Ecological Indicators 45 (2014) 692–703

Contents lists available at ScienceDirect

Ecological Indicators

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

Land management implications for ecosystem services in a South African rangeland

Katalin Petz[a,*], Julia Glenday[b,c], Rob Alkemade[a,d]

[a] PBL Netherlands Environmental Assessment Agency, P.O. Box 303, 3720 AH Bilthoven, The Netherlands
[b] Bren School of Environmental Science and Management, University of California Santa Barbara, 400 Bren Hall, Santa Barbara, CA 93106-5131, USA
[c] Living Lands, P.O. Box 237, Patensie 6335, South Africa
[d] Environmental Systems Analysis Group, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 2 November 2013
Received in revised form 19 May 2014
Accepted 21 May 2014

Keywords:
GIS
Mapping
Ecosystem degradation
Thicket restoration
Scenario
Environmental decision-making

ABSTRACT

In South Africa, restoration and sustainable management of historically overgrazed and degraded rangelands are promoted to increase biodiversity and ecosystem service provision. This study evaluates different land management scenarios in terms of ecosystem services in a South African rangeland, the Baviaanskloof catchment. As measured data were limited, we used simple models to quantify and map the effect of the different combination of agricultural, nature conservation and restoration practices on multiple ecosystem services. The land management scenarios were evaluated against management targets set for individual ecosystem services. Results highlight how the provision of ecosystem services is related to land management as unmanaged, pristine ecosystems provide a different mix of ecosystem services than ecosystems recently restored or managed as grazing lands. Results also indicate that historically overgrazed lands provide no forage, may retain 40% less sediment and have 38% lower biodiversity, while providing 60% more fuel wood and supplying two and half times more water (i.e. retaining less water), than pristine or restored lands. We conclude that a combination of light grazing, low input agriculture, nature conservation and restoration is the best for the sufficient provision of multiple ecosystem services. Applying such mixed management would improve biodiversity, ecotourism and maintain forage production and regulating services on farmers' land. This management option also fits into and further optimizes local decision-makers' vision regarding the future management of the area.

1. Introduction

Land conversion and intensification are major drivers of ecosystem degradation, biodiversity loss and ecosystem services (ESs) depletion (Nelson and Daily, 2010; Pereira et al., 2010). The increasing international concern about biodiversity loss and ES depletion resulted in the inclusion of ESs in the 2020 Aichi targets set by the Convention on Biological Diversity (Larigauderie et al., 2012). In South Africa, land conversion and overgrazing related to pastoralism impaired biodiversity and ESs, such as long-term forage production and water supply (van Jaarsveld et al., 2005; Palmer et al., 2006; Le Maitre et al., 2007). Recently targeted governmental environmental programmes have been established to support ecosystem restoration, sustainable land management and livelihood improvement (Milton et al., 2003). The Baviaanskloof catchment was chosen as a watershed-scale example of how policy and management changes could impact ES provision.

Like much of Southern Africa, the Baviaanskloof catchment is a relatively data-poor environment. A few plot-scale studies have been performed on the quantitative effects of vegetation degradation on hydrological and ecological processes in the larger region (e.g. van Luijk et al. (2013), Mills and Cowling (2006) and Lechmere-Oertel et al. (2005a)), but there has been little quantitative monitoring of most ecosystem processes and functions. In such a setting, information on ESs derived from maps and models can improve land management decision-making. In South Africa some ESs have been mapped and modelled using proxies that relate to land cover and land use (e.g. Egoh et al. (2010) and Reyers et al. (2009)). The combination of different land management practices, their impacts on the resulting land cover and ESs, and the effect of potential future management changes have been less studied in the region. In general, the consequences of alternative land use and land management options for a broader range of ESs are poorly

* Corresponding author. Tel.: +31 611738467.
E-mail addresses: katalin.petz@pbl.nl, katalin.petz@gmail.com (K. Petz), julia.glenday@gmail.com (J. Glenday), rob.alkemade@pbl.nl (R. Alkemade).

http://dx.doi.org/10.1016/j.ecolind.2014.05.023
1470-160X/

quantified (Carpenter et al., 2009; De Groot et al., 2010) and the integration of multiple ESs into land use and management decisions is still missing (Ehrlich et al., 2012).

This study aims to evaluate alternative land management scenarios by mapping and modelling multiple ESs in the South African Baviaanskloof catchment. Land management in the area is a combination of multiple agricultural, nature conservation and thicket restoration practices. Ecosystem restoration and conservation are land use options to increase biodiversity and the provision of a wide range of ESs (Benayas et al., 2009), whereas agricultural land use targets food production. These land uses can be managed with varying intensity, depending on management practices. Land management refers to human activities that affect land cover directly or indirectly (van Oudenhoven et al., 2012). Land management affects also vegetation, which can degrade as a consequence of intensive use or unwise land management (Reyers et al., 2009).

Prior to this work, future land management of the Baviaanskloof catchment was explored through stakeholder consultation. We build upon this, and apply scenarios to compare three alternative land management options that reflect stakeholders' preferences. Our study visualizes the spatial distribution of ESs, evaluates land management scenarios against targets set for these ES, and verifies whether the land management scenario preferred by stakeholders is also the most optimal in terms of ESs provision.

2. Methods

2.1. Study area: the Baviaanskloof catchment

2.1.1. Geography

The Baviaanskloof catchment (ca. 123,000 ha) is located in Eastern Cape, in South Africa (Fig. 1). The semi-arid catchment receives low and erratic precipitation in two annual rainfall peaks. Water is scarce and the recurring droughts are often followed by flood events (Jansen, 2008). The Baviaanskloof River runs west to east between two parallel mountain ranges. It feeds the Kouga Dam and supplies water to downstream cities, including Port Elizabeth (van Eck et al., 2010). An unpaved road along the river provides access to the area. The catchment is home to a proportions of seven of South Africa's eight biomes (Fynbos, Subtropical Thicket, Nama-karroo, Succulent Karoo, Grassland, Savanna and Forest), and is part of one of the Earth's biodiversity hotspots, the Cape Floral Kingdom (Boshoff, 2005; Crane, 2006). Savanna and grassland vegetation cover the valley-bottom and thicket shrubland and transitional vegetation cover the lower slopes (Fig. 1). The catchment has a high diversity of Albany subtropical thicket dominated by the succulent *Portulacaria afra* ('Spekboom') (Boshoff, 2005). The montane vegetation is composed of fynbos, evergreen small-leafed shrub vegetation (Fig. 1). This vegetation is (nearly) pristine. Most of the fynbos and parts of the thicket and grassland are protected under the Baviaanskloof Nature Reserve (van Eck et al., 2010). The catchment is home to protected (endemic) animal species (e.g. Cape mountain zebra, Black rhino, Cape leopard) (Boshoff, 2005). The area is popular for its beautiful scenery and wildlife, watched from the road. The Baviaanskloof Nature Reserve receives about 45,600 tourists and the rest of the catchment receives a further 10,000–12,000 tourists annually (Powell and Mander, 2009). This highly diverse catchment is facing pressures of land conversion and degradation. In historically overgrazed areas vegetation cover has been degraded and species diversity reduced, soil eroded and carbon stocks, and soil and water quality have declined (Lechmere-Oertel et al., 2005b; Mills et al., 2005). Most degraded vegetation is in the valley-bottom and on the lower slopes which are thicket dominated. Conservation interests emphasize sustainable utilization of biodiversity and thicket restoration, since the area became an UNESCO World Heritage Site (2004) (van Eck et al., 2010). Governmental land management programmes and some local stakeholders aim to facilitate thicket restoration and livelihood improvement (van Eck et al., 2010).

2.1.2. Stakeholders

Stakeholders include local communities, farmers, non-governmental (e.g. Living Lands[1]) and governmental organizations (Eastern Cape Parks and Tourism Agency[2]), and scientists. About 62% of the area belongs to the government and 36% of the area belongs to a few large-scale farmers. Local communities share the remaining land (Powell and Mander, 2009). Governmental lands form the Baviaanskloof Nature Reserve, managed by the Eastern Cape Parks and Tourism Agency. The reserve is located on the higher slopes and mountaintops. Farmed lands are located on the valley-bottom and lower slopes. In these areas, vegetation is mostly degraded and is partly converted to cropland. Farmers' main income is derived from animal and crop production and from tourism (Crane, 2006). Local communities live in three villages and share small patches of communal lands in the valley-bottom. They are highly dependent on local natural resources (wild food, fuel wood, medicinal plants, construction material, etc.), but both their resource access and income sources are limited. About 95% of the local households extract or collect natural resources, even if it is mostly restricted or prohibited (Rhodes University Consortium, 2007). The unemployment rate is high and many inhabitants obtain social security grants (Crane, 2006). The number of permanent residents is estimated to be 1000 people (Crane, 2006) in 463 households (CSIR Satellite Application Centre, 2010).

2.1.3. Land management

The main land uses in the Baviaanskloof catchment are agriculture, nature conservation, and thicket restoration. A part of the land is abandoned and not managed. The intensity of land use is related to crop choice, irrigation, animal choice, animal density and tourism infrastructure. Farmers set up hiking trails and tourist accommodation on their private lands to improve tourism. Agriculture, land abandonment and thicket restoration occur on farmers' private land. Management aimed at nature conservation occurs on all governmental lands and on some private lands.

Agriculture includes crop, livestock and game farming. Crops vary from farming maize as an annual crop in intensively used irrigated fields to perennial crops in non-irrigated orchards (olives, nuts) (Jansen, 2008). Livestock grazing is conventional with goat, sheep, cattle and ostrich production in fenced areas. Game farming is the raising of indigenous wildlife species, such as kudu (*Tragelaphus strepsiceros*), for tourism, sale or hunting.

Unmanaged lands are degraded private lands formerly used for agriculture, but not farmed at present.

Most formal nature conservation takes place in the Baviaanskloof Nature Reserve. Herbivores (Cape mountain zebra, Black rhino and Buffalo) were reintroduced in the reserve as part of conservation management (Powell and Mander, 2009). The (illegal) extraction of wood and other plant materials is a threat to conservation (Rhodes University Consortium, 2007). Conservation on private land means adopting wildlife-friendly management and removing fences for economic incentives. A voluntary agreement between Eastern Cape Parks and Tourism Agency and farmers facilitates the implementation of these arrangements (Crane, 2006).

Thicket restoration is a transitional land use on farmers' land. It ideally involves a shift from a degraded, abandoned or low grazing capacity, state to a nearly pristine state. Restoration is done by re-planting the pioneer *P. afra* (van Eck et al., 2010). This creates

[1] http://www.earthcollective.net/livinglands/.
[2] http://www.ectourism.co.za/.