this reflects how much a respondent is willing to pay (WTP) for a particular change in this attribute. This allows to determine marginal values for changes in the attributes and combinations of attributes.

In the choice experiment for the nature value explorer, respondents are asked to choose between different land use changes related to the creation of different types of nature area with different spatial and non-spatial characteristics and impacts on their current tax levels. Agricultural land use, with no particular nature or landscape value is the reference situation in the rural areas where these land use changes can take place.

Based on the information obtained in focus groups with lay-people and expert interviews, seven attributes were included in the CE: nature type including marshes, natural grasslands, forests, open water and swamps, heath land, inland dunes, and pioneer vegetation; species richness; spatial attributes including size of the area, accessibility, surrounding land use and distance to the respondents’ residence. Finally, the monetary attribute is a mandatory annual tax to be paid by all Flemish households to a fund exclusively used for the creation and conservation of nature areas in Flanders. The data were obtained from an internet survey conducted through a marketing bureau panel from which respondents were randomly chosen in three different provinces of Flanders. 3000 residents filled out the survey. After removing incompletes (no choice section) and protest bidders (6%), approx. 2300 respondents (approx. 10000 observations) where included in the analysis. The analysis of the socio-demographic information of the respondents suggests that the sample is mostly representative for the Flemish population (see (13)).

The resulting value function is used to value a nature area, according to some selected biophysical characteristics (nature type, size, surrounding land use, access and species richness) as well as household related characteristics (income, mean age, member of nature organizations, distance to the created nature area). This function for additional nature development in Flanders expressed in annual € per household can be written as:

WTP= 122 * pioneer vegetation + 93 * mudflat and marsh + 92 * natural grass land + 157 * forest + 133 * open water, reed and swamp + 133 * heath land and inland dunes + 0,05 * size in ha + 28 * species + 34 * availability of walking trails – 0,63 * distance in km + 8 * natural surroundings + 8 * residential surroundings – 15 * industrial surroundings – 0,36 * high number of species * age + 0,01 * monthly net income - 37 * % women+ 108 *% membership.

The respondents are willing to pay more for easily accessible nature but it is not dominant over the other attributes, so people also attach a high value to non-accessible nature . The nature type is important. Forests are valued highest ,followed by open water, swamps and heath land. Pioneer vegetation, marshes and grass lands are valued lowest.

As distance to the respondent's residence was an attribute in the survey, we automatically generate a distance decay function (15), which adjusts individual WTP downwards as respondents live further away from the proposed land use change. The number of households with positive WTP can thus be based on our empirical findings, rather than by making arbitrary assumptions about the relevant spatial size of the economic market. By combining the value function with GIS-data on number of households per spatial unit in the surroundings (up to 50 km), socio-demographic data and distances to the created area, the total amenity and non-use value of the land use change can be calculated.

As the choice experiment asked for the utility for one area with specific characteristiscs between 10 ha and 200 ha and substitution effects are not yet included in the function, we followed a pragmatic approach in downsizing the parameters of the value function on the basis of the size parameter so the function can also be used for upscaling to a more regional level or if multiple areas will be created.

2.2. provisioning services

The production of crops such as grains, vegetables and fruits which are the cultivated plants or agricultural products harvested by people for human or animal consumption as food. Agricultural services may under some schemes not be considered as ecosystem services but are referred to as environmental services. In this assessment, they are considered as ecosystem services. The main argument is that including provisioning services derived from agriculture or agro-ecosystems is essential in a tradeoff analysis. Furthermore, agricultural systems comply in a strict sense with the definition of an ecosystem (17).

For the valuation of this ecosystem service we use a pricing approach and try to estimate the market prices for animals and crops. The estimated value of the biodiversity resource based on market price is equal to the quantity of sold resource x (market price – costs related to production). We take the standard gross margin as indicator. The meat and dairy standard gross margins are linked to fodder production and so linked to the land use.

Wood can be used for different purposes going from construction material, packaging, raw material and energy. We use the study of (18) to estimate the potentially produced volume and multiply this with a harvest factor to know the actually produced volume. The produced volumes are generated only for the eight main commercial species (Beech, Oak, Poplar, European Larch, Scots Pine, Corsican Pine, Spruce, Douglas fir, deciduous and coniferous) per soil type. The soil type is based on the Belgian classification system (texture, drainage and profile, http://geo-vlaanderen.gisvlaanderen.be/geo-vlaanderen/bodemkaart/. Market prices per lot are used to estimate the value per m³.

2.3. Regulating services

2.3.1 Quantification

Valuing the change in quantities of different regulating services is a complex, but crucial element in the valuation of impacts on ecosystems (or the creation of new ecosystems). We often lack tools and models to assess the changes in physical, biochemical and ecological processes on the delivery of ecosystem services. The nature value explorer offers less detail then some specific models that focus in detail on a single service or area, but offers a more detailed and accurate assessment than fixed €/ha values per vegetation type. The latter are not preferred as for specific services, the vegetation type is not the major factor influencing the magnitude of the service and is insufficient to capture the spatial variation in the delivery of ecosystem services. At the same time, extensive, process based model calculations were considered too complicated and too computationally intensive to include in a web application to explore the impact on ecosystem services. Instead, quantification functions were developed that on the one hand take into account the main driving factors of the underlying ecological processes such as soil texture, groundwater level and vegetation type and on the other hand require little computation time. The quantification functions build on regional datasets (existing land-use/land-cover and soil map classifications) and studies to increase the accuracy and transparency.

The quantification of denitrification processes in wetland ecosystems is based on (19). Removal efficiency depends mainly on the residence time of the water in the ecosystems. For terrestrial ecosystems we used (20) to deduct potential denitrification. Removal efficiency depends on soil moisture and soil texture.

Carbon sequestration in soils is based on estimates from (21). They performed a multiple regression approach to assess the spatial distribution of Soil Organic Carbon (SOC) and its dependency on soil characteristics in Flanders, Belgium. We determine a potential maximal carbon content for a given soil drainage, vegetation type and soil texture. Changes in soil drainage and/or vegetation will change the potential maximal carbon content. The annual carbon sequestration potential is a percentage of the difference in potential carbon content and actual carbon content. This approach is process based and incorporates changes in potential storage and the associated temporal dynamics. Literature estimates of net ecosystem exchange range very broad, as they capture a moment and do not incorporate long-term dynamics and driving variables such as soil properties, climate, and soil hydrology. The N and P content of soils are indirectly derived from the carbon content. Based on analyses performed in Flanders, the C/N ratio varies between 10 and 30 depending on the nature type. Based on (22), we set the average N/P ratio at 15.

Carbon sequestration in forest biomass is linked to the method for wood production. The increment in biomass per ha per year is turned in the annual carbon sequestration per ha per year using the species-specific carbon density (23).

It is well documented that trees and vegetation can serve as effective sinks for air pollutants and PM10 (particulate matter < 10µg) and thus contribute to air quality improvement and related public health benefits (24,25). As PM10 is the most important pollutant, accounting for 60% of health impacts from environmental pollution (26), the focus of this analysis is on PM10. As there are no data available for Flanders, the estimates in the web application are based on removal factors for individual trees and shrubs from (27) and (28). The removal factors (expressed in kg/ha) are in the same range (+/- 50 %) of these used by (24) or (25) for grasslands. Trees and vegetation have also impact on other air pollutants, but there is more uncertainty about the removal factors and on the valuation of sinks.

Nature areas can contribute to the mitigation of noise from for example traffic. The effect of the soil and especially the vegetation is often underestimated in models for noise-simulation (29, 30). The service is only important when there are people affected. Noise mitigation for soft soils and forests is derived from (29) and (31). Huisman measured the decrease in decibel (dB(A)) based on the frequency of the source, the soil characteristics, the meteorological effects and the noise penetration in the forest. He found an average decrease of 6-16 dB(A)for 100 to 300 m wide forests.

2.3.2 Monetary valuation

We use a combination of avoided abatement costs (for nutrients and carbon sequestration), damage costs (for air pollution), hedonic pricing (for noise mitigation). The avoided abatement cost method is used to value nutrient removal, because due to the natural denitrification that an ecosystem delivers, costly abatement measures to obtain environmental goals can be avoided. The value of an additional kg nitrogen removed by an ecosystem can be derived from the marginal cost curve of nitrogen removal. This cost curve was calculated in preparation of the Flemish river basin management plan to reach a good water status according to the European Water Framework Directive (32, 33). The costs of the measure with the highest marginal cost included in the programme of measures to reach water quality objectives are 74€/kg N and 800€/kg P. Most measures have impact on both N and P, and it is therefore impossible to individually link avoided costs to separate pollutants. To avoid double counting, we estimate the value of nutrient retention for both pollutants but only apply the maximum value. The valuation of nutrients applied here is significantly higher than figures in literature, which vary between 2 and 20 €/kg for N. (34, 35) and 70 €/kg for P (36). This reflects on the one hand that nutrients are a large problem in Flanders and on the other hand that already a lot of relatively cheap measures (e.g. advanced treatment in waste water treatment plants) are taken and less cost effective measures are necessary to reach environmental objectives.

The benefits of carbon sequestration are not directly related to the place of sequestration, but rather experienced at a global level, through the impact on climate change. To assess the value of carbon sequestration by ecosystems, theoretically two approaches can be followed: 1) marginal damage costs; 2) avoided abatement costs. As impacts are global, the selected data are based on studies at the global level. The range of results of these studies is very broad, ranging from an external costs close to zero to 160 $1995 /tonne CO_2 (37, 38, 39). It is difficult to pick a meaningful average for these studies as it varies a lot in function of statistical models, inclusion of grey literature and older studies,… Against this background, we have chosen a central value of 50 €/tonne $C0_2$-eq., which is higher than recommended values for emissions in 2010 and close to recommended values for 2020. This value corresponds to 183 €/tonne of C. As this central estimate does however not reflect the value of CO_2 sequestration in the long run, it is recommended to use a higher value of 200 €/ton $C0_2$-eq (737 €/tonne C) for sensitivity analysis, especially for projects where C-sequestration in the longer run may be an important part of total benefits.

Air quality improvement for PM_{10} has important benefits for public health, especially related to cardiovascular and respiratory impacts (41). These impacts are typically valued using indicators related to avoided costs for health care and medicine, loss of productivity at the workplace and at home and willingness to pay to avoid suffering and loss of life expectancy. The data are based on results from air quality models for Flanders, dose-response functions and valuation data from European research projects (40, 41). We further account for the size and origin of the particles . This results in a value of 54€/kg PM_{10}.

To value noise mitigation we used a noise sensitivity depreciation index based on the results of two large studies using hedonic pricing (42, 43). Market value of properties decrease with 0.4% per dB(A) at lower noise levels (40 dB(A)) and 1.9% at higher noise levels (60 dB(A)).

3. Using the information

The use of all the numbers and functions in the tool are explained and illustrated in a separate manual. The manual bundles the methods and functions to quantify and value the ecosystem services, and gives the assumptions made. To help users better understand calculation procedures, each function is illustrated.

This manual and tool are not static. TIt was not possible to derive quantification functions for all ecosystem services. The quantification and valuation functions that are presented are built on the current state of knowledge and data-availability, but can be improved in the future when new scientific insights emerge and /or better data is available. The manual and reports can be found on the website of the nature value explorer.

Below we give an hypothetical example of a case calculated with the nature value explorer.
The case is the creation of a 190 ha wetland on a agricultural land (fields and meadows). The following output (Figure 1) is given after filling out the requested information on soil type, drainage and groundwaterlevels. More detailed information on the calculations can be exported.

Kwantificering van ecosysteemdiensten

Image of Figure 19-1

	Gebied	Eenheid
Ecosysteemdienst	**opstal**	
Belevings- en overdrachtswaarde:	1 052 582	huishoudens in 50km
Nitraatverwijdering via biologische denitrificatie:	0	kg N/jaar
C opslag in de bodem:	230	ton C/jaar
[illegible]	-4 360	kg N/jaar
[illegible]	-291	kg P/jaar
[illegible]iomassa van bossen:	0	ton C/jaar
N opslag in de strooisellaag en biomassa van bossen:	0	kg N/jaar
P opslag in de strooisellaag en biomassa van bossen:	0	kg P/jaar
Verbetering luchtkwaliteit(vnl. fijn stof):	-265	kg PM/jaar

Waarde van ecosysteemdiensten in euro/jaar

	Gebied	Totaal
Ecosysteemdienst	**opstal**	
Belevings- en overdrachtswaarde:		9 827 901
Nitraatverwijdering via biologische denitrificatie:	0	0
C opslag in de bodem:	42 061	42 061
N opslag in de bodem:	-322 668	-322 668
P opslag in bodem:	-232 553	-232 553
C opslag in de strooisellaag en biomassa van bossen:	0	0
N opslag in de strooisellaag en biomassa van bossen:	0	0
P opslag in de strooisellaag en biomassa van bossen:	0	0
Verbetering luchtkwaliteit(vnl. fijn stof):	-7 939	-7 939
Totaal:	-198 431	9 629 470

Let op: De natuurwaardeverkenner berekent niet de intrinsieke/absolute waarde van natuur. Deze is oneindig aangezien de mens van de natuur afhankelijk is voor zijn overleving. De natuurwaardeverkenner berekent de sociaaleconomische waarde van een (negatieve of positieve) verandering in de bijdrage die de door u bestudeerde natuurgebieden leveren aan de menselijke welvaart. Deze sociaal-economische waarde moet binnen een ruimer beslissingskader geplaatst worden naast andere niet-economische doelstellingen zoals instandhoudingsdoelstellingen.

Local intranet

FIGURE 19-1

4. Conclusion

The need for a valuation tool such as described in this paper is illustrated by the success of the webtool. Since its launch in September 2010, approximately 120 users are registered and 200 scenarios are simulated. The tool was originally set up for use in cost benefit analysis for large infrastructure projects with an impact on nature. Administrations also explicitly refer to the tool when setting up new cost benefit analyses related to infrastructure projects. In addition to this purpose, environmental NGOs see the tool also as a means to demonstrate the value of nature areas and to motivate investments in nature development/restoration.

Other organizations see the tool as a support for payments for ecosystem services. First cases for which the tool was applied are for policy appraisal on infrastructure decisions (transportation infrastructure), to support the development of effective flood risk management plans, to advocate the protection of existing natural areas and support the design of green, built-up areas.

The application illustrates the possibilities and limitations of a simple, ready to use assessment tool to provide scientifically based information for decision making and interaction with stakeholders. Even if some of the scientific underpinnings are subject to debate among scientists and the use of simplified models introduces additional uncertainty, it allows non-specialists to get an impression of the relative importance of different ecosystem services.

This tool is a first step. The methods and data are open for further elaboration, refinement and updates. Improvements require a transparent and open framework which has the advantage of frequent end-user feedback. This will help to trace methodological errors, define the focus for further development and refine the tool to better fit end-users' needs. During the following years the tool will be improved to make further applications possible and expanded with more ecosystem services, when new scientific information becomes available. Increasing end-user interaction is also a key feature contributing simultaneously to user-friendliness and scientific reliability. The objective is to establish a learning system allowing end-users to define case specific input values, pose questions, exchange results and experiences on a discussion forum and improve calculation procedures. Overall, the web application is aimed to provide a platform where the stakeholders of ecosystem services can exchange knowledge and further enhance practical methodologies. These knowledge exchanges are paramount to develop a multi-disciplinary research domain as ecosystem services assessment.

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