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# Quantification of the potential impact of nature conservation on ecosystem services supply in the Flemish Region: A cascade modelling approach

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


## 1. Introduction

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

Within the European Union the Habitat and Bird Directives are the main policy instruments for biodiversity conservation (EC, 1979, 1992). The European Habitats and Birds Directives require the Member States of the European Union to establish a network of protected areas to ensure the long-term survival of species and habitats that are threatened on a European scale (Evans, 2012). In 2015, there were 25,717 protected areas forming the NATURA 2000 network, covering 767,995 $km^2$ or about 18% of the EU-27 land territory (Kati et al., 2015). Nonetheless, the implementation of appropriate management for NATURA 2000 sites remains a big challenge (Kati et al., 2015). In the Flemish Region (Belgium), negative trends in the conservation status of several species and habitats were observed (RBINS, 2014) and additional measures need to be taken to counter this trend.

For each NATURA 2000 area in the Flemish Region, nature conservation objectives (NCO's) are defined for the habitats and species of European importance (Louette et al., 2015). To achieve the NCOs, measures and investments for nature restoration and

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management will be necessary. This includes land-acquisition, rewetting, top-soil removal, mowing, forest conversion, etc. The high costs that are associated with the NCOs became a subject of debate in the Flemish Region. On the other hand, the realization of the NCOs could also generate additional ecosystem services (ES).

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

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

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

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

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

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

This study provides a comprehensive, large scale, spatially explicit quantification and valuation of ES delivered by the NATURA 2000 network in the Flemish Region. First, we provide background information on the NATURA 2000 network in the Flemish Region, including more details on the NCO's and associated land-use changes. Next, we present the cascade ES modelling approach, which was developed in close collaboration with institutional