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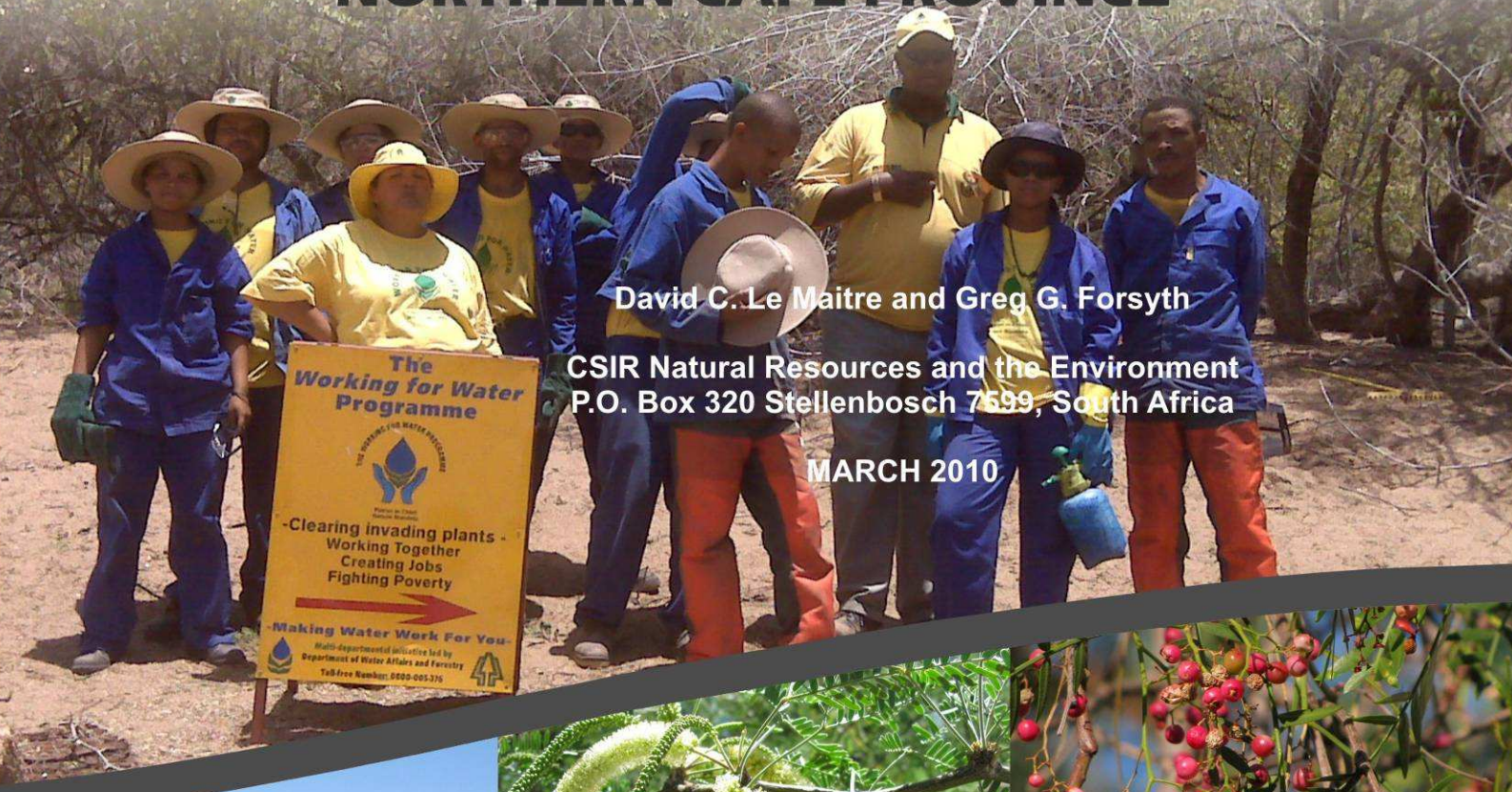
PRIORITIZING QUATERNARY CATCHMENTS FOR THE MANAGEMENT OF INVASIVE ALIEN PLANTS IN THE NORTHERN CAPE PROVINCE



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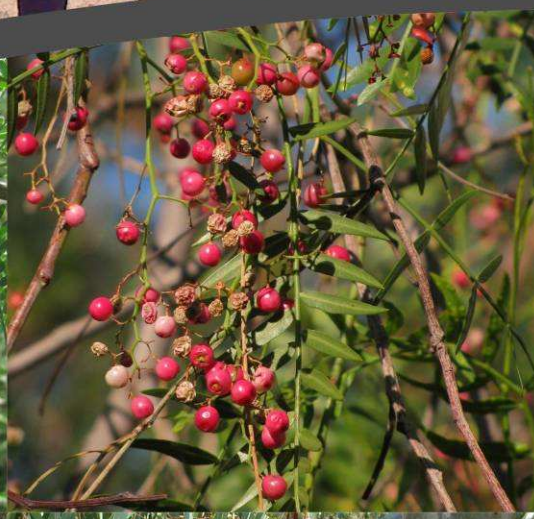

Prioritising quaternary catchments for invasive alien plant control within the Savanna, Nama and Succulent Karoo Biomes of the Northern Cape Province

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Executive Summary

Introduction

Invasive alien plant control requires the allocation of limited resources to control operations to maximise benefits. The priorities for such allocation are based on a mixture of fact and opinion, interpreted either subjectively or objectively, but often not explicitly so. This project sought to develop an approach that could assist managers and planners in the Working for Water Programme's Northern Cape Region to prioritise their activities with a degree of transparency.

We used the Analytic Hierarchy Process (AHP) to facilitate prioritization. AHP is a multiple criteria decision-making tool for setting priorities when both qualitative and quantitative aspects of a decision need to be considered, and for achieving group consensus.

Priorities in primary catchment D

The catchment of the Orange River (D), including a section of the Vaal River (Primary C) was divided into three sub-catchments using the biomes as follows: D_1 which includes D3 (Middle Orange, Seekoei) and D6 (Ongers, Brak); D_3 which includes D5 (Sak Hartbees) and D8 (Lower Orange) and D_3 which includes tertiary catchments C33, C91, C92 (Lower Harts and Vaal) and secondary catchments D4 (Kuruman, Molopo) and D7 (Middle Orange, Soutloop). In D_1 the five catchments with the highest relative importance rankings are D35K, D35H, D35B, D31E and D33K. These are located around protected areas along the Orange River and in the higher water yielding parts of this catchment unit. In D_2 the top catchments are D82J, D82H, D51A, D52A and D82K. Those in secondary catchment D8 include the Richtersveld National Park and the adjacent World Heritage Site and have high demand for groundwater. D51A and D52A are located in the headwaters of the Vis, a tributary of the Sak River. In D_3 the top priorities went to D42A, C92C, C91B, C33B and C33C. The first quaternary is located entirely within the Kalahari National Park. The others are located in areas where there is relatively high groundwater availability, a factor which was given high weight in the prioritization.

Priorities in primary catchment E

Forty-four of the quaternary catchments in the Olifants-Doring River catchment (E) were included in this assessment. The five quaternary catchments with the highest relative importance rankings are E23E, E23F, E23J, E31F and E23A. The first three have relatively high potential groundwater utilisation potential, extensive azonal vegetation and include portions of the Tankwa Karoo National Park. E31F has a relatively high registered groundwater use and extensive azonal vegetation while E23A has a relatively high potential groundwater utilisation potential.

Priorities in primary catchment F

A total of 35 quaternary catchments occur within primary catchment F (Namaqualand). The five most important quaternary catchments are F10A, F40C,

F10C, F50E and F50C. F10A has very high registered groundwater-use and includes parts of the Richtersveld National Park and the adjacent World Heritage Site. F40C has a high proportion in the Namaqua National Park while F10C includes most of the Namib Seashore Vegetation, the only threatened vegetation type in primary catchment F. F50C and F50E have relatively high volumes of potentially utilisable groundwater and surface water runoff.

Conclusions and recommendations

This study has been successful in applying the approach developed by van Wilgen et al. (2008) at a quaternary catchment scale in the Northern Cape. However, a number of follow-up actions will be needed if this approach is to deliver its full potential in terms of assisting the Working for Water Programme to improve its operations and its impact.

We recommend the following:

- That the techniques developed at the primary and quaternary catchment scale be adopted by Working for Water's national and regional planning offices to assist with prioritization, planning, and the allocation of resources to both existing and new projects on an ongoing basis.

- The priorities given in van Wilgen et al. (2008) should be used to guide the allocation of funds between the primary catchments and sub-catchments of the Northern Cape. Then the priorities identified in this study should be used to allocate funds amongst the quaternary catchments.

- That as soon as the National Invasive Alien Plant Survey has been completed by the Agricultural Research Council, its data on the current state of invasion should be replace the SAPIA data we have used for in this study.

- That a spatial database be developed to underpin effective comparisons of areas. This database could contain data relating to most of the criteria identified here, including mean annual runoff, the locality of important groundwater aquifers, the degree of water stress, conserved areas, threatened or critically threatened river and vegetation types, livestock production potential, the distribution of invasive alien species, land ownership, and the location of poverty nodes.

- Each Working for Water region should maintain existing datasets and revise them on a regular basis. This should not be longer than 3 years so as to coincide with the medium term expenditure framework (MTEF) of government.

- That the WfW programme develop a multi-criteria-based approach to prioritising local settlements and communities for inclusion in projects in the prioritised catchments. This prioritisation scheme should also take into account the opportunities for employment and capacity building through other extended public works programmes.

- That this work be published in the peer-reviewed literature. This will have a number of advantages, including (i) ensuring that the work is subjected to rigorous review; (ii) ensuring a permanent and widely-retrievable record of the work; and (iii) enabling the wider dissemination of the approach and results, particularly to other organizations involved in control operations.

Acknowledgements

We thank the Working for Water Programme of the Department of Water and Environment Affairs for funding this work. We thank Ms Debbie Sharp and her replacement Mr Vusi Lubisi, Mr Louwrens Ferreira and Mr Andrew Wannenburgh of the Working for Water Programme of the Department of Water and Environment Affairs for supporting the project and serving on the reference group.

The following managers, implementing agents and researchers are thanked for their informed and enthusiastic participation in the 1st workshop aimed at developing a model for assessing the priority quaternary catchments to clear in the portions of the Northern Cape covered by the Savanna, Nama and Succulent Karoo Biomes: Debbie Sharp, Louwrens Ferreira, Peter Ramollo, Mase Moshotlwa, Ayanda Mtshizana, Hugo Bezuidenhout, Julius Koen, Bennie Viljoen, Elise Lameyer, Elna van den Berg and Andrew Wannenburgh. The participants in the second workshop were: Vusi Lubisi, Mase Moshotlwa, Roy Mackenzie, Walter Barnett, Cecil Thebe, Dinah Cloete, Lucia Roman, Dennis Rispel, Patrick van Neel, Nico Byleveldt, Ismael Nagdee, Andrew Wannenburgh, Barbara Mashope, Ayanda Mtshizana, Agnes Maluleke, Geran Ngobeni, Masingita Maluleke, Patrick van Wyk and Peter Ramollo.

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Contents

Executive Summary i
Acknowledgements iii
Contents iv
Figures vi
Tables viii

1. INTRODUCTION 9

2. CAPACITY BUILDING 10

3. SCOPE OF WORK 11

4. APPROACH 13

4.1 WORKSHOPS TO DETERMINE RANKING CRITERIA 13

4.2 SPECIES SELECTION 14

4.3 GOALS AND CRITERIA 14

4.4 SPATIAL DATA SETS USED IN THE PRIORITISATION 14

4.5 SELECTING APPROPRIATE DATA 16

4.5.1 Capacity to maintain the gains 16
4.5.2 Improve the integrity of the water resource 16
4.5.3 Potential to spread 18
4.5.4 Value of the catchment for biodiversity 20
4.5.5 Potential for veld utilisation 20

5. RESULTS 22

5.1 SPECIES PRIORITISATION 22

5.1.1 Species selection 22
5.1.2 Goal and Criteria 23
5.1.3 Prioritised species 24

5.2 AREA PRIORITISATION 25

5.2.1 Goal and Criteria 25
5.2.2 Primary Catchment D_1 (Orange-Seekoei and Ongers-Brak) 27
5.2.3 Primary Catchment D_2 (Sak-Hartbees and Lower Orange) 30
5.2.4 Primary Catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts) 33
5.2.5 Primary Catchment E (Olifants-Doring) 36
5.2.6 Primary Catchment F (Namaqualand catchments) 39

5.3 OVERVIEW OF NORTHERN CAPE PRIORITY QUATERNARY CATCHMENTS 42

6. APPLYING THE PRIORITIES 44

7. CONCLUSIONS 46

8. RECOMMEDATIONS 47

9. REFERENCES 48

Appendix 1:	Priority invasive alien plants in the Fynbos, Nama Karoo and Succulent Karoo Biomes
Appendix 2	Participants in expert workshops

Figures

Figure 1: *Ranked criteria identified as significant for the purpose of prioritizing quaternary catchments within primary catchments in the Northern Cape Province for the clearing of invasive alien plants. Relative weightings, out of a total of 1.0, are given for each criterion.* 23

Figure 2: *The relative importance of the major invasive alien plants in the Northern Cape (Arid Savanna, Nama and Succulent Karoo Biomes) based on pair wise comparisons using the weighted criteria and sub-criteria contained in Table 4.* 25

Figure 3: *A hierarchical view of the goal, criteria and sub-criteria identified as significant for the purpose of prioritising the clearing of invasive alien plants from quaternary catchments in the Northern Cape.* 26

Figure 4: *The relative importance and ranking of the 46 top priority quaternary catchments out of the 63 in primary catchment D_1 in the Northern Cape Province.* 28

Figure 5: *Catchment (AHP) scores for each of the quaternary catchments primary catchment D_1. Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.* 29

Figure 6: *The 2009/10 budget for IAP clearing projects in primary catchment D_1 in relation to priorities identified in this study (see Figure 5). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.* 30

Figure 7: *The relative importance and ranking of the top 46 of the 72 quaternary catchments in the primary catchment D_2 (Sak-Hartbees and Lower Orange)* 31

Figure 8: *Catchment (AHP) scores for each of the quaternary catchments in primary catchment D_2 (Sak-Hartbees and Lower Orange). Red and orange shading indicates catchments having the highest priority for clearing invasive alien plants.* 32

Figure 9: *The 2009/10 budget for IAP clearing projects in the D_2 (Sak-Hartbees and Lower Orange) portion of primary catchment D in relation to priorities identified in this study (see Figure 8). The alignment is shown by deviations from the trend line. Each project's quaternary catchment is given in parentheses after the project name.* 33

Figure 10: *The relative importance and ranking of the 33 quaternary catchments in primary catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts).* 34

Figure 11: *Catchment (AHP) scores for each of the quaternary catchments in primary catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts). Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.* 35

Figure 12: *The 2009/10 budget for IAP clearing projects in D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts) portion of primary catchment D in relation to priorities identified in this study (see Figure 11). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.* 36

Figure 13: *The relative importance and ranking for the 44 quaternary catchments in the primary catchment E (Olifants-Doring)* 37

Figure 14: *Catchment (AHP) scores for each of the quaternary catchments in primary catchment E (Olifants-Doring). Red and orange shading indicates catchments having the highest priority for clearing invasive alien plants.* 38

Figure 15: *The 2009/10 budget for IAP clearing projects in primary catchment E in relation to priorities identified in this study (see Figure14). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.* 39

Figure 16: *The relative importance and ranking of the 35 quaternary catchments in primary catchment F (Namaqualand) in the Northern Cape Province.* 40

Figure 17: *Catchment* (*AHP) scores for each of the quaternary catchments or portions thereof in primary catchment F (Namaqualand) in the Northern Cape Province. Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.* 41

Figure 18: *The 2009/10 budget for IAP clearing projects in primary catchment F (Namaqualand) in relation to priorities identified in this study (see Figure 17). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.* 42

Figure 19: *The top priority quaternary catchments identified (red and orange shading) within each of the major primary catchment-based management units in the Northern Cape.* 43

Tables

Table 1: Spatial datasets used to determine composite scores to assign to each of the quaternary catchments in the study area based on the criteria and sub-criteria identified in the workshop. Quaternary catchments having the highest scores were assigned the highest priority. Sub-criteria in italics are sub-sub-criteria _____15

Table 2: A list of the species used for the modelling of the potential invasions based on the potential distribution envelopes generated by Rouget et al. (2004). _____19

Table 3: Grazing potential classes in large livestock units (LSU) per km^2 (Scholes 1998). _____21

Table 4: The 22 invasive alien plant taxa selected for prioritization from the Arid Savanna, Nama Karoo and Succulent Karoo Biomes in the Northern. Some taxa include several species _____22

Table 5: Nested criteria, with their relative weightings, identified as significant for the purposes of prioritising species in the Succulent Karoo, Nama Karoo and Arid Savanna Biomes of the Northern Cape for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each. The ones in italics are 2^{nd}-level sub-criteria and their totals are shown separately. _____24

Table 6: Nested criteria, together with the relative weightings, identified as significant for the purposes of prioritising quaternary catchments in the Northern Cape for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each. The ones in italics are sub-sub-criteria and their totals are shown separately. _____27

1. INTRODUCTION

Invasive alien plant control requires the allocation of limited resources to control operations to maximise benefits. The priorities for allocating resources typically are based on a mixture of fact and informed opinion and this information can be interpreted either subjectively or objectively. However, the information and the rationale behind the priorities are rarely made explicit so it is difficult to assess the validity of those priorities.

The CSIR has recently completed two studies on the prioritisation of species and primary catchments for the purposes of guiding invasive alien plant control operations. The first was for terrestrial biomes of South Africa and established national priorities (van Wilgen et al., 2008). The second was at a quaternary catchment scale and established priorities for the Western Cape region of Working for Water (Forsyth et al., 2009). These studies developed an approach and method that enables managers and planners in the Working for Water Programme to prioritise their activities in a way that is transparent, logical and defensible.

The biome-level study also developed methods for the identification of a priority list of (i) invasive alien plants, and (ii) areas (primary catchments) within the terrestrial biomes of South Africa that should be targeted for control by the Working for Water Programme. The biomes included the Fynbos, Grassland, Savanna (both moist and arid), Succulent Karoo and Nama Karoo.

Debbie Sharp of the Department of Water Affairs and Forestry (DWAF) asked the CSIR to assist in prioritising areas to clear within the Northern Cape Province by applying the methods developed for the biomes and the Northern Cape at a quaternary catchment scale.

This report presents the results of our study to determine the priority quaternary catchments to clear in each of the main primary catchments of the Northern Cape. We also make recommendations for further improvements to the prioritisation process and its implementation by the Working for Water Programme.

2. CAPACITY BUILDING

Capacity building is one of the three main goals of the Working for Water programme and there has been a lot of internal debate within the programme about whether or not this should be included in the goal for the prioritisation and as one of the criteria for defining priorities. Criteria relating to poverty alleviation, which is an aspect of capacity development, have been included in some of the previous prioritisation studies (e.g. Van Wilgen et al. 2008) but they have always been difficult to interpret and have got a low weight relative to biophysical factors such as impacts on water or other natural resources. Spatial data on the social factors and needs that Working for Water addresses, such as the distribution of poor or unemployed people are difficult to obtain at scales which are useful for these prioritization studies. The limited data that are at a suitable scale, such as the distribution of people and households living below the mean living level[1] at a scale of about 5x5 km (CSIR 2007), show that such people and households are to be found in every settlement, town and city in South Africa. The data also show that the percentages of these poor people are typically highest in the rural areas, especially in the former homelands, and that there are many more of them than the Working for Water programme can employ. All of these factors raise issues about whether and how to include social criteria in the prioritisation. The same arguments resulted in the external evaluation of the programme by Common Ground in 2002/03 recommending that strategic priorities for control projects should not be driven by poverty-relief-based targeting.

We suggest that this problem can be resolved by recognising that biophysical criteria set the spatial priorities (the "where" and "when") and the social aspects are critical when deciding how to implement the clearing projects in that priority area (the "how"). We recommend that WfW considers developing an AHP-based approach for prioritizing local settlements and communities to target for clearing projects. This assessment should include an evaluation of the potential for other extended public works programmes to complement it in meeting the social needs of local communities in priority quaternary catchments. This would be in line with the assessment of this kind would be in line with the recommended practice for extended public works programmes: "*The beneficiaries of the programmes should be locally based (residing in the local municipal area that the project is implemented in) individuals prepared to work on the specific EPWP. Skilled workers from other areas may be employed if they have skills that are required for a project and there are not enough persons in the local communities who have those skills or who could undergo appropriate skills training. However, this should not result in more that 20% of persons working on a programme not being from local communities. A proper skills audit should be conducted where possible, in an area where an EPWP is in operation*." (Anonymous 2009a).

[1] The mean living level is a standard poverty datum which is provided by Statistics South Africa and indicates the minimum annual income required to meet basic needs.

3. SCOPE OF WORK

This project is conducted as part of a collaborative agreement between the Department of Water Affairs and Forestry (DWAF) and the Council for Scientific and Industrial Research (CSIR). The work was guided and reviewed by a reference group, appointed by DWAF at the initiation of the project, in terms of the collaborative agreement. Members of the reference group are:

- Ms Debbie Sharp (Department of Water and Environment Affairs – Working for Water Programme, Kimberley), now replaced by Mr Vusi Lubisi
- Mr Louwrens Ferreira (Department of Water and Environment Affairs – Working for Water Programme, Kimberley)
- Mr Andrew Wannenburgh (Department of Water and Environment Affairs – Working for Water Programme)

The planned scope of the work recognised that the study was exploratory in nature and that with the resources and time available there was a strong possibility that not all the objectives would be fully met. The Northern Cape study showed that the Expert Choice 11.5 decision support software was able to deal semi-automatically with the large number of pairwise comparisons that we have had to carry out.

It was agreed at the outset of the study that the planned scope of the project and the schedule of activities would be as follows:

- The work would be limited to the three biomes: Savanna, Nama Karoo and Succulent Karoo that cover most of the Northern Cape. There are outliers of the Fynbos Biome in Namaqualand and the Roggeveld-Sutherland area but these were included in the Succulent Karoo Biome for the purposes of this study.
- The work would entail prioritising areas to clear at a quaternary catchment scale within the portions of primary catchments D (Orange), C (Vaal), E (Olifants-Doring) and F (Namaqualand) which occur in the Northern Cape. We initially selected all the quaternary catchments which fall partially or completely within the Northern Cape. Some catchments were subsequently excluded (C5 Riet-Modder, managed by the Free State) and the upper reaches of primary catchments J (Gouritz) and L (Gamtoos) which fall within the Northern Cape Province but fall under the Northern and Eastern Cape regions respectively. We also included some of the quaternary catchments in E and F which fall within the Western Cape but are the responsibility of the Northern Cape Region.
- The Analytic Hierarchy Process (AHP)[2] would be used to facilitate the prioritization of quaternary catchments using Expert Choice 11.5 decision support software (Anonymous 2009b).

[2] AHP is a multiple criteria decision-making tool for setting priorities when both qualitative and quantitative aspects of a decision need to be considered. It involves setting a goal, breaking it down into its constituent parts and then

- The criteria to use for prioritising the quaternary catchments for the clearing of invasive alien plants would be identified and agreed to at an expert workshop to be held in or near Kimberley.
- An obvious criterion was whether or not priority alien invasive species are present or likely to spread in a quaternary catchment. In this regard it was agreed that we would start with the list of priority species identified for the Arid Savanna, Nama and Succulent Karoo (see Appendix 1) by the recent CSIR study (van Wilgen et al., 2008). In the Western Cape study (Forsyth et al. 2009) we used data from Versfeld et al. (2008) as these were adequate for prioritising quaternary catchments based on the current extent and density of invasions. The Versfeld et al. (1998) data are not adequate for the Northern Cape. The next best choices are the SAPIA data or the data on *Prosopis* and the National Invasive Alien Plant Survey currently being prepared by the Agricultural Research Council. These would be assessed as alternatives.
- The work of Rouget *et al*. (2004) would be used to identify areas that are likely to become invaded by the species identified in the CSIR study as priority species for clearing.
- Where applicable and available we would also made use of river (Nel *et al.* 2007) and terrestrial (Driver *et al.* 2005) conservation prioritization datasets for various spatial scales.
- The assessment would focus on (a) the criteria and (b) the relative weighting of those criteria that will be used in prioritising the quaternary catchments and not on direct pairwise catchment comparisons. The primary reason for this is that the AHP approach requires a pairwise ranking and there are too many quaternary catchments in the primary catchments of the Northern Cape to make this feasible. We would therefore apply the procedures which we developed for automating these comparisons for the Western Cape Study (Forsyth et al., 2009).

The relevance of the study to the Working for Water Programme

The Working for Water Programme's strategic plan for 2008 – 2012 lists "the reduction of impact of existing priority invasive alien plant problems" as one of three primary goals relating to natural resource management. The other two are related to preventing problems, and building capacity to address problems. This project will assist in the identification of such priorities for control measures at a quaternary scale in the Northern Cape, which are not clearly defined at present.

assigning relative weights to each of these, thereby progressing from the general to the specific. Scoring is on a relative basis comparing one choice with another. Relative scores for each choice are computed with each level of the hierarchy. Scores are then synthesised through a model contained in Expert Choice. This yields a composite score for each choice at every level as well as an overall score.

4. APPROACH

4.1 WORKSHOPS TO DETERMINE RANKING CRITERIA

A two-day workshop was held at the Mosu Rest Camp, Mokala National Park near Kimberley on 10th and 11th December 2009. The workshop agenda is provided in Appendix 1. A total of 13 people participated in the workshop (see Appendix 2). They were mainly staff responsible for implementing Working for Water projects and representatives of conservation agencies.

The topics addressed at the workshop were:

- The findings of the CSIR study (van Wilgen et al., 2008) and the Western Cape (Forsyth et al. 2009)
- An explanation of the Analytic Hierarchy Process
- The current rankings of priority invasive alien plants for the biomes in question (See Appendix 1)
- The goal, criteria (objectives) and sub-criteria (sub-objectives) for prioritising quaternary catchments. These were captured on paper and using the Expert Choice software
- Pairwise comparisons (ranking) of the agreed criteria and sub-criteria using the Analytical Hierarchy Process approach in the Expert Choice software
- Identifying the datasets which are available to assist in the ranking of quaternary catchments for the criteria and sub-criteria

At this workshop we identified the criteria to use as a basis for the prioritisation of quaternary catchments within the primary catchments and sub-catchments we defined as sub-regional management units for the Northern Cape.

The most logical way to group the quaternary catchments into management units was to base them on the biomes used by Van Wilgen et al. (2008): Arid Savanna, Nama Karoo and Succulent Karoo. The original process of ranking the primary catchments within the Nama Karoo also identified the need to sub-divide the large and heterogeneous primary catchment D (Orange River) into two sub-units: an eastern and northern unit. The combination of the biomes and the previously defined management sub-catchments for the Name Karoo resulted in the selection of the following management units:

- D_1: The eastern Nama Karoo Biome including D3 (Orange-Seekoei) and D6 (Ongers-Brak); some of the headwater quaternaries fall in the Free State or the Eastern Cape.
- D_2: The western Nama Karoo Biome including D5 (Sak-Hartbees) and D8 (lower Orange); this management unit includes small areas of the Fynbos and Succulent Karoo Biome; some quaternaries fall in the Western Cape.
- D_3: The Savanna Biome which includes (a) portions of secondary catchments C3 (Lower Harts) and C9 (Lower Vaal). The Riet and Modder River catchments (secondary C5) fall under the jurisdiction of Working for Water in the Free State and were excluded; and (b) D4 (Molopo-Kuruman), excluding D41F (Phepane River)

because less than 10% of this quaternary catchment falls within the Northern Cape, and D7 (Middle Orange and Soutloop).

- E: The Succulent Karoo Biome including the inland quaternary catchments of the Olifants-Doring River system; the remaining quaternaries fall into the Western Cape. The areas of the Fynbos Biome in this catchment were grouped with the Succulent Karoo.
- F: The Succulent Karoo Biome of the Namaqualand catchments which includes some areas which fall in the Fynbos Biome; this includes secondary F6 which falls partly in the Western Cape.

A second workshop was held in Kimberley on the 24th of March 2010 to present the results to the area managers from Working for Water in the Northern Cape. It was organized by Mr Vusi Lubisi the Acting Deputy Director for the Northern Cape as Ms D Sharp had been transferred to the Western Cape in the mean time. The results of the prioritization were presented to the managers and discussed. The AHP process was then used to give the managers an opportunity to evaluate and modify the weights given to the area model in the 1st workshop. The weights on the main criteria and on the 1st-level sub-criteria were adjusted to reflect the managers' consensus view on the relative importance of the criteria and sub-criteria. The revised model is the one presented in this report as it is the one the managers have agreed among themselves to use.

4.2 SPECIES SELECTION

There are three main biomes in the Northern Cape: the Arid Savanna, Nama Karoo and Succulent Karoo. Van Wilgen et al. (2008) created separate lists for each of these biomes but the participants believed that it would be best to work with one consolidated list. The three separate lists were combined and some changes were made which left a final list of 22 species. Some of these species are emerging or seem to have expanded their ranges in recent times so there are few, if any SAPIA records. They were also not included in the major species whose potential distribution was modeled by Rouget et al. (2004) or the emerging species assessed by Mgidi et al. (2007) so these species could not be included in the data sets for potential invasions.

4.3 GOALS AND CRITERIA

The goal that was agreed on at the workshop was: "To reduce, control and ultimately eradicate IAPs to minimise their impacts on natural resources". The workshop participants (see Appendix 2) agreed on four main criteria, each of which had two or more sub-criteria. The Analytic Hierarchy Process (AHP) was used to compare each criterion to every other one at the same level and to assign weightings to each according to their relative importance (Saaty, 1990).

4.4 SPATIAL DATA SETS USED IN THE PRIORITISATION

The prioritization of the catchments requires that they are matched with an appropriate spatial dataset which can be the actual data or a suitable surrogate variable. The criteria and

sub-criteria chosen for the prioritization are summarized together with the spatial datasets in Table 1.

Table 1: ***Spatial datasets used to determine composite scores to assign to each of the quaternary catchments in the study area based on the criteria and sub-criteria identified in the workshop. Quaternary catchments having the highest scores were assigned the highest priority. Sub-criteria in italics are sub-sub-criteria***

Criterion	**Sub-criterion**	**Spatial data** [1]
Capacity to maintain the gains	Public conservation land	State protected areas (NSBA dataset update September 2007)
	Other protected land	Other protected areas (NSBA dataset update September 2007)
Value of the catchment for biodiversity	Conservation status of vegetation types	National Vegetation Map (Mucina and Rutherford, 2006)
	Conservation status of river systems	Nel *et al.* (2007) and South African 1: 500,000 river coverage (DWAF, 2004)
Potential to spread	Current invasion by priority species	South African Plant Invaders Atlas (Henderson 1998 and updates)
	Proportion of the catchment available for invasion	National Land Cover Database 2000 (Van den Berg *et al.* 2008)
	Potential invasion by priority species	Rouget *et al.* (2004)
Improve the integrity of the water resource	Maintain the integrity of the ground water systems	National Vegetation Map (Mucina and Rutherford, 2006),
	Water stressed catchments	Water Situation Assessment Model at quaternary catchment scale (WSAM, 2003) and Groundwater Resource Assessment II (DWAF, 2005)
	Maintain the integrity of the river systems	See below
	Azonal ecosystems including pans	National Vegetation Map (Mucina and Rutherford, 2006)
	Highest water yielding catchments	Water Resources 2005 (Water Research Commission) and Groundwater Resource Assessment II (DWAF, 2005)
	Rivers and wetlands	South African 1: 500,000 river coverage (DWAF, 2004) and the National Wetlands Database (J. Nel pers. comm. 2010) or Mucina and Rutherford (2006).
Potential veld utilisation	Game, bird and flower watching	National Vegetation Map (Mucina and Rutherford, 2006)
	Other harvestable products	National Vegetation Map (Mucina and Rutherford, 2006)
	Grazing and browsing	Areas of homogenous grazing potential (Scholes, 1998)
	Hunting and fishing	National Vegetation Map (Mucina and Rutherford, 2006), South African 1: 500,000 river coverage (DWAF, 2004)

[1] See reference section for complete references

4.5 SELECTING APPROPRIATE DATA

A summary of the data sets used, the rationale for using these to address the criteria underlying the revised hierarchy model approach, and methods are given below. We were limited in our choice to those datasets that were readily available (in the public domain) and covered the entire Northern Cape.

4.5.1 Capacity to maintain the gains

i) State protected areas

We used the state owned reserves from a recent version of the national protected areas database provided by J. Nel (personal communication, March 2010). These areas include those managed by South African National Parks, provincial nature conservation authorities and local municipalities. The controlling body has a legal mandate to manage the land for conservation objectives, including the control of invasive alien plants. The state protected area in each quaternary catchment was expressed as a percentage of its total area. The quaternary catchment with the greatest proportion in protected areas was allocated the highest weight.

ii) Other land

We used the private nature reserves provided in the most recent version of the national protected areas database provided by J. Nel (personal communication, March 2010). These are privately owned and, thus, are not as secure as state protected areas, but it is likely that some environmental protection practices, including invasive species control, are in place. The greatest weight was allocated to the quaternary catchment with the highest percentage of its total area in a privately protected area. It is important to note that, where private property occurs within a priority catchment, it will be treated together with state land in accordance with the policies of the Working for Water Programme.

4.5.2 Improve the integrity of the water resource

i) Maintain the integrity of the groundwater system

The variable should reflect the importance of clearing areas where there is, potentially a large groundwater resource. For the Succulent and Nama Karoo areas in the Western Cape we used buffered rivers and the azonal riverine vegetation as a surrogate for areas with high groundwater availability (Forsyth et al. 2009). Groundwater use is widespread and pervasive in the Northern Cape and occurs outside areas near rivers and in the Azonal Biome. The Groundwater Resource Assessment study (GRA II, DWAF 2005) provides an estimate of the utilisable groundwater volume (m^3 per km^2 per year) based on the aquifer characteristics and the recharge. We calculated the mean value for each of the quaternary catchments. The catchment with the most potentially utilisable groundwater got the greatest weight.

ii) Maintain the integrity of the river systems

- ***Azonal systems including pans***

  We extracted the azonal vegetation types, including pans from the national vegetation map (Mucina and Rutherford 2006) and calculated the area of the azonal ecosystems as a percentage of the total area of the quaternary catchment. The catchment with the highest proportion got the greatest weight.

- ***Highest yielding catchments***

  The surface water yield information was obtained from the Water Resources 2005 quaternary catchment dataset (Middleton and Bailey 2008). The units were the naturalised annual run-off volume in millions of m^3 per year which is a product of the size of the catchment and the depth of the runoff. Because the volume is affected by the area of the catchment, we converted the volumes to depth in mm as this gives a unit area value which can be directly compared between catchments. The data could also be expressed as m^3 per ha per year. The quaternary catchment with the greatest depth of runoff was given the highest weight.

- ***Rivers and wetlands***

  For the rivers we used the present ecological status class (Kleynhans 2000) of each reach of the national 1: 500000 rivers (DWAF 2004) as a surrogate for river ecosystem integrity. We combined classes A (entirely natural), B (largely natural) and C (moderately modified) as being important for conservation. We then calculated the proportion of the combined classes (A, B and C) as a proportion of the entire river length within each quaternary catchment. The greater the portion the greater the weight assigned.

iii) Water stressed catchments (water demand)

When the model was developed at the workshop we included a sub-criterion for water stress for giving catchments with little or no water availability a higher priority. While we were preparing the spatial datasets for inclusion in the model, we realized that we needed to distinguish between surface water, which is only available for a very limited part of the province (e.g. along the few perennial rivers) and groundwater which is widely used in this province. We added additional sub-criteria to allow for this and have currently given them an equal weight.

- ***Surface water resources***

  The data on water stress were obtained from the Water Situation Assessment Model (WSAM) database (WSAM, 2003). We used the quaternary yield balance (million cubic metres per annum) which is the difference between the available yield and the current demand in 1995. The yield was set at a 1: 50 year assurance level for the 1995 base year. Unfortunately there are no more recent estimates although the Department of Water Affairs is currently updating the WSAM model. In the Northern Cape all the yield balance values were ≥0 so we did not need to do any manipulation to adjust for negative values, unlike the Western Cape study (Forsyth et al. 2009). High yield balance values represent a substantial surplus, and values close to zero a small surplus with a risk of experiencing a deficit. The values were inverted for each of the primary catchment management unit by

subtracting the actual yield balance from the highest yield balance for a quaternary within that primary catchment. This means that the most stressed catchment will have the largest positive value and the greatest weight.

- ***Groundwater resources***

  Many catchments in the Northern Cape do not have perennial rivers and so the rivers have very low yields. However, extensive use is made of groundwater so we used an estimate of the registered groundwater use as a percentage of the recharge for each quaternary catchment from the Groundwater Resource Assessment II (DWAF 2005) dataset. The quaternary catchment with the highest percentage registered use was given the greatest weight.

4.5.3 Potential to spread

The participants in the workshop agreed on a list of 22 species, a number of which were not modelled by Rouget et al. (2004) or Mgidi et al. (2007). A number of the taxa identified comprise a number of species so we used a number of species for the potential distribution to compensate for these gaps.

i) Current invasion by priority species

Ideally we would have liked to have made use of the results of the National Invasive Alien Plant Survey being compiled by the Agricultural Research Council. However the results of this survey will only be released at the end of March 2010. An alternative source of information on the current distribution of invasive alien plants is the NBAL (**N**atural**, B**iology, **Al**ien) data for each invasive alien clearing project managed by either CapeNature or Working for Water. The disadvantage of using this data is that it is incomplete because it only records data about invasions in areas that have been cleared. The Western Cape study (Forsyth et al., 2009) used the estimated flow reduction per quaternary catchment from Versfeld *et al.* (1998) as a surrogate for the extent and impact of the current invasions. However, the mapping in that initial study is too incomplete for it to be considered representative of the Northern Cape. We resorted to the data on invasive alien plants contained in the SAPIA database (Henderson 1998). This is mapped at a quarter degree square (QDS) scale (roughly 20 x 25 km) but was the best we could obtain for the Northern Cape. We used the total number of records in each quarter-degree cell in the Northern Cape as a surrogate for the degree of invasion. We tested using only the records where species were frequent or abundant, but this left more than 3/4 of the QDS with no records. The quaternary catchment with the greatest number of records was given the greatest weight.

ii) Proportion of the catchment available for invasion

In the Western Cape study we used the proportion of untransformed land per quaternary catchment, based on the National Land Cover 2000 database, to estimate the potentially invadable area (Forsyth et al. 2009). Untransformed land excludes plantations, urban areas, mines and quarries, cultivated agricultural, improved grasslands and water-bodies. There is so

little transformed land in the Northern Cape that we did not reduce the potentially invadable area to the untransformed land.

iii) Potential invasion by priority species

We estimated the potential invasions by priority species using the combined list that was generated at the workshop which was based on those identified by van Wilgen *et al.* (2008) and supplemented by participants in the workshop. Data on the potential ranges (invasion envelopes) have been developed for a range of species by Rouget *et al.* (2004). The potential invasion envelopes are based on a model which predicts the potential for invasion as a probability. Areas with probabilities > 0.5 are considered likely to be invaded. The envelopes for each of the priority species were summed to create a single surface with the total number of species in each grid cell (1.6 km x 1.6 km). As a number of the taxa that were listed in the workshop included more than one species (e.g. Cactaceae with or without biocontrol) we included a range of the Cactaceae modelled by Rouget et al. (2004). We also tried to get a selection that would represent different habitat preferences and invasion patterns. The final list was:

Table 2: ***A list of the species used for the modelling of the potential invasions based on the potential distribution envelopes generated by Rouget et al. (2004).***

Species	Notes
Opuntia aurantiaca	Dryland, widespread
Opuntia ficus-indica	Dryland, widespread
Opuntia imbricata	Dryland, widespread
Opuntia monacantha	Dryland, widespread
Opuntia robusta	Dryland, widespread
Opuntia stricta	Dryland, widespread, particularly in the Savanna
Echinopsis spachiana	Dryland, widespread
Cereus jamacaru	Dryland, widespread
Atriplex lindleyi	Dryland, widespread in the Succulent and parts of the Nama Karoo
Eucalyptus camaldulensis	Riparian, perennial rivers
Prosopis glandulosa var torreyana	Widespread in the Karoo and Savanna, mainly on alluvial deposits with groundwater but also dryland
Prosopis glandulosa var torreyana x *velutina*	Widespread in the Karoo and Savanna, mainly on alluvial deposits with groundwater but also dryland
Robinia pseudoacacia	Riparian and dryland, grasslands
Schinus molle	Riparian and dryland, perennial and seasonal rivers, mainly Savanna and Nama Karoo
Salix fragilis	Riparian, perennial rivers
Arundo donax	Riparian, perennial and seasonal rivers
Eichhornia crassipes	Aquatic environments, including irrigation canals and dams

4.5.4 Value of the catchment for biodiversity

i) Conservation status of the rivers

We used the conservation status of the river signatures in each quaternary catchment as defined for the National Spatial Biodiversity Assessment (Driver *et al.* 2005; Nel *et al.* 2007) to estimate the conservation status. The conservation status is expressed as: Critically endangered, endangered, vulnerable and least threatened. We calculated the weight for each quaternary catchment using the sum of the lengths of the first three classes as a proportion of the total river length in each quaternary catchment. Quaternary catchments with the highest proportion were given the greatest weight.

ii) Conservation status of vegetation type

We used the conservation status of each vegetation type as given in the Mucina and Rutherford (2006). We first selected only the vegetation types rated as "Critically endangered", "Endangered" or "Vulnerable". The resulting areas were expressed as a proportion of the total area of each quaternary catchment. The catchment having the highest proportion received the greatest weight.

4.5.5 Potential for veld utilisation

We were not able to obtain suitable spatial datasets to estimate the weights for the different parts of the study area. This left us no option but to derive weights from the distribution of the different vegetation types and habitats. We selected the bioregions as a suitable compromise between the biomes, which were too heterogeneous, and the vegetation types which were too detailed.

i) Game, bird and flower watching

We gave these activities a high rating in the Arid Savanna bioregions for game viewing and in the Succulent Karoo for flower watching. The Nama Karoo bioregions were given a low rating and the grasslands a moderate rating. Estuarine vegetation was given a high rating for bird watching. Quaternary catchments with a high proportion of a bioregion with a high rating were given the greatest weight. Future assessments should consider including important endemic bird areas or summaries of endemic bird species distributions, as these are a good spatial surrogate for important bird watching areas.

ii) Other harvestable products

A range of plant products are harvested in the Arid Savanna, Nama and Succulent Karoo biomes including fuel wood, fibre, aloe leaves, herbs and medicinal plants but it is difficult to determine where harvesting takes place and harvesting is often on a very localized scale. The riverine woodlands are the main source of fuel wood, particularly in the Nama and Succulent Karoo. Woody species are widespread in the Arid Savanna but more so in the riparian or floodplain areas. Medicinal and herb species are widespread in all these vegetation types. We used the bioregions to derive a score per bioregion for the availability of woody plants and other harvestable products. The Eastern Kalahari Bushveld, Kalahari Duneveld and Alluvial vegetation (e.g. along the Orange River) were given a high rating. The Nama and Succulent Karoo, Desert Biome were given low ratings and the arid Grassland Biome a moderate rating.

Quaternary catchments with a high proportion of a bioregion with a high rating were given the greatest weight.

iii) Grazing

The relative value of the land for livestock production was estimated by calculating the grazing potential of quaternary catchments. This potential was derived from Scholes' (1998) estimates of sustainable mean domestic livestock production (Table 3). This approach may underestimate the carrying capacity for browsing antelope but as game farming only occurs in limited areas this probably would not significantly affect the outcome. Futuree assessments could place a greater emphasis on the Savanna and Nama Karoo Biomes because these two are important for game farming.

Table 3: ***Grazing potential classes in large livestock units (LSU) per km^2 (Scholes 1998).***

LSU range	LSU mid-point
0 - 1	0.5
1 - 2	1.5
2 - 3	2.5
3 - 4	3.5
4 -6	5
6 - 8	7
8 – 10	9
10 -14	12
14 - 18	16
18 - 22	20

We took the midpoint of each class, and multiplied it by the remaining area in that class in each quaternary catchment to get an area weighted mean grazing capacity. Catchments were prioritized according to the relative weights where the weights equalled the mean grazing capacity.

iv) Hunting and fishing

We were able to use the bioregional data for giving a weight for hunting but there were insufficient data for giving spatial weights for fishing so we excluded fishing. We gave hunting a high rating in the Arid Savanna bioregions, a moderate rating for the limited area of the Grassland Biome and a low weight everywhere else. Dr J. Koen (Environmental Affairs and Nature Conservation, Northern Cape Province) recommended that hunting be given a moderate weight in the the Nama Karoo in future assessments. Quaternary catchments with a high proportion of a bioregion with a high rating were given the greatest weight.

Calculating the weights used by the Export Choice Software

The Expert Choice software (Anonymous 2009) requires the weights of alternatives (quaternary catchments in this case) to be expressed as proportions that sum to one. For each of the criteria and sub-criteria used by the AHP model (Figure 4) we calculated the sum of the value for the corresponding variable for each quaternary catchment. Each quaternary catchment's value was then divided by the corresponding total to give the final weight.

5. RESULTS

5.1 SPECIES PRIORITISATION

5.1.1 Species selection

The consolidated list for the three main biomes in the Northern Cape included 22 species (Table 4). The current and potential distributions of a number of the species have not been modeled. For example, both *Caesalpinia gilliesii* and *Myriophyllum spicatum* have been recognised as important species since the modelling work done by Rouget et al. (2004) and Mgidi et al. (2007) so we do not have data on their potential distributions.

Table 4: The 22 invasive alien plant taxa selected for prioritization from the Arid Savanna, Nama Karoo and Succulent Karoo Biomes in the Northern. Some taxa include several species

Species (taxa)	Life Form	Biomes
Argemone species (Mexican poppies)	Annual herbaceous	All
Arundo donax (giant reed)	Tall reed	All along rivers
Annual grasses (*Bromus, Stipa, Hordeum)*	Annual grass	Succulent Karoo
Azolla filiculoides (red water fern)	Herbaceous	Freshwater (Waterbodies)
Atriplex lindleyi (sponge-fruit saltbush)	Multi-stemmed shrub	Succulent Karoo
Cacti with effective bio-control agents (*O imbricata, O. engelmannii, O ficus-indica*)	Spiny and un-armed succulent shrubs	All
Cacti without effective bio-control agents (*Echinopsis spachiana, Tephrocactus articularis*)	Spiny and un-armed succulent shrubs	All
Caesalpinia gilliesii (bird-of- paradise bush)	Large shrub	Arid Savanna
Echinopsis spachiana (torch cactus)	Cactus	All
Eichhornia crassipes (water hyacinth)	Herbaceous	Freshwater (Waterbodies)
Eucalyptus camaldulensis (red river gum)	Tall evergreen tree	All (riverine)
Myriophyllum spicatum (spiked water-milfoil)	Rooted submerged water plant	Freshwater (Waterbodies)
Nerium oleander (oleander)	Multi stemmed evergreen large shrub	Succulent Karoo rivers
Parkinsonia aculeata (Jerusalem thorn)	Medium tree	Arid Savanna
Pennisetum setaceum (fountain grass)	Perennial grass	Succulent Karoo
Prosopis species and hybrids (mesquite)	Multi-stemmed small tree	All, mainly Nama Karoo
Robinia pseudoacacia (black locust)	Large tree	Savanna (riverine?)
Salix fragilis (crack willow)	Large tree	All (riverine)
Salsola kali (Russian tumbleweed)	Shrub	Nama Karoo
Schinus molle (pepper tree)	Large tree	All
Tamarix ramosissima and T. chinensis (pink and Chinese tamarisk)	Shrub or small tree	All
Xanthium spinosum (boetebos)	Much branched annual	All, mainly Nama Karoo

5.1.2 Goal and Criteria

The workshop participants developed a goal and agreed to four criteria and a number of sub-criteria for prioritising invasive alien plant species in the Northern Cape. The goal was defined as:

"To contain, reduce and ultimately eradicate priority invasive alien plants to minimise their impacts on natural resources"

This, together with the four criteria and their sub-criteria can be seen in Figure 1, while the assigned weightings between criteria and sub-criteria are given in their order of importance in Table 4.

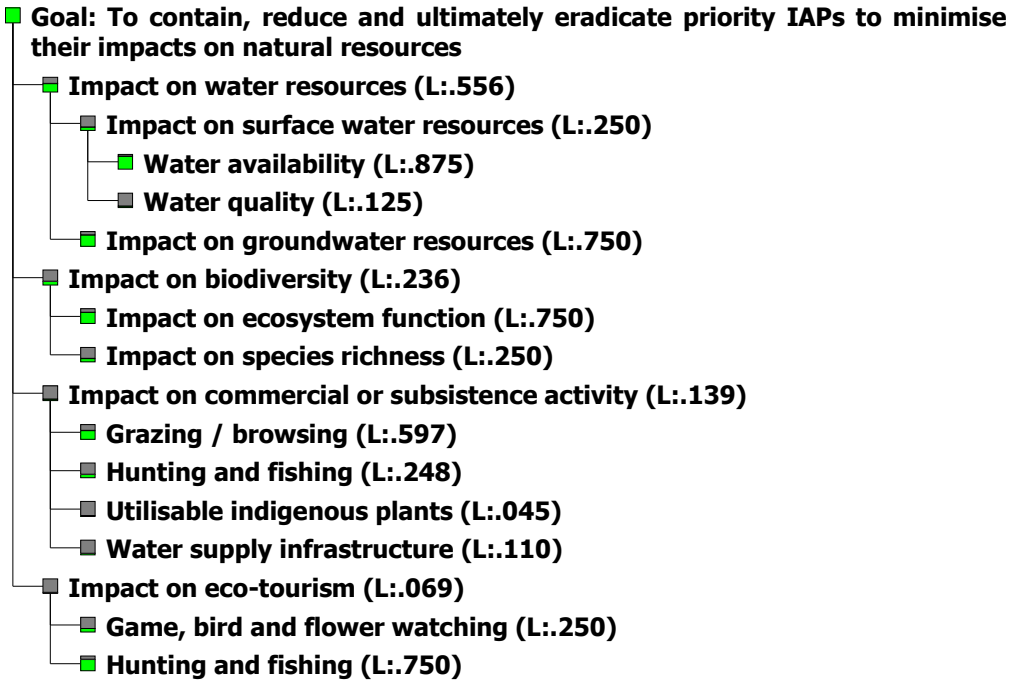

Figure 1: ***Ranked criteria identified as significant for the purpose of prioritizing quaternary catchments within primary catchments in the Northern Cape Province for the clearing of invasive alien plants. Relative weightings, out of a total of 1.0, are given for each criterion.***

The most important criterion identified was the impact on water resources which carried a weighting of 55.6%. This is followed by, in order of importance, the impact on biodiversity (23.6%), the impact on commercial or subsistence activities (13.9%) and impact on ecotourism (6.9%). The criteria were further divided into sub-criteria. For example, impacts on surface water resources and impacts on groundwater resources (Table 5).

Table 5: ***Nested criteria, with their relative weightings, identified as significant for the purposes of prioritising species in the Succulent Karoo, Nama Karoo and Arid Savanna Biomes of the Northern Cape for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each. The ones in italics are 2nd-level sub-criteria and their totals are shown separately.***

Criteria	Weighting assigned (%)	Sub-criterion	Weighting assigned (%)
Impact on water resources	55.6	Impact on ground water resources	41.7
		Impact on surface water resources	13.9
		- Water availability	*12.2*
		- Water quality	*1.7*
Impact on biodiversity	23.6	Impact on ecosystem function	17.7
		Impact on species richness	5.9
Impact on commercial or subsistence activity	13.9	Grazing and browsing	8.3
		Hunting and fishing	3.4
		Water supply infrastructure	1.5
		Utilisable indigenous plants	0.6
Impact on eco-tourism	6.9	Hunting and fishing	5.2
		Game, bird and flower watching	1.7
Total weight assigned	100		**100**

5.1.3 Prioritised species

A pair wise comparison between the 22 taxa was carried out using the criteria and sub-criteria defined by the participants (see Table 5). The results weighted with respect to the goal are shown in Figure 2. *Prosopis* species, *Eucalyptus camaldulensis*, *Arundo donax*, *Robinia pseudoacacia* and *Caesalpinia gilliesii* ranked as the top five priority invasive alien plants in the Northern Cape. The participants agreed that these weights reflected their perceptions of the relative importance of the species.

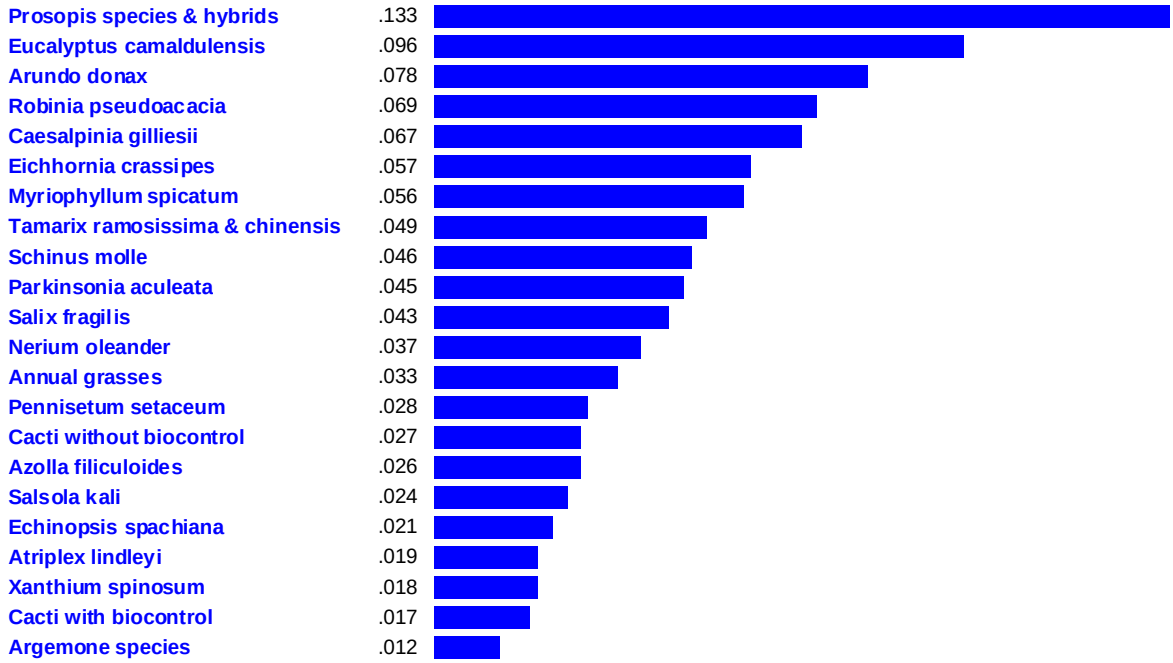

Figure 2: ***The relative importance of the major invasive alien plants in the Northern Cape (Arid Savanna, Nama and Succulent Karoo Biomes) based on pair wise comparisons using the weighted criteria and sub-criteria contained in Table 4.***

5.2 AREA PRIORITISATION

The quaternary catchments prioritised for the clearing of invasive alien plants are presented for the primary catchment based management units:

- D_1: Eastern Nama Karoo - Orange-Seekoei and Ongers-Brak
- D_2: Western Nama Karoo - Sak-Hartbees and Lower Orange
- D_3: Savanna - Middle Orange and Soutloop, Lower Harts, Lower Vaal and Molopo-Kuruman
- E: Succulent Karoo - Olifants-Doring River
- F: Succulent Karoo - Namaqualand catchments

For each of these we provide maps showing the location of the top priorities and bar diagrams showing the priorities.

5.2.1 Goal and Criteria

The goal defined for the species comparison was used for the area prioritization as well. The participants in the December 2009 workshop developed five criteria (and their sub-criteria) for prioritising the quaternary catchments in the Northern Cape. The weights assigned to some of the criteria and sub-criteria in the December 2009 workshop were revised by the WfW managers who attended the March 2010 workshop. The revised weights were used to

determine the priorities presented here. A hierarchical view of the goal and criteria can be seen in Figure 3 and the agreed weights of the criteria and sub-criteria are given in their order of importance in Table 6.

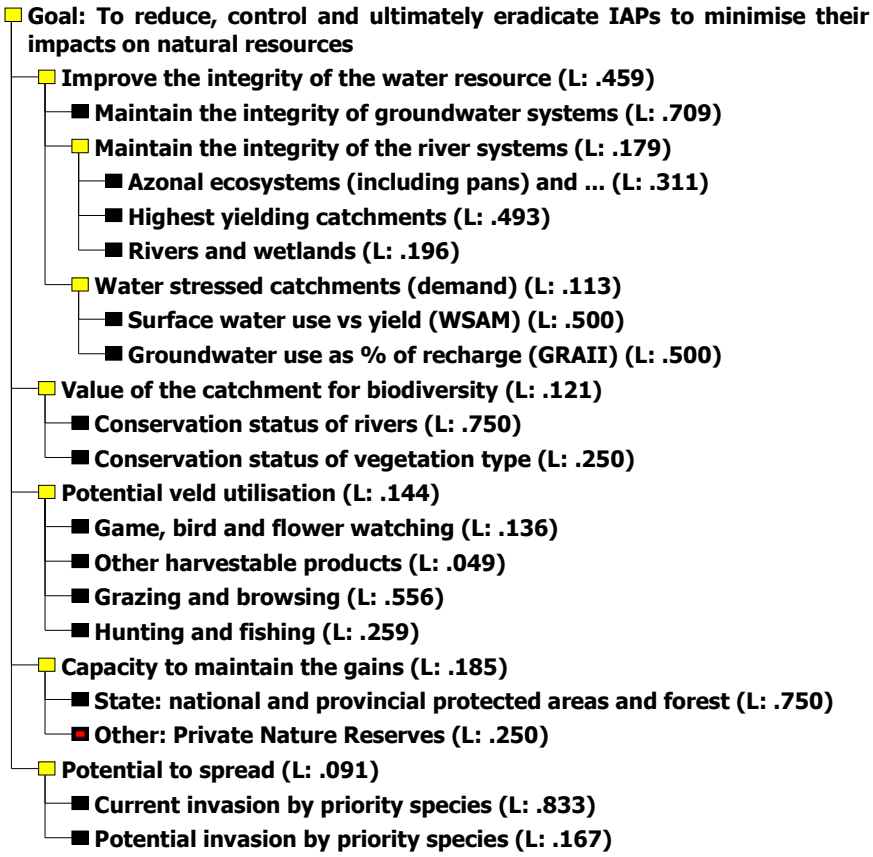

Figure 3: ***A hierarchical view of the goal, criteria and sub-criteria identified as significant for the purpose of prioritising the clearing of invasive alien plants from quaternary catchments in the Northern Cape.***

The most important criterion is the the ability to improve the integrity of the water resource with of 45.9% of the total weight. The next, in order of importance, is capacity to maintain gains made by any previous Working for Water project (18.5%) followed by the potential for veld utilisation (14.4%). The value of the catchment for biodiversity and the potential for invasive alien species to spread were assigned weightings of 12.1% and 9.1% respectively.

Table 6: ***Nested criteria, together with the relative weightings, identified as significant for the purposes of prioritising quaternary catchments in the Northern Cape for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each. The ones in italics are sub-sub-criteria and their totals are shown separately.***

Criterion	Weighting assigned (%)	Sub-criterion	Weighting assigned (%)
Improve the integrity of the water resource	45.9	Maintain the integrity of ground water systems	32.5
		Maintain the integrity of the river systems	8.2
		Azonal ecosystems (including pans)	*2.5*
		Highest yielding catchments	*4.0*
		Rivers and wetlands	*1.6*
		Water stressed catchments (demand)	5.2
		Surface water use	*2.6*
		Groundwater use	*2.6*
Capacity to hold onto gains	18.5	State protected areas	13.9
		Other protected areas	4.6
Potential veld utilisation	14.4	Game bird and flower watching	2.0
		Other harvestable products	0.7
		Grazing and browsing	8.0
		Hunting and fishing	3.7
Value of the catchment for biodiversity	12.1	Conservation status of rivers	9.1
		Conservation status of vegetation	3.0
Potential to spread	9.1	Current invasion by priority species	7.6
		Potential invasion by priority species	1.5
Total weight assigned	**100**		**100**

5.2.2 Primary Catchment D_1 (Orange-Seekoei and Ongers-Brak)

In catchment D_1 the five catchments with the highest relative importance rankings are: D35K, D35H, D35B, D31E and D33K (see Figures 4 and 5). These are include protected areas along the Orange River and in the higher water yielding parts of this catchment management unit. This is to be expected as the greatest weight was given to water resources (46%), and a high proportion of that was for groundwater availability (potential utilisation) and water stress, so these are important in determining priorities in quaternary catchments without protected areas. The next highest was for "maintaining the gains" with 19% of the total weight in the prioritisation model (Figure 3). The priorities given to the first two are much higher than those for the rest and the differences decrease rapidly after the first five.

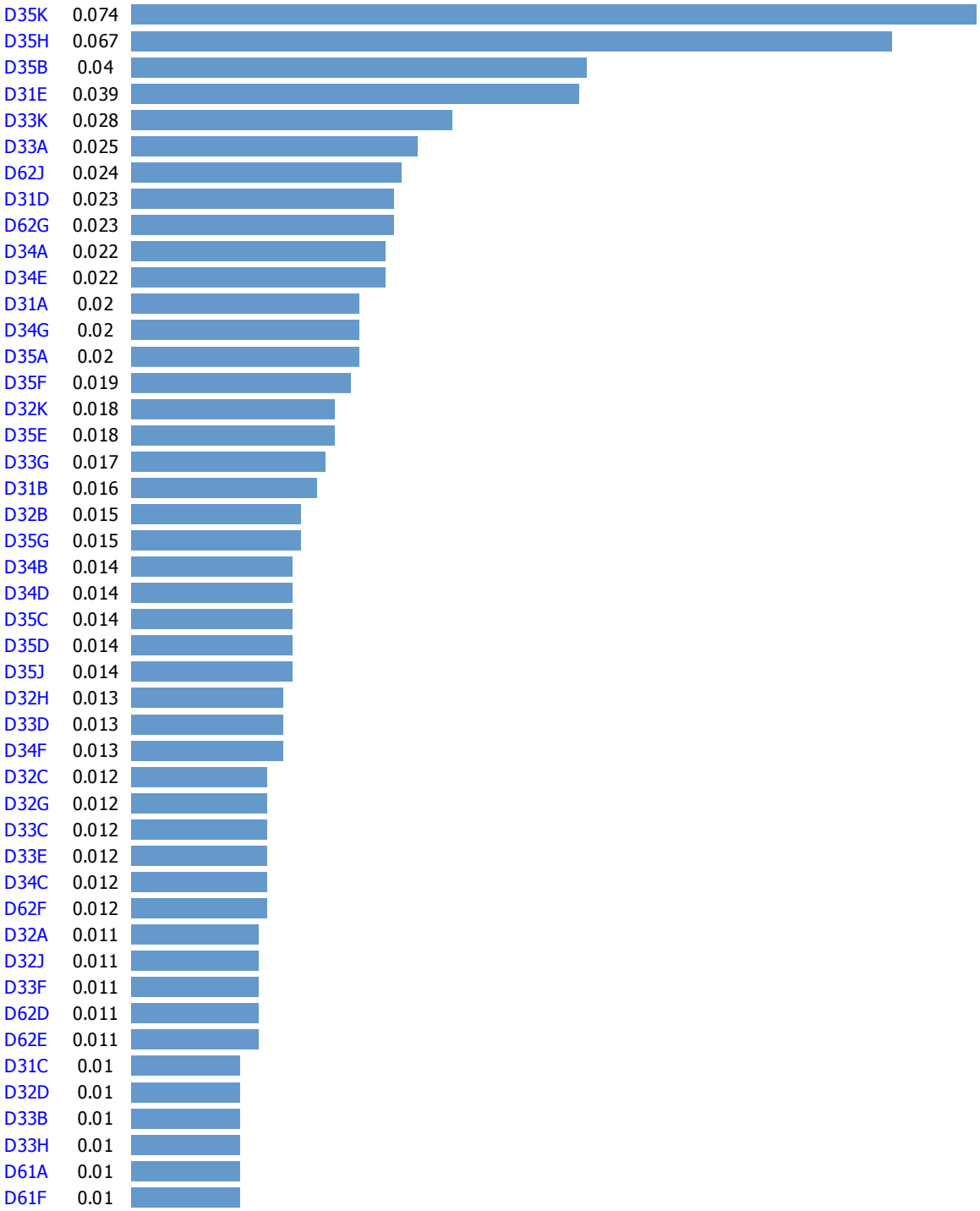

Figure 4: ***The relative importance and ranking of the 46 top priority quaternary catchments out of the 63 in primary catchment D_1 in the Northern Cape Province.***

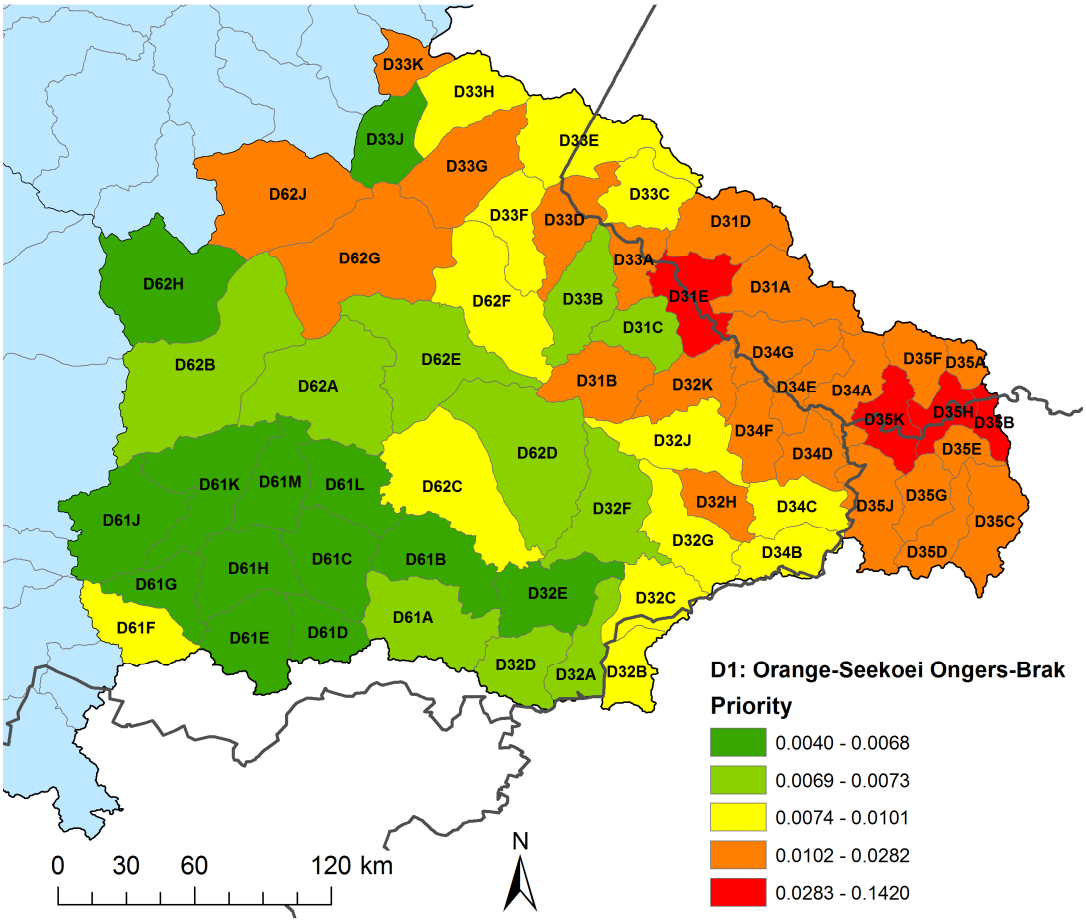

Figure 5*: *Catchment (AHP) scores for each of the quaternary catchments primary catchment D_1. Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.

The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for primary catchment D_1 indicates that those that are funded are quite well aligned (see Figure 6). The quaternary catchments with the highest priorities are D35K (0.074) and D35H (0.067). There are no projects in these catchments.

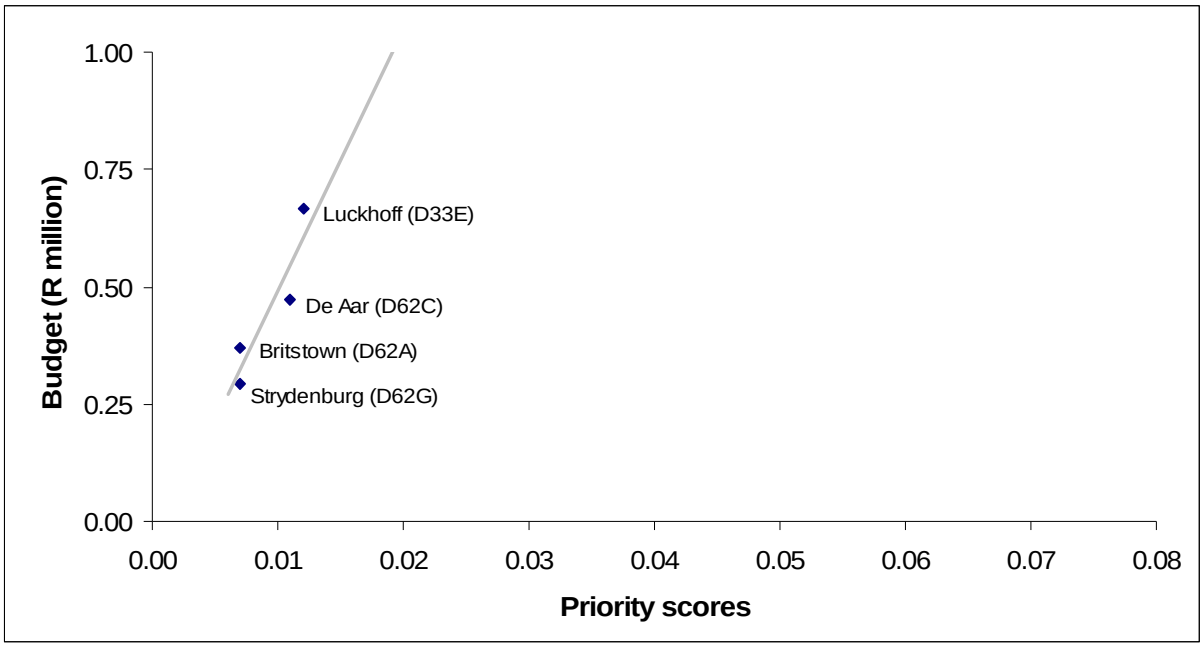

Figure 6: ***The 2009/10 budget for IAP clearing projects in primary catchment D_1 in relation to priorities identified in this study (see Figure 5). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

5.2.3 Primary Catchment D_2 (Sak-Hartbees and Lower Orange)

In catchment D_2 the five quaternary catchments with the highest relative importance rankings are: D82J, D82H, D51A, D52A and D82K (see Figures 7 and 8). Those in secondary catchment D8 include the Richtersveld National Park, the adjacent Richtersveld World Heritage Site (a community conservancy) and Nababeep Provincial Nature Reserve and have high registered groundwater use.

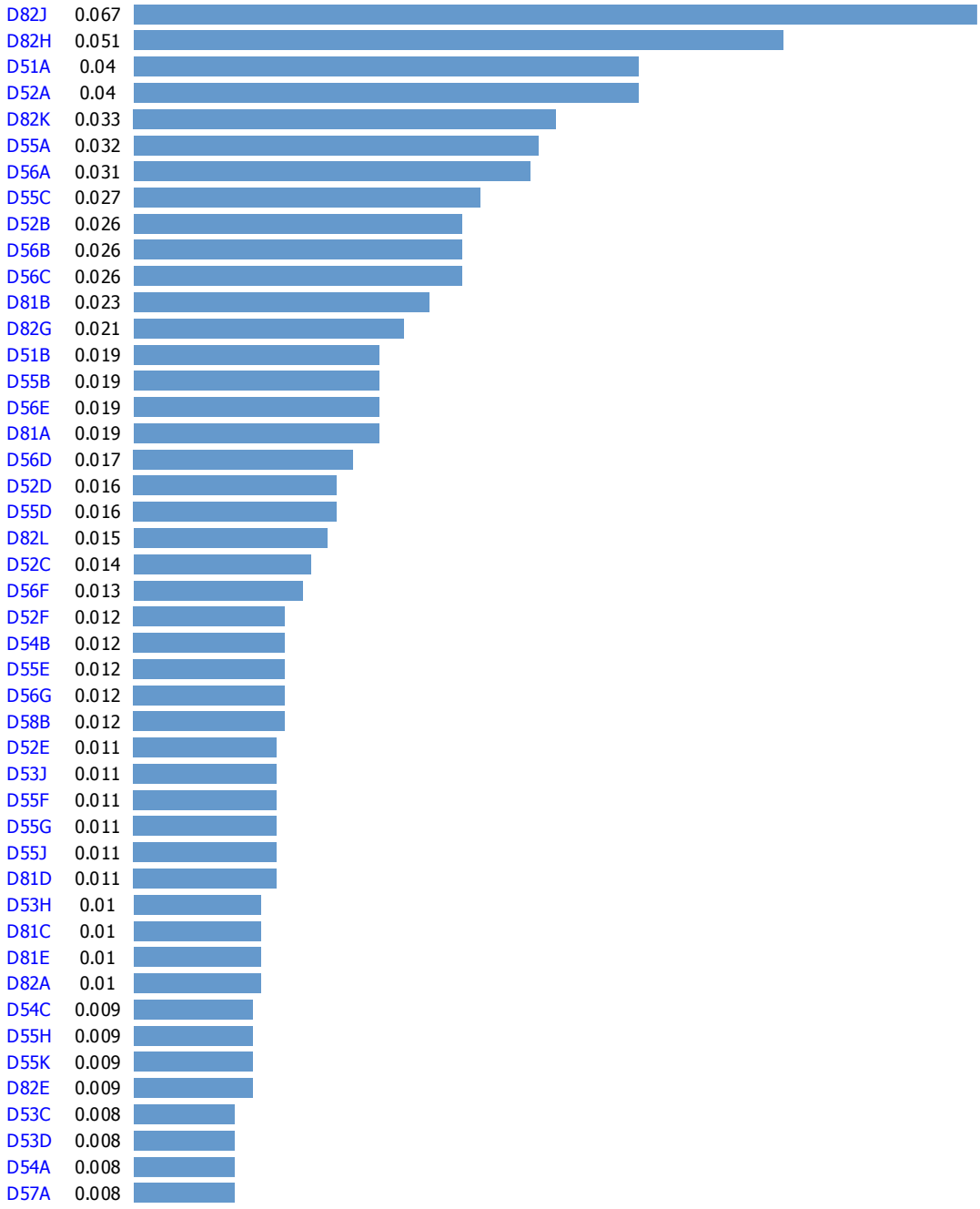

Figure 7: ***The relative importance and ranking of the top 46 of the 72 quaternary catchments in the primary catchment D_2 (Sak-Hartbees and Lower Orange)***

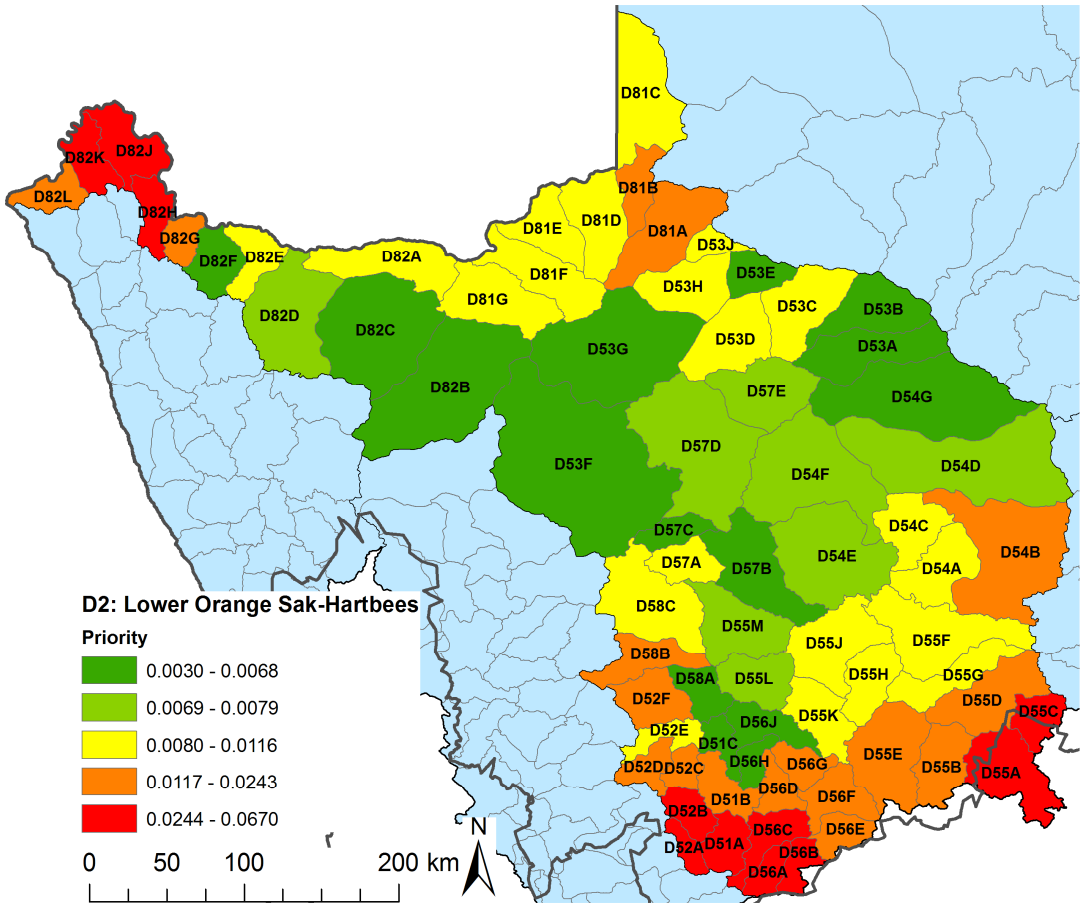

Figure 8: ***Catchment (AHP) scores for each of the quaternary catchments in primary catchment D_2 (Sak-Hartbees and Lower Orange). Red and orange shading indicates catchments having the highest priority for clearing invasive alien plants.***

The most important criterion is improving the integrity of the water resource and this is reflected in the inclusion of the headwater catchments of the rivers. D51A and D52A are located in the headwaters of the Vis River, a tributary of the Sak, are given a medium priority (Figure 8) because they have relatively high surface runoff and relatively high volumes of utilisable groundwater. The same applies to D55A and D55C. The headwater catchments generally only have low density invasions and the planning of projects needs to take this into account.

The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment D_2 (see Figure 8) indicates that they are not well aligned with, for example, quaternary catchment D82J (0.067) having too low an expenditure (see Figure 9). There are no projects in catchments D82H, D82K, D51A or D52A which have high priorities.

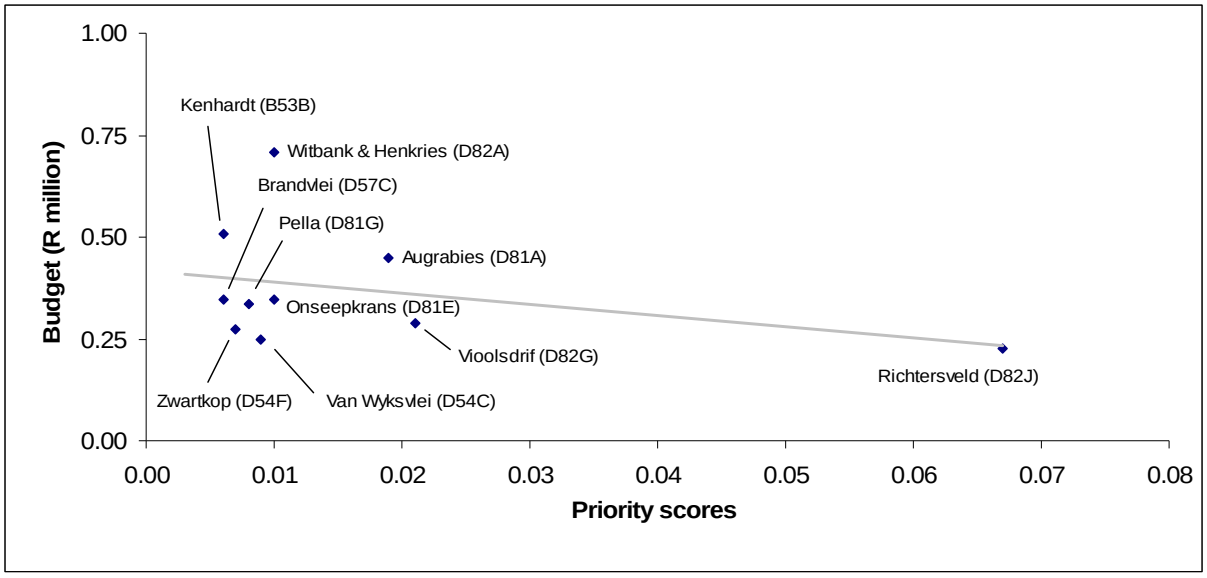

Figure 9: ***The 2009/10 budget for IAP clearing projects in the D_2 (Sak-Hartbees and Lower Orange) portion of primary catchment D in relation to priorities identified in this study (see Figure 8). The alignment is shown by deviations from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

5.2.4 Primary Catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts)

In catchment D_3 the five most important quaternary catchments are: D42A, C92C, C91B, C33B and C33C (see Figures 10 and 11). D42A is in the Kalahari National Park and got by far the highest priority, apparently because of the weight given to "maintaining the gains" by focussing on state protected areas. There is already an alien plant control project in the park so it can be skipped in favour of the 2nd priority: D92C. The other top priorities are located in areas where there is relatively high groundwater availability, a factor which was given high weight in the prioritization.

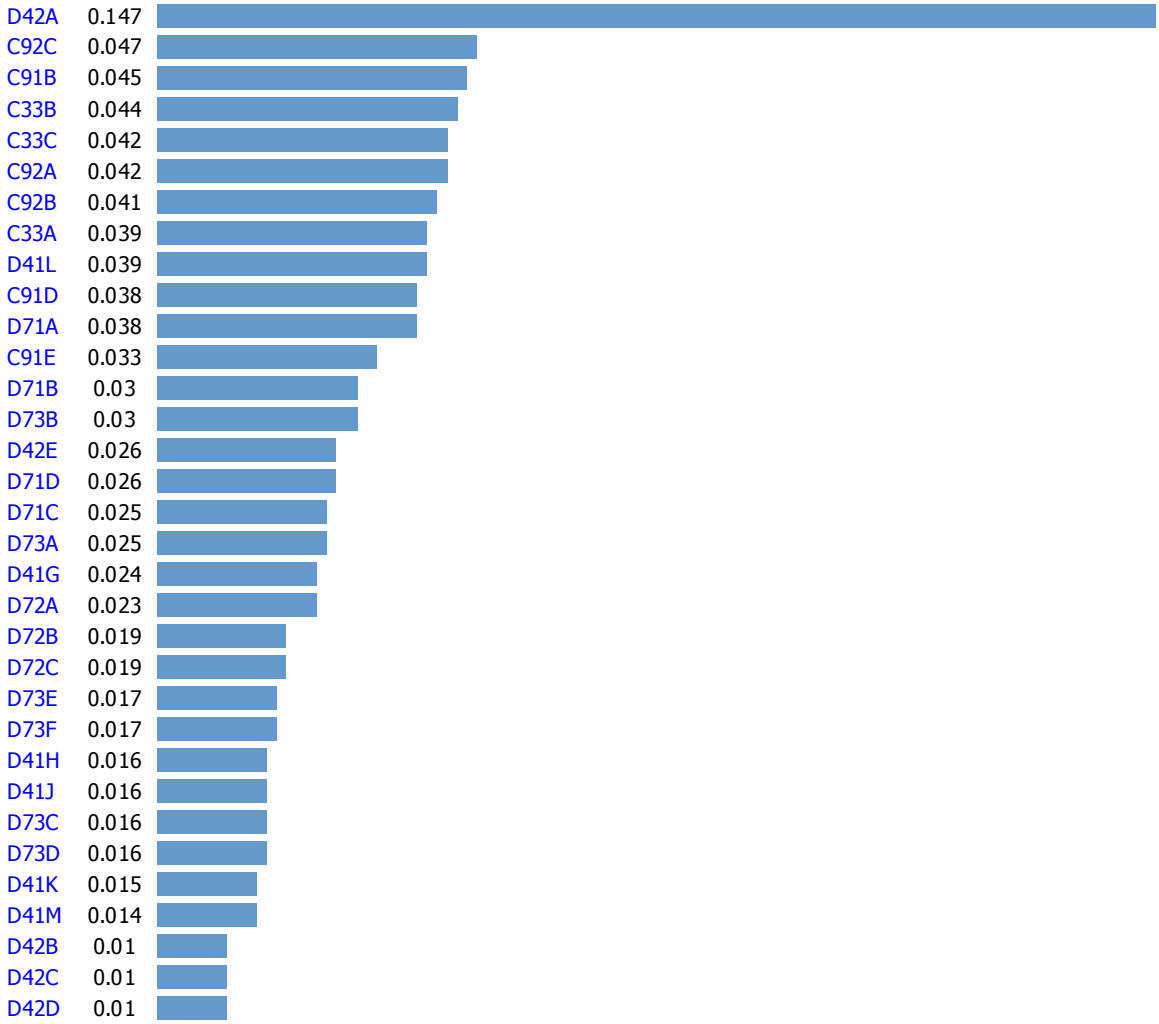

Figure 10: ***The relative importance and ranking of the 33 quaternary catchments in primary catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts).***

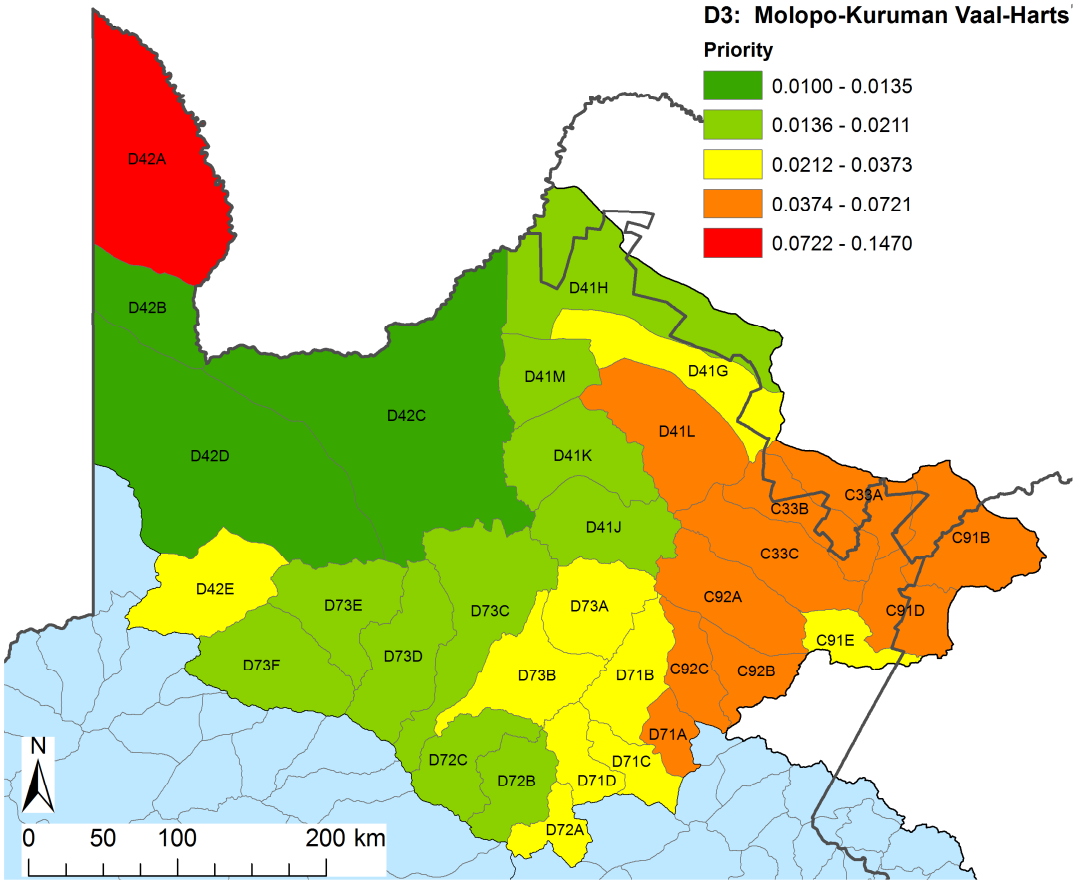

Figure 11: ***Catchment (AHP) scores for each of the quaternary catchments in primary catchment D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts). Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.***

The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment D_3 (see Figure 11) indicates that they appear to be poorly aligned (see Figure 12). The quaternary catchment with the highest priority is D42A (0.147). There is a South African National Parks project in this catchment so the top priorities should shift to the next most important ones: C92C, C91B, C33B, C33C and C92A. There are projects in the first two but their budgets are well below what they should be relative to their priorities.

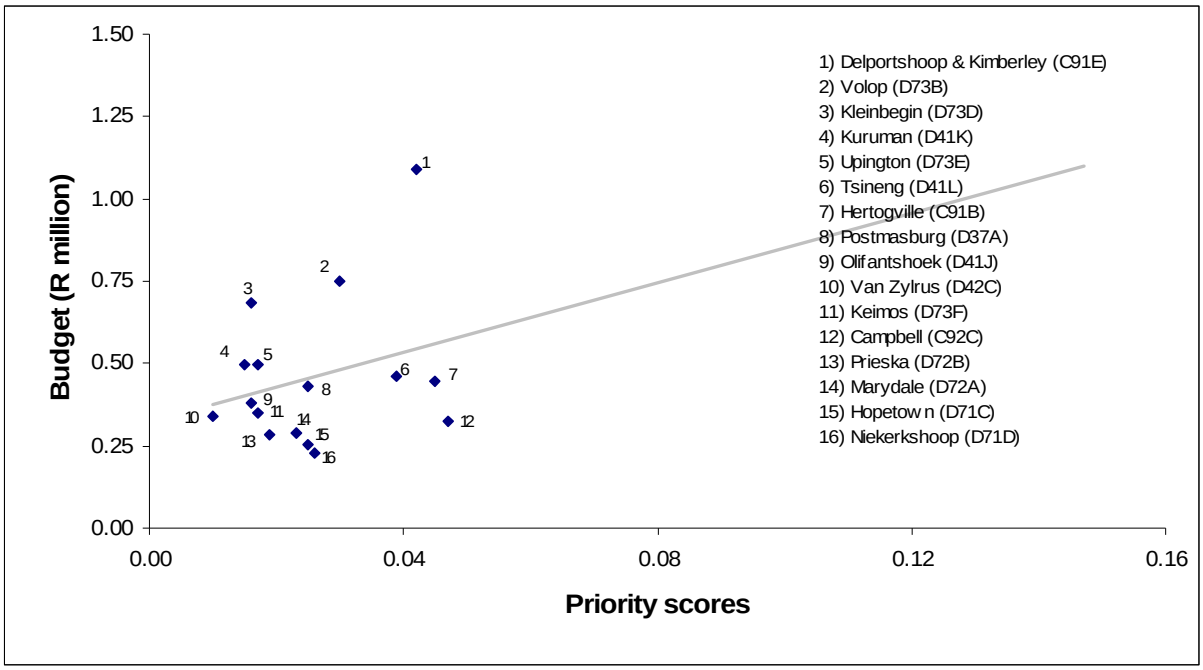

Figure 12: ***The 2009/10 budget for IAP clearing projects in D_3 (Molopo-Kuruman, Middle Orange, Lower Vaal-Harts) portion of primary catchment D in relation to priorities identified in this study (see Figure 11). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

5.2.5 Primary Catchment E (Olifants-Doring)

The five quaternary catchments with the highest relative importance rankings are E23E, E23F, E23J, E31F and E23A. The first three have relatively high potential groundwater utilisation potential, extensive azonal vegetation and include the Tankwa Karoo National Park. E31F has a relatively high registered groundwater use and extensive azonal vegetation while E23A has a relatively high potential groundwater utilisation potential. Thus water resources and their protection pay an important role together with protected areas in determining the overall priorities.

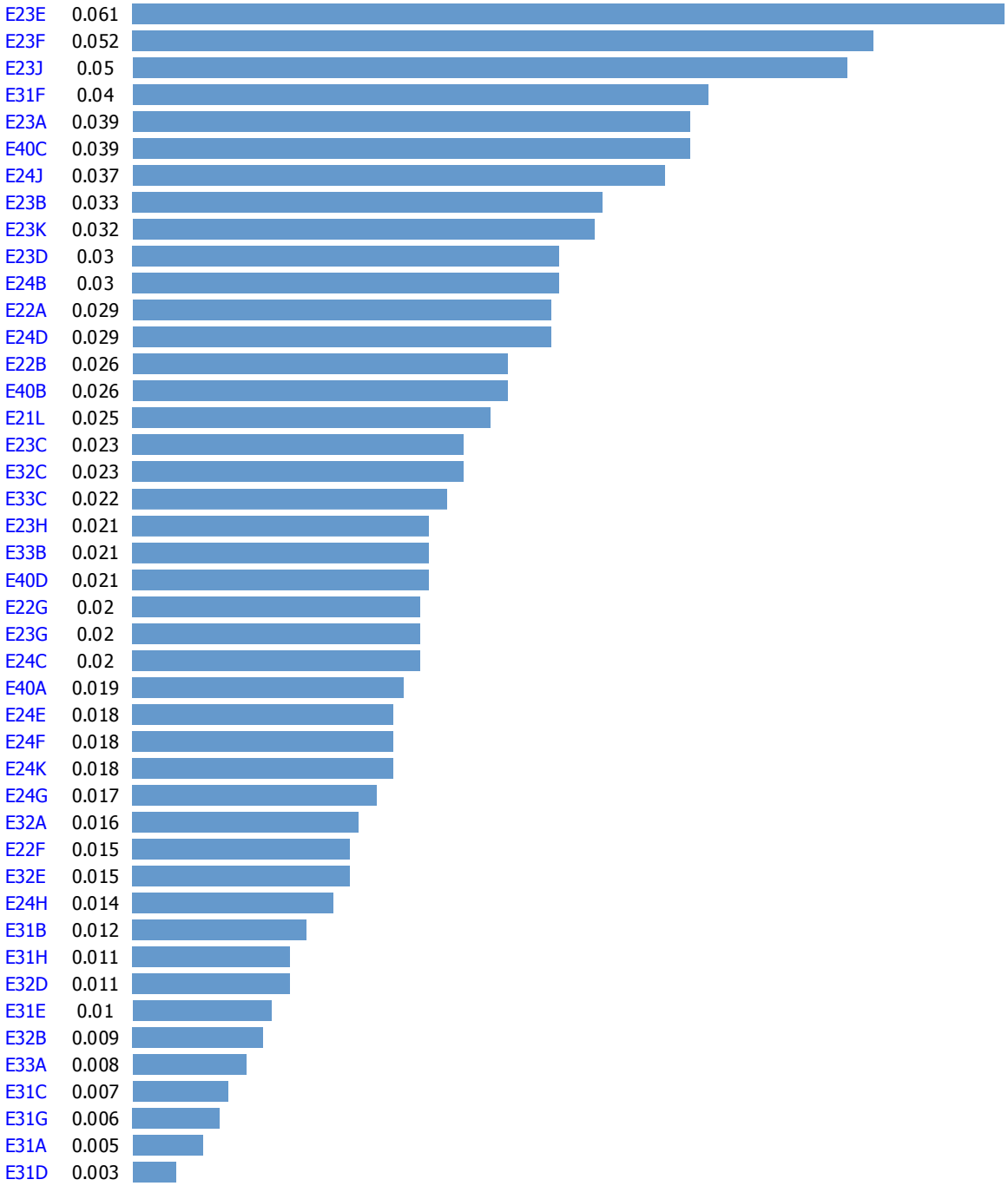

Figure 13: The relative importance and ranking for the 44 quaternary catchments in the primary catchment E (Olifants-Doring)

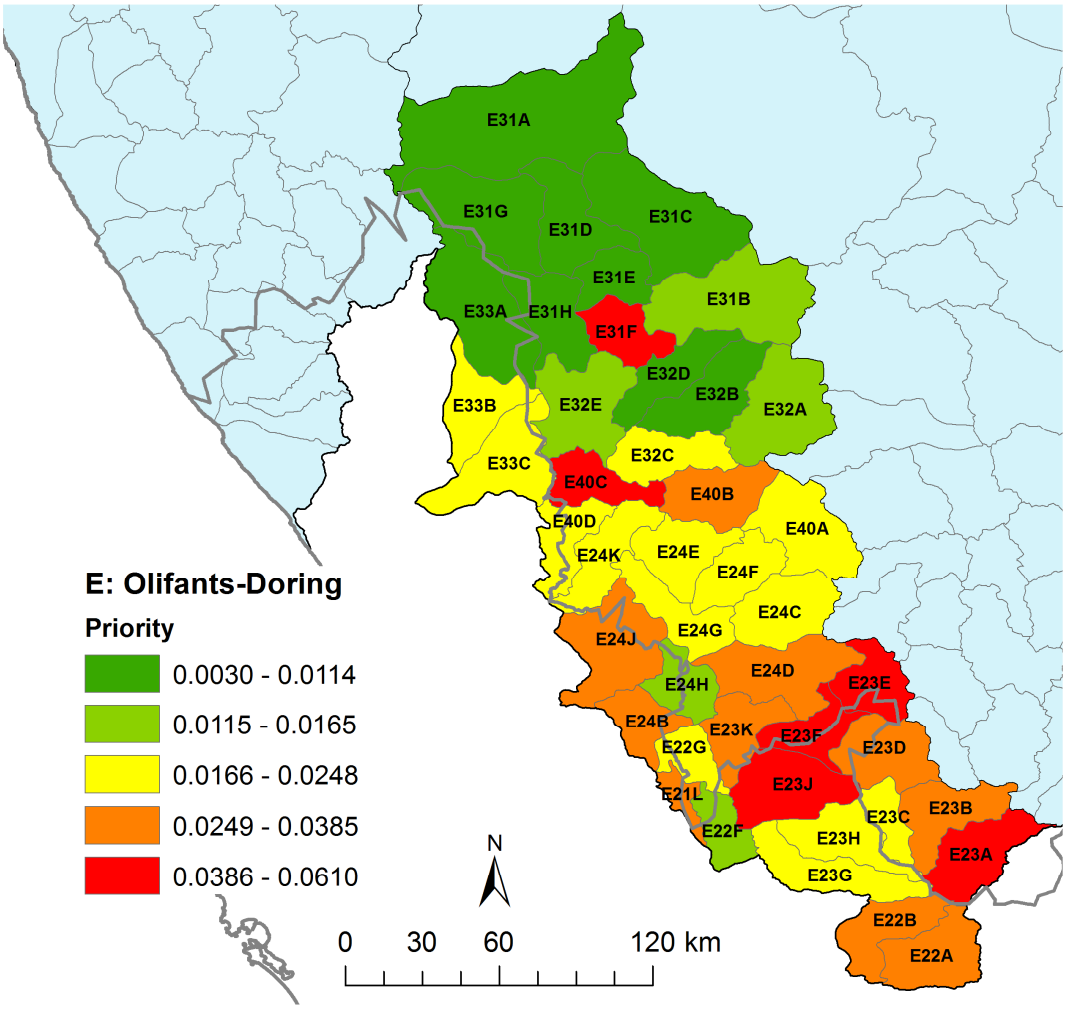

Figure 14: ***Catchment (AHP) scores for each of the quaternary catchments in primary catchment E (Olifants-Doring). Red and orange shading indicates catchments having the highest priority for clearing invasive alien plants.***

A comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment E (see Figure 14) indicates that they are, in some cases, quite well aligned (see Figure 15). The quaternary catchments with the highest priorities are E23E (0.061) and E23F (0.052). There are no Working for Water managed projects in these catchments but they do fall partly in the Tankwa Karoo National Park where there is a control project. The projects shown in the graph are all implemented by Working for Water in the Western Cape or by South African National Parks.

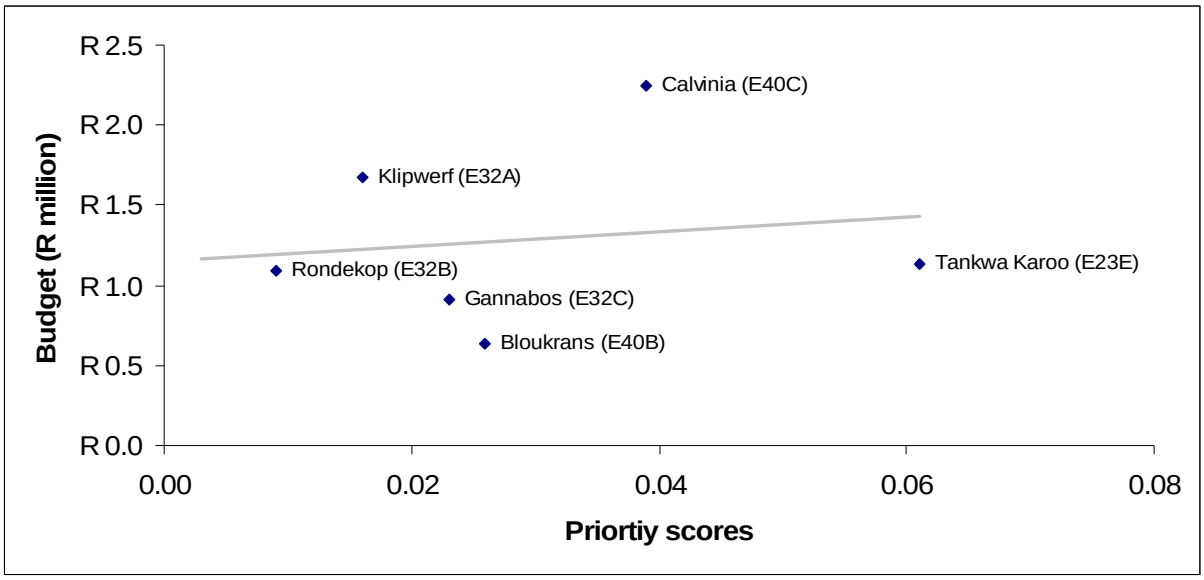

Figure 15*: *The 2009/10 budget for IAP clearing projects in primary catchment E in relation to priorities identified in this study (see Figure14). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.

5.2.6 Primary Catchment F (Namaqualand catchments)

This primary catchment falls almost entirely within the Succulent Karoo Biome with some limited areas of the Fynbos and Azonal Biomes. Here the five quaternary catchments having the highest importance rankings are: F10A, F40C, F10C, F50E and F50C (see Figures 16 and 17). F10A has very high registered groundwater-use and includes parts of the Richtersveld National Park and the adjacent World Heritage Site. F40C has a high proportion in the Namaqua National Park while F10C includes most of the Namib Seashore Vegetation (classified as Vulnerable). This is the only vegetation type currently considered threatened in the Namaqualand catchments (primary F) and thus gets a high priority. However, it is threatened primarily by diamond mining (Driver et al. 2005, Mucina and Rutherford 2006) and not by invasive plants. F50C and F50E have relatively high volumes of potentially utilisable groundwater and surface water runoff.

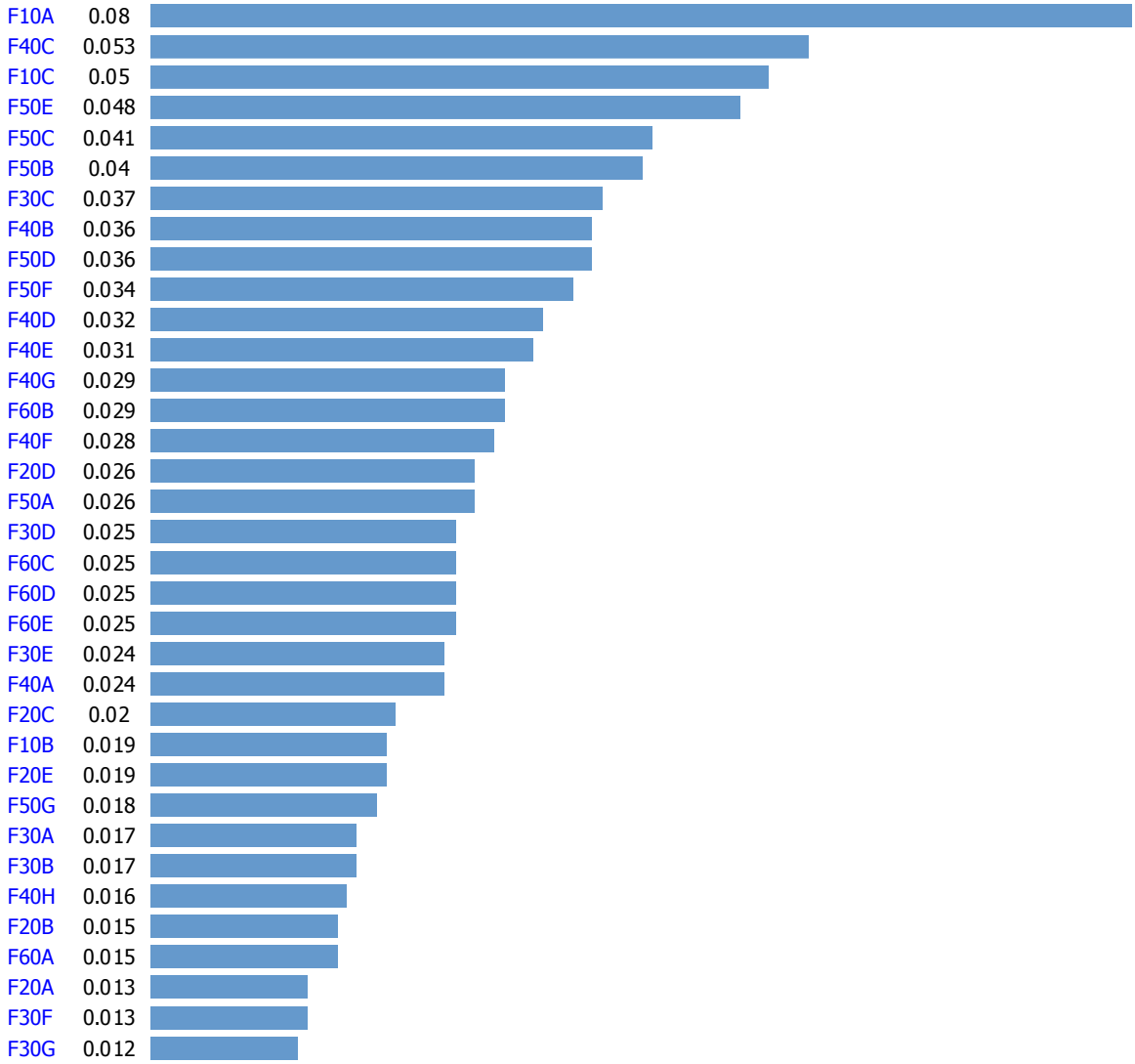

Figure 16: ***The relative importance and ranking of the 35 quaternary catchments in primary catchment F (Namaqualand) in the Northern Cape Province.***

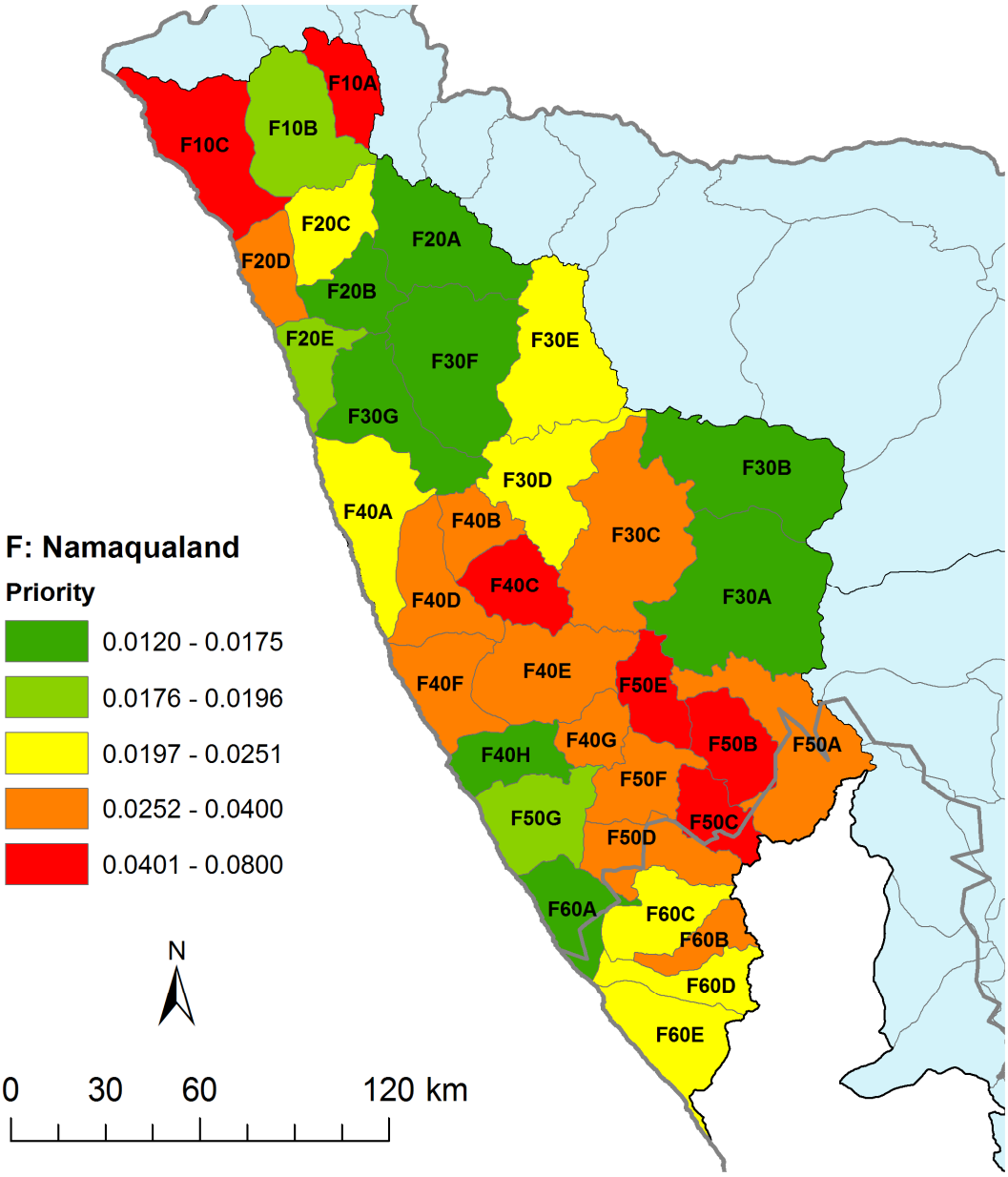

Figure 17: ***Catchment (AHP) scores for each of the quaternary catchments or portions thereof in primary catchment F (Namaqualand) in the Northern Cape Province. Red and orange shading indicates catchments having a higher priority for clearing invasive alien plants.***

A comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment F indicates that they are well aligned for the two existing projects (Figure 18). There is no projects in the quaternary catchment F10A which has the highest priority (0.080), but there is a project in F40C (0.053).

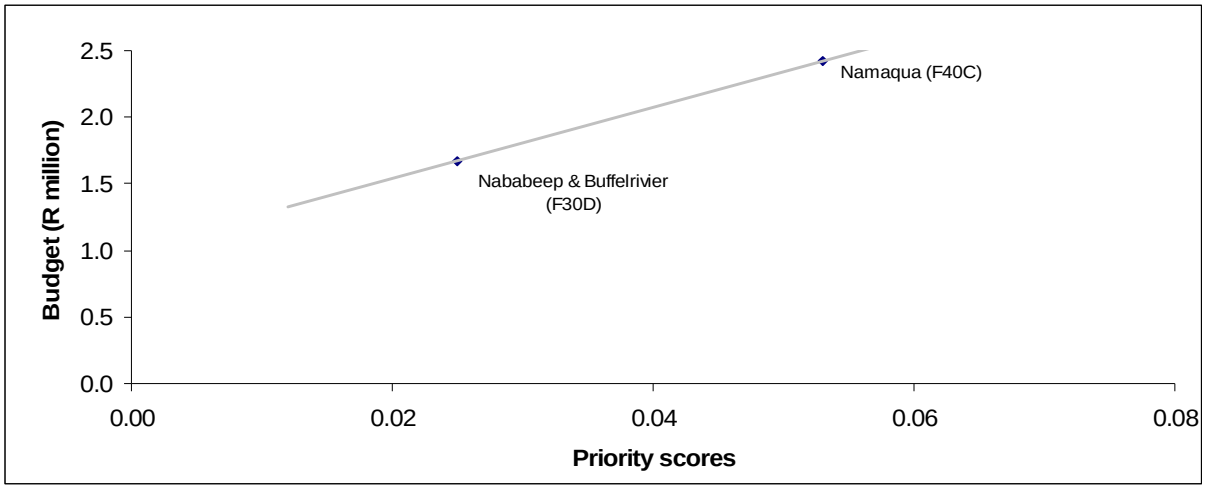

Figure 18: ***The 2009/10 budget for IAP clearing projects in primary catchment F (Namaqualand) in relation to priorities identified in this study (see Figure 17). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

5.3 OVERVIEW OF NORTHERN CAPE PRIORITY QUATERNARY CATCHMENTS

The top five priority quaternary catchments in each of the main primary catchments within the Northern Cape Province are shown in Figure 19. The highest priority catchments are mainly those that are important for water resources, occur around protected areas and have potential for veld utilisation. The results of this study contrast markedly with those from the Western Cape (Forsyth et al. 2009). There the quaternary catchments with protected areas, high water yields and a high potential for invasions tended to coincide in the mountain areas. This meant that the high priorities tended to group together so that clearing would have multiple benefits despite maintaining the gains being given a high weight. In this study the December 2009 workshop gave a high weight to maintaining the gains which tended to concentrate the high priorities in quaternary catchments which include protected areas. The revised weights, set in the 24 March 2010 workshop, gave the greatest weight to water resource protection (46%) so it has played the primary role and less emphasis has been placed on maintaining the gains and more on protecting water resources.

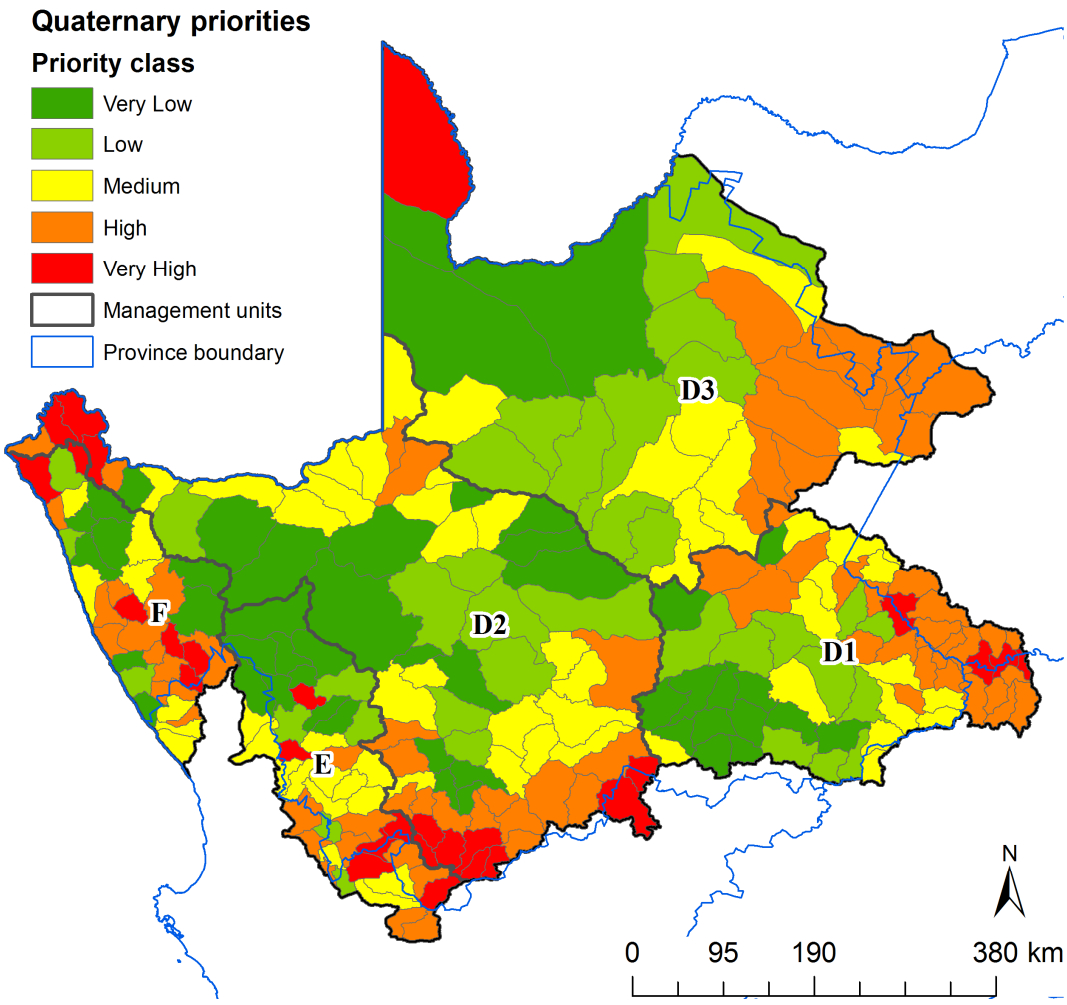

Figure 19: ***The top priority quaternary catchments identified (red and orange shading) within each of the major primary catchment-based management units in the Northern Cape.***

6. APPLYING THE PRIORITIES

The study by van Wilgen et al. (2008) assigned priorities to each of the primary catchments in each of the biomes. In a subsequent study, the different biomes were compared and ranked (Van Wilgen et al. 2010). This assessment found that at a national scale, the priorities for the biomes were: Succulent Karoo 0.070, Arid Savanna 0.063 and Nama Karoo 0.063. This indicates that the overall budget for the Northern Cape should be split more or less equally between the primary catchment-based units in each of the three biomes: Arid Savanna (D_3), Nama Karoo (D_1, D_2) and Succulent Karoo (E, F). The next split in the amounts allocated is at the level of the primary catchments. This should be roughly as follows, based on the findings of Van Wilgen et al. (2008). In the Arid Savanna Biome the two primary catchments (D Orange and C Vaal) were given equal priority and thus an equal portion of the resources. In the Nama Karoo Biome the highest priority was given to the Ongers-Brak-Seekoei portion of primary catchment D, indicating that D_1 should be given a higher priority than D_2. In the Succulent Karoo Biome, primary catchment E (Olifants-Doring) was given a higher priority than primary catchment F (Namaqualand). The final split is at the level of the quaternary catchment and should be based on applying the priorities as described below.

This assessment generated a prioritised list of quaternary catchments for each of the primary-catchment-based management units in the Northern Cape. These lists now need to be applied by selecting catchments in order of the priority. As noted above, some of these quaternary catchments already have projects within them. Some of these existing projects may be in low priority quaternary catchments while others may be in high priority catchments. There are cases where high priority quaternary catchments do not have projects. The approach that should be taken is one of gradual adjustment. The medium term economic framework projects that the annual budgets for the programme will increase substantially over the next three years. These additional funds should be allocated to high priority quaternary catchments where there are no projects at present. Existing projects should be continued unless there are other factors which clearly indicate that they should be phased out. When selecting new catchments from the prioritized lists, catchments where there are existing projects or which are located entirely in national parks, should be excluded and the next highest priority catchment should be selected. This is because the parks already have dedicated clearing budgets. Where the catchment is located partly, but not entirely, in a national park then the available information needs to be assessed to determine whether additional projects are needed in that catchment. More detailed assessments will be needed when the catchment includes provincial or local authority protected areas to determine how to support projects in those areas and in the catchment as a whole. The study area boundaries chosen for the assessment include a number of quaternary catchments where there are already projects which are being managed by the Free State or Western Cape regions of the programme. These catchments should be excluded from the Northern Cape lists and the catchments with the next highest priority should be selected.

Even though the top priority quaternary catchment identified in, for example, primary catchment D_2 may have a higher score than its counterpart in, for example, primary catchment D_1, it should still receive a lower allocation than the top priority in D_1 because the overall priority given to D_1 is higher. The reason for this is that each primary catchment contains a different number of quaternary catchments and the values for attributes (e.g. mean annual run-off or harvesting potential) and, thus, the weights given to each of the quaternaries differ between the primary catchments and so cannot be directly compared.

7. CONCLUSIONS

This study has identified the highest priority quaternary catchments for managing invasive alien plants within each primary catchment management unit in the Northern Cape and compared them with the current budget allocations. In most cases, the priorities and budgets are not well aligned, but in primary catchment E the existing projects and priorities are quite well aligned. In most cases the quaternary catchments with the highest priorities do not have projects at present. The regional Working for Water planning team and area managers need to assess how best to improve the current alignment between budgets and priority catchments over time.

The techniques we have developed to determine the priority areas for clearing invasive alien plants at a quaternary catchment scale are workable but it is not really clear whether the results correspond with what the managers and experts would intuitively expect. The difference that this new approach makes is that the managers can now evaluate the roles of the individual data elements which contribute to each score assigned by the Expert Choice (AHP) software and adjust them where necessary.

An advantage of using AHP is that it can handle a large number of alternatives enabling comparisons to be made on any number of quaternary catchments.

Our answers are only as good as the underlying spatial datasets but as new or revised datasets become available they can easily be accommodated by the hierarchy model and used to generate a revised set of rankings (catchment scores). On the other hand, as our understanding improves we can adjust the weightings assigned to the criteria and sub-criteria in the hierarchy model, and we can add or remove criteria and sub-criteria.

This study has 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 were considered important by the experts. For example, the contract-level (NBAL) data are only available in areas where Working for Water has active projects. Likewise, the management unit control plan data are also only available for areas included in project plants. This problem should be eliminated when the National Invasive Alien Plant Survey information becomes available. Other examples include the use of surrogate data, the limitations of Rouget's climate based models for determining the potential distribution of invasive alien plants, and the lack of information on the spatial distribution of game and other viewing, hunting and fishing, and harvested veld products.

8. RECOMMEDATIONS

This study has been successful in applying the approach developed by van Wilgen *et al.* (2008) at a quaternary catchment scale in the Northern Cape Province. However, a number of follow-up actions will be needed if this approach is to deliver its full potential in terms of assisting the Working for Water Programme to improve its operations and its impact. With this in mind, we recommend the following:

- That the techniques developed at the primary and quaternary catchment scale be adopted by Working for Water's national and regional planning offices to assist with prioritization, planning, and the allocation of resources to both existing and new projects on an ongoing basis.

- Each Working for Water region should maintain the existing datasets and revise them and the prioritisations on a regular basis. This should not be longer than 3 years so as to coincide with the medium term expenditure framework (MTEF) of government.

- The priorities given in van Wilgen *et al.* (2008) should be used to guide the allocation of funds between the primary catchment-based management units of the Northern Cape. Then the priorities identified in this study should be used to allocate funds amongst the quaternary catchments.

- That as soon as the National Invasive Alien Plant Survey has been completed by the Agricultural Research Council, the data on current state of invasion should replace the SAPIA dataset we have used for in this study.

- That a spatial database be developed to underpin effective comparisons of areas. This database could contain data relating to most of the criteria identified here, including mean annual runoff, the locality of important groundwater aquifers, the degree of water stress, conserved areas, areas of threatened or critically threatened conservation importance, livestock production potential, the distribution of invasive alien species and land ownership. We recommend using the Working for Water Information Management System (WIMS) to store the necessary data.

- That the WfW programme develop a multi-criteria-based approach to prioritising local communities for inclusion in projects in the prioritised catchments. This prioritisation scheme should also take into account the opportunities for employment and capacity building through other extended public works funded programmes.

- That this work be published in the peer-reviewed literature. This will have a number of advantages, including (i) ensuring that the work is subjected to rigorous review; (ii) ensuring a permanent and widely-retrievable record of the work; and (iii) enabling the wider dissemination of the approach and results, particularly to other organizations involved in control operations.

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APPENDICES

APPENDIX 1: PRIORITY INVASIVE ALIEN PLANTS IN THE ARID SAVANNA, NAMA KAROO AND SUCCULENT KAROO BIOMES

(A) The 8 invasive alien plant taxa selected for prioritization in the Arid Savanna Biome listed in order of importance (van Wilgen et al., 2008)

Species	Life form	Occurrence	Rank
Prosopis glandulosa (mesquite)	Tree	Widespread, densest on river floodplains and alluvial deposits	1
Populus x *canescens* (grey poplar)	Tree	Along perennial rivers	2
Schinus molle (pepper tree)	Tree	Widespread, particularly along rivers	3
Cereus jamacaru (queen of the night cactus) (not under biocontrol)	Cactus	Widespread	4
Melia azedarach (Persian lilac)	Tree	Along perennial rivers	5
Opuntia species	Cactus	Widespread	6
Robinia pseudoacacia (black locust)	Tree	Widespread, most common in higher rainfall areas	7
Arundo donax (giant reed)	Reed	Along perennial rivers	8

(B) The invasive alien plant taxa selected for prioritization in the Nama and Succulent Karoo biomes listed in order of importance (van Wilgen et al., 2008)

Species	Life Form	Occurrence	Rank
Prosopis x glandulosa (mesquite)	Multi-stemmed small tree	Nama and Succulent Karoo	1
Eucalyptus camaldulensis (red river gum)	Tall evergreen tree	Nama Karoo, Succulent Karoo and fynbos transition	2
Populus x canescens (grey poplar)	Tall deciduous tree	Nama Karoo, Succulent Karoo and fynbos transition	3
Arundo donax (giant reed)	Tall reed	Nama Karoo, Succulent Karoo and fynbos transition	4
Nerium oleander (oleander)	Multi-stemmed evergreen shrub	Succulent Karoo and fynbos transition	5
Tamarix ramosissima (pink tamarisk)	Small evergreen tree	Nama Karoo, Succulent Karoo and fynbos transition	6
Schinus molle (pepper tree)	Evergreen tree	Nama and Succulent Karoo	7
Myriophyllum spicatum (spiked water-milfoil)	Rooted submerged water plant	Nama and Succulent Karoo	8
Cacti without effective bio-control agents	Spiny and un-armed succulent shrubs	Nama and Succulent Karoo	9
Casuarina equisetifolia (beefwood)	Tall evergreen tree	Nama Karoo, Succulent Karoo and fynbos transition	10
Annual grasses	Annual grass	Succulent Karoo and fynbos transition	11
Caesalpinia gilliesii (bird-of- paradise bush)	Large shrub	Nama Karoo	12
Pinus halepensis (Aleppo pine)	Tall evergreen coniferous tree	Nama Karoo and fynbos transition	13
Cacti with effective bio-control agents	Spiny and un-armed succulent shrubs	Nama and Succulent Karoo	14
Atriplex nummularia (old man saltbush)	Erect multi-stemmed shrub	Succulent Karoo	15
Pennisetum setaceum (fountain grass)	Tufted perennial grass	Nama Karoo, Succulent Karoo and fynbos transition	16
Xanthium spinosum (boetebos)	Much branched annual	Nama and Succulent Karoo	17
Solanum elaeagnifolium (Satan's bush)	Herbaceous shrublet with annual stems and perennial roots	Nama Karoo	18

APPENDIX 2: PARTICIPANTS IN THE EXPERT WORKSHOPS

(a) Participants in the workshop held at the Mofele Camp in the Mokala National Park on 10 and 11 December 2009 to rank the importance of the criteria to use in prioritising quaternary catchments in the Northern Cape

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(b) Participants in the workshop held at the Town Hall in the Kimberley on 24 March 2009 to discuss the initial results and adjust the weights on the criteria uses to prioritise quaternary catchments in the Northern Cape.

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