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Research article

Valuing investments in sustainable land management in the Upper Tana River basin, Kenya

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ABSTRACT

We analyze the impacts of investments in sustainable land use practices on ecosystem services in the Upper Tana basin, Kenya. This work supports implementation of the Upper Tana-Nairobi Water Fund, a public-private partnership to safeguard ecosystem service provision and food security. We apply an integrated modelling framework, building on local knowledge and previous field- and model-based studies, to link biophysical landscape changes at high temporal and spatial resolution to economic benefits for key actors in the basin. The primary contribution of this study is that it a) presents a comprehensive analysis for targeting interventions that takes into account stakeholder preferences, local environmental and socio-economic conditions, b) relies on detailed, process-based, biophysical models to demonstrate the biophysical return on those investments for a practical, decision-driven case, and c) in close collaboration with downstream water users, links those biophysical outputs to monetary metrics, including: reduced water treatment costs, increased hydropower production, and crop yield benefits for agricultural producers in the conservation area. This study highlights the benefits and trade-offs that come with conducting participatory research as part of a stakeholder engagement process: while results are more likely to be decision-relevant within the local context, navigating stakeholder expectations and data limitations present ongoing challenges.

1. Introduction

In recent decades, a number of programs have emerged globally based on the recognition that investing in watershed services – linking downstream users who benefit from clean, flowing water with upstream landholders whose actions enhance or degrade those services – can be a proactive and flexible strategy for securing clean water while addressing other development and conservation goals (Bennett et al., 2016; Bremer et al., 2016; Talberth et al., 2013). Furthermore, private sector investment is increasingly seen as key to closing the growing funding shortage for water infrastructure globally (Rodriguez et al., 2012; Sadoff et al., 2015).

Such programs have succeeded in garnering significant public, private and philanthropic support, often based on the premise that they will result in a net positive social return-on-investment (ROI; Bennett and Carroll, 2014). That programs demonstrate such potential is a critical step to leverage multiple funding sources and to satisfy the increasing interest from investors in having credible estimates of financial or risk-related ROI for their investments (Bennett and Carroll, 2014).

A common issue cited by practitioners, although less visible in the policy rhetoric around investing in watershed management, is the critical importance of using best-available science to target investments in soil and water conservation activities in order to maximize the positive impacts downstream (Naeem et al., 2015; Rocha et al., 2012).

Further, a program's efficiency goals must also be balanced with issues of equity, local values, and feasibility in order to ensure the ongoing grassroots support necessary to long-term program success (Kolinjivadi et al., 2015; Pascual et al., 2014).

In this study, we focus on the recently developed Upper Tana-

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Nairobi Water Fund (referred to as "the Nairobi Water Fund") as an example of such a program. In 2012, local NGOs and stakeholders – including the Nairobi City Water and Sewerage Company (NCWSC) and Kenya Electricity Generating Company (KenGen, the State-owned energy company) – partnered with The Nature Conservancy (TNC) to design a watershed investment scheme to improve Nairobi's water security. The Nairobi Water Fund, launched in 2015, is now a Charitable Trust governed by an independent Board of Trustees (providing leadership, financial and communications support) and a Management Board, with broad institutional representation drawn from the private sector, public sector (including water, environment, and agricultural ministries), and nongovernmental organizations.

In the Upper Tana watershed, various soil and water conservation activities have previously been implemented through public and private funds raised by TNC and local NGOs. The primary focus of many of these programs has been to improve conditions locally, to reduce erosion and sedimentation into streams and to improve agricultural practices at the scale of individual farms or stream reaches.

Efforts to introduce watershed-scale management began with several analyses completed by a previous program, called "Green Water Credits," which was focused on connecting improvements from upstream activities with downstream services in a payments for ecosystem services (PES) scheme (Hunink et al., 2012). That project was not implemented, however, principally due to a lack of stakeholder participation which led to poor financial and political backing (Kauffman et al., 2014). These and other similar efforts have demonstrated that connecting quantifiable improvements in watershed performance with specific downstream beneficiaries, and clearly communicating their potential financial benefits, are essential to engage funders and stakeholders and to ensure the long-term sustainability of such schemes (Bremer et al., 2016; Kauffman et al., 2014).

In the context of payments for watershed services, several studies have used watershed modelling approaches to identify priority locations for soil and water conservation activities, and to quantify impacts that could result from program implementation (Hunink et al., 2013; Rocha et al., 2012). However, many studies use pre-defined scenarios (e.g., Quintero et al., 2009) or else estimates of current service delivery and/or threats to determine the locations of priority intervention areas (e.g., Rocha et al., 2012).

While some monetize the value of watershed interventions to specific beneficiaries, such as downstream hydropower (Guo et al., 2007; Sáenz et al., 2014), we are not aware of any studies that use spatially explicit models of ecosystem change that incorporate beneficiaries to target the nature and location of investments and subsequently assess their impact on multiple services. Furthermore, most studies consider only one or two benefit streams and usually focus on a single beneficiary, not considering many of the multiple alternative values that can accrue from conservation and restoration programs.

Finally, identifying priority locations and conservation activities is not simply a biophysical optimization problem. The particular socio-political context, values and power dynamics between stakeholders should all be included in the project design. Biophysically-optimal plans for watershed interventions are not as relevant or feasible when it comes to guiding implementation if sufficient attention has not been given to an engagement process that builds trust and incorporates relevant concerns (Kauffman et al., 2014; Kumar et al., 2014).

To address these issues, we describe a new methodology for evaluating potential soil and water conservation activities in the Upper Tana based on their contribution to specific ecosystem services (see, for example, Brauman et al., 2007; de Groot, 2006). Our approach links an ecosystem services targeting tool (Resource Investment Optimization System – RIOS) with a hydrologic model (Soil and Water Assessment Tool – SWAT) and a set of economic models to

1) Target watershed interventions based on both their benefits to the environment and their potential to influence ecosystem service flows;
2) Quantify the potential improvement in hydrologic services that would result from implementation of prioritized activities; and
3) Estimate the financial return-on-investment considering multiple stakeholders and benefit streams.

The project took place in an iterative stakeholder process to define the project scope, benefit streams, activities, feasibility constraints, costs, and budgets. Stakeholder engagement helped to ensure that the results are decision-relevant and tailored to the local context. The results of this study have been used for stakeholder outreach and to determine priority areas for the Fund to implement its activities.

2. Methods

2.1. Study area

The Upper Tana River basin covers approximately 17,000 km^2 with a population of about 5.3 million. Average annual rainfall in the basin ranges from approximately 2000 mm yr^{-1} at higher altitudes to only 500 mm yr^{-1} at lower altitudes, with an average annual potential evapotranspiration around 1000 mm (Jaetzold et al., 2006). It encompasses some of the most critical areas for water supply to the city of Nairobi and surrounding communities (the Aberdare Mountains and Mount Kenya), supports one of Kenya's most important agricultural areas, and supplies half of the country's hydropower output as well as 95% of the water supply for the city of Nairobi (Droogers et al., 2011).

Forests and wetlands in the Upper Tana play an important role in maintaining water quality and quantity. However, population is increasing in the middle and upper mountain regions, with rain-fed agriculture expanding into previously uncultivated areas and now representing about 60% of the overall land use (Hunink et al., 2013). Soil erosion contributes to loss of soil fertility and declining crop yields for the millions of smallholder farmers throughout the basin (Kauffman et al., 2014). Increasing sediment in the Tana River is affecting the quality of water and significantly impacting water treatment and infrastructure costs for NCWSC and other municipal water suppliers. KenGen, the leading electric power generation company in Kenya, produces about 80% of electricity consumed in the country, and is increasingly impacted by declining water yields, particularly during the dry season. For example, during the 2009 drought, KenGen's electricity sales dropped 12% compared to the previous year, a decline of USD 19.8 M (KenGen, 2010).

Based on a previous PES feasibility study that modeled water and sediment flows (Hunink et al., 2013), we identified three subwatersheds in the Upper Tana as key focus areas: Maragua, Sagana and Thika/Chania (Fig. 1). The Thika/Chania watershed was selected because of its critical contribution to Nairobi's water supply. NCWSC is one of the principal stakeholders in the Water Fund and a member of its original Steering Committee. A socio-economic baseline survey (Leisher, 2014) suggests that the Maragua watershed has similar land and water-use issues as the Thika/Chania, is of key interest as a significant source of sediment, and is also relevant for water supply, as NCWSC has plans for a new water diversion from that watershed. The Sagana watershed was selected as an important water source for the town of Nyeri, and for its

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