

ASPECTS OF THE REVEGETATION OF MOUNTAIN FYNBOS VEGETATION OF
THE SOUTH WESTERN CAPE, SOUTH AFRICA

BY

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ABSTRACT

The revegetation of severely disturbed areas using indigenous vegetation forms the topic of this thesis. Mountain Fynbos was chosen for the study because of its importance as a unique vegetation-type worthy of conservation. Unfortunately, this vegetation faces long-term threats associated with escalating development pressures, which include the demand for improved infrastructures. These factors are discussed and a process is developed for using indigenous vegetation to revegetate severely disturbed areas. This use of indigenous vegetation represents a significant and innovative move away from the traditional use of commercially available grasses in South Africa. Fynbos is adapted to periodic droughts and nutrient poor soils and as such has practical advantages over artificial plant covers in terms of its low maintenance requirements for long term establishment. Theoretical perspectives of disturbance and succession are contrasted with the requirements for revegetation as observed in the field. Three aspects which relate to the re-establishment of indigenous cover on denuded fynbos areas are analysed and covered in separate papers:-

- 1) The importance of topsoil for revegetation was assessed by comparing species richness and composition on two sets of plots on a gravel quarry. The first set was topsoiled while

the control remained as sub-soil. Species were grouped according to modes of dispersal, viz. "anemochores", "soil-borne" (geophytes, succulents and myrmecochores), and "other" (dispersal mechanism unknown). The recruitment of anemochores accounted for at least 50% of the species found on both disturbed areas, but only the topsoil plots had representatives of the soil-borne group. This led to a greater species richness and foliage projective cover on the topsoil plots. These factors, together with the observation that topsoil is more conducive to seedling establishment, indicates that topsoil is vital for the re-establishment of indigenous vegetation. The plots followed two different paths of succession: the flora on the sub-soil was reminiscent of Clement's primary succession, while that on the topsoil more closely resembled Egler's ideas of "old-field" succession. Results are discussed in relation to the significance of topsoil for revegetation with indigenous fynbos vegetation.

2) The success of various seed harvesting techniques was evaluated for the revegetation of denuded, topsoiled areas. Treatments assessed included: Hand Harvesting, Brushcutting, Imprinting, Chipping, Suction Harvesting and Suction Imprinting. The hypotheses tested related to the effects of treatments on vegetation establishment on experimental plots. Data were analyzed using DECORANA and TWINSpan and Shannon-Wiener indices of diversity were determined.

Results indicated that uncontrolled variables had an overriding effect on the establishing vegetation. However, when harvested material was applied as a mulch, it significantly increased the cover and species diversity of experimental plots.

3) The last paper assesses nutrient applications in situations where topsoil is unavailable for revegetation. A range of commercially available fertilizers was applied to a denuded sub-soil area. A Desirability Index, which reflects the species composition and diversity of plots, was evolved to assess the different treatments within Mountain Fynbos. Results indicate that an increase in species richness and cover corresponds to increases in nutrient addition. The Desirability Index shows that the combination of high nitrogen and phosphorus was the most successful treatment for enhancing species diversity and abundance over the study period.

Finally, a set of guidelines are presented for use by revegetation practitioners. These are based on the results of the thesis as well as observations made during personal involvement with revegetation programmes. Although the guidelines were developed for Mountain Fynbos, the general principles derived are also considered appropriate for successful revegetation of related vegetation-types within the Fynbos Biome.

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PREFACE

This set of experiments was designed by members of the Potchefstroom University - National Transport Commission (PU-NTC) Institute for Reclamation Ecology to answer many practical questions related to the revegetation of roadsides and quarries in Mountain Fynbos areas. Because of the lack of revegetation research in the fynbos, and because of the dearth of published material in this field, much basic research was, and still is necessary.

In this investigation one vegetation-type was studied as it was thought to be more profitable in such an heterogeneous biome. It was hoped that the knowledge and experience gained would enable extrapolations to be made to other vegetation-types and so avoid the need for more detailed and intensive research, which would be beyond budgetary constraints.

It is important to emphasize the practical nature of revegetation ecology which involves people with practicalities uppermost in their minds. This is evident from this set of experiments which were set up on a slope to

simulate roadside conditions - but neglecting to realise the implications of added variables to future data analyses.

I was employed by the PU-NTC Institute to collect and analyse results of their experiments. Unfortunately there were a number of inadequacies in the design of the various experiments, perhaps because too much was attempted for one investigation. For example, too many treatments were tested with insufficient controls. Therefore, few quantitative results have been forthcoming, although useful trends are indicated. The experimental design was beyond my control. However, data collection and analyses were as rigorous as possible under the circumstances, and inaccuracies have been indicated in the text.

This thesis is arranged in the form of three papers which cover various aspects of revegetation using components of the indigenous Mountain Fynbos vegetation in the western part of the Cape Province, South Africa. Each paper has been written as a separate entity for publication purposes and so there is, of necessity, some repetition.

Chapter 1 is the General Introduction which deals with the vegetation-type studied: its nature and its value to conservation; as well as the theoretical and ecological considerations necessary for the revegetation of indigenous vegetation. Chapter 2 is the first paper and discusses

species richness and composition resulting from the presence or absence of topsoil on a revegetated quarry. Chapter 3 compares a range of harvesting techniques such as brushcutting, hand harvesting and suction harvesting. Results were assessed in terms of the foliage projective cover and species diversity of establishing stands of vegetation. Chapter 4 considers nutrient application and its role in ameliorating sub-soil when topsoil is unavailable for revegetation. Chapter 5 is a General Conclusion of the thesis, and leads into Chapter 6 which puts forward a number of Practical Guidelines that I propose should be followed for the successful revegetation of a Mountain Fynbos area.

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CHAPTER 1

GENERAL INTRODUCTION

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GENERAL INTRODUCTION

Humanity's exploitation of the vegetation of the south western Cape of South Africa goes back many years. Initially it was the nomadic herders who increased the incidence of fire for the improvement of grazing (Botha, 1924). This increase took place over an existing natural fire frequency caused by the relatively rare events of lightning and sparks from falling rocks during landslides or earth tremors. This use of fire may have been on a large scale, as uncontrollable runaway fires are a feature of this highly flammable vegetation. As well as increasing burn frequencies, fires would have occurred indiscriminantly through the year. This would have been detrimental to the indigenous vegetation (van Wilgen, 1984) which benefits most from autumn burns. With the arrival of Europeans at the Cape in the sixteenth century, human impacts on the vegetation have been accelerating due to increasing human populations and technological advancements (Hall, 1978). Opposed to these exploitative forces is the accumulation of a greater understanding of the value of natural systems. The trend to revegetate denuded areas can be linked directly to increased conservation awareness, and the cumulative detrimental effect of human land uses on indigenous vegetation. This has encouraged South Africa's National Transport Commission to invest funds in revegetation

research, specifically that linked to road construction. This project was supported by such funding.

Heathlands, such as those studied in this project, are found in a wide range of climatic zones. They occur from the tundra and cool temperate regions of the northern hemisphere to the warm and seasonally dry heathlands in the mediterranean climate regions of South Africa and Australia. They are usually characterized by an evergreen sclerophyllous vegetation growing on acidic soils of a low nutrient status (Specht, 1979). This is the case for the fynbos heaths (Mountain Fynbos and Coastal Fynbos) which are ecologically restricted to such conditions (Moll & Jarman, 1984).

The Cape fynbos is an evergreen sclerophyllous vegetation divided into a number of ecological types by Moll et al. (1984) which includes heathlands and shrublands. Those found in the mediterranean zone of the south western Cape Province, South Africa, form part of the Cape Floral Kingdom (Good, 1974) which geographically corresponds to the Fynbos Biome. It is the smallest of the six floral kingdoms of the world (Takhtajan, 1969; Good, 1974) and covers only 0.04% of the earth's surface (Hall, 1978). Its region includes numerous enclaves of adjacent floras: these, together with the Fynbos Biome contain approximately 8550 species of vascular plants which include members of seven endemic

families, 198 endemic genera and 6252 endemic species (Goldblatt, 1978). Increasing agriculture, forestry and urbanization have greatly reduced this unique flora from an original 67 000 km² to 40 000 km² (Jarman, 1982; Moll & Bossi, 1984). Additional factors such as alien plant invaders, resort development and artificially increased fire frequencies are also having an effect. The result is that an increasing number of species are becoming endangered, vulnerable or rare (Hall & Veldhuis, 1985).

This study focuses on disturbances resulting from road projects and their related quarry sites in the Mountain Fynbos heathlands of the Fynbos Biome. Mountain Fynbos is associated with the quartzitic nutrient-poor soils of the Cape Folded Belt of the Table Mountain and Witteberg Groups (Campbell, 1983). It holds economic importance for the western Cape Province because of its role in the production of high quality water for domestic and farming uses; it is also the resource for a large wild flower export industry. Mountain Fynbos contributes much to the tourist potential of the area both scenically, and in providing space for extensive outdoor recreation. It is a diverse vegetation occupying heterogeneous habitats and having high levels of endemism and species diversity (Bond & Goldblatt, 1984). Consequently it is often described as being ecologically unique (Hall, 1978; Bond & Goldblatt, 1984) and has value for education, scientific study and conservation.

The western Cape Province includes a number of urban growth points with an increasing infrastructure linking it to other major centres. South Africa's road system is built to high standards of width, grade and sight-distance with older roads being upgraded on a regular basis. This has led to a situation where old historical routes are being affected. For example, scenic mountain passes are being widened and re-aligned for the greater efficiency of road transportation causing obvious scarring that has elicited public concern. Conservationists are agitating for a more ecologically acceptable solution to the revegetation of these sites than unaided natural recovery, particularly those adjacent to scenic areas.

Revegetation is also associated with the stabilization of mined areas, and the sealing of toxic wastes such as asbestos and heavy metals contained in mine dumps. This broad field involves practitioners who need definite guidelines to produce a successful end-product. Its very nature lends itself to experimentation, but unfortunately, because of the practical nature of the task, very little information is published in the open literature (Thorhaug, 1980). That which does appear is of a very specific nature and is not universally applicable. This lack of information led to the initiation of this study in the Cape fynbos of

South Africa to provide local guidelines for conserving highly valued plant and scenic resources.

During the last 15 to 20 years some limited practical work has been carried out in the Fynbos Biome by the Horticultural Section of the Provincial Roads Department, although this has been restricted by budgets (Matthaei, 1978). Other than this, studies of disturbance in the Biome have concentrated on fire (Kruger, 1983; Cowling, 1987). Some of these fire-related studies can be useful in predicting events occurring after severe artificial disturbances but there are many gaps in ecological knowledge which need to be identified and remedied. Guidelines for the revegetation of disturbed natural areas are needed in South Africa, as public pressure is being applied to construction, development and mining companies for the revegetation of utilised areas.

Disturbances resulting from road construction and quarrying have intense local impact, resulting in all vegetation and topsoil being removed from the site. Such a severe physical disturbance to a system reduces or stops physical processes such as organic matter production and breakdown, energy flow, nutrient circulation and water movement (Ovington, 1974). If left to nature it will be many years before these processes are restored. Revegetation seeks to reduce this period by restoring the landscape to a self-sustaining

system. Fynbos is seen as the ideal vegetation for re-establishment on denuded areas as it is virtually pre-adapted to marginal situations: it has evolved under nutrient-poor soil conditions and a summer drought period. This view contrasts with the traditional South African method of sodding or sowing with commercially available grasses.

ECOLOGICAL CONSIDERATIONS

The external factors limiting plant growth in a particular habitat can be divided into two primary categories (Grime, 1979): stress and disturbance. Stress is determined by the resources, which are either absent, limited, or abundant. Disturbance levels are determined by factors which destroy the plant biomass to different degrees, such as pathogens, herbivores and man. The intensities of stress and disturbance vary a great deal from site to site, and with time. Grime (1979) has put forward four permutations of stress and disturbance. These are 1) low stress and low disturbance, 2) low stress and high disturbance, 3) high stress and low disturbance, and 4) high stress and high disturbance. Only the first three are suggested as allowing plant growth. For the first three situations Grime proposes that three kinds of plant strategies enable plants to grow under these conditions: competitors (low stress, low

disturbance), stress tolerators (high stress, low disturbance) and ruderals (low stress, high disturbance). A quarry is an area which has lost all vegetation and topsoil through clearing in order to expose utilisable construction materials. This usually results in steep slopes, exposed sub-soil, and an absence of plant propagules and organic matter as in a typical primary succession (Clements, 1916), or a high stress - high disturbance situation sensu Grime (1979). Road cuttings have steep gradients and usually a poor nutrient-status because of the exposed sub-soil. Drainage is altered because of the compacted nature of the sub-soil and the changed gradients. Again a high stress - high disturbance situation sensu Grime. Therefore, according to Grime, plants cannot exist in quarries or on roadsides. In order to prevent such severe circumstances arising, conservative construction techniques should be encouraged. One possibility involves the separate retention of the topsoil layer from the overburden for later use in revegetation programmes. In addition, the collection and storage of seed material from the site should be compulsory. This would greatly facilitate the revegetation process and improve the end-product.

Colonizers have been termed weeds (Harper, 1977), ephemerals, pioneers (Clements, 1916), r-strategists (MacArthur & Wilson, 1967) and ruderals (Grime, 1979) because of common characteristics leading to successful

establishment under marginal conditions. Generally they are annuals or short-lived perennials which enables them to exploit environments that only become favourable from time to time. They are tolerant species with a wide ecological amplitude allowing them to grow in a broad range of habitats, normally too stressful for most plants. Flowering often commences early in the plant's development, and seed ripening is rapid. This early production and maturation of seed has possibly been selected for by repeated disturbances. These characteristics lend themselves to revegetation projects, affording rapid cover to reduce initial erosion by wind and water. But because these plants are generally short-lived, the revegetation ecologist may wish to introduce longer-lived species such as resprouters to lend greater long-term stability. This would occur with time, but for an economically based operation, it is necessary to shorten the establishment phase. This could be accomplished using topsoil containing plant propagules native to the area. Depending on the length of time the topsoil has been stored, differing amounts of seed will need to be added. These aspects need further experimental investigation as few studies have considered the importance of topsoil (e. g. Hargis & Redente, 1984; Abdul-Kareem & McRae, 1984).

The importance of vegetation stands adjacent to the disturbance should not be underestimated as an important

source of colonizing plant species. In an area such as the fynbos biome known for its strong winds, and a vegetation-type with a significant concentration of wind dispersed species (Levyns, 1966), this is an important factor worth further study. Thus an area neighbouring a youthful stand of indigenous vegetation may be easier to revegetate than some other, which may be an important factor when alternative sites are being screened for development.

A revegetation programme will have different aims depending on the future use of the land, such as for agriculture, recreation or peri-urban development. If it is to resemble its former undisturbed state, certain ecological factors need to be considered. These need to be defined and separated from the more practical aspects such as the control of erosion and the creation of an aesthetically acceptable community.

Ecologically, the aims of a revegetation programme should be related to the cover, stability, diversity, resilience and successional state of the plant communities. The ideal is a diverse, stable community with sufficient cover to control erosion, resist disturbance, and yet be able to progress successionally. It is of prime importance to resolve how these different factors interact and to understand the role they each play in the dynamics of a severely disturbed area.

According to Walker and Goodman (in prep.) stability can have two meanings:

1) Temporal stability, or lack of change over time. This is similar to the idea of resistance in which a community is resistant to change.

2) A stable equilibrium is one towards which a system will return when it has been disturbed. This can be related to resilience. Resilience refers to the amount of change a system can undergo and yet still return to its original equilibrium composition.

For successful revegetation one needs to determine the desirable features of the new community: temporal stability or a stable equilibrium which shows resilience? What are the ecological factors leading to these conditions? It seems that stability could be seen as a function of

- 1) resprouter presence;
- 2) species longevity;
- 3) reproductive potential (either vegetative or sexual);
- 4) the type of disturbance regime to which it is subjected (such as burning, mowing, or herbicide use);
- 5) time since initial disturbance;
- 6) and the dispersal characteristics and colonizing abilities of adjacent communities.

An understanding of these factors will determine how the system can be manipulated and managed.

Can a severely disturbed area be made productive? According to Grime (1979), if the level of stress is also high in the area, then no member of his three plant categories would be able to survive. This emphasizes the fact that it is important to characterize the area in terms of stress and disturbance when designing a revegetation programme. Since this will determine what changes need to be made to the area, as well as what types of plants can be introduced. The reduction of stress would relate to resources and could include such measures as irrigation, erosion protection, nutrient addition and the provision of shade. Stress tolerant plants comprise an extremely diverse group which have in common the fact that they are able to survive in continuously unproductive conditions (Grime, 1979).

The classical view of succession, often called relay floristics, put forward by Clements (1916) and others, states that "after a disturbance there is a succession of species that progressively occupy the site until a state of equilibrium is reached". This is defined as an assemblage of species which is able to reproduce indefinitely. This is termed "the climax", and is said to be in equilibrium with the environment.

Subsequently, these classical ideas have been challenged and modified. Clementsian dogma is seen as being too rigid and

deterministic. With more studies focusing on succession in the 1970's, it has become apparent that the changes taking place during succession could be attributed to differing colonizing abilities, growth rates and survival strategies (Drury & Nisbet, 1973). These suggested that Clementsian ideas did not adequately address the observed successional processes, and alternative theories were proposed.

Egler's model of succession (1954) is relevant to the field of revegetation, as he stresses the importance of the "initial floristic composition" or the surviving propagules on the site immediately after the disturbance. This he regarded as a critical factor governing the direction of succession and explaining the shifts in dominance, and the gradual emergence of species which may have been present during the succession but inconspicuous after the disturbance. Egler also emphasized the importance of certain species that are able to restrict the entry of other species onto the site. This contrasts with the Clementsian idea of one suite of species improving the site and thereby allowing the next to become established, but is similar to the "inhibition" model devised by Connell and Slatyer (1977).

Horn (1976, in Noble & Slatyer, 1980) has expressed similar ideas to Egler (1954), but goes further: his views are that extreme disturbances may result in a wide range of climaxes,

depending on the propagules that were able to survive the disturbance. This does not preclude later colonization of the area, although it can be restricted by the occupants of the site which may better be able to grow under post-disturbance conditions.

Drawing on the background of available theory and observations, and in partial opposition to the classical ideas of succession, Connell and Slatyer (1977; Noble & Slatyer, 1980) have put forward three pathways along which they perceive most successional progressions developing:

1) The "facilitation" pathway which reflects the classical idea of relay floristics, in which species assemblages make way for one another until a climax stage is reached.

2) The "tolerance" pathway, in which later species are able to become established only if they are able to tolerate the presence of earlier species. This is because they are adapted to growing at lower levels of resources.

3) The "inhibition" pathway and describes those situations where later succession species cannot become established in the presence of earlier sere species, which secure available resources and so inhibit the invasion of others.

In order to maximise the benefits of revegetation, it would be desirable to incorporate aspects of Connell and Slatyer's (1977) theory of succession into the revegetation programme. That is, some species are able to grow under extreme conditions and improve the habitat for the next suite of species, and some species are able to tolerate the presence of others and are able to colonize despite their presence, and are able to grow at lower levels of resources. But this method will not strictly follow any one model, as it will be attempted to establish later succession species in the presence of earlier ones. This is because one wants to short circuit the natural succession processes in order to develop a community on a severely disturbed area in the shortest possible time and requiring the least amount of maintenance.

Eventually, the ideal is to arrive at a situation where the species composition reaches a steady-state equilibrium. The resultant stand would be stable and resilient, and able to withstand or respond to the pressures of a roadside environment.

This introduction to the field of revegetation has sought to give a theoretical basis to the study, as well as to indicate the importance of the fynbos vegetation to conservation, and hence the necessity for the development of successful revegetation techniques.

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CHAPTER 2

SPECIES RICHNESS AND COMPOSITION OF TWO DIFFERENTLY TREATED
DISTURBED MOUNTAIN FYNBOS SITES

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SPECIES RICHNESS AND COMPOSITION OF TWO DIFFERENTLY TREATED
DISTURBED MOUNTAIN FYNBOS SITES

ABSTRACT

An experiment was initiated on a gravel quarry in mesic Mountain Fynbos vegetation to rate the worth of topsoil for revegetation projects. Topsoil, which had been stockpiled for 18 months, was returned to part of the area. Vegetation re-establishment on this site was compared to that on sub-soil. Species richness, species abundance and foliage projective cover were used as parameters. An adjacent stand of ten year old vegetation was sampled as a control. Species present on the plots were divided into groups according to modes of dispersal, *viz.* anemochores, soil-borne species (geophytes, succulents and myrmecochores) and other (dispersal mechanism unknown). The recruitment of anemochores accounted for at least 50% of the species found on both disturbed areas. In contrast to the sub-soil plots, the species richness of the topsoil plots included soil-borne species. Together with the greater suitability of topsoil for seedling establishment, this factor resulted in a greater species richness and foliage projective cover on the topsoil plots. The contribution of certain structural-functional groups appears to change with time, as shown by the reduced presence of anemochores, and the increase of proteoids and ericoids in the ten year old vegetation.

INTRODUCTION

Topsoil contains many components necessary for plant growth such as nutrients, organic matter and micro-organisms, as well as soil-stored seed and vegetatively active plant parts (Bradshaw & Chadwick, 1980). These all contribute to regeneration on denuded areas.

Observations in South Africa indicate that the reinstatement of topsoil is advantageous for restoring indigenous vegetation to disturbed areas (Romoff, 1986). In the United States legislation requires that topsoil be removed from an area prior to mining or quarrying with eventual redistribution over the area once it has been backfilled (Hargis & Redente, 1984). A similar situation exists with the bauxite mines in Western Australia (Tacey & Glossop, 1980; Glossop, 1981).

In southern Africa no detailed research has been published on the role of topsoil in the re-establishment of plant communities. Tacey and Glossop (1980), and Glossop (1981) have studied the effect of different topsoil stripping techniques on vegetation re-establishment with respect to cover, species richness and species composition within analogous plant communities in Australia. The three topsoil stripping techniques assessed were stockpiling; direct

return of the whole topsoil profile; and double stripping. In the last method most of the soil is stockpiled except the top 50 mm which is returned directly. The double stripping resulted in the highest species richness values and the best cover (Tacey & Glossop, 1980). This is because the viable seed load decreased with depth in the particular topsoil studied: in fact 93% of the seedlings were said to have germinated from the top 20 mm of soil. If this were the case in the fynbos, it would be worthwhile investigating the double stripping technique in terms of fynbos floristics as well as cost-effectivity. Such a study would be of special value to mining and construction projects where topsoil is stockpiled for long periods.

The present study was prompted by the different numbers and groups of species that became established on topsoiled and non-topsoiled areas of a gravel quarry 20 km south-east of Caledon in the Cape Province, South Africa. This site falls within the winter-rainfall area of the Fynbos Biome (Day et al., 1979). The study investigated the use of topsoil in mesic Mountain Fynbos (sensu Moll et al., 1984). It is hypothesized that the process of returning topsoil to a disturbed area will result in certain groups of species becoming established, such as geophytes and those with soil-stored seed. These species groups are not expected on the sub-soil areas. This hypothesis is tested using an adjacent stand of 10 year old, undisturbed vegetation as a control.

METHODS

Before initiation of quarrying the study area was cleared of vegetation and a layer of topsoil (depth unknown) was stockpiled. The topsoil contained plant propagules, organic matter and had a more sandy texture than the sub-soil. The latter had been exposed after approximately two meters of colluvial quartzitic gravel material was removed, and had a low organic and nutrient content, was light in colour, fine grained and compacted. Soil samples were taken from both areas and analyses were performed for P, K, Ca, Mg, and Na.

Eighteen months after quarrying the topsoil was respread over part of the disturbed area. Plots were laid out at random: six 150 m² plots over a 1500 m² topsoiled area; and three 80 m² plots over a 5600 m² area of sub-soil, the surface of which had been ripped using a bulldozer. The sub-soil plots were sampled after five, nine and 12 months (November 1984, March and June 1985, respectively), and the topsoil plots after 10 months (April 1985). An adjacent community of 10 year old natural vegetation was sampled for comparative purposes. The sampling intensity and size of quadrats varied depending on the regrowth (see Table 1). Plant cover, species richness (number of species per unit area) and species abundance (number of individuals per species) were recorded.

Table 1: Sampling intensity and size of quadrats of various aged sub-soil and topsoil plots

	Number of Plots	Size (m ²)	Age of Plots (months)
Sub-soil:	8	0.25	5
	5	0.50	9
	4	1.00	12
Topsoil:	5	1.00	10

As many of the species encountered had not yet produced identifiable flowering material, pressed specimens were labelled and classified to generic level (see Appendices 1, 2 and 3). The taxa were then grouped into categories according to modes of seed dispersal proposed by Ridley (1930) and van der Pijl (1969), *viz.* anemochores (wind-dispersed species), soil-borne species (geophytes and plants able to reproduce vegetatively), myrmecochores (ant-dispersed species), and "other" (those species in which the mechanism of seed dispersal is unknown).

RESULTS

Topsoil: Of the 53 species collected from plots in the topsoiled area, 20 (38%) belong to the Asteraceae, and 8 (15%) belong to the Poaceae (see Table 2). On the assumption that these have anemochorous seed, it would seem that at least half of the species collected colonised the topsoil from adjacent areas. This contention is supported

by Table 3 where species have been sequenced in order of importance depending on their frequency of occurrence in the study plots. Of the 13 taxa with a "high" importance rating (those occurring in at least three of the six study plots), Asteraceae comprise 46% (6/13) and Poaceae 30% (4/13). A high "importance" rating indicates an even distribution in plots as well as a large number of individuals. An even distribution would be expected from anemochorous seed, as was found.

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Table 2: Species collected on topsoil plots have been divided into two groups according to their mode of dispersal. The contribution of each group to species richness is shown

Dispersal Group	Number of Taxa n=53	
		%
<u>Anemochores</u>		
Asteraceae	20/53	37.70
Poaceae	8/53	15.09
Proteaceae	1/53	1.89
<u>Soil-borne taxa</u>		
Geophytes	4/53	7.55
Succulents	4/53	7.55
TOTAL	53	69.78

TABLE 3: Species importance as determined from abundances and frequencies of occurrence in the six topsoil study plots is shown

	Species (13)	% Asteraceae (6/53 = 46.15%)	% Poaceae (4/53 = 30.77%)
Common to 6 plots	I, B, Y	100	
Common to 5 plots	C, N	50	
Common to 4 plots	D, AA, G, UA, AB	20	60
Common to 3 plots	A, LA, J	33.33	33.33

Other groups of taxa were observed (Appendix 1). These included the succulents (three species of Crassula, one member of the Mesembryanthemaceae); and geophytes (Oxalis sp., Pelargonium sp., two members of the Iridaceae), each constituting 8% (4/53) of the total. These groups are distinguished by their capacity for vegetative reproduction, either from underground organs (geophytes), or from cuttings (the succulents).

For present purposes the succulents and geophytes will be termed "soil-borne" species. These were retained in the topsoil when it was stripped. The succulents would only have survived if they were on the surface of the stockpile, whereas the geophytes could have survived burial during the 18 months of stockpiling. The topsoil was stripped from a large area which presumably supported a number of varying communities similar to the pattern of distribution that occurs in the adjacent undisturbed vegetation. Therefore a patchy distribution of individuals in these two groups would be expected; and the reason for these species not attaining high "importance" ratings.

Three of the genera in Appendix 1 (Centella, Leucadendron and Thamnochortus) have been recorded as having myrmecochorous species (Bond & Slingsby, 1983). As the Centella sp. and Thamnochortus sp. have not yet produced

seed, it is uncertain whether these particular species are myrmecochorous. Leucadendron salignum is clearly not myrmecochorous because it has winged seed adapted for wind dispersal (Vogts, 1982). Although it has been postulated that myrmecochory is a recently evolved mechanism (Berg, 1981), the seed of L. salignum does not have an elaiosome (personal observation). It is not yet certain whether any of the other species are myrmecochorous.

Of the remaining species not included in these groups two species of Anthospermum and L. salignum appear to be anemochorous. The remaining ten species have not been ascribed to any of the groups as their dispersal mechanisms have not been established.

Despite these uncertainties, it appears that about 50% of the species growing on the topsoil after 12 months were wind-dispersed species.

Sub-soil: In contrast to the topsoil plots, significantly fewer species were noted, i.e. four in total ($t= 6.27$, $df= 7$, $P>0.01$). Again, at least 50% of these species are anemochorous (Table 4). Although this percentage is high, there are significantly less anemochorous species ($t= 5.37$, $df= 7$, $P> 0.01$).

Table 4: Taxa found on the three sub-soil plots have been divided into two groups according to their mode of dispersal. The contribution of each group to species richness is shown

Dispersal Group	Number of Taxa n=4	%
<u>Anemochores</u>		
Asteraceae	1/4 - 3/4	25 - 75
Proteaceae (<u>L. salignum</u>)	1/4	25
<u>Soil-borne taxa</u>	0	0

Natural vegetation: Appendix 3 shows a species list for an adjacent stand of 10 year old undisturbed mesic Mountain Fynbos. This allows a comparison of species between the natural vegetation, the vegetation establishing on the sub-soil, and that on the topsoil plots.

Table 5 indicates the various components of the natural vegetation and their importance in terms of species number and cover. Comparison of Tables 2 and 5, shows that with increasing age of the community, the Asteraceae become reduced in importance (from 37.7% of the total species to 17%), and the Proteaceae begin to emerge as a dominant group. Although the 10 year old vegetation appears to be relatively rich in geophytes (six species =13%), their cover is minimal ($x = 1.88 \pm 1.36$, $n= 8$). This would be due to the time after fire (10 years) and the resultant high value of total foliage projective cover for the area ($73.13\% \pm$

9.23). This is supported by Specht et al.'s model (1983) for the regeneration of post-fire vegetation in the fynbos where early in the pyric succession short-lived understory species were found to regenerate rapidly reaching a peak in foliage projective cover relatively soon. In contrast the longer-lived overstory species were observed to regenerate more slowly. The emerging overstory species caused a consequent decline in the understory species. The cumulative result of Specht et al.'s study (1983) was the observed constant increase in foliage projective cover which peaks at 10 to 15 years post-fire (depending on the hydrology of the site) and then levels off.

Table 5: The various components of the 10 year old mesic Mountain Fynbos are shown with their contribution in terms of species number and cover

Vegetation Component	Number of Species		Cover
	n = 46	%	%
Asteraceae	8/46	17.39	18.75
Proteaceae	7/46	15.22	15.00
Geophytes	6/46	13.04	1.88
Poaceae	4/46	8.70	6.38

In the present study the 10 year old vegetation appeared to be more structured than that on the topsoil and sub-soil plots, in having a clearly defined ground cover, understory, overstory and emergent story.

After 12 months of growth, the topsoil plots showed a mean foliage projective cover of 23.65%, whereas the sub-soil plots had a mean of 0.45% (Table 6). Thus the topsoil plots had a significantly greater cover ($t= 0.66$, $df= 30$, $P= 0.01$), although this was far less than that of the 10 year old stand.

Table 6: Comparison of the foliage projective cover of equal aged topsoil and sub-soil areas, together with that of an adjacent stand of 10 year old vegetation (s. d. is the standard deviation from the mean, and n is the number of plots)

Plot	Age	% Cover	s. d.	n
Sub-soil	12 months	0.45	0.19	12
Topsoil	12 months	23.65	7.48	20
10 Year Vegetation	10 years	73.13	9.23	8

DISCUSSION

The study was conducted 12 months after establishment of the topsoil and sub-soil plots in order to scientifically evaluate the primary seral stages occurring on a severely disturbed area. Because it was not possible to identify all plants to species level due to the lack of flowering material, it is necessary to emphasise the preliminary nature of the present investigation.

Results indicate that the recruitment of wind-dispersed species plays an important role in the colonization of the topsoil plots. Although anemochorous species constitute at least 50% of the species on sub-soil plots, this amounts to significantly fewer species (at most four). This explains the significantly lower foliage projective cover. Anemochorous species are also found in the 10 year old vegetation, but their importance is reduced by the emergence of overstory species. Overstory vegetation includes the ericoids (e. g. five Aspalathus spp.; three Erica spp.); as well as the proteoids (five genera, containing seven species).

Although the recruitment of wind-borne ephemerals contributes a significant number of species to the topsoil plots, other groups also enhance the species richness of the area. The succulents, geophytes and myrmecochores were conveyed to the site in the topsoil. These groups were not found on the sub-soil plots, but nevertheless contribute further to the vegetative cover of the 10 year old vegetation. Presumably they were present on the site before quarrying began, and were able to survive in the topsoil during the 18 months of stockpiling.

Over time stockpiles have been shown to become increasingly anaerobic, resulting in a loss of organic matter, a disruption of microbial populations, and a change in the

chemical and physical properties of the soil (Hunter & Curry, 1956; Miller & Cameron, 1976; Abdul-Kareem & McRae, 1984). However, some of these changes are reported to be reversible once the topsoil has been spread (Abdul-Kareem & McRae, 1984), but must have a permanent effect on certain plant propagules stored in the soil (Hinchman, 1980; McGinnies, 1980 both in Hargis & Redente, 1984).

The propagules contained in the topsoil, together with its suitability for plant establishment and growth is associated with a significantly greater species richness in comparison to the sub-soil plots. This value is also higher than that of the 10 year old vegetation (Appendices 1,2 and 3).

In terms of traditional successional theory, the flora on the sub-soil plots appears to substantiate the Clementsian concept (1916) of primary succession, as the species found are the most vagile ephemerals. Sampling of these plots during the first 12 months indicates that the recruitment of species is slow, because later seral species colonise from the edges of the disturbance (Connell & Slatyer, 1977).

This contrasts with the situation apparent on the topsoil plots where propagules from the previous stand of vegetation were present after the disturbance. This is similar to "old field succession" as described by Egler (1954). In an old agricultural field, seed and rootstocks remaining in the

soil after the disturbance influence subsequent species composition and the direction of succession. More recently Noble and Slatyer (1980) have made certain generalizations about succession, one being that the species composition following a disturbance is dependant on propagules which have persisted through the disturbance. This would not apply to the sub-soil plots because the topsoil was not replaced, and much of the sub-soil was removed during quarrying.

These hypotheses are substantiated by the observation that the topsoil plots, after 12 months, have several early seral species, e. g. ephemeral composites and grasses, as well as many taxa characteristic of later seres e. g. Erica, Aspalathus, L. salignum and Hermannia. The topsoil plots were also observed to support a greater species richness and foliage projective cover than the sub-soil plots. It follows, therefore, that structural vegetation development will proceed more rapidly. As would be expected of a later seral stage, the 10 year old vegetation has a greater foliage projective cover and a well developed structure.

CONCLUSION

Despite the preliminary nature of this work, results clearly demonstrate the vital importance of topsoil for revegetation work. Firstly, it represents a ready source of soil-stored

seed, and secondly, an important "seed trap" providing the necessary environment in which recruited propagules can become established. In contrast to the ripped sub-soil, it results in a more rapid cover and a greater species richness. Time will show whether or not the succession generated by the early species composition on the topsoil will result in a natural community capable of stabilising the soil, reducing the erosion, and blending with surrounding Mountain Fynbos communities.

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APPENDIX 1

List of taxa collected from the topsoiled study area during April and May 1985

ANEMOCHOROUS TAXA

- | | |
|--|----------------------------------|
| Asteraceae (20 species) | Poaceae (7 species) |
| A - <u>Hypochoeris</u> sp | G - <u>Pentachistis</u> sp |
| B - seedling | O - <u>Plagiochloa uniolae</u> |
| C - seedling | AA-unknown |
| D - <u>Hypochoeris</u> sp | LA- <u>Dactylis glomerata</u> |
| E - <u>Phaenocoma prolifera</u> | TA-unknown |
| F - <u>Hypochoeris</u> sp | UA- <u>Cynodon dactylon</u> |
| I - <u>Stoebe fusca</u> | GB-seedling |
| L - <u>Elytropappus rhinocerotis</u> | |
| P - <u>Helichrysum</u> sp | WA-Cyperaceae |
| X - <u>Chrysocoma/Cotula</u> seedling | |
| Y - <u>Athanasia trifurcata</u> | Rubiaceae (2 species) |
| Z - <u>Metalasia</u> sp | DA- <u>Anthospermum</u> sp |
| CA- <u>Ursinia</u> sp | HA- <u>Anthospermum</u> sp |
| FA- <u>Stoebe</u> sp | |
| IA- <u>Helichrysum</u> sp | Proteaceae (1 species) |
| JA- <u>Helichrysum/Elytropappus</u> sp | MA- <u>Leucadendron salignum</u> |
| QA- <u>Echium</u> sp | |
| SA- <u>Cotula</u> sp | |
| KA- <u>Erigeron capensis</u> | |
| NA- <u>Gnaphalium</u> sp | |

SOIL-BORNE TAXA

Geophytes

- Oxalis sp
EA-Iridaceae
XA-Aristea africana
ZA-Pelargonium sp

Succulents

- GA-Crassula sp
OA-Crassula sp
RA-Crassula sp
Q - Mesembryanthemaceae

Myrmecochores

- R - Centella sp
W - Thamnochortus sp

OTHER TAXA

- M - Hermannia sp
N - Selago sp
S - seedling
U - Erica sp
Asp-Aspalathus sp
AB-Polygonaceae
J - Pharnaceum/Coelanthum sp
PA-Chenopodiaceae
YA-Campanulaceae
ZB-Struthiola sp
HB-unknown
IB-unknown

CHAPTER 3

A COMPARISON OF SEED HARVEST TECHNIQUES FOR THE REVEGETATION
OF A DISTURBED MOUNTAIN FYNBOS AREA IN THE WESTERN CAPE,
SOUTH AFRICA

University of Cape Town

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ABSTRACT

A range of seed harvesting techniques was assessed for use in the revegetation of a topsoiled area. The experimental site was a quarry adjacent to indigenous stands of vegetation available for harvesting. The following harvest techniques were compared: Hand Harvesting, Brushcutting, Imprinting, Chipping, Suction Harvesting, and Suction Imprinting. A number of hypotheses were tested: a) would the foliage projective cover (FPC) of a revegetated site be a result of the harvesting technique used; b) would this observed FPC be a result of the time of year in which the material was harvested; and c) could the species diversity of the revegetated site be attributed to the harvesting technique used. DECORANA and TWINSPAN were used for data analysis. Results indicated that a single or combination of unaccountable variables had a greater effect than the applied treatments. These results were explored, and trends have indicated the importance of the mulching effect of applied harvested material which increased cover and species diversity above that of a control.

INTRODUCTION

The Fynbos Biome (Kruger, 1979) is roughly equivalent to Capensis (Taylor, 1978), one of the world's six floral kingdoms as described by Takhtajan (1969). Fynbos has a very diverse flora occupying heterogeneous habitats. This has resulted in a high level of endemism and a concomitant high conservation rating (Hall & Veldhuis, 1985). With increasing human population pressures, this vegetation is threatened by increasing urbanisation and development (Jarman, 1982). Fortunately, a growing conservation awareness is pressurizing developers not only to revegetate disturbed areas, but to use indigenous species (Romoff, 1986). Revegetation is termed successful when there is a rapid initial cover of pioneers, followed by an accumulation of species resulting in a diverse stand that blends with the surrounding indigenous vegetation. However, very little indigenous seed is available commercially, partly because harvesting from particular species is labour intensive and difficult in a biome characterised by heterogeneous habitats, and partly because demand is unpredictable. Accepting that local species are best adapted to their own areas, generalist methods of harvesting aimed at gathering seed from the whole community are favoured. This is in contrast to practices in grassland areas of southern Africa where a limited number of suitable, commercially available grass species are used. For the purposes of fynbos

revegetation where a highly diverse product is desirable, other techniques need evaluation.

South Africa's revegetation skills are inferior to First World countries such as Australia and the United States, yet our transportation standards rate with the best in the world. High standards and continuing construction programmes afford the opportunity to experiment with, and implement a variety of revegetation techniques.

No quantitative comparison of revegetation techniques has been published for the Fynbos Biome. Because of its high conservation status (Hall & Veldhuis 1985), the scale of disturbance requires the development of revegetation skills. The experiment reported on here was designed to provide this knowledge.

The following hypotheses were tested: a) is the observed foliage projective cover (FPC) a result of the harvesting technique used; b) is the resultant FPC dependent on the time of year of harvest; and c) does the harvesting technique have any affect on the species diversity of the plots.

It is predicted that the FPC will be affected by the choice of technique because each focuses on variable seed-stores in the soil and canopy. Also, FPC and species diversity are

predicted to be affected by season of harvest because of phenological characteristics of the fynbos, the majority of seed being ripe in autumn.

METHODS

The study area was situated in the Caledon District, Cape Province, South Africa. It consisted of a gravel quarry with an adjacent stand of mesic Mountain Fynbos (sensu Moll et al., 1984). It experiences cool wet winters (mean day-night temperature 13.6° C) and warm dry summers (mean day-night temperature 19.6° C). The soil is nutrient-poor with a low pH and is derived from quartzitic parent material. The site is located on a slope of 4.5 degrees facing SSE.

Preparation for the experiment involved the spreading of a layer of the original topsoil (10 to 15cm thick) over the disturbed quarry area. The topsoil had been stockpiled prior to mining 18 months before. One hundred plots (10 x 15m) were laid out allowing for three replicates of thirty treatments and controls. Treatments consisted of spreading seed-bearing material harvested in different ways and at different times of the year over the plots. Treatment replicates were harvested from three areas (sites A, B and C) of young (8 years post-fire) mesic Mountain Fynbos chosen for their homogeneity.

The following harvest techniques were employed: Hand Harvesting (H), Brushcutting (B), Imprinting (I), Chipping (C), Suction Harvesting (S), and Suction combined with Imprinting (SI).

Hand harvesting (H) is aimed at collecting fruiting bodies held on the plants. Serotinous seed was selected, as well as the current season's crop. A disadvantage of this technique is that male inflorescences of dioecious species as well as flower heads and immature fruits were harvested.

Brushcutting (B) is carried out with a forage harvester that cuts all vegetation 5 - 10 cm above the ground, depending on the terrain. The cut material acted as a mulch as well as a seed source. This was raked up and placed directly on the randomly allocated plots. A problem was that wind tended to blow the material around which is why the Imprinting technique was tested.

Imprinting (I) was implemented using a bulldozer which was driven over spread brushcut material to incorporate it into the ground. This is not a practical technique on steep slopes and involves an added expense.

Chipping (C) was carried out with the use of a garden shredder. Material was first brushcut and then fed into the

shredder which produced chips approximately 7cm in size. This material was found to lodge well on uneven ground.

Suction (S) harvesting makes use of a motor-driven industrial "vacuum cleaner" which sucks seed and fruiting bodies from plants and the litter layer. In this way, drier material and litter were collected, including such things as soil microflora and ants. This could be significant in a flora where myrmecochory plays an important role (Bond & Slingsby, 1984).

Suction Imprinting (SI) is a multiple treatment: material was brushcut and removed to the establishment plot. Then the same harvest area was suction harvested in order to collect material that had escaped collection. This was then placed on the establishment plot.

The application of Hand and Suction harvested treatments was carried out every two months for a year, while Brushcutting, Imprinting, Suction Imprinting and Chipping treatments were carried out twice during the summer and winter of the same year. The experimental design is shown in Figure 1. Five permanent 1X1m quadrats were randomly placed in each treatment plot for sampling. Variables measured were species abundances and total foliage projective cover (FPC).

Data were collected 12 and 18 months after the experiment was established. Species identification was difficult because of the lack of fruiting material on the immature plants.

Descriptive statistical techniques were used to highlight trends in the results. Data were classified using TWINSpan (Hill, 1979a) and ordinated by detrended correspondence analysis (DECORANA, Hill, 1979b), a form of reciprocal averaging that ordines plots and species simultaneously (Hill & Gauch, 1980). Student's t-test was used to find differences between the results of the treatments, and between the Shannon-Wiener indices of diversity (Siegel, 1956).

At a later stage topsoil depths were measured by digging small holes at random over the experimental site.

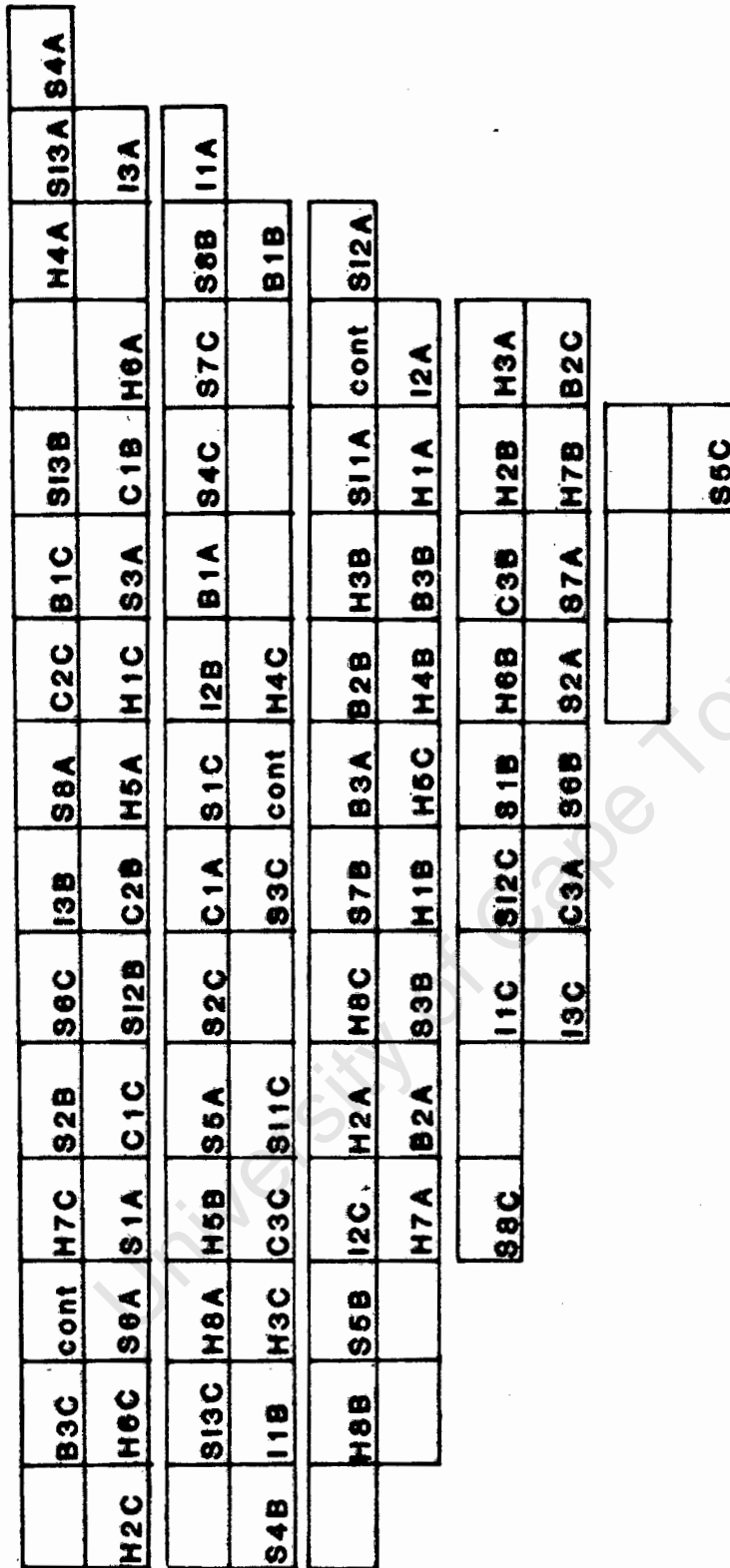


Figure 1: The experimental design is represented here. Plots are 10 X 15m² and are arranged on a SSE slope of 4.5 degrees. Each plot is coded according to treatment (where S= Suction Harvesting, H= Hand Harvesting, B= Brushcutting, C=Chipping, I= Imprinting and SI= Suction Imprinting); month of harvest (where 1= June, 2= August, 3= October, 4= December, 5= February and 6= April); and replicate A, B or C.

RESULTS

Species abundance data were tested for similarity between treatments using TWINSpan and DECORANA. Groupings for 12 month and 18 month old data were found to be identical. All Euclidian distances were equal to zero and no successional trajectories were apparent after this period of time. Therefore only the 18 month old data will be discussed. Figure 2 shows the DECORANA ordination on which the four major TWINSpan divisions are superimposed. When referring to Figure 3, one can see that when the four TWINSpan divisions are superimposed on the experimental plots, they fall into blocks suggesting some form of overriding environmental effect, rather than the influence of the randomly applied treatments.

Cover, diversity and season of harvest data were further investigated to qualify these trends. An investigation of FPC values shows that the majority of treatments result in the same or greater cover than the control. However, treatments do not differ significantly from each other.

The Shannon - Wiener index of diversity was used to highlight differences resulting from the various techniques (Table 1). This index shows that the majority of treatments produce a significantly greater species diversity than the control. In addition, the Chipping treatment had a greater

species diversity than the Brushcutting (probably because the material was less susceptible to wind removal), and the Suction Imprinting combination is better than the Imprinting technique (as was expected because it is a double treatment). Otherwise treatments did not differ from each other.

Table 1: Shannon - Wiener indices of diversity were calculated for all treatments and controls, and were compared using Student's t-test. Treatments showing significant differences are shown below (numerals refer to time of year of harvest, i. e. 1= June, 2= August, 3= October, 4= December, 5= February, and 6= April)

Suction Imprinting 2 > Imprinting 1

Imprinting 1 < Hand Harvesting 6

Brushcutting 1 < Chipping 1

Brushcutting 3 < Chipping 1

Control < Imprinting 1, Suction Harvesting 1, Suction Harvesting 6, Brushcutting 1, Brushcutting 3, Suction Imprinting 1, Suction Imprinting 3, Chipping 2

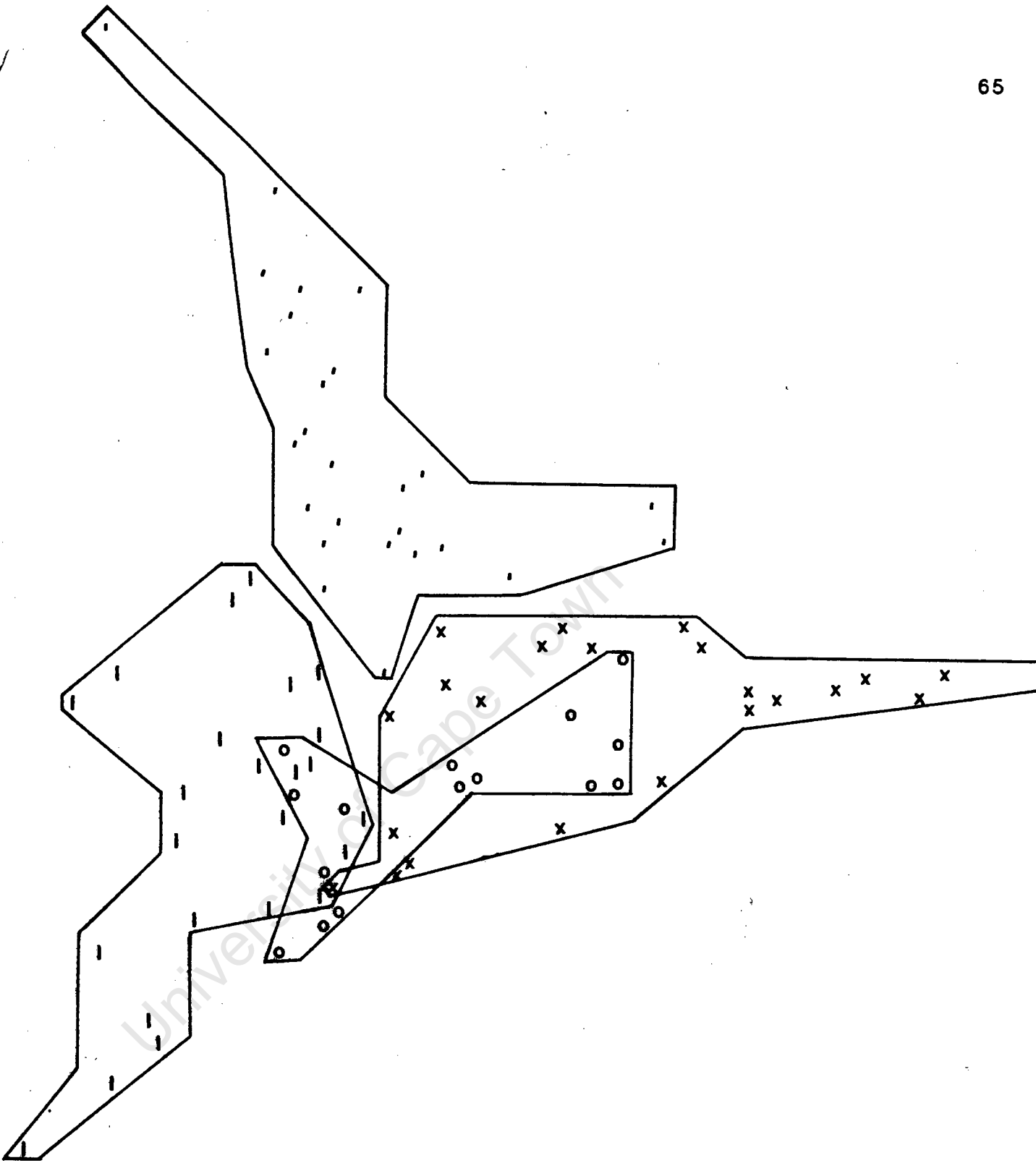


Figure 2: DECORANA was used to ordinate vegetation data from 18 month old plots. These data were also classified using TWINSpan. The resulting four major divisions have been superimposed onto the ordination. TWINSpan divisions are represented as: 1= x , 2= ' , 3= | , 4= o

	B3C	cont	H7C	S2B	S6C	I3B	S8A	C2C	B1C	SI3B		H4A	SI3A	S4A
H2C	H6C	S6A	S1A	C1C	SI2B	C2B	H5A	H1C	S3A	C1B	H6A		I3A	
	SI3C	H8A	H5B	S5A	S2C	C1A	S1C	I2B	B1A	S4C	S7C	S8B	I1A	
S4B	I1B	H3C	C3C	SI1C		S3C	cont	H4C				B1B		
	H8B	S5B	I2C	H2A	H8C	S7B	B3A	B2B	H3B	SI1A	cont	SI2A		
			H7A	B2A	S3B	H1B	H5C	H4B	B3B	H1A	I2A			
	S8C				I1C	SI2C	S1B	H6B	C3B	H2B	H3A			
					I3C	C3A	S6B	S2A	S7A	H7B	B2C			
														S5C



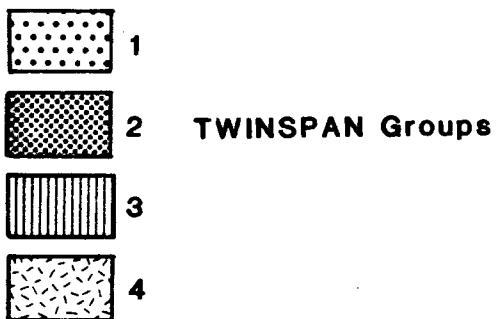
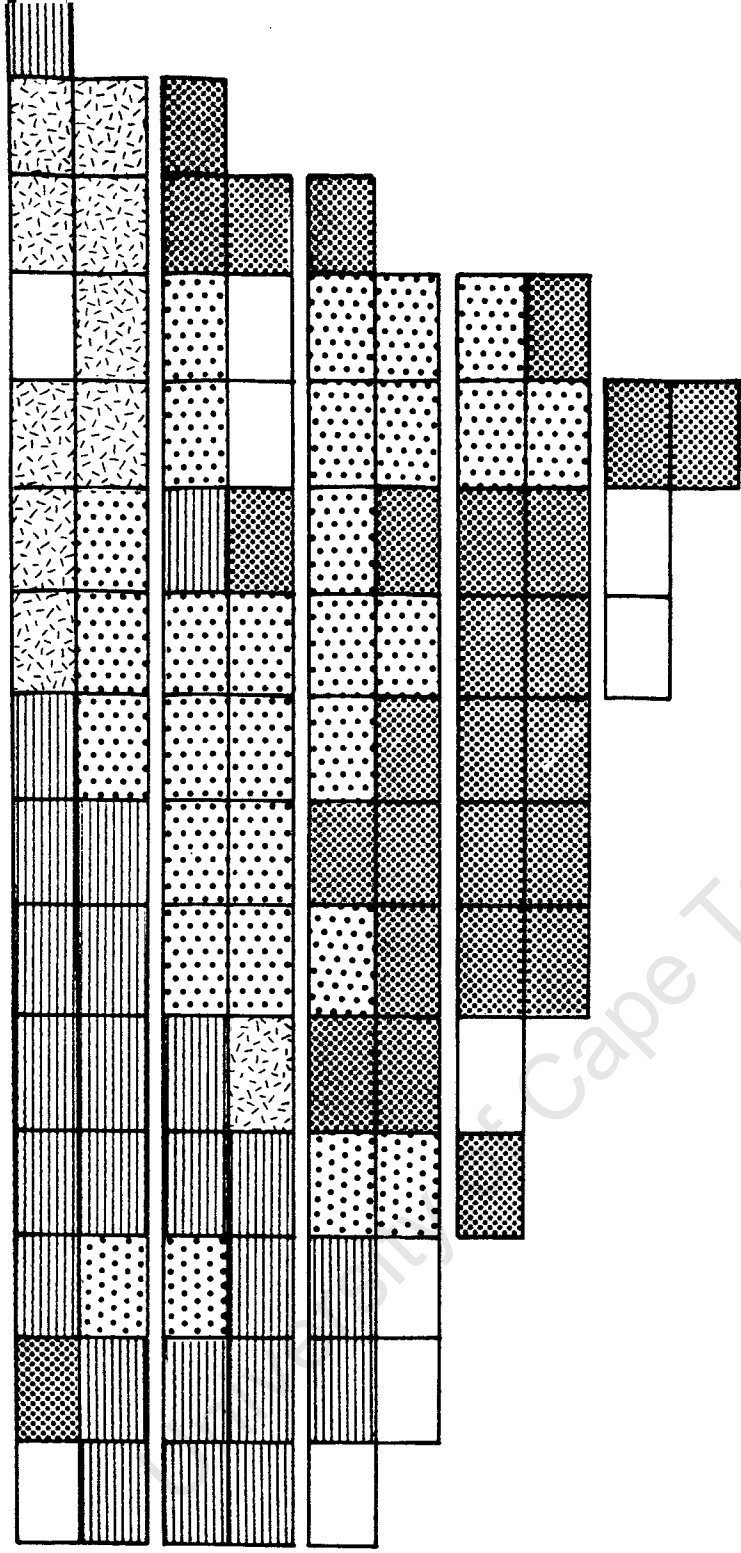


Figure 3: The four major TWINSpan groups have been superimposed on a layout of the experimental plots showing the formers' non-random positioning.

When comparing the FPC resulting from different harvest times of the year, Hand harvesting shows differences between spring and summer. However, this is not apparent in the other treatments.

The distributions of dominant species over the experimental area were studied. An attempt was made to find patterns and to relate them to some causative factor. However, this was unsuccessful.

Because of these uncertain results, investigations into environmental factors were carried out. Topsoil depth and predominant wind direction data were collected. Table 2 shows the average depths of the topsoil for plots falling into the four groupings; the predominant wind was south-east in summer and north-west in winter, and the nutrient levels were low but more or less constant over the area.

Table 2: Topsoil depths were collected from plots falling into the four TWINSPAN groupings. Columns 1,2,3 and 4 refer to those groupings shown in Figure 3

TWINSPAN Group	1	2	3	4
Topsoil Depths (cm) n=7	10	12	12	13
	9	40	10	16
	10	40	15	10
	8	9	6	7
	8	15	12	14
	8	24	12	10
	10	22	10	14
Average Topsoil Depth per Group (cm)	9	23.1	11	12

DISCUSSION

Differences were expected between treatments because of the selectivity of the harvest techniques. However, this was not apparent. The expected effect may have been masked by propagules stored in the topsoil and from seed blown onto the site. Otherwise environmental factors on the site are playing an important, although unexpected role. This could explain why control plots come out in different groupings of the TWINSPAN analysis indicating that they are governed by their position on the slope.

Results were unexpected and further tests were carried out to elucidate. However, the more obvious environmental factors were ruled out. Topsoil depths over the site were

not correlated with the four TWINSPAN divisions, and neither were the predominant wind distributions or nutrient analyses.

Because of the variability of the data and the poor experimental design, only trends can be extracted from the results. These indicate the importance of harvested material, in whatever form, because this increases the diversity and cover of the plots above that of the control. As has been shown in Chapter 2, topsoil, as long as it is stored correctly, contains seed and plant propagules which contribute to the resulting growth of the establishing plots. Perhaps then, the harvested material in these experiments is acting as a mulch rather than as a seed source. It increases the organic content of the disturbed area, providing a suitable microhabitat in which seed can lodge, germinate and become established. It would have been interesting to test this by the inclusion of a treatment in which a seed-free organic source such as wheat straw was added to a topsoiled plot. This would have financial implications, as a great deal of money is expended on the harvesting of indigenous seed material and its rapid transportation. This also has implications for the harvest areas which are disturbed to some degree by the gathering of material (Griffin & Hopkins, 1981).

This indicates that the most cost-effective harvesting treatment should be used, because so long as seed is introduced to the disturbed area the result will be an improvement on the control.

CONCLUSION

This experiment has given some answers but has also raised more questions. Trends show that harvested material is beneficial, increasing species diversity and in some cases cover. Why this should be is not clear, but one possibility is that harvested material acts as a mulch which ameliorates conditions on the exposed plots. Whether or not a particular harvesting technique is better than any other is unclear as results are variable, and differences are not often significant. Environmental factors could be important but unfortunately there were too many variables to single out causative factors. Certainly environmental factors are of relevance to the practicalities of setting up a revegetation project. Problems were experienced with wind disturbing harvested vegetation once it was laid on the plots, and winter run-off was found to wash away less stable areas. Despite these drawbacks, results do emphasise the role of the correct microhabitat in which seed can germinate and become established.

An unknown in fynbos revegetation is the role of fauna. Are seed predation and burial rates significant? This needs to be studied in fynbos where myrmecochory is known to play a significant role. In a highly disturbed area the non-myrmecochorous invasive argentine ant (Iridomyrmex humilis) is likely to abound - are they preying on the harvested seed and reducing the material to a seed-free mulch?

A rapid method of resolving the ambiguities of these results would be to choose two harvest techniques and a treatment of seed-free organic mulch and set up a small experiment with sufficient replicates and controls in order to show whether mulch does indeed play a greater role than seed sources. Good qualitative results would be greatly relevant to revegetation contractors in the fynbos. Suitable stands of the correct indigenous vegetation are not often available for harvesting and no expense is spared transporting harvested material as rapidly as possible to ensure that no composting and consequent loss of seed viability occurs. The impact of harvesting for revegetation is obviously not desirable.

This experiment would have been better designed if fewer treatments were chosen with more controls. It was set up on the slope of a quarry because of its availability and proximity to suitable harvest sites, but this has contributed to the variability of the results. It would

have been more appropriate to choose a flat homogeneous area and to incorporate wider buffer zones between the treatment plots. Then results could more confidently be attributed to applied treatments. Nevertheless, this experiment has served a useful purpose in indicating trends and highlighting revegetation questions for the future. Further work of this nature must be encouraged in fynbos areas which are important to conservation but are threatened by development.

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CHAPTER 4

NUTRIENT APPLICATION FOR THE REVEGETATION OF DISTURBED
FYNBOS AREAS

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NUTRIENT APPLICATION FOR THE REVEGETATION OF DISTURBED
FYNBOS AREAS

ABSTRACT

Commercially available fertilizers were applied to a highly disturbed heathland site to investigate their role in the re-establishment of indigenous vegetation. High and low concentrations and combinations of nitrogen and phosphorus were tested. A Desirability Index was developed for the fynbos heathland to gauge the success of different treatments. This considered the species diversity resulting from the treatments, and more importantly, it assessed the type of species making up the diversity and their suitability for revegetation purposes. Variables such as species richness and cover all showed an increase in value with an increase in nutrient addition. Results indicate that the combination of high N and P are the most successful in this instance, but conclusions stress the importance of soil analyses.

INTRODUCTION

It is generally considered that topsoil is important when restoring indigenous vegetation to heavily disturbed areas (Quilty, 1975; Hargis & Redente, 1984), but there are occasions when little, or none is available. This could be caused by a thin topsoil layer, by losses through inadequate planning at the start of construction projects or by contamination with the seed of invasive alien plants. Therefore the determination of suitable methods to ameliorate sub-soil by chemical means is often necessary. For this reason the present experiment was designed to investigate the effect of a range of commercially available fertilizers on the re-establishment of indigenous Mountain Fynbos. The site had been severely disturbed and only sub-soil was available for revegetation.

The fynbos of the south-western Cape, South Africa, is able to grow in oligotrophic soils because of adaptations that have evolved in response to the environment (Mitchell et al., 1984). It has an highly evolved flora with many endemics and has been categorised a primary heathland (Specht, 1979; Moll & Jarman, 1984) unlike northern hemisphere heathlands that are derived floras. This edaphic determination of vegetation structure concurs with Beadle's work (1966) which shows that soil properties can affect floristics and vegetation structure.

Studies dealing with nutrient additions in heathlands are relevant to this study. Because indigenous heath species are more productive than agricultural species grown under nutrient-poor conditions (Specht & Groves, 1966; Grundon, 1972) fynbos is favoured for revegetation purposes in the south-western Cape. Its use is seen as cost-effective when the financial implications of fertilising and irrigating are considered.

The rapid revegetation of disturbed areas around development projects such as road cuts and fill slopes is vital for the protection of the engineering works. It is necessary that vegetation cover is introduced as soon as possible to control erosion. If these attempts lead to an indigenous sward it is a bonus and so should be planned, but it is important to realise that the first aim of revegetation is erosion control.

The secondary role of revegetation in the Fynbos Biome is the restoration of the indigenous vegetation because of its high conservation rating. It comprises Taylor's Capensis (1978) which is rated as the smallest and richest of the six floristic kingdoms of the world (Takhtajan, 1969). Its diversity of species and heterogeneity of habitats supports a large tourist industry which would be affected by the increasing number of impacts on the environment.

Because of the practical nature of revegetation work, very little published literature is available (Thorhaug, 1980). Studies to investigate the effects of nutrient additions in heathlands have shown the following trends: phosphorus applications lead to phosphorus toxicity and hasten maturation and flowering in Australian heath stands (Specht, 1963; Heddle & Specht, 1975). Standard fertilizers cause seedlings to die before establishment (Christensen, 1974; Heddle & Specht, 1975; McGrath, 1979), allowing the colonization of non-endemics at the expense of original components (Koch & Pickersgill, 1984). This causes a shift in floristics from a sclerophyllous to an herbaceous vegetation (Specht & Groves, 1966; Connor & Wilson, 1968).

Despite these findings, situations often arise in contracting where topsoil is unavailable. Therefore techniques of ameliorating the subsoil need to be found when revegetation is required.

METHODS

A sandstone gravel quarry was used for the experiment. The area was ripped with a bulldozer to break up the sub-soil surface. Plots of 10 X 8m were laid out with 1m buffer strips between alternate plots. Then the various fertilizer treatments were applied and worked into the soil.

Treatments used were High N+P (100kg N/ha and 71kg P/ha), Low N+P (50kg N/ha and 30kg P/ha), High N (56kg N/ha), Low N (14kg N/ha), High P (105kg P/ha), Low P (21kg P/ha), and Control (no nutrients added). A regular mixture of seed and mulch material, that had been harvested from an adjacent stand of fynbos by means of a brushcutter and suction harvester, was evenly applied in a 3-6 cm layer to all plots.

Sampling was carried out at five, nine, 13, and 25 months after establishment. Stratified random sampling was used (Muller-Dombois & Ellenberg, 1974), five 1X1m quadrats being placed in each of the three replicates. Variables measured were species richness, species abundance and total foliage projective cover.

Statistical analyses: after an arcsine transformation (Zar, 1974), mean cover values were compared using a one-way ANOVA followed by a Newman-Keuls multiple range test (Zar, 1974). Species richness values for different treatments were compared using the Mann-Whitney U-statistic (Siegel, 1956).

Pielou (1986) has commented that to gauge the success of a revegetation project it is as necessary to assess the species composition of an area as it is to measure the diversity. With this in mind I developed a Desirability Index as a measure for comparing treatments and their

revegetation success. This index takes into consideration characteristics of the species growing under a particular treatment which maybe advantageous for revegetation purposes. Experience has shown that the ideal species for fynbos revegetation is a resprouting perennial found in mixed communities, that takes four to eight years to set seed and develops a large canopy to reduce the impact of raindrops, thereby reducing erosion. Each species can be rated according to these criteria (Table 1), and then by adding the rating of each species found in a particular treatment, an index can be calculated for each treatment (Table 2).

Table 1: In order to rank species for the Desirability Index each was scored (score is between brackets) for the five different categories as presented. The ideal plant for fynbos revegetation is therefore a perennial fynbos resprouter taking four to eight years to reach maturity and having a high canopy cover

-
- 1) Annual (1) or Perennial (5)
- 2) Agricultural weed(0) Renosterveld element(2) Fynbos element (5)
- 3) Years to maturity: 0-3yrs (1) 4-8yrs (5) 9-15yrs (4)
- 4) Canopy cover of individuals: 0-5%(1) 6-15%(2) 16-30%(5) >30%(5)
- 5) Category: reseeder (3) resprouter (5) geophyte (2)
-

Table 2: After species had been rated according to Table 1, those occurring under each treatment were added to give the Desirability Index of each treatment. Indices are displayed for 13 and 25 months data.

Treatments	Diversity Indices for	
	13 Months	25 Months
High N+P	169	218
Low N+P	143	212
High P	112	180
Low P	86	150
High N	59	116
Low N	59	90
Control	59	75

RESULTS

Soil analyses (Table 3) indicate a poor nutrient status for the subsoil which is lower than that shown by the adjacent topsoil.

Table 3: Results show soil analyses of samples taken from sub-soil areas before the experiment was initiated. Samples of an adjacent area of topsoil have been analysed for comparison

	pH		AVAILABLE PLANT NUTRIENTS (ppm)				
	KCl	H ₂ O	P	K	Ca	Mg	Na
TOPSOIL	5.05	5.6	<3	45	224.5	79.5	25
SUBSOIL	4.25	5.1	<3	32.5	79.5	55	28

	SOIL TEXTURE (%)			
	SAND		SILT	CLAY
	COARSE	FINE		
TOPSOIL	65	27	6	2
SUBSOIL	51	24.5	18.5	6

The High N+P treatment results in the highest cover (Fig. 1) (significant at $p=0.001$, Newman-Keuls test, Zar, 1974) for both 13 month and 25 month data. No other treatment differs significantly from any other or the control.

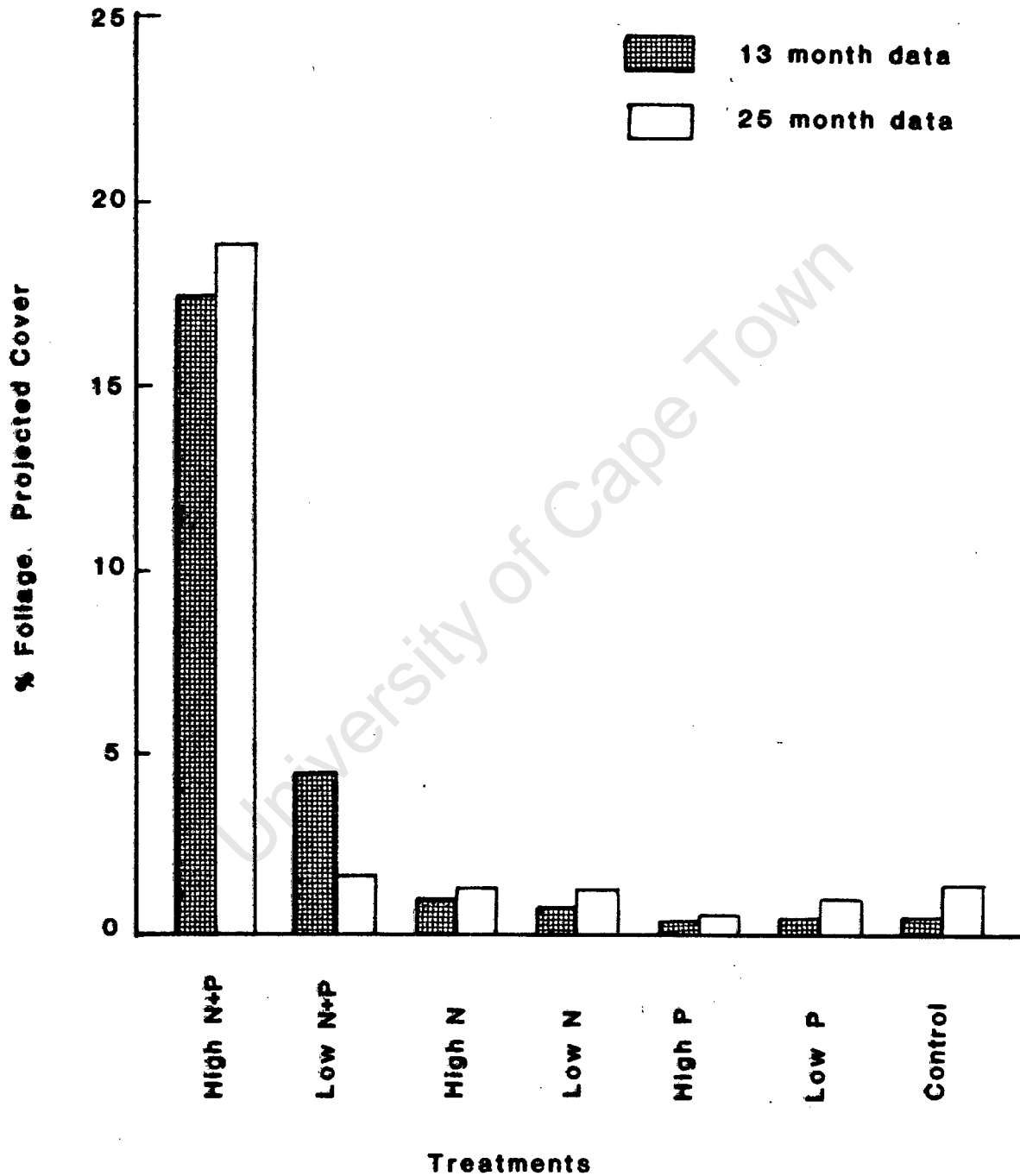


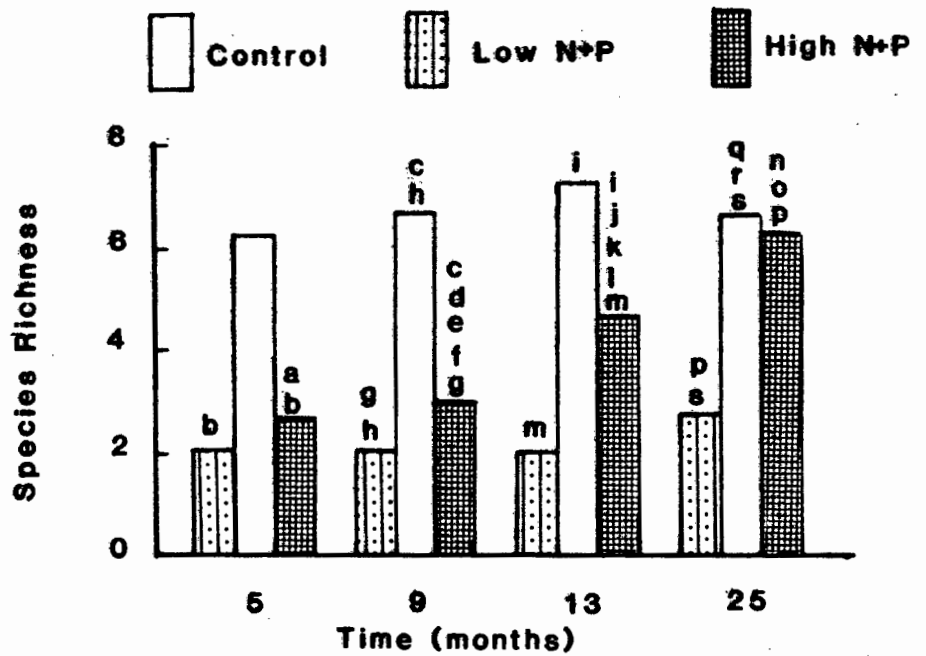
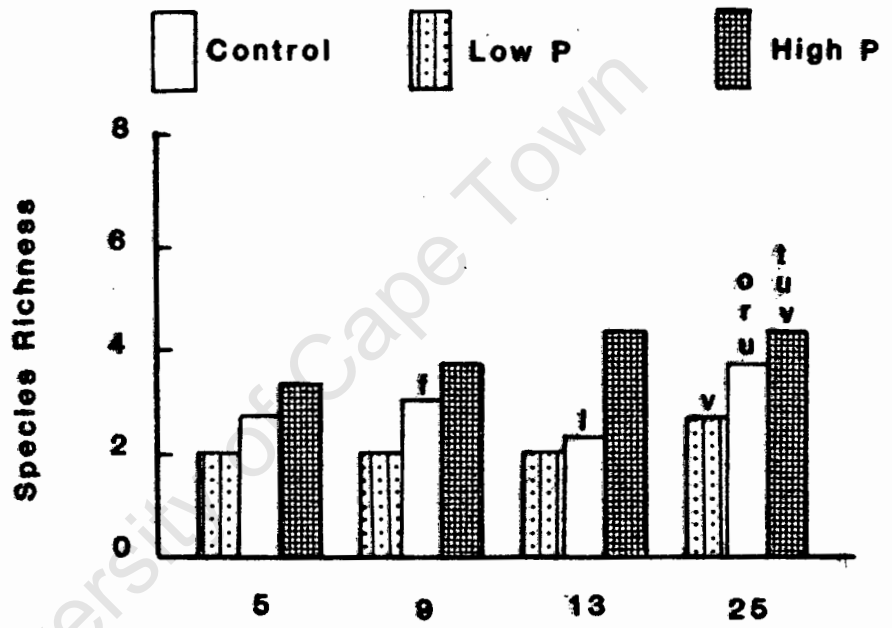
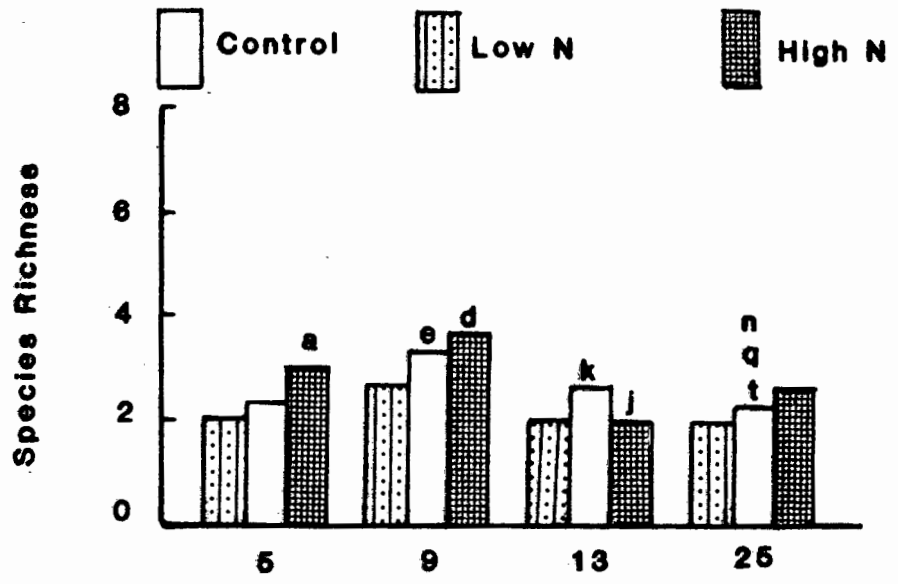
Figure 1: Percentage foliage projective cover of the treatments is shown after 13 and 25 months growth.

Species richness data (Fig. 2) show the accumulation of species over a two year period. After five months only the High N treatments (N, N+P) differ from the control. Nine months after establishment the High N+P treatment differed significantly from all other treatments, as well as Low N+P from the control. At the thirteenth month of sampling, High N+P again differed significantly from all other treatments. After 25 months the position is more complex with the P treatments beginning to show an effect.

As important as the above factors to revegetation, is the actual composition of species found in each treatment. Table 2 shows how treatments compare once Desirability Indices have been calculated. Of interest is to note the change from 13 to 25 months after the experiment was established: all have increased indices indicating that Desirability Indices can be dependent on the age of treatments as new species are accrued.

Figure 2: Species richness data of treatments after 5, 9, 13 and 25 months growth. Bars with common letters are significantly different at the 1% level

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DISCUSSION

These results from a Mountain Fynbos site show trends found in other mediterranean-type ecosystems (particularly Australia), although most nutrient addition experiments reported on in the literature involve stands of vegetation rather than cleared ground.

Variables considered all show an increase in value with an increase in nutrient addition. Initially, this seems contradictory when considering fynbos adaptations to nutrient-poor conditions, but can be explained by the near sterility of the sub-soil that was used in the experiment.

An important criterion of successful revegetation is a rapid increase in indigenous cover that persists, allowing colonization by later seral shrubs. This cover must develop rapidly enough to prevent erosion.

The High N+P treatment shows the greatest success, being the only one differing significantly in cover from the control and having a high species richness. The other treatments seem to suppress the cover initially, there being a greater increase in the second year.

The Desirability Index again places the High N+P treatment before the others, showing that this treatment results in desirable species in addition to an increased cover and species richness. Although this means a greater financial input initially, fertilizers are one of the least costly elements of a revegetation programme. This extra investment appears to increase the cover five-fold. The High N+P treatment is the most successful after one year, but after two years the Low N+P treatment reaches a similar value of desirability. This might suggest that the Low N+P treatment is a cheaper, though equally effective alternative, but it is important to remember that the reduced cover, especially during the first year could allow the spread of invasive weeds especially in the fynbos where elements of the Australian biota have taken hold.

CONCLUSION

This short-term study shows that the use of fertilizers for revegetation project is advantageous when topsoil is unavailable as it increases cover and species diversity. However, it is important to remember that fynbos is adapted to a nutrient-poor environment, and that an oversupply of nutrients would be detrimental. This emphasizes the importance of soil analyses to enable the correct choice of fertilizers.

Again it is necessary to stress that the primary function of revegetation is stabilization of the soil surface, because only once this occurs can a plant community be developed. Although important, conservation is a secondary issue in this context and if erosion control and a conservation-worthy sward is to be developed, the revegetation programme must be planned and carried out in phases.

Unfortunately I was constrained by the design of the experiment, which I was employed to sample and analyse. There are a number of faults that have limited the resulting information. Ideally the design should have included more replicates and wider buffer strips between treatments. It should also have been established on level ground. This would have enabled a more rigorous statistical treatment with more information resulting. However, it is important to note that the reasoning behind the design was to test a range of commercially available fertilizers under road-side conditions which necessitated the slope and a large number of treatments.

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APPENDIX

Each species was scored for its suitability to revegetation according to the five different categories which are described in Table 1

Categories	1	2	3	4	5	Index of Desirability (Total)
<u>Aizoaceae</u>	1	1	1	5	3	11
<u>Anthospermum aethiopicum</u>	5	5	1	1	3	15
<u>Aristea africana</u>	5	5	1	1	2	14
<u>Aulax umbellata</u>	5	5	5	1	3	16
<u>Bruniaceae sp</u>	5	5	5	1	5	21
<u>Elytropappus gnaphaloides</u>	5	2	1	5	3	16
<u>Eriospermum sp</u>	5	5	1	1	2	14
<u>Helichrysum sp</u>	1	5	1	1	3	11
<u>Leucadendron salignum</u>	5	5	5	1	5	21
<u>Metalasia tenuifolia</u>	5	5	1	3	3	17
<u>Oedera imbricata</u>	5	2	1	1	3	12
<u>Phaenocoma prolifera</u>	5	5	1	1	3	15
<u>Pharnaceum sp</u>	1	2	1	5	3	12
<u>Prickly composite</u>	1	1	1	1	3	7
<u>Protea repens</u>	5	5	5	1	3	19
<u>Senecio sp</u>	1	1	1	1	3	7
<u>Senecio sp</u>	1	1	1	1	3	7
<u>Stoebe fusca</u>	5	5	1	5	3	19
<u>Stoebe sp</u>	5	2	1	5	3	16
<u>Taraxacum sp</u>	1	1	1	1	3	7
Poaceae *	5	1	1	5	5	17
Restio spp. **	5	5	5	5	5	25
Seedlings ***	3	2	3	1	3	12

* all Poaceae were grouped as the species are indistinguishable in the juvenile stage.

** all Restionaceae were grouped as the species are indistinguishable in the juvenile stage.

*** all seedlings were grouped as they are indistinguishable at this stage.

CHAPTER 5

GENERAL CONCLUSIONS

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GENERAL CONCLUSIONS

The foregoing three papers have dealt with different aspects of revegetation in a Mountain Fynbos environment. The availability of the quarry site, as well as the establishment of the experiments by personnel of the PU-NTC Institute for Reclamation Ecology prior to my involvement, have largely determined these routes of investigation. Unfortunately the experimental design was not sufficiently rigorous to eliminate chance results due to unmeasured variables. However the statistical analyses were as stringent as possible under the circumstances. This means that only general trends can be extracted from the data. Nevertheless, in a floristic kingdom lacking any reported indigenous revegetation research, these trends have important implications for fynbos areas.

The comparison of vegetation re-establishment on sub-soil and on topsoiled sites has demonstrated the importance of topsoil. As was indicated, the addition of the latter led to an increased cover as well as a greater species richness. The species richness of the topsoiled plots consisted of geophytes, succulents and myrmecochores which are all soil-borne species. These were not found on the sub-soil plots. This result lent further support to the results of the second paper which compared the influence of various harvesting techniques on the revegetated area. It seems that whatever the subsequent treatment, the mere presence of

topsoil made a positive contribution to the diversity of the re-establishing vegetation. No differences were found between the effects of the various methods of harvesting material, although all resulted in cover and species diversity greater than the control. Although the topsoil and sub-soil plots differed in species composition, both supported wind dispersed taxa. This clearly indicated the importance of anemochores in the colonization of disturbed areas. Although the percentage of anemochores was much the same on both types of plots, their numbers differed in favour of the topsoiled plots. One can conclude from this that the topsoil provides a more suitable environment for seedling establishment. The flora colonization on the sub-soil plots seems to substantiate Clement's concept of primary succession. In contrast, the vegetation on the topsoil plots which originated from propagules carried in the topsoil, is reminiscent of Egler's "old field succession".

The above discussion brings into focus the importance of topsoil handling and storage techniques. The few studies that investigate these aspects, provide conflicting results. For example, there is a lack of consensus on the effects of compaction and long-term storage on seed within topsoil heaps. Some authors suggest the detrimental effects of storage are reversible (Abdul-Kareem & McRae, 1984), while others disagree (Hinchman, 1980; McGinnies, 1980; both in

Hargis & Redente, 1984). These areas of disagreement should be a priority for investigation in the light of results obtained in this study which indicates the vital importance of topsoil for Mountain Fynbos revegetation.

The comparative investigation of seed harvesting techniques for the revegetation of a topsoiled area produced unexpected results. Although the treatments were randomly applied, the TWINSPAN groupings do not reflect this. When the four broad classification divisions are superimposed onto the experimental plot layout they fall into blocks suggesting some form of overriding environmental effect. The more obvious environmental factors were ruled out namely topsoil depth, nutrient content and predominant wind directions. One can conclude that the expected effect may have been masked by propagules stored in the topsoil and from seed blown onto the site. Therefore only broad trends could be extracted from the data. These indicate the importance of harvested vegetative material because it results in an increase in the diversity and cover of the plots above that of the control. This material seems to be acting as a mulch rather than as a seed source and increases the organic content of the soil providing a suitable microhabitat in which seed can lodge, germinate and become established. Therefore the most cost-effective harvesting technique should be used for fynbos revegetation.

The third paper assesses the situation where topsoil is unavailable for revegetation owing to factors beyond the control of the ecologist. Such factors could include a lack of planning for revegetation: for example, the loss of topsoil through mixing with overburden; or contamination of topsoil during storage by alien plant invaders which are a particular problem in the fynbos vegetation. This paper investigated the potential of nutrient application to ameliorate sub-soil. A varied range of commercially available nutrients, incorporating different levels of nitrogen and phosphorous, were applied. Contrary to expectations species richness and cover were found to increase with an increase in nutrients added. The Desirability Index was developed to determine the significance of the results for revegetation purposes. An increase in species diversity is insignificant if it represents undesirable species such as those not indigenous to the area, or alternatively, short-lived ephemerals that will not contribute much to the stability of the site.

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CHAPTER 6

PRACTICAL GUIDELINES

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Since revegetation studies are applied, this investigation would be meaningless without producing a set of guidelines for practitioners in the field. Therefore, I have proposed guidelines based on a synthesis of results and observations made during personal investigations of revegetation in Mountain Fynbos areas.

For a particular revegetation project to succeed, it is important for the practitioner to be aware of the human factors involved in a construction programme. Examples are the civil engineer who, in South Africa, is ultimately responsible for the managing of the project which is normally severely constrained in terms of time and finance; the ecologist who all too often has a theoretical background; and the public who want the development to go ahead at minimal cost and with minimal impact on the environment. All have different vested interests and so different aims and terms of reference for judging the project's success. All points of view need to be integrated for the revegetation practitioner to have credibility and co-operation. For example, in the construction of a road the engineer requires rapid stabilization of road cuts and fill slopes. If this is not achieved, drainage channels will become blocked by sediment-rich run-off and the road-bed may become undermined. A relatively easy solution can be achieved with the use of alien perennial grasses together

with fertilizers. But this precludes the colonization of indigenous vegetation which can neither germinate through a thick sward, nor respond to high nutrient additions, particularly in a heathland environment. In the same situation, the ecological purist would try to introduce indigenous vegetation similar to that of surrounding areas. Therefore, the revegetation scientist or practitioner has to develop a compromise which is essential for a good working relationship and the ultimate success of the project.

Revegetation has a greater chance of success if it is planned and phased into the construction programme. In addition, a good management programme is essential for its long-term success. The revegetation process can be divided into three stages:

- a) pre-construction;
- b) during construction; and
- c) post-construction.

a) Pre-construction: This is the planning and design phase. It is essential that the revegetation scientist is involved when there is still scope for change in designs. The revegetation scientist should provide information on the sensitivity of the vegetation to development, the presence of any endangered or protected flora, and the suitability of the existing vegetation for revegetation purposes. If endangered plant populations are present it may be possible

to change the alignment of roads or the positioning of buildings at this early stage. The input of the revegetation scientist is also necessary to ensure that adequate finance is available for revegetation.

The phasing of revegetation should be considered when time schedules are being drawn up. In Mountain Fynbos it is important that seed is sown in late summer or autumn before the cool rainy season. It may also be possible to strip topsoil from one section and lay it immediately on some other section to reduce storage time and safeguard the soil stored seed load. This phasing is essential for success; especially in large projects such as strip mining or sub-economic housing schemes where it is cheaper to strip vast areas of vegetation at a time thus leaving the ground bare and susceptible to erosion and alien plant invasion.

The revegetation scientist should also have an input in the planning of site access and infra-structure, as well as the placing of quarries or borrow-pits. It is advisable to limit the extent of the proposed construction site by fencing to reduce trampling, littering and the possibility of fires. Access roads should be laid out at the start of construction, and all vehicles restricted to them. In this way patches of vegetation can be retained and incorporated into the eventual landscaping and revegetation of the site.

During the year prior to construction an intensive seed harvesting programme should be carried out under botanical guidance. Seed must be stored under appropriate conditions. Extra seed of suitable species should be acquired from suppliers where possible, and seed and cuttings of larger shrubs should be propagated in a nursery for later planting. When the site is cleared for construction, the brushwood should be kept for mulching and soil stabilization. The brushwood should be kept as dry as possible, and stored so as to prevent compaction. In this way it may be possible to retain part of the seed bank held on the plants.

Topsoil should then be removed independently from the subsoil. Storage should be for the shortest possible period in low 1-2m high piles. Soil must be prevented from compacting as this destroys its physical and chemical properties with detrimental consequences for the seed stores.

Experience has shown that specification of an appropriate site for storage of soil is important. Examples of unsuitable sites are those in the vicinity of a stand of alien invasive plants that have a seed rain of many hundreds or even thousands of seeds per square metre; or those in an area where construction machinery is parked as this could lead to extreme compaction and contamination with oil or diesel.

b) During Construction: Unless the project is vast, and is being developed in stages, there is not much revegetation work to be done during this period. At this stage the site will have been cleared, topsoil would have been stockpiled, and collected seed and harvested vegetation will be in storage. Extra mulch and seed-bearing vegetation may also be collected from adjacent areas of similar vegetation if available. It is recommended that vegetation is harvested in strips leaving buffer areas behind to lessen the impact on the vegetation. This should ensure a rapid recovery, especially in the case of fire. Alternatively, material can be collected from fire-breaks cleared in suitable areas.

If budgets allow, nursery-based propagation of cuttings and germination of seedlings is a useful goal. This expenditure would be appropriate in the case of development taking place in recognised conservation areas. Examples could include building of reservoirs or road systems.

In the case of road-building, where rock blasting is necessary, it is important to recommend "rough-blasting" to the engineer. In this process, the rock face will be left rugged with many crevices and ledges in which soil and plants may eventually establish. This needs to be explained to the engineer who has been trained to demand smooth, well-finished blast-faces from sub-contractors.

At this stage it is important to protect undeveloped areas from the range of impacts traditionally associated with construction. This could include the dumping of rubble, the passage of heavy vehicles, trampling and the stockpiling of materials. The most effective way to do this is by fencing off work areas, as well as incorporating a penalty clause in the contract. This would ensure that workers are more careful on site.

c) Post-Construction: This can be divided into two parts:

- i) the implementation of revegetation programmes when topsoil is distributed and areas are planted or sown; and
- ii) the management phase which is essential for the long-term success of the project.

i) Slope preparation needs to be carried out with care to ensure successful root development and slope stabilization. The sub-soil should be scarified to ensure a good interface with the topsoil. Subsequently, the topsoil is spread, preferably by hand to prevent compaction. The surface should be left rough as seed and mulch will lodge better on rough than on smooth surfaces. Engineers pride themselves in creating smooth surfaces and straight lines, but they should realise that these are not always appropriate.

If soil analyses infer a need for nutrient or mulch addition either to alter the pH or the organic content of the soil,

they should be carried out at this stage and worked into the soil.

It is recommended that slopes are kept at a gradient of 1:1.5 or less for successful revegetation. If slopes are as steep as 1:2 then physical methods of stabilization are necessary. A range of techniques are available from the relatively inexpensive placement of rocks and poles horizontally across the slope, to the more sophisticated and more expensive use of revegetation cylinders which are tubes of extruded nylon netting packed with soil, mulch and seed which are pegged horizontally across the slope and covered with topsoil. These techniques have in common the ability to reduce surface run-off and silt-loads as well as the capacity to retain soil on the slope sufficiently well until plant cover is established.

At this stage, slopes may be spread with mulch and seeded. Locally, this is usually done by hand, although recently, some hydroseeders have been modified to use "unclean" seed which has been suction harvested. This is then sprayed onto the soil surface.

In South Africa, it has been common practice to hydroseed the slopes with a grass mixture to secure the indigenous material until germination and establishment occur. Observations indicate that this practice can be detrimental

to indigenous vegetation establishment if exotic perennial grass species are used together with high concentrations of fertilizers. The grasses establish more rapidly than the fynbos and shade it out, sometimes invading adjacent areas. Fertilizers suited to these grasses are normally too concentrated for fynbos. This results in a shift in species away from the desired indigenous sward. In situations where hydroseeding is thought necessary, such as on steep slopes which experience high rates of run-off, it is advisable to use small amounts of exotic annual grasses with low fertilizer application rates. This will enable the grasses to establish in their first season but will ensure that subsequent seed set is poor. The grass stand will provide initial stabilization, but the low nutrient additions will not preclude fynbos establishment. This will ensure that the exotic grasses decrease rapidly with time.

An alternative to grass, is the use of "takifiers" which are chemical solutions or emulsions that are sprayed onto the slope. They can be in the form of dust suppressants which are valuable in the large scale sub-economic housing developments on the sandy Cape Flats, or they can be in the form of an emulsion such as bitumen, molasses, sewerage or paper-pulp which virtually glues material onto the slope. Observations indicate that this added expense is not warranted in fynbos revegetation.

At this stage, any material propagated in the nursery can be planted out on the prepared areas. If budgets allow, irrigation may be beneficial during the hot dry summer period of the mediterranean climate zone. It should only be used intermittently when conditions are extreme to increase seedling survival during the first summer period.

ii) Management: Once the slopes have been revegetated, a period of observation follows. The resulting vegetation must be monitored to assess whether additional seeding or planting is necessary, and whether erosion is occurring. During the dry summer irrigation may be warranted but should not be given unnecessarily as it could reduce the drought resistance of individuals.

Management in the long-term will depend on the initial goals of the project, and should not be neglected. If the goals go beyond a rapid stabilization of the slope merely for erosion purposes then monitoring should be on a regular basis recording such things as species persistence and colonization of the area. Species may be assessed for their successional significance in terms of the theory discussed in Chapter 1. The ideal is a diverse, stable community with

sufficient cover to control erosion , resist disturbance, and yet be able to progress successionaly. The monitoring of such stands and the recording of all revegetation measures used will lead to a greater understanding of revegetation in a Mountain Fynbos situation.

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