Journal of Environmental Management 185 (2017) 1–10

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

An assessment of the effectiveness of a long-term ecosystem restoration project in a fynbos shrubland catchment in South Africa

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ARTICLE INFO

Article history:
Received 25 May 2016
Received in revised form
8 September 2016
Accepted 24 October 2016
Available online 1 November 2016

Keywords:
Acacia
Best practice
Ecosystem management
Invasive alien species
Pinus

ABSTRACT

The long-term effectiveness of ecological restoration projects is seldom reported in the scientific literature. This paper reports on the outcomes of ecosystem restoration following the clearing of alien *Pinus* plantations and associated alien plant invasions over 13 years from an 8000 ha mountain catchment in the Western Cape Province, South Africa. We examined the goals, methods and costs of management, and the ecological outcomes in terms of reduced alien plant cover and native vegetation recovery. While the goals were not explicitly formulated at the outset, they were implicitly focussed on the conservation of water resources, the restoration of biodiversity, and the provision of employment. Initially, most (>90% of the area) was occupied by *Pinus* and *Acacia* invasions, mostly at low densities. The cost of control (initial clearing and up to 16 follow-up visits to remove emergent seedlings) amounted to almost ZAR 50 million (14 ZAR ~ 1US$). Although the cover of alien plants was greatly reduced, over 1000 ha still support dense or medium invasions (>25% cover), and the area occupied by scattered *Pinus* plants increased by over 3000 ha to >5700 ha. A reliance on passive restoration had not yet resulted in full recovery of the natural vegetation. The mean number of species, and total projected canopy cover on 50 m^2 plots was lower in cleared than in comparable reference sites with pristine vegetation (21 vs 32 species/plot, and 94 vs 168% cover respectively). While the project is ongoing, we conclude that the entire area could revert to a more densely-invaded state in the event of a reduction of funding. Several changes to the management approach (including the integrated use of fire, a greater use of power tools, and active re-seeding of cleared areas with indigenous shrubs) would substantially increase the future effectiveness of the project and the sustainability of its outcomes.

1. Introduction

Human-induced transformation of ecosystems accelerated during the latter half of the 20th century, leaving very few areas unaffected. The situation has reached a point where conscious trade-offs need to be made regarding the optimal configuration of landscapes that will deliver the most benefit to humanity, in the form of ecosystem services and the protection of biodiversity (Millenium Ecosystem Assessment, 2005). As a result, many projects worldwide seek to restore degraded or transformed ecosystems to a condition where they will deliver an arguably better set of benefits in future (Perring et al., 2015; Stanturf et al., 2014; Suding et al., 2015).

Successful restoration efforts depend on setting specific goals and implementing well-planned, effective operations. Restoration attempts should set clear objectives (Clewell and Aronson, 2007), and then assess whether or not progress towards achieving those goals is being made (Holl and Aide, 2011; Sainsbury et al., 2000). Most assessments of restoration efforts focus on ecological aspects of restoration activities (Brudvig, 2011), but how the projects are implemented and managed should also be evaluated (Suding et al., 2015). Regular monitoring will inform decisions on the allocation of limited resources, and on adaptive management (Epanchin-Niell and Hastings, 2010; Holl and Aide, 2011; Sainsbury et al., 2000), but this is seldom done (Ruiz-Jaen and Aide, 2005). The documentation of case studies and their outcomes over the long-term is

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http://dx.doi.org/10.1016/j.jenvman.2016.10.053
0301-4797/

therefore desirable for illustrating how effective they are (Menz et al., 2013; Suding et al., 2015; Wortley et al., 2013).

We took advantage of a rare opportunity to examine an ongoing long-term restoration effort in a South African mountain catchment. The land had been used for pine plantation forestry from the 1930s. Pine trees (genus *Pinus*) provide valuable timber, but are also invasive, spreading to adjacent unplanted areas (McConnachie et al., 2015) and impacting negatively on water resources (Le Maitre et al., 1996). In the late 1990s, a decision was taken to phase out plantation forestry. The plantations and surrounding land in the catchment were cleared of alien vegetation and restored as part of the South African government's national invasive species control program (Working for Water, van Wilgen and Wannenburgh, 2016). Since 1995, this programme has created jobs for impoverished workers by contracting out invaded areas for clearing projects (Koenig, 2009). The goals of the program are to restore the native fynbos (shrubland) vegetation, to enhance water runoff, protect biodiversity and provide employment (van Wilgen and Wannenburgh, 2016). Billions of rands have been spent on alien tree and shrub control across the country, improving water yield and providing employment (Marais and Wannenburg, 2008).

The value of the restoration scheme described here hinges on the removal of invasive alien plants (including plantation trees) and subsequent restoration of natural vegetation. In this study, we assessed the outcomes of ecosystem restoration following the clearing of *Pinus* plantations and alien plant invasions in the surrounding landscape over 13 years from the upper catchment of the Berg River in the Western Cape Province, South Africa. We examined the goals of restoration, the methods employed to achieve the goals, the costs of management, and the ecological outcomes in terms of reduced alien plant cover and native vegetation recovery. Based on this assessment we make recommendations for improving management in future.

2. Methods

2.1. Study areas

We assessed restoration activities in the upper Berg River catchment in the Western Cape Province, South Africa (33° 56′ S, 19° 02' E; Fig. 1). Mean annual rainfall is ~1500 mm, and the natural vegetation is sandstone fynbos shrublands, ranging in height from 0.5 to 2.5 m (Rebelo et al., 2006). The terrain is rugged and mountainous, with many steep slopes. Soils in the area are composed of coarse sands derived from sandstones of the Table Mountain Group (Cape Supergroup), and are mostly shallow and rocky. Detailed soil profiles are provided in van Wilgen and Kruger (1985). The project area covered about 8000 ha, about 25% of which had been in plantation (Fig. 2). Lower, relatively less steep portions of the catchment had been planted as early as the 1930s with pines, primarily *Pinus pinaster* and *P. radiata*. Invasive alien *Acacia* trees and shrubs, predominantly *A. longifolia*, also occurred in the unplanted parts of the study area, notably along drainage lines and floodplains of the Berg River.

From the late 1960s, the Department of Forestry conducted invasive plant clearing operations throughout the Berg and neighbouring catchments, but records of these control operations have not survived. In 2001, following a severe fire in 1999 that burned most of the catchment, the state leased the plantation to the private forestry company Mountain to Ocean (MTO). The privatisation of timber plantations was based on economic assessments of their viability, and roughly 40 000 ha of plantations in the Western Cape were considered economically unviable and were earmarked for deforestation and transfer to conservation authorities (Louw, 2004, 2006). Because of anticipated financial loss from these plantations due to their unviability as well as the proposed construction of the Berg River dam, MTO harvested the standing timber from most of the planted area between 2001 and 2004. When MTO withdrew in 2005, Working for Water appointed the Cape Winelands District Municipality to implement alien plant control operations in the upper Berg River catchment (Fig. 2). These operations included follow-up on cleared plantations to remove regrowth, as well as clearing all invasive alien trees and shrubs from the adjacent catchment and floodplains that had not been afforested.

We assessed the effectiveness of clearing on vegetation recovery by comparing sites in the upper Berg River catchment to nearby areas where vegetation survey data were available. These included a site at Jonkershoek (McDonald, 1985), and one at Zachariashoek (van Wilgen and Kruger, 1985, Fig. 1). The geology and soils are similar to the Berg River catchment; mean annual rainfall is 1700 mm at Jonkershoek, and 1500 mm at Zachariashoek. The Zachariashoek site had historically been invaded by alien shrubs in the genus *Hakea*, which were cleared in the late 1960s (van Wilgen and Kruger, 1981), while the Jonkershoek site had no history of invasion.

2.2. Goals of management

The goals of management, and the methods used to achieve those goals, would ideally be set out in a management plan. However, there was no formal management plan for this project area. In 2002, a business plan had been written for a project in an adjacent area of the catchment. Although the Working for Water program goals were alluded to, the document included no specific, measurable objectives. We therefore attempted to document the management goals by reviewing a number of sources. The sources included assessments of the extent of the alien plant problem, and the magnitude of its impacts, published in the peer-reviewed literature; annual plans of operation that provided details of control operations; a spatial database of alien plant distribution and cover, and the costs of control; and interviews with project managers, including the project manager who had overseen the Berg River operations since their initiation in 2001.

2.3. Elements of best practice, and control methods used

We evaluated the methods used to control alien plants in the Berg River project by comparing them to approaches that would be considered to be best practice. These methods included mechanical and chemical control, biological control, the development of schedules for follow-up treatments, the integrated use of fire, and the spatial configuration of control interventions. The elements of best practice were obtained from studies and reviews published in the peer-reviewed literature, and the approaches actually employed were obtained from a review of the spatial database, as well as through interviews with project managers.

2.4. Extent, cost and effectiveness of control

We obtained information on the extent and cost of control from the Department of Environmental Affairs' spatial database. This database delineates fixed management units on which control operations (initial clearing and follow-up) are carried out. Each management unit has an estimate of alien plant cover for each species present; cover is assessed when the unit is first worked on, and re-assessed prior to any subsequent follow-up clearing. The records covered 13 years (2001–2014). Individual assignments on management units were contracted out to service providers, who were paid on completion of tasks assigned. The cost of each