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RESTORATION OF ALIEN-INVADED RIPARIAN SYSTEMS

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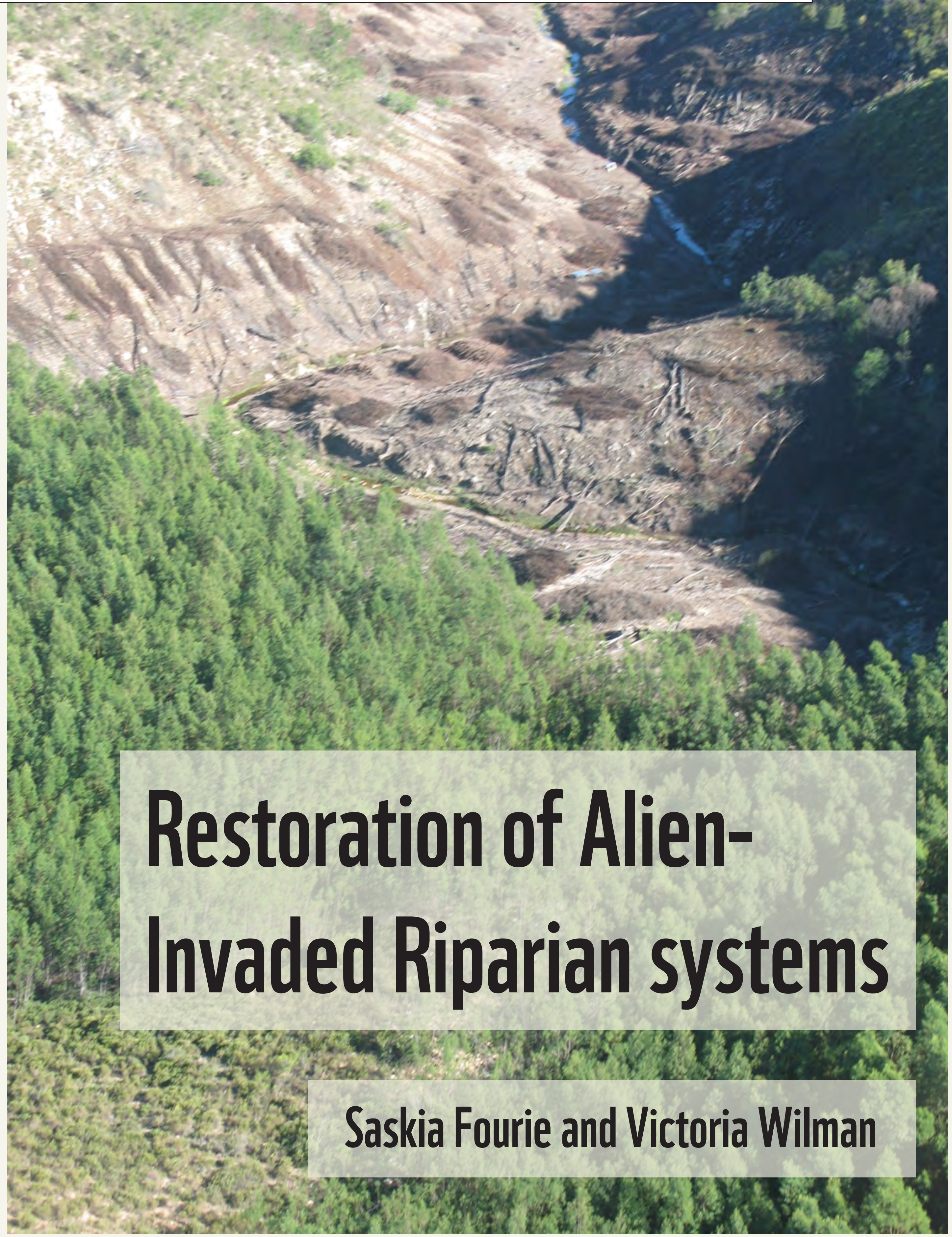

Restoration of Alien-Invaded Riparian systems

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WWF is one of the world's largest and most experienced independent conservation organisations, with over 5 million supporters and a global Network active in more than 100 countries.

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CONTENTS

1 INTRODUCTION

Invasive alien plants (IAPs) are one of the largest causes of ecological degradation and loss of ecosystem services worldwide. In South Africa rivers are particularly prone to invasion by woody alien species and most of our rivers have been invaded to some degree.

The impacts of invasive plants, such as wattles, can be severe, and include the following:

- Decline in available water
- Displacement of indigenous species
- Loss of productive land
- Loss of hydrological functioning
- Erosion and loss of soil
- Siltation resulting in reduced dam capacity
- Increased fire and flood risk
- Loss of biodiversity
- Decline inland value

Removal of IAPs is crucial in addressing the negative impacts above, but in some situations rivers have degraded to such a degree that they are not able to self-restore and their ability to deliver basic functions, e.g. flow and filtration, has been compromised. In these cases, additional interventions in the form of active restoration such as seeding or planting, are required to return river functions and prevent further degradation. The establishment of an indigenous vegetation cover also suppresses alien regrowth and is a pre-requisite for the long-term control of IAPs.

This document sets out to guide land owners and other IAPs managers in the restoration of alien invaded riparian systems. It aims to provide information on the principles of the restoration of invaded riparian systems and presents guidelines for the decisions and implementation of clearing and restoration projects.

The decision process for such projects can be complex and the “best” solution may not always be possible, and often the benefits and drawbacks of various management decisions have to be weighed up against one another. To add to the complexity, no two streams or landscapes are the same, and each land owner or manager’s particular circumstances will differ. This makes it impossible to provide easy “recipes”. This document therefore aims to assist land owners and managers in understanding the underlying principles of effective restoration in order to enable them to draft their own action plans.

It should be noted that in some situations the decision process (and actions like stream stabilisation) may require specialists who can be called upon to assist project managers with site-specific restoration plans (see useful contacts in Appendix A). This may especially be advisable before embarking on large-scale, expensive restoration operations.

Rehabilitation and restoration

Several terms exist and are often used interchangeably. The two main terms are:

- Rehabilitation: the re-introduction of important ecosystem functions, e.g. water infiltration or erosion control, but not necessarily biodiversity.
- Restoration: originally defined as the reconstruction of former functions and characteristic ecosystem structure, communities and species. It is also now used to define the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed.

In this document, the term "restoration" will be used as defined in the broader sense above.

We also make a distinction between passive restoration, where ecosystems are allowed to self-recover after the factors causing degradation (alien invasion) are removed, and active restoration, such as re-introducing plant species through seeding or planting after the removal of IAPs.

Riparian zones

Riparian zones are the fringes of rivers or streams and form the boundary between aquatic and terrestrial ecosystems. They are affected by riverine processes such as flooding, and typically support a distinctive vegetation that differs in structure and function from adjacent terrestrial vegetation.

Riparian vegetation can be divided into lateral zones (see Figure 2)

- The in-channel vegetation
- Vegetation on the wet bank, which remains moist and is subjected to frequent flooding
- Vegetation on the dry bank, which is not flooded every year and is generally drier
- Vegetation on the slopes adjacent to the river. This vegetation still affects riparian functioning, and since these areas are often invaded as well, management guidelines for these zones are included in this document.

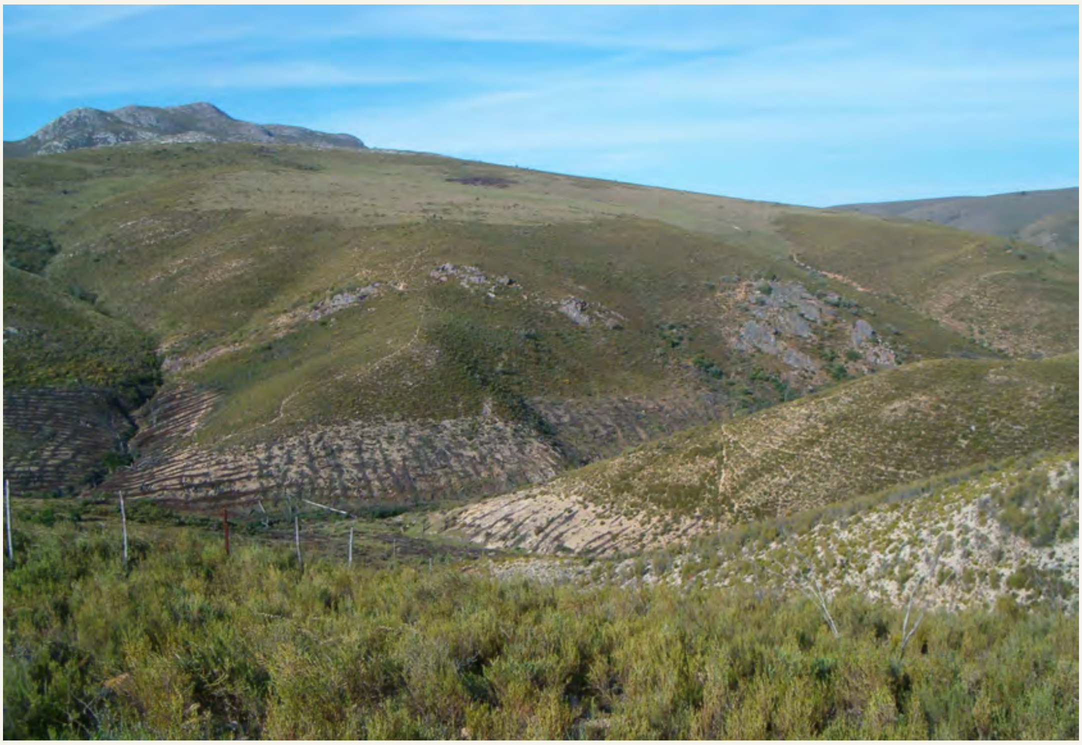
The link between invasion, clearance and restoration

South Africa has considerable experience in the clearing of IAPs, mainly developed through the Working for Water (WfW) Programme. However, the emphasis has often been on alien control rather than restoration. Some IAP clearance methods can be detrimental to recovery instead of optimising restoration, and result in further degradation. Examples of these are included in Section 8.1.

The management of invasive alien species and restoration are closely linked, and it is crucial that clearing is viewed as an integral part (as well as the first step) of the restoration process.

Some overarching principles for the restoration plan

- Halt the cause of degradation
- Do not increase degradation through restoration interventions, either on-site or off-site
- Conserve what remains
- Recognise that it may not be possible to address all factors contributing to degradation
- Identify and address missing ecosystem processes
- Prioritise
- Set targets
- Plan carefully
- Work efficiently



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The pictures above show an example of a riparian system which has lost the capacity to recover unassisted after clearing of invasive alien species. This tributary has received an initial clearance ten years ago and has had more than seven follow-up treatments.

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The pictures above show some impacts of invasive species; poor water quality, loss of flaw and hydrological functioning and flow, channel incision and bank undercutting, loss of indigenous vegetation

1.1 DOCUMENT OUTLINE

A large number of variables can combine to produce an infinite number of scenarios and it is therefore impossible to provide detailed restoration plans for every contingency. This document has been divided into two parts, in an attempt to provide the guidelines necessary for most South African landscape managers to draft their own action plans.

Part I presents an overview of the clearing and restoration assessment and planning processes. It describes the steps and principles that are used to make management decisions as follows:

- Provides the guidelines on how to undertake a macro- or landscape level assessment
- Establish clearing and restoration priorities
- Describes the outcomes that can be expected for different invasion scenarios
- Provides some examples of flow-charts that can be used to guide decision-making
- Provides an example of how to use the above information to develop a strategic clearing and restoration plan for a given area
- Concludes with a section on the monitoring and evaluation process

Part II consists of the detailed information and tools that are needed to guide and inform the decisions taken in Part I. The information in Part II can also be used to develop moredetailed restoration plans for implementation Part II describes:

- The condition of uninvaded or reference sites which can be used to compare restoration targets to
- The biophysical and socio-economic factors that will influence the decisions taken regarding clearing and realistic restoration targets
- An overview of clearing methods and how clearing impacts on restoration
- Methods for active restoration and the propagation of plants

It must be emphasised that restoration planning is not a linear, but an iterative process. For example, once the broad-scale strategic restoration plan has been developed, detailed planning will require an assessment of all the resources required for the implementation of the plans. It may then be necessary to reconsider the targets or schedules and adjust the proposed detailed action plans according to available resources.

Although we have tried to avoid too many technical terms, this is not always possible, and a glossary is provided at the end of the document with explanations of more technical terms.

The following figure illustrates the restoration assessment planning process. The various components are documented in this report.

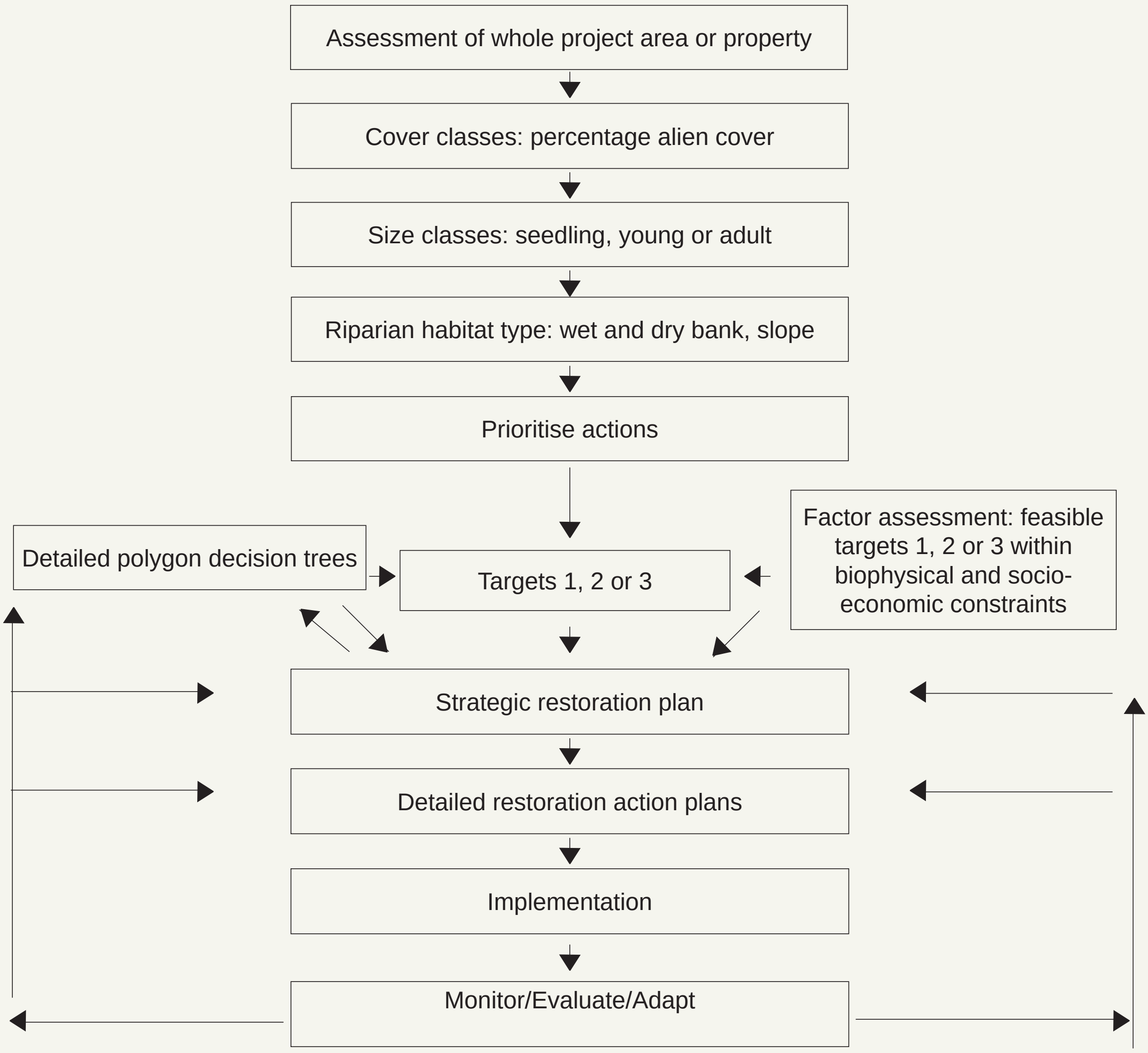

Figure 1. The restoration assessment and planning process

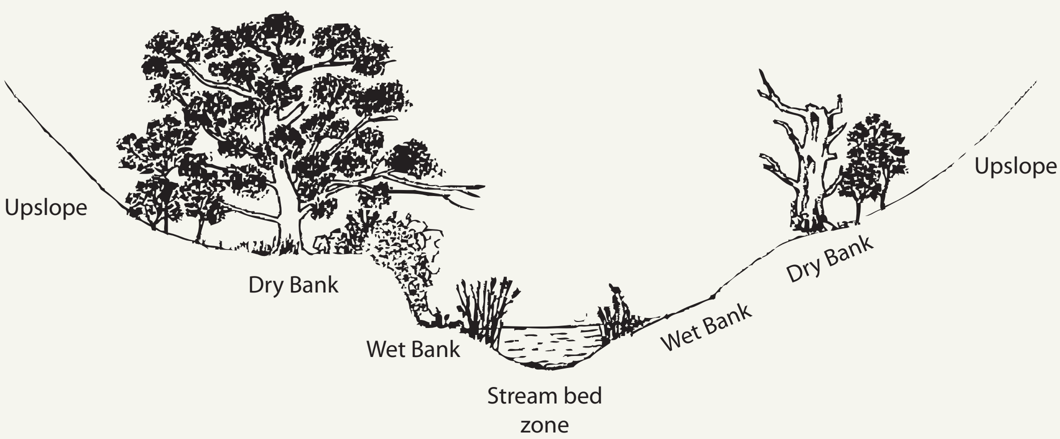

Figure 2. The lateral zonation of a riparian system (after Sieben and Reinecke, 2008)

An aerial view of a closed canopy (100%) old black wattle invasion (top), and a view under the dense canopy (bottom). Note the lack of any indigenous vegetation


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PART I

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2 MACRO-SCALE DECISIONS: FOCUS ON THE LANDSCAPE

A first-level, macro assessment of the entire area or landscape is crucial before starting on an IAPs management and restoration programme to optimise landscape-wide planning, implementation and resource allocation. A macro assessment begins by mapping and dividing a bigger landscape with different topographies and vegetation types into similar portions (see Section 2.1 and Figure 3 below). These portions are referred to as "polygons" or "vegetation units". These polygons are then prioritised, based on various principles that are described in Section 2.2.

Figure 3. An example of landscape map

2.1 STEP 1: MAP INVADED, CLEARED AND INDIGENOUS AREAS

Obtain an up-to-date map of the whole area. An example of a map is included above (see Figure 3). For broad-scale, strategic planning a 1: 10 000 orthophotomap or aerial photograph (orthorectified) can be used, but it is preferable and more accurate to use a finer-scale map for detailed polygon mapping where a horizontal accuracy of 2-5m is desirable. These can be obtained in digital format or as hard copies from National Geo-spatial Information (see Appendix A), or contact your local WfW office for assistance. Google Earth can also be useful in obtaining images, but these are not orthorectified and cannot be used to calculate areas.

Using the map, delineate the boundaries of the invaded portions of the property as accurately as possible. Each invaded polygon must be relatively homogenous in the following aspects:

1. The age or size of the IAP (see Table 1)
2. The degree of invasion (using either aerial cover or stem densities (see Table 2)
3. The alien species (if mixed, indicate the percentage cover of each species)
4. Distinguish between the lateral riparian zones (wet and dry banks) and slopes (see Figure 3)

Also indicate the cleared and indigenous areas on the map, and any other barriers to recovery, e.g. channel incision, headcuts or transformed land (ploughed and cultivated).

Assign a unique code or number to each polygon, (see Table 3, page 24), and calculate the surface area thereof. A one-hectare grid marked on a transparent sheet which can be overlaid in the field can assist with this. GIS-based data capture, mapping and storage can be very useful if available.

Table 1: Height, canopy size and stem diameter characteristics for different IAPs size classes (Working for Water, 2003)

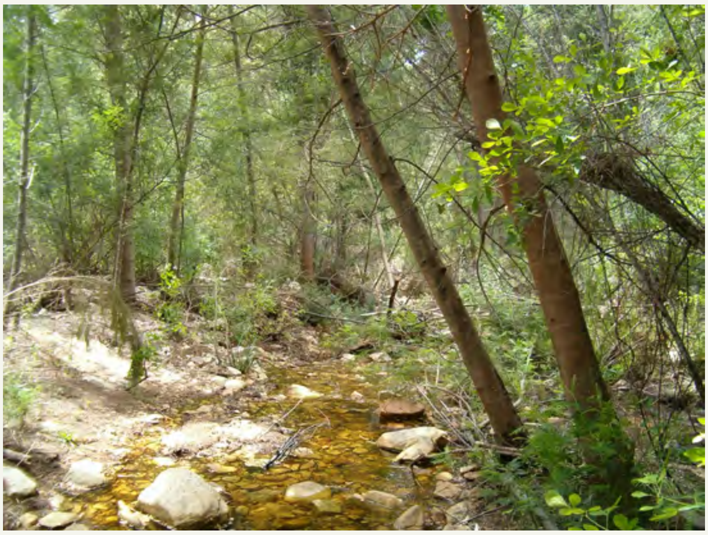
Characteristic	Size class	Tall shrubs	Medium trees	Tall trees
	Examples of species	Hakea species	Long-leaf wattle, Rooikrans, Port-Jackson willow, myrtle	Pines, Black wattle Blackwood
Height (m)	Seedling (s)	<0.5	<0.5	<0.5
	Young (y)	0.5 1.5	0.5 2.0	1.0 4.0
	Adult (a)	>1.5	<2.0	>8.0
Canopy diameter (m)	Seedling (s)	<0.3	<0.5	<0.5
	Young (y)	0.3 1.0	0.5 1.5	0.5 2.0
	Adult (a)	>1.0	>1.5	>2.0
Stem diameter (cm)	Seedling (s)	<1	<2	<2
	Young (y)	1-4	2-8	2-8
	Adult (a)	>4	>8	>8

Table 2: Cover and density classes of common woody invasive alien plants.

	Size class	Tall shrubs	Medium trees	Tall trees
	Examples of IAPs	Hakea	Long-leaf wattle, Rooikrans, Port-Jackson willow	Pines, Black wattle Blackwood
		Stems/hectare	Stems/hectare	Stems/hectare
Low (0-25%) cover				
Density	Seedling (s)	<55 000	<20 000	<20 000
	Young (y)	<12 000	<5 000	<3 200
	Adult (a)	<5 500	<2 200	<1 200
Medium (25-50%) cover				
Density	Seedling (s)	55 000-200 000	20 000-70 000	20 000-70 000
	Young (y)	12 000-40 000	5 000-17 000	3 200-11 000
	Adult (a)	5 500-17 000	2 200-7 600	1 200-4 300
Dense (50-75%) cover				
Density	Seedling (s)	200 000-340 000	70 000-120 000	70 000-120 000
	Young (y)	40 000-70 000	17 000-30 000	11 000-20 000
	Adult (a)	17 000-30 000	7 600-20 000	4 300-7 600
Closed (75-100%) cover				
Density	Seedling (s)	>340 000	>120 000	>120 000
	Young (y)	>70 000	>30 000	>20 000
	Adult (a)	>30 000	>20 000	> 7 600


High-density invasions (>75%), with small diameter stems, and little or no indigenous vegetation cover


Examples of lower-density invasions, with some remaining indigenous vegetation




Examples of lower-density invasions, with some remaining indigenous vegetation

2.2 STEP 2: PRIORITISING POLYGONS

Prioritising polygons is very important to ensure containment of the invasion, prevention of further degradation, optimal use of resources, and the most effective macro-strategy. The following sections indicate in which order portions should be cleared to achieve the above (refer to Section 8.1 for detail on clearing methods).

Remember that the priorities interact and that the order can be flexible, depending on the specific context. For example, young growth in riparian areas will have preference to young growth in a terrestrial area.

It is also imperative to plan for follow-ups, especially of previously dense, cleared areas and following a fire. Failure to follow up in time can greatly increase effort, costs and degradation and the investment in initial clearance could also be lost. When planning initial clearing, ensure that enough resources are available to do follow-ups on time (see also Sections 7.2 and 8).

While Sections 2.2.1 and 2.2.2 give the motivations for establishing the first two priorities, there are also other considerations (see Sections 2.2.3 - 2.2.6) that can supersede these and which should be considered before deciding on the final priority of where to work first.

2.2.1 Priority 1: Low densities and young growth

The first priority is to prevent an increase in invasion, contain spread and prevent further degradation. This can result either from an increase in density or the rapid growth of young infestations, both of which can increase the extent of invasion exponentially. The two following situations are therefore priorities for action:

- Areas with young (small) growth, e.g. many small seedlings after a fire.
- Areas with low levels of infestation, to prevent them increasing in density and resulting in more work and degradation.

Dealing with these areas first will give maximum return at the lowest cost.

2.2.2 Priority 2: Riparian infestations

Invasive plants grow more rapidly in riparian areas where more moisture is available, and they can cause more degradation than in invaded areas further upslope. Prioritise these areas, in order of increasing density, although the subsequent considerations must also be taken into account and may influence the order of priority.

2.2.3 Subsequent priorities

Polygons must be controlled in order of increasing density (while taking above guidelines into account). Areas with alien densities of more than 75% should be left for last, as these areas will not greatly increase in density and leaving them will not result in much more degradation or work, compared to lower-density infestations.

2.2.4 Additional priorities

There are also some other considerations or requirements which can interact with the priorities above to dictate a different order of priorities. These include the following:

- Clear from top of catchment down, to avoid re-infestation from higher up. Invader species which spread most aggressively should be controlled before less aggressive invaders.
- Integrate clearing with planned control burns, as this will affect priorities. Fire may result in dense young stands of seedlings (high priority), or may eliminate young aliens, e.g. pines and hakeas.
- Clear areas of IAPs before they set seed.
- Prioritise new invasions in otherwise natural veld, as opposed to new invasions in a transformed landscape, such as an old field.
- Clear emerging or new additions to the IAP mix, e.g. if poplar appears on a property where it has not been found before, it must be cleared before it spreads.

- Sensitive or areas of high biodiversity – it may be desirable to remove nearby threats to these areas.
- Clear most cost efficient areas first, e.g. some easily accessible areas will require fewer resources to clear than less accessible areas. While this is a valid consideration, bear in mind that the areas further away will remain invaded, and in the case of younger or less densely infested areas, will increase exponentially in terms of cost and effort.
- Connectivity – restoring connectivity in a river by clearing an invaded portion between more natural portions will assist the restoration process as well as benefit other riparian ecosystem services like re-establishing corridors etc.
- Specific needs, e.g. the landowner may need to clear a specific portion of land for use (e.g. grazing, ecotourism venture etc.).
- If biological control (biocontrol) agents are active in the area, some refuges, i.e. uncleared areas, should be left intact for these agents to persist. The gall wasp on long-leaved wattle is an example (see Section 8.1).
- Time actions with seasons, e.g. only foliar spray seedlings after spring, or use a dry period to kill off seedlings.
- Leave areas where long-term management (e.g. of re-invasion, fire, hydrology, grazing) is not feasible.
- It may also be advisable to leave polygons that will need active restoration until the restoration material, i.e. seeds and /or plants, are available. This may prevent areas staying bare for long periods and becoming more degraded, for example through loss of topsoil or re-invasion. In the case of young, dense growth this benefit has to be traded off against the increase in size and therefore clearing effort and associated damage.

2.2.5 Effect of changes over time on priorities

Young growth and less dense areas can change very rapidly, increasing in size and / or density. This must be taken into account as priorities may change over time. Any other changes which will influence priorities must also be factored in, e.g. in the event of a fire.

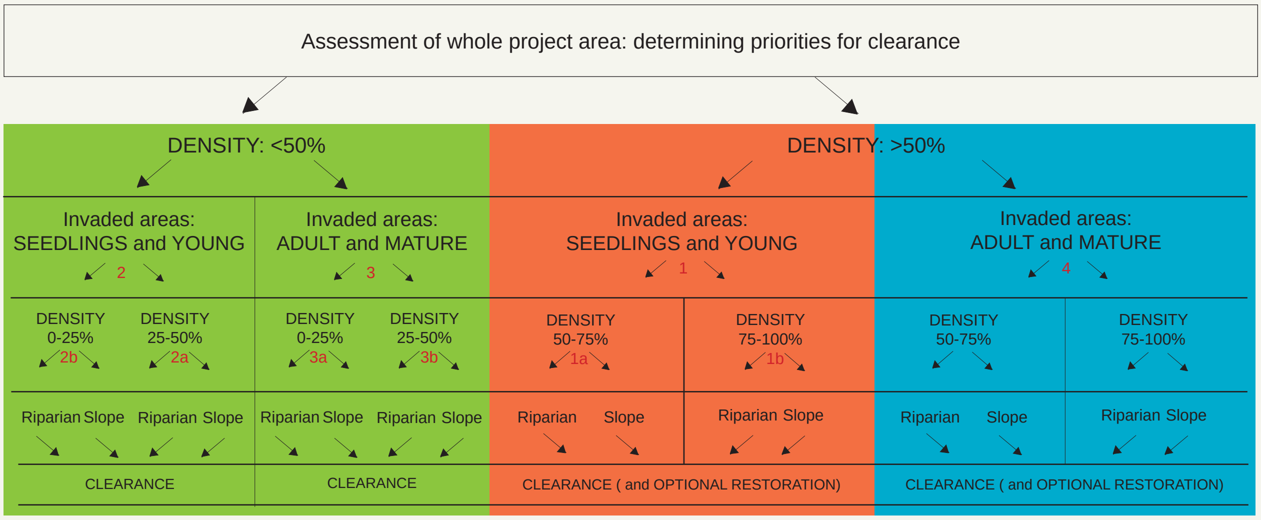
2.2.6 Areas which may need active restoration

The macro-scale assessment will also assist with identifying areas that are not likely to recover without intervention and may need active restoration. Riparian systems are relatively resilient and in most situations can recover function and structure after careful clearance, provided that there are no other major disturbance factors. However, some long and densely-invaded stands (75-100% cover) do not self-recover and will need additional intervention to restore function as a basic minimum, or vegetation structure and diversity. This will be discussed further in Section 7, but the main factors presenting a barrier to recovery are the following:

- Areas that have experienced more than three fire cycles under invasion
- Areas that have formed closed stands for more than 30 years, especially through invasion by resprouting species like wattles and gums

2.3 SUMMARY

A flow chart summarising the above information and priorities is presented below (see Figure 4). The numbers in red indicate the order of priority for control, i.e. 1a should be controlled first, followed by 1b, 2a and so on. The order of priorities will be used in the action plans described in Section 4.



• Numbers in red indicate priority of clearance actions

Figure 4 Macro-scale assessment

3 MICRO-SCALE DECISIONS: FOCUS ON POLYGONS

After the landscape has been mapped and divided into uniform polygons and the priorities for clearing and restoration have been established, the next steps focus on the polygons themselves.

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Target 1: Replace vegetation cover, decrease erosion, increase infiltration and restore more natural stream flow. Natural vegetation structure and diversity is still absent

This begins with an assessment of the biophysical as well as socio-economic factors that are relevant to any given polygon and which will influence the management decisions thereof. These include an understanding of the historical conditions, the current level of ecosystem degradation of both project site and catchment, other environmental variables and the proposed future land use. Many of these factors and their influence on decision-making are discussed in more detail in Section 7.

Returning heavily infested and damaged areas to pristine conditions may be possible given sufficient time and money, but it is important to understand that this may not be realistic. It is therefore necessary to set clear and achievable targets for each polygon. This not only serves to guide the restoration plan, but also provides a framework for monitoring and assessing the progress and success of the restoration project.

Three broad target conditions are proposed, in increasing order of ecological integrity and resilience:

- Target 1: Restore basic ecosystem processes and functions; i.e. provide vegetation cover, decrease erosion, increase infiltration, restore more natural stream flow
- Target 2: In addition to the above, restore natural vegetation structure, i.e. representatives of different growth forms like shrubs and sedges
- Target 3: Restore basic ecological functions, natural vegetation structure and diversity; i.e. the vegetation will be similar to natural vegetation, with representatives of all growth forms and species. Restore more natural stream flow and geomorphology.

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Target 2: Replace vegetation cover and structure, decrease erosion, increase infiltration and restore more natural stream flow. Natural diversity has not yet been achieved

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Target 3: Replace vegetation cover, structure and diversity, decrease erosion, increase infiltration and restore more natural stream flow. These areas will resemble natural, uninvaded streams

3.1 DECISION TREES

This document cannot possibly describe every restoration scenario, but to illustrate the principles involved in clearing and restoration decision-making, decision trees for three generalised polygon conditions are described below. These decision trees draw on the factors described in Section 7 as well as the more detailed methodologies of clearing, restoration and propagation outlined in Sections 8, 9 and 10.

SEEDLINGS AND YOUNG (ALL ZONES)

Where IAP cover is less than 75%, take great care not to damage remaining indigenous vegetation through use of herbicide or poor quality clearing

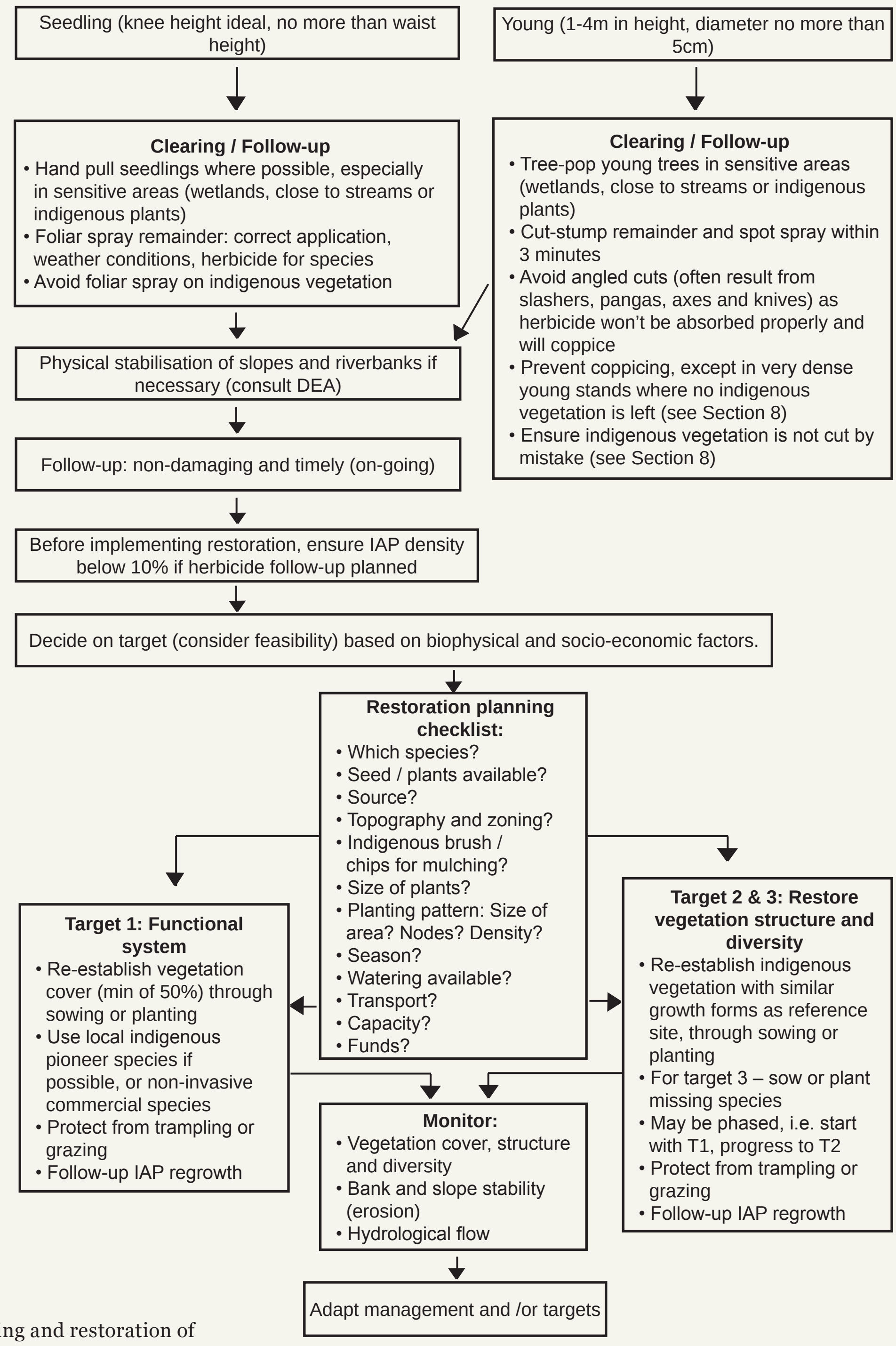

Figure 5 Decision tree for clearing and restoration of areas invaded by IAP seedlings and young growth

ADULT AND MATURE - RIVER (WET AND DRY BANK, IN FLOOD ZONE)

NEVER CLEAR MORE THAN CAN BE FOLLOWED UP IN TIME!

Minimise fire damage:

• Very important to minimise damage
• For felled biomass, always burn under cool conditions when soil is wet
• Stack biomass remainder in piles no larger than 1.2m on sand bars or rocky areas, and burn before next rainy season.
• If controlled burn planned, stacks must be at least 4m apart
• Burn on sand or rock where possible, away from any indigenous vegetation
• Stack piles can also be "fed" during controlled burn, which decreases burn areas
• Shale and granite soils: burning more damaging than sandy soils, and erosion likely to result

Notes on flood and biomass:

• Below flood line, biomass has to be removed before next flood event.
In the Western Cape the rainy season is more predictable than further east - take into account when planning
• In both scenarios, do not clear more than can be removed or burnt before next flood event

Notes on restoration:

See next page

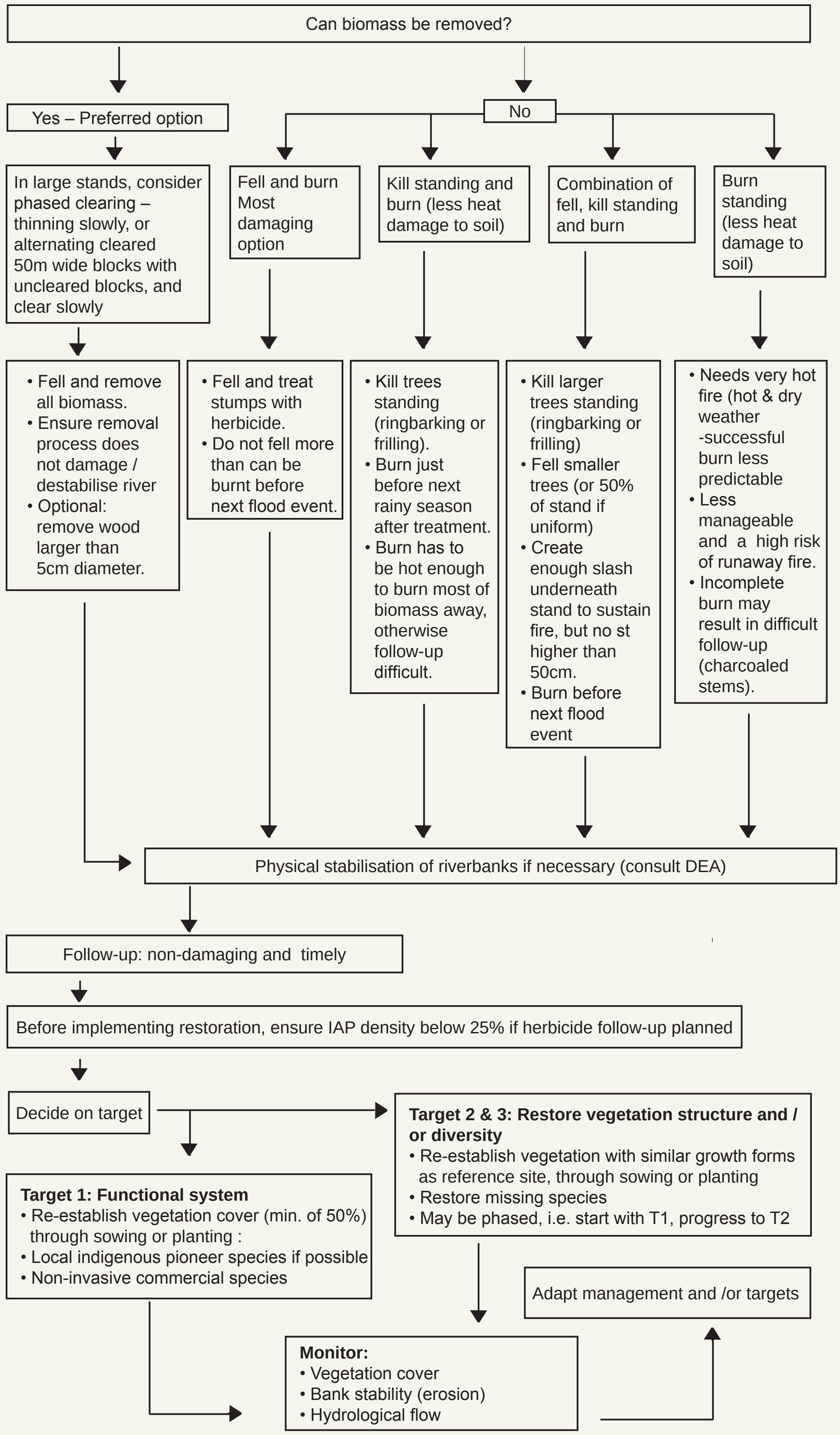

Figure 6 Decision tree for clearing and restoration of areas invaded by mature IAPs in the wet and dry bank zones

ADULT AND MATURE – RIVER (SLOPES)

75% COVER: T1 & T2

NEVER CLEAR MORE THAN CAN BE FOLLOWED UP IN TIME!

Note on fire damage:
See previous page

Notes on flood and biomass:
See previous page

Notes on restoration:
- Sowing will take longer to achieve target than planting and is often less successful
- Higher density planting will achieve quicker results
- Access is a very important consideration when planning planting
- Planting is more expensive
- Protect from grazing and trampling

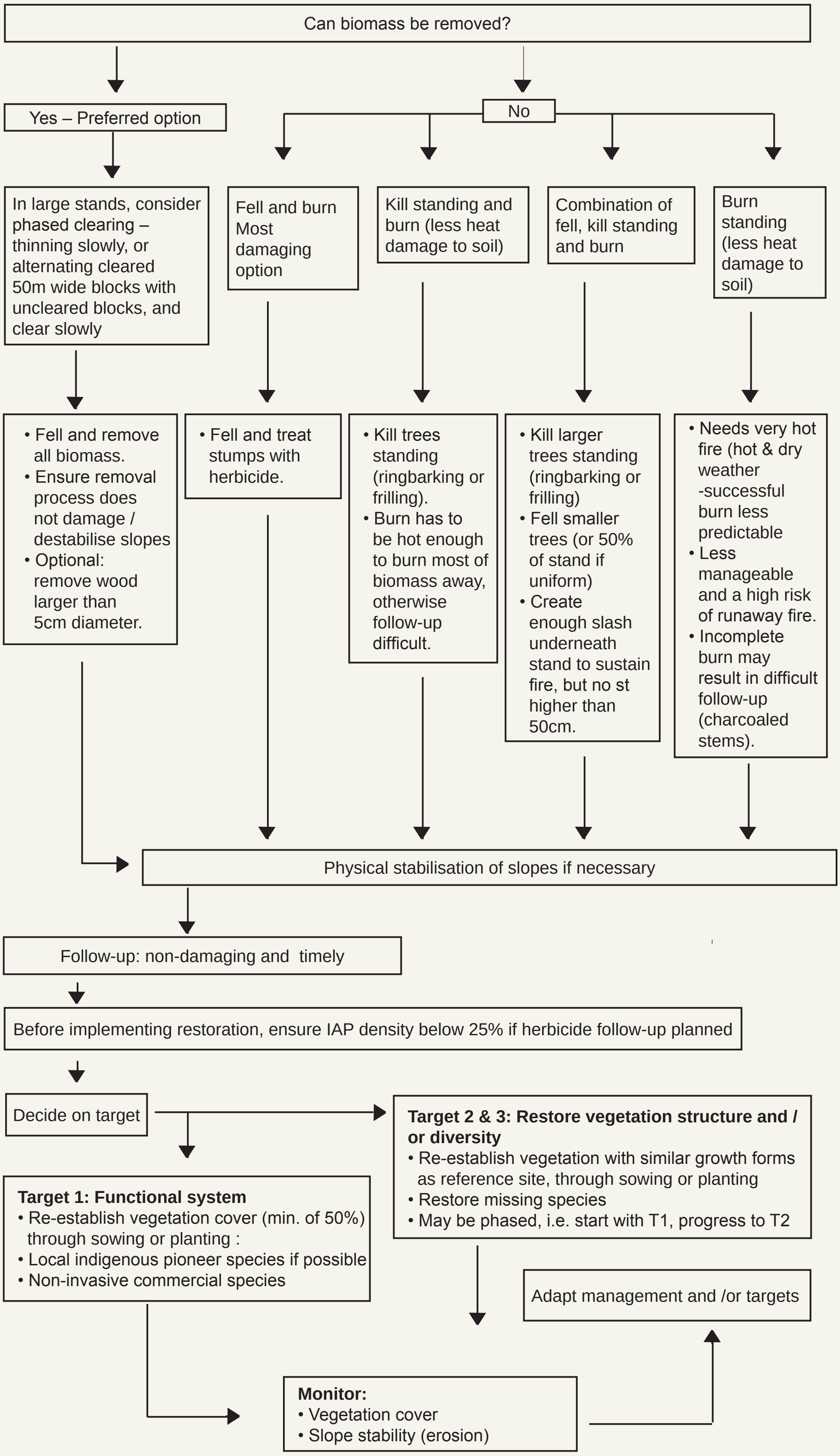

Figure 7 Decision tree for clearing and restoration of areas invaded by mature IAPs on slopes

4 STRATEGIC RESTORATION PLAN

The decision trees in Section 3, which have been designed for three generalised conditions, provide the basis of a strategic restoration action plan for the entire landscape. Working for Water has developed a template for IAP clearance, called a Management Unit Clearing Plan (MUCP), which can be downloaded from their website (see Appendix A). In this section the basic template has been developed further to provide an example of a strategic restoration plan, for both clearing and active restoration at a landscape level. A hypothetical example of such a clearing and restoration plan is shown on page

The strategic restoration action plan will draw on the following:

- *the information and priorities determined during the macro assessment*
- *the biophysical factors (Section 7.1) and the establishment of achievable targets determined in the micro assessment*
- *the guidance provided by the decision trees in Section 3.1*
- *information on resources as well as methodologies on clearing and restoration contained in Sections 7.2, 8 and 9.*

The strategic restoration plan makes it possible to plan according to capacity and available labour. It summarises methodologies and schedules, priorities and allocation of resources. The plan allows a projection of required follow-ups and long term maintenance, and the estimated time that this will require. Work load is likely to be the main resource constraint, and is therefore used as the main planning factor. WfW uses number of person-days (PDs) to estimate the workload for clearance, i.e. the number of days that one person will need to complete a task (this is further explained as part of labour resources in Section 7.2.2, and more information can be accessed from the WfW website).

As emphasised in previous sections, do not start clearing unless the full cycle of follow-ups and long term maintenance can be also implemented. After the first draft of the plan, the timing of actions can be re-assessed and adjusted according to capacity. For instance, Table 3 indicates that in year one, 135 PDs are required, which may be more than the landowner can afford. If so, one of the actions planned for that year will therefore have to be adjusted, and since follow-ups can't be delayed, the best option would be to delay starting clearing in some polygons, in order of least priority or splitting the clearing over more than one year in these polygons.

Although the strategic plan uses PDs as the main resource factor, further detailed planning will be needed to calculate the other resources (equipment, herbicide, transport etc. – see Section 7.2) required for implementation of the plan. WfW also uses an annual plan of operations (APO), and a template can be downloaded off the WfW website (see Appendix A).

Other resources such as transport and equipment are likely to be proportional to the PDs for any given area and situation, e.g. the more PDs the higher transport costs will be. However, if restoration is planned, seeds and /or plants could also be a significant cost, depending on density and other factors discussed in Sections 7, 8 and 9), and will not necessarily be proportional to PDs.

Should the plan indicate that the scope of the project is not feasible in terms of time scales and resources, the scope and desired targets should be reconsidered and the process reviewed until feasibility is attained.

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Table 3: An example of a management unit clearing and restoration plan

	Species	Area ha)	Density	Age	Zone	Indigenous vegetation remaining (%)	Clearing Priority	Aspect	Gradient (degrees)	Access	Geo-morphology	# of past fire cycles under invasion	# of follow-ups	Target (short-medium term)
1	Blackwattle, bugweed	3	90	s	rip	5	1			present, but poor road	braiding	3	2	2
1														
2	Blackwattle	6	20	y	slope	30	1	W-facing	15	none		2	1	
3	Blackwattle	3	90	y	slope	0	1-2	E-facing	25	present, but poor road		2	1	
4	Poplar	7	40	y	rip	20	1			present, but poor road		1	2	
4	Bramble		30	a/y	rip		1							
5	Blackwattle	4	70	a	slope	30	5	S-facing	40	none				
6	Pine, Hakea	5	50	s	slope	50	2-3	S-facing	5-35	present, but poor road		>3	>5	
7	Black wattle	1.5	20	y	slope	<5	2-4	S-facing	25	present, but poor road				
7														
8	Blackwattle	4	100	a	rip	<5	7			good	braiding, deep incision	>4	>4	
8														
9	Black wattle	2.5	100	a	rip	<5	8			difficult	braiding, deep incision	>4	>4	
9														
10	Blackwattle, gum	8	85	a	rip	20	9			no access			2	
11	Black wattle	3	85	a	rip	15	5			good		2	2	
12	Black wattle	7	20	a	land scape	40 (mainly grasses)	6			none		1		

Comments and notes to explain priorities and actions above

1	High priority (seedlings in a riparian area). Will grow fast and quickly become much larger problem. Foliar spray both black wattle and gum as soon as possible. Since 3 fire cycles experienced, degree of re-establishment of indigenous vegetation not certain. Indigenous vegetation should start re-establishing within a year. If not, consider restoration (see below).
1	Given Target 2 and assuming no indigenous regrowth, an option for restoration would be sowing a mixture of indigenous pioneer species, particularly grasses and herbs at about 10kg/ha. Ideally, in addition to sowing, plant a mixture of species such as *Miscanthus, Pelargonium, Themeda* and *Helicrysum,* although access may be a problem. Plugs will be easier to get to site. Planting density will depend on indigenous regrowth, but in combination with seeding, a density of 100 plants/ha is recommended. Plant in autumn after rain. Monitor. Further inplanting to supplement missing species can be done at a later stage if necessary (see Section 9).
2	Cut-stump & herbicide. Indigenous cover high, so take extreme care not to kill indigenous plants with herbicide. With careful follow-up indigenous vegetation recovery will be good, and no active intervention will be necessary.
3	Lower priority than polygons 1 & 2, since growth is slower. However, tackle before young growth becomes large and there is a big increase in biomass and labour. No indigenous vegetation, and dense, small-diameter stems, which will be difficult to cut-stump and treat with herbicide. Rather cut as low as possible, and foliar spray coppice. At edge of infestation, where there is some indigenous vegetation, cut-stump and poison stems, taking care not to kill indigenous plants. Monitor indigenous regrowth, but since less than 3 fire cycle and one follow-us, indigenous recovery should be good and no active intervention should be necessary.
4	Poplar is an emerging weed on this property, with its first occurrence here. This is thus a high priority, to prevent further spread from this source. It is also young, and killing it before it gets bigger will prevent build-up of biomass, requiring increased labour. Cut-stump and apply herbicide on cut stem. This is a very aggressive resprouter and also coppices from suckers. Monitor every 6 months, foliar spray and coppice. No active intervention should be necessary, as indigenous cover is still high, as long as follow-ups do not damage indigenous vegetation.
4	Also emergent species on property - kill as priority before it spreads. Cut-stump larger shrubs and apply herbicide, foliar spray any younger shrubs.
5	Steep area, difficult to work. Kill trees standing by frilling or ringbarking. Indigenous cover good, so should not need active restoration.
6	A burn recommended method of control. This needs to take place before IAPs set seed. Burn needs to be synchronised with surrounding controlled burn, or a firebreak will be needed to contain it. Use cleared polygons 1, 3, 4 and 7 as barriers, and burn towards south (including polygon 12 after frilling) or create fire break to contain.
7	Cut-stump. Given that area has had more than 3 fire cycles under invasion, has been followed-up more than 5 times, and has low current indigenous vegetation cover, it is likely that this will need active intervention to re-establish vegetetation.

Clearing Priority	Method	person days/ha for initial treatment	PDs for follow-up treatment	PDs for 1st treatment (initial or follow-up)	Schedule of treatments and PDs												
					yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10	yr11	yr12	yr13
1	foliar	5.1	5.1	13.77	13.77	9.945	6.12	2.295	0.765								
								12									
	lopping	22.5	5.1	27	27	1.53											
	lopping/ brushcut	22.5	5.1	60.75		60.75	9.945	6.12	2.295	0.765							
	lopping	22.5	5.1	63	63	14.28	5.355	1.785									
	cut-stump, foliar	15	5.1	31.5	31.5	1.785	1.785										
	frill	19.84	5.1	55.55					55.55	9.18	4.08	1.02					
	burn	?		10			10		5								
	lopping	22.5	5.1	6.75				6.75	0.3825								
	restoration								22.35								
	fell & remove off-site	50	5.1	200							200	15.3	10.2	5.1	102		
	restoration													55.6			
	thin, frill & burn	30	5.1	75								75	9.5625	6.375	3.1875	0.6375	
	restoration													5			
	thin, frill & burn	30	5.1	204									204	24.48	14.28	4.08	2.04
	cut-stump and remove	50	5.1	127.5					127.5	9.18	5.355	1.53	0.765	40.8			
	frill	19.84	5.1	27.78						27.78	1.785	1.785					
				TOTAL	135	89	33	29	214	47	211	95	225	137	18	5	2

7	Being a north-facing, dry and rocky slope, restoration will be more difficult. An annual and /or perennial grass can be sown in spring, or some hardy shrubs like *Athenasia, Stoebe, Pelargonium* and *Elytropappus* can be planted in autumn, with or after a rain event (see Section 9 and Appendix B). Access will make getting plants to site difficult, but if possible, plant at a density of up to 1600 plants/ha. Plant in autumn with or after rain.
8	Fell and remove all wood preferred option, and is possible since access is good. The next best option to remove and use larger biomass (>6cm diameter) and stack remainder above flood line, or stack all wood above flood line. Avoid burning stacks if possible, especially if all biomass is stacked, as fires will be severe. If burning stacks can't be avoided, follow recommendations in Section 8.2 (stacks < 1.5m, burn in cool conditions etc.). Thinning IAPs slowly and removing wood is also option, as this will prevent large areas being exposed at once, and may assisst natural regeneration. Burn standing is also option, after thinning the stand by cutting smaller stems or just cutting approximately 30%, frilling the remainder and burning when dry. This will prevent damage to the soil and soil seed banks. Burning has to take place before flooding causes damage - so time between rainy seasons. Easiest would be when a controlled burn is planned for the surrounding area, as it will be difficult to contain a fire when burning standing. Schedule for follow-up within 6 months after a fire, as wattle seed bank and regrowth will be high. Restoration will likely be needed, since this area has been long and densely invaded, with more than 4 fire cycles under invasion and more than 4 follow-up treatments.
8	The incised river will make it difficult for vegetation to re-establishand will hamper hydrological functioning. To address this, plant sedges on the wet bank zone, especially at the downstream end of the polygon. If this does not work, consider consulting with experts whether structural engineering solutions may have to be considered. Restoration can be done by sowing or planting, since access is good. Planting will yield quicker results. Sow annual grass, or indigenous species, at rate of 10kg/ha, or plant mix of species (*Themeda, Miscanthus, Athenasia, Helichrysum, Pelargonium*) (see Section 9 and Appendix B) in autumn. It will be preferable to have plants ready for restoration once clearing is complete, especially if used for suppression of regrowth (will need high density). Aim for about 1600 plants/ha.
9	Since there is no access, fell & remove not option. Fell, stack and burn before flood event (rainy season), following recommendations for burning in Section 8.2. Consider mosaic clearing, to prevent opening up large sections at one time, and to facilitate natural regeneration. Burn standing as described for polygon 8 is also an option. Restoration is likely to be needed.
9	Restoration will probably be confined to reseeding as descibed in Section 9.4, as access (incised channel) will prohibit planting.
10	Follow same recommendations as for Polygon 9.
11	Although this is a dense, old stand , which places it at lower priority than younger, less dense stands, it is at the top of the catchment, and therefore acts as source of alien seeds being washed downstream. This makes it higher priority. In addition to this, the catchment above this is in good condition, and clearing this portion will improve connectivity above and below this polygon. Lastly, an ecotourism facility is planned for this polygon, which also affects the priority ranking. For best indigenous recovery, fell and remove wood, or use for construction of camp site. Avoid burning. No restoration should be necessary, although some missing species can be added to improve biodiversity - this will be best (quicker) achieved through planting.
12	Although low density, trees are mature and density will increase very little unless there is a fire. They are also in transformed landscape zone, which makes them lower priority - other polygons more urgent. Frill and leave. Monitor after fire or once a year (if no fire) for seedlings, and foliar spray if necessary. Transformed land - grasses & weeds, so target 1 appropriate.

MONITORING, EVALUATION AND FEEDBACK

Any management plan requires ongoing feedback and reviews. In this regard monitoring and evaluation are critical to determine the progress and success (or failure) of restoration interventions, and to enable improvements. Early detection of problems and corrective action may save a lot of time and money.

The following should be considered in planning monitoring and evaluation:

- Who will do the monitoring?
- How often will they be monitoring the place ?
- Which variables will be monitored?
- Where and how monitoring data will be stored?

Also:

- Ensure that data is precise and focussed to inform management and actions
- Ensure that the monitoring will be effective over long time periods (years)
- Ensure that monitoring can be undertaken by different observers
- Recognise that variables may change over time
- Establish baselines (starting conditions) as part of monitoring
- Factor in the effects of natural disturbance cycles of fires and floods

The main indicators that should be included as part of monitoring and evaluation are the following:

- Geomorphology (measure channel width and depth, using permanently marked locations)
- Soil erosion (use steel pins or silt traps to measure erosion or deposition)
- Vegetation cover (establish permanent plots, use fixed-point photography)
- Vegetation structure (permanent plots to measure changes in growth-form density)
- Vegetation composition (permanent plots to measure changes in species composition)

The size of plots depends on the vegetation structure and homogeneity of the site. Smaller plots (2 x 2m) are easier and quicker to sample and monitor than larger plots (e.g. 5 x 5m or 5 x 10m). However, where shrubs and trees are present, smaller plots may not capture the vegetation structure adequately and larger plots may be required.

It is also advisable to monitor progress against a reference site (See Section 6).

PART II

6 REFERENCE SITES

A reference site is an uninvaded riparian system in a natural (pristine) condition. These are important as reference points for establishing the level of ecosystem degradation. The success of restoration interventions and target conditions also needs to be measured against a reference site.

Since most riparian systems have been affected by disturbance in some way or another, reference conditions may be hard to find, especially in the lowlands. In addition, no two rivers are the same, and specialist advice may be needed to choose a reference site. The geomorphology of a reference site must also be intact.

There are many different fynbos communities within the Fynbos biome; ensure that you use the same community for a reference site as the target area. Appendix B contains lists of recommended species for the eastern and western sections of the Fynbos Biome, and these can also be used as indicative of reference conditions.

The following characteristics should be similar to the project area when choosing a reference site:

- Catchment characteristics (catchment length and drainage area)
- Geology and soil type
- Topography (slope and aspect)

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Examples of reference sites. These sites have not been invaded or disturbed

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7 FACTORS AND PREDICTORS FOR MANAGEMENT DECISIONS

There are many ecological, social and economic factors that will influence the decisions taken regarding clearing and realistic restoration targets. Targets should consider the historical conditions, the current levels of ecosystem degradation of both project site and catchment, other environmental variables and the proposed future land use. Targets should also be measured against a reference site (See Section 6)

Returning a severely degraded river to a pristine state is virtually impossible, or may be very costly and take long. Before starting restoration, it is necessary to recognise these limitations, and to establish some feasible and attainable targets within these constraints. The factors below will help the landowner or project manager to decide which goal will be attainable and what the constraints and /or opportunities will be to achieve this goal.

7.1 BIO-PHYSICAL FACTORS

7.1.1 Invasion density

Invaded areas with IAP cover of less than 75% and no other major disturbance factors, e.g. roads or dams, will recover without additional intervention if clearing is implemented carefully (avoiding the impacts listed in Section 8) so as not to cause further degradation.

However, areas with IAP cover of above 75% can be more problematic and do not always self-recover to a functional system in the short term (5-10 years), depending on number of fire cycles, length of invasion and other factors (see remainder of Section 7). These areas may need additional intervention in the form of restoration.

7.1.2 Invasive species

The characteristics of some species make it harder to eliminate them or for the invaded areas to self-restore after clearing. Generally, areas that have been invaded by wattles (*Acacia* species) and gums *(Eucalyptus)* do not self-recover as easily as areas that have been invaded by pines and *Hakea*. This also depends on the density, length of invasion and fire history (see Sections 7.1.1, 7.1.3 and 7.1.4).

7.1.3 Age of invasion

The longer the area has been invaded, the more difficult it will be to restore. Generally, areas that have been densely invaded for longer than 30 years, will have lost indigenous soil seed banks, and vegetation will re-establish with difficulty.

7.1.4 Fire

Fire can form an important part of the IAP management strategy, and is a major driver of regeneration in fynbos. Therefore, fire should be integrated into the restoration plan. However, the unnaturally large volumes of biomass that are generated during the invasion process can cause intense fires, with temperatures of over 900°C at the soil surface, which result in severe damage to natural vegetation and effectively sterilises the soil and the soil seed bank. For this reason, fires may not be appropriate in some situations or not until the large fuel loads have been removed. Recommendations for minimising the damage through the use of fire are presented in Section 8.2.1.

Even if fire is not planned as part of the management strategy, an accidental fire can cause severe damage and should be avoided through proper planning.

Generally, areas which have had more than three fire cycles under invasion are not likely to recover without intervention in the form of active restoration, especially if felled IAPs were burnt.

Too-frequent fires can also arrest natural recovery, as many indigenous species need to reach maturity and set seed between fire intervals. A short interval between fires will not allow these species to set seed, and the non-sprouting species may be eliminated unless an adjacent source of seeds is present, or the species is actively re-introduced. Burning can also change the vegetation composition, promoting quick-colonising, wind-dispersed species such as grasses, sedges and herbs.

Assessing whether a fire has caused enough damage to require active restoration is not always easy after the event. Although a survey after a year following fire should indicate whether active restoration is required (e.g. if there has been little regeneration of indigenous species), waiting poses the risk of erosion and loss of topsoil if the area remains exposed for this long.

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High volumes of biomass (left) result in high-intensity fires, which damages the soil and soil seed banks (right)

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High intensity fires can result in temperatures in excess of 900°C on the soil surface.

7.1.5 Additional disturbance and condition of the broader catchment

Disturbance factors such as ploughing or roads within the riparian buffer, or bridges and dams upstream, can also cause degradation and hinder recovery. Upstream or adjacent sources of alien seed will result in continuous re-infestations, which will require on-going management and hamper recovery.

If a catchment is highly disturbed, transformed or fragmented, it will probably not be possible, or will be extremely expensive, to restore to a reference or Target 3 condition.

Above is an example of the dilemma of managing the broader catchment. In this case the landowner below the boundary is clearing black wattle, and the upstream landowner is not. The stream will therefore continue to be re-infested by upstream sources of propagules, e.g. *Acacia* seeds, and will also be affected by altered hydrological flow and sedimentation processes, which will hinder recovery

7.1.6 River order

Generally, recovery of natural riparian vegetation and functioning is achievable in mountain stream catchments and foothills. Exceptions are the following:

- The catchment has been transformed and degraded, e.g. by dams or roads
- Indigenous propagules are lacking upstream and in the surrounding area
- Closed *Acacia* stands have received a fell-and-burn treatment

Most lowland floodplain rivers in the Fynbos Biome have a long history of degradation and invasion and will be difficult to restore to pre-invasion conditions. A more realistic target will be to restore ecosystem functions, e.g. bank stabilisation and water filtration.

River order will also influence the ease of establishment of plants during active restoration. It will be more difficult to actively establish vegetation within the flood zones in lower-order rivers that experience frequent floods, as the plants may be dislodged by flood events before they take root. Supplementing missing species will be easier if there is some vegetation remaining to provide protection. Restoration actions within frequently flooded areas should aim to establish plants in the drier season to avoid flood damage, while during the wetter season it will be preferable to establish plants on the dry bank and slope areas.

7.1.7 Lateral zones

After removal of IAPs, in-channel and wet bank vegetation often re-establishes naturally and quicker than vegetation on the dry banks and adjacent slopes, unless subject to high-energy flooding (see Section 7.1.6). This also depends on the availability of sources of propagules upstream (see Section 7.1.12).

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These pictures clearly indicate the quicker recovery of vegetation in-channel and along the wet bank zone as opposed to the dry bank and upslope drier zones

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7.1.8 River geomorphology

There is a tendency for channel widening and incision in the presence of wattles. These channels can act as canals, draining water and soil moisture from the adjacent banks and drying these out, which will reduce natural recovery. In addition to this, the "canal" channels water during high rainfall events, resulting in high velocity flows. This is exacerbated by a lack of vegetation in invaded channels, and can result in further damage to the river channel (incision and widening). Due to incision, the natural braiding (many channels) of river systems is often lost, negatively impacting on river function and recovery. Conversely, depending on the topography and hydrology, alien stands in foothills can accumulate sediments which can alter river geomorphology. This will inhibit post-clearance recovery if the indigenous seed bank is buried too deep for seeds to germinate.

It is not always easy to determine whether the river channel has been incised or sediment has been deposited. The best way to do this is to compare with adjacent, uninvaded and unimpacted reference sites. Failing that, a specialist may be needed to do this assessment.

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Examples of deeply incised channels

7.1.9 Indigenous species density

The density and composition of the remaining indigenous vegetation will indicate the degree of degradation or transformation. If some indigenous vegetation is left prior to clearing, soil seed banks and propagules are likely to still be present. If not, seed banks may still be present if there has been no other disturbance such as ploughing or long term dense invasion with more than three fire cycles.

7.1.10 Soil and soil seed banks

Vegetation is completely dependent on soil, and this is one of the most important factors that will determine recovery, especially the upper in 5-10cm, where seeds are stored. Topsoil is often lost during the invasion and clearing process, especially if felled biomass has been burnt, making it much harder for vegetation to re-establish.

7.1.11 Size of invaded area

The size of an invaded portion is important; areas that are too large (more than 200m across) will not easily receive propagules from adjacent areas and recovery will be impaired.

7.1.12 Source of propagules

In addition to the size of the invaded area, which determines proximity to indigenous propagules, the surrounding veld condition will also influence regeneration from natural sources. If the surrounding vegetation is mostly transformed, no propagules will be available.

In riparian corridors, most propagules enter the system from upstream sources. If upstream sources are not available due to invasion or degradation, recovery will be limited.

7.1.13 Topographical factors

Steeper slopes are more prone to erosion, especially after a fire. They are also more difficult to work on, and this has to be taken into account when planning clearing and restoration. Generally, north-facing slopes are drier and more rocky than south-facing slopes, and natural vegetation is sparser. It is therefore more difficult to establish vegetation on these drier slopes.

Narrow valleys are more protected from fire than open valleys, which will assist with fire management and preventing fire damage, thus promoting recovery. However, access to narrow valleys is often a problem (see Section 7.1.14), which can hinder restoration activities like the removal of biomass.

7.1.14 Access

Access, both to site and on-site, can present a serious constraint to clearing and restoration. Increased distance from supply and service centres can make restoration activities much more complicated and costly, and can affect productivity of teams. Bad quality roads aggravate this situation.

Transporting heavy loads (e.g. plants) can damage roads, especially if vehicles are not suitably equipped to do so (e.g. non-4x4-wheel vehicles on gravel roads). Poor roads can also result in damage to plants during transport and may make it difficult to get plants to site.

On-site access will affect the ease and time required for tasks (see Section 7.2.2). It will also determine the feasibility of some activities, e.g. planting, removing felled biomass from the site etc.

7.2 RESOURCES

Much effort can be wasted if resources are not available at critical stages. It is therefore very important to ensure that sufficient human and financial resources are available before embarking on clearance and /or active restoration.

Costs will be very site-specific, but some general factors to consider when developing costs are listed in Table 6 below. It may be necessary to reconsider the proposed target, actions and restoration plan once an assessment of required resources has been made. As part of planning, consider issues like the servicing of equipment and whether fuel is readily available. Can herbicide be obtained easily and reliably? A reliable herbicide supply is essential, so as not to delay follow-ups. The availability of resources will be influenced by the factors such as access.

7.2.1 Equipment and herbicide

The correct equipment is needed to work efficiently. Some of the basic equipment that may be needed for alien clearing (see Section 8.1) includes the following:

- Saws, axes, knives
- Loppers (ratchet loppers)
- Tree-poppers
- Herbicide knapsack sprayers and spraycans
- Herbicide, dyes, wetting agents (use registered herbicides as recommended for specific alien species, see below)
- Jugs, funnels, containers for herbicide
- Protective clothing (overalls, gloves, gumboots, rainsuits etc.)
- First-aid kits and refills
- Power tools like chainsaws and brushcutters may also be required

Consider issues such as the following:

Is the servicing of the equipment and fuel readily available? Can herbicide be obtained easily and reliably? A reliable herbicide supply is essential, as delayed follow-ups due to lack of herbicide can waste all previous efforts and result in a much worse situation.

Herbicide volumes can be estimated using the comprehensive tables developed by WfW (see Appendix A for contact details), which recommend certified herbicides and volume per hectare. Make sure to use the herbicide with the correct active ingredient, according to instructions on label. Some herbicides require a wetter, and some herbicides need diesel as a carrier. Herbicides that require diesel must be avoided if possible, and must not be used in the riparian zone or for foliar spray. An extract of one of the WfW tables is presented below (for black wattle). More information on the use of herbicides is provided in Section 8.3.

Table 5: Herbicides recommended for the management of invasive alien plants (extract)
(Compiled by: T Bold, WfW National Offices)

TREATMENT DETAIL				APPLICATION DETAIL				PLANNING DETAIL		
Species	Size class	Treat-ment	Herbicide	Dosage	Herbicide (litres)	Mix Litres	% Mix.	Density	Estimated Product Litres/Ha (or kg)	if Mix volume Litre/Ha
Wattle, Black (Acacia mearnsii)	Seedlings	Hand pull	None							
	Seedlings and up to 1 m tall	Foliar spray	triclopyr (butoxy ethyl ester) 240 g/L EC Ranger 240 EC adjuvant incl. (L6179)	50ml/10 Litres water and 0.1% Dye	0.05	10	0.5	Closed / Dense	1.50	300
			triclopyr (butoxy ethyl ester) 480 g/L EC Garlon 4 EC (L3249) & 480 EC (L4916), Triclon EC (L6661), Viroaxe EC (L6663)	25ml/10 Litres water and 0.5% Wetter & Dye	0.025	10	0.25	Closed / Dense	0.75	300
	Up to 2m tall & Coppice	Spot spray	triclopyr (butoxy ethyl ester) 240 g/L EC Ranger 240 EC adjuvant incl. (L6179)	150ml/10 Litres water and 0.1% Dye	0.15	10	1.5	Closed / Dense	4.50	300
			triclopyr (butoxyethyl ester) 480 g/L EC Garlon 4 EC (L3249) & 480 EC (L4916), Triclon EC (L6661), Viroaxe EC (L6663)	75ml/10 Litres water and 0.1% Wetter & Dye	0.075	10	0.75	Closed / Dense	2.25	300
	Mature	Bark strip	None	Strip into the ground						
		Cut stump	triclopyr (-amine salt) 360 g/L SL Lumberjack 360 SL (L7295), Timbrel 360 SL (L4917)	300ml/10 Litres Water and 0.5% Wetter & Dye	0.3	10	3	Closed / Dense	6.00	200

If active restoration is planned, how will plant material be obtained? Is it envisaged that a nursery will be constructed and operated? (See Section 10.1) Equipment that may be needed for propagation includes (see also Sections 9 and 10):

- Bags/trays
- Seed
- Soil
- Water
- Spades, rakes, hoes
- Bags for carrying plants to site

What vehicles are available for transporting labour, equipment and /or plants? Consider ease of servicing and fuelling the vehicles.

7.2.2 Labour

What sources of labour are available, and what are the types and levels of skills available? Check that action plans for both clearance and restoration are compatible with levels of skills. Where does the workforce live? Does accommodation need to be provided? If the planned labour force does not live on site, how far do they need to travel to site and what transport is available?

WfW uses the number of person-days to estimate the workload for clearance. Workload is measured as the number of days that one person will need to complete a task. For example, it will take one person 120 days (i.e. 120 PDs) to clear four hectares of dense wattle. A team of two people will clear this in 60 days, three people in 40 days and so on). An experienced project manager should be able to estimate the number of PDs needed, but the standards that WfW have developed (see following tables) for clearance can also be used for this purpose. An example of person day standards is given below and more information can be sourced from WfW (see Appendix A). Little work has been done on developing estimated PDs for active restoration, and the estimates used here are based on a pilot study undertaken in the Kouga catchment. There are many variables that can affect the PDs estimates, such as terrain, underfoot conditions, team structure, soil depth etc., and the PDs may have to be adjusted for specific conditions. Riparian systems are often very challenging, with braided channels, steep sides and poor access making working conditions difficult. Removing the felled IAPs from the riverbank is time-consuming, and often takes longer than anticipated. This must be taken into account when estimating the workload and time needed.

Table 4: Work load estimates for clearing in number of person-days per hectare for closed (100%) infestation (developed by H. Neethling from original norms tables) (see WfWwebsite, Appendix A)

(s = seedling, y = young, a = adult, PDs = person days)

Species Class	Size	Method	Dry land PDs/ha	Riparian Zone PDs/ha
Seedlings	s	Foliar	5.10	5.10
Seedlings	s	Hand pull	6.38	6.38
Non-sprouting trees	y	Lopping / Pruning	10.37	15.56
Non-sprouting trees	a	Frilling	13.69	13.69
Non-sprouting trees	a	Felling	17.00	25.50
Sprouting trees	y	Lopping / Pruning	15.00	22.50
Sprouting trees	a	Frilling	19.84	19.84
Sprouting trees	a	Cut-stump	24.65	36.98
Sprouting creeper	y	Foliar	6.38	6.38
Sprouting creeper	a	Cut & spray	10.37	15.56
Herbaceous spp.	y	Foliar	6.38	6.38
Herbaceous spp.	a	Cut & spray	10.37	15.56
Cactus spp.	y	Foliar / Direct Injection	6.38	6.38
Cactus spp.	a	Cut & Spray / Direct Injection	10.37	15.56
Grass spp.	y	Foliar	5.10	5.10
Grass spp.	a	Cut & Spray	10.37	10.37

Table 5
Work load estimates for reseeding (Based on McConnachie 2012)

Reseeding	Number of Person days	Planting
Sowing seed (full hectare)	20.48	Plugs
Sowing seed (half of hectare)	10.24	Cover plant
Sowing seed (quarter of hectare)	5.12	Shrub

Table 6
Work load estimates for planting (Based on McConnachie 2012)

PLUGS (PDs required)			SHRUBS (PDs required)	
Density	Steep, rocky slopes	flat, soft soil	Steep, rocky slopes	flat, soft soil
100/ha	0.75	0.34	1.01	0.82
200/ha	1.49	0.68	2.02	1.63
400/ha	2.98	1.36	4.04	3.26
1600/ha	11.93	5.43	16.15	13.06
2200/ha	16.40	7.47	22.21	17.95
10 000/ha	37.27	16.98	50.48	40.80
5 000/ha	74.54	33.96	100.96	81.60

7.2.3 Management and Expertise

Assess the levels of expertise and knowledge available, as well as capacity in terms of time. The expertise and management that is needed will also depend on what is envisaged for the restoration plan, e.g. whether on-site propagation will take place.

Required management will depend on the level of skill of the labour force – the less skilled the labour force, the more management may be required, especially at the beginning of the process.

Table 7: The main factors to consider when estimating clearing costs

IAP	Terrain	Labour
Species	Slope	Type – skilled/unskilled
Density	Access	Number of people
Area	Transport	Task rate (person-days/ha)
Height	Equipment	Unit cost per person
Growth stage	Obstructive vegetation	Availability
Location		Training
Technique		Camping allowance
Equipment		Accommodation
Herbicide		

7.2.3.1 Collective management

Investigate the possibility of getting more landowners or stakeholders involved; pooling resources can make clearing and restoration more cost-effective. A conservancy may be a good solution to achieve this, and may also make it easier to access funds or assistance. Also investigate outside sources of funding or assistance (see Appendix A), such as WfW, LandCare, the local Catchment Management Agency or municipality.

7.2.4 Financial resources

In addition to the labour required for planting or reseeding, which has been dealt with in Section 7.2.2, active restoration will also require seeds or plant material. The costs for this will vary widely, and is very site-specific, as discussed in Section 7.2.2.

The main factors affecting restoration costs are the following:

- Method of re-introduction (e.g. reseeding or planting) and the costs of either seed or plants (see Section 9 for information on methods)
- Source of restoration material (e.g. propagated on site vs. bought from outside sources)
- Density of planting
- Choice of species – some grow faster and establish better; this will reduce costs. The density of planting can be reduced by using species that establish quickly to provide a good ground cover. Some plants may be scarcer and cost more. See Appendix B for a list of recommended species
- Size of plants – bigger plants (e.g. in a bag as opposed to plug tray) are more expensive to grow, transport and plant, but attain a larger cover faster
- Access to site and means of transport
- Cost of water and soil
- Efficiency of transport and labour

The costs per method increase in the following order:

- Mulch with indigenous seed-bearing brush (approximately R3 500/ha)
- Sowing (approximately R5 000/ha) (depends on seed source and species, and application rate) success may vary (see Section 9)
- Planting: most expensive, but wide range of costs depending on factors mentioned above (see Table 7 and information below)

To calculate the costs of active restoration by means of planting, determine the following:

- Cost per stem per species (either to buy or produce)
- Desired density
- Number of plants
- Transport costs (from source to site)
- Labour costs (see Section 7.2.2 for PDs)

A costing example for active restoration in the form of planting is given on the next page (see Table 8). This uses the PD norms from Section 7.2.2 and WfW payment rates to convert to costs. Two scenarios are presented, the first column indicating low costs under optimal conditions and high efficiency, e.g. using small plants in plug trays instead of larger plants in bags (see also Section 9.5), optimising transport and working efficiently. The second column shows higher costs, which can result from working under difficult conditions (challenging access and underfoot conditions), using larger plants, working inefficiently, etc.

Depending on the level of degradation and the desired target, decide on the density that is required. In very degraded areas where all indigenous vegetation has been lost, the optimal density is between 2 200 – 5 000 plants/ha. This will be costly, although costs will be less in easy terrain and can be brought down by using plugs only.

Decisions on density will also be determined by the size that the adult plant will attain, and how fast it grows to this size (see Section 9.5 on trade-offs involved in deciding on the size of plant used). At a density of 2 200 plants/ha, species that each grow to 1.5m x 1.5m will provide a cover of 50% in a bare area. Plants that grow to a 1m x 1m size will need a density of 5 000 plants/ha to provide the same cover. Consider species, targets and function carefully. Some recommended species are included in Appendix B.

A target in a less denuded area may only require the addition of some missing species and /or guilds, e.g. shrubs; in these cases densities and costs can be greatly reduced (e.g. a density of 100 - 200 plants/ha). Bear in mind that established plants will act as seed sources for the restored area.

It is advisable to first undertake small-scale trials to see which methods and species perform best, and accurately determine site-specific costs under various conditions before rolling out on a larger scale. Survival rates are site and species-specific, and will also vary according to environmental conditions at the time of implementation. A wide range of 30% - 80% survival rate has been reported.

Table 8: Two scenarios (high and low costs) for active restoration (planting). (Based on data from McConnachie, 2012) Density is presented as number of plants per 10m x 10m, as this is easy to visualise, but the next column converts this to number of plants/ha

Density	Number of plants/ha	Cost/ha	Cost/ha
1 plant/100m²	100	R 175.00	R 902.00
2 plants/100m²	200	R 350.00	R 1 804.00
4 plants/100m²	400	R 700.00	R 3 608.00
16 plants/100m²	1 600	R 2 800.00	R 14 432.00
22 plants/100m²	2 200	R 3 850.00	R 19 844.00
50 plants/100m²	5 000	R 8 750.00	R 45 100.00
100 plants/100m²	10 000	R 17 500.00	R 90 200.00

Activities	Cost/stem (low)	Cost/stem (high)
Propagation	R 0.65	R 4.22
Transport	R 0.20	R 1.30
Planting	R 0.90	R 3.50
Total cost/stem	R 1.75	R 9.02

8 CLEARING AND PASSIVE RESTORATION

IAP clearance is an integral and crucial first part of restoration, and the way in which clearing takes place can greatly influence recovery and avoid the need for costly restoration interventions. Clear to maximise restoration! Although more careful clearing can be slower and more costly initially, it is definitely much cheaper and efficient in the long term than poor-quality clearing involving multiple follow-ups which are costly and damaging.

The most important principles for clearing are:

- Prioritise areas and actions
- Choose a manageable area
- Clear properly
- Prevent damage to indigenous vegetation and ecosystems

8.1 CLEARING METHODS

Clearing and IAP management generally consist of the following phases:

- Initial control
- Follow-up of IAP regrowth
- Long-term maintenance

WfW has been instrumental in developing approaches and methods for clearing for many years. Try to integrate the following approaches where they are appropriate:

- Mechanical – e.g. felling, using equipment such as saws and loppers
- Chemical – using herbicides
- Biocontrol – use of biological control agents (information is available on WfW and the Agricultural Research Council websites. See Appendix A for contact details)
- Restoration and revegetation, whether passive or active, suppresses regrowth, and can therefore also be considered part of integrated IAP management.

The main initial control methods are the following:

- Fell only: IAPs are cut (and herbicide immediately applied on the stumps of reprouters)
- Fell and burn: IAPs are cut (herbicide applied to stumps of resprouters), biomass is burnt when dry enough or at a later stage
- Fell and remove: IAPs are felled (herbicide immediately applied to resprouter stumps), biomass is removed (or at least any wood with a diameter larger than 5cm)
- Kill standing: trees are killed standing through frilling, ringbarking, stem injections or painting stems with herbicide
- Combinations of the above, e.g. felling smaller trees and killing larger trees standing

IAPs can regenerate very quickly and in vast numbers from soil-stored seed banks, or through resprouting from coppice or root suckers. Follow-up of regrowth after initial clearing is thus of utmost importance as failure to follow-up in time can make invasion much worse than before initial clearing.

The main follow-up methods consist of the following:

- Hand-pulling seedlings
- Foliar application of herbicide on seedlings, generally by spraying, but sometimes by wiping herbicide on foliage
- Pulling out young trees with a tree-popper
- Using fire to kill young IAPs

Clearing using a chainsaw

Very comprehensive information on the above clearing methods can be sourced from CapeNature, the WfW website and other resources (see Appendix A). The most important impacts of these methods (including when they are not applied correctly) and ways to reduce these impacts and optimise recovery will be discussed below.

The most damaging impacts of control are caused by the following:

- Build-up of biomass, combined with fire and flooding
- Herbicide
- Poor-quality clearing and /or follow-up

Repeated invasion cycles and /or lack of timely follow-up lead to loss of indigenous vegetation,as well as the build-up of biomass. This results in the repeated fire and clearing impacts listed above. These all interact to compound degradation and reduce natural restoration potential.

8.2 BIOMASS

As discussed in Section 7.1.4, the high volumes of biomass resulting from the clearing of IAPs can result in severe and damaging fires. In addition to this, the biomass (slash) left below the flood-line can cause damage (see Section 8.2.1). This section presents some recommendations on how to deal with biomass and minimise these impacts.

8.2.1 Fire and floods

Fire can be a very useful tool, and can form an integral part of the IAP management for the following reasons:

Fire triggers:

- The mass germination of *Acacia* seeds, most of which can then be eliminated during a follow-up
- Regeneration of many fynbos species

Fire removes:

- Invasive seedlings and seeds and therefore assists control. This is especially useful for the control of *Hakea* and pines, as they don't resprout
- Felled trees and biomass, which pose a risk if left in the flood-line, as the debris can cause logjams or scour the rivers and cause damage to downstream infrastructure. These should be removed to above the flood-line, but in many invaded tributaries, especially in upper water catchment areas, it is impossible to remove the felled biomass as they are narrow, steep-sided or inaccessible. Often, the only solution is to burn this biomass.
- The high volumes of biomass generated through the felling of invasive vegetation, which make follow-up operations easier
- Slash which inhibits the recovery of indigenous vegetation

However, if used incorrectly, the negative impacts of fire (Section 7.1.4) can outweigh the positive impacts listed above, and this section presents some recommendations on how to minimise these impacts.

The preferred solution is to remove all biomass from the site. If this is not possible, remove larger-diameter biomass (woody stems >5cm diameter) from the site to reduce fire impacts, and stack remaining fine material in heaps of no higher than 1.5m and no wider than 3m. These stacks should be at least 4m apart, so that they can be burned in a controlled manner if required. Where possible, locate stacks on rocky areas or sandy soil where damage will be minimal. The burning of these stacks should take place under cool conditions when the soil is moist.

Harvesting and using the biomass can also be used to offset the costs of clearing, but ensure that harvesting takes place in a controlled manner. Contractors who harvest for profit often don't apply herbicide on the stumps, and leave behind resprouting stumps and a mess of slash and debris, which will hinder follow-ups and recovery. Ensure that remaining slash is stacked properly (see above) and prevent the extraction process from causing damage to the indigenous vegetation and riverbanks, for example by limiting extraction points.

Many viable secondary industries have been established and it is worth investigating these options. Obviously, ease of access to markets will be an important consideration. Getting adjacent landowners involved to upscale efforts (e.g. share chipper and trucks) will also make removal of biomass and /or secondary industries more viable. Also liaise with organisations such as WfW and LandCare, as they could assist (see Appendix A).

Secondary uses and /or industries like the following options can be considered, depending on species:

- Building
- Fuel wood
- Charcoal
- Chipping for energy production or industries such as composting or chicken or pig farms

However, many riparian areas are very remote and access is difficult, and removal of biomass is not an option. In these cases, other options for dealing with biomass have to be considered.

Where possible, consider kill-standing methods (ringbarking or frilling) to decrease the biomass on the ground and minimise fire damage. The standing dead trees can be left on site or can be burned (during a controlled or uncontrolled fire) at a later stage.

To prevent flood damage from felled IAPs, biomass has to be removed to above the flood zone. As a general rule, biomass has to be moved 30m away from the riverbank, but it is preferable to determine where the highest flood-line is through local knowledge and /or previous flood debris lines, and to move stacks above that line. If the terrain makes moving the biomass unfeasible, burning the biomass before the next rainy season should be considered, applying the recommendations above.

Where burning is planned as part of the control operations, delay this as long as possible after the initial clearing treatment, as biomass will decay over time, which will reduce fire intensity and impact.

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Biomass left in the flood zone can result in large debris dams, cause scouring and downstream damage during flood events (left). Also, if this biomass burns, it will also cause severe damage to the indigenous vegetation. The picture on the right shows a chipper, as one of the solutions to decreasing biomass

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This tributary was scoured from a 2m-wide channel to a channel 10m across and 2m deep by IAP biomass and debris during a flood event

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These four pictures show the difference in recovery between a burn-standing treatment, where the biomass was not concentrated on the ground, and where the cleared areas received a fell-and-burn treatment.

In the last picture (bottom), indigenous pioneer species have re-established where the IAPs were burnt standing (solid arrow), as opposed to the area where only wattle seedlings have re-established in the area which a received fell-and-burn treatment (dashed arrow)

8.2.2 Thinning

This method can be more appropriate in old dense stands, especially in areas where the target vegetation is riparian scrub and /or forest. Slowly thinning the IAPs opens up gaps and allows indigenous vegetation to re-establish, while still being afforded some protection, as many plants, especially scrub and trees, have difficulty establishing in exposed conditions. Re-establishment of indigenous vegetation can either be passive, i.e. just allowing indigenous vegetation to establish, or active, by planting in gaps.

This method can also be used in combination with kill- and /or burn-standing, where smaller trees (or a certain percentage of trees, e.g. 50%) are felled, creating a thin layer of dry biomass under the thinned canopy, which will not cause damage to the soil if burnt. The remainder of the trees can be killed standing and left to burn when a natural or controlled burn.

Another variation is to clear strips of dense stands, alternating with uncleared invaded strips, until some indigenous vegetation has re-established on the cleared strips, before clearing the remainder. This can prevent exposing large areas which may be more susceptible to soil damage and erosion.

The disadvantage of thinning is that standing aliens will continue to rain seed onto the cleared strips, but if there is already a large soil seed bank, the addition of another year or two of seed is negligible.

8.3 HERBICIDE

It is difficult to avoid impacts when using herbicide, however, there are a number of important principles which will minimise damage:

- Minimise use of herbicide as far as possible
- Try and avoid repeated herbicide applications
- Use as specified (active ingredient, carrier and wetting agents, dilutions, dosage, storage, take environmental conditions like wind or rain into account)
- Always use dye
- When applied during cut-stump treatment, ensure that application is immediate – within one minute of cutting[1]
- Use selective herbicides as recommended for each species
- Try to avoid persistent and mobile herbicides
- Try and avoid foliar applications as much as possible
- Avoid spraying or spilling on the ground (or in streams!)
- Do not foliar spray trees larger than waist height – these should be treated using a cut-stump method.

In an area where there is a relatively high percentage of indigenous cover, the use of foliar spray to kill seedlings is particularly damaging, as it is difficult to avoid indigenous plants. Rather use spot spraying or use manual methods such as hand-pulling or loppers. Working more slowly is worth it to avoid the loss of indigenous vegetation, and manual removal should be used in highly sensitive areas. Larger saplings can also be manually removed by means of a tree popper.

[1] There is some contention about the maximum delay between cutting and applying herbicide. Herbicide instructions vary between brands, and although most recommend applying herbicide immediately, some allow for application for as long as 3 hours after cutting. Recent research, however, indicates that the plant cells start closing up immediately after cutting, preventing the entry of herbicide, and recommends that herbicide is applied immediately, between ten seconds and three minutes after cutting).

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The above are examples of indigenous plants that have been killed through the negligent application of herbicide

Another difficult situation develops when a large alien soil seed bank has built up over time, and the area is then burned. This triggers large-scale germination, and if not treated in time, can result in very high densities of young IAPs stems (sometimes up to 400 000 stems/ha – this equals 40 stems/m^2). The best way to treat these is by means of foliar application, before indigenous plants have had time to re-establish and be killed by the herbicide. The seedlings can also be left during the dry season to die off and decrease in density, but the stand has to be monitored to ensure that they do not get too large to foliar spray. Where possible, protect or avoid any indigenous plants. This can be done by hand pulling seedlings in the area around the indigenous plants or by placing protective cones over the indigenous plants during spraying operations.

However, when seedlings are not treated in time, and grow too large (>1m) for a foliar application, they have to be treated with a cut-stump method. Because the stems are so small and dense, it is very difficult to apply the herbicide to all stems, and coppice rate is often very high. In these cases, stems can be cut as low as possible in the dry season, and no herbicide applied. Any coppice can be treated with a foliar herbicide application. Note that this is only recommended in very dense stands with no indigenous vegetation, and that the stems must be less than 2-3cm in diameter. In less dense stands this must be avoided, as many indigenous species will be killed by the foliar spray. Avoid getting herbicide on the ground and spraying dense stems with a foliar application method. Rather use the method described above under these circumstances.

Some *Acacia* and gum species are vigorous resprouters, and when cut, resprout lower down in a multi-stemmed fashion, creating many stems which are much harder to treat. It is therefore imperative to ensure that the cut-stump is implemented properly to prevent having to redo this (with double the effort, costs and herbicide impacts), other than in a few select circumstances. It is generally more cost-effective in the long-term to spend more resources on a thorough initial clearance than to have to return several times to re-do the job with more environmental impacts which may necessitate active restoration.

Some causes of resprouting are the following:

- Bark and stem are split and herbicide is not absorbed properly – this often happens when the wrong cutting implement is used or is too blunt
- Stem is cut at a sharp angle and herbicide runs off – this often happens when slashers are used. In addition, these sharp stems, especially on steep slopes, are a major safety hazard. Rather use loppers
- Herbicide is not applied immediately - this is a very common and critical problem, and is often related to team structure, where the herbicide applicator cannot keep up with the person cutting

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A stand with high-density, small-diameter stems (top). These are particularly difficult to treat, and in the picture below, a foliar spray has been used to spray the stems to speed up work. This contaminates the soil and is very wasteful

8.4 POOR-QUALITY CLEARING

Poor-quality clearing can result from the problems described in Sections 8.2 and 8.3, or can simply be due to negligence, rushing or lack of quality control. A common problem is that teams are under time pressure and that they rush their tasks. This often results in damage, as is illustrated in pictures below.

Another common problem relates to poor implementation, as is illustrated in the picture on the right below. Here larger trees were felled before smaller stems, and a lot of time and effort was wasted afterwards cross-cutting through large slash to cut smaller stems, many of which will have been missed.

8.5 SCHEDULING FOLLOW-UPS

Timely follow-ups are of utmost importance, as failure to follow-up in time wastes resources and may make the situation worse than before starting the interval between initial clearing and subsequent follow-up operations is species-dependant. For example, a two to three year gap can be left between initial clearing and the first follow-up with scattered pine, but black wattle and eucalypts must be followed up in the following year. In some cases, a follow-up may be required as soon as 6-8 months depending on the species, location and intervening weather conditions: for example, seedlings in moister areas like riverbanks.

Seasons can also be used to an advantage; for example, many young seedlings will die off during the dry season, reducing follow-up efforts and costs.

The picture on the left shows a high coppice rate (over 70%) in an area with a high density of small-diameter stems, resulting from poor practice. One of the reasons for this is that blunt instruments (pangas) are used to cut the stems, causing split and angled stems. The picture on the right shows a coppiced, multi-stemmed wattle.


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The picture on top is an example of indigenous vegetation that can be left if cleared carefully – the indigenous plants in the area surrounding the block were cut alongside the wattle stems. The picture below shows team members trying to get to smaller stems under large slash piles

9 ACTIVE RESTORATION

This section deals with the more detailed methodologies to actively restore abiotic variables, i.e. restoration of the physical environment, and restoration of biotic variables, e.g. vegetation. It also discusses the factors to consider when planning these restoration actions. Before embarking on a restoration project, refer to overarching restoration principles outlined in Section 1.

9.1 RESTORATION OF ABIOTIC VARIABLES

9.1.1 Incised river channels, steep banks and headcuts

Changes in river geomorphology can have a large impact on recovery. The best way to address this is to try and work with the natural processes operating in the system, and to recognise that some changes already in place may be irreversible. This can avoid or minimise costly interventions, for example hard engineering structures such as weirs or gabions. Rivers are complex and dynamic systems, and these structures can have unforeseen negative impacts as well as being costly, and thus need to be used judiciously. Always consult the Department of Environmental Affairs before planning and construction in a river.

After clearing, vegetation re-establishes most easily along channel margins due to the availability of moisture. However, where steep, bare river banks exist, as is the case with a deeply-incised river, recovery may be slow as plants cannot easily establish on these banks. These banks are generally unstable after clearing, but given time should flatten and stabilise as vegetation regrowth takes place. Regrowth of indigenous vegetation (especially reeds or sedges) will encourage sediment deposition and the development of a narrower channel within the previously widened channel.

Where sediments have deposited under an alien stand , the successful germination and establishment of indigenous plants can also be inhibited. After alien clearance, these sediments should be allowed to flush out into the river system.

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An example of bank slumping in the pictures after clearing of IAPs, with re-adjustment of slope and establishment of indigenous vegetation. The picture shows an example of an area with a lower gradient below an invaded and incised channel, where sediment is being trapped. *Cynodon* and Kikuyu have established on this site.

Bank slumping, undercutting and flushing of sediments will introduce sediment into the channel, from where it can be carried downstream during floods. Increased downstream sedimentation could therefore be a concern, especially if a water storage reservoir is threatened. It is recommended that locations downstream which have a high potential for sediment deposition, but still close to the eroding section, are identified. These are areas which have the combination of a shallow channel, a wider valley floor and a low channel gradient. This potential should be used by increasing channel and riparian zone roughness, for example by encouraging vegetation growth. However, it is important that some sediment continues downstream to prevent channel incision.

9.1.2 Erosion and loss of topsoil

Steep and denuded slopes will be prone to erosion, especially after a fire. Erosion and loss of topsoil can be mitigated by stabilising these slopes until vegetation establishes. Barrier lines on natural contours can be very effective in stabilising the soil and preventing runoff and erosion, as well as slowing water flow on bare slopes. This can be done by using cut IAP logs and pegging them at intervals of 5m at right angles to the slope. Brushwood from felling operations or stones can also be used for stabilisation in the same manner. This method can be used in combination with planting and /or sowing.

9.2 RESTORATION OF VEGETATION

There are three main methods which can be used to actively re-introduce plants into degraded environments:

- mulching, either in combination with the methods below or as a stand -alone treatment, which can also assist with re-introducing seed
- reseeding by sowing seeds directly in-field
- planting established plants in bags or other containers, or by transplanting from adjacent areas directly into the target area

A combination of any of the methods above may yield the best results, e.g. mulch can help stabilise the soil on slopes making it easier for plants to establish. For any of the methods, it is advisable to undertake small-scale trials first to test the viability of a method, before embarking on a particular strategy on a large scale. This reduces the risk of expensive, large-scale mistakes and failures.

Ideally, propagation material (seeds or cuttings) should be collected from a pristine habitat close to the area to be restored and should come from the same catchment to prevent genetic contamination which can harm local populations. Harvesting locally will also reduce collecting costs. If collections are made from nature reserves or conservation areas, the correct permits must be acquired from authorities before commencing with collection.

Do not actively restore where a high rate of IAPs regeneration is expected and where foliar herbicide will need to be used, as this type of follow-up can cause a high rate of mortality of indigenous plants. The only exception to this is where very high densities of pioneer species are planted or seeded to suppress regrowth. In this case, make sure follow-up does not damage restoration efforts.

9.3 MULCHING

Mulching can limit erosion, suppress weeds, help retain soil moisture and add organic material to the soil. A seed-bearing mulch from nearby cut indigenous vegetation can also be effective as a method to re-introduce seeds. Brush from fire-breaks can be used for mulching.

Organic mulches (especially wood chips) use up soil nitrogen during decomposition, and can therefore assist with reducing the nitrogen content of the soil. This is beneficial to the establishment of fynbos species, as fynbos is found on nitrogen-poor soils. Avoid wood chip sources from wattle or gum, since allelopathic compounds in the wood may inhibit the growth of indigenous vegetation. Hydraulic mulches, using a slurry of mulch and seed, is also an option (see Section 9.4.3).

Straw can also be used as a mulch, but may introduce undesirable weeds into the area through seeds. Organic netting such as jute netting can be used in combination with straw, and although more expensive, is highly effective. It may be suitable for smaller, select areas.

9.4 RE-SEEDING

This is a cheaper restoration method, than using established plants in the form of plugs and /or bags. It is often also the only method that can be used in inaccessible areas, other than direct transplanting in the field (see Section 9.5.8) or mulching. However, most indigenous plants establish more slowly and in lower densities from seed compared to planting. A combination of planting and seeding may yield the best results. Practitioners have often also not much success establishing vegetation from just seeding after clearing.

If the soil is very degraded, e.g. when much of the topsoil and organic material has been lost, it will be even harder for seedlings to establish. This will be exacerbated on steep slopes, where any remaining soil and seeds will wash away unless stabilised as described in Section 9.1.2.

9.4.1 Which species?

This will largely depend on availability, as source populations may be limited, but the following are general principles to guide decisions. The desired target condition (Section 6) will also influence choice of species.

The following characteristics are most important in choosing suitable plant species for restoration:

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This picture shows the suppression effect that grass (dashed arrow) can have on the regrowth of wattle species with almost no re-growth in plots where grass was planted (solid arrow)

- Easy to obtain (e.g. seeds, cuttings, rootstock etc.)
- Easy to grow – species which germinate or establish from cuttings easily
- Fast-growing
- Species which provide good ground cover and /or stabilise the soil
- Generalist species - those that do not have narrow habitat requirements, and can grow easily under both moist or dry soil conditions
- Resprouting species, especially in fire-prone areas
- Species which can suppress regrowth, such as *Virgilia* or certain grasses

Recommended species for Eastern and Western fynbos are included in Appendix B.

Pre-treating seeds to break dormancy and /or stimulate germination is preferable, and most fynbos species need smoke as a stimulant (see Sections 10.2.4 and 10.2.5). This will not be required if the area to be seeded has recently burnt.

In a heavily degraded area where a quick vegetation cover is required to hold the soil in place, grass and pioneer species seeds can be most efficient. The first choice would be locally harvested grasses, e.g. *Themeda triandra, Digiteria eriantha, Agrostis* and *Miscanthus capensis*. The second option would be to use commercially available grass seeds of species that grow in the area. Grass cover can be reduced at a later stage through the use of herbicide to allow fynbos species to re-establish. Alternatively, sow a commercially available, non-invasive grass such as *Eragrostis teff, Lolium perenne or Avena sativa* to provide initial soil surface stability. After some vegetation cover has established, slower growing and climax fynbos species can be sown or planted in.

9.4.2 Which season?

The best results are achieved by sowing during the rainy season: in autumn in the Western Cape and in early spring in the Eastern Cape. Seeds sown too far in advance of the rainy season can be lost to predation by rodents, ants and birds before they germinate.

9.4.3 Methods

Hoe hard and crusty soil lightly before seeding. Broadcast the seed directly on the ground and rake in lightly. Cover with a thin layer of indigenous brush (preferably seed-bearing) or wood chips. On slopes where soil and seeds are likely to wash away, stabilise slopes as described in Section 9.1.2.

There are no standardised seeding rates, but approximately 10kg cleaned seed per hectare for pioneer and herbaceous species, and 1kg of seed heads per hectare for taller overstorey species (e.g. *Protea or Leucadendron*) is recommended.

Hydroseeding is also an option and will yield better results, but is very expensive. It may be an option for high restoration priority areas, and may be more feasible if landowners share costs.

Restoration trials in the Kouga catchment. The picture on the left shows different treatments. The picture on the right shows a close-up of newly established plants

9.5 PLANTING

Using established plants to re-instate vegetation in the field requires more effort and is more expensive than using seeds, but generally establishes a cover much faster and more effectively. As discussed in Section 7, the cost will vary greatly on species and density, and other factors such as distance from source and access.

9.5.1 Which species?

The same principles apply as with re-seeding (see Section 9.4). The desired target condition will also determine choice of species, e.g. if the goal is to reinstate missing or rare species. Do not propagate short-lived pioneer species, as this wastes resources; rather re-establish them by direct seeding.

9.5.2 Season and timing

Planting in the field should ideally take place during the rainy season. Timing will also affect the size of plants, which can influence costs and success considerably. For example, if planting is scheduled for the rainy season in late winter, but propagation starts too late and the plants are not ready yet, planting may be delayed until the next rainy season. By that time the plants will be much bigger and may require transplanting into larger containers. These will be much more costly to transport and plant. They may also become root bound, or disturbed more during hand ling and therefore establish less well. Thorough planning is therefore essential.

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Restoration trials in the Kouga catchment of the Eastern Cape. The picture on the left shows the planted strips a year and a half after planting, and the picture on the right two years after planting

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Restoration trials two years after planting. Some species, in this case *Miscanthus capensis* and *Pelargonium capitatum* established well, grew quickly and covered a relatively large area (1.5m x 1.5m). These are therefore considered suitable species for restoration. *Pelargonium* also established equally well along the riverbank and on the dry, rocky slopes, making it a versatile species to use. The picture at the bottom shows the size of black wattle trees were which were left to coppice (this equals two years growth), underscoring the importance of timely follow-ups.

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Examples of overgrown plants – these are wasteful in terms of resources used during the propagation phase, are difficult to handle and will not establish well

Carrying plants to site

9.5.3 Method

The plants are transported to the restoration site and kept watered until they are planted. Plan so that plants do not remain out in the field for too long or over weekends without watering. Care should be taken during the transportation stage that rough handling does not damage plants. Plants should be placed deep enough into planting holes to allow for a shallow depression around the plants to collect moisture. It is preferable that they are given an initial watering at planting.

9.5.4 Transport

Consider transport carefully during the planning phase, as this may present many logistical challenges and consume a large proportion of resources. Optimise transport, e.g. if plants are transported over some distance, use a larger truck which can carry more plants. Ensure that the transport is equipped suitably for plants to prevent damage and loss during transport.

Attempt to minimise handling between source and destination – the more loading and offloading takes place, the higher the costs and the more damage is done to the plants.

The plants in the picture on the left have become overgrown, making them difficult to transport. In addition, the method of transport is not suitable, as they will suffer windburn and damage. The picture on the right shows the damage resulting from poor transport and handling.

9.5.5 Size of plants

There can be a trade-off between size, cost and survival. Larger plants cost more to produce, transport and plant, but produce a cover faster and may survive better under adverse conditions, although this is not always the case. Factor this into planning and costing (see Section 7.2).

9.5.6 Local site topography

Lateral zoning has to be observed when seeding or planting, as some plants are limited by the availability of moisture. For example, many sedges will only grow in the wet bank zone where moisture is permanently available, whereas other species like the shrub *Dodonea* need drier conditions. Aspect also has to be taken into account in species selection, as north-facing slopes are much drier than south-facing slopes. Species with wide habitat tolerances are therefore easier to work with.

Lateral zones can also influence the degree of flood risk that plants are exposed to, and this has to be considered when planning restoration. Use plants that are quick to establish, or which can establish from vegetative parts that may be washed downstream during floods (e.g. *Isolepis prolifera*).

Soil type and depth, slope and rockiness will affect the ease of planting. Soils are generally shallower on north-facing slopes, making it more difficult for vegetation to establish, whereas it is easier for plants to establish in deeper and moister soils, e.g. along riverbanks and south-facing slopes.

It is much harder to work on steeper slopes, which are usually also more rocky, and this may limit planting. Try and work with the local topography, i.e. plant in depressions below rocks on steeper slopes, where soil is generally a bit deeper and there is some protection for plants to establish.

Also consider the fire risk in the area where restoration is planned; open valleys are more prone to fires than narrow valleys, and this will affect which species can be re-established. In fire-prone areas try to use fire-tolerant resprouters such as *Halleria*.

9.5.7 Protection from trampling/grazing

Newly restored areas must be protected from grazing and trampling until the vegetation has become established.

9.5.8 In-field transplanting

Plants can also be harvested from adjacent indigenous areas, ideally from a site where the vegetation will be destroyed due to cultivation or construction, and transplanted directly into the site. This method is especially suitable for plants that can be split, e.g. sedges and grasses (see also Section 10.3). This method can greatly reduce costs, but survival can be less. It is therefore essential to do this only when the soil is wet, e.g. shortly after (or during) rain. Check with the nearest conservation authority whether permits are required.

9.5.9 Living-soil amendments

Adding soil from natural areas (living-soil amendments) can assist in facilitating the recovery process, since this soil will contain seeds and beneficial microbes. Obviously other areas should not be degraded through the removal of soil, and soil should either be taken from areas like construction sites, or harvested in small volumes from adjacent intact areas, with care being taken not to damage these sites unduly.

9.5.10 Maintenance after planting

If water is readily available, the indigenous plants can be watered if necessary. It is critical that timely follow-ups of IAPs take place and that these do not harm the restoration efforts.

10 PROPAGATION

The following section presents information on propagating plants for restoration (by Victoria Wilman). A more detailed report can be accessed from the World Wildlife Fund (WWF) website (see Appendix A).

Plants can be propagated from seeds or vegetatively, (by means of cuttings, rhizomes or layering).

The benefits of seeds vs vegetative propagation:

- Plants propagated from seeds are genetically variable and may produce a more resilient community
- Propagating from seed is sometimes the only available way to propagate a species
- Propagating from seeds is generally cheaper and easier, as many seeds can be sown in a tray in a short period of time
- Transmission of certain diseases can be avoided by sowing seed instead of vegetative propagation
- Some seed-grown plants tend to be healthier and more vigorous

The limitations of growing plants from seed are that seed can only be collected at certain times of the year and some species require particular seasons, temperatures or treatments for germination.

Vegetative propagation has the following advantages:

- Plants which do not produce viable or abundant seed can still be grown.
- Plants can still be propagated when there is no seed available.
- In some cases they can be produced throughout the year without having to wait for particular seasons
- In a similar amount of time, plants produced from cuttings can be larger than plants grown from seed

Again, it is advisable to undertake small-scale trials first to test the viability and cost of either method for a particular species, before embarking on a method at a large scale.

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10.1 NURSERY

An on-site nursery reduces transport costs and can be built quite simply for general plant production from seed. If necessary, a more specialised greenhouse can also be built.

10.1.1 Factors to take into account when building a nursery

Before setting up the nursery some planning should be done to ensure efficient plant production and eliminate future problems. An unsuitable site and poorly planned nursery layout will ultimately increase the cost of operations or lead to unnecessarily high seedling losses. Choice of plant species and propagation methods should be taken into account before setting up the nursery, to determine what kind of facilities will be needed.

10.1.2 Site selection

When setting up a nursery to grow plants for restoration close to the restoration site, the climate will automatically be ideal for the growing of the plants from seed during the correct season. This eliminates the need for specialised temperature control. However, sites should be selected that are protected from drying winds and should be situated within a favourable micro-climate for growing plants, where they will not be in continuous shade or in a "frost pocket". The area should be relatively level and could be on a very slight (2%) slope to facilitate drainage and eliminate pooling of water in the nursery. There should be sufficient space available for the necessary structures as well as open growing areas, good road access for the delivery of propagation media and potting soils, and loading areas for the transportation of plants to the restoration site. It should be close to a source of clean water for irrigation. Because no potential nursery site is perfect, site selection inevitably requires some compromise.

10.1.3 Infrastructure

The first requirement in planning the facilities is to determine the proposed activities for the nursery, and the space needed for each at start-up and as the nursery exp and s. For a small nursery growing plants used for restoration, the following facilities will be needed:

- A seed house for germinating seeds and some hardy cuttings
- A shade-house for hardening off seedlings after transplanting into bags
- An open growing area for growing and hardening plants before transporting to the field
- Optional: a cutting house or greenhouse for the propagation of more specialised cuttings

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The picture on top show raised benches made from treated poles strung with taut wire, on which to place germination trays in the seed house, and the picture below shows an outside growing area for the hardening-off of plants prior to transportation to the field for planting

10.1.4 Sanitation

One of the most important factors of plant propagation is sanitation. Many plants are lost due to various pathogens and insect pests because sanitation is not well managed. Everything should be clean or sterilised from the beginning of the process to the end. Propagation facilities (places where cuttings are made, seeds are treated etcetera.) should be separate from storage areas and media mixing areas. Tables, equipment, greenhouse benches and floors should be washed down regularly where possible and disinfected with sodium hypochlorite, Jeyes Fluid or bleach. Irrigation water should ideally be chlorinated to kill algae and pathogens.

10.1.5 Propagation media

The propagation medium is critical to the success of plant propagation. The ideal medium should supply the correct balance of air and water for the developing root system. It should be sufficiently firm and dense to hold the seeds and cuttings in place during rooting or germination. The mixture should be easy to wet (not hydrophobic) and retain enough moisture, while being sufficiently porous to allow excess water to drain away and oxygen to reach the roots. It should be free of weed seeds, pathogens and harmful organisms. Some common components of propagation media include pine bark, peat, vermiculite, perlite and coarse sand. A mix of one part fine bark and one part coarse sand is relatively inexpensive and makes a good medium.

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Filling bags for plants (above), and milled bark used for propagation medium and mulch (on the right)

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10.1.6 Propagation containers

Seeds can be sown in various containers and into open beds. Containers include flats, which are shallow plastic seed trays with drainage holes in the bottom, and plug trays or multi-trays which are divided into many smaller sections for sowing seed or rooting cuttings. The latter have the advantage that the seedling or rooted cutting can be easily removed from the tray for potting without damaging the roots and they can be used to grow and transport smaller plants more cheaply in them. Root-trainers are made of pre-formed, hinged plastic sheets that fold together and lock, forming a set of four containers fitting into a special plastic tray. The vertical grooves ensure that roots grow vertically and not spirally and the sides can be opened to inspect the roots. Paper, fibre or peat pots are biodegradable and can be planted with the plant. They work best where plants are held in them for a short time before planting and have the advantage that roots are not disturbed during planting.

Flat seedling trays (top) and polystyrene plug trays (bottom)

10.2 PROPAGATING FROM SEEDS

10.2.1 Collecting seeds

When collecting from wild populations, not more than 20% of available seed should be collected at one time from each plant, to allow for continued maintenance of the population. Seeds should also be collected from different plants in the area to ensure a good gene pool in the rehabilitated populations.

Seed collecting requires good planning and knowledge of flowering and seed-producing times for the required species. Seeds should be collected at the right stage of development and this is usually when they are in the process of natural dispersal. This can be recognised by changes in fruit or seed coat colour, fruits splitting or breaking open, seeds rattling, seeds that are hard and dry or some seeds having already dispersed. A seed is usually ready for harvest when it can be removed from the plant easily. The seeds from serotinous species may be picked at any time, but the seeds of the current year's cones may not be ripe and should be left on the plant.

In some cases a balance has to be found between early and late harvesting to obtain the maximum amount of good quality seeds. If collection is delayed too long, fruits and /or seeds may have already been released from the plant, or they may be eaten by birds or animals.

There are many different techniques that can be used for collecting seed; the most appropriate will depend on the species and how the seeds are dispersed. Hand-picking is the simplest technique and works best in species where seeds are shed over a long time-period and where fruits are easily accessible. Containers can be strapped around the waist, leaving both hands free for collecting. For tall trees or species that produce clusters of seeds at the ends of branches, long tree pruners can be used to remove entire clusters from the plant. For species that disperse their seeds via a trigger or ballistic dispersal mechanism, or when protection of the seeds from animals and birds is required, bagging of seed heads may be the necessary choice. A mesh bag or a bag made from a material that will let air and light through is fixed loosely over the undispersed seed heads and tied in place around the branch. The seeds will be captured in the bags as they are shed. Shaking the branches of trees or shrubs will dislodge ripe seeds which can be collected on a tarpaulin laid on the ground beneath the plant. Some seeds in follicles, pods, capsules or cones can be harvested before they are fully mature and then dried. Branches can be cut or seeds removed and placed on canvas or in open trays to dry for one to three weeks, until seeds are released. Grasses, restios and other species with erect infructescences can be collected by stripping. The seed heads are grasped at the base, the hand is pulled upwards, gently dislodging the seeds, which can be transferred to a collecting bag.

Some seeds can be collected from the ground beneath the tree, but care must be taken not to collect seed that has been damaged by insects. It is sometimes beneficial to collect seed from the ground, especially where birds and fruit-bats have roosted. These seeds have been naturally scarified and will germinate easily. When seeds are collected, they should be stored in paper or cloth bags and never in plastic bags. Seeds with fleshy fruits can be initially stored in plastic bags or in buckets while collecting, however, the flesh should be removed as soon as possible and the seeds transferred to paper or cloth bags.

10.2.2 Seed cleaning

Once the seeds are dry, they can be cleaned if required. This involves separating the seed from the outer seed coat, and separating seed from chaff or other non-seed plant material that invariably gets collected with the seed. Hand-sorting is the simplest method and is mostly used to clean large seeds or seeds with minimal chaff; for example, seeds that are in pods need only be taken out of the pods. Depending on the seed, it can be lightly crushed e.g. dried *Aloe* spp., to break up the outer seed coat, or rubbed through wire mesh to separate seed from capsules, e.g. *Erica* spp.

The resultant mix can then be winnowed or screened by passing it through various sizes of mesh. With certain seeds, the chaff can be removed by carefully throwing seed into the air and catching it again, or pouring it back and forth from one container to another; a slight breeze will carry the chaff away and leave the heavier seeds to fall into the tray. Chaff can be left with the seeds if used for direct seeding at restoration the site.

Fleshy fruit or berries need a slightly different treatment to dry fruits. In general, fleshy fruit is easiest to handle if it is ripe or over-ripe, but this is seldom the case as seeds need to be collected before birds and animals eat them all. With ripe seeds, the flesh must be removed from these seeds for storage and sowing. The berries can be squashed and the seeds extracted by hand. Alternatively, they can be treaded in tubs, rubbed through screens under running water, or soaked in water which softens the flesh, making it easier to remove the flesh from the seeds in the water. Another method to remove seeds from small seeded fleshy fruits is to use an electric blender with the metal blade having been replaced with a piece of rubber tubing. It is fastened at right angles to the revolving axis of the machine. A mix of fruit and water is placed in the blender and stirred for about two minutes. When the pulp has separated from the seed, the pulp can be removed by flotation. The seeds and pulp are placed in water so that the heavy, viable seeds will sink to the bottom and the lighter pulp and empty seeds will float.

Fermentation is a method which works well for species with sticky or milky flesh such as *Sideroxylon inerme*. The seeds can be placed in a strong plastic bag with a litre of water, three tablespoons of sugar and a sachet of instant yeast. These ingredients are mixed thoroughly and the bag is sealed. Leave the bag like this for three to four days until the bag has swollen, the fermentation process is well under way and the flesh falls off the seeds. They can then be washed in water. Sticky seeds such as *Pittosporum viridiflorum* can be rolled in fine dust and wiped with a piece of rough coarse hessian. The dust absorbs a large amount of the sticky mucilage and both are wiped off.

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Seeds collected in paper bags and set out to dry before cleaning (top) and scarifying seeds by nicking with a knife (bottom)

10.2.3 Seed storage

All seeds must be completely dry before storage. Store seeds in a cool and dry place in paper or other porous bags, and protect from predation by dusting with an insecticide like Karbadust.

The seeds from various species remain viable for different periods of time, and may not germinate if stored longer than one year. The seeds of a few species may lose viability even quicker, and should be used sooner. For information on seed viability, contact Kirstenbosch (Appendix A).

10.2.4 Seed dormancy and germination

Many fynbos species will germinate after being exposed to moisture and light, but some seeds have dormancy mechanisms that prevent germination, and require additional treatment before they will germinate. The processes and /or conditions for this can be very specific and vary between species. Methods for breaking dormancy include mechanical scarification (especially hard-coated species), treatment with hot water or dry heat, acid scarification, the use of chemicals such as gibberellic acid and leaching.

Many fynbos species also require fire-related germination cues like smoke (described in Section 10.2.5).

10.2.5 Smoke treatment

Smoke treatment can be carried out by placing previously sown seed trays or open paper bags in a polythene tent. A mixture of dry and green fynbos material is ignited in a metal drum and the resulting smoke is pumped into the tent using bellows or a compressed air-line. This system allows the smoke to cool before it enters the tent. The seed trays remain in the tent for about two hours, after which they are removed and watered.

Alternatively, trays can be placed in a polythene tent, fynbos material can be ignited inside a small metal drum, and then dampened down to create smoke. The drum is placed inside the tent and the tent sealed while the chemicals in the smoke settle onto the soil in the trays. They can be removed after two hours and watered.

Kirstenbosch seed primer (see Appendix A) can also be used to stimulate germination in seeds. The seed primer is absorbent paper which has been impregnated with smoke solution and a range of germination stimulators and then dried and sealed in a polythene packet. Water is added to the paper and seeds are soaked in the resulting solution for 24 hours.

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Treating seeds with smoke to break their dormancy, using a small smoke tent (left above) and smoke primer (above)

10.2.6 Factors affecting germination of seeds

There are four main environmental factors which affect germination and plant growth: water, oxygen, light and temperature. In seeds, the first part of the germination process is the imbibition or absorption of water. There should be enough water continuously available in the propagation medium for the germinating seed. If the medium is allowed to dry out once the germination process has begun, the embryo will die. Different species require light or darkness to germinate. Seeds that require light, should be sown on the surface and either left, or covered only lightly with fine bark or vermiculite. Seed requiring darkness should be sown deeper or can be placed in a dark area until germination has started. Respiration takes place in all viable seed; in dormant seed it may be slow but oxygen is still required. The respiration rate increases during germination and the propagation medium in which the seeds are sown should be well aerated. Germination can be severely hampered and hindered by sodden, oxygen-poor environments. Favourable temperature is another requirement for germination; some seeds will germinate over a large range of temperatures, whereas others require a narrow range. Some seeds have minimum, maximum and optimum temperatures at which they germinate. The best practice is to find out about the natural ecology and germination of each species and mimic these conditions as closely as possible.

10.2.7 Sowing the seed

Before filling the seed trays, they should be cleaned and sterilised by washing them in Jeyes Fluid, and placed in the sun to dry. A general seedling medium contains milled pine bark, coarse sand and some vermiculite. The seedling medium is mixed up thoroughly on a clean concrete surface in a sheltered area, and the trays filled to a level about 10-20 mm below the rim. This is to keep the water and medium from spilling over the rim during watering. The medium should be levelled and patted down gently to create a uniform surface, and watered with a very fine rose before sowing the seed.

Sowing seed (top) and hardening off plants (bottom)

Seeds should be sown evenly and sparingly over the surface of the tray; seeds sown too densely become overcrowded, compete for resources and create an environment more conducive to disease. Very fine seeds can be mixed with sand, broadcast over the surface and gently tamped down to give them good contact with the growing medium. Medium-sized seeds can be broadcast or sown in furrows. Large seeds can be sown in rows and pushed gently into the medium. All seeds can be covered with vermiculite, sifted bark or sifted propagating medium. Unless light-requiring, seeds should generally be planted to a depth of three to four times their diameter.

Seeds should be watered with a very fine hose and labelled carefully with the species name, sowing date and place collected. Seeds can be treated with a fungicide such as Apron C or Previcur after sowing to prevent losses due to damping off. Seed trays are then placed in the seed house and should be watered so that they are kept moist enough for the seeds to germinate without becoming waterlogged. Exact watering schedules depend on species, propagation medium and environmental conditions such as temperature and humidity.

10.2.8 Growing out

After germination, seedlings remain in the seed house until they have produced at least two true leaves, after which they can be pricked out or transplanted into plant bags or plug trays. At this stage they are moved to a shade house which is similar to the seed house except that the shade-cloth should provide 20-40% shade cover, and it does not need raised benches unless the primary container in this stage is the plug tray. Watering at this stage is reduced to begin accustoming plants to the harsher realities of the outside world. Plants should remain in the shade house for a minimum of 10 days or longer depending on species, after which they can be moved to open growing areas (see Section 10.4).

10.3 PROPAGATING FROM VEGETATIVE MATERIAL

Stem cuttings can be taken from the tips of a plant with a terminal bud or from secondary sections of the stem. Some plants can be propagated from either of these, but many plants root best from tip cuttings. Cutting material should be collected in the cool, early mornings and stored in plastic bags containing a tiny amount of water to keep the cuttings moist. Cuttings should not be covered in water for prolonged periods. The cuttings should be kept moist, cool and turgid at ALL times.

Cuttings should be made using sharp and sterilised secateurs and placed in plug trays which have been filled with a rooting medium. Cutting medium should be well aerated and well drained while still being able to retain moisture. A mix of one part polystyrene and one part bark, or one part coarse sand and one part bark can be used. Plain sand is also sometimes used for making cuttings. Rooting hormones can be used to speed up rooting and are sometimes necessary for hard-to-root species. An inexpensive, easy to use and effective rooting hormone is Seradix, which comes in various strengths; Seradix 1, 2 and 3.

Herbaceous *Pelargonium* cuttings

10.3.1 Stem cuttings

Stem cuttings can be grouped into the following types:

- Softwood cuttings
- Herbaceous cuttings
- Heel cuttings
- Semi-hardwood cuttings
- Hardwood cuttings

More detail on how to make these cuttings can be accessed from the full propagation report on the WWF website (see Appendix A).

10.3.2 Offsets and division

Offsets are produced by some species such as Cycads, some Aloes and many bulbs. An offset is a lateral shoot or branch that develops from the main stems. Offsets can be removed by cutting close to the main stem with a sharp knife. Some offsets may have already produced roots and can be planted directly. If they are not sufficiently rooted they can be placed in a rooting medium and treated in the same way as a leafy stem cutting.

Many herbaceous perennials and grasses produce their new shoots from crowns at the surface or just below ground level. These can be increased by division. The plant is lifted, usually in the spring just before new growth begins and either separated by hand or cut into sections with a knife or other sharp instrument. These can then be planted straight into the field or into bags for growing on.

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The picture above shows the division of *Miscanthus capensis,* and the picture on the right shows the division of shrublets which produce new shoots from crowns

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10.4 GROWING ON AND HARDENING OFF

Once the plants grown for restoration have been successfully propagated, they need some time to establish and grow, and are planted into containers and placed in shade for a few weeks until they are ready to move out into the sun.

Before planting into the field, plants need to become accustomed to full sun, wind and little water, a process called hardening off. This requires an open growing area with no shade that is divided into beds with a regular irrigation system in place. Watering is reduced at each stage to prepare plants for planting into the field. Hardening off is particularly important when growing for restoration, as they only receive water from natural rainfall after they are planted.

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12 GLOSSARY

ALLELOPATHY is when a plant produces one or more biochemicals that influence the growth, survival, and reproduction of other organisms. These biochemicals are known as allelochemicals and can have positive or negative effects on other organisms.

ECOLOGICAL INTEGRITY and RESILIENCE: A healthy ecosystem has a high ecological integrity and is able to provide more ecosystem services than a degraded or damaged ecosystem. It is also more stable and resilient to disturbances such as fires or floods.

Many trees can form new growth from the stump or roots if cut down; this is called RESPROUTING or COPPICING.

SEROTINY is an adaptation to survive regular fires. Serotinous plants protect their seed in a cone or woody fruit and release these after fire. Many fynbos species such as Proteas and Leucadendrons, as well as exotic pines and Hakeas exhibit this phenomenon.

GEOMORPHOLOGY is the scientific study of land forms and the processes that shape them.

A PROPAGULE is any plant material which can be used to propogate a new plant, e.g. a seed.

A CONSERVANCY is a registered voluntary association between land users/ landowners who co-operatively wish to manage their natural resources in an environmentally friendly manner without necessarily changing the land -use of their properties.

Vegetation can be divided into groups or GUILDS according to various characteristics such as regeneration modes, pollination or seed dispersal modes, growth forms, etc. A fully functional and healthy community requires a good balance of the major GUILDS.

HYDROSEEDING is a restoration technique that uses a slurry of seed and mulch which is sprayed over the ground. It is also referred to as hydraulic mulch seeding or hydro-mulching.

BIOMASS refers to biological material, and is used in this report to describe the products that originate from felling IAPs, i.e. logs or branches.

A BRAIDED RIVER contains a number of channels, often separated by small and often temporary islands called braid bars.

Rivers are classified according to size, from small first ORDER streams to the large 12th ORDER rivers. The first ORDER stream are the smallest and flow into larger second ORDER stream, which in turn flow into the next ORDER and so on. The ORDER therefore is an indication of the size and strength of a stream. Anything larger than a sixth ORDER stream is considered a river.

BIOPHYSICAL FACTORS refer to the physical, chemical and biological characteristics of the environment , e.g. soil, geology etc. SOCIOECONOMIC FACTORS refer to the social and economic characteristics of an area and it's inhabitants, for example the level of income, spending, capacity etc.

An area that is HOMOGENEOUS is uniform in composition or character, e.g. supports vegetation of the same age or species.

GENETIC CONTAMINATION or GENETIC POLLUTION refers to the introduction of species or varieties of plants into an area where they don't naturally occur. These plants can hybridise with local species and weaken the local plant populations.

ECOSYSTEM SERVICES: Natural and healthy ecosystems provide services from which we benefit, such as clean water and air, prevention of soil erosion and waste absorption and breakdown. These are referred to as ecosystem services.

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13 BIBLIOGRAPHY

Blanchard, R., Holmes, P.M., 2008. Riparian vegetation recovery after invasive alien tree clearance in the Fynbos Biome. South African Journal of Botany 74, 421-431.

Cilliers, C.D., Esler, K.J., Boucher, C., 2004. Effects of alien plant management and fire on soil seed banks and regeneration in the Cape Peninsula National Park, South Africa. South African Journal of Botany 70, 705-712.

Cowling, R.M. (Ed.), 1992. The Ecology of Fynbos: Nutrients, Fire and Diversity. Oxford University Press, Cape Town, South Africa.

CSIR, 2000. Guidelines for indigenous vegetation restoration following invasion by alien plants. CSIR (Environmentek Report ENV-S-C 2000-144). 51 pp.

Galatowitsch, S.M., Richardson, D.M., 2005. Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape. Biological Conservation 122, 509-521.

Holmes, P.M., Richardson, D.M., van Wilgen, B.W., Gelderblom, C., 2000. Recovery of South African fynbos vegetation following alien woody plant clearing and fire: implications for restoration. Austral Ecology 25, 631-639.

Holmes, P.M., Richardson, D.M., Esler, K.J., Witkowski, E.T.F., Fourie, S., 2005. A decision-making framework for restoring riparian zones degraded by invasive alien plants in South Africa. South Africa Journal of Science 101, 553-564.

Holmes, P.P, Esler, K.J., Richardson, D.M., Witkowski, E.T.F., 2008. Guidelines for improved management of riparian zones invaded by alien plants in South Africa. South African Journal of Botany 74, 538-552.

Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

Parker-Allie, F., Richardson, D.M., Holmes, P.M., 2004. The effects of past management practices for invasive alien plant control on subsequent recovery of fynbos on the Cape Peninsula, South Africa. South African Journal of Botany 5, 804–815.

Sieben, E.J.J., Reinecke, M.K., 2008. Description of reference conditions for restoration projects of riparian vegetation from the species-rich fynbos biome. South African Journal of Botany 74, 401–411.

WESSA-KZN. 2008. Invasive alien plants in KwaZulu-Natal. Management and control. A Wildlife Handbook. KwaZulu-Natal Branch of the Wildlife and the Environment.

Working for Water, 2003. Standards for mapping and management of alien vegetation and operational data. Volume 2 (of 2) guidelines. Version 4.1. Department of Water Affairs and Forestry.

Theses and reports produced as part of the Riparian Pilot Project:

Diaz-Gonzalez, J.D., 2009. Technical Report of the Restoration of a section of the Witteklip River as part of the Pilot Project for Rehabilitation of the Kouga River. Master Final report, Universidad Politecnica de Madrid.

McConnachie, M., 2012. Cost-effectiveness and ecological restoration: The case of Working for Water. PhD thesis, Rhodes University, Grahamstown.

Pietersen, A., 2009. A fluvial geomorphological study of river rehabilitation in the Kouga region, Eastern Cape. MSc Thesis, Rhodes University, Grahamstown.

Van der Waal, B.W., 2009. The influence of *Acacia mearnsii* invasion on the soil properties in the Kouga mountains, Eastern Cape, South Africa. MSc Thesis, Rhodes University, Grahamstown.

Wilman, V., 2011. Plant propogation techniques and recommendations. Growing for restoration. 33 pp.

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14 APPENDIX A: FURTHER RESOURCES AND USEFUL CONTACTS

World Wide Fund for Nature:
http:/www.wwf.org.za

Working for Water (Control of alien invasive plants):
http://sites.google.com/site/wfwplanning/Home
http://www.dwaf.gov.za/wfw

CapeNature:
http://www.capenature.org.za

Agricultural Research Council (ARC) for biocontrol:
www.arc.agric.za

LandCare:
http://www.nda.agric.za

Society for Ecological Restoration:
http://www.ser.org

Legislation:
http://www.info.gov.za/documents/acts/index.htm r (all acts) or
http://www.dwaf.gov.za/wfw/legal for summary

National Geo-spatial Information (previously Chief Directorate: Surveys and Mapping):
http://www.ngi.gov.za

Kirstenbosch:
http://www.sanbi.org

Millenium seed bank:
http://www.sanbi.org

Fynbos Forum:
http://www.capeaction.org.za

15 APPENDIX B: SPECIES RECOMMENDED FOR RESTORATION

Western Cape (adapted from Holmes *et. al.* 2008)

Scientific name	Growth form	Regeneration mode	Propagation method		
			Seed	Split	Cutting
WET BANK					
Calopsis paniculata	Restio	Reseeder	■	■	
Elegia caffra	Restio	Resprouter	■		
Isoleps prolifer	Sedge	Reseeder		■	
Juncus capensis	Rush	Reseeder		■	
Juncus lomatophyllus	Rush	Reseeder		■	
Pennisetum macrourum	Grass	Reseeder	■	■	
Salix mucronata	Shrub/Tree	Resprouter			■
Prionium serratum	Graminoid	Resprouter		■	
DRY BANK					
Anthospermum aethiopicum	Shrub	Reseeder	■		
Berzelia lanuginosa	Shrub	Reseeder	■		
Brabejum stellatifolium	Shrub/Tree	Resprouter	■		
Brachylaena nerifolia	Shrub/Tree	Resprouter	■		
Cliffortia graminea	Shrub	Resprouter			■
Diospyros glabra	Shrub	Resprouter	■		■
Erica caffra	Shrub	Reseeder	■		
Leucadendron salicifolium	Shrub	Reseeder	■		
Metrosideros angustifolia	Shrub/Tree	Resprouter			■
Morella serrata	Shrub	Resprouter			■
Passerina corymbosa	Shrub	Reseeder	■		■
Pentaschistis pallida	Grass	Reseeder	■		
Psoralea pinnata	Shrub	Reseeder	■		
Rhus angustifolia	Shrub	Resprouter	■		■
Tribolium uniolae	Grass	Reseeder	■		
Virgilia oroboides	Shrub/Tree	Reseeder	■		

All year rainfall areas (adapted from Holmes *et. al.* 2008)

Scientific name	Growth form	Regeneration mode	Propagation method		
			Seed	Split	Cutting
WET BANK					
Anthospermum herbaceum	Forb	Reseeder	■		■
Blechnum spp.	Forb/Fern	Reseeder	■		
Carpha glomerata	Sedge	Resprouter	■	■	
Chironia baccifera	Forb	Reseeder	■		
Cliffortia graminia	Shrub	Resprouter			■
Conyza ulmifolia	Forb	Reseeder	■		
Cyperaceae spp.	Sedge	Resprouter	■	■	
Cyperus textilis	Sedge	Resprouter	■	■	
Elegia asperifolia	Restio	Resprouter	■		
Ficinia capillifolia	Sedge	Resprouter	■	■	
Ficinia oligantha	Sedge	Resprouter	■	■	
Fuirena spp.	Sedge	Resprouter	■	■	
Tristachya leucothrix	Grass	Resprouter	■	■	
Helichrysum epapposum	Forb	Reseeder	■		
Helichrysum umbraculigerum	Forb	Reseeder	■		
Isolepis cernua	Sedge	Resprouter	■	■	
Isolepis prolifer	Sedge	Resprouter	■	■	
Miscanthus capensis	Grass	Resprouter	■	■	
Rumohra adiantiformis	Forb/Fern	Resprouter	■		
Senecio rigida	Forb	Reseeder	■		
Prionium serrata	Graminoid	Resprouter		■	
Chrysanthemoides monilifera	Shrub	Reseeder	■		
DRY BANK					
Cheilanthes viridis	Forb/Fern	Resprouter	■		
Chrysanthemoides monilifera	Shrub	Reseeder	■		
Alloteropsis semialata	Grass	Resprouter	■	■	
Anthospermum herbaceum	Forb	Reseeder	■		■
Berzelia commutata	Shrub	Reseeder	■		
Cliffortia strobilifera	Shrub	Resprouter			■
Erica caffra	Shrub	Reseeder	■		
Halleria lucida	Shrub	Resprouter	■		
Helichrysum cymosum	Forb	Reseeder	■		
Helichrysum petiolare	Forb	Reseeder	■		
Merxmuellera cincta	Grass	Resprouter	■	■	
Passerina filiformis	Shrub	Reseeder	■		■
Pelargonium cordifolium	Shrub	Reseeder			■
Knowltonia cordata	Forb	?			■
Phylica axillaris	Shrub	Reseeder	■		■

Phylica buxifolia	Shrub	Reseeder	■		■
Polygala virgate	Shrub	Reseeder	■		
Psoralea pinnata	Shrub	Reseeder	■		
Rapanea melanophloeos	Shrub/Tree	Resprouter	■		■
Rhus spp.	Shrub	Resprouter	■		■
Senecio chrysocoma	Forb	Reseeder	■		
Senecio rigida	Forb	Reseeder	■		
Themeda triandra	Grass	Resprouter	■	■	
Ehrharta erecta	Grass	Resprouter	■	■	
Pelargonium capitatum	Shrub	Reseeder			■
Pelargonium cucullatum	Shrub	Reseeder			■
Carpobrotus edulis	Forb	Resprouter			■
Burchellia bulbalina	Shrub	Resprouter			■
Euclea natalensis	Shrub/Tree	Resprouter	■		■
Ficinia ramoisissima	Sedge	Resprouter	■	■	
Stoebe plumosa	Forb	Reseeder	■		
Senecio pterophorus	Forb	Reseeder	■		
Cymbopogon plurinoides	Grass	Resprouter	■	■	
Otholobium caffra	Shrub	Reseeder	■		
Dodonea angustifolium	Shrub	?	■		
Metalasia densa	Shrub	Reseeder	■		
Cliffortia lineraifolia	Shrub	Resprouter			■
Anthospermum aethiopicum	Shrub	Reseeder	■		
Selago corymbosa	Forb	Reseeder	■		
Heteropogon contortus	Grass	Resprouter	■	■	
Digiteria eriantha	Grass	Resprouter	■		
Virgilia divaricata	Shrub/Tree	Resprouter	■		