Prioritisation of established terrestrial environmental weeds for asset protection in South Africa

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Summary Invasions by alien plants are a significant threat to the biodiversity and functioning of ecosystems and the services they provide. The South African Working for Water program was established to address this problem. It needs to formulate objective and transparent priorities for controlling established terrestrial environmental weeds in the face of multiple and sometimes conflicting demands. This study used the analytic hierarchy process (a multi-criteria decision support technique) to develop and rank criteria for prioritising alien plant control operations in South Africa.

Stakeholder workshops were held to identify a goal and criteria and to conduct pair-wise comparisons to weight the criteria with respect to invasive alien plant control. The combination of stakeholder input (to develop decision models) with data-driven model solutions enabled us to include many alternatives (water catchments) that would otherwise not have been feasible. We selected spatial datasets and used them to generate weights that could be used to objectively compare alternatives with respect to agreed criteria.

The analysis showed that there are many high priority catchments which are not receiving any funding and low priority catchments which are receiving substantial allocations. Clearly, there is a need for realigning priorities, including directing sufficient funds to the highest priority catchments to provide effective control. This approach provided a tractable, consensus-based solution that can be used to direct control operations.

Keywords Prioritisation, established species, environmental weeds, asset protection, Working for Water.

INTRODUCTION

South Africa is home to a large and growing number of invasive alien species. Reasons for this include the long history of colonial occupation (dating back 360 years), and the many and varied ecosystems all of which currently harbour populations of well-established invasive alien species. Plants are the most noticeable group of invasive alien species in South Africa, occupying large parts of the country. Almost 9000 alien plant species have been introduced to South Africa, of which 381 have been listed as invasive in draft legislation, though there are others that are also invasive.

Asset protection According to a 'four by three' framework for the management of biological invasions, there are four stages of invasion, dependent on the extent and abundance of the species concerned (pre-introduction; initial incursion; expansion; and dominance), and three broad types of management responses that would focus either on managing single species (a species-based approach), or managing priority areas invaded by one or more species (an area-based approach), or managing the pathways that are responsible for the spread of invasive species (a pathway-based approach). For the 'dominance' stage of invasion, the broad management approach would be the development and implementation of an integrated alien species control programme in a given area to restore, as far as possible, key ecosystem services and functioning, or to reduce the impacts on invasion by multiple species (DEA 2014).

Established species Nel *et al.* (2004) classified 117 invasive alien plant species in South Africa as 'major invaders'. These were defined as being well established and already having a substantial impact on natural and semi-natural ecosystems. They suggested that 'major invaders' were likely to constitute the prime concern for managers, and projects aimed at their control should receive the largest proportion of available funding over the next few decades. Of these 117 'major invaders', 22 species were classified as 'widespread and abundant'.

Working for Water Invasive alien plant control operations in South Africa were scaled up dramatically in 1995. Projects were initiated based on: the presence of management capacity, which was found, for example, in national and provincial conservation organisations, larger municipalities, and water boards; a focus on alien plants with high water use, mainly trees in catchments and along rivers; and the imperative to create employment in impoverished rural areas. This has been supplemented by the development of biological control options that target selected priority alien plant species, the promulgation of legislation that requires landowners to deal with the problem; and the encouragement of systems of payment for ecosystem services that will generate funding to support control programs (Van Wilgen *et al*. 2011).

However, Van Wilgen *et al.* (2012) found that despite substantial spending, control operations were in many cases applied to a relatively small portion of the estimated invaded area, and invasions appear to have increased, and remain a serious threat. Their findings suggest that South Africa's national-scale strategy to clear invasive alien plants should be substantially modified if impacts are to be effectively mitigated. Rather than attempting to control all species, and to operate in all areas, a more focused approach was called for.

MATERIALS AND METHODS

Stakeholder workshops Between 2008 and 2012, the Working for Water program convened 25 workshops with over 300 stakeholders representing various interest groups in a series of prioritisation exercises, aimed at identifying those areas where invasive alien plant control was most needed, and where such control would bring the largest returns on investment. In 2012, all the criteria that had been identified in a series of prioritisation exercises were pooled to develop a 'generic' prioritisation model.

Multi-criteria decision making We used a multi-criteria approach known as the analytic hierarchy process (AHP) (Saaty 1990) to identify and weight criteria for comparing the alternatives (units to be prioritised, in this case quaternary catchments), and to carry out the prioritisation. AHP involves the following steps: defining a goal; identifying criteria and sub-criteria to assess alternatives in terms of their suitability for achieving the goal; making pair-wise comparisons of the criteria and sub-criteria to establish their relative importance; and making pair-wise comparisons of the alternatives with respect to the criteria, or (as in our case) making use of spreadsheets containing data relevant to each of the criteria.

The Expert Choice (Anon. 2004) software package implements AHP in a form that is convenient and explicit and can be used interactively in workshops to define the goals, criteria, sub-criteria and their relative importance. The software also has the option of importing pre-determined weights for each alternative from a 'data grid', and, if such data are available, their use can replace the time-consuming pair-wise comparisons of large numbers of alternatives with respect to each of the criteria. We prioritised the quaternary catchments separately within each primary catchment because each primary catchment is managed separately (Forsyth *et al.* 2012).

Identification of criteria and development of a prioritisation model Analytic hierarchy process requires that the alternatives to be prioritised (in this case quaternary catchments) be compared with each other with regard to an agreed goal and supporting criteria; and these criteria can in turn be divided into sub-criteria. We identified a goal, criteria and sub-criteria during workshops, and weighted these in a process that requires the cross-comparison of each criterion with each other criterion in terms of their relative importance for the achievement of the agreed goal. Similarly, sub-criteria were compared to each other, to determine the relative importance of sub-criteria within each criterion. In this process, participants used their own understanding, and debated the relative importance of each comparison until consensus was achieved. Expert Choice (Anon. 2004) facilitated this process, as it continuously updates an inconsistency ratio, which allowed for the identification of inconsistent comparisons. For example, if criterion A was rated as more important than criterion B, and B was rated as more important than C, then a subsequent allocation that rated C as more important than A would show up as inconsistent. When inconsistencies arose during the model-building process, we used the opportunity to debate the relative importance assigned to each criterion, and to re-assign weightings until the inconsistency ratio was within acceptable limits. An inconsistency ratio of 0 indicates perfect consistency; it is recommended that the inconsistency ratio should not exceed 0.1, and we took this into account when building our prioritisation model (Forsyth *et al.* 2012).

Comparison of alternatives Once criteria had been agreed on, we identified spatial datasets that would allow for objective comparisons to be made between alternative quaternary catchments with regard to each of the criteria. Following the workshops, the weighting of the alternatives was completed mechanically, using the identified datasets. For each of the criteria used by the model we calculated a weight for each catchment based on the value in the respective spatial datasets we used. The area-based calculations were done using the ArcGIS software (ESRI, 1990) and the other calculations were done using spreadsheets. The value of the output for each catchment was then divided by the corresponding total to give the final proportion or weight. The final weights were imported directly into the AHP model which then calculated the weights for each quaternary catchment for each criterion and the goal (Forsyth *et al.* 2012).

RESULTS AND DISCUSSION

Development of a prioritisation model The 'generic' prioritisation model identified five criteria (divided hierarchically into 16 sub-criteria) that were judged to be the most important and consistently used, and used these to derive an overall, national-scale map of priorities (Table 1).

Model outputs The analysis showed that there are many high priority catchments that are not receiving any funding and low priority catchments that are receiving substantial allocations. Clearly, there is a need for realigning priorities, including directing sufficient funds to the highest priority catchments to provide effective control. This approach provided a tractable, consensus-based solution that can be used to direct control operations.

The exercises have also made us aware of a number of shortcomings regarding the available spatial data and, in other instances, the lack of appropriate spatial data to represent the criteria and sub-criteria that are considered important during the workshops.

Combining stakeholder input and spatial data These exercises have demonstrated the potential for combining stakeholder priorities (to identify and weight criteria) with spatial datasets to derive a set of priority areas. We prioritised 1946 quaternary catchments using 16 criteria. This could not have been completed manually in a workshop environment as it would have required over 100,000 cross-comparisons. However, by using spatial data to generate weights for each alternative (quaternary catchments) relative to the criteria, Expert Choice (Anon. 2004) enabled us to automate this evaluation process.

Challenges in implementation These prioritisation exercises have not yet had a great influence on the re-direction of funding to priority quaternary catchments

Table 1. Generic area-based prioritisation model based on a synthesis of the 1st, 2nd and 3rd level criteria used to prioritise species in the national and regional level assessments. The weights show their proportional contribution to the whole model. Their sum is equal to one.

1st-level criterion	2nd-level-criterion	3rd-level-criterion	Weights
Impacts on water resources	Surface water	Yield: current or future	0.34
		Water quality	0.04
		Stress from human demand	0.06
	Ground water	Recharge protection	0.04
		Yield: current sustainable abstraction	0.01
		Stress from human demand	0.01
Biodiversity protection	Threatened terrestrial vegetation types and critical biodiversity areas		0.15
	Threatened, intact and free flowing rivers; and wetlands		0.08
Biodiversity and ecosystem services	Natural resource utilisation	Forage for grazing and browsing in natural rangelands	0.03
		Useful, harvestable natural products	0.01
	Tourism and cultural routes and sites		0.01
	Regulating services	Soil stability	0.09
		Flood regulation (river bank stability)	0.01
Invasive alien plants	Current invasions (species weighted)		0.10
	Potential invasions (species weighted)		0.05
Socio-economic (poverty)	Poverty		0.04

in practice. Almost all of Working for Water's projects were initiated prior to the prioritisation exercises. The re-direction of funding, should it be needed, would have to take several additional issues into account. These include the need to complete projects already initiated prior to prioritisation, and to honour contractual commitments and capacity constraints. Future prioritisation processes will also have to be broadened to include the management practice of 'payment for ecosystems' (Van Wilgen *et al.* 2011).

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