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Analysis

Restoring and managing natural capital towards fostering economic development: Evidence from the Drakensberg, South Africa

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ABSTRACT

Can a payment for flows of ecosystem goods and services system, following appropriate management and restoration of natural capital produced in rural areas of a developing country, be developed in a way that benefits communities, the commercial sector and the environment? This fundamental question acts as rationale for conducting an in-depth assessment as to whether the development of markets for ecosystems is both appropriate and sufficient when dealing with the restoration of natural capital of two degraded study areas within the Maloti–Drakensberg mountain range in southern Africa, which is a fire-prone grasslands ecosystem. The mountain range is South Africa's most strategic source of fresh water. While occupying less than 5% of South Africa's surface area, it produces 25% of the country's runoff through rivers, major dams, and national and international inter-basin transfers.

Addressing the question, the study develops an integrated hydrology–ecology–economic model based on the functional relationships between these three aspects in managing and restoring the natural capital of the two study areas. It was found that the benefits of introducing improved management practices exceeds cost in low to medium degraded quinaries, but not in heavily degraded quinaries. The economic return on the water (baseflow) produced by such a system of improved land use management, however, far exceeds that of conventional (construction-based) water development programmes and offers meaningful economic and market development opportunities.

1. Introduction

Payments for ecosystem services (PES), by which land owners' and users' are compensated for a change in land use management practices that will increase the flow of ecosystem services, in South Africa have been well-described (Blignaut et al., 2007, 2008; Letsoalo et al., 2007; Turpie et al., 2008; Marais and Wannenburgh, in press). This South African evidence builds on and extends conceptual and fundamental work in this field by Wunder (2007), Pagiola (2008), Wunder et al. (2008), and many more. In all these cases it has been highlighted that, not unlike any other market, some of the fundamental requirements for the development of such a payment for ecosystem services system is the need to have a willing buyer and a willing seller of a particular services at an agreed price as facilitated by and through a functioning institutional arrangement. In this paper we will consider these aspects with respect to the ecosystem services rendered by improved catchment management in South Africa's prime mountain catchment, the Maloti–Drakensberg mountain range.

The Maloti–Drakensberg mountain range is a fire-prone grassland ecosystem of which 25,000 km^2 is protected as a World Heritage Site. It qualifies for this status on two grounds, cultural (due to the more than 40,000 Khoisan/Bushman rock art paintings) and for its unique biodiversity with 2520 species of higher plants (Blignaut et al., 2008). This mountain range is South Africa's largest and most strategic source of fresh water and it depends on the integrity and health of the grassland ecosystem to protect this source of water. While occupying less than 5% of the country's surface area, it produces 25% of the country's water runoff (Schulze, 1997; Diederichs and Mander, 2004), and is supplying water to much of the southern African sub-continent through rivers and inter-basin transfers. A threat to this water source, however, is the fact that a remaining 25,000 km^2 is not protected and subject to varying intensive and extensive forms of agriculture by

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both commercial and subsistence farmers (Blignaut et al., 2008). This portion of the mountain is subject to degradation in the form of vegetation loss (bare soils) and soil erosion resulting from incorrect fire management, as well as the combination of inappropriate grazing management regimes and improper stocking rates. The combination of these factors is affecting both the quality and quantity of water runoff and baseflow. Additionally, the degradation leads to an increase in sediment production and the resultant silt built-up in dams, biodiversity loss and the loss in carbon storage and the carbon sequestration potential of the soils and the vegetation cover. Past efforts, through regulations, to improve fire and grazing management regimes and stocking rates have been largely unsuccessful as the level and spread of degradation is currently still ongoing.

The aforementioned failure of regulation is due to both the land owners and users ignorance about the legislation, and the non-enforcement thereof as a result of capacity and resource constraints. This begs the question: Can markets do better? This is especially true in the light of the rapid rise and interest in the development of markets and payments for ecosystems goods and services (PES) over the past decade. Based on this, the question we wish to address here is: Can a payment for flows of ecosystem goods and services system, following appropriate management and restoration of natural capital produced in rural areas of a developing country, be developed in a way that benefits communities, the commercial sector and the environment? To answer this question, we commence by describing the study area and the required management interventions, and discuss the impact of sustainably managed grasslands on the water flows in the respective sub-catchments. This is followed by a cost–benefit analysis of introducing such interventions, which include both restoration and the maintenance of natural capital. It should be noted that we, for purposes of this paper, consider restoration and rehabilitation synonymous as being "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER, 2002).

2. Study area

Given the vast area and the large number of factors impacting on the management of the entire Maloti–Drakensberg mountain range, the study focuses on two specific water catchments: one in the north of the Drakensberg mountain range known as the Upper-uThukela and one in the south, known as the Upper-Umzimvubu. These catchments differ topographically, are spatially removed, and enjoy different levels of degradation with the northern site ecologically much healthier than the southern site. Given these differences they provide for the spectrum of variances one will be faced should one wish to scale-up restoration and the development of markets throughout the entire system. The National Government identified these two catchments as priority catchments and requested that they be analysed.

The Upper-uThukela catchment in northwest KwaZulu-Natal forms the northeast border with the Royal Kingdom of Lesotho and is located between latitudes 28° 33′ and 29° 04′ and longitudes 28° 53′ and 29° 20′. The catchment comprises 1876.19 km² and is made up of nine Quaternary Catchments (QC) — V11A to V11H and V11J — shown in Fig. 1. This topographically rugged area ranges in altitude from ~1150 m in the east to ~3300 m along the northwest to southeast trending top of the Drakensberg mountain range in the west. The sub-delineations of the QCs have mean sub-catchment slopes ranging from 3.8% to 52.1%. Mean Annual Precipitation (MAP) varies from 745 mm to 1660 mm in the mountainous sub-catchments, mostly between October and March. Natural vegetation in this area belongs to the grasslands biome and comprises tall grasslands in the east, short sourveld in the foothills with alpine type grasslands in the high Drakensberg. The high rainfall over the summer period has both led and contributed to erosion along the slopes (Everson et al., 2007). The area comprises a mixture of rural communities and commercial farmland. The rural communities rely heavily on natural resources and practice subsistence agriculture which includes both livestock and crop farming.

The Upper-Umzimvubu catchment in the south of the mountain range contains the upper Kinira (Tertiary Catchment 33) and Tina (Tertiary Catchment 34) tributary catchments of the Upper-Umzimvubu River. The catchment lies between latitudes 30° 15′ and 30° 46′ and longitudes 28° 14′ and 28° 41′, comprises 3977.71 km² and forms the southeast border with the Royal Kingdom of Lesotho. This catchment is therefore more than double the Upper-uThukela catchment and is made up of the 11 QCs, *viz*. T33A to T33E and T34A to T34F (Fig. 2). The mean QC altitudes of this study area range from ~1530 m in the east to ~2050 m in the west and mean sub-catchment slopes range from 6.5% to 29.1%. These mountains are therefore considerably lower and the slopes less steep than in the case of the Upper-uThukela. MAP across these catchments varies only slightly, between 735 mm and 900 mm, while the low altitude range precludes the presence of alpine grassland. These differences are noteworthy since many of the variations in the results, as discussed below, are because of these topographical differences.

3. The model

3.1. Hydrological modelling based on ecological realities

3.1.1. Introduction

We selected the daily time step ACRU agro-hydrological simulation model (Schulze, 1995 and updates) as an appropriate simulation tool with which to make the assessments between (i) the impact on baseflow, stormflow and sediment yield under a business-as-usual, unmitigated scenario and (ii) a scenario which included the land use management changes as discussed earlier. We chose this model based on the fact that it can distinguish explicitly (through its internal representations of hydrological processes) between the generation of stormflows, baseflows, total sub-catchment and accumulated flows as well as sediment yields, on a daily/event-by-event basis for the various land management scenarios sketched above. It should be noted that the model is based on 50 years of daily rainfall and temperature data. The 50 years of daily rainfall values for each quinary were derived from Lynch (2004), after which a rigorous rainfall station selection procedure was followed (Kunz, 2004) and numerous quality control checks were undertaken (Warburton and Schulze, 2005). Daily temperature values were taken from research by Schulze and Maharaj (2004), who then applied regional lapse rate corrections to adjust station data to be representative of the typical altitudes of Quinary catchments. A detailed description of the entire catchments database set-up can be found in Schulze et al. (2005).

With regard to the model itself, ACRU is arguably one of the most comprehensively tested hydrological models in South Africa. A review by Schulze and Smithers (2004) verifying the model's internal state variables and model output against observed data revealed that the model's streamflow generating mechanisms (e.g. initial abstractions, baseflow releases, hydrograph routing) have been verified in 7 studies, catchment runoff in 31 studies (including 9 done internationally in the USA, Eritrea, Germany, Zimbabwe and Swaziland), flood estimation in 4 studies in the RSA and USA, wetland processes in 3, groundwater levels in 3 and water quality constituents in 4 studies. Based on these verifications it has been concluded that the outcomes of the model could be considered robust.

The model has also been populated, on a quinary basis, with all the quinary specifics such as land cover (using the national land cover data base), prevailing land use management regimes, and typography. Given the significant degree of uncertainty, no provision for the plausible impacts of climate change has been made.

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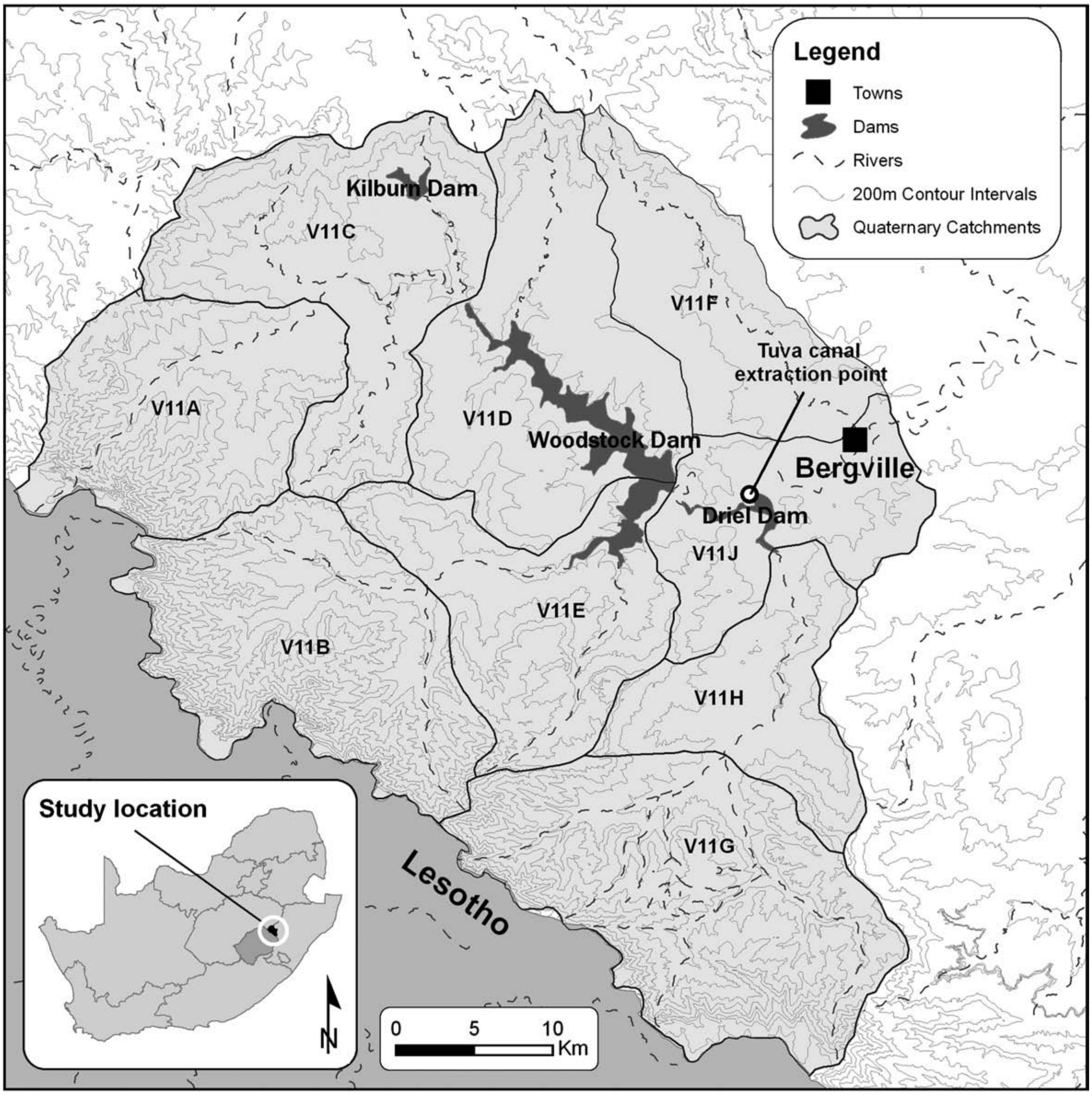

Fig. 1. Location of the Quaternary Catchments making up the Upper-uThukela case study area.
Source: Kindly produced by the Institute for Natural Resource. 2009.

3.1.2. Land use data

Given that the objective is to seek a payment mechanism which compensates people for a change in land use practice and thereby optimises water flows, it was important to develop an understanding of the various water-related flows both before and after restoration and/or change in land use. This was done on a spatially sensitive basis. Within many quaternary catchments (QCs) considerable physiographic heterogeneity exists and natural sub-zones occur. These differences are essentially altitude related since rainfall, temperature, soil properties and land uses are all aspects affected by altitude. Each sub-zone will therefore have different hydrological responses to changes in land use management regimes. For this reason each QC was sub-delineated further into three Quinary catchments. In an effort to employ a consistent methodology of sub-delineating QCs into Quinaries according to altitude-determined "natural breaks" in the topography (and not into equal area sub-divisions), the Jenks' Optimisation Procedures in ArcInfo were applied to sub-divide each QC into three Quinaries. These three Quinaries are the upper, middle and lower Quinaries of each QC, designated as Quinaries 1, 2 and 3. The outflow of the lower Quinary in a QC does not enter the upper Quinary of the next downstream QC because valley bottoms feed into valley bottoms and not into valley headwaters.

This spatial sub-division made it possible to decide upon quinary-specific management interventions that are based on the experimental knowledge of grassland ecologists (Everson et al., 2007). These management interventions included "present" and "attainable" veld (or grassland) management scenarios and are discussed in more detail below.

3.1.3. Land use management interventions

3.1.3.1. Upper-uThukela

3.1.3.1.1. Present condition before intervention. Based on expert opinion by resident and practicing ecologists (Everson et al., 2007) and satellite imagery, the "present" veld management scenario in the Upper-uThukela, the upper Quinaries are assumed to be completely intact and in their natural state according to Acocks' (1988) natural vegetation classification, i.e. veld is well managed with little grazing, largely due to inaccessible steep terrain. The middle Quinaries are assumed to have their natural vegetation in a 70% condition, i.e. they enjoy a basal cover (the area of ground covered by the living basal portions of plants) equal to that of 70% of what one would have expected intact basal cover would have been. The areas are therefore lightly grazed but not overgrazed. The accessible lower Quinaries are heavily overgrazed, with the condition of their respective veld types consisting of only 15% basal

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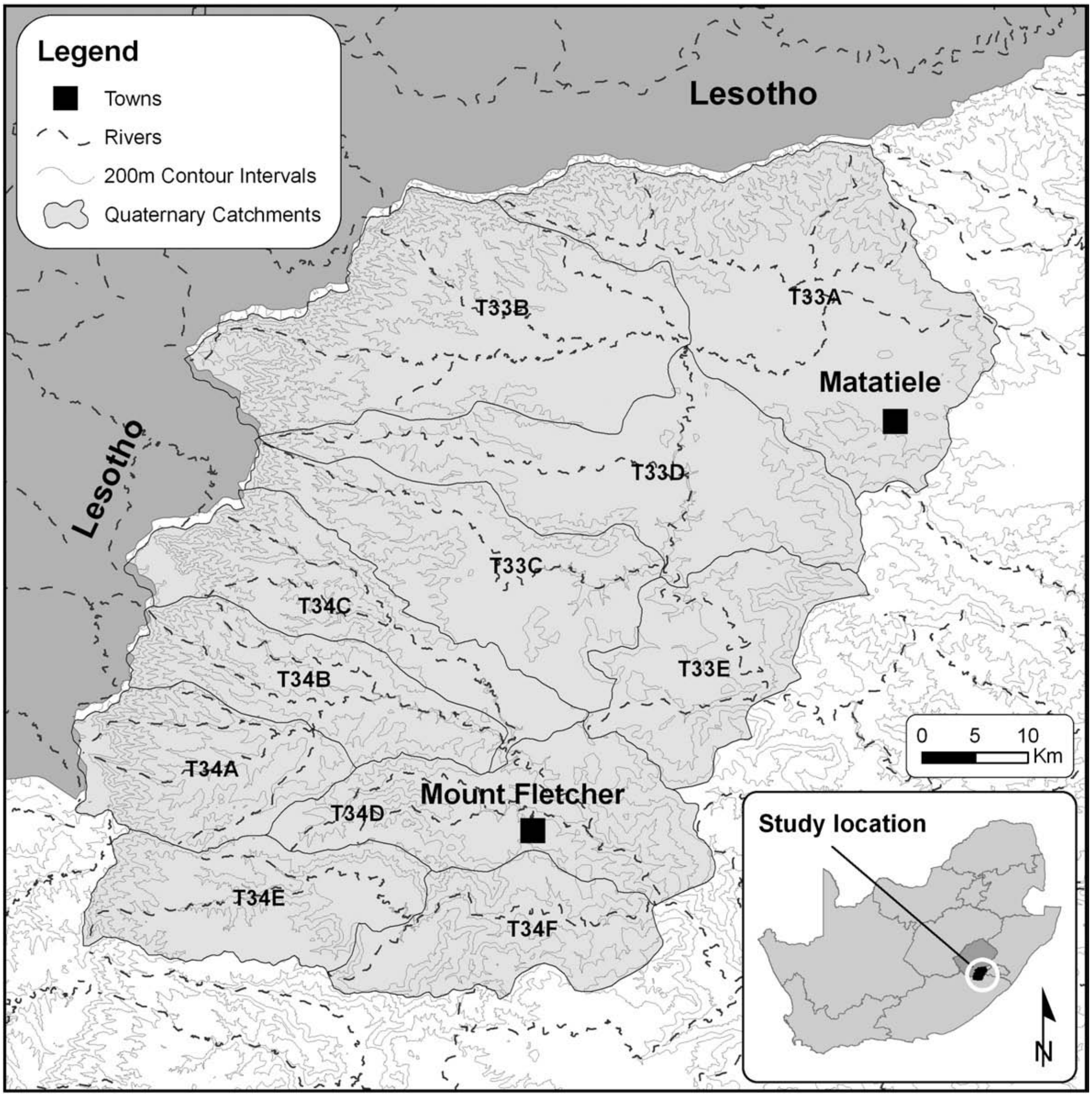

Fig. 2. Location of the Quaternary catchments making up the Upper-Umzimvubu case study area.
Source: Kindly produced by the Institute for Natural Resource. 2009.

cover of grass tufts which remain after overgrazing. In all Quinaries an annual early winter (June) veld burn is taken as the norm.

3.1.3.1.2. Attainable condition after intervention. Once restored, the “attainable” veld management scenarios envisage a 100% condition (i.e. well managed) of the respective baseline grasslands in all Quinaries, with a spring burn only every second year, as recommended by ecologists and practiced as a general rule of thumb allowing for spatial variations by Ezemvelo KZN Wildlife. This practice is augmented by rotational grazing and reduced stocking rates to achieve the required outcome (Tainton, 1999; Tainton et al., 1999; Fynn et al., 2003; Uys, 2006; Reynolds et al., 2007, and Manson et al., 2007).

3.1.3.2. Upper-Umzimvubu

3.1.3.2.1. Present condition before intervention. The Upper-Umzimvubu veld management scenarios are much more complex than those of the Upper-uThukela. Firstly, a distinction is made between areas under *natural grasslands* versus areas identified in satellite imagery as already being *degraded natural grassland*. It is assumed that these areas are degraded to such an extent that it would not be possible to restore them using market-based instruments. In present conditions, the *degraded natural grassland* of the respective natural vegetation represented by Acocks' (1988) veld types in all three Quinaries of all Quaternaries are in a 15% condition due to overgrazing and, additionally, are subject to an annual early winter burn. The areas currently under *natural grassland* (and not already degraded) are lightly grazed (i.e. 70% condition) in the upper Quinaries, but significantly overgrazed (i.e. 15% veld condition) in the middle and lower Quinaries, in addition to being subjected to annual June burns. The Upper-Umzimvubu therefore experiences much greater resource use pressure than the Upper-uThukela in the lower and middle Quinaries due to being generally lower in altitude with less steep slopes and therefore more accessible to livestock.

3.1.3.2.2. Attainable conditions after intervention. An “attainable” condition for the *natural grasslands* (i.e. those areas not yet degraded) in the Upper-Umzimvubu catchment would be a 100% veld condition (essentially no grazing) in the upper Quinaries, with a 70% condition (controlled rotational grazing) in the middle and lower Quinaries with spring burns every second year (Tainton, 1999; Tainton et al., 1999; Fynn et al., 2003; Uys, 2006; Reynolds et al., 2007; Manson et al., 2007). However, the already *degraded natural grasslands* in all bottom Quinaries are in such a poor state that it is considered neither financially feasible nor practical in the short term to restore the veld. Therefore these areas are assumed to remain in a heavily degraded state.

The outputs of the hydrological model, namely changes in baseflow and sediment yield, were fed into an economic model to determine the economic implications of the changes in land use practices.

3.2. The economic model

Arguably the single most challenging obstacle to overcome in establishing a payment for ecosystem services (PES) system is the search for a common currency among ecologists, hydrologists and economists. The need for such a common currency arises from the fact that it is necessary to link hydrological responses (i.e. changes in baseflows, stormflows and sediment yields) to a measurable land use management change that has a measurable impact on an ecological indicator. These linkages are required to develop a payment mechanism which enables compensation to participants based on measurement of an ecological indicator which reflects a change in land use and associated improvements in hydrological responses. The cost of the land use management change must then be compared to the benefits of such a change for society at large to establish the economic viability of such an intervention.

We identified basal cover as an outcome of management that can be measured and which is directly linked to the effectiveness of management and, importantly, is also a direct driver of hydrological processes. With this in mind, we developed an integrated systems model (Fig. 3) to describe the interaction between the economic viability and management interventions, land use changes, the change in the state of an ecosystem and hydrological changes. These interactions are depicted in Fig. 3 using "+" and "−" signs to indicate whether a positive or negative correlation exists between variables. The circles in the figure indicate management interventions which, in this case, are assumed to be (i) grassland restoration — that is the reseeding/restoration of denuded areas and the restoration of erosion gullies through the construction of gabions, and (ii) fire and stock management change to ensure rotational grazing and a biennial spring burn.

These management changes will lead to a range of beneficial ecological impacts. The benefits of these interventions are improved basal cover, and improved grasslands and riparian ecosystem functioning (which includes improved soil carbon storage through both the avoidance of top soil losses and the increase in above-ground biomass' ability to generate soil carbon — the most notable carbon sequestration

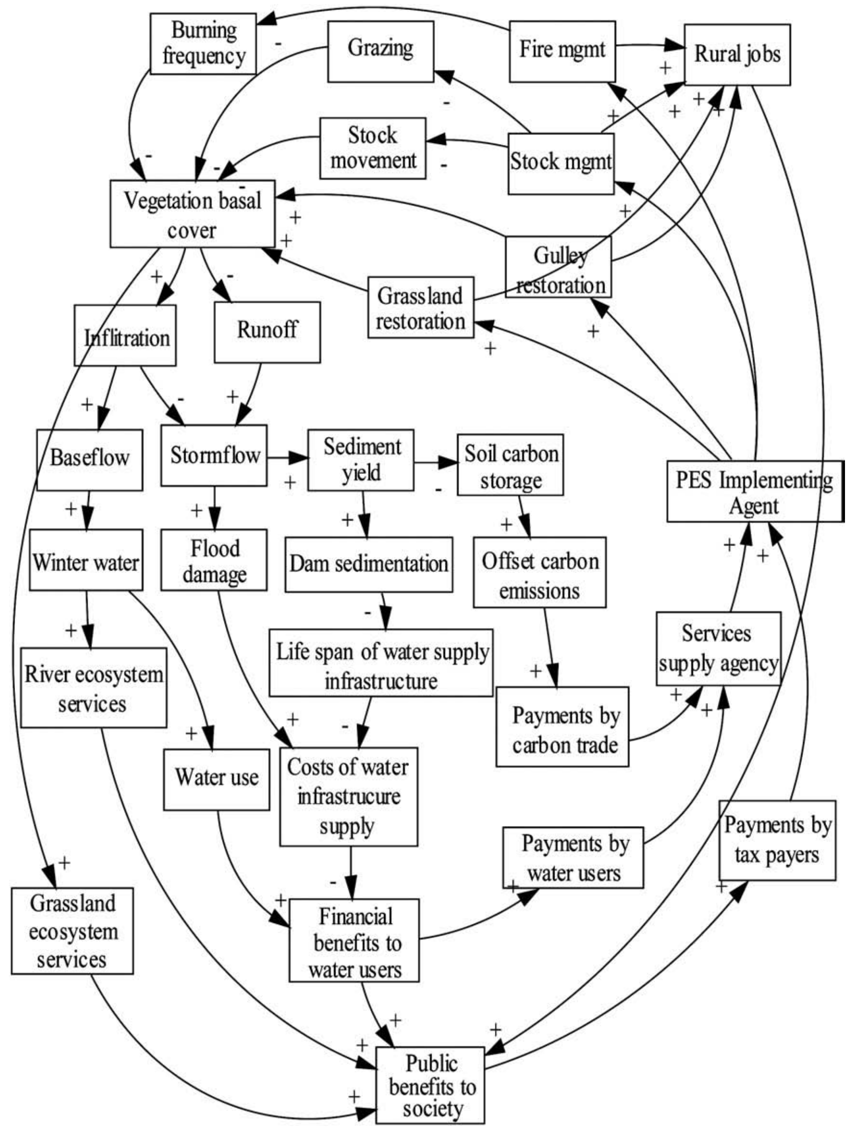

Fig. 3. Functional relationships among the range of variables in the integrated ecology–hydrology–economic model indicating the expected impact of the management intervention on basal cover and a change in basal cover on hydrological responses and its subsequent impacts on the economy and the economic instruments required to effect the required change. The "+" and "−" signs indicate whether a positive or negative relationship exists between variables.
Source: MDTP, 2007.

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service of grasslands) (Knowles et al., 2008). There are a range of beneficial hydrological impacts because of the improved basal cover (see Fig. 3). These are improved infiltration, a reduction in stormflows, an enhancement in baseflows during winter months, and a reduction in sediment yields. These positive hydrological and ecological impacts have a range of beneficial economic implications. These include a reduction in flood damage and dam sedimentation, which leads to a reduction in the cost of managing the dam infrastructure. Additionally, the improvement in the low-flow season baseflows leads to improved and sustained economic activity which, in turn, is anticipated to lead to more or sustained jobs in the rural areas and, hence, increased income for those areas. Secondary economic activities such as local trading (e.g. formal and informal sector retailing), services provision (e.g. herding, child minding, security, traditional healing and thatching), and additional tourism opportunities (e.g. guiding, accommodation and pony trekking), are also possible, but have not been quantified in the model. From the above it should be evident that while the full extent of restoration and management cost (also including the opportunity cost of the foregone returns from unsustainable agriculture calculated as the difference between the current returns and the expected returns from sustainable agriculture practices) has been included, only the immediately viable and marketable benefits, i.e. additional base flow in winter, sediment reduction and carbon storage, has been quantified. This therefore provides for the most conservative approach and avoids "selling" services for which there are no immediate market.

To convert the economic benefits, i.e. improved base flow, sediment reduction and increased carbon storage, to financial flows rely on the application of various economic instruments such as those indicated in Fig. 3. These are actual and direct payments for ecosystem goods and services by the beneficiaries of the respective services. In doing so, the market for ecosystem goods and services links the so-called first (formal) economy to the second (informal) economy of the country by potentially contributing substantially to economic development in general. This outcome is aligned with the notion that for any restoration or conservation strategy to be successful in a developing country context, it has to be an economic development strategy as well (Aronson et al., 2007). To facilitate the establishment of such a market institution and to ensure the enactment thereof requires a considerable degree of social capital among all the stakeholders.

4. Quantifying the benefits and the costs of a change in land use management and restoration

4.1. Hydrological modelling: Results

A summary of the results from the hydrological model are provided in Table 1 indicating the changes in baseflow and sediment. Note that the results are for the entire 27 and 33 Quinaries of the QCs of the Upper-uThukela and Upper-Umzimvubu catchments respectively.

From Table 1 it is evident that the hydrology–ecology and economic model interaction for the same set of suggested land use changes differs substantially between the Upper-uThukela and the Upper-Umzimvubu. While the Upper-uThukela yields much more

Table 1
Simulated changes in winter (April–September) baseflow and annual sediment yield after introducing land use management changes and restoration compared with the current, unmitigated situation for all 60 quinaries in the two catchments.

Upper-uThukela					Upper-Umzimvubu				
	Area	Change in winter baseflow	Change in winter baseflow	Reduction in sediment yield		Area	Change in winter baseflow	Change in winter baseflow	Reduction in sediment yield
	ha	m^3 at the 50% percentile	m^3/ha	ton		ha	m^3 at the 50% percentile	m^3/ha	ton
Quinary1	2047	22,950	11	8966	Quinary1	8290	0	0	9106
Quinary2	7344	48,167	7	23,423	Quinary2	19,898	97,182	5	422,664
Quinary3	11,304	1,601,230	142	278,352	Quinary3	38,756	104,634	3	452,781
Quinary4	4944	263,252	53	51,049	Quinary4	7948	−226,113	−28	1542
Quinary5	9149	665,228	73	38,068	Quinary5	13,942	201,435	14	596,298
Quinary6	11,184	3,177,185	284	553,314	Quinary6	38,016	403,770	11	1,134,013
Quinary7	4925	54,732	11	7448	Quinary7	1509	−5044	−3	4617
Quinary8	7745	239,085	31	7236	Quinary8	10,754	146,070	14	404,066
Quinary9	12,294	777,270	63	74,076	Quinary9	24,434	88,416	4	254,271
Quinary10	2156	83,916	39	2189	Quinary10	3389	−7623	−2	7797
Quinary11	5378	90,762	17	6193	Quinary11	12,268	116,059	9	326,589
Quinary12	16,430	199,398	12	48,914	Quinary12	30,407	138,992	5	385,938
Quinary13	5254	230,912	44	10,853	Quinary13	10,929	−6458	−1	16,959
Quinary14	6257	181,685	29	14,685	Quinary14	2578	14,382	6	71,203
Quinary15	6896	618,228	90	68,531	Quinary15	13,168	54,477	4	243,860
Quinary16	988	7144	7	1197	Quinary16	3930	−74,907	−19	1015
Quinary17	5217	0	0	3298	Quinary17	10,533	175,236	17	381,559
Quinary18	9571	44,001	5	14,154	Quinary18	9601	100,402	10	229,738
Quinary19	5367	160,640	30	48,166	Quinary19	3143	6010	2	9342
Quinary20	16,930	1,130,391	67	51,507	Quinary20	8458	134,504	16	329,854
Quinary21	9075	2,609,304	288	461,622	Quinary21	12,991	58,973	5	−619
Quinary22	1,544	17,676	11	6594	Quinary22	5098	−79,902	−16	797
Quinary23	3755	−17,754	−5	6899	Quinary23	11,877	192,661	16	494,374
Quinary24	7933	444,535	56	62,292	Quinary24	11,185	68,918	6	−667
Quinary25	1547	15,252	10	1184	Quinary25	10,306	8544	1	20,739
Quinary26	3314	5310	2	4353	Quinary26	11,522	25,668	2	164,049
Quinary27	9071	198,705	22	29,817	Quinary27	12,314	46,848	4	275,546
					Quinary28	2860	−143,310	−50	821
					Quinary29	16,621	914,497	55	501,252
					Quinary30	7298	221,315	30	239,046
					Quinary31	6800	−99,105	−15	14,655
					Quinary32	5314	368,764	69	133,795
					Quinary33	11,634	891,547	77	254,441
Total	187,619	12,869,204	69	1,884,379	Total	397,771	3,936,842	10	7,381,437

Source: MDTP, 2007.

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baseflow during winter, the same simulated interventions reduce sedimentation much more dramatically in the Upper-Umzimvubu. These differences are attributed to current land use activities and the relative intactness of the natural resources which are vastly different.

These results therefore indicate that the management of upstream land uses can have marked influences on downstream hydrological responses. These hydrological responses are not necessarily so strong in terms of changes in overall annual streamflows (which remain relatively constant), but rather because of changes in the components of streamflow. Baseflows are shown to increase during the low-flow winter months while stormflows are reduced during high-flow summer months, and higher order hydrological responses such as sediment yields have been reduced. The outcome of this hydrological study on two contrasting catchments has set the scene to (i) assign monetary values to questions relating to downstream water beneficiaries who may be willing to pay/reward upstream land users for environmental stewardship in managing their land better for more sustained/cleaner water production, and (ii) to evaluate whether benefits can be sustained.

We will turn to addressing these issues now.

4.2. Economic feasibility assessment: Results

To determine the economic feasibility of the interventions mentioned earlier, we decided (following Marais and Wannenburgh, 2008) to calculate the Unit Reference Values (URVs) for both catchments. The URV is the ratio of the present value of all costs incurred over the economic life span of the project divided by the present value of the total benefits over the economic life span of the project. It should be noted that URV's can also be calculated as the present value of the all costs incurred over the economic life span of the project divided by the present value of the total water yield. We, however, do not follow this practice here. A URV value greater than 1 indicates that the present value of the cost of the project exceeds the present value of the benefits. While no benchmark URV values exist for "good" and "bad" projects, a typical, constructed, water development project, such as a dam's URV is between 2 and 4 (Geringer, personal communication, 2007). The present value of the cost therefore exceeds the present value of the benefits several times over. This is mainly due to very low water tariffs, but high construction and finance cost. The value of using URVs here, as opposed to the more conventional benefit cost ratio, is that URVs are, in South Africa, calculated by the water engineers of Department of Water Affairs and Environment to assess and compare the viability of any water augmentation scheme. By following this approach the study team could therefore actively engage with decision makers using a metric they are familiar with. Table 2 presents the key assumptions in calculating the URVs. However, the following aspects should be noted:

- The economic life of any given water development project is generally between 40 and 50 years. We assumed 50 years.
- The cost component comprises:
  - capital cost, i.e. the upfront cost of restoring natural capital, which includes the cost of reseeding the grasslands and the restoration of erosion gullies where required; and
  - the annual operation and maintenance cost that includes labour, land or resource management cost.
- The benefits that have been valued comprise:
  - The value of additional baseflow during winter;
  - The value of reduced siltation; and
  - The value of additional carbon storage, the reduction of carbon leakage through erosion and the value of avoided carbon loss.
- Other benefits which have not been valued comprise:
  - Promotion of biodiversity;
  - Combat of desertification; and
  - The value of reduced stormflow.
- While it is permissible to use a negative discount rate in conditions such as these to reflect the increasing value over time of a steadily decreasing stock of natural capital (Blignaut and Aronson, 2008), positive discount rates (i.e. 4%, 6% and 8%) — normally used for evaluating the feasibility of a project in the built environment (the construction sector) — were used as an extreme conservative measure of the value of the interventions suggested.

Table 2
Economic feasibility of the "payment for environmental services" model: assumptions[a].

Variable	Upper-uThukela	Upper-Umzimvubu
Cost of restoration		
Cost of restoring grassland: reseeding/ha	R6200	R6200
Cost of restoring erosion gullies/ha	R55,500	R55,500
Cost of fire operation and management		
Commercial farm land/ha	R9.00	R9.00
Communal land/ha	R18.00	R18.00
Conservation area/ha	R11.70	R11.70
Mixed commercial/Communal/ha	R13.50	R13.50
Mixed commercial/Conservation/ha	R10.35	R10.35
Mixed communal/Conservation/ha	R14.85	R14.85
Cost of grazing operation and management/ha	R19.30	R19.30
Operation and management overhead % of total cost	20%	20%
Current raw water charge R/m^3	R0.13	R0.74
Economic value of water: Low R/m^3	R1.40	R1.45
Economic value of water: Medium R/m^3	R3.29	R3.29
Economic value of water: High R/m^3	R6.90	R6.90
Economic value of sediment R/m^3 (medium estimate of the value of water)	R3.29	R3.29
Average water price: Price charged for water /kl	R0.30	R0.70
Average price of CO_2	R65.00	R65.00
Above and below ground Carbon seq.: Ave. t/ha	2.25	2.25

Source: MDTP, 2007.
[a] 1US$ = R8.

The URVs for all 60 Quinary Catchments in the two study areas were calculated individually based on the assumptions mentioned above, allowing for each Quinary's unique characteristic. The summary of the results is shown in Table 3, using a discount rate of 6%, which effectively provide the quantitative relationship between the effect of the introduction of rotational grazing and a reduced and changed burning regime on water flow, carbon storage and the generation of silt. From these results it is evident that the URVs are above 1, i.e. the cost of producing the water is higher than the market value thereof, if the value of the additional winter baseflow is included. It is considerably more expensive per unit of water in the Upper-Umzimvubu than it is in the Upper-uThukela. This is because the degree of degradation is so much lower than in the Upper-Umzimvubu. Much more water over a smaller area is also released at a considerably lower cost. However, the project compares very favourably with other water development projects in the built environment where a URV of between 2 and 4 is the norm. When one adds the value of silt-reduction and carbon sequestration to the equation, the picture changes dramatically with resultant URVs below 1. In the Upper-Umzimvubu this is primarily the result of a reduction in sedimentation and the ensuing improvement of the water quality.

5. Discussion

5.1. Synthesis

The Maloti–Drakensberg mountain range is the largest and most strategic fresh water source for South Africa. It supplies much of the country's water through rivers and inter-basin transfers. The mountain's grasslands cover, which is essential for maintaining a regular and quality flow of water, has been and is continuing to be transformed through various forms of inappropriate land use. This implies that the streamflow in the dry season is reduced, while summer flows are exacerbated leading to flooding, soil erosion, reduced grassland productivity, seasonal water scarcity, poor water

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Table 3
Economic feasibility of the "payment for environmental services" model: results at a 6% discount rate[a].

	Upper-uThukela	Upper-Umzimvubu
Unit reference values[b]		
Water only: Allowing only for management cost	1.13	3.24
Water only: Allowing for both management and capital cost	1.66	8.28
Total benefits: Allowing only for management cost	0.22	0.19
Total benefits: Allowing for both management and capital cost	0.32	0.48
Absolute values of key variables		
Total additional baseflow: m^3	12,869,204	3,936,842
Sediment reduction: t/y	1,884,379	7,381,437
Sediment reduction: m^3/y	1,256,252	4,920,958
Carbon sequestration: t/y	129,976	338,480
Value of water sales: R/ha/y for 50 years	R20.12	R8.06
Value of all benefits: R/ha/y for 50 years	R96.05	R123.95
Restoration cost: Total cost over 7 years/ha	R170.27	R655.28
Management cost: R/ha/y for 50 years	R20.23	R23.14
Net present value of water: R/ha/y for 50 years	−R185.33	−R820.50
Net present value of all benefits: R/ha/y	R1011.60	R1006.14
Number of jobs: During restoration	279	1548
Number of jobs: During maintenance	127	307
Total management costs: R/y	R3,795,061	R9,202,899
Total restoration costs over seven years R/y	R31,945,410	R260,652,840
Total water sales R/y (year 5 and onward)	R3,860,761	R2,755,789
Economic value of water Low R/y	R18,016,886	R5,708,421
Economic value of water Medium R/y	R42,339,681	R12,952,210
Economic value of water High R/y	R88,797,508	R27,164,210

Source: MDTP, 2007.
[a] 1US$ = R8.
[b] Unit reference values are the ratio of the present value of all costs incurred over the economic life span of the project divided by the present value of the total benefits over the economic life span of the project. An URV value greater than 1 indicates that the present value of the cost of the project exceeds the present value of the benefits.

quality and increased water insecurity. In addition, the life span of water storage and abstraction infrastructure is seriously reduced through accelerated sedimentation.

In the past, several mountain catchments in South Africa have been managed for water on an intuitive basis, i.e. no direct link between the state of the natural capital, the cost of either restoring or managing the natural capital and water flows have been made. This study has, for the first time, quantified the benefits and costs of mountain catchment management. Research in the Upper-uThukela and the Upper-Umzimvubu catchments confirmed that biennial spring burning, grazing at recommended stocking rates using a rotational grazing system (which includes cattle), and restoration of degraded grasslands has significant impacts on:

- reducing summer run-off stormflows,
- increasing infiltration and thereby increasing winter baseflows,
- maintaining the ecological reserve, i.e. the mandatory minimum baseflow to keep ecosystem services functioning, in rivers,
- reducing soil erosion, and
- increasing the soil carbon content.

When quantifying these benefits the models are based on dose–response functions where the dose is the land use management change and the response the change in baseflow and sediment yield. Both the dose and the response have been based on expert opinion, but have not been monitored and evaluated over long periods of time. Such detailed research is important to improve the quality of the data. The data pertaining to the cost of restoration and land use management was based on field research in the areas concerned and interviews with land use managers and can be accepted as a good representation of the reality. Prevailing market prices for carbon and the raw water tariffs were used to determine the benefits. Considering the limitations above, it can be expected that in the Upper-uThukela, good management practice could generate an additional 12.8 million m^3 in winter river baseflows, with a sales value of R3.8 million per annum and could add value to the economy of between R18 million and R88.7 million per year. With only 4 million m^3 surplus currently available in the Upper-uThukela basin, the additional water represents a 320% increase in surplus or allocable water. In terms of the whole uThukela basin, the additional water represents a 23% increase in allocable water. The same action can reduce sediment yields by 1.2 million m^3, with a value of R4.1 million per annum in cost savings, and carbon sequestration could add another R8.7 million per annum. In total, the sales of services from the Upper-uThukela could generate R16.7 million per annum. The costs of management on the other hand would be R3.8 million per annum and restoration could cost R31.9 million during the first seven years.

In the Upper-Umzimvubu good management practice could generate an additional 3.9 million m^3 in winter river baseflows with a sales value of R2.7 million per annum. The additional water could add value to the economy of between R5.7 and R27.1 million per annum. Importantly, access to water in periods of scarcity reduces rural household vulnerability in an area where there is no water impoundments and where a high percentage of households rely on river water (direct extraction) as their primary water source. In terms of erosion, the reduction in sediment is 4.9 million m^3 per annum and this has a value of R16.2 million per year. Carbon sequestration could add R21.9 million per annum. In total, potential sales of services could amount to R40.7 million per year. Management costs are estimated to be R9.2 million per annum, with restoration costs reaching R260 million for a seven-year period. Importantly, catchment management becomes increasingly feasible when more than one of the services is marketed. As costs and benefits vary between catchments, some catchments show that restoration and management is financially feasible with only baseflow being marketed, while other catchments require baseflow enhancement, sediment reduction and carbon sequestration to be marketed before their management becomes financially feasible.

Management of these two study areas has the potential to generate 1800 restoration-related jobs per year for the first seven years of the intervention and almost 500 permanent jobs in catchment management.

5.2. Implementation and institutional options

From the discussion above it is clear that the restoration and management of natural capital can compete very favourably with the built environment and can render a positive return on investment. Catchments could therefore be considered in some sense as large water storage facilities with the riparian zones as the "water distribution networks". Perhaps the management and maintenance of natural capital should not be considered much different from that of any large water storage facility? Prudent catchment management offers an exciting alternative to increase the yield of water supply systems, to complement, and even postpone if not replace the need of conventional infrastructure augmentation. This will require a significant change in mindset among decision makers and may very well need to be accompanied by further research on the subject. From an environmental impact perspective of course, there is little competition; with the effect of dams almost always being negative and catchment restoration (if managed effectively) nearly always positive.

The last aspect that should be addressed here concerns the institutional framework within which such a payment for ecosystem services could be rendered. In other words: What institutional arrangement would be appropriate and most effective to access funding for, for example, water quality, water flow, carbon and biodiversity payments? The latter are two relatively new and specialised areas and as a result, there is likely to be a role for carbon and/or biodiversity brokers. The reason for this is that it will probably be necessary for projects (in this

Table 4
Watershed management or watershed security supply chain establishment requirements.

Actions	Potential actors	Incentive	Outputs required	Required skills and capacity	Institutional requirements
Buying the service	Department of Water Affairs Water utilities	Increased yield	Greater baseflow	Understanding the relationship between environmental flows and watershed management	Authorisation to charge water consumer for costs of watershed management
		Prolonged dam lifespan	Reduced sediment yields	Understanding the requirements to develop a new supply chain in watershed management	Authorisation to expand extend public works programme to include watershed management
		Rural job creation Meet legal environmental flow requirements	Increased rural jobs in watershed management		Paradigm shift in department thinking regarding the role of watersheds in addressing supply constraints
	Business sector	Water or carbon neutral	Science to confirm that intervention results in additional supply — water or CO_2 sequestration		Policy to invest in watershed management
		Social responsibility			Paradigm shift among board members and shareholders about sustainability
Establish an agreement between sellers of services and associated community	Consultants	Business opportunity	Agreement within community to collaborate	Facilitation of common property resources management regimes	Leadership in communal areas
	Communities	New income generating opportunities	Delegated representatives of community interests	Understanding the change in productivity and outputs delivered and the consequent costs and benefits of the intervention	Mechanisms to share benefits of payments for ecosystem services within tribal communities
	Conservation agencies	Improved natural resource production, conservation and access	Identification of costs and benefits of the intervention		Mechanisms to sustain compliance to agreement within community
			Institutional arrangements per site		Set of agreed sanctions to deal with free riders
Establish an agreement/contract between buyers and sellers of services	Conservation agencies and the listed buyers and sellers	Increased income, increased watershed services, improved biodiversity	Legal document that outlines terms of payments, services qualities supplied, delivery times, dealing with variances, auditing frequency, etc.	Networking, facilitation and contracting skills	Enforcement mechanism
Coordinating the implementation of activities and the exchange of services and payments	Conservation agencies	Meet provincial conservation objectives	Coordination of actions and activities among market transactors	Finance management	Financial management system to receive and disperse payments
		Achieve conservation goals	Supply technical expertise to land managers	Restoration and ecosystem management	A policy that provides a mandate to develop payment for services systems
		New income stream	Manage the finances flow between the buyers and sellers	Carbon sequestration and water management science	A mandate to oversee or implement land management activities
			Ensure the agreement is implemented	Conflict resolution	A willingness to engage in a new and complex market
			Ensure sustained compliance with the agreement	Common property management Managing social–ecological systems	
Watershed management	Landowners and/or resource managers	Additional income streams	Fire management	Veld and stock management skills	Willingness to engage in new land use practices
		Enhanced land values	Grazing management	Restoration skills	Community structures to develop plans and to implement joint actions
		Enhanced access to ecosystem services	Restoration	Organisation capacity to coordinate joint actions	Community trust to receive payments for rewarding community performance
		Enhanced livestock security	Improve and sustain good vegetation cover	Managerial and budgeting skills	
Implementation management support	Local business people/consultant or rural development NGOs	Business opportunity	Transparent financial accounting and equitable sharing of benefits	Financial management	A community structure for dealing with the PES project
	Community structures e.g. Trust	Sustainable business	Resolutions of community conflicts	Consensus around benefits sharing	A trust to deal with payments for joint community actions
			Community capacity building	Project management, communication and dealing with free riders	
			Coordination of joint activities	Mentoring finance management	
Auditing service	Government	Minimise additional costs	Verification that agreed management actions have been implemented	Project monitoring and evaluation	Criteria for evaluation and verification
	Conservation agencies	Learning by doing with community	Verification that agreed vegetation cover is delivered	Grassland ecology	Agreement on the criteria and measurement techniques
	Consultants	Business opportunity	Remote sensing of fire		
Authorising or certification of services exchange	Reputable national organisation and/or government department	Ensure that a resource is managed according to legal and quality requirements	Certification based on an audit report	Project evaluation	Criteria for evaluation and verification Agreement on the criteria and measurement techniques

case catchments or sub-catchments) to be "packaged" for presentation to prospective clients, whose needs are likely to be very different. In theory, there are a range of options available across a broad spectrum of institutions when one considers the possible and most suitable options to implement such a "packaged" programme. When selecting the best institutional vehicle it is clearly of utmost importance to consider whether they have the requisite skill sets, and whether they have available capacity to undertake the work. Catchment Management Agencies (CMAs) are, ultimately, the best and most logical option, primarily because protection and conservation of water resources is precisely the role defined for them in terms of the National Water Act of 1998. Unfortunately these newly envisaged institutions are still in the formative stages of development in South Africa. Once they are in place, they must play a major role in this work. In the meantime, and even after the establishment of the CMAs, for any PES system to work requires the focused and dedicated attention of a range of institutions — listed in Table 4.

From Table 4 it is evident that there is a range of actions or tasks, with encompassing responsibilities. Establishing a PES project is therefore unlikely to be the responsibility and function of any single institution. PES should much rather be considered to be the outcome of a multi-institutional collaborative effort and organisational process.

While it is inappropriate to suggest here who or which agency should be responsible for each of the identified tasks listed in Table 4, we do wish to emphasise that a key to the successful implementation of PES is the determination who or which institution should act as the coordinating centre, the project "champion". We recommend that, within the context of the study areas, this function be fulfilled by local or regional conservation agencies. They are the agencies that have a vested interest in the project to succeed, conventionally they have good information about the prevailing on the ground activities, people and actions, and they would be best suited to direct the restoration and management actions. It also shortens the communication channel when working with a local or regional conservation agency than with government offices that are removed.

The importance of the institutional arrangements to undertake the implementation of such an initiative cannot be underestimated. The level of analysis carried out in this work can best be described as being at the "pre-feasibility" or "conceptual" level. If the project were to proceed to the next level of analysis, i.e. a detailed feasibility assessment, then a more rigorous assessment of institutional options would be desirable. Typically this would set out desirable criteria or characteristics of the institutional arrangements and then assess the options available against these. This type of work is inherently subjective in nature to some extent but this would facilitate a more thorough and analytical approach. It has to be acknowledged that the history of efforts involving communal land and assets are patchy at best. This is borne out in the South African context by failures with respect to resettlement on agricultural land given recent coverage in a number of press articles. This is certainly a key risk to the project and again emphasises the importance of the appropriate institutional arrangements. This will also need to be evaluated in more detail in the detailed feasibility phase, taking into account the particular situational factors relevant to the communities in these two catchments.

6. Conclusion

Can a payment for flows of ecosystem goods and services system, following appropriate management and restoration of natural capital produced in rural areas of a developing country, be developed in a way that benefits communities, the commercial sector and the environment? This is the question we asked at the onset of this paper. Given the discussion above we have to conclude that, under certain conditions, it is definitely viable, not only financially but also institutionally. This is made possible by the fact that payment for ecosystem services is no longer a completely new concept and neither is the management component required to make it possible. The authors are not aware of any impediments within South African legislation that would hinder the implementation of a payment for ecosystem services project of such a nature. It is also desirable from both a rural development and a social equity perspective to embark on such an incentive rather than regulatory-based approach towards land use management. This opportunity could equally apply to other mountain communities in high-rainfall areas, and is an important consideration given that surface waters have been fully allocated to users in many catchments in South Africa. A fairer distribution of water is a key objective of the South African Government but redistribution is contentious and costly. Freeing up additional resources is therefore a much better option in most cases.

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