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Design and impact assessment of watershed investments: An approach based on ecosystem services and boundary work

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ABSTRACT

Watershed investments, whose main aim is to secure water for cities, represent a promising opportunity for large-scale sustainability transitions in the near future. If properly designed, they promote activities in the watershed that enhance ecosystem services while protecting nature and biodiversity, as well as achieving other societal goals. In this paper, we build on the concepts of ecosystem services and boundary work, to develop and test an operative approach for designing and assessing the impact of watershed investments. The approach is structured to facilitate negotiations among stakeholders. Its strategic component includes setting the agenda; defining investment scenarios; and assessing the performance of watershed investments as well as planning for a follow-up. Its technical component concerns data processing; tailoring spatially explicit ecosystem service models; hence their application to design a set of "investment portfolios", generate future land use scenarios, and model impacts on selected ecosystem services. A case study illustrates how the technical component can be developed in a data scarce context in sub-Saharan Africa in a way that is functional to support the steps of the strategic component. The case study addresses soil erosion and water scarcity-related challenges affecting Asmara, a medium-sized city in Eritrea, and considers urban water security and rural poverty alleviation as two illustrative objectives, within a ten-year planning horizon. The case study results consist in spatially explicit data (investment portfolio, land use scenario, impact on ecosystem services), which were aggregated to quantitatively assess the performance of different watershed investments scenarios, in terms of changes in soil erosion control. By addressing stakeholders' concerns of credibility, saliency, and legitimacy, the approach is expected to facilitate negotiation of objectives, definition of scenarios, and assessment of alternative watershed investments, ultimately, to contribute to implementing an adaptive watershed management.

1. Introduction

Watershed investments (WIs) offer a promising opportunity to effect large-scale transformative changes that promote human wellbeing while protecting life-supporting ecosystems, in the near future (Guerry et al., 2015; McDonald and Shemie, 2014). They consist of governance and financial mechanisms that secure clean water for cities, and operate primarily by engaging upstream communities and nature conservation organizations (Higgins and Zimmerling, 2013). If properly designed, they can guarantee multiple positive outcomes, including enhancement of selected ecosystem services, such as erosion control and nutrient retention, protection of nature and biodiversity, and promotion of other societal goals (e.g. poverty alleviation). Indeed, they can be an effective tool for implementing adaptive watershed management that emerges as a collective effort of stakeholders who engage in iterative learning cycles, to meet an array of objectives (Cortner and Moote, 1994; Gleick, 2000; Pahl-Wostl, 2002; Pahl-Wostl et al., 2011). Their real-life implementation, however, is an arduous challenge that requires "linking diverse sets of actors and knowledge systems across management levels and institutional boundaries" (Kowalski and Jenkins, 2015).

Ecosystem services-related considerations are increasingly included in decision-making (Abson et al., 2014; de Groot et al., 2010; Haase et al., 2014; Maes et al., 2012) and more specifically in impact assessment processes (Geneletti, 2015; Geneletti et al., 2016; Landsberg et al., 2013; Mandle et al., 2015). The concept of ecosystem services, defined as the direct and indirect contributions of ecosystems to human wellbeing (TEEB, 2010), provides a framework for integrating biophysical and socio-economic matters, to address critical planning and management questions. Spatially-explicit modeling of ecosystem services allows generating and exploring future scenarios of watershed management, and optimizing co-benefits, for example by exploiting synergies between ecosystem services (Howe et al., 2014). Examples of spatially-explicit ecosystem service modeling to optimize synergies between economic, social, and environmental objectives can be found in Geneletti (2013);

Abbreviations: WI, watershed investment; RIOS, Resource Investment Optimization System; LULC, land use and land cover; TW, Toker watershed; Ag-mgmt, agricultural vegetation management.

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Lawler et al. (2014) and Polasky et al. (2008). In the case of WIs, in particular, ecosystem service modeling translates into spatial terms the consequences of different investment options, putting in direct relation the transformations in the landscape with the spatial distribution of their impacts.

Boundary work, an important tool for WIs, is a promising approach for facilitating knowledge co-production and its collaborative implementation, linking diverse stakeholders. Cash et al. (2003) have originally defined it as a set of measures "put in place by any organization that seeks to mediate between knowledge and action". Recently, Clark et al. (2016) proposed a boundary work framework, providing helpful and practical guidance to adopt the most appropriate strategy for each specific context. To our knowledge, their framework is yet to be applied to support an actual process of transfer of knowledge into action, involving WIs.

In this paper, our aim is to support an effective implementation of WIs by jointly exploring the concepts of ecosystem services and boundary work. We here propose an operative approach for designing WIs, and assessing their impact both within and beyond the watershed. The approach defines a set of objectives and related investment scenarios. For each investment scenario, it then applies a relative-ranking method based on the biophysical factors that drive ecosystem services to design investment portfolios. Hence, it generates future land use scenarios that represent the implementation of the investment portfolios. Finally, for each future land use scenario, it spatially models the impact on a set of selected ecosystem services, and it uses the results to assess the performance of the investment scenarios as well as to plan for a follow-up.

The aforementioned methodological steps are comparable to those of a typical impact assessment that integrates ecosystem services (Landsberg et al., 2013) and are coherent with an objective-led assessment that aims at maximizing positive social, environmental, and economic outcomes, rather than simply minimizing negative impacts (Bond et al., 2012; Pope et al., 2004; Hacking and Guthrie, 2006). In particular, this study attempts to address an emerging need to "embed resilience thinking into impact assessment; using participatory workshops; and emphasizing adaptive management", as recently suggested by Bond et al. (2015). As they put it, 'business as usual' impact assessment ought to move towards an objectives-led, visioning approach; focus on uncontrollable threats; promote use of analytic-deliberative techniques; focus on embedding resilience in scenarios, and on uncertain events; and recognize the necessity of continual adaptation to changing circumstances. Therefore, in the proposed approach, we emphasize the fact that the design and impact assessment of WIs should involve stakeholders in a dynamic process of co-production of relevant knowledge, and its collaborative implementation. Our approach distinguishes between a "strategic" and "technical" component, thus identifying those aspects that are the most crucial for effectively and timely addressing concerns of different stakeholders, in order to ensure credibility, saliency, and legitimacy (Cash et al., 2003; Clark et al., 2016), throughout the process of interaction, and beyond.

Finally, a case study illustrates how the technical component can be developed in a data scarce context in sub-Saharan Africa in a way that is functional to support the steps of the strategic component identified in the proposed approach. We consider the Toker watershed (TW) and its homonymous reservoir, which are the main water supply for Eritrea's only major city, Asmara. The TW is affected by soil erosion- and water scarcity-related challenges, which hinder the city of Asmara from meeting its growing water needs and, at the same time, exacerbate poverty of rural communities. We assume two illustrative objectives for investments in the TW: urban water security and rural poverty alleviation. The application of the proposed approach to this case study addresses two key questions, reformulated after Vogl et al. (2015) as follows:

i. Which activities, when, and where in the watershed yield the greatest returns, under different investment scenarios?
ii. What is the impact of watershed activities on a selected ecosystem service?

In Section 2, we provide the theoretical background of boundary work, specifying its integration in the proposed approach. In Section 3, we describe the approach, clarifying the rationale and the boundary work considerations behind each step. In Section 4, we present the case study application of the technical component, specifically, answering the two key questions above. In Section 5, we discuss the results; finally, in Section 6, we generalize our findings to draw overall conclusions.

2. Theoretical background of boundary work

According to Clark et al. (2016), boundary work, intended as a fundamental tool for WIs, consists of any effort put in place to manage tension that arises at the interface between stakeholders that have differing views on what represents relevant knowledge. Thus, boundary work is an innovative concept that helps understand, and manage the challenges arising from the interactions between stakeholders involved in production and use of knowledge, and its transfer into action (Cash et al., 2003; Clark et al., 2016). Three attributes of boundary work increase the likelihood of its success: participation (i.e. a meaningful participation in agenda setting and knowledge production); accountability (i.e. governance mechanisms to ensure accountability of boundary work put in place); and boundary objects (i.e. collaborative products that are adaptable to different stakeholder perspectives) (Clark et al., 2016; Star and Griesemer, 1989). Three criteria define the effectiveness of boundary work: credibility (i.e. technical adequacy in the handling of scientific evidences); saliency (i.e. relevance to the problem at hand); and legitimacy (i.e. fairness, unbiasedness, and respectfulness of all stakeholders) (Cash et al., 2003; Mitchell et al., 2006). Finally, three functions operatively characterize boundary work: communication (i.e. an active, iterative, and inclusive communication); translation (i.e. translation of concepts to facilitate mutual understanding); and mediation (i.e. mediation to resolve potential conflicts) (Cash et al., 2003; Clark et al., 2016).

Boundary work is a dynamic process that has to address diverse types of "tension" at the interface between stakeholders (Parker and Crona, 2012); it thus needs to consider the embedding socio-ecological system, accounting for its contextual (i.e. relatively stable) and contingent (i.e. relatively changeable) factors as well as the relative influence of the involved social actors. Applied to WIs, this means it is important to gain a good understanding of the embedding socio-ecological context, exploring the roles and possible interaction between the stakeholders, to determine the boundary work needed to achieve a theoretical potential, and gain an optimal transfer of knowledge into action. Thus, the need to define timely measures of participation and accountability, and to highlight boundary objects that could be realized during the process of WIs design and assessment, specifying appropriate strategies of communication, translation, and mediation to be deployed. In the light of the considerations above, and given that stakeholders have differing concerns of credibility, saliency, and legitimacy, the overall effectiveness of boundary work should be seen as an emergent outcome of this dynamic process.

3. An operative approach for the design and impact assessment of WIs

In this section, based on the boundary work considerations above, we tailor and propose an operative approach for the design and assessment of WIs. Taking into account the different stakeholders concerns and related boundary work needs, the approach distinguishes between a strategic component (mainly addressing saliency and legitimacy) and a technical component (mainly addressing credibility) (Fig. 1). Each