Journal of Arid Environments xxx (2017) 1–12

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Identifying ecosystem service hotspots for targeting land degradation neutrality investments in south-eastern Africa

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A R T I C L E I N F O

Article history:
Received 15 November 2016
Received in revised form
17 May 2017
Accepted 31 May 2017
Available online xxx

Keywords:
Participatory mapping
Spatial assessment
UNCCD
South-Africa
Tanzania
Zambia

A B S T R A C T

Land degradation response actions need motivated stakeholders and investments to improve land management. In this study we present methods to prioritise locations for degradation mitigation investments based on stakeholder preferences for ecosystem services. We combine participatory and spatial modelling approaches and apply these for Zambia, South Africa, and Tanzania to: i) prioritise ecosystem services in each country; ii) to map the supply of these ecosystem services in each country, and; iii) prioritise areas important for investment for the continuous delivery of these ecosystem services based on their vulnerability to land degradation. We interviewed 31 stakeholders from governmental and non-governmental organizations to select the most important ecosystem services per county. Stakeholders were also asked to indicate on national maps the hotspots of these ecosystem services and locations with a high degradation risk. We then assessed the supply of the stakeholder-selected ecosystem services and land degradation risk using GIS-based spatial models. We found that for each country the spatial extent and magnitude of ecosystem services supply and land degradation based on GIS data coincides with stakeholder knowledge in some locations. In the context of supporting national level policy to achieve land degradation neutrality as proposed by the United Nations Convention to Combat Desertification we argue that the correct representation, the level of acceptance, and use of modelled outputs to support decisions will be greater when model outputs are corroborated by stakeholder knowledge. Ecosystem services that are identified as “important” by diverse stakeholder groups have a broader level of awareness and could therefore drive motivations, commitments, and actions towards improved land management, contributing to land degradation neutrality.

1. Introduction

Land degradation is a major threat to ecological functioning, food production and livelihood development across the world (Barbier, 2000; MA, 2005; Bindraban et al., 2012). It affects the biological and economic productivity of land due to processes such as soil erosion, salinization, soil crusting, loss of soil fertility, and depletion of seed banks and vegetation cover (Kairis et al., 2014). According to the Millennium Ecosystem Assessment about 10–20 percent of all drylands, which include arid, semi-arid and dry sub-humid areas, are degraded across the world (MA, 2005). A large portion of the world's drylands are located in sub Saharan Africa, where local people's livelihoods are very closely linked to accessible natural resources and ecosystem services (Barbier, 2000). With land degradation, the supply of these resources and services to humans decreases.

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http://dx.doi.org/10.1016/j.jaridenv.2017.05.009
0140-1963/

Several policy measures have been put in place to halt and reverse land degradation for continued food production and livelihood development (Stringer and Dougill, 2013). With the establishment of the United Nations Convention to Combat Desertification (UNCCD) in 1994 a large international response to address land degradation issues in drylands was initiated. Through National Action Programmes (NAPs), country Parties to the UNCCD aim to improve the conditions of people and ecosystems affected by land degradation by maintaining and restoring land and soil productivity, and mitigating the effects of drought (UNCCD, 2016). These country-level NAPs set targets and define actions to halt and reverse land degradation in an integrated way. Many of the actions of the NAPs also contribute to the United Nations global Sustainable Development Goals that aim for a land degradation-neutral world by 2030 (Target 15.3) and the restoration and conservation targets of the international Convention on Biological Diversity (Aichi Target 15).

The UNCCD considers the goal of no-net-increase of degraded land at national and global levels as their central remit, whereby the condition of land resources to support ecosystem services and enhance food security is maintained or improved through sustainable use and management of soil, water and biodiversity, i.e. achieving Land Degradation Neutrality (LDN) (Orr et al., 2017). Achieving LDN requires significant investment in improved land rehabilitation, degraded ecosystem restoration, and land stewardship. To promote and manage investments in sustainable land management and land rehabilitation efforts, the UNCCD spearheaded the development of an LDN Fund (Maillard and Cheung, 2016). Robust science is needed to ensure investments are targeted to the locations which will achieve the greatest monetary and non-monetary returns with low risks (Crossman and Bryan, 2009).

A key challenge for assessing the diverse returns on LDN investments is the integration of social-economic and environmental data and values (Winslow et al., 2011). The concept of ecosystem services -human benefits from nature- offers a framework for incorporating diverse processes linking ecological data to social and/or economic values (Díaz et al., 2015). The benefits humans obtain from ecosystems are a function of ecological functioning and human inputs (Willemen et al., 2008; Maes and Jacobs, 2015). Quantitative assessments of a wide range of ecosystem services helps to make explicit the many benefits, avoided costs, and trade-offs of improved land management (Naidoo and Ricketts, 2006; Hauck et al., 2013; Clec'h et al., 2016), and provide important baselines for measuring returns on investment in land rehabilitation, restoration and sustainable land management (ELD Initiative, 2015; Schröter et al., 2015). The visualization of key ecosystem services through mapping can be an effective vehicle for motivating people to engage in sustainable land management, conservation and restoration (Pettit et al., 2011; Darvill and Lindo, 2015; Klein et al., 2015).

There are many ways to map ecosystem services (Gomez-Baggethun et al., 2010; Martínez-Harms and Balvanera, 2012; Crossman et al., 2013). These include spatial, GIS-based models to provide detailed estimates of ecosystem services supply and value using location-based data. In addition, participatory approaches that use knowledge and expertise from people in the study area are increasingly applied to map ecosystem services, especially in attempts to better match science with societal needs (Brown and Fagerholm, 2015). A general point of concern for all mapping approaches is the unknown or poorly presented level of accuracy and representation of the ecosystem service maps (Schulp et al., 2014; Willemen et al., 2015a). This shortcoming impedes the uptake of science to support decision making (Walsh et al., 2015). The large investments required to achieve LDN, and the need to ensure funds are spent in locations where they can deliver the greatest benefits, demands approaches that robustly quantify ecosystem services most important to the decision makers and land managers who will take the investment risks. Approaches that integrate methods, data, and stakeholder views result in comprehensive and less biased information for decision support, compared to single-method approaches (Voinov et al., 2014; Law et al., 2015; van Oort et al., 2015).

In this study we combine participatory and spatial modelling approaches in three countries in Africa affected by land degradation, South Africa, Tanzania and Zambia, to: i) prioritise ecosystem services based on their importance in the country; ii) to map the supply of these ecosystem services, and; iii) prioritise areas that are most likely important for investment for the continuous delivery of these ecosystem services based on their vulnerability to land degradation. We identify locations where, if land degradation is halted, could provide best returns on investments. The priority areas we identify are locations that are particularly rich in key ecosystem services, but are also at high risk from degrading pressures according to both spatial model outcomes and stakeholder's perceptions.

2. Methods

2.1. Study area

Our study focuses on Zambia, South Africa, and Tanzania that for large parts are classified as drylands (Fig. 1). These countries are not only signatories to UNCCD but have ratified the convention with the commitment to undertake considerable efforts in tackling land degradation. However, they have also encountered barriers to implementation due to insufficient resources, weak institutional capacity, and/or inadequate legal support, as indicated in their national reports on UNCCD implementation (http://www.unccd.int).

Land-locked Zambia covers around 753,000 km^2 with a population of about 14.5 million. Average annual rainfall ranges from about 600 mm in the south-west of the country, to over 1200 mm in the north-east (Environmental Council of Zambia, 2008). The seasonality of the rainfall causes rainfall deficits in some parts of the country. Agriculture and copper mining are the two most important components of the Zambian economy (Central Statistics Office, 2014). Agriculture is predominantly rain fed, with less than 10% irrigated (Environmental Council of Zambia, 2008). Small-scale farmers account for over 80% of farmers with central Zambia being the agricultural centre of the country. In the north-west of the country, close to the border with the Democratic Republic of Congo, a 'new copper belt' is emerging. In this area, new mining sites are opened, rapid deforestation rates are observed, and the growing population causes an increasing demand for firewood. Zambia's national programme for combating desertification and mitigating effects of drought has identified the main drivers of land degradation as deforestation for agricultural purposes, soil erosion, high demand for fuelwood and charcoal use, overgrazing, institutional, policy and legal issues, and large scale developmental projects (Kalaba, 2016).

South Africa covers approximately 1.22 million km^2 with a population of about 53 million. Average annual precipitation varies from less than 50 to 3000 mm (Egoh et al., 2008). The country's arid climate, combined with the predominance of shallow soils with limited irrigation potential, and relatively high population of rural subsistence farmers, places much of the country at risk of land degradation. Agriculture contributes to about 10% of employment and only about 13% of the country can be used for crop production due to aridity (van Heerden et al.,

Please cite this article in press as: Willemen, L., et al., Identifying ecosystem service hotspots for targeting land degradation neutrality investments in south-eastern Africa, Journal of Arid Environments (2017), http://dx.doi.org/10.1016/j.jaridenv.2017.05.009