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Conflicting interests of ecosystem services: Multi-criteria modelling and indirect evaluation of trade-offs between monetary and non-monetary measures

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ABSTRACT

Ecosystems provide services for many stakeholder groups, often with a conflict of interests that hampers sustainability. Core to these conflicts is the challenge of trading-off monetary and non-monetary measures. Using the boreal forest as a case, we present a socio-ecologically integrated trade-off model for partly competing services (wood, game hunting, livestock grazing). Drawing on multi-criteria analyses (MCA), we found that wood production unequivocally yielded the highest net present value, but led to a substantial reduction in the performance of hunting and grazing. By imposing multiuse conditions set as minimum performance of the less profitable services, we evaluated the opportunity costs of multiuse without directly pricing non-commodities. We also quantified normalized indices of realized performance potential to evaluate the cost of multiuse with a single, joint metric. Both approaches consistently showed that accepting a rather small loss in one service may secure large gains in other services. By democratically providing a combined monetary and non-monetary evaluation, our approach should facilitate broader acceptance for the decisional metrics among stakeholders. It thereby has the potential to mitigate conflicts, feeding into the larger scheme of adaptive management.

1. Introduction

With a steadily rising human population and increasing needs for renewable resources, policymaking for ecosystems services is more challenging than ever (Lindenmayer et al., 2012). Such intensification of pressures on resources raises the potential for conflict between stakeholder interests, because most ecosystems are utilized for different and competing services (de Groot et al., 2010). This is counterproductive to sustainability, given that conflicts exacerbate overexploitation (*sensu* the tragedy of the commons, Hardin, 1968) (Redpath et al., 2015). In some cases conflicts may be socially productive by disrupting skewed distribution of benefits (Tjosvold, 1991). More typically, however, conflicts also hamper socioeconomic value creation (Arancibia, 2013; Hotte 2001), a proclaimed goal of many nations around the globe (Bioeconomy Council, 2013; OECD 2009).

Our ability to solve these conflicts is limited by a lack of scientific approaches that can aid in comprehensively identifying the optimal management strategy when stakeholder interests clash (Maxwell et al., 2014; Redpath et al., 2013). There is broad consensus that incorporating the views of all interest groups is essential for managing conflicts (e.g., Dennis et al., 2005; Kyllönen et al., 2006). With ecosystem services, comprehensive approaches typically must involve trading off multiple interests (Rodríguez et al., 2006; Schlueter et al., 2012), adding complexity to the challenge. At the heart of these shortcomings is a persistent dichotomy between monetary and non-monetary goals, and the inherent difficulties of finding joint decision metrics that the opposing parties can agree upon (Wam, 2010).

How and whether we should evaluate non-marketable ecosystem services is no small debate. Alternative currencies have been put forward, such as energy (McKibben, 2007) or happiness (MacKerron, 2012), but the decisional power remains in the favour of interests operating in monetary markets (Adamowicz, 2004). Non-monetary measures are nevertheless imperative to the sustainable use of ecosystem services as the limits ultimately are biophysical, not economic (Fischer et al., 2007). Advancement of ways to calculate and combine decision metrics in trade-off protocols is therefore gaining research focus (Diaz-Balteiro and Romero, 2008; Ostrom, 2007; Schlüter et al., 2014). Poff et al. (2010), for example, illustrate a most comprehensive use of compromise programming to aid multi-criteria decision planning by simultaneously optimizing multiple objectives

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(e.g., plant productivity, biodiversity, streamflow rates, habitat suitability and willingness-to-pay for recreation opportunities). This much-aspired inclusiveness comes with a cost of immense trade-off complexity, which forces us to measure service performances by some kind of normalized indices. Planning participants typically find it difficult to interpret such relative indices (Kangas et al., 2001), and prefer to base their decisions on hands-on measures like biomass or money (but see Adamowicz, 2004, p. 439). Along with the ongoing and promising development of multi-criteria analysis (collectively labelled MCA), we advocate to simultaneously explore other ways of implementing trade-off assessment without direct pricing, yet within the ruling scheme of monetary exchange protocols (for a recent review of established and suggested such approaches, see Schuhmann and Mahon, 2015).

Aiming at socio-ecological integration, we outline a dynamic trade-off model for the optimization of ecosystem services with partly conflicting stakeholder interests, when land sharing is the preferred option. The inclusion of non-monetary goals and concerns adds new dimensions to the underlying traditional Pareto optimization. Drawing on goal programming (Tamiz et al., 1998), we made factorial comparisons of both monetary and non-monetary output from scenarios with contrasting service priorities. By imposing multiuse conditions set as minimum performance of the less profitable services, we evaluated the opportunity costs of multiuse without direct pricing of the non-commodities (Fig. 1). Drawing also on elements from compromise programming (Zeleny, 1974), we additionally quantified normalized indices of realized performance potential to evaluate the cost of multiuse with a single, joint measure. By democratically providing a comprehensive monetary and non-monetary evaluation, our approach should generate broader stakeholder acceptance for the decisional metrics (Ostrom, 2007; Milner-Gulland 2011). It thereby has the potential to mitigate conflicts, feeding into the larger schemes of adaptive management, such as the management strategy evaluation (Mapstone et al., 2008) or multi-criteria decision support (Kangas and Kangas, 2005).

2. Model framework

2.1. Model objectives

We used the Nordic boreal forest as a case study, with three partly competing services: wood production, game hunting (moose *Alces alces*) and livestock grazing (sheep *Ovis aries*, cattle *Bos taurus*.) Here we test four scenarios with contrasting objective functions: (1) prioritize wood production (WOOD), (2) prioritize game hunting (HUNT), (3) prioritize livestock grazing (GRAZ), and (4) prioritize multiuse: i.e. maximize total performance given various levels of multiuse conditions (TRI-0=no such conditions, TRI-L=low levels, TRI-H=high levels). The TRI-L and TRI-H represent non-Pareto solutions, where we imposed conditions as minimum performance of less-profitable services.

We ran the model as a non-linear numerical optimization problem (NLP in GAMS 20.7, Windows NT) using the CONOPT3® solver (Drud, 2006). We first solved our objective function by applying a maximization statement on the net present value equation of interest (Eqs. (1)–(4), depending on the ecosystem service to be prioritized). As an alternative to these objective functions based on net present value, we also optimized the model using normalized indices of realized performance potential (Eq. (7)). Here we applied a parallel to the approach used in compromise programming of minimizing the distance to an ideal, but unattainable point (Zeleny, 1974). By minimizing the sum of these distances across all three ecosystem services, we could further explore the effects of multiuse by assigning equal or different weights to each service. Different weighting of services may be crucial in the final decision process when non-commodities are involved (Hajkowicz, 2008).

2.2. Model structure

To facilitate readability we have kept most of the mathematics in the supplementary appendix. In the following, equations with an A in front refer to this appendix. The growth of both tree and animal populations were modelled with a stage-structured version (Usher, 1966, 1969) of basic Leslie matrices (Leslie, 1945) (Eq. A1–A6). The model is projected at one-year intervals over a finite planning period,

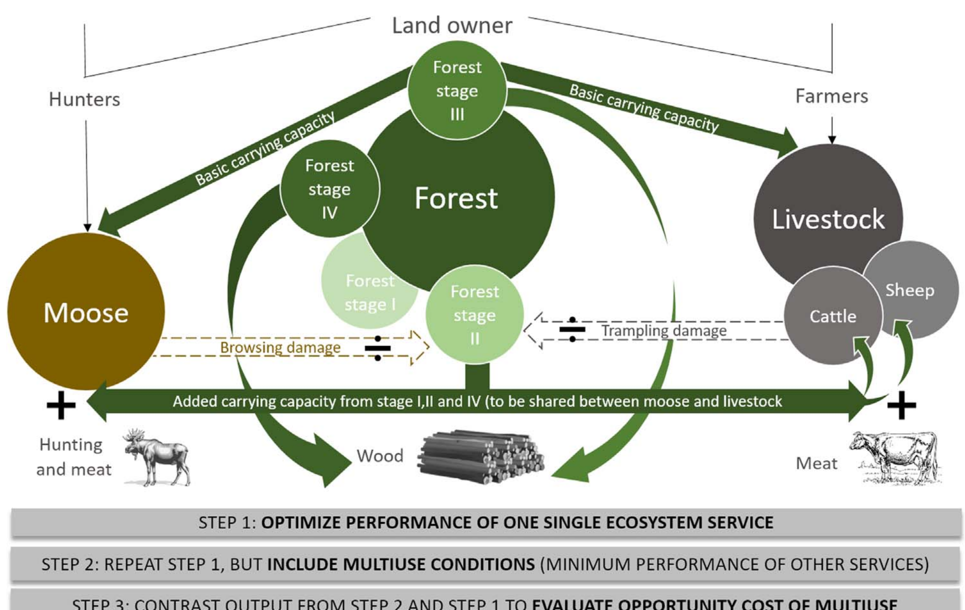

Fig. 1. The use of one ecosystem service may both impede and facilitate other services, as partly illustrated above using forest as a case: wood logging in older forest (stages III-IV) substantially contributes to food carrying capacity for moose and livestock, but livestock cause trampling damage and moose cause browsing damage to the new recruitment of trees (stages I-II). In our trade-off model, we sequentially assess the effects of favouring single or all stakeholder groups on not only monetary output (net present value), but also goods and services (hunting, wood and meat). Because different stakeholder groups have different goals and gains, also of non-economic value, trading-off the conflicting services using only a monetary measure is likely to exacerbate conflict.