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The lack of consideration for ecosystem services (ES) values in current decision making is recognised as one of the main reasons leading to an intense competition and arguably unsustainable use of well-located available land. In this article, we present a framework for the Valuation Of Terrestrial Ecosystem Services (VOTES), aiming at structuring a methodology that is applicable for valuing ES in a given area through a set of indicators that are both meaningful for local actors and scientifically constructed. Examples from a case study area in central Belgium are used to illustrate the methodology: a stepwise procedure starting with the valuation of ES at present. The valuation of the social, biophysical and economic dimensions of ES is based on current land-use patterns. Subsequently, scenarios of land-use change are used to explore potential losses (and/or gains) of ES in the future of the study area. With the VOTES framework, we aim at (1) incorporating stakeholders' inputs to widen the valuation process and increase trust in policy-oriented approach; (2) integrating valuation of ES with a sustainable development stance accounting for land-use change and (3) developing suggestions to policy-makers for integrating ES monitoring in policy developments.

Keywords: participatory valuation; ecosystem services; land-use change; socio-ecological systems

1. Introduction

The concept of ecosystem services (ES) establishes a link between biodiversity and human well-being (MEA, 2005; TEEB, 2010) in a cascade flow from the natural to the human world (Haines Young & Potschin, 2010). The natural environment, in its broadest sense, offers numerous amenities, which can be used to the benefit of people. For example, a good soil quality (an ecosystem structure) allows an efficient food production (an ES), which can contribute to a better diet (a benefit to Humankind). Therefore, the loss of biodiversity is not only an environmental problem but also a major issue for society's sustainable development and human well-being (Haines Young & Potschin, 2010; MEA, 2005; TEEB, 2010).

Despite this inherently anthropocentric characteristic (see, e.g. de Groot, Wilson, & Boumans, 2002; Fisher, Turner, & Morling, 2009), ES are mostly and too often modelled

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on the basis of biophysical or economic indicators only (Nelson et al., 2009). The social and cultural aspects of the value of these services are therefore largely ignored. However, Costanza (2000) argues that, in order to conduct appropriate valuation of ES, one must address the question: who votes? Is it *Homo œconomicus*, *Homo communicus* or *Homo naturalis*? Costanza further argues that in doing valuation of ES, one needs to consider a broader set of goals that include ecological sustainability and social fairness, along with the traditional economic goal of efficiency. Ergo with this article, we argue for an **integrated** valuation of ES, in the sense that the assessment of ES must be equally applied to the social, biophysical and economic dimensions of those services. Of course, these three facets are quite different in nature and thus different scientific methods are required for collecting information and defining indicators along each dimension of the ES investigated. Nonetheless, they are only different viewing angles of the same object. Thus, the three dimensions are interconnected, must be considered jointly and are not mutually exclusive. In addition, we argue for an integrated **valuation** of ES, in the sense that the assessment must go beyond technical measurements of ES by acknowledging the importance of ES for the end-users community (the beneficiaries), i.e. the value given by people to ES ('the social dimension of ES'), the ability of ecosystems to provide such services, i.e. what is to be valued in nature for maintaining those services ('the biophysical dimension of ES'), and the relative worth, the utility, of such services for the economy, i.e. the monetary value of ES (which we refer to here as 'the economic dimension of ES').

The strategic individual and collective decisions taken in order to meet a sustainable land development may vary from place to place, from community to community (Costanza, 2000; Hein, van Koppen, de Groot, & van Ierland, 2006). Therefore, some authors argue that it is crucial to confront the point of views of scientific and non-scientific actors (policy-makers, private landowners, citizens, land-users, etc.) in order to assess the sustainability of local ecosystems through the services they can provide to the local community (Barnaud, Antona, & Marzin, 2011). The confrontation and the exchange of ideas between scientists and non-scientists are crucial for the emergence of creative processes that will eventually allow the elaboration of ecosystem management plans that satisfy all parties to a large extent. A participatory phase is also crucial to identify the relevant indicators that will help monitor these plans and will make sense to the stakeholders (i.e. anyone for whom the study is of interest, including policy-makers and ES beneficiaries) involved to embrace another management standpoint (Cowling et al., 2008).

A participatory approach can serve many purposes, and there are various styles of interaction amongst the actors involved (see Van Herzele, Collins, & Tyrväinen, 2005 for a review). Rather than seeking the so-called transformative outcomes, such as raising awareness or sense of ownership, the objective of participatory modelling and valuation in this study is largely instrumental in nature, i.e. using participation as a tool for enhancing the quality of the ES valuation process, including the identification of relevant indicators and future trends. Through taking account of local knowledge about the environment in which people live, work and spend their leisure time, the valuation of ES – and subsequent management of them – will be more sensitive and responsive to local conditions and needs, drawing on a multiplicity of values. However, participatory approaches that aim to value ES have seldom been implemented (see, as counter-examples, Castoldi & Bechini, 2010; Kaplowitz & Hoehn, 2001; Wilson & Howarth, 2002).

Three important caveats are to be drawn from the lack of integration and of participation in ES valuation processes. First, a sustainable management and use of ecosystems requires an integrated approach in which local stakeholders have a central role as they are the direct beneficiaries of this provision of services. Second, focusing biodiversity management onto human needs would deliver more integrated policy and management at a landscape-scale and be more firmly directed towards human well-being (Haines Young & Potschin, 2010). Thus, the links between ecosystems, the services they provide and the benefits that people enjoy from them must be set out clearly as part of the valuation process. Third, despite an increasing awareness for sustainable landscape management, policy designers still lack dedicated tools to evaluate and monitor ES. Therefore, the insights on ES processes gained through valuation must help to incorporate appropriate indicators in policy documents.

In this article, we present a starting point for addressing these caveats with a framework for the Valuation Of Terrestrial Ecosystem Services (VOTES; www.votes-project.be), developed in a research project. With the VOTES framework, we aim at structuring a methodology that is applicable for valuing the ES available in a given area through a set of indicators that are both meaningful for local actors and scientifically sound. The framework is meant to be applicable to other study areas, but examples from a study area in central Belgium are used throughout the article to illustrate the methodology.

The lack of consideration for the value of ES in current decision making is recognised as one of the main reasons leading to an intense competition over well-located available land (TEEB, 2010). Consequently, the size and distribution of the agricultural, semi-natural and forest ecosystems are expected to vary dramatically. Land-use change is a human-induced factor widely identified as having a dramatic impact on ecosystem structure and processes and hence on the services they provide (Lambin et al., 2001; MEA, 2005; Turner et al., 1997). Other authors further insist that land-use change affects all types of ES (Foley et al., 2005; Metzger, Rounsevell, Acosta-Michlik, Leemans, & Schroter, 2006; Quetier, Lavorel, Thuiller, & Davies, 2007; Schröter et al., 2005). However, previous studies that tried to value ES were either conducted at a broad scale using simple 'benefit transfer' approaches (i.e. estimating ES economic value from available information in another completed studies relating to another location or context) which do not allow for analyses of change in value under new land-use conditions or were conducted at a fine scale, over small spatial and temporal extents and only focusing on a single ecosystem (Nelson et al., 2009).

Therefore, the VOTES framework explicitly refers to the spatial and temporal dimensions of ES in the valuation process of this 'natural capital' for human society. The spatial distribution of land-uses affects the amount of ES available in the study area at a given point in time. Changes of the land-use patterns through time may modify strongly the quantity and the quality of ES in that area in the future. The current configuration of the landscape result from past management decisions and are taken into account. Nonetheless, the challenges regarding a sustainable landscape management require taking a prospective posture.

In order to address these complex spatio-temporal dimensions, in combination with the social, biophysical and economic dimensions, we propose a stepwise procedure starting with valuations of ES at present. The valuation of the social, biophysical and economic dimensions of ES relates to current land-use patterns but result from past socio-economic and climatic trends that are taken into account. This first step allows defining an appropriate set of meaningful indicators for monitoring the evolution of ES provisioning. Subsequently, scenarios are used to explore potential losses (or gains) of ES in the future of the study area with respect to socio-economic, climate and land-use changes. Scenarios provide plausible narratives or pathways to the future, which have the strength of being understandable by a broad range of stakeholders (Cowling et al., 2008). Amongst these, a sustainable development scenario is developed with the contribution of key stakeholders, in order to anticipate future challenges for ES provisioning, relating to a sustainable landscape management and decision making. Scenario narratives are crucial benchmarks for exploring potential changes (temporal dimension) of land-use patterns (spatial dimension) and hence to identify potential shifts (trends) of indicators from the current situation (Murray-Rust et al., 2011; Rounsevell & Metzger, 2010). Finally, key stakeholders are confronted with the indicator trends in order for the local community to debate and gain insights on the potential consequences of a set of decisions about landscape management and use.

In summary, with the VOTES framework, we aim at (1) incorporating local knowledge with stakeholders' inputs (including ES beneficiaries) in a multi-dimensional ES valuation process (see Section 2.2); (2) taking a sustainable development stance accounting for future land-use change (see Section 2.4) and (3) developing suggestions to policy-makers for integrating ES valuation and monitoring in policy developments (see Section 3).

2. Materials and methods

2.1. Case study area

As we propose a novel holistic and multi-dimensional approach to the valuation of ES, we decided to focus on a relatively limited spatial extent yet showing a range of ecosystems and management issues. The study area consists of four contiguous municipalities mainly belonging to the river Dyle's catchment in central Belgium, covering a total area of about 164 km^2 (see Figure 1). Two municipalities are located in the Flemish Region (Flanders: Oud-Heverlee and Bierbeek) and two in the Walloon Region (Wallonia: Beauvechain and Grez-Doiceau).

The area displays a wide range of ecosystems [types of natural and semi-natural land-use include grassland, forest, intensive agriculture, organic agriculture (though limited in

Figure 1. The VOTES project study area in Belgium.

area), orchards, a network of ponds, streams and rivers, gardens and parks, etc]. It notably contains the Meerdaalwoud–Heverleebos forest complex for which an economic valuation study has been performed (Moons et al., 2000). The study area mostly covers the loamy plateau of central Belgium, allowing large agricultural parcels exploitation, besides the east bank of the river Dyle characterised by sandy-loam slopes. The valley bottom includes a series of wetlands that are currently designated as Natura 2000 sites.

The area has a strong peri-urban character, being located between the larger cities of Leuven (north), Brussels (northwest) and Wavre-Louvain-la-Neuve (southwest). The pressure from residential development (and related activities, such as commercial, infrastructure and leisure) is the highest, leading to an intense competition for the use of limited land surfaces. Housing is dispersed and leads to fragmented natural habitats. Increased urbanisation combined with the effects of climate change is likely to increase pressures on local ES (Reginster & Rounsevell, 2006), hence emphasising the need for carefully designed policies focusing on preventive and adaptive measures. For instance, an adequate management of ecosystems and land-use/land cover may reduce the negative effects of climate change. Indeed, climate change effects can be expected to be negative for some ES (e.g. risk of floods) but positive for others (e.g. productivity of some crops can be expected to increase with increasing atmospheric CO_2).

By using municipal boundaries to delimit the study area, we intend to engage with stakeholders involved at that level of authority, recognising that although the causes of ES losses are often regional or even global, solutions are best designed at the local and individual scales (Cowling et al., 2008). We believe that the case study provides a representative example of a situation that also occurs elsewhere and hope that the findings of our study may be applied to other areas in Belgium and beyond.

2.2. An integrated valuation framework

In order to meet our objectives (i.e. of participation, integration and policy suggestions), we have developed the VOTES framework whose originality is to do an integrated valuation of ES in a spatially and temporally explicit way, proceeding stepwise (see Figure 2).

First, we need to assess current values of ES and how these are mediated by land use. This step requires (1) identifying with the participation of local stakeholders what ES they value currently and to which extent they benefit from them (see Section 2.2.1); (2) identifying the land uses relating to these ES (distinguishing vegetation cover, soil type, management practice, slope, etc.) and identifying the related ecosystem processes that can be modelled in practice (see Section 2.2.5) and (3) identifying what ES can be estimated in monetary terms (see Section 2.2.9).

The resulting current key services valued (socially, biophysically and/or economically) are tabulated. This allows (1) synthesising the three-dimensional valuation exercise and (2) deriving a set of appropriate (multi-dimensional) indicators relating to the benefits local people may gain from these services (see 'Translating the values of ecosystem services into indicators' in the next section). This table of ES is the spine of the VOTES framework.

Second, we need to identify current trade-offs and synergies between ES. This identification should not only be done with the set of indicators but also through the land uses that are offering these ES (see Section 2.3.1). Only with a spatially explicit way services 'hot spots' and 'holes' can be located in the study area. The spatial identification is also critical because future landscape management plans are to be drawn from the current situation. Therefore, local decision-makers are to be informed at best on local potentials (i.e. spots with large variety of services) and weaknesses (i.e. spots where there is a lack of service).

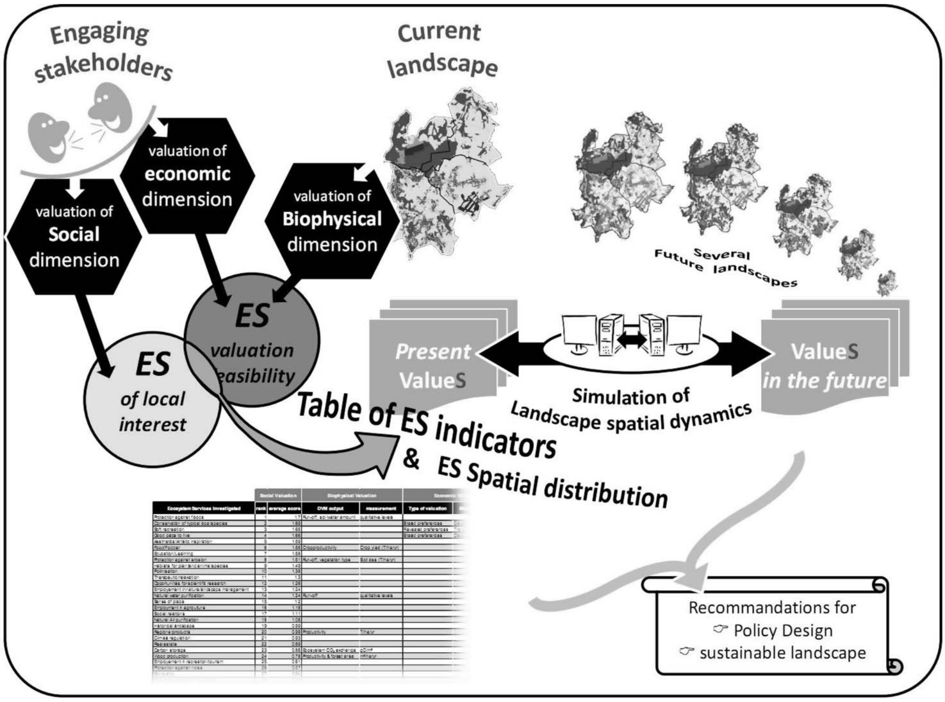

Figure 2. Conceptual framework for VOTES.

Third, we need to explore how ES values may change in the future, i.e. in relation to land-use change. This step requires modelling and simulations of the complex interactions between natural and socio-economic drivers leading to these changes, in a temporally explicit way (see Section 2.3.2).

Fourth, we need to explore how ES trade-offs and synergies may change in relation to future land-use dynamics. This is where scenarios come into play. Subsequently, this step requires going back to the ES beneficiaries in order to confront their impression about potential changes in their area. The aim is to identify what changes are perceived as a threat and what changes are perceived as an added value (compared to the current situation).

Finally, we want to suggest policy instruments for including ES and indicators into decision-making in order to better account for ES values in socio-economic activities (see Section 3).

2.2.1. The social dimension of ES

The aim with our valuation of the social dimension (dubbed 'social valuation' hereafter) is (1) to gather information on what local actors (individuals, policy-makers, civil servants, elected representatives, landlords, local NGOs, etc.) value in their living environment and why it is important to them; (2) to better understand the mental framework used by different groups of people when valuing ES and (3) to identify institutions, organisations and individuals who can affect and/or who are affected by these services. The method is a combination of and an adaptation of existing techniques as suggested by Biggs et al. (2011), who state that current social assessments are too often limited to listing relevant stakeholders and to collecting spatial human-use data.

Social perceptions play an important role in determining the importance of the functions of (semi-)natural ecosystems for human well-being (de Groot et al., 2002). The challenge with the social valuation of ES is to deal with a variety of stakeholders who may have different views, values and interests. Empirical evidences are collected through face-to-face interviews, including open discussion, structured ranking and map description. An open discourse reflects the social and decisional contexts of individual's ES valuation, including perceived trade-offs and synergies between specific ES. A ranking exercise is a particularly suited tool to explore criteria that different groups of people find relevant when evaluating different options or items (Chambers, 1994; Leeuwis, 2004; Raymond et al., 2009). The ranking exercise serves a double purpose (see also Leeuwis, 2004). First, it encourages a respondent to discuss why a service may be important or not. By doing so, we gain an insight into the mental framework that different people apply when evaluating ES. Second, it allows deriving a classification of ES by order of importance for the local community. The synthetic ranking is to be used together with the valuation of the two other dimensions when defining the set of meaningful indicators, since de Chazal et al. (2008) stress the need to treat social and biophysical systems jointly, emphasising the role that values play in shaping assessments.

2.2.2. Selecting respondents

The first main component of the social valuation phase is the identification of potential interviewees, the respondents, who are the beneficiaries of ecological functions that deliver services and are identified based on an integrated assessment (document and map analysis, interviews with informants, etc). This requires a preliminary identification of potential ES and the selection of a number of land-use or land management changes with clear effect on ecosystem values (and relations between them) in the study area. A mix of natural resources management experts with good local knowledge can provide relevant information for identification and recognition of relevant ES at the local scale (Slootweg & van Beukering, 2008). This includes, e.g. nature and forest managers, people in charge of the design and implementation of agri-environmental measures or landscape development in the study area, municipal civil servants responsible for environment and/or land-use planning.

Hein et al. (2006) define stakeholders within ES valuation research as 'any group or individual who can affect or is affected by the ecosystem services'. For the VOTES project, we selected respondents being in a position to shape actions and opinions regarding land-use or land management changes or who might be affected by these changes (either as gainers of losers). Both institutional (policy-makers, civil servants, etc.) and individual (farmers, residents, etc.) stakeholders are to be considered. In particular with regards to institutional respondents, it is important to cover different sectors (agriculture, forest and nature conservation, flood protection, etc.) because often each of them tend to overlook the effects their plans may have on ES linked to other sectors (Slootweg & van Beukering, 2008). The key is to select respondents who represent a broad spectrum of viewpoints. Through purposive sampling, information-rich cases for study in depth can be selected (Barbour, 2001; Kuzel, 1999). If appropriate, non-proportional quota sampling (see, e.g. Tashakkori & Teddlie, 2003) can be used to assure that smaller groups are adequately represented in the sample.

2.2.3. Conducting interviews

The second main component of the social valuation phase is the valuation of ES *per se*. The frameworks the respondents use for ES valuation are assessed using semi-structured interview techniques. The interview design is based on the work by Bryan, Raymond, Crossman, & Macdonald (2010), Cast et al. (2008) and Raymond et al. (2009) and is structured in three parts:

(1) *Open-ended questioning:* What the interviewee values in the environment and why; what views he/she has on nature; what role the respondent plays, has played or will play in land-use management; and what changes he/she has seen in the past and is expecting to see in the future.
(2) *ES-based prompting:* What listed services are important to the interviewee and why. The list is a compilation of most common ES (after MEA, 2005; TEEB, 2010) evenly separated in three laymen themes (see Table 1): production (10 ES), regulation (11 ES) and culture (11 ES). For each listed ES, the interviewee is asked to indicate the ES the extent to which they find a service important and to justify the choices made. This discussion gives more insight into the framework used by the respondents to value ES.
(3) *Map prompting:* Where are, to the respondents' view, the most important ES located in the municipality he/she lives. This mapping exercise gives more insight on the effective use of the environment by the respondents.

2.2.4. Synthesis and analysis

Results of such interviews are rich in content, thus complex to synthetise and analyse. The first level of analysis is the identification of the ES gathering a majority of interest within the diversity of respondents' answers during the second part of the interview. The five qualitative levels are given a value from –2 to 2 and computed across the list of respondents. The resulting scores are calculated as the average importance given to each listed ES (see first column in Table 2). These scores indicate which ES were pinpointed as '(very) important' by a majority of respondents without much controversy (top rows in Table 2). The rationale behind the ranking is to guide the valuations of the biophysical and economic dimensions.

Conversely, the more in-depth parts allow for questioning and probing about the reasons behind valuations linking the valuations with the respondents 'views on nature and their (environmental) values'. Because ranking exercises give an impression of the average priorities that the participants may have (Leeuwis, 2004), it is also important to establish separate priority rankings for the different groups under study so as to avoid making invisible significant differences of valuation between them. Such differences, if they exist, would provide valuable clues to the nature and causes of synergies and conflicts between different ES as well as the trade-offs made by stakeholders. We do not detail this part of the social valuation analysis here because it goes beyond the objectives of this article.

2.2.5. The biophysical dimension of ES

The list of ES presented to the respondents is a derived product of the presence of biodiversity, including ecosystem structure, processes and functions, in the case study area (TEEB, 2010). Hence, the valuation of the physical and biological environment (dubbed 'biophysical valuation') is an essential part of the VOTES framework that provides knowledge-based case for safeguarding ES (Heal, 2000). As summarised by Cowling et al. (2008), this includes 'knowledge on the types and location of the biophysical features that provide ESs, the spatial and temporal flows of services in relation to beneficiaries, and the *impacts of land and water transformation* on delivery' (our emphasis).

Table 1. Ranking table of ecosystem services used for the valuation of the social dimension.

	Not at all important	Rather unimportant	Not important nor unimportant	Rather important	Very important	Comments
1. Provisionning services	Goods and services provided in the environment					
Wood production						
Biofuel						
Pollinisation						
Food/fodder						
Regional products						
Hunting						
Berry/plant picking						
Empoyment in agriculture						
Employment in nature/landscape management						
Employment in recreation & tourism						
Real estate						
2. Regulating and supporting services	Result from the capacity to regulate climate, water and nutrient cycles, earth surface processes, biological processes					
Natural water pufication						
Natural air purification						
Climate regulation						
Carbon storage						
Protection against floods						
Protection against erosion						
Regulating pests and diseases						
Protection against noise						
Habitats for plant and animal species						
Conservation of typical local species						

(*Continued*)

Table 1. (Continued).

	Not at all important	Rather unimportant	Not important nor unimportant	Rather important	Very important	Comments
3. Cultural services		Creating opportunities for recreation, learning, local identity, etc				
Soft recreation						
Hard recreation						
Esthetics/Artistic inspiration						
Spirituality						
Therapeutic/Relaxation						
Social relations						
Education/Learning						
Opportunities for scientific research						
Good place to live						
Sense of place						
Historical landscape						

Table 2. Valuation of the social, biophysical and economic dimensions of ecosystem services.

	Ecosystem servicesvaluation				
Dimensions:	Social		Biophysical		Economic
Ecosystem services \ Valuation:	Average score	Indicator of popularity	Measurments @ parcel level	Measurments @ study area level	Monetarisation method
Protection against floods	1.70	1	Water retention capacity	Water run-off peaks (#/yr)	Avoided local cost ?
Conservation of typical local species	1.69	2	Farm management intensity	Densities of farm management types	Discourse-based valuation∗
Soft recreation	1.68	3	Within open-access area?	Densities of open-access non-artificial areas	Travel cost method∗
Good place to live	1.66	4	Types of land cover (#/yr)	Landscape diversity index	Discourse-based valuation∗
Aesthetics/Artistic inspiration	1.59	5			
Food/Fodder	1.58	6	Biomass productivity (T/ha/yr)	Yield (T/ha/yr) per crop categories including livestock	Profit (€/T/yr)
Education/Learning	1.58	7			
Protection against erosion	1.51	8	Soil loss (T/ha/yr)	Soil loss (T/ha/yr)	Avoided local cost ?
Habitats for plant and animal species	1.49	9	Is natural/protected area?	Landscape fragmentation index	
Pollinisation	1.38	10			Market prices (indirect) ?
Therapeutic/relaxation	1.30	11			
Opportunities for scientific research	1.26	12			
Employement in nature/landscape management	1.24	13			Number of people employed ?
Natural water purification	1.24	14	Water retention capacity	Water run-off peaks (#/yr)	

(*Continued*)

Table 2. (Continued).

Dimensions:	Ecosystem servicesvaluation: Social		Biophysical		Economic
Ecosystem services \ Valuation:	Average score	Indicator of popularity	Measurments @ parcel level	Measurments @ study area level	Monetarisation method
Sense of place	1.20	15			
Employment in agriculture	1.18	16			Number of people employed ?
Social relations	1.11	17			
Natural Air purification	1.08	18			
Historical landscape	0.99	19			
Regional products	0.99	20	Biomass productivity (T/ha/yr)	Yield (T/ha/yr) per regional products	Market prices (indirect) ?
Climate regulation	0.93	21			
Real estate	0.89	22			Market prices (direct) ?
Carbon storage	0.86	23	CO_2 exchange (gC/m^2)	Carbon sequestration (Total tons of C)	Pollution permit Market ?
Wood production	0.78	24	Biomass productivity (T/ha/yr)	Wood categories (mVha/yr)	Market prices (direct) ?
Employement in recreation/tourism	0.61	25			Number of people employed ?
Protection against noise	0.57	26			
Spirituality	0.54	27			
Regulating pests and diseases	0.22	28			
Berry/Plant picking	0.18	29	Biomass productivity (T/ha/yr)	Shrubs productivity (T/ha/yr)	
Biofuel	−0.15	30	Biomass productivity (T/ha/yr)		
Hunting	−0.81	31			
Hard recreation	−0.95	32			

The two prerequisites to the spatio-temporal modelling of the landscape are (1) matching the land use (LU; i.e. biophysical structures managed by man) to each service and (2) estimating ES provision in relation to each land use. In that context, 'land use' refers to the combination of vegetation cover and the techniques managing that cover. The crossed correspondence LU–ES can be embedded in a dynamic vegetation model (DVM) accounting for the evolution of the natural environment, a key feature when one wants to model and dynamically simulate the evolution of a landscape. DVMs are tools perfectly appropriate for the valuation of the biophysical dimension of ES. First, they provide the required spatio-temporal framework since they are designed to simulate vegetation dynamics over spatial grids that may include up to several hundred thousands of grid cells. Second, they are process-oriented models that are able to describe both ecosystem structure and functions. Third, they provide a synthetic view of ecosystems and landscape units since they are able to describe several types of vegetation (including competition of different plant types) or ecosystems over a very wide climatic range and they integrate submodules for related physical or biogeochemical systems, such as surface energy budget, hydrology and soil biogeochemistry, which allows to valuate a large variety of ES. There are, however, several caveats: (1) DVMs have been built for and are usually used over large spatial domains, such as continents or countries; (2) they do not generally include anthropogenic factors influencing land-use change dynamics and (3) some processes may be too simplified to allow a precise valuation of some ES.

2.2.6. *Dynamic vegetation modelling*

The DVM used in the VOTES project is adapted from the CARAIB model, a DVM originally designed to describe non-managed ecosystems dynamics over large spatial extent and at coarse resolution, with detailed representations of land-use, land cover and soil properties (Dury et al., 2011; François et al. 1998, 1999; Gérard, Nemry, François, & Warnant, 1999; Laurent, François, Bar-Hen, Bel, & Cheddadi, 2008; Otto, Rasse, Kaplan, Warnant, & François, 2002; Warnant, François, Strivay, & Gérard, 1994). CARAIB is made of five different modules dealing with (1) soil hydrology, (2) photosynthesis and stomatal regulation, (3) carbon allocation and biomass growth, (4) litter and soil carbon dynamics, and (5) vegetation cover (see Figure 3). The spatial resolution of the standard version of the simulator is 10' $\times$ 10' in longitude and latitude. For the VOTES project, CARAIB is adapted so that the grid cells correspond to land parcels ($\sim$1–10 ha). Each grid cell is assigned one of the following four different classes of vegetation cover: (1) natural ecosystems, (2) managed grasslands, (3) crops and (4) bare soil/residential areas. Forests and wetlands will be assimilated to natural ecosystems and will thus use the standard species/BAGs competition scheme of CARAIB. The standard competition scheme will also be used for simulating the second class of vegetation cover, i.e. meadows and pastures in the case study area. Here, trees are assumed to be absent, so that competition occurs only among the herb-type species or BAGs. In addition, regular disturbances due to grazing are explicitly considered. A specific module is built-up for crops. It includes all main crop species cultivated on the study area and allow for crop rotation (different succession of crops lead to different levels of remaining nutrients in the soil and of carbon sequestration). Bare soil and residential areas are assumed to be devoid of vegetation. Gardens and parks are assimilated to grasslands or forests if their size is significant to avoid neglecting their contribution to vegetation productivity.

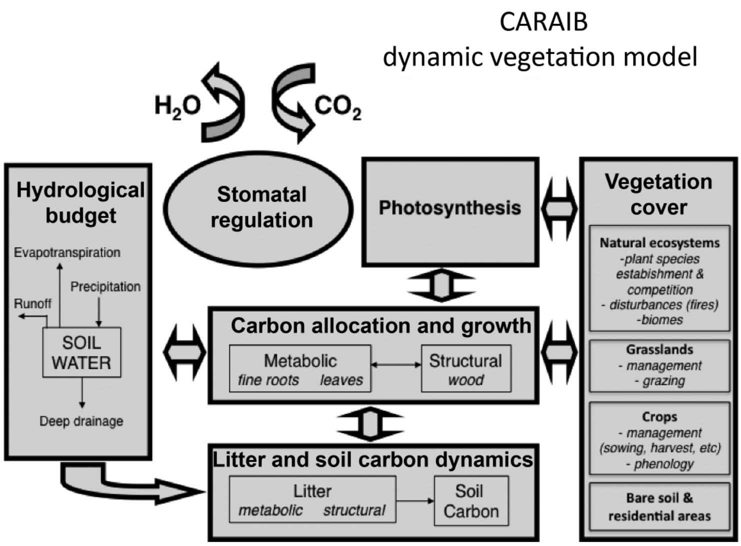

Figure 3. Overall structure of the CARAIB dynamic vegetation model adapted for the VOTES framework.

2.2.7. Inputs, outputs and measurements

Climate and other environmental parameters (e.g. atmospheric CO_2) are the primary inputs to the DVM. From local meteorological station (the station of the military airport located in Beauvechain in our case study area), the average climatological values of the monthly meteorological variables (minimum and maximum air temperature, precipitation, percentage of sunshine hours, air relative humidity and wind speed) are to be extracted in order to build a reference data set over a time period of the past (e.g. 1985–2000).

With these inputs, the CARAIB simulator calculates for each grid cell all major water fluxes (evapotranspiration, run-off, etc.) and CO_2/carbon fluxes (photosynthetic assimilation, net primary productivity, autotrophic and heterotrophic respiration, etc.). The resulting outputs at each time step and for any given time span (e.g. a year or a decade) are, at the parcel level, (1) ecosystem productivity (derived from biomass net primary production), (2) soil carbon stocks (derived from CO_2 cycle and fluxes), (3) water run-off (derived from water cycles and fluxes) and (4) soil loss estimates (based on the universal soil loss equation derived from run-off measurements, land cover, agricultural practices and environmental inputs such as the soil texture, i.e. the proportion of sand, silt and clay).

2.2.8. Beyond the parcel land use, the landscape

The adapted DVM allows building a look-up table matching a variety of land uses to specific vegetation dynamics, a crucial step before performing simulations of the landscape dynamics (see Section 2.3.2).

Also, the simulator outputs (the link vegetation-LU) can be transformed into meaningful indicators (such as soil erosion or agricultural yields, as illustrated in Figure 4) of the biophysical state of the landscape at the level of the case study area, with respect to its capacity in providing the ES investigated (the link LU–ES). In addition, the use of a

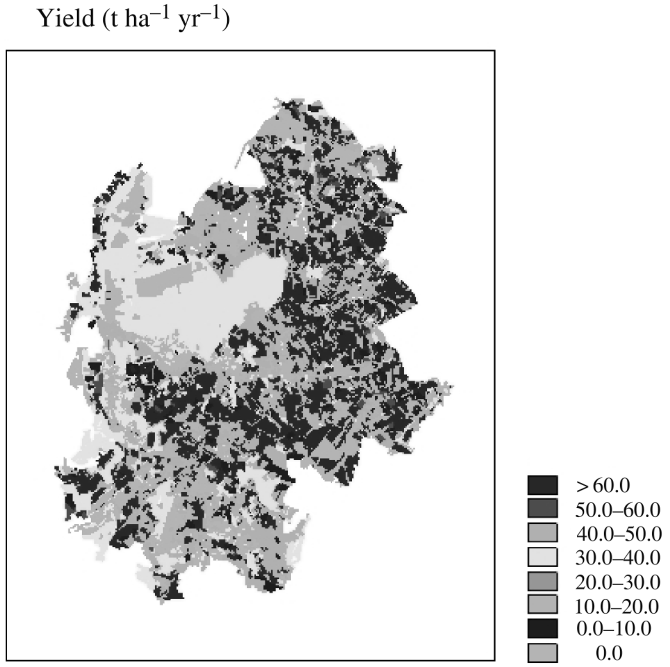

Figure 4. Example of an indicator (yield) derived from an output (biomass productivity) of the dynamic vegetation model CARAIB used for the valuation of the biophysical dimension of ecosystem services (food/fodder).

standard geographical information system allows performing spatial metrics on the current land-use pattern to return an additional number of measurements, such as landscape fragmentation or diversity (see 'biophysical dimension' columns in Table 2).

2.2.9. The economic dimension of ES

In addition to their social and biophysical values, ES may also have a monetary value to the local community (dubbed 'economic valuation'). However, this value is rarely made explicit (beside marketed goods) and therefore considerations related to the preservation of ES are rarely taken into account for landscape planning. Estimating the monetary value of ES is complex since there is no market for most services and requires methodological precautions when making indirect measurements (e.g. making clear what is actually measured in relation to the service to be valued; stating explicitly the limitations when presenting the results to stakeholders; etc.).

In this study, we explore, adapt and develop a cost–benefit analysis. The principle of the method is to put in balance two states of the studied system, with and without a given attribute, and to measure the differences between the financial net benefits of each case, i.e. the profits gained by the community (Salverda, 2004). For example, the economic valuation of the provisioning services of a forest versus those of an intensively cultivated field compares the wood/fibre production profits to the food/fodder production profits. The challenges involved in the cost–benefit analysis relate not only to the measuring of these profits but also to the methods used for collecting the information and for synthesising it over the societal, temporal and spatial dimensions of the studied system.

To get a complete economic estimate of all ES, one should estimate their total economic value (TEV). The TEV can be divided into two groups of values: use values and passive values. The use values contain the direct (market-based and production uses; e.g. these can be material as wood production or immaterial as forest recreation) and the indirect uses (benefits from services supporting the production and consumption, such as regulatory functions; e.g. sequestering carbon dioxide, birds nursery and food chain regulation). Meanwhile, passive values are represented by the option value (value attached to the potential future benefits or potential uses of a resource in order to avoid its extinction; e.g. forests, as an increasing number of pharmaceutical and medical values are discovered), by the existence value (derived from the contentment of individuals to the potential future of environmental resources, even though they will never get to 'use' it; e.g. fundraising the conservation of the Amazonian forest or species for which it is an habitat) and by the bequest value ('more to altruistic motives' some individual value the continued existence of a resource for the future possible benefit from its use by others unknown to them, or for their own future progeny). However, no study so far has yet estimated the TEV of ES.

For the VOTES project, given the time and resource constraints, only the use values were evaluated (beside marketed agricultural goods for which prices are known). In addition, a selection of the quantifiable services must be performed because not all ES are quantifiable in economic terms (cf. Table 2). Ideally, these ES should be important socially (highest scores in the social dimension column) and should have been valued in their biophysical dimension.

We have decided to only use primary data instead of using, e.g. the 'benefit transfer' method (which implies the use of data derived in a specific context but applied to another context) for two reasons. First, we are lacking studies in Belgium that could be used with the benefit transfer method. Second, primary data collection should increase stakeholders' trust in the results as they can clearly understand how it was collected. As an illustration, we detail below the valuation of the economic dimension of two ES: soft recreation via the travel cost method and conservation of biodiversity and wildlife via the discourse-based method.

2.2.10. Soft recreation

Soft recreation includes non-consumptive forms of recreation: walking, observing nature (notably bird watching), picnic sites, viewpoints and simply tourist-driving along uplands roads and also the health and educational benefits of outdoors activities. This ES is classified as a cultural service. The valuation method used is the 'travel cost' method, which evaluates individual preferences for non-market goods where consumption is commensurate with the costs of travel to acquire it (En Chee, 2004). It allows gathering information on travel costs, onsite expenses and capital expenditure. The steps followed are (1) selection of an appropriate ecosystem within the case study area (here, the focus is on the largest woodland areas within our case study, i.e. the Meerdaalwoud and Heverleebos, which are most used for soft recreation); (2) perform a survey with onsite questionnaire and face-to-face interviews for getting information on the respondent's (a) travel behaviour (city of origin, frequency, time spent on site, best spots and motivations), (b) transportation costs (number of kilometres covered, mean of transportation, cost, time of the journey, money spent for activities/accommodation onsite and other place visited) and (c) socio-economic profile (job, level of study, domestic revenue, age and marital status); (3) estimate cost of travel, infrastructure and accommodation and (4) calculation of the use value with an appropriate statistical model.

2.2.11. Conservation of biodiversity and wildlife

Values given to biodiversity and wildlife are dependent on individual perceptions and understanding, and may be more related to the iconic charismatic nature of particular species. The method commonly used is based on stated preferences valuation, such as contingent valuation. However, reliance on individual preferences to construct social values has serious pitfalls (see Hanley 2010 or Costanza 2010) for more detail about these pitfalls).

In this project, we decided to focus on discourse-based and group deliberation methods instead of the contingent valuation method in order to test if the former methods may counter the disadvantages of the latter. In the group deliberation method, the valuation approach is based on principles of deliberative democracy and the assumption that public decision-making should result not from the aggregation of separately measured individual preferences but from open public debate (Wilson & Howarth, 2002). The objective is to encounter a 'fair' outcome which involves no envy by any individual of another (Holcombe, 1983), reaching the goals of economic efficiency and social equity and ensure free and open group deliberation about the value of ES (Blamey & James, 1999; Coote & Lenaghan, 1997; Jacobs, 1997).

To ensure that all major ecosystems are covered by economic valuation, similar valuations (focusing on the use values) are performed for the agricultural and urban areas using direct cost and prices. In this way, the cost–benefit analysis is performed using the scenarios of land-use change, which should allow for a comparison of the economic loss or gain of ES resulting from changing from one land use to another.

2.3. Integrating ecosystem services dimensions and indicators

As Steffen (2009) argues, without improved knowledge of the dynamics of socio-ecological systems, it is almost impossible to design appropriate management tools or even the adaptive intervention experiments needed to inform policy and management. Therefore, it is crucial to bring altogether the knowledge gathered in the social, ecological and economic valuation.

With the social valuation, we identify through face-to-face interviews the owners and beneficiaries of ecological functions that actually deliver services, which are then valued within their social and decisional contexts. The focus is therefore primarily on the requirement of ES provision in the study area. With the biophysical valuation, we model the flows between ecological functions that actually deliver services in order to identify the relationships between ES and the land use. The focus is therefore primarily on the location of ES, i.e. the land-use spatial distribution, in the study area. With the economic valuation, we estimate the benefits of ES with market prices for goods production or estimated prices for manmade land-use functions through costs–benefits analyses, such as the benefits of urbanisation versus the costs of losing ES. The focus is therefore primarily on the monetarisation of ES present in the study area.

The social, biophysical and economic measurements are compiled into one integrated table (Table 2), allowing identifying the ES of crucial importance to the local community that can be scientifically monitored along either one or both of the other dimensions, biophysics and economics. This integration should sketch out a holistic picture of the socio-ecological system studied, emphasising the 'human-in-the-environment' perspective that the Ecosystems Approach promotes (Haines Young & Potschin, 2010; MEA, 2005; Rounsevell & Metzger, 2010). The aim is not to define a common artificial unit (the valuations foci are quite different) but to allow targeting on the conflicts and trade-offs between services with respect to their providers, beneficiaries and location.

As an example, let us consider the ES 'protection against floods'. It was ranked first in valuation of the social dimension with an average score of 1.70 (out of a maximum of 2) and little diversity in the respondents' answers (74% said it was 'very important', 24% said it was 'important'). Both the rank and the score can thus be considered and used as indicators of the social importance to provide such an ES in the study area. From the valuation of the biophysical dimension, we obtain information about water run-off and soil water saturation (in mm/day and % of saturation, respectively). These outputs can be turned into one qualitative indicator of the capacity of a parcel to retain water, relating to the land use. Hence, different bundles of land uses with a similar level of protection against flood can be aggregated at the scale of the river Dyle's catchment, indicating where the service is best located (e.g. high capacity for woodlands, medium capacity for grasslands, low capacity for intensive agricultural land and no capacity for artificial surfaces). The economic valuation of a 'protection against floods' is much less straightforward because there is no out-of-the-box method for putting a price (rather an avoiding cost in this case) on such a service. One convenient way would be to use insurance premiums, considering they are correlated to the risk of floods: the added cost paid by households living in a flood-prone area can be aggregated for the whole study area. However, most premiums are not related to specific local conditions. Indeed, insurance companies yearly adapt their premium (at least in Belgium) based on (1) accident (in its broadest sense) statistics collected at the postcode level and (2) considering whether they had to pay back too much money overall the last year. From the latter, repeated storms and related flooding events that occurred during the past few years actually lead to a general increase of about 5% of premiums in Belgium. In other words, the increasing costs for the companies are supported by everyone, and not only those mostly exposed to flooding. Hence, increasing flood protection at the local level through ES improvement will have neither direct nor significant effect on insurance premiums.

This highlights three other considerations about valuation (in its broadest sense). First, the importance of targeting an appropriate object that is actually representing the ES to valuate (see above example). Second, the question of to whom the value benefits: to a private operator (e.g. farmers benefit from food production), to a specific group (e.g. cycling groups benefit from soft recreation infrastructure) or to everyone (e.g. the entire local community benefit from better flooding protection)? Finally, the crucial importance of considering explicitly the spatial and temporal dimensions of ES, as explained hereafter.

2.3.1. The spatial dimension of ES

As can be gathered from the above example, ES may have different values and indicators depending on the scale at which they are assessed. The geographical dimension of ES valuation complexity should therefore be taken into account. The challenge is to adequately match LU and ES with considerations for both their respective spatial extent (what is the scale to be used for identifying each ES?) and their many-to-many relationships (one LU can contribute to several ES; one ES may relate to several LU). As an illustration, consider a small strip of land along an agricultural field covered with grass:

(1) Standing alone, the parcel offers a niche for plants and animal species in a specific spot. Therefore, that particular LU may contribute, at the scale of the parcel, to the ES 'Conservation of typical local species' (ranked 2nd in Table 2).

(2) In combination with a variety of other LU applied to other parcels in the larger vicinity, the grass strip enhances the viewpoint scenery, at the scale of the landscape. Therefore, this combination of LU contributes to the ES 'Landscape aesthetics' (ranked 5th in Table 2).
(3) Likewise, for the same combination of parcels and/or in combination with other agro-environmental measures applied to the neighbouring parcels, the grass strip may contribute to water run-off mitigation, relating to the 'Protection against floods' ES at the scale of a river catchment (ranked 1st in Table 2).
(4) The grass strip may also be part of the ecological network of the entire case study area, provided it is well distributed amongst the other (semi-)natural land patches. Therefore, it may also contribute, at the scale of the community, to the ES 'Habitats for plant and animal species' (ranked 9th in Table 2).

In consequence, the contribution of different LU to the provision of ES greatly depends on the minimum spatial extent(s) for the service to exist: parcel, local neighbourhood, river catchment, etc.

We believe that synthesising such a contribution is crucial when performing participatory research because stakeholders can picture more easily the theoretical implications of such land-use change over such ES and express their own knowledge within the same communication framework (see Figure 5 for an example of an illustration card). The comparison of different views should help gain insights. Moreover, when applied to a case study area, LU location in a landscape allows a spatial analysis of these values (concentration, dispersion, neighbourhood effects, etc.). Finally, a representation of LU in direct relation to ES values should constitute the foundation for a holistic analysis of trade-off and synergies. Indeed, compatible and conflicting land uses for ES provisioning can be put in balance from a theoretical point of view when observing their relative positions within the multi-dimensional space of ES.

2.3.2. The temporal dimension of ES

In order to measure future states of the landscape, i.e. changes in ES provision resulting from potential land-use changes, we need a dynamic model. This is an important component of the VOTES framework as it is the spatially explicit depiction of alternative land-use features (Cowling et al., 2008). Dynamic models have the advantage of not only providing a description of key ecosystem units and functions but also of depicting their interactions in space and time. These models describe the interactions between land-use, climate and environmental changes to project their combined impacts on ecosystems structure and functions under given scenarios for the future.

Considering the challenges faced by society today regarding sustainable landscape management, the framework is designed as a prospective tool. Hence, the emphasis on future land-use dynamics, future socio-economic evolution and future climate change. Nonetheless, the past is not ignored. Simulations start from the present, including current LU distribution, which implicitly acknowledges previous dynamics since the present state of the socio-ecological system is the result of past actions. As an illustration, the simulator used to explore future changes of the biophysical system starts from 'present-day' initial conditions. Such a tool is calibrated with data acquired at least over the last few decades, which guarantees that the past evolution in the system is taken into account. Similarly, the respondents' answers rest upon their past experience. However, knowledge of the past may not be sufficient to explore the possible evolution(s) of a system in the future since the

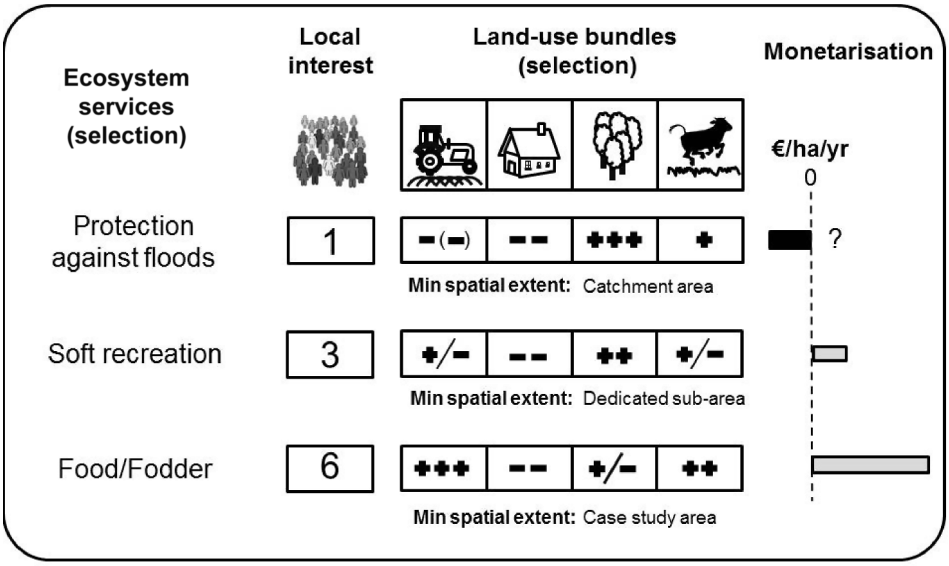

Figure 5. Example of how the importance of land uses could be integrated in an illustration card representing the multi-dimensional space of ecosystem services.

socio-economic and climatic context in the future have not been encountered to the identical in the past. Hence, an understanding/modelling of the (potentially new) processes involved is necessary to simulate future plausible evolution(s) of the system.

The use of ES should be limited to sustainable levels to guarantee their continued availability (de Groot et al., 2002). These sustainable use levels should be evaluated within a complex system framework (Limburg et al., 2002), i.e. by taking into account the interactions between ecosystem functions, which requires a dynamical representation of the ecosystems, and the social systems (Boumans, Costanza, Farley, Villa, & Wilson, 2002).

In order to do so, we combine the DVM (used for the valuation of the biophysical dimension), accounting for the evolution of the natural environment, with a spatial agent-based model (ABM), representing the societal and spatial components of the complex system under study (see Murray-Rust et al., 2011 for details). This emerging technique in geocomputation allows capturing systems dynamics, complexity and properties that can lead to multiple, interacting and conflicting processes, self-organisation and emergence (amongst many others, Bousquet & Le Page, 2004; Gilbert & Bankes, 2002; Parker, Manson, Janssen, Hoffmann, & Deadman, 2003; Phan & Eds, 2007).

Therefore, the range of the DVM primary inputs is extended for including socio-economic and environmental changes described in the explored scenarios (e.g. new agricultural practices and milder climatic conditions). Then, the ABM simulates spatially and dynamically land-use change resulting from agents' behaviours and land management choices as a response to these socio-economic and environmental changes (Murray-Rust et al., 2011).

Running the couple DVM–ABM simulator for a recent period of the past (e.g. 2000–2010) will allow for its calibration and to produce maps of the current situation in terms of land-use, land cover and ES locations and values. Likewise, simulations under different scenarios, which depict distinct policy contexts and broader-scale socio-economic implications, will provide information on potentially new spatial distributions of ES. These changes over time allow updating the set of indicators for defined time steps (e.g. every 10 years) and for each scenario. Moreover, vectors of change (of indicator values) can be drawn when, for instance, an agricultural parcel is converted into a residential area or when a farmer decides to convert practice from intensive to organic farming with more agro-environmental measures.

2.4. Integrating ecosystem services dimensions for sustainable ecosystem services management

The valuation results, set of indicators, illustrative cards and maps of land-use change (i.e. communication tools) can then be presented to stakeholders during the course of a workshop, gathering every person interviewed plus any other local people interested by the subject. Results are presented for the state of existing ES in the case study area and their current estimated values. The aim of this plenary is to confront, at the scale of the area, the scientific picture of current ES to the societal picture held by the participants. Subsequently, several subgroups of stakeholders should be defined in relation to known and potential conflict zones such as agro-environmental measures requests, afforestation/deforestation schemes, river corridor plans and residential development projects. Each group will assess three scenarios of change with the help of the communication tools, as different possible alternatives for the future of the case study area. Possibly, other appropriate visualisation techniques, such as cards synthesising the main landscape outcomes, could be used. The final aim of these following subsessions is to find win-win-win situations (i.e. in economic, environmental and social terms) which will recognise both short- and long-term needs, balance a full portfolio of ES and increase the resilience of managed landscapes (Foley et al., 2005) in order to define a sustainable and acceptable scenario for the future of the local community.

3. Discussion and conclusion

In this article, we presented a conceptual framework developed for the valuation of ES in an integrated manner using participatory modelling. After Costanza (2000), de Groot et al. (2002) and Nelson et al. (2009), we argue that valuation of ES must be applied equally in their three main dimensions: people, nature and economics. In addition to these authors, we stress the importance of using the spatial and temporal dimensions of ES as well because the distribution of land uses (i.e. spatial patterns) affects the amount of ES available in a given area and at a given point in time. We use an integrated DVM–ABM to simulate the spatio-dynamic evolution of ES in case study in central Belgium. As a result, an original representation to combine the three values within their time–space context is proposed in the form of multi-dimensional cards synthetising the necessary land use for providing such ES.

Based on this unified – but not simplistic – representation of ES values, we aim to derive appropriate guidelines to include ES valuation in extant policy measures for our case study, such as into strategic environmental assessments (SEA) and sustainability assessments (SA). SEA is a major tool for policymakers to promote sustainable development by integrating environmental considerations into strategic decision making for a wide range of actions and development sectors (Treweek, Therivel, Thompson, & Slater, 2005). Cases studied by Slootweg & van Beukering (2008) provide evidence that valuation tools of ES can be integrated in the SEA process, providing information much wanted by decision-makers. Moreover, in all cases studied, valuation of ES resulted in major policy changes or decision making on strategic plans (Slootweg & van Beukering, 2008). Likewise, SA is a ‘systematic and iterative process for the ex-ante assessment of the likely economic, social and environmental impacts of policies, plans, programmes and strategic projects’. Its main aim is ‘to improve the performance of the strategies by enhancing positive effects, mitigating negative ones and avoiding that negative impacts be transferred to future generations’ (Verheem, 2002). Compared to SEA, where the focus is on the environmental impacts, SA has a broader and more integrated scope, which is more than the sum of sectoral economic, social and environmental issues (Pope, 2003). The SA approach coincides with the developed conceptual framework for the valuation of ES. Integrating the VOTES methodology within SAs will increase the attention towards ES within development and planning discussions.

The main aim with the participatory steps was to improve the quality of the valuation, especially in its social dimension. After meeting respondents, we realise it could be a first step towards greater appropriation of the ES concept by the various stakeholders involved in the project, from citizens to local decision-makers. Graphic tools if well-chosen and properly applied have the capacity to facilitate stakeholder interaction. But at the same time it should be recognised that the same tools influence the content of the interaction: the knowledge that stakeholders bring to the table (Van Herzele & van Woerkum, 2008) and the type of arguments that are exchanged (Van Herzele & van Woerkum, 2011). Thus the tool actively participates and shapes the social interaction.

Whilst our framework is being initially implemented in the study area described in this article, it should be generic enough to be implemented elsewhere. It is too early to judge whether this will be completely successful, but we may nevertheless anticipate some limitations, as detailed below.

Some authors argue that the uncertainties related to the concept of ES and their valuation are so large (e.g. different values for different actors and values may change through time) that there is a need for a change in scientific posture when studying ES (Barnaud et al., 2011). For Funtowicz and Ravetz (1994), when societal and scientific uncertainties are strong, scientists must recognise a plurality of forms of knowledge and elicit a phase of dialogue between researchers, decision-makers and citizens. In such a post-normal posture, the key of success is the quality of the interaction leading to decision making. A successful landscape management indeed also requires strong political devotion and large participation of stakeholders, beside an adequate valuation framework.

In the framework proposed in this article, uncertainties are large and, in many cases, impossible to quantify. This is especially due to the scenario-based approach taken. Such an approach prevents to account for potential changes in values that may arise from changes in the offer of ES in the future. Nonetheless, the approach has the merit to already provide indications on the directions of change in the provision of ES for the future of the studied area. This is a necessary step when one targets a sustainable management of the local landscape. Besides, vectors of change in the importance of ES might also be derived from that point, although with caution, since it is based on a strong assumption of stable human preferences, which is debated by, amongst others, Costanza (2000) and Hein et al. (2006).

Whilst our framework is indeed participatory, it does not always confront the point of views of actors. For example, in the valuation of the social dimension, we interviewed each stakeholder separately. Barnaud et al. (2011) argue that the point of views of all stakeholders should rather be confronted from the start of a project to build a collective consensus on what ES should be prioritised and favour the emergence of win-win solutions later on in the project by anticipating potential trade-offs and synergies collectively, as well as distributional issues. Likewise, stakeholders are only partly involved in the development of the scenarios (i.e. for the building of the normative storyline). Therefore, the coupled DVM/ABM simulator developed in this project, whilst very efficient at deriving precise indicators of ES and ES change, may perhaps appear as a black-box to some stakeholders. To prevent this, a companion modelling approach could be implemented (Bousquet, Barreteau, Le Page, Mullon, & Weber, 1999). Such an approach assumes a completely transparent modelling process, in which stakeholders participate in every step of the development of the multi-agent systems. However, the development of biophysical indicators of ES and ES change alone requires a quite complex modelling of vegetation processes and land-use interactions (e.g. erosion occurs because of a certain combination of land covers along a hill slope). The challenge is thus to make this process-based calculation transparent enough for decision-makers without jeopardising the scientific precision of the simulator. In addition, this approach requires being much more flexible on the timeframe than we were and is much more time demanding for stakeholders' contribution. In that sense, the interviews did not request too much of stakeholders' time. With this first positive contact, the door is open for further, deeper and longer collaborations and should help tightening the links between local practitioners and scientists.

Building on this mutual trust, we should be able to question the outcomes of the valuation with stakeholders and suggest improvements to the methodology. Indeed, the framework proposed should not be seen as a one-off method but rather as the first step of an iterative process towards participatory valuation of ES by taking into account the several dimensions of sustainable landscape management within their spatial, temporal, community and decisional context.

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