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Analysis

Integrating ecology and economics in understanding responses in securing land-use externalities internalization in water catchments

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ABSTRACT

Securing sustainable upstream land-use externalities internalization in developing countries' water catchments continues to be a serious challenge. Uluguru water catchment in Tanzania presents a compelling case for analysis. The catchment is currently under downstream–upstream conservation subsidy arrangement. However, lack of information on the long-term impacts of the approach on the functioning and distribution of benefits threatens its sustainability. Based on system dynamics framework, this study developed an integrated ecological-economic model to evaluate the long-term impacts of this arrangement on the functioning and distribution of benefits. The model was also used to compare the arrangement with other economic instruments in the same respect. Simulation results indicate that the scheme has a potential of securing conservation goals without compromising upstream well-being. Taxing crop inputs and outputs also has a potential securing conservation goal, but at the expense of upstream well-being. Tax cuts on inputs to tree fruit and basic domestic goods also secure conservation goals without compromising upstream well-being. These results show that a downstream–upstream subsidy scheme is better for achieving upstream land use externalities internalization without compromising distribution of benefits among beneficiaries and well-being of upstream land holders than taxing crop inputs and outputs.

1. Introduction

The decline in the quality and quantity of ecosystem services which a society derives from water catchments is of growing global concern (UNEP, 2007). In recent years the world has witnessed water catchments being plagued by problems such as water pollution, habitat destruction, intensive water abstraction, increased sedimentation in rivers draining them, changes in water flows, inadequate socio-environmental flows, and land degradation (TEEB, 2010). The literature attributes this to patterns of demographic, social and economic changes that generate intensive and extensive exploitation of ecosystems for production of consumption goods (Dasgupta, 2008). This problem is more profound in developing countries where people are confronted with poverty and food insecurity. In these countries, exploitation of water catchment ecosystems is characterised by high rates of, and low investment in, the internalisation of externalities (Skoufias, 2012). The overall result of this situation is the alteration of the long-term capacity of ecosystems to provide provisioning, regulating, supporting and cultural ecosystem services at levels that can sustain current and future welfare.

Water catchments are extremely complex and dynamic systems which make the prediction of their response to human exploitation on ecosystem services delivery and distribution unpredictable (Kremen, 2005). The ecosystems services they supply result from interactions of interwoven components linked by complex stabilising and reinforcing feedback loops, which determine the pattern and pace of system functioning, response and resilience to external stresses (Margolis and Naevdal, 2008). Apart from the system interaction complexity limitations, the divergence in the incentives faced by individual decision makers (upstream land holders) presents another limitation to the prediction of response. According to van Noordwijk et al. (2004), there is some divergence between what is privately and socially optimal among upstream land holders.

To slow down the harm done to such extremely complex ecosystems, scientists have been testing models that base their management on integrating ecological knowledge with economics (Jogo and Hassan, 2010; Costanza et al., 2002). The argument here is that the approach is capable of taking into account the multi-scale impacts on ecological, hydrological and economic welfare. Scientists also propose using economically viable mechanisms for internalisation of externalities to handle the chronic poverty and food security constraints facing the majority of poor and resource-constrained developing country land users (Mwanyoka et al., 2010; Molua, 2005). The literature argues that such mechanisms have the potential to produce both private and social

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benefits and by so doing, address the survival needs of poor developing country land users while concurrently producing public goods. Partly as result of these insights, in recent years there has been an increase in research interest and activity among economists and ecologists on integrating knowledge about ecosystems and economics in deriving policies for managing complex ecosystems and landscapes, and in using economically viable ecosystem management practices for internalisation of externalities (Meadows, 2004; Polasky et al., 2005).

Nonetheless, attention has recently begun to be given to market-based incentives to complement the traditional command and control policy instruments in the management of water catchments (Pagiola, 2008; Engel et al., 2008). The argument here is that the later instruments acting on their own have not exploited the potential of upstream land holders and downstream ecosystem services beneficiaries in achieving conservation goals (Muñoz-Piña et al., 2008). The market approach is also considered ideal in developing countries contexts, given its potential to address the survival needs of upstream land holders who are relatively poorer than downstream ecosystem services users by improving their economy (Pagiola, 2008). Equally, the literature argues that price-based (taxation) instruments can induce behavioural change among upstream land users by rewarding those who practise sustainable land use practices and by reducing the market price share for products produced from destructive land use practices (TEEB, 2010).

However, some key empirical questions relating to the policy relevance of economically viable land use practices, as well as market- and price-based interventions in water catchment management, remain unresolved. These involve questions such as whether it is necessarily true that they can simultaneously exploit the potential of upstream land holders and downstream ecosystem services users without compromising the benefits flow, given that water catchments are extremely complex with unpredictable response to interventions. Will they address the challenges facing the management of water catchments, given that there exist divergences in the incentives faced by the individual decision maker? What policy and economic scenarios are important to support them to yield the intended ecological, hydrological, and private economic benefits? The flip side of these questions is: what are the effects of the trade-offs that are going to occur as a result of these interventions on the long-term distribution of benefits between upstream and downstream users? These are important questions to be addressed, if the goals of sustainable management of water catchments are to be achieved through these instruments.

The rest of this paper is presented as follows. In Section 2 we introduce the Uluguru water catchment in Tanzania, which is currently experiencing environmental degradation with a subsequent decline in the quality and quantity of ecosystem services supply. Section 3 presents the ecological economics modelling methodology adopted in this study. Section 4 presents the results and discussion, while the conclusions and policy recommendations are presented in section 5.

2. The Uluguru Water Catchment

The Uluguru water catchment (07°00′ south and 37°40′ east) presents a compelling case for an empirical analysis of the long-term response of the catchment system to management interventions. The catchment is extremely important in supplying ecosystem services to 151,000 residents in the catchment and 6 million others living downstream (URT, 2010). It is also a major biodiversity reserve, hosting Tanzania–Malawi endemic bird species, as well as primate species that include the black and white colobus monkey, which attracts visitors and researchers from all over the world (Doggart et al., 2005). However, in recent years the catchment has been under pressure emanating from intensive conversion of natural vegetation cover to crop land. Cultivated area has increased from 7% to 32%, with a concomitant decline in areas under natural forests, open woodland, and bush land from 8 to 6%, 40 to 20% and 23 to 11%, respectively, between 1960 and 2010 (URT, 2010). The 2010/11 land use data show that 40% of cultivated area is under banana, 24.5% under paddy, 15.3% under fruit trees, and 11.7% under cassava, making these the major crops (CARE and WWF, 2010). This has resulted in a deterioration in the quality of catchment ecosystem services by increasing the level of sediment load in the main Ruvu River from 0.13 t/m^3 to 0.4 t/m^3 (URT., 2011). Equally important, streams and rivers draining the catchment have been changing their courses during the rainy season which increases flooding risk, and the costs of producing potable water and dredging irrigation channels downstream (URT., 2005).

To address this effect, CARE and WWF initiated a series of interventions beginning in 2006 with the key objective of motivating behavioural change among upstream land holders. The organisations are facilitating the emergence of a market linkage between the many upstream ecosystem services suppliers and two major downstream catchment ecosystem services beneficiaries (Coca-Cola Kwanza Ltd. and DAWASCO), whose profitability to a large extent is influenced by the quality of the water. The organisations, basing their efforts on the 2009 Water Act, facilitated the signing of a memorandum of understanding between the two companies and "Wakulima wa Kuhifadhi na Kutunza Vyanzo vya Maji[1]", the upstream land users' community-based organisation. Equally, the government also intends to introduce taxes on crop production to reduce pressure on the catchment (URT, 2009). However, these initiatives are threatened by a lack of understanding on the long-term responses of the catchment system and their effect on upstream socio-economic objectives. To enhance these efforts, this study developed an integrated ecological economic model and applied it to simulate the long-term response of the system to these policy regimes and its effects on certain important socio-economic objectives of upstream and downstream ecosystem services beneficiaries, over time. The model was selected based on its ability to link different components that build the system into a single model that simplifies system response to exogenous factor analysis (Meadows, 2004).

3. Methodology

3.1. The Analytical Framework

The primary objective of the analysis is to understand the long-term response of the catchment system to the management regimes intended to induce internalisation of land use externalities, which is expected to result in sediment load reduction in the rivers draining the catchment. The study based its analysis on fruit tree farming as an economically viable and best land use practice. Fig. 1 illustrates the major components, interactions and feedback loops in the Uluguru water catchment. Following Nobre et al. (2009), the catchment is modelled as consisting of four major interacting components: (i) human component, (ii) land use component, (iii) hydrological component, and (iv) economic component.

The four components interact as follows: in response to the policy interventions, households decide on the best way to allocate their production resources (land size, seeds, seedlings, capital, labour, etc.) between crop and fruit production in the human component at time t. The impact of such land use choices determines the vegetation covering the catchment in the land use component at time t + Δt, which in turn affects the catchments sediment supply, as reflected in the quality of water flowing downstream in the hydrological component. The crops and fruits outputs are eventually harvested and utilised by the human component, quantified in economic value as net revenue accrued from land use decisions, in the economic component. The net income accrued from crop and fruit sends a signal to the human component through a feedback loop, which determines household land use choices in the next decision making cycle. It follows that in this model, the balance

[1] Translated to mean "Farmers for the conservation and care of natural water sources"