Rethinking ecological rehabilitation in arid and winter rainfall regions of southern Africa

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TRI-P-MINING FOR TITANIUM, DIAMONDS, gypsum, silver and other industrial minerals is expanding in the arid, winter-rainfall areas of South Africa and Namibia. Although economically important, and a provider of employment and training for local people, mining is damaging thousands of hectares in biologically diverse environments where vegetation growth and recovery is limited by aridity, wind and nutrient-poor soils.

Since 1998, the Environmental Conservation Act has been applied to all land-use that transforms natural vegetation. The legislation limits environmentally damaging activities and requires that developers build costs of ecological rehabilitation into their operational budgets. Additional incentives for rehabilitation are the International Conventions on Biodiversity and Desertification that commit South Africa and Namibia to reduce and mitigate the negative social and ecological effects associated with some types of agriculture and industry.

Compliance with mitigation and rehabilitation requirements cannot be enforced without ecological expertise. At present there are no guidelines for re-establishing self-sustaining vegetation in damaged west coast environments, where conditions are windy and the meagre rainfall is restricted to winter months. To explore the problem, I convened a workshop entitled ‘Vegetation rehabilitation in Fynbos, Renosterveld, Karoo and Strandveld’ at the University of Stellenbosch in October 2000. It attracted 120 delegates including academics, consultants, environmental managers from agriculture and mining, and students. Here I highlight some of the disappointments reported, and suggest approaches to rehabilitation that, on the basis of success in adjacent biomes, may be worth testing.

Disappointments
Agronomic approaches (cultivating, fertilizing, reseeding, irrigating) are frequently used in strip-mine rehabilitation in southern Africa. They work well for establishment of planted pasture where the rainfall is adequate to sustain this crop, but have failed in arid areas of southern Africa (<200 mm annual rainfall, CV >30%). Philip Desmet (University of Cape Town) noted that sowing annual pasture grasses in this region under temporary irrigation gives a brief illusion of success while the grasses are green, but does not lead to self-sustaining vegetation cover. Recovery of vegetation was no better where annual grasses were sown with straw mulch that was added to reduce wind speed.

Plantings of Australian saltbush (Atriplex nummularia) have persisted for many years on disused wheat-fields on the west coast and in the Karoo, but do not appear to facilitate the development of ecologically or aesthetically diverse vegetation. Indigenous plants of the arid west coast apparently germinate in sub-canopy micro-sites that are protected from sun and wind, and are usually well supplied with mycorrhizal symbionts. Conditions on large areas of sandy or silty, and often saline, mine-spoil that require rehabilitation are very different, being exposed to sun, wind and salting soil particles.

Additions of water (particularly in the dry season), fertilizers and non-indigenous plants are a waste of money, particularly if such inputs cannot guarantee the establishment of self-sustaining vegetation. It is likely that the resilience that will ensure that vegetation cover persists on a rehabilitation site through drought and flood, heat and cold, fire and disease, can only be achieved if diverse and self-perpetuating plant and animal communities are established. Clearly it is in the interests of mining companies and the environment that ways to achieve this goal be found.

Successes, general principles and opportunities
Although no one offered a tried and tested recipe for rehabilitation in the arid winter-rainfall areas, some general principles (Table 1) emerged from accounts of successful rehabilitation in allied fynbos, Karoo and Kalahari vegetation types. These now need testing in the west coast Strandveld, Namaqualand and Namib.

Working towards goals. Goals set for rehabilitation by companies or consultants should be clear and ecologically as well as economically feasible. Goals vary from stabilization and aesthetic improvement to re-establishment of such ecological services as control of flooding or dust, to restoration of the ecosystem to its ‘natural’ condition. Once defined, goals should be made clear to engineers and construction site workers, so that misunderstandings do not frustrate rehabilitation efforts.

For example, where goals include restoration of landscape shape and function, the original materials (such as rocks, logs and topsoil) needed to re-establish this should be conserved. According to Charlie Boucher (University of Stellenbosch), effective communication between ecologists, engineers and labourers was crucial to the re-establishment of fynbos on cuttings in Du Toitskloof Pass, where large boulders, that give the area its aesthetic character, provide shade and reduce runoff, were replaced (correctly orientated and randomly spaced) in the rebuilt landscape.

Retaining living components. In planned disturbances there is an opportunity to salvage some of the animals, plants and microbes from the intact ecosystem. Participants agreed that topsoil salvage and replacement was critical for rehabilitation. Soils should be transferred immediately rather than being stockpiled as storage kills fungi, microbes, seeds and soil animals. Translocation of plants,

Table 1. General principles for ecological rehabilitation in the arid and winter-rainfall regions of southern Africa.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tr>
<td>1.</td>
<td>Set clear and ecologically and economically feasible goals for rehabilitation</td>
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<td>2.</td>
<td>Salvage living components of the ecosystem</td>
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<td>3.</td>
<td>Use locally adapted, indigenous plant and animal species</td>
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<td>4.</td>
<td>Retain and capture resources (organic matter, nutrients and water)</td>
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<td>5.</td>
<td>Mimic the original uneven shape of the landscape</td>
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<td>6.</td>
<td>Enable plants and animals to assist in the rehabilitation process</td>
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<td>7.</td>
<td>Do not rely on traditional agricultural and horticultural approaches</td>
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<td>8.</td>
<td>Keep good records of what works and what does not work</td>
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<td>9.</td>
<td>Budget sufficient time and money for rehabilitation</td>
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although costly, was recommended for re-establishment of vegetation structure. Large plants attract birds and insects that assist in pollination and seed dispersal, or shed seeds directly into the impoverished ecosystem. Boucher suggested that translocated plants contributed to the rehabilitation process, even if they died, because the soil on their roots included microbes and fungi that re-establish decomposition and symbiotic processes.

The use of locally adapted, indigenous plant species for rehabilitation has been successful in fynbos, Strandveld, Karoo, Namib and Kalahari. Many indigenous plants of the winter rainfall and arid region have internal fungal symbions (arbuscular mycorrhizae), whereas alien cover-crops such as ryegrass are non-mycorrhizal, and many non-indigenous perennial species are ectomycorrhizal. The use of annuals and non-indigenous species is therefore unlikely to facilitate return of self-sustaining natural vegetation. Nicky Allsopp (Agricultural Research Council) pointed out that if indigenous plants and their symbionts are to be successfully re-established, they need to be maintained in fresh soil until they are translocated to the rehabilitation site.

Re-establishing natural patterns and processes. Recent textbooks on restoration ecology focus on the importance of retaining and capturing nutrients, water and propagules. The re-establishment of natural processes (mineral cycling, resource capture, pollination, dispersal, recruitment) is essential for achieving enduring rehabilitation success. This is why Antje Burke (EnvironScience) recommends the analysis of landscape processes and patterns in the early stages of rehabilitation planning.6,7 Wind and water can effectively deliver seeds and plant nutrients and help to re-establish natural clumped patterns in vegetation if directed through use of appropriate traps and barriers. Traps can be constructed by mechanical soil pitting or ripping (tiling), or by brush packing and mulching. However, Andre van Rooyen (Agricultural Research Council) demonstrated that design greatly influences the results of these techniques. His innovative experiments with grid, spiral and star-shaped brush-packs on denuded communal grazing land in the dune fields of the Kalahari indicated that grid-shaped packs reduced wind speed, but were ineffective in trapping seeds except around their perimeters. Star-shaped brush-packs, on the other hand, harnessed the dispersal power of the wind, trapping seeds and fine particles and leading to patchy re-vegetation of dunes.

Biodiversity and aesthetics as well as practicality, cost and effectiveness should be considered when selecting traps and barriers. Unevenness of the ground and spatially variable patterns in sediment and litter deposition partly control animal as well as plant biodiversity, because scattered rocks, depressions and fallen branches provide nest and shelter sites for animals. Traps and barriers may lead either to anthropogenically linear, or to more natural patchy arrangements, of plants. Ideally, rehabilitation should mimic the original uneven shape of the landscape rather than aiming for a neat and engineered appearance.

Plant and animal assistants. In the Succulent Karoo and Strandveld the sparse plant cover is arranged as mixed species clumps sometimes called fertile islands. In arid climates the benefits of clumping (protection from heat, wind and herbivory, trapping of organic matter, water, mycorrhizal spores) may outweigh the negative effects of competition for resources, leading to clumped (or spotted) vegetation forms where wind is the major resource driver. Trials are currently in progress in the Succulent Karoo to test the effectiveness of re-establishing vegetation in clumps as opposed to non-clumped designs. Similar trials are needed for Strandveld rehabilitation sites.

Animals, including burrowing rodents, birds and some insects, can facilitate rehabilitation by importing seeds and organic matter and improving soil permeability and fertility. At one hyper-arid winter-rainfall site in the southern Namib, vegetation recolonization of 30-year-old mine dumps was limited to colonies of Brant’s whistling rat (Brateromyos brantsi). Features that encouraged use of the rehabilitation site by animals, including bird perches and soil mounds, may possibly hasten autogenic succession.

Record keeping and budgeting

Environmental managers and consultants responsible for mitigating damage associated with development or farming need information on what works and what does not work in arid and winter-rainfall areas. By keeping records of all treatments and their outcomes (including failures), practitioners could develop protocols for rehabilitation in this region. Estimates of rehabilitation costs and time schedules are vague at present. It is clear, however, that aridity reduces rate, and increases risks and costs, of rehabilitation.

Since development in arid southern Africa is likely to increase in future, arid zone restoration ecologists should discard recipes developed in mesic environments and meet the challenges of working with the elements and local biota to rebuild self-sustaining and diverse ecosystems.

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