Ecosystem Services 32 (2018) 125–133

Contents lists available at ScienceDirect

Ecosystem Services

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

Can control of invasive vegetation improve water and rural livelihood security in Nepal?

Mark Everard[a,*], Nishikant Gupta[b], Prem S. Chapagain[c], Bharat Babu Shrestha[d], Guy Preston[e], Prakash Tiwari[f]

[a] University of the West of England (UWE), Coldharbour Lane, Frenchay Campus, Bristol BS16 1QY, UK
[b] International Centre for Integrated Mountain Development (ICIMOD), Post Box # 3226 Kathmandu, Nepal
[c] Central Department of Geography, Tribhuvan University, Kathmandu, Nepal
[d] Central Department of Botany, Tribhuvan University, Kathmandu, Nepal
[e] Department of Environmental Affairs, 14 Loop Street, Cape Town 8001, Private Bag X4390, Cape Town 8000, South Africa
[f] Department of Geography, Kumaun University, Nainital, Uttarakhand, India

ARTICLE INFO

Keywords:
Invasive species
Water security
Socio-ecological systems
Sustainability
Conflict
Poverty

ABSTRACT

Nepal's predominantly rural population depends on the ecosystem services of heterogeneous mountainous landscapes that are degrading under changing climate and development pressures. Invasive alien plants (IAPs) compound threats to ecosystem services including water resource security from mid-hill springs, though implications for Nepal's water resources are under-researched. South Africa's Working for Water (WfW) programme addresses linked policy priorities related to IAP management including water, biodiversity and employability. We use the STEEP (Social, Technological, Environmental, Economic, Political) framework to explore success criteria behind WfW and their potential translation into the geographically, culturally and politically different Nepali context, including local considerations at three sites in Kavrepalanchok district. An adapted WfW approach could potentially contribute to water, food, biodiversity, forest, soil, gender equity, community development and security outcomes in Nepal, delivering national and international policy priorities. Evidence from study sites suggests four priority IAPs – *Lantana camara*, *Ageratina adenophora*, *Chromolaena odorata* and *Pinus roxburghii* – of differing characteristics, extents of invasion and perceived impacts at selected sites requiring control. These initial observations warrant trial management of IAPs in a test area with monitoring to evaluate outcomes for water, food and livelihood security, with potential for subsequent regional or national roll-out of a management programme.

1. Introduction

Biological invasions, arising from deliberate and/or accidental introduction into areas where species were formerly absent, can have major impacts on native biodiversity and ecosystem services (Collins et al., 2002; Gurevitch and Padilla, 2004; Ricciardi, 2007; Bezeng et al., 2017; Davis et al., 2011; Mason et al., 2017; Vaz et al., 2017), driving a global trend towards biotic homogenisation in human-modified landscapes (Smart et al., 2006). The impacts of invasive alien plants (IAPs) include competition with native species and degradation of resources, including water and soil minerals (Richardson and Van Wilgen, 2004; Ehrenfeld, 2010). Despite global concerns and often significant management efforts at local and regional scales, invasive species continue to proliferate (Sankaran et al., 2005; IUCN, 2011; Secretariat of the CBD, 2014).

IAPs generate multiple, potentially significant challenges including impacts on water security, particularly in water-stressed environments, affecting linked ecosystem services such as food production, soil erosion and fire risk, disproportionately affecting poorer and marginalised people especially in mountain regions (Asbjornsen et al., 2007). In Australia, evaporative loss from one hectare of alien willows (*Salix* spp.) equates to water use by 17 households (Doody and Benyon, 2011). Water security is one of the primary negative impacts associated with many IAPs in South Africa, particularly trees such as Australian *Eucalyptus* and *Acacia* species that have far greater evaporative loss compared to native species (Dye and Jarmain, 2004). Rooting depth is a key factor in depletion of water recharge (Seyfried and Wilcox, 2006). In South Africa, IAPs are conservatively estimated to use 2.9% of mean annual runoff (Le Maitre et al., 2016), with reductions of more than

* Corresponding author.
E-mail addresses: mark.everard@uwe.ac.uk (M. Everard), nishikantgupta@live.in (N. Gupta), gpreston@environment.gov.za (G. Preston).

https://doi.org/10.1016/j.ecoser.2018.07.004
Received 8 January 2017; Received in revised form 4 July 2018; Accepted 6 July 2018

25% in many catchments and a likelihood of increasing reductions if IAPs are allowed to spread unchecked (Van Wilgen et al., 2008). Species physiology, especially species-specific evapotranspiration rates in different environments, plays a major role in the likely impacts of IAP species on water resources (Le Maitre et al., 2015). Consequently, IAP removal can improve water yields, reducing impacts on ecosystem services such as grazing with associated benefits (van Wilgen et al., 2008). The significant role that native forests play in local regulation of the water cycle (Aragão, 2012) may also be disrupted by IAPs. Removal of invasive trees and protection of native forests may therefore be significant for water supply, flow regulation and other ecosystem services and associated livelihoods in heavily invaded tropical forests worldwide (Cavaleri et al., 2014). Notwithstanding the general global tendency for increasing invasion, there are significant regional successes in tackling IAPs for societal benefits. A particular effective example is the Working for Water (WfW) programme in South Africa, operating since 1995 as a resource protection and employment programme administered through the Department of Public Works with the support of multiple government departments.

The impacts of IAPs on water resources in mountainous areas, including in Nepal, have not received a great deal of research. The Federal Democratic Republic of Nepal ('Nepal') is a landlocked country located in the Central Himalayas, spanning a mountainous and substantially forested landscape of over 147,000 km^2 bordering China to the north, and India to the south, east and west. Central Asian Mountain Ecosystems (Yessekin, 2005) and forests (Shvidenko et al., 2005) benefit indigenous communities through provision of diverse ecosystem services. However, Nepal's mountainous, forested ecosystems are degrading under climate change, population growth and development pressures, with significant consequences for many vulnerable and marginalized communities dependent on their services (Körner and Spehn, 2001; Chaudhary et al., 2016). Contemporary Nepal has become a fragile, low income country with high rates of population growth, poverty and male out-migration, compounded by gender inequality (Khadka et al., 2014). Impacts of a major earthquake in April 2015 and concurrent political instability exposed structural weaknesses, marginalised groups suffering disproportionately due to their inability to access water, forest and other ecosystem resources (The Conversation, 2015). These factors combine to threaten environmental sustainability and the flow of ecosystem services upon which rural livelihoods depend, potentially increasing civil unrest and the likelihood of conflict.

IAPs compound pressures on the natural environment and socio-ecological resilience. Lowe et al. (2004) catalogued "100 of the world's worst invasive species" of which eleven IAP species occur in Nepal, six native and five alien, all of them potentially problematic (Budha, 2015; Shrestha, 2016). Sankaran et al. (2005) listed seven top IAPs in the Asia Pacific region, all noted as problematic in Nepal (*Chromolaena odorata* (siam weed); *Eichhornia crassipes* (common water hyacinth); *Lantana camara* (lantana, big-sage); *Leucaena leucocephala* (white lead tree); *Mikania micrantha* (bitter vine); *Ageratina adenophora* (crofton weed or kalobanmara); *Ageratum conyzoides* (tropical whiteweed, billygoat, or gandhe); and *Parthenium hysterophorus* (santa-maria)). Nepal ranks third among the countries most threatened by biological invasions, particularly impacting agricultural production (Paini et al., 2016). Invasive species colonising Nepal's forests and agro-ecosystems continue to adversely affect forest regeneration, farm productivity and livestock health (Poudyal and Adhikari, 2013; Bhatta et al., 2015).

Nepal's mid-hills support about 50% of the total national population, dependent on natural springs as fresh water sources for domestic consumption, irrigation and small hydropower. However, the reliability of these water resources is problematic, with mid-hill springs drying out or substantially decreasing in water flow over the past decade (Chapagain et al., 2016; ICIMOD, 2009, 2015; Dixit et al., 2009). The availability and quantity of water is a principal pressure upon communities and the environment (IPCC, 2007), though knowledge gaps about water resources in Nepal currently hamper objective assessment and appropriate management (WECS, 2011). The role of IAPs in compounding water insecurity in Nepal has not yet been thoroughly reviewed, though studies have been conducted on secondary effects including the implications of some species for agricultural productivity (such as Poudyal and Adhikari, 2013; Siwakoti et al., 2016), although evidence from other localities suggests that impacts may be significant in water-stressed situations. Further study is required into the likely impacts of priority IAPs and their management as a means to secure water and other natural resources underpinning societal wellbeing.

This paper reviews what is known about likely impacts of IAPs on water and livelihoods in Nepal's mid-hills and explores the potential for translating principles underpinning South Africa's WfW programme into the biogeographically, culturally and politically differing context of Nepal as a contribution to enhancing ecosystem services underpinning the needs of the rural community. It achieves this by: (1) characterisation of success factors underpinning the South African WfW programme using the STEEP (Social, Technological, Environmental, Economic, Political) model; (2) characterisation the Nepali context using the STEEP model; (3) observed and perceived relevance of IAPs for water management at local sites in Nepal; and (4) discussion of the potential for implementation of a WfW-based approach in Nepal.

2. Methods

An overview of South Africa's WfW programme and some key outputs was derived from literature review and inputs from the Director of the WfW programme in South Africa. Key aspects of the programme were stratified using the STEEP model to explore some of the multiple, interconnected factors contributing to the success of the programme. Though STEEP was initially developed to assess global change issues (Morrison and Wilson, 1996), it has been applied to analyse systemic relationships in different domains of human activity including meeting sustainability goals (Steward and Kuska, 2011), including the deployment of appropriate technology and associated governance systems in management of water, ecosystem service flows and dependent development issues in South Africa, Europe and India (Everard et al. 2012; Everard 2013, 2015). STEEP is also a suitable model for integrating different types of knowledge (Aretano et al., 2013). STEEP is used here as a basis for potential translation of WfW principles into Nepal's significantly different context.

A field visit was made to three sites in the Jhiku Khola sub-catchment to the east of Kathmandu in Nepal: a rural farming community (Keraghari); a community forest (Tinpiple); and an intensively-cultivated river valley (Panchkhal), all in Kavrepalanchok District (Fig. 1). The purpose of the field visit was to study livelihoods, IAP species and their locations, and the perceptions local people have about them. The sites were visited on Saturday 17th December 2016 in dry weather conditions. The field team spanned a range of expertise, including four of this paper's authors (Everard, Gupta, Chapagain, Shrestha) with Himalayan ecological, climate change, socio-economic, botanical and ecosystem service expertise, also including a development scientist (Narendra Raj Khanal) and a manager of the NGO *Tuki Association Sunkoshin* that supports the development of rural communities (Hemanta Dangal).

Primary evidence-gathering at the three field sites comprised: (1) meetings with representatives (N varying from 12 to 5 per site including approximately equal numbers of men and women) of resource-dependent communities (Fig. 2); (2) empirical observations backed up by the