Ecosystem Services xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Ecosystem Services

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

Strategic water source areas for urban water security: Making the connection between protecting ecosystems and benefiting from their services

Jeanne L. Nel [a,b,*], David C. Le Maitre [c], Dirk J. Roux [b,d], Christine Colvin [e], Janis S. Smith [c], Lindie B. Smith-Adao [c], Ashton Maherry [f], Nadia Sitas [c,g]

[a] Institute for Environmental Studies, Faculty of Science, Vrije Universiteit Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands
[b] Sustainability Research Unit, Nelson Mandela Metropolitan University, Private Bag X6531, George 6530, South Africa
[c] Natural Resources and the Environment, Council for Scientific and Industrial Research, P.O. Box 320, Stellenbosch 7599, South Africa
[d] Scientific Services, South African National Parks, Private Bag X6531, George 6530, South Africa
[e] WWF-South Africa, P.O. Box 23273, Claremont 7735, South Africa
[f] Centre for General Education, Durban University of Technology, P.O. Box 1334, Durban 4000, South Africa
[g] Department of Conservation Ecology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa

A R T I C L E   I N F O

Article history:
Received 3 February 2017
Received in revised form 21 June 2017
Accepted 28 July 2017
Available online xxxx

Keywords:
Water towers
Ecological infrastructure
Catchment stewardship
Water resource management
Sustainable development goals
Knowledge co-production

A B S T R A C T

Strategic water source areas are those areas that have a relatively high natural runoff in the region of interest, which is made accessible for supporting the region's population or economy. These areas contribute substantially to development needs, often far away from the source. This disconnect between ecosystem service supply and use means that the social-ecological impacts of development decisions in these areas may not be obvious to users and decision makers. We identified 22 strategic water source areas in southern Africa linked to major urban centers. We quantified the population size and economy they support, and their current levels of protection. We found that strategic water source areas form only 8% of the land area but contribute 50% of the runoff. When linked to downstream urban centers, these areas support at least 51% of South Africa's population and 64% of its economy. Yet only 13% of their land area is formally protected. We recommend using multiple strategies for the legal protection of these areas. Identifying strategic water source areas and their links to downstream users offers an opportunity for achieving synergy in spatial planning across diverse policy sectors, and enables new patterns of collaboration between government, business and civil society.

1. Introduction

Protecting water source areas to secure water supply is not a new concept. Protection of the Catskills water source area, which supplies water to New York City, is a well-known success story that has reported high returns on investment (Chichilnisky and Heal, 1998)[1]. Similarly, restoration and protection of the Tijuca Forest in Rio de Janeiro to protect the city's water supply dates back to the second half of the 19th century (Trzyna, 2014). The benefits of protecting water source areas stem from maintaining the capacity of ecosystems to regulate the quality and quantity of water over time (Brauman et al., 2007), which in turn provides ecosystem services to downstream users. In an urban context, ecosystem services from water source areas include provisioning services such as water for domestic and industrial uses, regulating services such as dilution of waste, and cultural services such as aesthetic, recreational, sense of place and identity associations (Cosman et al., 2012). These ecosystem services translate into benefits such as reduced water quality treatment costs and improved health, leading to an overall improvement of human well-being.

Water source areas often only occupy a small fraction of the land surface area but supply a relatively high amount of water to the surrounding region (Meybeck et al., 2001). Deterioration of water quality and quantity in water source areas can therefore have a disproportionately large impact on downstream users who are often a far distance away. This disconnect between source and use means that the full social-ecological impacts of development in these areas are often not apparent to decision makers or users. These impacts could be positive (e.g. restoration activities

* Corresponding author.
E-mail address: jnel4water@gmail.com (J.L. Nel).

[1] Exact values are a matter of debate (Kenny, 2015; Appleton and Moss, 2014; Sagoff, 2005).

http://dx.doi.org/10.1016/j.ecoser.2017.07.013
2212-0416/© 2017 Published by Elsevier B.V.

to enhance soil permeability or soil retention, protection of land), or negative (e.g. coal mining, over-abstraction of water by farmers, pollutants from intensive farming activities, or increased streamflow reduction from water-consuming non-native trees and timber plantations). Identifying important water source areas and making more explicit linkages between ecosystem service supply and use can mend this disconnect, and promote the protection of these areas. A recent global study by Harrison et al. (2016) appeals for increased attention to protecting upstream water sources for safeguarding water flows and enhancing water security. They showed that protected areas already offer good potential to safeguard water sources, with almost two-thirds of the world's population living downstream of protected areas.

Originally, important water source areas were identified based on water supply only, by locating mountain areas that supply disproportionate runoff compared to adjacent lowland areas (Meybeck et al., 2001). These areas are termed 'water towers', but stakeholders of this study prefered to use the term 'strategic water source area' (Table 1). The latter term links more explicitly to a geographical area, and uses 'strategic' to imply that it is not an exhaustive identification of all water source areas. In addition, we broaden the original definition of water towers by considering both water supply and human use factors. Strategic water source areas are thus those areas that have a relatively high natural runoff in the region of interest, which is made available for supporting the region's population or economy through water supply schemes.

While the concept of protecting water source areas is not new, recent global policies and planning requirements for sustainable development represent new opportunities for mobilizing businesses and governments around this issue. For example, the 2030 Agenda for Sustainable Development and associated Sustainable Development Goals (SDGs) call for achieving water access for all, while promoting the sustainable management of water resources (UN, 2015). SDGs 6 and 15 are particularly relevant to water source areas because they include explicit commitments to the protection and restoration of water-related ecosystems and their services (Griggs et al., 2013). The 193 countries that subscribe to the SDGs, including South Africa, need to establish national development plans on how they will contribute to these targets. Identifying strategic water source areas and their links to downstream users enables a more comprehensive assessment of different development options, and their impact on urban water. Global Aichi targets set by the Convention on Biological Diversity also offer a good policy opportunity for strategic water source areas. These targets strive to conserve ecosystems that are of particular importance for biodiversity and ecosystem services, through protected areas and other effective area-based conservation measures (CBD, 2010). Identification and incorporation of strategic water source areas into national protected area networks will make an important contribution toward CBD targets, but requires an expansion of the conventional focus of protected areas on terrestrial ecosystems to also prioritize freshwater ecosystems (Pittock et al., 2015) and ecosystem service provision (García-Llorente et al., 2016; Palomo et al., 2013).

Although strategic water source areas have been identified at a global level (Viviroli et al., 2007), application to national planning and decision making requires enhancing the spatial resolution of the global map and adding country-wide detail on water transfer schemes, access and use. The latter is especially important for arid and semi-arid countries, where inter-basin transfers are frequent, and thus water resources are used by more than just the lowland population of the surrounding basin. In this paper, we identify strategic water source areas for southern Africa at an appropriate scale for national planning. We focus on surface water resources, while recognizing that groundwater source areas should also ultimately be identified, particularly in areas with a high dependency on groundwater. We then link the identified strategic water source areas to the water supply systems of major urban centers, quantify the amount of urban water supplied by strategic water source areas, and relate this to the population size and economic value of each area. We assess current protection levels of strategic water source areas and conclude with generalized recommendations for incorporating this ecosystem service perspective into both sustainable development planning and protected area expansion elsewhere in the world.

2. Methods

2.1. Co-production of maps with stakeholders

Several maps of water source areas have been developed in South Africa over the years (Nel et al., 2011; Driver et al., 2005; Ross, 1961), with little or no traction in policy and decision making. To improve uptake, we used an iterative participatory process (*sensu* Nel et al., 2016) to co-develop the map of strategic water

Table 1
Key limitations of previous water source area maps and ways in which these were addressed.

Barrier to uptake	How we addressed this barrier
No acceptable common terminology for referring to these areas resulting in confusion, especially around terms too immersed in engineering-based solutions (e.g. 'water towers', 'water factories', 'high water yield areas')	Sought extensive stakeholder input on the collective name for these areas, as well as a definition. Later also sought consensus on names for each water source area
Broaden from a water supply focus only to include information of water access and use, particularly since some strategic areas are not necessarily those with the highest runoff	The initial map, focussing on water supply, was developed using natural mean annual runoff (MAR). Thereafter, national water resource planners and national demand data were consulted to identify gaps based on water demand by major urban development or economic nodes.
Mapping strategic water source areas using runoff data at catchment, or even sub-catchment, is too coarse because it is difficult to separate the actual source areas from the surrounding lowlands even if the sub-catchments are relatively small	Disaggregated catchment runoff data to $1' \times 1'$ resolution using a rainfall-runoff model, so that variability in runoff could be detected within sub-catchments
National water resource planners and engineers were reluctant to use runoff data that was not endorsed by their departments	Applied an adjustment factor to the $1' \times 1'$ data so that the runoff data matched that of the sub-catchment outlet in the data used by their departments
Previous maps were too detailed, with too many areas identified, making them difficult to apply in strategic, national-level planning	Focused on identifying the most strategic areas at a national level, rather than an exhaustive map of all water source areas. Water supply was mapped using percentage runoff relative to national runoff rather than catchment runoff, and water use focused on areas identified in the national development plan as major urban development or economic nodes.
Local scale delineations, rather than $1' \times 1'$ pixels, are preferred	Beyond the scope of this national scale work – needs attention at local scale