Ecological Economics 69 (2010) 1253–1261

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

# Common pool resource management and PES: Lessons and constraints for water PES in Tanzania ☆

Brendan Fisher [a,*], Kassim Kulindwa [b], Iddi Mwanyoka [c], R. Kerry Turner [a], Neil D. Burgess [d,e]

[a] Centre for Social and Environmental Research on the Global Environment, University of East Anglia, Norwich, NR4 7TJ, United Kingdom
[b] Economic Research Bureau, University of Dar es Salaam; PO Box 35096, Dar es Salaam, Tanzania
[c] World Wildlife Fund Tanzania Programme Office, Dar es Salaam PO Box 63117, Tanzania
[d] Conservation Science Group, University of Cambridge, Cambridge, CB2 3EJ, UK
[e] Conservation Science Program, World Wildlife Fund, Washington DC 20037, USA

ARTICLE INFO

*Article history:*
Received 8 May 2009
Received in revised form 17 August 2009
Accepted 3 November 2009

*Keywords:*
Ecosystem services
Common pool resources
Payments for ecosystem services
Water payments
Tanzania

ABSTRACT

Research into common pool resources from the field and in the laboratory has provided a series of insights for the successful management of such resources. The consequences of action and inaction in managing common pool resources are often most strongly felt (gains or losses) by local people. Several ecosystem services can be considered CPRs but in some cases the benefits of (mis)management are enjoyed by one group while the costs are levied on another group. Here we discuss some of the key findings of the CPR literature and how these relate to key considerations for using PES as a management tool. We focus on the role that ecosystems play in regulating water flows in two basins in Tanzania where feasibility studies have been conducted for the potential implementation of PES for water. We find that the lessons from CPR research shed light on some of the key implementation problems for PES mechanisms, and provide a useful guide for highlighting important user-resource considerations especially in contexts similar to East Africa.


## 1. Introduction

Payments for Ecosystem Services (PES) have become an important mechanism for linking conservation outcomes to market-based incentive approaches. Clear arguments in the literature have been made as to why direct payments for sought after outcomes are more cost-effective than "combined approaches" such as integrated-conservation development programs. Additional research has shown the potential for 'double dividend' payoffs in terms of biodiversity conservation and poverty reduction (van Wilgen et al., 1998). There is also the spectre of win–win–win scenarios where conservation can deliver the provision of ecosystem services, biodiversity protection and livelihood improvements (Miles and Kapos, 2008). While the benefit of creating such situations is great and should be investigated, on the ground interventions need also to be informed by empirical research and detailed case studies. For example, research into whether the poor really do gain in PES schemes clearly needs to explore the direct impact on the poor over time, and also recognize that if PES programs proliferate there may be macro-economic impacts (Bulte et al., 2008). This impact may come in the form of changing food prices, labor and land costs indirectly conditioning the poor's livelihoods.

In this paper we use lessons from research on common pool resource (CPR) management to assess implementation impediments that arise when trying to manage and market complex services like those delivered by ecosystems. Drawing on the work of CPR scholars, we focus our discussion on enabling characteristics of CPR for successful management of natural resources (see Ostrom, 1990; Ostrom et al., 1994; Agrawal, 2002). These include characteristics of the resource itself, of the user groups, of existing institutions and of the relationships among these. The importance of understanding these characteristics is applicable to the design of PES interventions due to the rival and non-excludable characteristics of many ecosystem services. We draw on the literature for examples of the interplay between PES and some of the suggested key CPR management principles by looking at two case studies for a water PES in Tanzania. The case studies (Pangani River Basin and Rufiji River Basin) share some of the typical impediments already shown to exist in PES schemes in developing countries; such as the lack of formal property rights (Pagiola et al., 2005), poor monitoring capacity (Wunscher et al., 2008) and information asymmetries (Corbera et al., 2007a,b). We add to this literature by discussing particular challenges embodied in an East African context. We believe that this is the first attempt to look at the institutional issues of PES in East Africa, and the case studies are based on a feasibility studies for potential PES for water in two large basins. Drawing on stakeholder interviews,

☆ This article is a contribution to the forthcoming Special Section "Payments for Ecosystem Services: Alternative Approaches from Ecological Economics", edited by Unai Pascual, Esteve Corbera, Roldan Muradian and Nicolas Kosoy.

* Corresponding author. Present address: Program in Science, Technology and Environmental Policy (STEP), Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ, 08544, USA.
*E-mail address:* bpfisher@princeton.edu (B. Fisher).

0921-8009/$ – see front matter © 2010 Published by Elsevier B.V.
doi:10.1016/j.ecolecon.2009.11.008

government reports, household surveys and workshop results we suggest that consideration of CPR management principles is likely to aid the implementation of PES systems in East Africa.

## 2. CPRs, Ecosystem Services, and PES

Common pool resources are typically defined in economic terms as resource systems that are rival and non-excludable. In other words, CPRs are systems where it is difficult to exclude users through physical or institutional barriers and where the use of the resource by one person or group leaves less for another (Ostrom et al., 1994). Deep-sea fisheries are an example — where one agent's exploitation leaves less for others and at the same time it is difficult to exclude other users from exploiting the resource. In some cases this type of fishery is also an open-access resource, meaning there are no rules, regulations and management regimes connected to the resource itself. However, not all CPRs are open access. Common property regimes arise when rights and rules are associated with CPR use, and are developed through collective action or shared ownership (Dietz et al., 2002). This differs from the more statutory private property regimes, which are typically tied to individuals, not user groups.

Many ecosystem services operate under the characteristics of CPRs, i.e. they are rival and non-excludable (or at least excludability is costly). For example, water provision from catchment and cloud forests — its use is difficult to exclude across a landscape and the use by one person leaves less for another. An additional complexity in governing ecosystems and ecosystem services is that the use of one service or benefit can in many cases affect the level of provision and appropriation of other services (in addition to the rivalry of the service itself). For example, all of the ecological processes that allow a landscape to regulate water flows and provide water in rivers over time provide a final service to humanity i.e. fresh water. This freshwater in turn can lead to benefits of irrigated crops, drinking water and hydroelectric power generation. This freshwater could also be important in fish production. However, one user's extraction for irrigation upstream, not only leaves less of the resource for downstream irrigation, but may also affect fish populations, channel stability, recreation potential and several other benefits.

The difference between CPRs and ecosystem services is perhaps a subtle one. CPRs are systems or resources that deliver services or benefits to people, while ecosystem services are the processes of ecosystems that deliver benefits. Water regulation, timber provision (net primary productivity), and carbon sequestration are all services that flow from some system which could be a CPR such as a community forest. Therefore there is often a direct relationship between managing CPRs and ecosystem service delivery. We do not manage "water regulation" but rather we manage the system which provides water regulation.

This is where PES ties in. PES is a tool designed to use an economic incentive system for protecting, ensuring or augmenting the delivery of benefits to human from natural systems (see Bulte et al., 2008; Engel et al., 2008; Muradian et al., 2010-this issue). Decades of CPR research have focused on the characteristics that lead to better management of systems for delivering such benefits to user groups. Three seminal works on understanding enabling factors are Wade (1988), Ostrom (1990) and Baland and Platteau (1996). Agrawal (2002) synthesized the findings from these studies into six main facilitating characteristics for sustainably managing CPRs — summarized as:

- Small resource size and knowledge of the resource boundaries by stakeholders facilitate better management.
- Small stakeholder group size, shared norms and interdependencies enable management.
- Proximity of resource users (and other stakeholders) to the resource facilitates management success.
- Governance rules must be clear in nature and seen as appropriate by local stakeholders.
- The better the overlap between the resource system (and forces which affect it) and the governance institutions, the more likely management will be successful.
- Understanding/forecasting potential exogenous factors (e.g. technology, demographic shifts) can help build more resilient management.

PES implementation lessons are already coming to similar conclusions as the CPR research. This overlap has been acknowledged in institutional analyses of PES (see Corbera et al., 2007a,b; Clements et al., 2010-this issue; Muradian et al., 2010-this issue), but here we explicitly use the major enabling principles of CPR management and link them to current experiences in PES and to two case studies in Tanzania looking at the feasibility of PES for water. Our main goals are to 1) understand if utilizing the CPR literature sheds additional light on design and implementation of PES and 2) see if in a context such as East Africa, where many resources are open access, CPR management lessons could assess potential problems with future PES for water schemes.

## 3. Case Study Areas — Rufiji and Pangani Basins

Both the Rufiji and Pangani basins drain from the Eastern Arc Mountains and surrounding lowlands, and flow to the Indian Ocean (Fig. 1). The Pangani Basin also drains Mount Kilimanjaro. The Eastern Arc Mountains are an area of great importance for global biodiversity, one of the world's 34 hotspots, and a globally important ecoregion for biological diversity (Mittermeier et al., 2004; Burgess et al., 2004, 2006). It is also an area undergoing continual degradation of the landscape — having lost 11% of its primary forests and 41% of its woodlands since 1970 (Doggart and Burgess, 2005). These mountains are also important sources of timber and fuel wood as well as water for irrigation, domestic water provision and generation of hydroelectricity (Doggart and Burgess, 2005). The hydroelectric power generated by flows originating in the Eastern Arcs represents about 60% of all electricity generation in Tanzania (The Economic Survey, 2007). Hence the Tanzanian government and NGO community have been exploring ways to set up PES schemes. Some progress has been made, but there is no overall PES framework for the country at the present time. The only operational PES scheme is in the Ruvu Basin, centred on a small sub-catchment within the Uluguru Mountains.

The main water PES activities until now have involved the production of feasibility studies in the Pangani and Rufiji Basins and their findings form the basis of this paper (Kulindwa, 2005; Mwanyoka, 2005; Kulindwa et al., 2006). We use insights from both studies since they represent investigations in different contexts.

### 3.1. The Rufiji Basin

The Rufiji Basin covers over 175,000 km$^2$ — about 20% of Tanzania. It is an extensive area of land that includes mountains, savanna woodlands, farmland areas, and extensive wetlands. Farmed areas cover around 50% of the basin, and are mainly concentrated in the mountains and in the peripheral lowlands where the rainfall is highest. The largest part of the basin experiences longer dry seasons and shorter wet seasons, but there are also mountain regions such as the Udzungwa and Southern Highlands that have a less seasonal climate and provide the main water catchment areas in the dry season. It has been observed that of the total annual flow, about 65% to 80% passes in the wet season (5 months). The basin has 82 forest reserves, predominantly in upper catchment areas, and there are also National Parks and Game Reserves, primarily in the lowlands. The population has doubled in the basin in the last two decades and currently more than 3 million people live in the basin. The main livelihood activity is subsistence agriculture. Hydroelectrical capacity is large, with the Kihansi, Kidatu and Mtera reservoirs

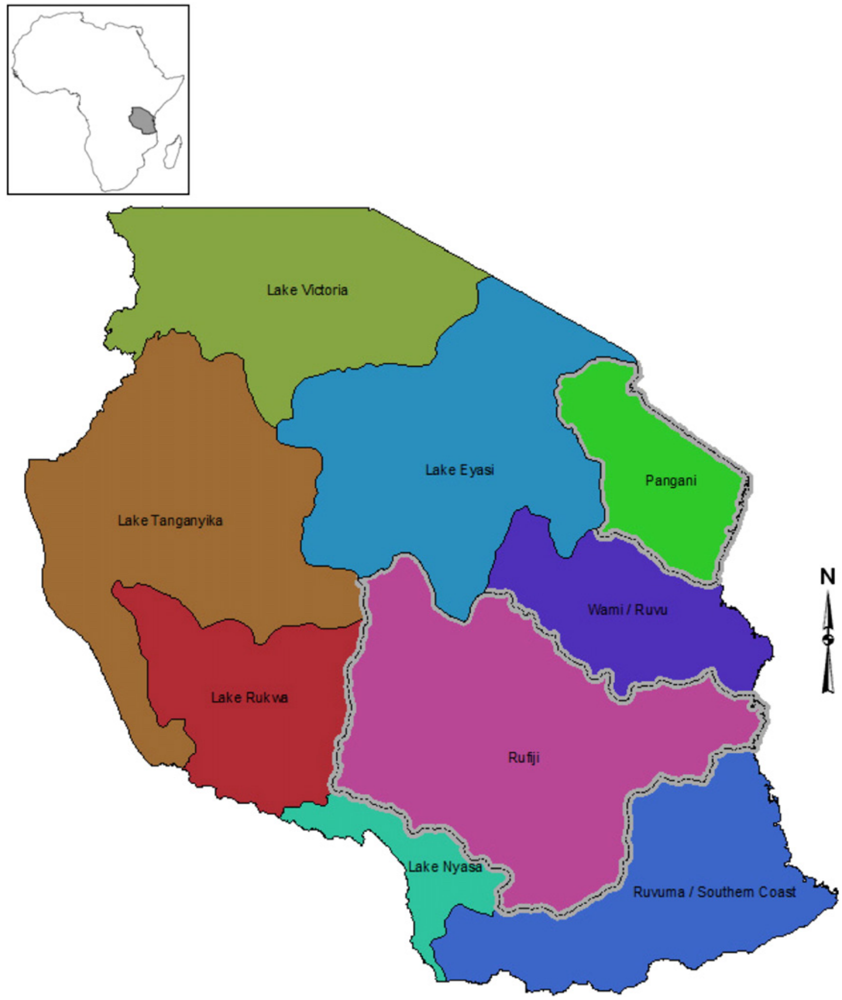


**Fig. 1.** Map of Tanzania showing the nine major water basins including the two case study areas — Pangani and Rufiji Basins.

producing over 30% of Tanzanian electricity supply — all being sourced from the Udzungwa Mountains within the Rufiji Basin (The Economic Survey, 2007). Water is also used for commercial production of rice and sugar cane in the Kilombero Valley. Population growth in the lowlands, agricultural expansion and the dependence of growing coastal cities on hydroelectric power, especially Dar es Salaam, are driving the need for better catchment management, but this need is also exacerbated by declining river flows in the catchment (Mtalo et al., 2005). PES has been highlighted as a possible response tool for better catchment management in this basin with the hope that a PES would entail the more efficient capture of funds that should be paid to the Basin Authority from water users, and an agreed way to allocate the funding to include conservation and land management activities.

The case study presented is based on a feasibility study for a potential PES for water in the basin. The study covered 20 villages with an average of 40 households per village interviewed (total 811 households interviewed — Kulindwa et al., 2006). The sample was stratified by several income levels (village dependent) and household interviews were conducted from randomly selected households within income groups. The sample was representative of the overall village income composition. In order to get a general understanding of the village setting, a focus group meeting, which guided the team in the sampling was held prior to the interview. Officials from both regional and district levels, including those responsible for agricultural and livestock development, water engineers, natural resources and catchment management, and wetlands were also engaged.

### 3.2. The Pangani Basin and Sigi Catchment

The Pangani River Basin draws its name from the Pangani River, a large river located in the northeastern part of Tanzania. The river has its sources in the rain catchment slopes of Mt. Kilimanjaro and Mt. Meru. The total catchment area of the basin is 56,300 $km^2$. Areas surrounding the mountain blocks are dry Acacia savanna in the main. Dense agriculture occurs in the wetter areas around Kilamanjaro, in the mountains, and close to the coast. The basin supports water demand for domestic and industrial use in three major urban centres and several small towns. Another major use is hydropower generation. The present hydropower generation capacity across the Pangani Basin stands at more than 74 MW. Dams in the Pangani produce round 12% of Tanzania's hydroelectric power. Irrigated agriculture is among the major consumptive uses of water in the basin with increasing irrigation activities in the areas of Arusha (flowers) and Kilimanjaro (paddy and sugar cane). Evidence shows that water flows in the Pangani River in both dry and wet seasons are declining and at the same time the quality of water is also declining (Mtalo et al., 2005). During the past decade and a half, population in the catchment area has grown by 32% to about 3.2 million people from 2.4 million people in 1988. Both population growth and immigration into the catchment contribute to growing basin population, however it is difficult to disentangle the relative contributions of each given data availability. Immigration is driven by land opportunities, goods soils and decent rainfall for staple crops.

**Table 1**
Major water users in the municipality of Tanga.

| Registered water user | Average monthly consumption ($m^3$) |
|---|---|
| Tanga Cement Company | 45,450 |
| Tanzania Harbors Authority | 14,290 |
| Maweni Prisons | 5652 |
| Tanga Municipal Council | 4670 |
| Mjesani Sisal Estate | 3000 |
| East Usambara Tea Company | 2100 |
| Tanzania Railways Cooperation | 1482 |
| Vocational Education & Training Authority | 1726 |
| PEE PEE Company Ltd 995 | 995 |
| Amboni Spinning Mills Ltd | 916 |
| Motel Panor | 920 |
| Mkonge Hotel | 850 |
| Tanga Pharmaceuticals and Plastics Ltd | 530 |
| Hotel Kola Prieto Ltd | 575 |
| Simba Lime Factory | 440 |

The case study is the combination of two feasibility studies for water PES in the Pangani Basin (Kulindwa, 2005), with one focused particularly on a sub-catchment drained by the Sigi River, called the Sigi catchment (Mwanyoka, 2005). More than 95 key informant interviews were conducted across the basin and in Dar es Salaam; 60 individual households in the Sigi catchment were interviewed and representatives of the 15 major water users (~25% of water consumption) in the municipality of Tanga were interviewed (see Table 1). The sample strategy was to elicit opinions from the people whose livelihoods directly rely on dry season water flows, timber and non-timber products as well as engage with those who are likely to inform management decisions.

The rationale for the PES exploration in this basin is similar to that in the Rufiji Basin. Increasing urban, rural and irrigation demand for water with falling river flows focused the Pangani River Basin Authority to try to more effectively collect funds from water users in the basin, and to then allocate these to various uses — including the conservation of forests and the improvement of land management practices. The initial exploration of the PES issues in this basin have led to a series of proposals, and options being explored by the IUCN and Tanzanian partners — but so far there has been no actual PES project operationalized on the ground.

## 4. Common Pool Resources — Management Lessons Learned and Application to PES

Investigation of the factors that enhance or inhibit management of CPRs has addressed systems across scales from individual forests to entire oceans (Keohane and Ostrom, 1995). The phenomena studied (and managed) are varied, from collective management of watersheds, to fisheries, and to common property financial assets (Pretty, 2003). Three seminal works on understanding enabling factors are Wade (1988), Ostrom (1990) and Baland and Platteau (1996). These works have several insights in common for understanding the 'hows' and 'whys' of (un-)sustainable management for CPRs. Agrawal (2002) synthesized the findings from these studies into six main facilitating characteristics for managing CPRs. Below we briefly describe these characteristics and link them to findings in the PES literature and to our Tanzanian case studies to help draw out and systematize the challenges of PES implementation in an East African context.

### 4.1. Resources System Characteristics

Both the size of a resource and the knowledge of its boundaries are important characteristics for managing CPRs. Case studies have shown that small-scale resources are much easier to manage in a sustainable way — for obvious reasons. Comparisons have been made between management of Maine's lobster fisheries (relatively small scale) and the exclusive economic zones of countries (large scale) for fish exploitation (Ostrom, 2008), with the former being a better example of management success. Equally crucial is a clear understanding of the boundaries of the biophysical system. Ecosystem services are delivered based on spatial relationships among ecological functions, physical processes, and beneficiary-characteristics (Naidoo et al., 2008; Turner and Daily, 2008). The more proximate and defined a CPR system is to the user group the easier these relationships are to understand and therefore manage. Common pastureland with a clearly delineated edge has management advantages over open sea fisheries, both could be open access or come under some common property management regime. However, the former system with more defined boundaries would be easier to manage.

With regard to system boundaries, in the Sigi catchment of the Pangani Basin in Tanzania, 73% of the survey respondents recognized the importance of the upstream catchment forests for regulating river flows in their area. This level of awareness was also prevalent across the entire Pangani basin. However, acknowledgement of the potential functioning and size of the system was counterbalanced by a large number of respondents in the Sigi catchment referring to one of the key forests – the Amani Nature Reserve – as being the "Finnish Forest," owned by the Finnish International Development Agency (FINNIDA). However, the nature reserve is actually owned and managed by the Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism, and the Finnish presence in the area was to assist government in the establishment of the reserve and to develop a management plans and the relevant infrastructure for the area. The size of the system is partially responsible for the confusion over different forest governance regimes (i.e. it is hard to keep tabs on who 'owns' what), but this example also highlights the lack of effective involvement of the local community. It also hints that perhaps the size of the resource – a catchment of over 56,000 $km^2$ – is one that might be difficult to manage through a PES until at least basic knowledge about the resource and governance regimes is widespread — a current difficulty in Tanzania. Certainly agents cannot act in line with rules and regulations if they do not know where those rules and regulations apply.

The Rufiji Basin is an even larger catchment area (175,000 $km^2$). While CPR management lessons do not automatically preclude that such large areas can be managed successfully, the size of these basins in Tanzania means that widespread understanding of the characteristic of the resource will likely be crucial for PES design. The likely response is working on critical sub-catchments as in the only pilot PES in Tanzania on the Ruvu River. The system or sub-system boundary for critical catchments is only likely to be known after further hydrologic modeling becomes available.

### 4.2. Resource User Characteristics

Just as it is important to know the boundary of the biophysical system it is also important to understand the extent of the user community. Small group size typically improves the ability of the group to self-manage and self-monitor for potential adverse behavior. Small is a relative term and different CPR and CPR arrangements will have different size-effectiveness relationships, based at minimum on the size of the resource and the tools available to monitor the resource. Olson (1965) described a group to be too big when the contribution of one individual is not discernable to the total provision of the good. Certainly this definition is hard to operationalize, and a more pragmatic approaches suggests that larger groups can be successful in managing CPRs, however the additional time, effort and financial costs for ensuring cooperation with rules and regulation may be a limiting factor (Dietz et al., 2003). Generating information about the actions of resource users can be a substantial transaction cost likely to increase with size of the user group (See Muradian et al., 2010-this issue this issue for assessment of transaction costs in PES schemes). Treating micro-finance funds as a CPR under common property — one of the design criteria learned over time by some micro-finance institutions was that user groups need to be small enough to limit free-ridership and keep coordination manageable (Abbink et al., 2006).

Additionally, the diversity and the extent to which the user groups are spread geographically are also important user group characteristics which affect the management of CPRs. Shared norms, past interactions and some degree of interdependency have all been noted to strengthen community management groups and are all modulated by some degree by the geographical extent of the community. For example, in Loma Alta, Peru, once the interdependency between groups converting the cloud forests and downstream catchment farmers was understood — there was rapid cooperation for catchment management (Becker, 2003). Shared norms amongst users (those stepped in common culture), and small stakeholder groups (>200) also facilitated creation of a cloud forest reserve in Loma Alta (Becker, 1999). Knowledge of the system boundary and its functional boundary were critical in establishing the Loma Alta reserve as an important common for fog capture. In addition, small group size has been shown to be effective in PES schemes in Bolivia and Ecuador for similar reasons (Asquith et al., 2008; Wunder and Alban, 2008). A key strategy for overcoming the problem of large user groups is if the group can be managed into smaller sub-groups increasing chances of trust, cooperation and the ease of self-monitoring (Marshall, 2005).

In the Pangani Basin, with over 3 million inhabitants, user group size is certainly a consideration. Looking just at the urban water consumption (Table 1) we can see the all of the major users are institutional or commercial. The major downstream consumer is the Tanga Cement Company whose water withdrawals comprise 6% of all water consumption. Abstraction for cement production is likely to increase since a new plant has been recently established. In this municipality, there are approximately 14,000 registered water users and over 13,000 of these users are domestic users, but over 25% of all water in Tanga is consumed by just 15 registered users. Other users include sisal plantations, flower growers, paddy farmers, hotels and domestic users. While all groups in the basin would benefit from more continuous water flows in a context of relative scarcity, such a diverse set of users has fostered the type of water use conflicts seen the world over. The Tanzania Electric Supply Company (TANESCO) has been at loggerheads with farmers about increased water abstraction for irrigation upstream of the Nyumba ya Mungu hydroelectric dams. On the other hand several farmers perceive basin management as a ploy to deprive them of their historical customary right to use water for irrigation. Between July 2003 and September 2004 there were 39 registered conflicts in the Pangani basis. These included conflicts between upstream and downstream users, livestock keepers and farmers, villages and institutions, and 16 cases where users were consistently not getting the supply which they registered for. Additionally, in the Sigi catchment people believe that the private Eucalyptus plantations have a serious impact on water, and villagers in Mbomole noted that streams seem to be drying up. The scientific reality of this is currently unknown, however that is of little importance as management and any future PES will depend on trust and the perception of fairness (Dietz et al., 2003; Ostrom and Nagendra, 2006; Corbera et al., 2007a,b). Fairness as a criteria for PES payments, design and implementation is a critical criteria to establish legitimacy as discussed elsewhere in the Special Issue (see Pascual et al., 2010-this issue). In the Pangani Basin the issue of how actors perceive the fairness and legitimacy of any potential PES has led to three different models for PES implementation. One is a system where the basin water authority collects payments from water users and distributes it as they see fit for water management. The second proposal is getting large water users (institutions and industry) to pay directly to communities near important catchment forests (with NGO facilitation). The third model is halfway-house involving water payments going to the Eastern Arc Trust Fund and managed from there compensating identified ES providers. All of these models have various costs and benefits each interacting with group size and dynamics.

**Table 2**
Registered water users in the Rufiji Basin.

| Type of water users | Number of registered water users |
|---|---|
| Commercial and Industrial | 33 |
| Domestic | 397 |
| Irrigation | 586 |
| Fish farming | 21 |
| Hydropower | 39 |
| Livestock | 72 |
| Multipurpose | 6 |
| Total | 1154 |

In the Rufiji Basin there are 1154 registered water users. This tiny fraction compared to the total number of abstractions in a basin with over 3 million people. The diversity of stakeholders formalized through water registration is shown in Table 2. Major user groups include small and large-scale irrigators, fish farming enterprises, domestic users, commercial users, hydroelectric power stations, livestock holders and tourism related enterprises (typically game reserve lodges). Like in the Pangani Basin there are potentials for many water conflicts given the diversity of actors and the declining river flows. Current ongoing conflicts include those between farmers and fisheries, between farmers and livestock keepers, between National Parks and Reserves and farmers, and a conflict between the hydroelectric authority and an environmental lobby.

Here, the size and diversity of the user communities and the existing conflicts are factors which are likely to provide challenges for implementing water PES schemes. The resolution of water conflicts in such a context can mean the difference between making a living and simply living. Across the EAM districts on average 40% of households do not have access to an improved water source and over 30% of people are living below the national basic-need poverty line. In themselves the type and severity of the conflicts do not dictate implementation failure, nor would PES implementation mean that conflicts would be erased. However, it is in just this type of complex setting that (analogous to CPRs) the various users groups need to be brought together by some formal or informal institutional arrangement in an attempt to adjudicate a solution that might be beneficial across the society — PES design, carefully considered, could provide this opportunity. Here the design would need to accommodate insights about the existing relationships (Pascual et al., 2010-this issue), past histories and shared (differing) user group norms (Muradian et al., 2010-this issue).

### 4.3. Relationship between Resource System and Users

Another lesson to come from CPR studies is the importance of the spatial concordance of the resource itself and the user group (see Agrawal, 2002). Community forests and reserves are more easily managed when the user group is adjacent to the forest. This concordance is also what makes coastal and inland fisheries arguably more manageable than open sea fisheries. As an illustrative example, the spatial extent and temporal lag of activities along the Colorado River typify how difficult it can be to manage common property, where one user group (Mexican farmers) and the resource production (headwaters) are disconnected in space and time (Postel, 2000). In this case, the dynamic interplay of water permits in western US states, changes in timing and level of water flows, and increasing demand mean that Mexican farmers are receiving less and less of the Colorado River, and the river itself rarely makes it to the Sea of Cortez anymore.

A high level of dependence upon the resource by the user group, and equitably distributed benefits from the resource are also important enabling characteristics of successful CPR management. For instance, in the community of Chumbah, Cambodia, high dependence on forest products for fuel wood, charcoal and building materials fostered community concern for the deteriorating local environment — this was spurred on by the inequitable distribution of benefits, realized after the community allowed a logging company to harvest part of their forest (Fisher, 2001). As mentioned, there is a high level of dependence of user groups in Tanzania on timely river flows. The distribution of the benefits of regulated water flows has already been shown to be of concern in both case studies.

Hydrological services by their nature are going to be distributed across time and space. Theses dynamics can make it difficult for water-related PES schemes to ensure the link between the ecological system functioning, its management and the user groups. For example in a water PES scheme in Bolivia downstream farmers showed some skepticism about whether their payments actually led to conservation, while at the same time upstream providers expressed fear of expropriation of their land through contracts and payments (Asquith et al., 2008). In cases where there is uncertainty about how the system works, it has been shown that pre-existing beliefs play a key role in assessing the legitimacy of a PES scheme (see Muradian et al., 2010-this issue). Uncertainty in system function is not unique to water-related services, but is more the rule than the exception (see Pascual et al., 2010-this issue).

This parallels results from the Sigi catchment survey in the Pangani basin, where most upstream users felt that downstream user groups – industry, hotels, sisal plantations and urban dwellers – benefited much more from water flow protection. In addition, interview respondents felt that their livelihood options were being foreclosed but received little remuneration. Over 60% of respondents said there were no personal incentives for catchment management. The general feeling by upstream locals was that conservation was a represented a net loss for them. Such feelings accelerate the situation where communities become adversaries rather than being allies of conservation efforts. This perception of loss implies that any PES would at minimum have to meet the perceived opportunity costs of potential ES suppliers in order to ensure compliance with any PES rules and regulations.

Across the Pangani Basin as a whole, many users felt that they never get the amount of water promised by the water rights they purchase. A claim by the Tanzania Plantation Company Limited was that they were not getting the amount of water they paid for due to declining flows in the Ngaresero River. An even more practical problem arises when one wants to know the amount of water users actually abstract. Most water users do not have gauges to measure the amount of water they extract. Linking this to other findings in the field it is likely that in the absence of appropriate gauging, users are likely to hold onto beliefs regarding their level of water use (Muradian et al., 2010-this issue), which might predictably come as an underestimate.

The situation is not very different in the Rufiji Basin where a lack of monitoring and gauging hampers the ability to understand how current distribution of water benefits is allocated. However, it is known that the largest consumptive users are a relatively small number of irrigators, using 26% of the known abstraction. In both cases, the relationship between the systems and the users groups needs to be better understood if PES is going to be successful and seen as legitimate. An important first step therefore may be to enhance the ability to measure and monitoring water use before considering further user fees.

### *4.4. Institutional Arrangements*

CPR management is a function of the formal and informal institutions that govern and oversee access to the resource (Ostrom, 1990). Governance rules must be clear in nature and seen as appropriate by local stakeholders. Similarly, if the rules are seen to come from another stakeholder group (or from 'above') then the legitimacy of the rules and compliance by local stakeholders is greatly compromised (Marshall, 2005). An example of the difficulty of implementing rules without local stakeholder 'buy-in' is where the Tanzanian Maasai must comply with national hunting laws of the Tanzania that forbid killing large mammals (a resource for the country generating large inflows of tourism dollars). However, these laws made from 'above' are often not considered legitimate as 1) killing lions is part of the culture elevating boys to manhood status and 2) lions represent a threat to Maasi livestock. Both reasons have led to systemized disregard for the rules and therefore retaliatory hunting is especially widespread (Kissui, 2008).

By contrast, when rules are made collaboratively and openly, CPR management is likely to deliver on its specified objectives. In Rajasthan, India, participatory watershed management was initiated through a series of inclusive conferences for program design and objective setting where village concerns were a key input, facilitating ability to carry out jointly derived management plans (Krishna, 1999). While inclusiveness in design can be a route towards a local context of fairness, in some PES schemes a particular 'fair' solution may be inefficient in cost-effectiveness terms (Alix-Garcia et al., 2008; Pascual et al., 2010-this issue). Understanding this potential tradeoff will be crucial for PES design in Tanzania. In the Rufiji Basin there is ample skepticism that contributing an additional water payment will return better water flows. Hence water conservation approaches on the demand-side might be more cost-effective, for example limiting wastage or increasing the efficiency of irrigation.

Rules guiding water use and management in Tanzania are currently obscured in a shroud of cultural belief, tradition and poor information flows. Several users in the Pangani Basin have the cultural belief that water is a gift from God, and that monetary payment represents a disjoint with their belief. There is also a tradition of water abstraction without acquiring legal water rights. This is fostered by the nonexistence of water meters and gauges, and monitoring activities by the relevant authorities in the Rufiji Basin Water Authority. Sanctions are also problematic, as currently there is inadequate legal provision to deal with non-payers that are registered let alone users who are not. Making matters worse, a general finding in PES systems is that minor infractions to PES contracts have been shown to be difficult to monitor (Wunscher et al., 2008).

It is difficult for rules to be locally sanctioned in a setting where beliefs are not shared (water as a gift from God *versus* water as an economic good and information is not equally distributed across stakeholders. For example, Rufiji users are unsure of what conservation activities are going on). Institutional legitimacy and efficiency will likely increase when based on a foundation of trust (Marshall, 2005). Trust diminishes the need for monitoring regulation compliance. Trust across buyers and sellers has been argued to be essential in particular PES systems (Corbera et al., 2007a,b; Vatn, 2010-this issue), and therefore potential PES systems in Tanzania must recognize the existing information asymmetries, belief diversity and resultant possibility of mistrust.

Additionally, despite strong arguments that PES should focus on ecological outcomes, social acceptance of terms is crucial as PES occurs in a social system. Would poor water users paying rich land owners be acceptable (Muradian et al., 2010-this issue)? The payments themselves, the sanctions for rule breaking, and contingency flexibility need to be transparent and well understood for PES to carry the social acceptance needed for it to be a successful mechanism. In our Tanzania setting, where many of the residents of basins under consideration for PES are food insecure, any restriction on their capability set would be questionable. PES design would need to consider how a payment that currently pays the opportunity costs of involvement has to be flexible enough to float when that opportunity cost rises. For example, a year of high international food prices may increase the opportunity cost of a landowner entered into a PES scheme. For any PES to be successful in terms of social outcomes this lost cost would have to be included into a contract adaptation, especially in a place where high instances of poverty and vulnerability to drought converge, such as in the dryland systems which occur throughout Tanzania. Because of this poverty–vulnerability nexus land owners need to maximize returns each year, a PES must be flexible to deal with this issue. It must also prepare for the dynamic effect of introducing monetary incentives e.g. if the income gain is used to increase stocking rates this may deliver an unanticipated net cost (Bulte et al., 2008).

### 4.5. Relationship between Resource System and Institutions

There are important characteristics of the relationship between the biophysical system and the institutional system that governs the resource for CPR management. Knowledge about how the biophysical system works is required for proper institutional handling and management.

With regard to PES systems, the high uncertainty around a causal link between the ecological functioning, services delivered, and land use means that it is difficult to establish just what a program can deliver (Wunder et al., 2008; Muradian et al., 2010-this issue). For example, in Costa Rica it has not been conclusive that PES itself is responsible for any additional service gains (Pagiola, 2008). Historical baselines in many settings are hard to establish (Asquith et al., 2008), and research to clearly link land use and service delivery is likely to greatly increase transaction costs of any PES (Pascual et al., 2010-this issue).

In the Pangani Basin, the service delivery to downstream beneficiaries is reported adequate — with more than 70% of domestic respondents in the city of reporting satisfaction with water supply. Although there are close to 14,000 registered water customers in Tanga (13,140 domestic users; 235 institutional; 464 commercial; and 115 industrial) only 0.65% of revenue collected goes to Pangani Water Basin Office and none of this goes directly to forest management, which is common across basins (Mwanyoka, 2005). This is worrying in an area of expanding land use change and degradation. The institutional link feeding back into the biophysical system has yet to be operationalized. Here, the biophysical system responsible for regulating water flows is disconnected institutionally from the main means to protect it, i.e. financial investment.

Being able to link the institutional system to the management of the biophysical system through a market has several impediments — one being the estimate that only 7% of water users pay any fees at all. The Pangani Basin Water Office is confronted with a number of problems all of which demonstrate the importance of understanding the system–institutional link. Turpie et al. (2003) identified several key problems in this basin: (i) water users abstracting more water than allocated in their water permits, (ii) use of water without formal water permit, especially by traditional furrows, (iii) inadequate monitoring of inefficient use of water by abstractors, (iv) inability to formulate integrated planning, development and management of water resources, (v) inadequate human resources and (vi) inadequate enforcement mechanism of regulations and by-laws.

In the Rufiji Basin, impact of the social system on the ecological system is pronounced. In the Usangu plains which are the watershed areas in the southern highlands supplying the Great Ruaha River, a combination of heavy grazing and trampling, and inefficient use of water for irrigation has resulted in the reduction of water in the rivers within the basin. In 2005–2006, the hydropower plants in the Basin, which had previously produced more than 80% of the total hydro-electrical production in the country were reduced to about 50% due to severe water shortage in the Mtera Dam. In addition, increased forest clearing, cultivation and other livelihoods activities have been brought about by the rise of population in the upper part of the Basin. With this background, survey respondents were quite forward with a willingness to pay for catchment management, but only if they could be assured that water quality and quantity would be improved. Here once again our knowledge of the system is likely only to produce an 'informed' guess about what a PES can actually deliver.

### 4.6. External Environment

Finally, the environment exogenous to the resource and user systems may also foster or impede sustainable management of a CPR. Larger scale demographic movements, changing market opportunities and demand are often major drivers to changes in land use, management and human activities (Agrawal, 2002). For example, in an extensive review of the factors driving deforestation around the world, Geist and Lambin (2002) demonstrate that macro-economic trends are a key underlying cause of deforestation. The role of new roads in changing local management conditions has also been shown to be a major exogenous factor that is likely to affect any more local CPR management (Chomitz and Gray, 1996). Other exogenous considerations include the development of low-cost technologies that either help (monitoring equipment) or hinder (portable mills) resource management; foreign aid allocation and changing government regimes. All of these could impede, augment or make obsolete local management institutions.

In the Tanzanian context, technological alternatives are unlikely to make catchment management obsolete. Both borehole wells and tapping into deep-water aquifers require substantial capitalization at the local and national scales respectively. The Rufiji Water Basin Office reported a 58% budget shortfall in 2005, and a fee collection rate of 16% on water users. Capitalization is a long-term problem in Tanzania, and therefore catchment management is likely to remain as the most cost-effective towards improving water provision and regulation.

In regard to the effects of larger scale market trends, Tanzanian catchment forests are already likely being affected by Chinese demand for hardwoods (Milledge et al., 2007). Another exogenous factor is poverty and primary resource dependence, since over 90% of Tanzanians rely on firewood for cooking and heating (Sheya and Mushi, 2000), it is likely that poverty plays an important role in conditioning water flows through the advancing degradation of woodlands and forests (Doggart and Burgess, 2005).

## 5. Discussion

Lessons from CPR management research can provide insights for potential PES implementation, not only in an East African context, but more generally where scarce funding, inadequate monitoring and limited scientific certainty dominate. Table 3 provides a summary of the previous discussion of how CPR lessons can (and have) informed PES design and can highlight impediments to PES implementation in our Tanzanian context.

For example, understanding the boundaries of the socio-ecological system is a crucial design element for PES implementation. While our ecological knowledge on the boundary of an ecological system (say watershed) may be sufficient for scoping a management intervention, our knowledge of discrete interactions between components of the system is still at an early stage. For example, we may be able to relate surface water flows to a certain type of land cover or use, but our knowledge of how flows change across time and space related to conversion of individual parcels is speculative. In our Tanzanian context this is compounded by low capacity to monitor water withdrawals and stream flows.

The above discussion points to a number of other lessons for our study sites. With regard to resource size, schemes should be unrolled on the strategic areas of the basin, working at a sub-basin level. This might also help to inform stakeholders of the functioning, condition and governance of local forests and woodlands. Another lesson points to settling existing conflicts prior to, or in coordination with, PES design. Active resolution of water conflicts should help ease some potential stakeholder reservations towards PES. Using existing networks of outreach programs and NGOs to help inform potential ES providers and buyer of how the resource system works in our case study areas could also be a lesson transposed from CPR management.

**Table 3**
CPR management lessons for PES design and implementation and findings from Tanzania case studies (*first two columns modified from Agrawal (2002)).

| | CPR considerations | PES analogs | Tanzania cases |
|---|---|---|---|
| Resource size | The size of the resource and knowledge of its boundary are both characteristics that can enable better management. Although scale is relative, typically the smaller the resource the easier it is to carry out management principles. | Ecosystem services are delivered from nested processes. Microscale nutrient exchange affects macro-scale biomass production. As scale increases in a system so does the ecological complexity. This invokes the importance of subsidiarity. | The size of the case study basins may be too large for easy implementation. Knowledge of the boundaries and governance regimes of the forests also need to be improved. |
| Group characteristics | The size of the stakeholder group, the level to which they have shared norms, and interdependencies across groups are all characteristics that have been shown to affect CPR management. Smaller group size, more common histories and norms and more interdep | Both the level to which ES buyers 'trust ' the providers to deliver a service, and the level to which the providers 'trust ' the PES scheme and its initiators have been shown to affect performance, implentation and legitimacy of PES. The number of participants (size) is also likely to affect cost of PES implementation and may therefore total limit ES delivery. | Only a small number of water users are actually registered users, therefore it might be difficult to understand all stakeholder needs. Existing conflicts among user groups are varied in nature (i.e.there is not a single solution to over coming different preferences). |
| Resource–group relationship | When the resource is in close proximity to most of the stakeholder groups, better management is enabled. The level of dependence on the resource can affect its management — the higher the level of dependence the more incentive to manage it properly. | Where the resource providing the ecosystem service is far removed from the beneficiaries (e.g. carbon offsets), the verification of the effectiveness of intervention has been deeemed critical for buyers. | In both case studies there was skepticism of whether providers and payments could actually deliver better service. Upstream stakeholders voiced concern that the downstream beneficiaries reap greater benefits under existing management. |
| Institutional arrangements | Governance rules must be clear in nature and seen as approriate by the majority of stakeholders. Ideal rules are derived from inclusive processes and not be seen as 'top-down.' | Broad stakeholder inclusion, buyers and sellers of ES, should be involved in design and monitoring. PES contract allocation should be transparent, and the contracts themselves should have some flexibility to acknowledge changing opportunity costs. | Cultural, religious and rights-based beliefs are common reasons why registering for 'water rights' is not seen as legitimate. Monitoring and sanctioning of existing registered users is limited due to budget constraints. |
| Resource–institution relationship | Both an institutional knowledge of how the biophysical system works and spatial overlap between the processes that deliver the resource and the governing institution are enabling factors for succesful management. | PES schemes should show that the intervention can deliver the service it promises. The scheme should be able to monitor system function over time, as well as monitor use, costs and benefits over time. | There is little to no existing institutional or financial link between managing upper catchments and water delivery downstream. No existing spatially explicit biophysical models of how the landscape regulate waster flows. |
| External environment | Exogenous factors such as demographic and technological changes can greatly affect the success of management. For example, improved low-cost technology for monitoring a resource may greatly enable management, where rapid population growth could hinder it. | Technological changes and population pressures (including changing preferences) affect how PES schemes are monitored, negotiated and implemented. Technology advances can make monitoring, compliance or defection easier; or for example, changes in global price of hardwood could affect local contract compliance. | Hardwood demands from Asian and Middle Eastern markets are macroprocesses affecting Tanzania forest management. Widescale poverty and population growth rate of over 2% are also likely to affect potential PES effectiveness. |

A clear monitoring plan (and budget) should be developed before implementation. On the institutional front, better integration of policies between say Ministry of Natural Resources and Tourism and the Ministry of Water and Irrigation should be commenced (preliminary conversation on this type of integration is just now occurring).

## 6. Conclusion

We have shown that there are many concerns regarding implementation of a PES scheme in Tanzania. The six enabling criteria discussed here from the CRP management literature have provided a guide for assessing the Tanzanian PES case studies. All of the criteria highlighted areas that should be of concern for PES schemes. Our investigation of these parallels in Tanzania was just exploratory and there are likely many other lessons in the CPR literature that can shed light on some problems for PES implementation. This is likely to be the case in many parts of the world currently considering PES implementation.

A recent major call from the CPR and sustainability literature is to remember that in complex socio-ecological systems there are no panaceas (Ostrom et al., 2007). This goes for PES as a CPR management solution — where no single mechanism is going to solve all of the disparate problems with managing complex socio-ecological systems. While there are clearly no panaceas, care must be taken to make sure that the lessons we learn while heading down the PES path were not already learned in other contexts, with other literatures, and other buzzwords. Here we think that the opportunities for PES systems to learn from CPR management are great.

## Acknowledgements

UNDP-GEF through the Forestry and Beekeeping Division funded the work in the Rufiji Basin. The Critical Ecosystem Partnership Fund and the WWF Tanzania Programme Office paid for the work in the Sigi Basin. The World Conservation Union (IUCN) Eastern Africa Regional Office funded the work in the Pangani Basin. We would also like to thank the Water Basin Authority managers and their staff for sharing data, and the same for villagers and owners and managers of farms and factories in the study basins. Special thanks to the special issue editors for their time and constructive feedback. This paper was improved thanks to the comments of two anonymous reviewers. Valuing the Arc through the Leverhulme Trust funded the time of Brendan Fisher and Neil Burgess to complete this paper.

## References

Abbink, K., Irlenbusch, B., 2006. Group size and social ties in microfinance institutions. Economic Inquiry 44 (4), 614–628.
Agrawal, A., 2002. Common resources and institutional sustainability. The Drama of the Commons. National Academy Press, Washington DC, pp. 41–86.
Alix-Garcia, J., De Janvry, A., Sadoulet, E., 2008. The role of deforestation risk and calibrated compensation in designing payments for environmental services. Environment and Development Economics 13, 375–394.
Asquith, N.M., Vargas, M.T., Wunder, S., 2008. Selling two environmental services: in-kind payments for bird habitat and watershed protection in Los Negros, Bolivia. Ecological Economics 65, 675–684.

Baland, J., Platteau, 1996. Halting Degradation of Natural Resources: Is There a Role for Rural Communities. Clarendon Press, Oxford.
Becker, C.D., 1999. Protecting a Garua forest in Ecuador: the role of institutions and ecosystem valuation. Ambio 28, 156–161.
Becker, C.D., 2003. Grassroots to grassroots: why forest preservation was rapid at Loma Alta, Ecuador. World Development 31, 163–176.
Bulte, E.H., Lipper, L., Stringer, R., Zilberman, D., 2008. Payments for ecosystem services and poverty reduction: concepts, issues and empirical perspectives. Environment and Development Economics 13, 245–254.
Burgess, N.D., D'Amico Hales, J., Underwood, E., Dinerstein, E., Olson, D., Itoua, I., Schipper, J., Ricketts, T., Newman, K., 2004. Terrestrial ecoregions of Africa and Madagascar: a continental assessment. Island Press, Washington DC.
Burgess, N.D., D'Amico Hales, J., Ricketts, T., Dinerstein, E., 2006. Factoring species, non-species values and threats into biodiversity priority-setting across the ecoregions of Africa and its islands. Biological Conservation 127, 383–401.
Chomitz, K.M., Gray, D.A., 1996. Roads, land use, and deforestation: a spatial model applied to belize. World Bank Economic Review 10, 487–512.
Clements, T., John, A., Nielsen, K., An, D., Tan, S., Milner-Gulland, E.J., 2010. Payments for biodiversity conservation in the context of weak institutions: comparison of three programs from Cambodia. Ecological Economics 69, 1283–1291 (this issue).
Corbera, E., Brown, K., Adger, W.N., 2007a. The equity and legitimacy of markets for ecosystem services. Development and Change 38, 587–613.
Corbera, E., Kosoy, N., Tuna, M.M., 2007b. Equity implications of marketing ecosystem services in protected areas and rural communities: case studies from Meso-America. Global Environmental Change—Human and Policy Dimensions 17, 365–380.
Dietz, T., Dolsak, N., Ostrom, E., Stern, P.C., 2002. The drama of the commons. The Drama of the Commons. National Academy Press, Washington DC, pp. 3–36.
Dietz, T., Ostrom, E., Stern, P.C., 2003. The struggle to govern the commons. Science 302, 1907–1912.
Doggart, N.D., Burgess, N.D. (Eds.), 2005. State of the Arc in 2005: special issue on Eastern Arc Mountains monitoring baselines: The Arc Journal, vol. 19, pp. 1–32.
Engel, S., Pagiola, S., Wunder, S., 2008. Designing payments for environmental services in theory and practice: an overview of the issues. Ecological Economics 65, 663–674.
Fisher, B., 2001. Sustainable Discourse and Sustainable Development in Cambodia: A Qualitative Study. University of Oxford, Oxford.
Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52, 143–150.
Keohane, R.O., Ostrom, E. (Eds.), 1995. Local Commons and Global Interdependence: Heterogeneity and Cooperation in Two Domains. Sage, London.
Kissui, B.M., 2008. Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Animal Conservation 11, 422–432.
Krishna, A., 1999. Large-scale government programmes: watershed development in Rajasthan, India. In: Hinchcliffe, F., Thompson, J., Pretty, J., Guijt, I., Shah, P. (Eds.), Fertile Ground: The Impacts of Participatory Watershed Management. Intermediate Technology Publications, London, UK.
Kulindwa, K., 2005. A feasibility study to design payment for environmental services mechanism for Pangani River Basin IUCN East African Regional Office, Nairobi.
Kulindwa, K., Msambichaka, L.A., Lokina, R.B., Hepelwa, A.S., Mngodo, R., Swai, R., 2006. A Study to Establishing Mechanism for Payments for Water Environmental Services for the Rufiji River Basin in Tanzania. Economic Research Bureau, Dar es Salaam.
Marshall, G.R., 2005. Economics for Collaborative Environmental Management: Renegotiating the Commons. Earthscan, London.
Miles, L., Kapos, V., 2008. Reducing greenhouse gas emissions from deforestation and forest degradation: global land-use implications. Science 320, 1454–1455.
Milledge, S.A.H., Gelvas, I.K., Ahrends, A., 2007. Forestry, Governance and National Development: Lessons learned from a Logging Boom in Southern Tanzania (TRAFFIC East/Southern Africa, Tanzania Development Partners Group, Tanzania Ministry of Natural Resources and Tourism).
Ministry of Finance and Economic Affairs, 2008. The Economic Survey 2007. Dar es Salaam, Tanzania.
Mittermeier, R.A., Robles-Gil, P., Hoffmann, M., Pilgrim, J.D., Brooks, T.M., Mittermeier, C.G., Lamoreux, J.L., Fonseca, G., 2004. Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions. Cemex, Mexico.
Mtalo, F., et al., 2005. Hydrology of the Eastern Arc Mountains. Ministry of Natural Resources and Toursim, Forestry and Beekeeping Division, Dar es Salaam.
Muradian, R., Corbera, E., Pascual, U., Kosoy, N., May, P.H., 2010. Reconciling theory and practice: an alternative conceptual framework for understanding payments for environmental services. Ecological Economics 69, 1202–1208 (this issue).
Mwanyoka, I.R., 2005. Payment for water services as a mechanism for watershed management: the case of the Sigi Catchment, Tanga, Tanzania WWF Tanzania Program Office, Dar es Salaam.
Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R., Ricketts, T.H., 2008. Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences of the United States of America 105, 9495–9500.
Olson, M., 1965. The Logic of Collective Action. Harvard University Press, Cambridge.
Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge.
Ostrom, E., 2008. The challenge of common-pool resources. Environment 50, 8–20.
Ostrom, E., Nagendra, H., 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. Proceedings of the National Academy of Sciences of the United States of America 103, 19224–19231.
Ostrom, E., Gardner, R., Walker, J., 1994. Rules. University of Michigan Press, Ann Arbor, MI, Games and Common-Pool Resources.
Ostrom, E., Janssen, M.A., Anderies, J.M., 2007. Going beyond panaceas. Proceedings of the National Academy of Sciences of the United States of America 104, 15176–15178.
Pagiola, S., 2008. Payments for environmental services in Costa Rica. Ecological Economics 65, 712–724.
Pagiola, S., Arcenas, A., Platais, G., 2005. Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. World Development 33, 237–253.
Pascual, U., Muradian, R., Rodríguez, L.C., Duraiappah, A., 2010. Exploring the links between equity and efficiency in payments for environmental services: a conceptual approach. Ecological Economics 69, 1237–1244 (this issue).
Postel, S.L., 2000. Entering an era of water scarcity: the challenges ahead. Ecological Applications 10, 941–948.
Pretty, J., 2003. Social capital and the collective management of resources. Science 302, 1912–1914.
Sheya, M.S., Mushi, S.J.S., 2000. The state of renewable energy harnessing in Tanzania. Applied Energy 65, 257–271.
Turner, R.K., Daily, G.C., 2008. The ecosystem services framework and natural capital conservation. Environmental and Resource Economics 39, 25–35.
Turpie, J., Ngaga, Y., Karanja, F., 2003. A preliminary economic assessment of water resources of the Pangani River Basin. Economic Value, Incentives for Sustainable Use and Mechanisms for Financing Management. IUCN— East African Regional Office, Nairobi, Tanzania.
van Wilgen, B.W., Le Maitre, D.C., Cowling, R.M., 1998. Ecosystem services, efficiency, sustainability and equity: South Africa's Working for Water Programme. Trends in Ecology & Evolution 13, 378.
Vatn, A., 2010. An Institutional Analysis of Payments for Environmental Services. Ecological Economics 69, 1245–1252 (this issue).
Wade, R., 1988. Village Republics: Economic Conditions for Collective Action in South India. ICS Press, San Francisco.
Wunder, S., Alban, M., 2008. Decentralized payments for environmental services: the cases of Pimampiro and PROFAFOR in Ecuador. Ecological Economics 65, 685–698.
Wunder, S., Engel, S., Pagiola, S., 2008. Taking stock: a comparative analysis of payments for environmental services programs in developed and developing countries. Ecological Economics 65, 834–852.
Wunscher, T., Engel, S., Wunder, S., 2008. Spatial targeting of payments for environmental services: a tool for boosting conservation benefits. Ecological Economics 65, 822–833.