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The economics of landscape restoration: Benefits of controlling bush encroachment and invasive plant species in South Africa and Namibia

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ABSTRACT

Bush encroachment and alien plant invasions alter the composition and/or balance of species in natural ecosystems and impact biodiversity, land productivity and water availability. Therefore, the appropriate control and management of bush encroachment and alien plant invasions can restore ecosystems services and enhance the provision of timber and non-timber products to society. To understand the economics of land impacted by bush encroachment and alien plant invasions, we valued a selected number of ecosystem services from landscape restoration in South Africa and Namibia. In Namibia, the estimated value of ecosystem services from the restoration of bush encroachment was US$5.8 billion. In South Africa, the estimated value of ecosystem services from the restoration of bush encroachment was US$2.1 billion, and US$6.6 billion from the restoration of alien plant invasions. The most valued ecosystem service benefit assessed was water, followed by timber products and wood-fuels such as biomass to electricity, and then grazing. The value of these ecosystem services are considerable compared to the direct costs involved to clear invasive alien plants and control bush encroachment. This clearly illustrates that the management of invasive alien plants and bush encroachment can deliver significant ecosystem services benefits whose value outweighs the costs of restoration.

1. Introduction

Ecosystems deliver a wide range of benefits to society by providing, supporting and regulating services such as clean water, food and air (Costanza et al., 1997; De Groot et al., 2012). Despite the fact that all life depends on services derived from functional ecosystems, the Millennium Ecosystem Assessment (2005) revealed that over last 50 years approximately 60% of global ecosystem services have declined. In South Africa and Namibia, an important driver of ecosystem decline is bush encroachment and the spread of invasive alien plant species (Richardson, 1998, Richardson and Van Wilgen, 2004, Walker et al., 2004, Kraaij and Ward, 2006). Both bush encroachment and invasive alien plant species are known to compromise ecosystem function, and thereby reduce the ability to deliver a suite of ecosystem services that underpin economic productivity and sustainable development (Favretto et al., 2016; Reed et al., 2015).

Bush encroachment is the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass to bush ratio, a decrease in biodiversity, and a decrease in carrying capacity (De Klerk, 2004). Bush encroachment has an estimated extent of 26–30 million hectares in Namibia, and 10–20 million hectares in South Africa (Bester, 1999; Kraaij and Ward, 2006). The encroachment of woody plants in southern Africa occurs mainly in the grasslands and savannas (Kreuter et al., 1999; De Klerk, 2004; Ward, 2005; Dougill et al., 2016). The dominant species responsible for this encroachment are: *Acacia mellifera, Acacia reficiens, Acacia tortilis, Acacia nilotica, Acacia karoo, Dichrostachys cinera, Termanalia sericia, Rhigozum trichotomum and Tarchonanthus camphoratus* (Kraaij and Ward,

Abbreviations: N$, Namibian dollars; US$, US dollars; ZAR, South African Rand; t, metric tonnes. All biomass expressed on a dry mass basis; ha, hectares. 1 ha=0.01 km^2; CO_{2eq}, greenhouse gas emission in carbon dioxide equivalents

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2006). In the most severely encroached areas, up to 75% of the surface can be occupied by a single bush species (De Klerk, 2004) resulting in impenetrable thickets that suppresses the growth of the understory grasses, and excludes game and cattle from ranging. Together with increased water use, this results in a loss in carrying capacity and productive use of rangelands for both cattle and game. This threatens the livelihood of both commercial and communal game and livestock ranchers (Condon, 1986; Dean and Macdonald, 1994, O'Connor et al. 2014). Bush encroachment is driven by the mismanagement of rangelands- through overgrazing, the suppression of bushfires, and the exclusion of some browsing game species. In addition, the increasing carbon dioxide concentrations in the atmosphere are favouring the growth of woody biomass and bush encroachment (Bond and Midgley, 2012, De Klerk, 2004; Ward, 2005; Walker et al., 2004).

Biological invasions involve the introduction, establishment and spread of alien species into areas where they do not occur naturally. Biological invasions threaten biodiversity and ecosystem functioning. Many species from different taxonomic groups have been introduced to support industries such as agriculture, forestry, mariculture, horticulture and recreation which can contribute to economic development (Sharma et al., 2010). Biological invasions are increasing due to human-mediated disturbance of land and soil, global changes in climate and biogeochemical cycling, and an increased dissemination of propagules from growing global trade, transportation and migration (Le Maitre et al., 2000, 2004). Of the estimated 9000 plant species introduced to South Africa, 198 are currently classified as being invasive (Working for Water, 2016). The main woody invasive alien plant species were part of large afforestation programs in the past and include various *Acacia*, *Eucalyptus*, and *Pinus* species (Richardson, 1998). The ecosystems in higher rainfall regions harbour the majority of alien plant invasions (Le Maitre et al., 2000; Van Wilgen et al., 2008); while in drier regions the invasions are limited mainly to *Prosopis* spp. (mesquite) in the alluvial watercourse and plains (Harper-Simmonds et. al. 2015; Tree Altas). Many of these species have spread and proliferated from plantations to become invasive in the adjacent landscape, or were from large scale introductions of invader species in the late 1800 s aimed at stabilising sand dunes (Hobbs, 1988; Noble, 1989; Richardson and Cowling, 1992; Richardson and Van Wilgen, 2004; van Wilgen et al. 2001). The impacts of invasive alien plants on South Africa's terrestrial and freshwater ecosystems have long been recognised and led to the Department of Environmental Affairs establishing the Working for Water programme in 1995 (Richardson, 1998; Van Wilgen et al., 2008). Since then, significant progress has been made in the clearing of invasive alien plants, and the programmes have expanded to address the various threats to the productive use of land and water, and the functioning of natural systems from invasive alien species, wildfires and land degradation. In doing this work, they help ensure meaningful livelihoods for those employed from marginalised communities and develop opportunities for value added industries (DEA-NRM, 2015). However, to date, relatively little cost recovery has been obtained in these restoration programmes in the form of payment for ecosystem services restored, nor from the value adding opportunities of using woody biomass for timber products, wood fuels and electricity.

Since both bush encroachment and alien plant invasions alter the composition and/or balance of species in natural ecosystems, they cause land degradation and denudation with a loss of ecosystem services. Land restoration requires the appropriate management of bush encroachment and alien plant invasions with remedial action involving control, containment, and eradication (Reed et al., 2015). In order to increase our understanding of the economics of landscape restoration in Namibia and South African, we estimate the value of the benefits from key ecosystem services (water availability, grazing capacity, carbon, timber, wood fuels and electricity) that are provided through the appropriate management of bush encroachment and invasive alien plants.

2. Methodology

The research methodology used in this study followed the 6+1 approach of the United Nations Convention to Combat Desertification (UNCCD) Economics of Land Degradation (ELD) Initiative, which establishes a common approach for determining robust cost-benefit analysis to inform decision-making processes (ELD, 2015a). The key steps of inception, geographical characteristics, types of ecosystems and valuation used to guide this research were: -

2.1. Inception and geographical characteristics

The inception of the study was driven by the need to understand the extent of bush encroachment and plant invasions and impacts on ecosystem services. This required the mapping of bush encroachment and alien plant invasions. Bush encroachment affects an estimated 26–30 million hectares of land in Namibia, covering eleven of the fourteen political regions of Namibia. In the southern and western regions of the country, bush encroachment does not appear to be a significant problem, but moving north-east in the direction of increasing rainfall, the bush densities tend to increase (Honsbein et. al. 2009). From a number of surveys and field studies conducted over several years, the spatial extent of bush-encroached zones in Namibia has been produced (Bester, 1999). Information on the plant species in these bush-encroached zones were used to determine the biomass of bush encroachment (Birch et al. 2016).

In South Africa, bush encroachment was identified on untransformed areas (cultivated areas or those used for plantation forestry were excluded from the analysis) using land cover data (SANBI BGIS, 2010 LandCover). Areas of encroachment were defined as those where the percentage woody thickening was > 20%. We also limited our analysis to the arid savannas (rainfall < 680 mm) as above this threshold it is possible to get closed canopy formations naturally and this would be difficult to distinguish from bush encroachment (Sankaran, 2005).

The extent of invasive alien plants in South Africa was extracted from the National Invasive Alien Plant Survey (NIAPS) which mapped the condensed hectare coverage of 27 alien plant taxa (Kotzé et al., 2010). Aerial surveys were conducted across tertiary catchments to estimate the spatial distribution or density of woody biomass for the alien plant invaders. Most of the Northern Cape was not included in NIAPS study, although recent estimates of *Prosopis* invasions in this province are estimated to be 1.48 million hectares in extent (0.36 million condensed hectares, Vanden Berg 2010). The biomass from plant invasions was estimated from geospatial mapping data (Kotzé et al. 2010); using the extent and density of the invasive alien plants (Le Maitre 2000 and unpublished). Only the main woody (> 20% lignin) tree species were considered- *Pinus, Acacia, Eucalyptus, Hackea, Prosopis and Poplar* spp. Namibia does not have extensive plant invasions, or is not monitoring and reporting on them, and therefore could not be mapped.

2.2. Ecosystem services and economic valuation

Literature reviews and the expert knowledge of stakeholders were used to understand the key types of ecosystem services affected by bush encroachment and plant invasions. This identified several provisioning services (water availability, wood materials, wood fuels and electricity, and grazing capacity) and a regulating service (ecosystem carbon) that were considered as the ecosystem services impacted by bush encroachment and plant invasions, and therefore important to value. Many other provisioning, regulating, cultural and habitat ecosystem services were not valued. This study is therefore a partial economic assessment of key benefits from landscape restoration that can contribute to an assessment of the total economic value of invasive alien plant and bush encroachment management (Total Economic Valuation framework;

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