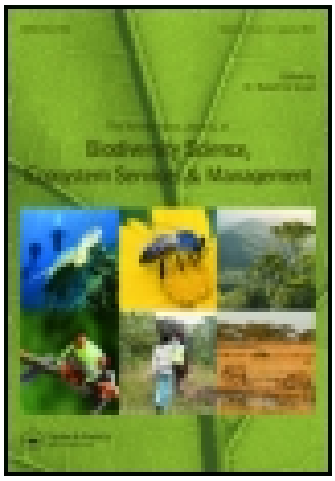

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Local assessment of changes in water-related ecosystem services and their management: DPASER conceptual model and its application in Taita Hills, Kenya

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Fresh water provisioning is a crucial ecosystem service (ES) in the agrarian societies of East Africa. Water resources are highly dependent on several other ES such as the water retention capacity of vegetation and the purification properties of soil. However, ES are constantly challenged by dynamic changes within water–land–vegetation–human relations. Environmental policies usually address immediate anthropic pressures but overlook multiple historical stressors, or 'drivers'. This article presents a local assessment of changes in the water-related ES in the Taita Hills, Kenya, applying the Drivers, Pressures, Actions, State, Ecosystem services, Responses (DPASER) model, adapted from the Drivers, Pressures, State, Impacts, Responses (DPSIR) framework, boosted with ecosystem services and human actions and combined into a historical perspective. A review of the legislation, interviews, participatory mapping, timelines and focus group discussions were used in data gathering. The results indicate that land demarcation in the 1960s and consequent land privatization have been the main drivers of change in water-related ES, since these determined the prioritization of agricultural production over conservation of forests, wetlands and rivers. This case study shows that the degradation of water-related ES is strongly linked to historical development of land ownership and loss of commonality, and suggests enhancement of inter-sectoral management.

Keywords: ecosystem services; environmental changes; environmental management; local institutions; Taita Hills; water resources

1. Introduction

Ecosystem services (ES) are benefits to humankind from nature and important for human well-being (Costanza et al. 1997; Tallis & Polasky 2009). These services include provisioning services such as water and food, regulatory and maintenance services such as climate and water regulation, soil formation and nutrient cycling, and cultural services such as recreational and spiritual benefits (Haines-Young & Potschin 2013). According to the Millennium Ecosystem Assessment (2005), human activities have accelerated degradation of ES worldwide since the 1950s, especially due to increased resource demands of the rapidly growing human population. The high rate of degradation can also be attributed to poor management of natural resources, worsened by insufficient regulatory mechanisms. This can be ascribed to ES either being poorly understood, undervalued or indeed not recognized at all by management institutions and the public (Costanza 2000; Daily et al. 2009). Nevertheless, institutions often play a key role in guiding resource management, implementing policies, mediating values, creating incentives that support natural resource users' decisions and solving the problems of 'collective action' (Poteete & Ostrom 2004).

In semi-arid East Africa, fresh water provisioning, regulation and purification services provided by aquatic, forest, wetland and soil ecosystems are among the most crucial and contested types of ES (Vörösmarty et al. 2005; Raleigh & Kniveton 2012). In this study, we focus on the Taita Hills, in south-eastern Kenya, where the overuse of natural resources and consequent environmental degradation (e.g. Newmark 1998; Pellikka et al. 2009; Erdogan et al. 2011) are placing pressure on water-related ES. We use historical analysis to trace the changes undergone by water-related ES during the last few decades and assess the factors that have created a situation of unsustainable management (Mosse 1997; Adger et al. 2003). Finally, we evaluate the applicability of the ES approach to water resource management in the study area.

Before describing the case study, we first introduce the ES approach in water management and evaluate how that approach has been adopted in Kenya. We seek answers through the analysis of the institutional acts and legislation influencing the local governance of natural resources, as well as the responsibilities and tasks undertaken by either individual, collective or governmental actors.

1.1. *ES approach to water resource management*

Natural resource management has been dominated by sectoral approaches mainly focusing on either specific risk limitation or outcome maximization (Tallis & Polasky

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2009; Kelble et al. 2013), which have been reflected in management decisions that overlook a wide set of ES, often resulting in socially and ecologically harmful unintended consequences to these services. As water resources are cross-sectoral, it is necessary to understand the linkages between them, the supporting ecosystems and the related social systems (Wallace et al. 2003). Subsequently, there has been a shift towards ecosystem-based management approaches that focus on ES and that adequately capture the complexity and dynamics of local human–biophysical systems and aim to improve integrated action between sectors (Kelble et al. 2013). For example, although the relation between forest conservation and water resources is generally recognized (Postel & Thompson 2005), a case-specific complexity needs to be acknowledged. The impacts of reforestation or afforestation depend on the land-use type replaced by forest (Mango et al. 2011), the extent of the forested area (Croke et al. 2004; Li et al. 2007) as well as the spatial scale where the impacts are being observed (Ellison et al. 2012). In tropical areas with characteristic wet and dry seasons, a possible consequence of the increase in cultivated land or grassland at the expense of forested area is an increase in rainy season flows and reduction in dry season flows, which is related to the reduced maintenance of the base flow (Croke et al. 2004; Mango et al. 2011). The hydrological value of tropical montane cloud forests is also considered very significant since these forests are capable of capturing moisture from the atmosphere that provides additional water for the ecosystem (Hamilton & Cassells 2003; Bruijnzeel 2004). Therefore, cooperation between forestry and water sector management should be strong.

Cook and Spray (2012) suggest that an ES-based approach could complement Integrated Water Resources Management (IWRM), currently considered a leading, yet highly criticized, approach in water resources management (Biswas 2008; McDonnell 2008). ES and IWRM approaches have many similarities, because they both support integrated management of water and land resources and allow for the negotiation of 'trade-offs between human and environmental needs with the aim of fostering sustainability' (Cook & Spray 2012, p. 97). However, the ES approach considers sustainability over a longer term than IWRM. Indeed, the ES approach is more elaborate in that it considers the human–ecological nexus while IWRM is rather vague in this regard. Nevertheless, the ES approach is likely to face similar criticism faced by IWRM concerning its implementation. As both ES and IWRM approaches treat the ecosystem as a stakeholder in water management, there is still a need to translate the interdependence between human and environmental well-being into actual improved water governance.

1.2. ES approach to water management in Kenya

In Kenya, water resources management has until recently been guided by the Water Act 2002, described as 'An Act of Parliament to provide for the management, conservation, use and control of water resources and for the acquisition and regulation of rights to use water […]' (GoK 2002, p. 940). A new water bill has been drafted, but during this research it had not come into effect and therefore we do not consider it in this article. The Water Act 2002 does not contain any direct reference to ES other than water as a resource and commodity. However, it obligates the ministry responsible for water resources management to formulate a National Water Resources Management Strategy and review it regularly (GoK 2002, p. 949, sec 11(1,2)). Currently, the strategy for 2010–2016 is in place. It recognizes water as a finite and scarce resource and highlights the need for public participation and commitment to other IWRM principles in water resources management (MEMR 2012). The Water Act 2002 also requires that the six regional offices of the Water Resources Management Authority (WRMA), responsible for the management and protection of different catchment areas in Kenya, develop Catchment Management Strategies whose contents are in line with the national strategy (GoK 2002, p. 952, sec. 15(1)). The water resources of the Taita Hills are under the management of Athi River Catchment WRMA Mombasa Sub-Region Office. However, at the time of writing, the previous Athi River Catchment Management Strategy had expired and was in the process of being updated (WRMA 2012). Implementation of catchment management strategies is disseminated to sub-catchment levels through Water Resource Users Associations (WRUAs) (GoK 2002, p. 953, sec. 15(5)), which are organized community groups. WRUAs are responsible for conserving catchments locally and are obliged to create sub-catchment management plans consistent with regional catchment management strategies.

The establishment of local level sub-catchment management plans is still an ongoing process. During our fieldwork in February–September 2013, we were able to access two such plans in the Taita Hills. Both contain a chapter on 'Catchment and Riparian Conservation', which summarizes the assessment of catchment degradation and 'measures to rehabilitate catchment and riparian areas, including soil and water conservation practices' (WSTF & WRMA 2009, p. 27). Even though the sub-catchment management plans do not directly mention ES, the inclusion of catchment and riparian conservation and linkages between trees and water resources in the strategy can be regarded as an understanding of the principles of IWRM and ES approaches. WRUAs are also entitled to receive WRUA development cycle funding for implementing catchment conservation activities such as tree nurseries, afforestation, gully control, building check dams and run-off drainage structures. To date, however, the enforcement of catchment protection activities has been rather weak in Kenya (WRMA 2012).

2. Methods

2.1. Study area

Taita Hills (3°25′S, 38°20′E) is a mountain massif located in a semi-arid part of south-eastern Kenya, approximately 150 km from the Indian Ocean (Figure 1). The inter-

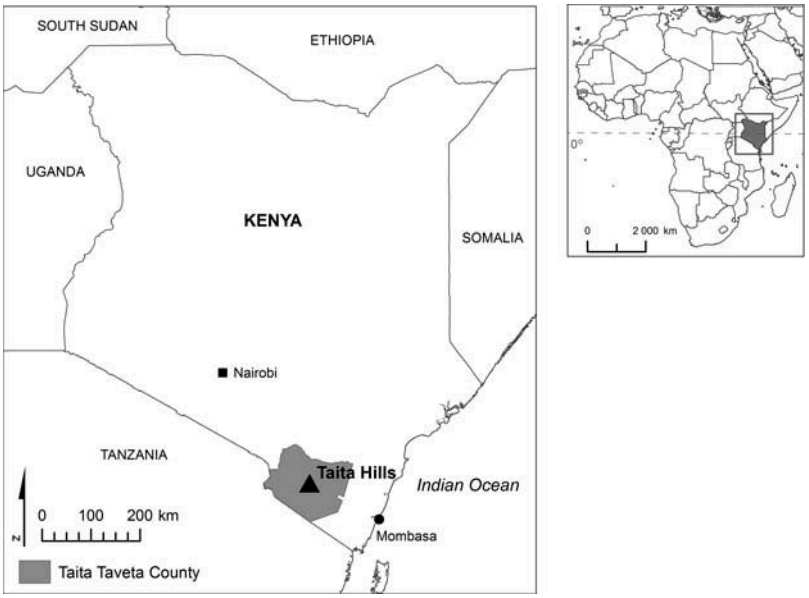

Figure 1. Location of the Taita Hills in Taita Taveta County in South-Eastern Kenya.

tropical convergence zone affects the climate of the area causing a bimodal rainfall pattern. The so-called long rains arrive along with the south-eastern trade winds in March–May and north-eastern trade winds bring the short rains in November–December. Mist and cloud precipitation occurs year round in the upper parts of the hills (Pellikka et al. 2009). Due to the orientation of the hills and orographic rainfall pattern, the north-western slopes receive less rainfall than the other slopes. According to data from the Kenya Meteorological Department, the average annual rainfall in the upper parts was around 1100 mm in 1989–2005, whereas in the lower middle zone it was only 500–700 mm (Maeda 2011). The Taita Hills form the northernmost part of the chain of the Eastern Arc Mountains, which have been covered by cloud and rainforests for tens of millions of years (Rogo & Oguge 2000). However, during the past 200 years, and especially since the 1960s, indigenous forest cover has decreased significantly (Newmark 1998; Pellikka et al. 2009).

The majority of the people in the Taita Hills obtain their livelihood from small-scale family agricultural holdings (KNBS & SID 2013). The poorest subsistence farmers who have small farms normally consume all the food they produce, whereas some households with larger land areas are occasionally able to produce surplus maize, beans, bananas, green grams, oranges, vegetables or livestock products for sale in the local markets. Due to the high demand, especially when the seasonal rains fail, some food commodities are imported to Taita formally and informally, for example, from Tanzania (Taita Taveta County 2013). Income from the sale of crops and livestock products varies between seasons, but normally it forms around 10–12% of the income of Taita Taveta County (NDMA 2013a, 2013b, 2014a, 2014b). The majority of the income still comes from casual labour on the sisal estates or irrigation schemes, as well as from remittances from family members working outside the county. Many households also sell tree products such as fruits, nuts and timber (Soini 2005). Charcoal burning is considered among the coping mechanisms, especially in the lowland ranches when other sources of income are reduced (KNBS and SID 2013), and its production forms typically 6–7% of the county's income (NDMA 2013a, 2013b, 2014a, 2014b).

In the upper parts of the Taita Hills, water for agricultural and domestic uses is commonly fetched from rivers and streams. Households capable of paying for water can be connected to a water supply system provided by Taita Taveta Water and Sewerage Company (TAVEVO). In addition, small-scale community-managed water projects provide water for people in several areas. Other water sources include ponds, dams, springs, wells, boreholes and rain water (KNBS and SID 2013). During the dry season, especially in the lowland areas, people may need to rely on water vendors who transport water from the hills or more distant areas.

Due to the large topographical variation, the Taita Hills include many ecological zones, causing high spatial variation in water-related ES. Therefore, two catchments covering different climatic zones were selected as case study areas for this study (Figure 2). Wundanyi catchment (14.6 km^2) is located at higher altitude (1258–2104 m), where rainfall is abundant and temperatures are lower. Mwatate catchment covers a larger area (79.1 km^2), extending from moist, high altitudes to dry lowland areas (831–1909 m).

2.1.1. *Environmental management and the problem of land ownership in the Taita Hills*

Land ownership is a crucial issue in environmental management in the Taita Hills because it determines access to and use of natural resources, including water. The process

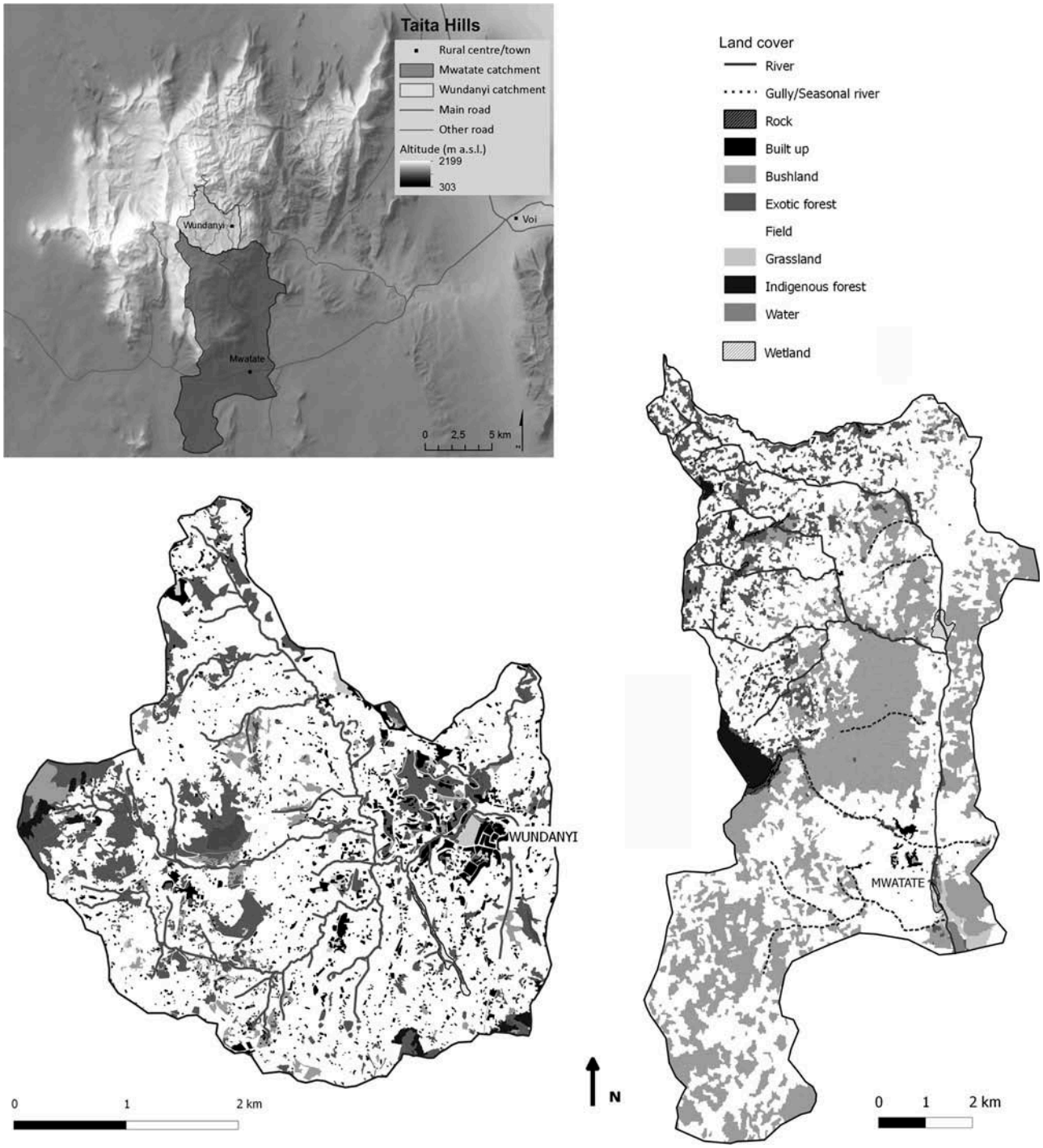

Figure 2. Locations of Wundanyi and Mwatate catchments in the Taita Hills and their land cover and surface water resources.
Land cover source: Clark & Pellikka (2009); rivers, gullies and wetlands were added to the maps based on aerial photographic data and fieldwork from this study.

of land demarcation was introduced in the Taita Hills under the Land Adjudication Act of 1967 (Waaijenberg 2000) that had its roots in the so-called Swynnerton Plan (Swynnerton 1954). This plan aimed at increasing production and intensifying agricultural development in Kenya by surveying all high-quality agricultural land and consolidating fragmented holdings. Prior to land adjudication, farmers had access to land in various agro-ecological zones in the Taita Hills, which enabled the continuous production of food even when there was drought in some areas (Waaijenberg 2000). It also allowed the resting of agricultural areas to reconstitute their fertility. Land ownership was collective and based on *kichuku* (kin groups). Even during that time those *kichuku* that had settled first in a given *iganza* (neighbourhood) possessed larger land areas than those groups that had settled later. However,

land tenure reform and the introduction of private ownership aggravated the inequalities in access to land and decreased the capacity of farmers to adapt their farming activities to varying climatic conditions (Mkangi 1983; Fleuret 1988). Furthermore, population growth and a patrilineal inheritance system have caused excessive land subdivisions and intensification of land use. Consequently, the average area of cropland per household in the Taita Hills is currently only one to two hectares (Waaijenberg 2000). Therefore, it is frequently seen that there is inadequate space to grow food and have indigenous trees and wetlands within the same farm, which makes the protection of water-related ES problematic.

2.2. *DPASER framework for a qualitative assessment of water-related ES and their management*

The assessment of the current state of ecosystems and their changes over time can inform decisions, strategies, regulations and policies at different scales, which will shape the future management and use of water-related ES (Atkins et al. 2011). A framework proposed to facilitate this assessment is the Drivers, Pressures, State, Impacts, Responses (DPSIR) model (e.g. Bowen & Riley 2003). This framework has found broad application in ecosystem assessments due to its capacity to improve communication between policymakers, stakeholders, and scientists (Kelble et al. 2013). The DPSIR model presents a chain of causal links starting with 'drivers' – the underlying factors promoting environmental change. These drivers create several or many 'pressures' on the system. These pressures then change the 'state' of the system, causing 'impacts' on ecosystems and society, eventually leading to 'responses', which include the environmental management decisions (Mace & Baillie 2007; Atkins et al. 2011).

Kelble et al. (2013) suggested that a major problem in applying the DPSIR framework for integrating scientific ecological knowledge and describing human interaction with ecosystems is that it does not explicitly include ES. They proposed a new model, EBM-DPSER, where they replaced impacts, which in the original model represented only negative anthropogenic impacts, with 'ecosystem services' (ES) to include also positive changes to the model. The EBM in the model refers to the ecosystem-based management approach, which highlights a holistic perspective and integration of individual sectors in order to improve resource management efficacy and sustain ES (Slocombe 1993; Rosenberg & McLeod 2005). In this model, the ES link people to the state of the ecosystem, which is determined by the condition of its measurable physical, chemical, and biological attributes (Kelble et al. 2013). These attributes, on the other hand, include the characteristics that define ES. Kelble et al. also suggested that the structure of the model should be a causal network rather than a chain, as in the original DPSIR model.

The EBM-DPSER model aims at objective quantification of the complex interactions between human society and ecosystems, and assumes the availability of measured data of the biophysical attributes of the ecosystems. Therefore, it cannot be adapted for qualitative research without adjustments. In this study, we modify the EBM-DPSER model towards a qualitative approach in which human perception and historical experience of the environmental changes play a key role. In line with the traditional DPSIR framework, we highlight the drivers of change, because we think that it is important to be aware of the historical trajectories in order to understand the changes in the ecosystem and avoid declensionist narratives in environmental management that blame the local farmers for environmental destruction (Davis 2006). The analysis of the drivers, both social and biophysical, is limited to those affecting the study area directly. However, it is evident that each driver is affected by preceding networks of interactions in varying spatial and temporal scales. We also suggest that both the DPSIR and EBM-DPSER models do not adequately recognize the role of concrete human actions that follow the pressures, which would be important especially in a small-scale assessment. Therefore, we propose a revised model, Drivers, Pressures, Actions, State, Ecosystem Services, Responses (DPASER), where an 'actions' class is added. The structures of the original DPSIR model, the EBM-DPSER model of Kelble et al. (2013) and the proposed DPASER model used in the current study, are presented in Figure 3.

2.3. *Data gathering and analysis*

Data for the study were gathered in February–September 2013 in Wundanyi and Mwatate catchments. The major part of the data consist of 44 semi-structured interviews. We selected the informants from different local government departments and agencies working in sectors that influence the management of water-related ES in the Taita Hills (Table 1). In addition, we interviewed those key informants involved in water resources management within the community who could attest to changes in ES in the catchments. These included chiefs, village elders, private companies, WRUAs, non-governmental organizations (NGOs) and other organized community groups. The interview questions were designed to collect information on the respondents' perceptions of the state and changes in water-related ES, their roles in managing the ES and the challenges they faced. The public officers and other informants selected have the mandate to address local environmental issues and regulate the use of natural resources, and thus their priorities and strategic views inevitably affect the management of these resources. However, their answers are subjective and hence a qualitative analysis of their views is needed. We also used secondary data from various documents published by the Kenyan government and other institutions to validate the information provided by the informants.

Other methods complemented the interviews. We organized two community workshops, one in each study

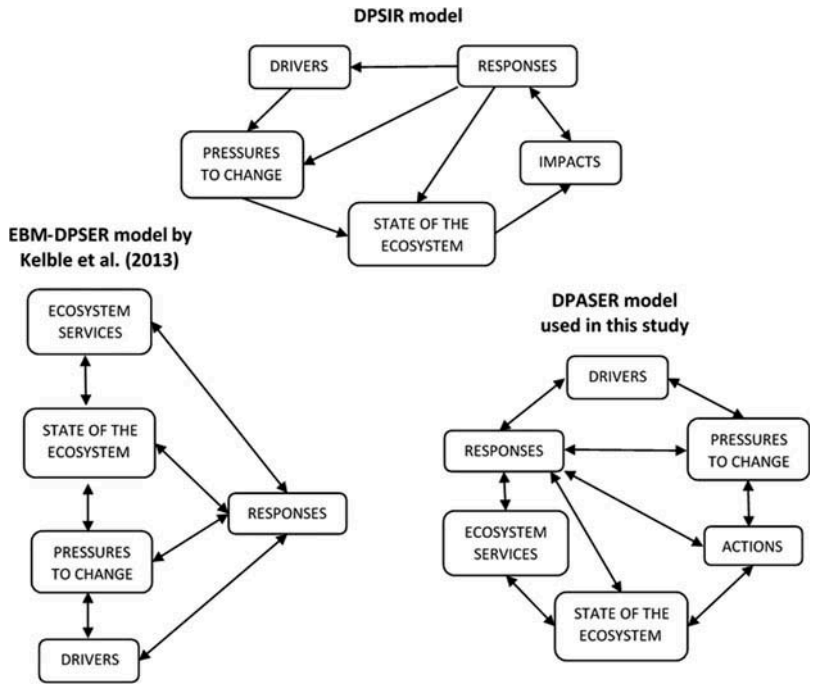

Figure 3. The original DPSIR model (Kelble et al. 2013, adapted from Figure 1, p. 2), EBM-DPSER model proposed by Kelble et al. (2013, adapted from Figure 2, p. 5), and DPASER model introduced in this study. While the DPSIR model stresses the role of drivers and the EBM-DPSER model focuses on ES, DPASER integrates both factors. The latter model also recognizes the concrete human actions that cause changes in ecosystems.

catchment, at the first stage of data collection in February 2013. The workshop participants included forest, water user, conservation and tree nursery groups, farmers and fish pond owners (Table 2). A total of 23 and 32 participants from Mwatate and Wundanyi catchments, respectively, took part in these workshops. The workshops included participatory mapping and timeline exercises as well as focus group discussions. Subsequently, transect walks were carried out to observe the issues within the areas identified during the workshops as important to water-related ES. Concluding workshops with the same community groups and institutional representatives interviewed were organized in both catchments in February 2014 in order to validate the research findings.

We used content analysis in order to integrate information from the interviews, timelines, participatory mapping exercises, focus group discussions and transect walks into the DPASER model. Analysis of the changes that have occurred in water-related ES is thus based on the perceptions of the local institutional representatives and community groups and their voluntary actions. Quantitative measurements of the condition of the ecosystem attributes are not considered in this study, because consistent regular measurements of, for example, river water quality and discharges are not available. The responses and management decisions are also influenced by national- and international-scale scientific findings and policies, the full-scale analysis of which is beyond the scope of the current study.

3. Results: DPASER framework analysis of water-related ES in the Taita Hills

In this section we analyse the main drivers, pressures and human actions affecting the ecosystems of the Taita Hills and move on to describe the current state of these ecosystems and changes in water-related ES. Finally, we examine the responses undertaken by local institutions and community groups. The results of the analysis are summarized in Figure 4.

3.1. Drivers, pressures and actions causing environmental change

Many local institutions and community groups blame increased human population for intensification of deforestation activities and encroachment of springs and wetlands, especially in the highland areas of Wundanyi and Mwatate catchments. This claim is understandable since the highland areas are densely inhabited. However, we suggest that population growth alone does not explain the severe degradation of the environment. Instead, we argue that degradation originates from the land consolidation and privatization processes of the 1960s. The local county council indicated that although the land adjudication process tried to take into consideration and set aside sensitive ecosystems to be managed as communal areas, many important water and forest ecosystems were still left within private lands. In order to continue farming, land owners needed to cut down trees which led to a large-scale increase in deforested area. Furthermore, rivers were used

Table 1. Institutions and experts interviewed and their operational areas. Wundanyi and Mwatate catchments fall under the jurisdiction of institutions operating at Taita and Mwatate District levels, respectively. Institutions operating at Taita Taveta County and coastal region/national levels cover both catchments.

		Jurisdiction/operating area			
Institution/expert	Number of interviews	Taita District	Mwatate District	Taita Taveta County	Coastal region/ national
Government departments and agencies					
Coast Water Services Board	2		x		x
County Council Water Office	1		x		
District Agricultural Office	2	x	x		
District Fisheries Office	1	x			
District Irrigation Office	1	x	x		
District Land Reclamation Office	1			x	
District Water Office (Coastal Water Services Board District Area Coordinator Office)	2	x	x		
Geology County Department	1			x	
Kenya Agricultural Productivity and Sustainable Land Management Programme	1			x	
Kenya Coastal Development Project, Hazina ya Maendeleo Pwani, County Liaison Office	1			x	
Kenya Forest Service	3		x	x	
Ministry of Lands, Department of Land Adjudication	1		x	x	
National Drought Management Authority	1			x	
National Environment Management Authority	1			x	
Water Resources Management Authority	5				x
Provincial administration					
County Council Clerk's Office	1	x			
Village elders	4 (15)*	x	x		
Community-Based Organizations (CBOs)					
Star CBO (TAVEVO) Water kiosk	1		x		
Taita Environment Initiative	1	x	x		
Water and irrigation projects	4 (10)*	x	x		
Water Resources Users Associations	3 (36)*	x	x		
Non-Governmental Organizations (NGOs)					
World Vision (Water, Sanitation and Health project)	1		x		
Companies					
Taita Taveta Water and Sewerage Company (TAVEVO)	1			x	
Teita Sisal Estate Ltd	2		x		
Wildlife Works	1		x		
Scientific expert					
Professor, University of Nairobi	1				x
Total number of interviews	44				

Notes: × denotes the jurisdiction/operating area of the interviewee.
*Number of respondents interviewed.

Table 2. Community groups attending Wundanyi and Mwatate workshops in 2013.

Activity	Wundanyi workshop	Mwatate workshop
Agriculture	Chapa Kazi group	Kipusi Valley banana development group
	Kajire group	
	Kitivo group	
	Lukundo group	
	Mbirwa Caregivers	
	Mwakishesha Irish Potato group	
Conservation	Taita Taveta Wildlife Forum	Chawia Environment Committee
		Dawida Biodiversity Conservation Project
		Kidaya Ngerenyi Network
		Taita Taveta Wildlife Forum
Fish farming	Wundanyi Fishpond group	
Forests	Iyale Community Forest Association (CFA)	Kenya Forest Service representativeMabono/ Wichwala (Susu Forest)
	Wesu/Mbili/Weni Mwana CFA	SuNdiFu CFA
Tree nurseries	Irienyi group	Taita Environmental Initiative
		Mseto group
		Star group
Water	Iyale/Msidunyi Water Project	Lower Mwatate WRUA
	Kidakiwi Water Project	Mambisi Dam
	Toro Water Project	Mwasineyi Water Project
	Wundanyi Water Resources Users Association (WRUA)	Ngulu Dam GroupUpper Mwatate WRUA

as boundaries of demarcated land areas and hence current land titles cover areas up to river banks.

There are still some forests and wetlands that have not been demarcated and on which no one is supposed to encroach. However, illegal logging and cultivation have become common in those areas due to lack of productive land in privately owned areas. One example of an area where much illegal encroachment takes place is the Kipusi valley, which forms the central-eastern part of the Mwatate catchment. It contains one of the most important wetlands in the study area. Although this wetland is natural, the locals call it 'Ngulu Dam'. The encroachment of the wetland started in 1978 when the chief of the area had to allow local farmers to cultivate the land around the wetland in order to acquire food during a severe drought. However, the clearing of land did not stop after the drought and people still think that the wetland is the only place they can have reliable agricultural production, given the generally dry conditions in the lowlands of the catchment. According to estimations by local people, the size of the wetland has reduced from 16 to 12 ha due to encroachment.

Some respondents considered the planting of exotic trees, mostly *Eucalyptus* species, responsible for reducing water resources. According to local people, these were introduced in Mwatate in the 1930s and in Wundanyi in the 1950s by the colonial settlers. These trees draw much water from the soil (Scott & Lesch 1997; Scott et al. 2005), and the locals informed us that they were initially used to drain off excess water from the areas designed for cultivation, construction or recreation. Local people subsequently noted the commercial value of wood from these fast-growing exotic species. However, most institutions now value indigenous trees because they recognize their important climate- and water-regulation properties, and have therefore started to encourage their replanting. Most local people still prefer exotic trees because they grow more rapidly and produce more immediate economic returns, while indigenous trees take many years to mature: 'In fact you might die before you get the products', one respondent stated. The Kenya Forest Service also supports commercial forestry, which plants exotic tree species.

Some respondents also claimed that the introduction of new technologies, such as power saws, have simplified the felling of trees for timber and thus increased the cutting of indigenous trees and growing of exotic trees. Furthermore, general poverty and lack of employment drive people to turn their attention to local forest resources.

Many respondents also indicated that rainfall variability has increased in the Taita Hills by explaining that it is currently common for seasonal rains to arrive late or to be scarce. Some people believe that this is related to ongoing global climate change.

3.2. *State of the ecosystems and changes in water-related ES*

Cutting down of indigenous trees has reduced the water-retention capacity of the catchments and thus diminished water provisioning in the Taita Hills. Water levels in many springs, rivers and streams have decreased and some have even completely dried up during the last 50 years. According to elderly locals, this gradual reduction in water levels peaked during the 1980s and 1990s. Previously, especially the area in the hilly upper zones of Wundanyi catchment used to be wet throughout the year:

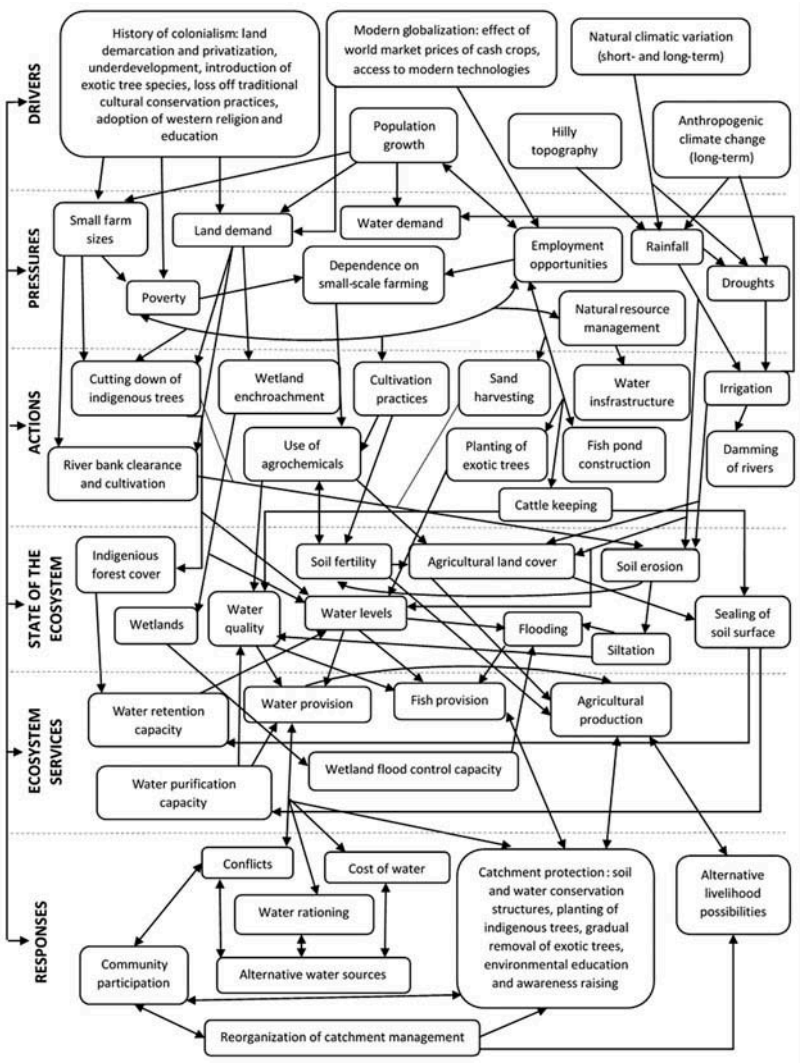

Figure 4. DPASER model for water-related ES in the Taita Hills. The arrows indicate either one-way (single arrow) or reciprocal (double arrow) impact between different components. The responses create an anthropogenic feedback mechanism that affects many ecosystem services, state of the ecosystem, human actions, pressures and, to a lesser extent, drivers (long arrow on the left). Historical drivers, such as the period of colonialism, cannot change, but policy making can address adequately their induced pressures.

> The area was wet. […] because of those indigenous trees, whenever you passed below the forests, you will think it's raining, but it's not raining, every time the ground was wet. (Interview with a district irrigation officer (grew up in Taita), Wundanyi, 11 June 2013.)

The clearing of vegetation has also exposed land to enhanced erosion. This decreases soil fertility and, together with sand harvesting, increases the siltation of rivers and dams. According to some interviewees, water quality has also diminished in areas where cultivation activities take place around natural sources such as springs, due to contamination from agrochemicals and eroded soil. However, where springs arise from protected areas, the water is clean and safe for human consumption.

Since communities depend mainly on local natural sources for their domestic and agricultural water needs, water scarcity has become one of the biggest challenges people currently face especially in the dry lowland areas. Water scarcity reduces agricultural and horticultural production in the area. According to the Ministry of Water and Irrigation, lowered water quantity is one of the major limiting factors for irrigation in the area. The irrigation potential area of Taita District is 582 ha and that of Mwatate District is 595 ha, but the areas currently only realize 52 and 70 ha, respectively (Ministry of Water and Irrigation, unpublished report).

Along with reduced water provisioning, food provisioning in the form of fish in natural streams has also ceased. Elderly locals report that they used to go fishing in the rivers of the Taita Hills when they were young but nowadays there are no fish because of the reduced water levels and quality. According to locals, fish provisioning stopped during the 1950s and 1960s in the rivers and is currently available only in the wetlands of the lowland Mwatate catchment during the rains. On the other hand,

fish production has become an important livelihood in the hills again since the introduction of Kenya's Economic Stimulus Programme in 2009, which supported the construction of fish ponds in the area. However, some locals claim that the fish ponds use too much water and contribute to the pollution of natural streams, even though, according to the Fisheries Department, seepage and chemical and water use in fish ponds is controlled.

3.3. *Institutional and community responses to the degradation of water-related ES*

Downstream water users suffer more from reduced water provisioning than those living in upstream areas. For example, people in lowland Mwatate catchment depend on water from spring sources up in the hills. During the dry season, competition for water increases causing conflicts among users. Most of the water sources dry up and people in the lowlands have to travel longer distances to access water. In August 2013, the average distance required for households to access water was 2.37 km and fetching water took 1.7 hours per household per day (NDMA 2013a). This has implications for the welfare of local people, in particular because during the driest months, people buy water from private vendors at a cost ranging from 20 to 80 Kenyan shillings (0.2–0.9 US dollars) per 20l of water. In comparison, buying water straight from the suppliers during the wet season only costs 2–5 Kenyan shillings (0.02–0.06 US dollars) per 20 l.

Many local institutions and community groups are currently involved in tree planting and reforestation initiatives aiming to protect the catchments. Tree planting is mainly motivated by the Forest Policy, implemented through the Forest Act 2005 by the Kenya Forest Service, which requires them to attain 10% tree cover in Kenya by 2020 (MEMR 2007). This goal has been strenuously adopted by the Ministry of Agriculture, and hence the Agriculture Act on Farm Forestry Rules 2009 requires farm owners to maintain at least 10% forest cover on their land holdings (GoK 2012a, Cap 318). These rules provide guidelines on the types of tree to be planted, stipulating that 'the species or varieties of trees planted should not have adverse effects on water sources, crops, livestock, soil fertility and the neighbourhood and should not be invasive'. Specifically, the rules stipulate that no agricultural landowner is allowed to grow or maintain any *Eucalyptus* species on wetlands and riparian areas.

Several institutions also carry out interventions related to soil and water conservation. For example, the Ministry of Agriculture and World Vision promote establishment of structures that can conserve soil on the farms. These include terraces on the hilly areas to control erosion. Zai pits and V-bunds absorb rainwater and maintain soil moisture for longer periods, enabling crops to grow even during the dry season. Another activity undertaken by the Ministry of Agriculture is riverbank protection. For the financial year 2012–13, the Wundanyi office set a target to implement 35 km of riverbank protection and conservation activities. Other interventions include education and awareness programmes. The Ministry of Agriculture educates farmers about environmentally friendly cultivation techniques to mitigate catchment degradation. The Ministry of Livestock and local NGOs are also training local farmers to explore alternative livelihood options that demand less land and water, such as beekeeping and poultry and rabbit farming. Local institutions also emphasize the need to increase rainwater harvesting. However, the necessary facilities for this are often not available as funds are limited. Several institutions are also undertaking different strategies to develop alternative water sources such as boreholes, dams, water pans and shallow wells in drier lowland areas of the catchments. Furthermore, in order to prevent overuse of water resources, the County Council of Taita Taveta and the Ministry of Water, together with local chiefs, carry out regular patrols along the rivers when water levels at the intakes decrease.

Since some of the major water sources in the Taita Hills have now become seasonal, Mwatate County Council is now opting to look for other reliable sources elsewhere. Some of the plans include sourcing water from neighbouring districts from perennial sources, such as Mzima Springs in Tsavo West National Park, north-west of the Taita Hills, or Lake Challa on the Tanzanian border. Some institutions have suggested even more drastic measures, such as resettling people living in the hills to the lowlands and planting trees in the higher areas in order to reverse catchment degradation.

4. Discussion

4.1. *Challenges in implementing the ES approach to water management in the Taita Hills*

Natural resource managers face numerous challenges in trying to implement interventions to sustain water-related ES. Some of these challenges stem from practical aspects such as limited technical and financial capacity, while others arise because of the absence of adequate legislation or authority to enforce regulations. Lack of adequate numbers of field staff and extension officers has made it difficult for government agencies to follow up the implementation of regulations such as those concerning riverbank protection and water abstraction. For example, the nearest regional WRMA office is located in Mombasa, 180 km from the Taita Hills, and therefore WRMA officers do not visit the area very often. This has made the implementation of catchment management strategies in the Taita Hills difficult, including building the capacity of the WRUAs, which usually consist of ordinary community members with no expertise or technical know-how concerning water management. Most local operators are aware of the existence of WRMA but have no collaboration with it. The Upper Mwatate Sub-Catchment Management Plan blames the lack of sensitization by WRMA for illegal abstractions. In addition, no water allocation plan has been made for the area to date (Upper Mwatate WRUA et al. 2012).

Local institutions also indicate that enforcement has been difficult since the last amendment of the Chiefs' Act in 1997, which significantly reduced the authority of local chiefs. In its current form, the Chiefs' Act gives local administration officers a mandate to issue orders for preventing the pollution or obstruction of water sources, regulating the cutting of timber and prohibiting the destruction of trees (GoK 2012b). However, their power is limited by the weak sanctions they can impose on defaulters, with fines not exceeding 500 shillings (5.78 US dollars) – an amount that can very easily be raised by any defaulter. Protection of riparian areas is regulated by the Agriculture Act on Basic Land Usage Rules, 1965, issued by the Ministry of Agriculture, which restricts cultivation, soil disturbance, vegetation clearing or livestock grazing on any land lying within 2 m from a small watercourse and 30 m from a large watercourse (GoK 2012c, Cap 318). However, according to the Ministry of Lands, officers cannot control actions on private land once it is registered.

Reforestation initiatives, despite being quite popular among the institutions and the community, have also faced challenges in the Taita Hills. Many tree-planting activities have failed due to poor coordination and organization. For example, farmers have been encouraged to grow tree seedlings but once these are ready for planting, there is no system in place to market the seedlings for distribution. Furthermore, there has been insufficient capacity to sustain planted trees to maturity. Sometimes locals do not offer full support for these initiatives, or curtail the efforts owing to their traditional beliefs. For example, on one occasion, a local institution planted 40,000 seedlings to rehabilitate a degraded area. However, some locals started a forest fire during the dry season and destroyed all the trees, because they believed that this practice would attract rainfall.

Reforestation is also a controversial issue. Although local informants claim that there was more water in the past when the indigenous tree cover was greater, there is insufficient scientific research being carried out regarding the forest–water nexus and complex feedbacks and trade-offs between various ES in this area. As shown by the review by Ellison et al. (2012), reforestation may decrease water provisioning on a small scale (<1–10 km^2) but increase it at regional and global scales through intensification of the water cycle. Thus, there is a chance that the water-related benefits of reforestation remain largely external to the area. Even if the water retention service of the forests increased the year-round water availability in lowland areas, it might be difficult to convince people living in upstream areas of the benefits of reforestation when it reduces the area of land available for cultivation or growing of exotic trees. Motivating people to plant trees in their fields would require the creation of alternative livelihoods. In the workshops organized during the fieldwork, some participants also suggested that people living in lowland areas should pay people in upstream areas for planting trees and protecting water sources. However, development of a 'payment for ES' mechanism would require careful planning and reconsideration of the nature of land property rights in order to make the mechanism sustainable. Previous critical studies have shown how the biophysical environment has been impacted negatively by applying the principles of natural resource governance through mechanisms such as monetary valuation, privatization and enclosure (Heynen et al. 2007; Minoia 2012).

Despite the challenges faced by institutions in protecting catchments, there is also a positive outlook among them. Most institutions are designing alternative strategies for enabling local people to maintain their livelihoods while ensuring environmental sustainability. The Ministry of Agriculture, for example, rather than completely banning cultivation along riverbanks, is encouraging farmers to plant crops that do not need regular cultivation, such as napier grass, sugarcane and bananas. Furthermore, to ensure the sustainability of interventions as well as to provide validity and 'ownership' of responses, institutions are increasingly using local communities to manage ecosystems while encouraging community-driven initiatives, such as community water projects. Ultimately, maintaining and improving local farmers' income should be the key target of resource management, because only in that way it is possible to reduce the pressures on water-related ES in the long term.

4.2. *Applicability of the ES perspective to water resource management*

Although water-related ES are highly valued by institutions and community groups in the Taita Hills, they are prioritized differently across various sectors and uses. Most institutions still focus on single-sector management approaches, concentrating their responses only on issues specific to their sectors, which stems from the division of labour between different government institutions. Therefore, we suggest that the integration of sectors and the ES approach should be focused more on training of officials and community groups involved in water resource management.

Some institutions also overlook the crucial connections among natural and social systems' components. The ES approach has not yet shown capability to fix this issue. Generally, the problem seen is in incorporating the knowledge provided by social sciences and knowledge other than 'scientific' into ES-based management (Cook & Spray 2012). For example, in the Taita Hills, the local people possess traditional knowledge on ES (Himberg 2011) that would provide valuable information for water resource management. In addition, the significance of local practical knowledge and skills, *mētis* (Scott 1998), which can be transferred into explicit knowledge only partially, if at all, should also be acknowledged in all management initiatives by empowering community member participation. This has already been attempted in some projects, but many project coordinators have failed in motivating communities to share their skills, especially if monetary compensation is not available. However, in the

Taita Hills, where the objective scientific measurement data of the ecosystem attributes are fragmented, non-existent or not easily accessed, institutional and community responses and environmental management strategies need to be based on qualitative assessments of the state of the ecosystems and non-scientific knowledge. This is also the case in many other areas in the developing world. We suggest that the DPASER model used in this study and participatory data collection methods could facilitate assessment of the ecosystems and ES in such data-poor regions.

When utilizing the ES approach in water resource management, we must also be aware of the potential consequences on the attitudes of community members and natural resources managers towards nature. Reconceptualizing the environment as a bundle of services creates a risk of according only instrumental value to nature, being viewed as a means to an end, which often leads to commodification of nature (McCauley 2006). This leaves considerable space for unsustainable behaviour towards the environment. For example, what would motivate people to protect an ecosystem that does not provide them with adequate amounts of pure water or provides water that is not accessible to them? This is not to say that environmental management and protection should be based on some vaguely defined intrinsic value of nature or ES (Justus et al. 2009), but rather that one must become aware of the potentially negative outcomes of the dichotomy: 'nature as a service provider/human beings as service users'. Consequently, environmental management should reconcile the aspects of commonality of rights and responsibility to overcome exploitation based on individual property rights (Ostrom 1990; Poteete & Ostrom 2004). A review of common resources management studies by Oldekop et al. (2010) showed that community management of forest resources may lead to positive conservation outcomes, but that strong institutional management structures are also needed. However, governance of natural resource management should both include preventive actions and support livelihood options to strengthen ES values, rather than focusing on mere legal and sanctioning frameworks.

5. Conclusion

In this study, we analyse water-related ES in the Taita Hills from a historical perspective using the DPASER conceptual framework adapted from the DPSIR model. The study brings into focus different drivers and thus the diverse aspects of agency, not only the individual (or household) end-users who are constrained by marginalized resources. The study highlights the importance of history, including reforms in land policy and regulations that have contributed to changes in ecosystem dynamics.

In the Taita Hills, links between various ecosystem functions and water resources are generally well recognized by government officers and community groups involved in natural resource management, and are currently included in several management guidelines. However, the single-sector governance and legacies of short-sighted land consolidation processes have been drivers of environmental deterioration. It appears that land adjudication in the 1960s did not comprehensively consider the protection of crucial forests, river banks and wetlands during the allocation of titles. It also obscured the status of river and spring water as common pool resources, since currently many farmers consider that they own the water that crosses their land or borders it. Privatization has also made land and water resources less accessible to many. Furthermore, land adjudication was an act of myopia since it did not consider natural population increase. If this land adjudication had been based on common lands rather than rigidly imposed private holdings, it would have been easier for farmers to use the land more flexibly for their subsistence.

What we argue is that technical restoration and sectoral responses to environmental protection cannot provide durable solutions to problems of endangered ES. Rather, we suggest that the current development trajectories can be reversed by enhancing multi-sectoral cooperation and reconsidering the conditions of private ownership of land and resources. The ES approach provides a good framework for looking at these issues, but it also requires functioning and well-coordinated management structures. Decreasing institutional authority should not mean that individuals become solely responsible for the exploitation of resources. Rather, community groups should be provided with sufficient supporting structures, which would enable them to make sustainable management decisions. Furthermore, it is important to increase the level of scientific study on the forest–water nexus in order to support conservation decisions that fit local circumstances and motivate communities to adopt them. There is considerable uncertainty about the future of water resources in the Taita Hills considering the drastic changes that have occurred over the last 50 years. Therefore, it is important to conceive a participatory action plan to empower people into making sustainable choices in times of crisis.

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