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Short Communication

Using ecosystem services in decision-making to support sustainable development: Critiques, model development, a case study, and perspectives

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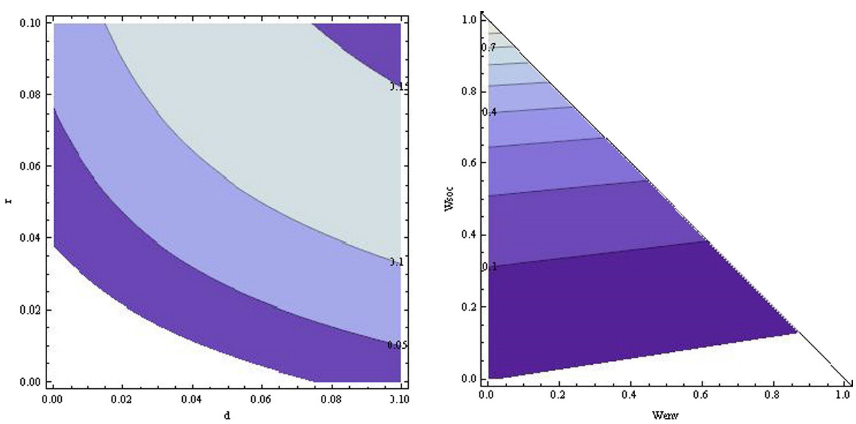
HIGHLIGHTS

- ESS to stress changes rather than impacts and interdependencies in time and space
- From CBA to MCA to assess ab initio either good or bad and non-marginal changes
- Sustainable development to apply at least 3 categories familiar to stakeholders
- Decisions depend on time and space discount rates, weights, loss aversions
- ESS to highlight crucial issues in decision-making rather than to take decisions

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper, I propose a general, consistent, and operational approach that accounts for ecosystem services in a decision-making context: I link ecosystem services to sustainable development criteria; adopt multi-criteria analysis to measure ecosystem services, with weights provided by stakeholders used to account for equity issues; apply both temporal and spatial discount rates; and adopt a technique to order performance of the possible solutions based on their similarity to an ideal solution (TOPSIS) to account for uncertainty about the parameters and functions. Applying this approach in a case study of an offshore research platform in Italy (CNR Acqua Alta) revealed that decisions depend non-linearly on the degree of loss aversion, to a smaller extent on a global focus (as opposed to a local focus), and to the smallest extent on social concerns (as opposed to economic or environmental concerns). Application of the general model to the case study leads to the conclusion that the ecosystem services framework is likely to be less useful in supporting decisions than in identifying the crucial features on which decisions depend, unless experts from different disciplines are involved, stakeholders are represented, and experts and stakeholders achieve mutual understanding.

1. Introduction

Ecosystem services are defined as the benefits that ecosystems provide to humans (Nunes et al., 2014). This definition is anthropocentric (a point of debate, even though ecosystem management decisions are

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taken by humans); it is based on flow, since it refers to services; it depends on context, time, and space; and it mimics weak sustainability, since it refers to benefits. Nonetheless, it is sufficiently broad that it includes both short-run and long-run benefits as well as use values (direct, indirect, optional, bequest) and non-use values (bequest, existence).

Three remarks are essential to understand the use of ecosystem services in decision-making: the analysis often disregards how the services are quantified, it is hard to assign relative weights to the services, and the services have more than ecological implications. I will discuss each of these points in turn.

First, the *measurement* of ecosystem services as natural or biological capital (Lange and Naikal, 2014) disregards the economic benefits from the flows of services and ignores their spatial and temporal interdependencies. In contrast, measuring ecosystem services as replacement costs (Barbier, 2014), willingness to pay or to accept (Seidl et al., 2014), marginal revenues (Brander et al., 2014; Kumar and Chen, 2014; Sumaila et al., 2014), or shadow prices (Smith and Gemma, 2014) makes strong economic assumptions (e.g., perfect information, full compliance, complete property rights) that may be incorrect. In addition, it ignores spatial interdependencies (e.g., edge effects, fragmentation, transportation and distance costs) and temporal interdependencies (e.g., inertia, irreversibility and tipping points). Indeed, decision-making requires quantification (Markandya and Pascual, 2014), for which an assessment of many features is crucial, so that cost-effectiveness is insufficient (Narloch et al., 2011), and a consideration of the many interdependencies is essential (i.e., choices influence the opportunities of others today and tomorrow), so that cost–benefit analysis (CBA) is inadequate (Laurans and Mermet, 2014).

Because of these problems, ecosystem services could be *better* measured by means of a multi-criteria analysis that involves stakeholders, including both citizens and experts, and for which equity and uncertainty should be considered. Appropriate methods range from rankings of alternative spatial and temporal scenarios to constrained spatially and temporally explicit optimisation. In other words**,** whereas a computable general equilibrium model ignores the problem's spatial and temporal dimensions (Palatnik and Nunes, 2014), the scenario approach in ARIES (Bagstad et al., 2014) and in inVEST (Dissanayake et al., 2014) ignore the temporal dimension, and QUICKScan (Winograd et al., 2014) only accounts for large spaces (Waage, 2014).The uncritical application of CBA could lead to a commodification of ecosystem services, although deliberative valuation could be used to partially solve this problem by eliciting stakeholder preferences (Gowdy and Parks, 2014).

Second, in the case of multiple ecosystem services that each have a given function, it is hard to quantify the *relative weights* to be attached to each service within a realistic framework (Comino et al., 2013), even when double-counting issues are tackled (Fu et al., 2011). Indeed, experts are irrelevant in this context (Scholz and Uzomah, 2013), since values are involved that require input from stakeholders, who are unlikely to be familiar with ecosystem services. In that case, a scenario based on sustainable development could be more appealing (Volchko et al., 2013), with the goal of attaching weights to at least three *sustainability criteria* (i.e., economic, social, and environmental criteria).

Third, there are two contrasting perspectives on the range of consequences. On the one hand, ecosystem services cover a *wider* range of consequences than open economic systems; ecosystem services do not assume, a priori, that changes to the *status quo* are either good or bad, whereas open economic systems implicitly consider any change to be bad. On the other hand, ecosystem services cover a *narrower* range of influences than open economic systems; this is because ecosystem services refer to the indirect benefits from biodiversity through concepts such as resilience, whereas open economic systems stress the direct values from biodiversity through concepts such as existence. In particular, natural resources provide goods and services to humans (i) whether the resources are extracted, as in the case of renewable resources with a regeneration process that depends on stocks (e.g., fish) or are independent of stocks (e.g., surface water), or that are non-renewable (e.g., oil); (ii) whether they provide ecosystem services that will be converted into goods and services (e.g., flood protection for buildings, plant pollination for agriculture); and (iii) whether they provide natural assets (e.g., biodiversity) that support ecosystem services (e.g., resilience). In other words, ecosystem services can be used to justify biodiversity conservation for the sake of ecosystem resilience alone, although the modern ability to store genetic resources in a genetics bank may decrease the value of this function. In addition, ecosystem services could justify biodiversity conservation based only on a specified context. For example, biodiversity metrics will differ among spatial scales due to the effects of scale on factors such as the number of species, genetic distance between species, and interrelations among species.

Thus, biodiversity conservation could be *better* supported outside the ecosystem services framework by referring to strong rather than weak sustainability, to stocks rather than flows, to ethics rather than benefits, and to existence values rather than use or option values. Strong sustainability or biodiversity conservation for ethical reasons could nonetheless be depicted within a multi-criterion analysis by applying relative weights fixed at 1 for the environment and the temporal and spatial discount rates fixed at 0.

In the present study, my goal was to show that decisions such as implementing a research platform (a physical laboratory) inside a protected marine area (Coria et al., 2014) within the ecosystem services framework, with potentially cumulative explicit synergies and trade-offs among evaluation of ecosystem services (Palmer and Di Falco, 2014), depends non-linearly on several factors: the discount rates used (i.e., a *temporal dimension*); the local, regional, or international contexts applied (i.e., a *spatial dimension*); the relative weights attached to the sustainable development criteria (i.e., *equity issues*); and the loss aversion expressed by stakeholders (i.e., *uncertainty issues*). For simplicity, this can be considered as a simple yes/no choice rather than as target levels with defined timing and location of the actions.

In other words, by considering all emphasised features at a given point in time (unlike in other case studies of evaluation of ecosystem services), and by emphasising sustainable development within a marine area (rather than the ecosystem services it provides) for the first time, I will show that the evaluation in an ecosystem services framework is likely to be more useful in identifying the crucial features on which decisions depend than in supporting decisions.

Note that the approach I will follow resembles *marine spatial planning*, since it emphasises some trade-offs in resource uses (von Haaren and Albert, 2011). Moreover, I have used some temporally and spatially continuous functions (De Lara and Doyen, 2008) to depict reversibility of changes, and have used threshold functions to depict the possibility of irreversibility of consequences (Guntenspergen, 2014). Finally, my approach resembles *strategic environmental assessment*, since it includes the values of stakeholders, which are expressed by using relative weights (Athanas and McCormick, 2013).

2. An operational and consistent approach

Laurans et al. (2013) highlighted the fundamental inadequacies and crucial inaccuracies of economic valuation of ecosystem services to support decision-making in general, and in particular for the design of policy instruments. However, they took for granted the use of ecosystem services based on monetary CBA values to support decision-making. In contrast, I will retain the ecosystem services approach by moving away from CBA valuations.

Lele and Srinivasan (2013) emphasised that the values of ecosystem services exist whether or not there are users of these services. Moreover, CBA is inadequate because of several problems: the fundamental non-monetizability of certain values (e.g., merit goods, biodiversity, public goods); the uncertainty, non-linearity, and potential