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Fire and post-fire soil erosion in the Western Cape, South Africa: Field observations and management practices

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ABSTRACT

This Minor Field Study addresses the fire and post-fire related issues in the Western Cape Province, South Africa. The study was carried out in May to July 2002 and consists of two parts: Post-fire water repellency in the Cederberg (study 1), and Management practices and perceptions of fire-related issues in the Western Cape (study 2). Study 1 aims to achieve a better understanding of the temporal and spatial variability of water repellency (hydrophobicity) in unburnt and burnt areas. The study also aims to find differences in water repellency in fynbos and Pine (alien) vegetation. The water repellency measurements were done by using the Water Drop Penetration Time test (WDPT). The results showed no tendency of water repellency in the soil. Early rain and frequent rainfall in 2002 is likely to have destroyed any water repellency present. Study 2 aims to provide an up-to-date synthesis of management perceptions and awareness of erosion impacts due to fires and, also, to identify and prioritise research questions to assist rational management of post-fire conditions. Different organisations and authorities were interviewed and additional information was obtained from existing reports, a fieldtrip and Internet. The results support that the alien vegetation clearing is an important issue in the Western Cape. The studied organisations/authorities focus on the prevention of invasion and clearing of alien vegetation. The post-fire soil erosion issues are dealt with on an ad hoc basis. Further, the studied organisations/authorities have a strong focus on employment. The discussion concludes that the fire-related issues need additional research for a more complete scientific understanding. The communication between the studied organisations/authorities and scientists could also be improved.

Keywords: South Africa, Western Cape, Cederberg, post-fire soil erosion, water repellency, alien vegetation, fynbos, volunteers, management, alien vegetation clearing

1. Introduction

1.1 BACKGROUND

South Africa is a country experiencing strong urbanisation with rapidly growing cities. These heavily populated cities demand a large supply of water and may, if they continue to grow, face water shortages. At the same time, South Africa is a country of highly variable precipitation. Water resources are scarce and limited in most parts of the country. In the Western Cape (Figure 1), the Cape metropole region has been expanding rapidly over the past 20 years. Water resources for the Cape metropole region are primarily found in the Western Cape mountain catchments.

A major problem contributing to decreasing water supply in the mountain catchments is the invading alien vegetation. Generally, alien species require more water than the indigenous, fynbos vegetation. Replacing fynbos forest in the Western Cape with pine (an alien specie) resulted in a decrease in stream flow by up to 50% due to their higher water consumption (Van Wyk, 1987 in Enright, 2000). As water resources are critical to the economic growth of the region, this poses serious problems (Binn *et al.,* 2001).

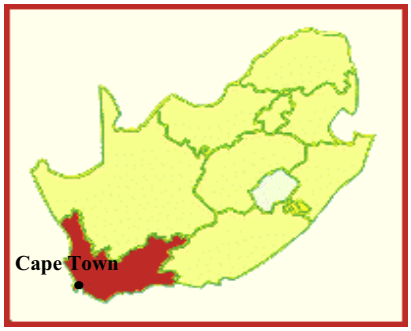


Figure 1. The Western Cape province is situated in the south-west part of South Africa.(Linx Africa, 2003)

Also, alien vegetation gives a poor ground cover compared to the indigenous vegetation, which could result in surface runoff and soil erosion (Appendix 1). In the Western Cape, the most important alien invaders are trees or large shrubs, especially species of *Acacia* and *Pinus*. These alien plant species were introduced mainly by European colonists in the mid 1600's following the widespread clearance of the indigenous forest vegetation (Meadows, 1998). They have expanded their distribution both through widespread intentional planting and natural dispersal (Meadows, 1998). Invasions by alien vegetation have resulted in a reduction of indigenous plant cover and in the loss of indigenous plant species diversity (Rossouw, 1997).

The indigenous bush vegetation, fynbos, which dominates the Western Cape region, is dependent on burning to be able to re-germinate. The natural process is that fynbos burns, ideally with frequencies between 10-12 years. The ecologically right season for these fires is in the late summer (NBI, 2002). Since humans entered the region, these cycles have been disturbed, leading to increasing numbers of accidental fires (van Wilgen *et al*., 1987). The presence of alien vegetation will increase the potential fuel load and further enhance the risk of fires and the intensity of the fires. The fire risk will also increase where there is a mix of fire-prone vegetation and settlement (Parker, 2000).

In January 2000 two large wildfires in the Cape Peninsula burned over 8000 ha of mountain land (Scott *et al.,* 2000). Major parts of the wildfires were wind-driven events enhanced by drought conditions, high temperatures, low humidity and dry vegetation

(Parker, 2000). The fires were more intense and severe than fires that normally occur in fynbos vegetation. This was caused by the intermittent dense stands of alien vegetation that occurred in many areas (Jenks *et al*., 2000). Ninety percent of the burnt area was invaded by alien vegetation. The alien plants increased the fuel load and fire risk because of their faster growth rates and greater age than fynbos. The alien vegetation was also a cause of the high intensity of the fires (Scott *et al.,* 2000). For these reasons, the January 2000 fires are considered as a culmination of years of environmental mismanagement and poor planning (Thomas and Poswell, 2000).

Generally, fires contribute to changes in soil properties with the establishment of water repellency as one important factor (Scott *et al.,* 1997). Water repellency (hydrophobicity) could form when vegetation with a large biomass containing allophanes (oil) burns. This phenomenon is more common with alien species compared to fynbos. Water repellency is usually found a few centimetres below the soil surface (Appendix 2a). The water repellent layer will reduce the water infiltration capacity. Decreased water infiltration results in immediate surface runoff and erosion (Appendix 2b). Fire induced water repellency in the Western Cape region has many times been suggested as the most important contributing factor to accelerated soil erosion. One example of this is the northern slopes of Table Mountain. Scott *et al.* (1991) suggest that reduced infiltration of precipitation and enhanced concentration of surface flow on the slopes lead to sheet, rill and gully erosion.

The problems surrounding alien vegetation invasion, changed fire regimes, and water repellency and soil erosion fundamentally affect the water and soil resources in the Western Cape. This is a critical issue for all sectors of the population, but as costs for basic water and agricultural products increase, affect the poorest communities the hardest (e.g. Scott, 1993 and Meadows, 1998).

The problem of post-fire erosion hazards in the Western Cape region is widely recognised as a potentially major environmental problem. So far, it hasn't been subjected to a rational management plan. In order to achieve such a plan, a more complete scientific understanding is needed for post-fire slope conditions. To study the process of water repellency and how it appears in different vegetation and soil types, will help to achieve a better understanding and anticipation of the post-fire soil erosion.

1.2 AIMS AND OBJECTIVES OF THE STUDY

This study aims to look into the water repellency dynamics, as well as the management issues related to fires in the Western Cape. The project is divided into a fieldwork part, (study 1) and a review of management perceptions and practices (study 2). The aim of study 1 is to achieve a better understanding of the temporal and spatial variability of water repellency in unburnt and burnt areas. The study also aims to find differences in water repellency in fynbos and pine (alien) vegetation. The fieldwork focuses on water repellency as a key factor in post-fire erosion potential.

The management study involves assessment of current management perceptions and practices on post-fire erosion impacts in the Western Cape. The aim of the management review is to achieve the following objectives:

- To provide an up-to-date synthesis of management perceptions and awareness of erosion impacts due to fires.
- To identify and prioritise research questions to assist rational management of post-fire conditions.

1.3 LITERATURE REVIEW

Water repellency and post-fire soil erosion has been linked in many studies. Since this seems to be a common problem in the Western Cape, the region has been subjected to research the last 20 years. Still, there are contradictions and obvious lacks in understanding of the process and impact of water repellency.

Many authors have described the theory of fire-induced water repellency and following soil erosion (e.g. Boelhouwers *et al.,* 1996 and Scott, 2000). In South Africa, several studies have taken place that supports this hypothesis. The importance of understanding the interactions between vegetation type, soil heating, fuel load and soil wetness and how it affects fire-induced water repellency is often highlighted in the literature. A study by Scott (1993) in four different South African mountain catchments (two fynbos catchments and two timber plantation catchments with Pine and Eucalyptus) established that the hydrological response of catchments after fire is determined by a number of interacting factors. Scott (1993) suggested that the following conditions in a catchment might lead to hydrological and soil erosion responses after fire:

- A high level of soil heating, which in turn is a function of fuel load, fuel type, soil wetness and weather conditions. High soil temperatures are related to induced water repellency and post-fire erodibility.
- Loss of ground cover due to the shading out of low-growing vegetation happens in the timber plantations and the sites will be bare and further exposed after fire.
- Wildfires are more likely to occur in hot, dry weather conditions and when soil and fuel moisture is low.
- Soil between the Eucalyptus and Pine sites showed a high level in water repellency, which partly generated surface runoff in the post-fire situation. The eucalyptus soils had high inherent levels of water repellency, while the pine soils only had high levels after fire. The fynbos soils showed a minor tendency in increased water repellency after fire.

Scott further explains the links between induced water repellency and different vegetation types in another South African study from 2000. It is described that water repellency is a common feature in South African timber plantations. Plantations of eucalyptus, wattle and indigenous evergreen forest in general, induce a high level of water repellency in their soils, relative to other vegetation types in forestry regions in South Africa (Scott, 2000).

Not all water repellency is fire related. Water repellency may also occur due to the natural decomposition of hydrophobic materials. Studies have shown that natural decomposition of hydrophobic compounds could lead to 'natural' water repellency (not fire-induced repellency). In areas where the soil has naturally high water repellency, fire may have a very little effect on water repellency. In fact, extremely hot fires could destroy the hydrophobic layer (Doerr *et al.,* 2000). Water repellency is also known to develop naturally in coarse textured soils and relates to coating of hydrophobic substances of the particles. In the Cape Flats, Western Cape and the coastal sands of Zululand it has been found that sand is particularly water repellent (Scott, 2000). The soils in the Western Cape region are largely sandstone-derived with sandy textures (Cambell, 1983). This feature could be an important contributing factor that makes the soil more prone to develop water repellency.

Scott *et al.* (1997) describe the importance of understanding the natural soil erosion rates and the human influences on this in the Western Cape. Wildfires provide an inherent risk during the summers. Especially high intensity wildfires in the late dry season have the potential to cause large increases in stormflow and sediment yields in burned catchments. This is particularly the case in timber plantations, which provides higher fuel loads and may be concentrated in slash piles (Scott *et al.,* 1997). Boelhouwers *et al*. (1996) documented that the wildfire in 1993 at Devil's Peak, Cape Town, caused the formation of a water repellent layer, which inhibited normal infiltration leading to greatly enhanced surface runoff causing mudflows, rill and gully erosion.

In a study by Euston-Brown (2000), soil erosion and vegetation recovery was monitored after the fires in Fish Hoek, 1999 and Cape Peninsula, 2000. In terms of measurable effects the fires in alien infested areas were on average about 65% more severe (more damaging) than the fires in fynbos. The passage of fire can enhance the water repellent layer lower down in the soil profile. It is likely that the repellent layer tends to be thicker and more persistent on deeper sandy soils than on TMS (Table Mountain Sandstone). The rockiness of the TMS soils is also providing sites where water can percolate through the water repellent layer (Euston-Brown, 2000).

In a historical overview by DeBano (2000), the progress in understanding water repellency is described from the early 20th century to date. The past 30 years have witnessed an increased interest in water repellency. The studies have generally taken place in countries having Mediterranean climate, e.g. the USA (California), Spain, Portugal, Australia and South Africa. Still, a lot more information is needed to be able to understand the formation and breakdown of water repellency and its implications (Doerr *et al.,* 2000). Additional research should focus on isolating the erosional impact of water repellency from other factors. So far, few studies have quantified the impact of water repellency on overland flow and soil erosion because of the difficulty of isolating its effect from other factors (Shakesby *et al.*, 2000). Other issues related to water repellency that need more research are the thresholds of soil moisture content and the length and intensity of dry periods. Also, spatial dynamics of hydrophobic conditions, the mechanisms and speed by which hydrophilic conditions develop in periods of wet weather are important issues (Shakesby *et al.*, 2000).

1.4 CLIMATE AND GEOLOGY

The Western Cape province is situated in the south-western part of South Africa. The area of the region is 129 370 km^2 (Provincial government of WC, 2003). The dominant local lithologies are sandstone and quartzite that are underlain by granites (Appendix 3). The soils are mostly sandy, shallow and nutrient-poor (Rossouw, 1997).

The Western Cape region has a Mediterranean-type of climate. Winter rainfall, associated with the passage of frontal systems occurs during the period June to September. The summers are dry and warm (Meadows, 1998) (Figure 2).

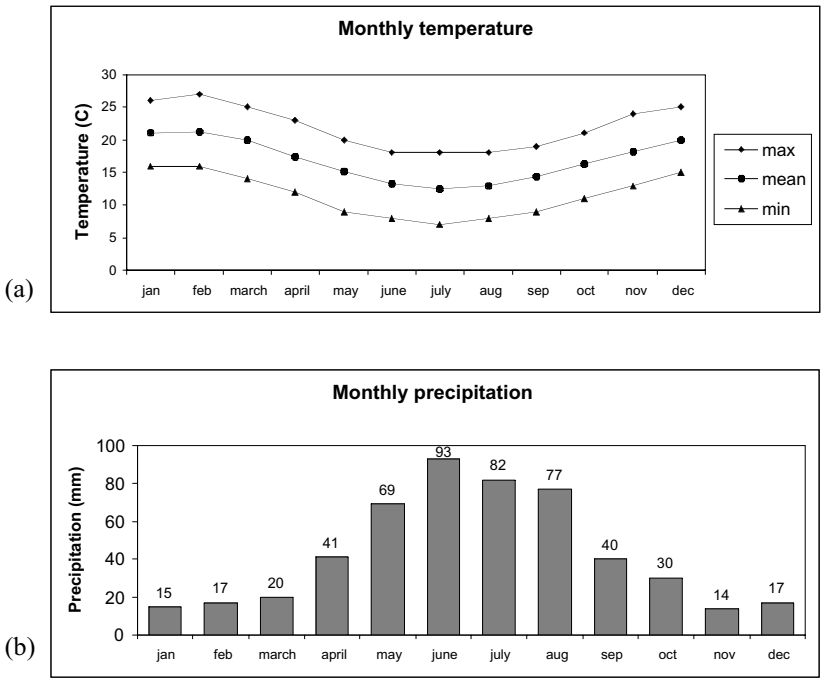


Figure 2. Climate summary statistics for Cape Town: (a) monthly maximum, minimum and average temperatures (b) monthly average precipitation (South African Weather Bureau, 2003).

The Western Cape region holds a floral kingdom with more than 8500 species. The predominant vegetation is the indigenous fynbos, which is a small, fine-leafed shrubby vegetation (CPNP, 2000). The two primary land uses in the mountains of Western Cape are conservation management of the nature and water supply by periodic burning of the fynbos vegetation and timber production from plantation of pine trees (Scott *et al,* 1997).

2. Study 1: Post-fire water repellency in the Cederberg

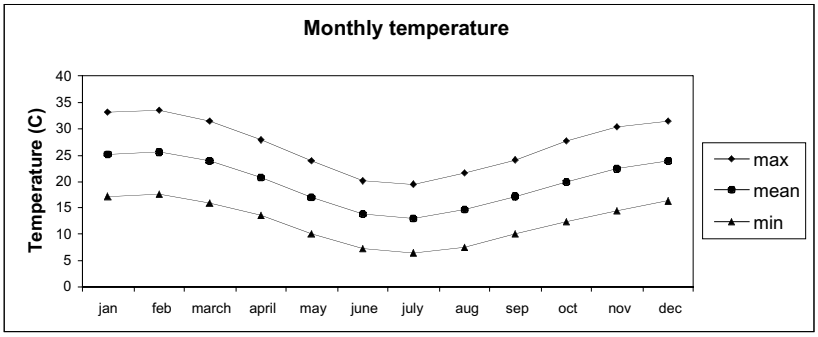
The aim of the study is to achieve a better understanding of the temporal and spatial variability of water repellency in unburnt and burnt areas. The study also aims to find differences in water repellency in fynbos and Pine (alien) vegetation. The fieldwork focuses on water repellency as a key factor in post-fire erosion potential.

2.1 STUDY AREA

The Cederberg Nature Reserve is situated 200 km north of Cape Town. The reserve is about 71000 ha and the terrain is mountainous. The area stretches from the Middleberg Pass at Citrusdal to north of Pakhuis Pass at Clanwilliam (CNC, 2003). The fieldwork was done in Algeria, a small village with a camping site in the Cederberg valley (see Appendix 3). Our studies took place across the camping site on the south-facing slope.

The climate in the Cederberg is Mediterranean (Figure 3). Most rain falls in the winter. During the winter, night temperatures can drop to below 0°C and heavy frost may occur. It often snows in the higher parts. In the summer, temperatures may reach 40°C. The south-easterly winds that are dominant in the summer contribute, together with lightning, to a high fire risk. (CNC, 2003)

(a)



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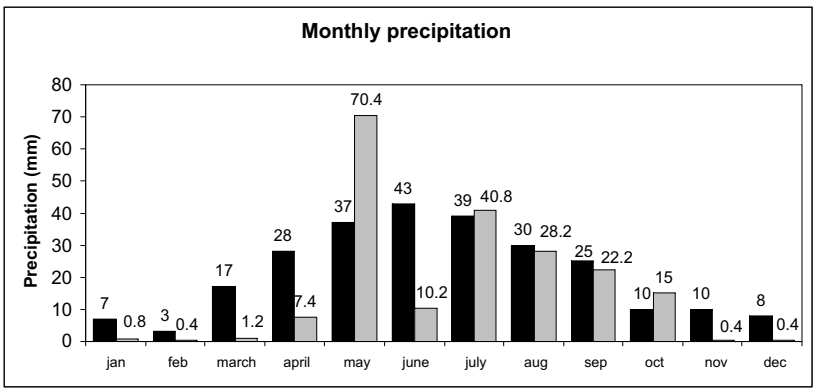

Figure 3. Climate summary statistics for Clanwilliam: (a) the monthly maximum, minimum and average temperatures, (b) the monthly average precipitation (black) and monthly precipitation total for 2002 in Clanwilliam (gray). (South African Weather Bureau, 2003)

(b)

The rocks in the Cederberg are composed of sandstone and shale formations of the Cape Supergroup. These were deposited between 500 and 345 million years ago. Typical for the Cederberg are the weathered sandstone formations. The Cederberg Mountains fall within the catchment area of the Cape Fynbos region and are managed as a source of water. The soils are mostly sandy (CNC, 2003). The vegetation in the Cederberg is predominately mountain fynbos, but alien vegetation occurred at the study site in Algeria, where Pine had been planted for timber production. Also, eucalyptus was planted at the camping site. Pine is common both on the north- and south-facing slopes.

The Cederberg Mountains were proclaimed a wilderness area in 1973. This is the highest possible conservation status in South Africa. The area is a popular recreational destination. European settlers began stock farming in the Cederberg area in the eighteenth century. From 1903 to 1973, there was an exploitation of natural products. Large amounts of cedar wood, rooibos tea and rockwood bark were harvested. Since wood was in great demand for construction purposes, lots of cedar trees were chopped down in the Cederberg Mountains. In 1967 the removal of cedar trees was halted and other forms of exploitation ended in 1973 (CNC, 2003).

2.2 METHOD

Algeria in the Cederberg was chosen as the study area for the fieldwork due to a fire in February 2002. Both alien vegetation (e.g. Pine, Eucalyptus) and indigenous fynbos vegetation where burnt. The recent fire and the type of vegetation burnt made Algeria suitable as a study area for the project.

Water repellency measurements

Water repellency measurement was done by using the Water Drop Penetration Time test (WDPT) (Doerr, 1999). The WDPT test involves placing a water drop on the soil surface and measuring how long time it takes for the water drop to penetrate into the soil (Figure 4). Distilled water was used and dropped on the surface by a pipette.

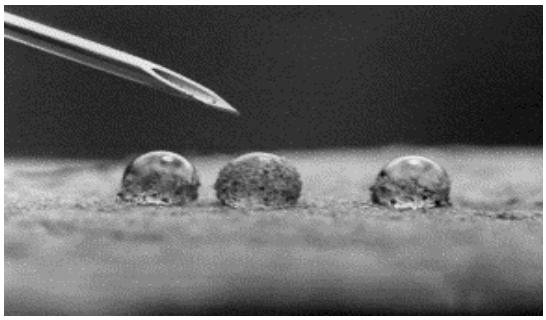

Figure 4. Water drops resisting infiltration into soil due to water repellency (Doerr *et al.*, 2000).

Four study sites were chosen, fynbos-burnt, fynbos-unburnt, alien-burnt and alien-unburnt. At each study site a 10×10 meter plot was established. To enable the spatial variability measurements, 16 points were evenly selected. To measure the temporal variability, 5 points were randomly selected in each grid. The temporal variability measurements were repeated every day during the study period with the frequency of 24 hours.

At all the measuring points readings were taken at four levels – at the surface, at 2, 5 and 10 cm depth. The soil was determined as water repellent if the drop did not infiltrate within 2 minutes.

2.3 RESULTS

Water repellency

The proposed water repellency measurements where done during a three week period in May/June 2002. Unfortunately, there was a lot of rain during this period causing high soil moisture (see Figure 3 b). The measurements showed no tendency for water repellency in the soils, which was consistent for all the measuring points in all vegetation types and soil levels. The absence of water repellency effects allowed more attention to be focused on management of this fire event and its consequences.

Figure 5. The study site in Algeria, Cederberg, the slope is south-facing. Water repellency plots are indicated as follows: unburnt pine (UP), unburnt fynbos (UF), burnt pine (BP) and burnt fynbos (BF). (photo: I. Florberger).

The fire event

The fire risk is very high in the Cederberg area during the dry months between November and April. The most recent fire in Algeria, Cederberg was on the 24th February 2002. The fire was accidental and started 2 km north of Algeria. It moved fast in a south-easterly direction towards the camping site. Close to the campsite, where Eucalyptus earlier had been cleared, the fire burned with high intensity. The whole event lasted two days. In 1998/99, there was another intensive fire above the campsite. This fire was also accidental and started about 4 km south-east from Algeria. The fire spread fast in the direction to Algeria. It was mainly fynbos that burnt and the fire caused very little soil erosion.

Rehabilitation measures

Soil erosion has been a major problem in the Cederberg. The fire damages the soil and makes it more susceptible to erosion. Additionally, the mountainous terrain with steep slopes and rain during winter contributes to making the soil prone to erosion. The rehabilitation work after a fire starts with trying to sow seeds of fynbos. This is then monitored for some time. If the method doesn't work, the next approach is to start building erosion protection. Occasionally, volunteers have helped the management team when extra people were needed, e.g. helping out with the building of soil erosion

protections. The volunteering work is also a way to get people more involved in the conservation management.

The section up to a waterfall, (see Fig 6, 7 and Appendix 4) near the Algeria campsite, used to be a eucalyptus plantation. It was removed in 1996. Following soil erosion in the same year, the slope was stabilised. During the winters of 1996-98, fynbos seed was sown to enhance natural vegetation recovery. Before the fire in February 2002, no vegetation in this section was removed. At the time of the fire the fynbos vegetation was in the process of recovering after alien plant clearing operations. Dominant species at the site was slangbos (*Stoebe plumosa)* which caused high fuel loads and contributed to enhanced fire intensity. The rehabilitation method involving sowing of fynbos seeds is normally done in disturbed areas, e.g. in areas where plantations have been removed and in areas that are specifically prone to erosion.

Figure 6. This section was exposed to fire in February 2002. Logs were put up along the contours of the slope in order to prevent soil erosion. There is a gully in the middle of the section. (photo: J.Fernqvist)

(a)  (b) 

Figure 7. The logs are preventing soil from eroding further down the slope. To the left (a), viewing upslope, to the right (b), viewing downslope. Note the sediment trapped behind the logs. (photo: I.Florberger, J.Fernqvist)

3. Discussion and conclusion

The measurements did not show any tendency of water repellency during the study period. This does not imply that there was no water repellency present after the fire event in February 2002. Other studies have shown that water repellency could break down as precipitation increases soil moisture conditions (Boelhouwers *et al.,* 2000). The lack of water repellency development could also be a result of low fire intensity. This is mainly caused by low fuel load, windy conditions (rapid fire movement) and high soil and fuel moisture. The dry season before the fire event in February 2002 should result in high intensity fires and development of water repellency. Though, the study-site indicated that the fire intensity was low. Both Pine and fynbos vegetation were still standing and were only partly burnt and damaged.

The winter rain begun late in 2002 but the amount of precipitation during our field survey in May was double the average (see Figure 3b). This caused an increase in soil moisture, which is a possible explanation to the lack of water repellency. The high frequency of rain events during our study period did not allow the soil to dry out. If the soil had dried out, water repellency is likely to have occurred as found elsewhere in the Western Cape (Boelhouwers *et al.,* 2000). Especially in Pine areas there is a high natural water repellency, which could be expected to appear at the study-site (Boelhouwers *et al.,* 2000). Since there was no water repellency at all, the most likely explanation is high soil moisture conditions influenced by high precipitation. For future water repellency measurements, we recommend to do the study immediately after the fire event. For a better scientific understanding the following questions needs to be answered: spatial and temporal patterns/variability of water repellency and the relationships of water repellency with vegetation, substrate and fire intensity.

The erosion event close to the waterfall near the Algeria campsite could be a result of many, related parameters. Water repellency might have been present before the heavy winter rains started. Other contributing parameters were probably the absence of vegetation (the fynbos vegetation was in the process of recovering after alien vegetation clearing), the steepness of the slope and sandy, erodible soil type and soil thickness.

The discussion concludes the following:

- Above average rainfall during our field period is likely to have destroyed any water repellency present in the soil.
- The erosion event is probably a combined result of different factors, such as water repellency, no vegetation cover, steep slope, sandy soil and heavy rainfalls.

4. Study 2: Management practices and perceptions of fire-related issues in the Western Cape

The study involves assessment of current management perceptions and practices on post-fire erosion impacts in the Western Cape. The aim of the management review is to achieve the following objectives:

- To provide an up-to-date synthesis of management perceptions and awareness of erosion impacts due to fires.
- To identify and prioritise research questions to assist rational management of post-fire conditions.

The study focuses on alien vegetation clearing and the prevention of alien vegetation spreading. This is an important key factor in the fire and post-fire soil erosion cycle. Alien vegetation contributes to more intensive fires, which creates more erodible conditions leading to soil erosion. The expansion of alien vegetation on the Cape Peninsula is viewed in Appendix 5.

4.1 METHOD

The key question was to do an assessment of the current management perceptions on the post-fire erosion impacts in the Western Cape. The information was obtained through interviews, a fieldtrip, existing reports and Internet.

Interviews were done with the following organisations/authorities:

- Cape Nature Conservation, Algeria, Cederberg.
- Department of Water Affairs and Forestry: Working for Water program, Cape Town.
- Cape Nature Conservation, Stellenbosch.
- Ukuvuka, firestop campaign, Cape Town.
- South Peninsula Municipality, Cape Town.
- Cape Peninsula National Park, Silvermine Park.

Most of the organisations/authorities were contacted through e-mail and telephone by suggestion from our supervisor Stephen Holness. Some of these suggested other organisations/authorities where there was further information. Reports were received from the above mentioned organisations (except Cape Peninsula National Park) and also from the Council for Scientific and Industrial Research in Stellenbosch.

Through Ahmed Khan (Working for Water programme), Douglas Euston-Brown was contacted. He works with different consulting projects concerning biology and geology. Commissioned by the Department of Water Affairs and Forestry, Euston-Brown did a study on the influence of vegetation type and fire severity on catchment stability after the fires on the Cape Peninsula in March 1999 and January 2000. Together with him we went on a fieldtrip around the Cape Peninsula. We visited some of his study sites and looked at the alien clearing work in the area.

4.2 RESULTS

Alien vegetation clearing has been recognised as a very important issue in the Western Cape. The alien vegetation consumes high amounts of water, which in the long term will decrease the water yield. The biodiversity is threatened because of their rapid spreading and also, fire in the alien vegetation results in erosive prone condition on the slopes.

The alien clearing and post-fire erosion issue is a major component of the studied organisations/authorities work. They are dealing with the issues in different ways and to different extent. The network between the organisations/authorities is presented in Figure 8. The results are presented under appropriate headings.

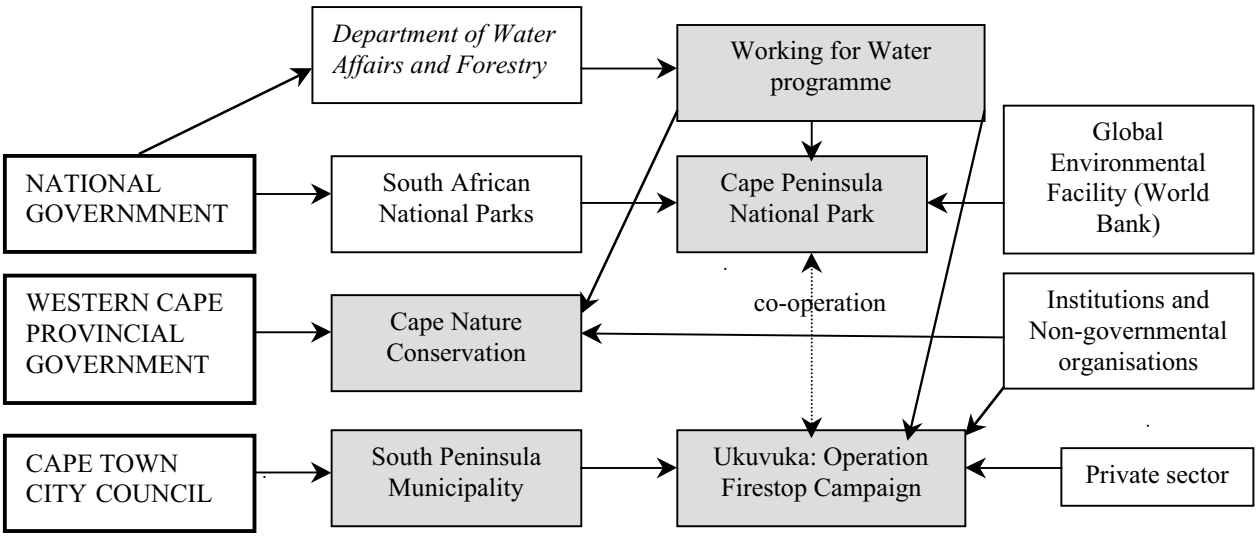

Figure 8. The figure describes the network of the studied organisations/authorities (the shaded boxes) and their relations with other organisations.

4.2.1 Aims and objectives of the studied organisations/authorities

Ukuvuka: Operation Firestop Campaign

The campaign was established in February 2000 as a result of the big fires in January the same year. Ukuvuka´s role is to facilitate and add capacity to the local authorities and Cape Peninsula National Park. The central aim of the Ukuvuka Campaign is the removal of alien vegetation, particularly in the areas of Cape Town, that are vulnerable to fire. Ukuvuka´s first key target area is the land and its plants, where they aim to control the invading alien plants and rehabilitate fire-damaged areas. The second key area involves communities and individuals, where Ukuvuka helps out to create employment, training and poverty relief for disadvantaged people. Protection of the most vulnerable communities from fire and promotion of co-operation and social cohesion between communities is also an important issue. The third key aim is to assist institutions to implement integrated fire management plans and manage the urban edge.

The campaign has a four-year mandate to achieve its goals (it will end in March 2004). Additional objectives include an effective communication and education programme, and

also, an accountable administration. Ukuvuka managers hope that their campaign becomes a role model for similar projects in South Africa.

Working for Water programme

The Working for Water programme (WfW) was established in 1995 and is a project lead by the Department of Water Affairs and Forestry. The "mission statement" of the WfW involves the following: "The Working for Water programme will sustainably control invasive alien species and optimise the potential use of natural resources, through the process of economic empowerment and transformation. In doing this, the programme will leave a legacy of social equity and legislative, institutional and technical capacity." Further, the programme aims to enhance water security, improve ecological integrity, and restore the productive potential of land. The programme also aims to invest in the most marginalised sectors of society. All of the above is included in 300 projects in different parts of South Africa.

Social development is a very important part of the Working for Water programme. The aim is principally to relief poverty, but they also want to optimise benefits in general. The targets for social development in 2002 were as follows:

- To create 18 000 jobs every year, for previously unemployed individuals
- Allocate 60% of these jobs to women, 20% to youth (persons under 23 years) and 2% (minimum amount) to disabled persons.

Additional targets concerning social development in 2002 was to ensure that every worker gets at least 2 days of training per month and receives an hour of HIV-AIDS awareness a quarter of a year. The projects should also have a steering committee and have access to childcare.

Cape Nature Conservation

The Cape Nature Conservation (CNC) is a public institution with the statutory responsibility for biodiversity conservation in the Western Cape province. Their key function is to manage for biodiversity. They control the conservation and work on the reserves through extensional labour, lead by conservation managers. Further goals are to enthuse and involve all South African citizens, especially the youth, in environmental conservation. CNC also wants to stimulate the economy through sustainable use of natural resources, and maintains supervision of the Cape Floral Kingdom.

Cape Peninsula National Park

The Cape Peninsula National Park (CPNP) was established in 1998. The park consists of the Peninsula mountain chain that stretches from Signal Hill in the north to Cape Point in the south. The CPNP vision is to create "a park for all, forever". They address themes such as park establishment, biodiversity, cultural heritage, planning and development and, visitor management. Since 1998, the CPNP has grown to nearly 22100 ha, which is about 73% of the entire Cape Peninsula Protected Natural Environment (CPPNE). The CPPNE is the proposed core area of park, which covers about 29000 ha. CPNP are planning for further extension in this area (see land tenure map, Appendix 5).

South Peninsula Municipality

The South Peninsula Municipality (SPM) is a part of Cape Town City council, which oversees and supervises alien clearing activities. SPM have a nature conservation division

that aims to manage the reserves in the South Peninsula Municipality area and to provide environmental education.

4.2.2 Co-operation between the studied organisations/authorities and funding

Ukuvuka: Operation Firestop Campaign
The Ukuvuka Campaign involves partnership with the public sector through the National Government (represented by the Working for Water programme, the Department of Environmental Affairs and Tourism, and the South African National Parks), the provincial Western Cape government and the City of Cape Town. These have together contributed with R30 million to Ukuvuka. They have also got substantial funding and partnership from the private sector, particularly from: Santam (insurance company) with R20 million, the Cape Argus (newspaper), Nedbank and Total (oil company). Ukuvuka is also supported by institutions such as the National Botanical Institute.

Ukuvuka co-operate closely with Cape Peninsula National Park in alien vegetation clearing work.

Working for Water programme
Working for Water programme is governmental funded. It started in 1995 with a budget of R25 million. The governmental funding in 2000/2001 was the following: R230 million from the Poverty Relief Fund, R87 million from the Department of Water Affairs and Forestry, and R6.5 million from the Department of Social Development. Up to 90% of the budget of 2000/2001 was spent in almost 300 projects across the country.

The programme is also in partnership with the South African National Parks. Together they work with controlling invading alien vegetation and social development through creation of jobs.

Cape Nature Conservation
CNC co-operate with the following: The national, provincial and local government, non governmental organisations, civil society organisations, academic institutions, conservation authorities, neighbouring communities and conservancies, international agencies and business organisations. The CNC is also the largest implementing agent for the Working for Water programme.

The National government, the Cape Town City Council and the Department of Water Affairs and Forestry are financing the Cape Nature Conservation. The establishment of the Working for Water programme brought an increased interest in CNC from the government which lead to increased funding. The Department of Water Affairs and Forestry, together with multiple funding partners, fund about 35% of CNC's operating costs through the Working for Water programme. The Board currently generates about 8% of its own income.

Cape Peninsula National Park
CPNP was established in 1998. Part of the start-up costs, $6,3 million was financed by the Cape Peninsula Biodiversity Conservation Project, which, in turn was funded by the Global Environmental Facility (GEF).
The local authorities (the South Peninsula Municipality and the Cape Town City Council) gave CPNP a capital of R10.1 million a year for a five year period to subsidise the start-up costs of the park. The Working for Water programme provides funding to CPNP for alien vegetation clearing projects, with the use of labour from local, disadvantaged communities.

4.2.3 Methods for alien vegetation clearing

Ukuvuka: Operation Firestop Campaign
Ukuvuka tries to clear alien vegetation according to the most "site-appropriate" method for a specific site and species. Generally, the alien clearing undergoes the following process:

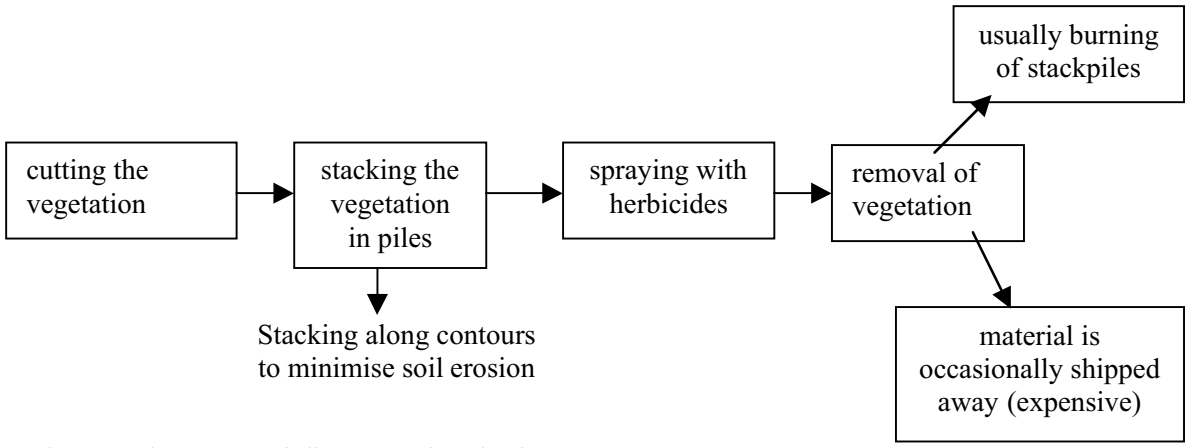

Figure 9. The process of alien vegetation clearing.

The most effective method of alien clearing that Ukuvuka have used, involves cutting the alien vegetation, spraying the tree stumps with herbicides and then stacking it in areas with no erosion problems and eventually burn it (Figure 9). At steep vulnerable slopes they cut the alien vegetation and remove it from the area, which is expensive. Another method used involves trying to kill the plants while they are standing, through injection of herbicides.

When clearing the alien vegetation, the material is put along contours on the slopes and the clearing is done in rows to avoid exposure of whole surfaces. By leaving vegetation around the cleared rows, soil erosion problems will decrease. This method is particularly used on sandy slopes. Ukuvuka have also practised controlled, preventative burning (Burning takes place in the winter period to avoid uncontrolled wildfires). Ukuvuka plans to clear 3367 ha of alien vegetation on the Cape Peninsula. So far, (July 2002) 32% of this have been achieved.

Figure 10. Stackpile of alien trees, Cape Peninsula.
(photo; I. Florberger)

Working for Water programme
Working for Water programme claims that any control programme for alien vegetation must include the following 3 phases:

- Initial control: drastic reduction of existing population of alien vegetation
- Follow-up control: control of seedlings, root suckers and coppice growth
- Maintenance control: sustain low alien plant numbers with annual control

Cape Nature Conservation
CNC's key function is "management for biodiversity". Fire is used as a tool to maintain biodiversity, e.g. old fynbos is burned in a controlled situation because it needs fire to re-spread. CNC is involved with the alien clearing since it is considered as a threat to biodiversity. The method used when clearing alien vegetation is generally cutting and then burning. This is similar to the way Ukuvuka deal with the alien vegetation clearing.

Cape Peninsula National Park
The CPNP's clearing methods depend on which species they are working with. E.g. the herbicide "timbrel" is used to prevent the spreading of Port Jackson (*Acacia saligna)* and spraying of "garlon" controls seedlings. There are also different methods used concerning the stacking of cleared vegetation:
Stacking → leaving the cleared vegetation 10-15 years to decompose (used occasionally)
Stacking → burning: (there is a fire risk if the burning take place next to houses)

Occasionally, e.g. when it's too dangerous to burn in stackpiles considering the risk of uncontrolled fires, the wood is chopped into 10cm pieces. People living nearby have the possibility to take away the wood and use it (firewood etc.). The chopping method is very expensive. (E.g. to clear 4 ha (4 soccer fields) costs R350000 if chopped and removed compared to R90000 if the wood is cut and burnt.)
The CPNP burn the stack piles in the winter, (June – August) when it's rainy. They block burn the stack piles or burn them one by one in a heap. The park will implement a controlled burning program, with blocks burned in a 12-25 year interval.

About 40% of the park are threatened by medium to dense infestation of alien vegetation (Appendix 5). Approximately 6000 ha of the area that is managed by CPNP have been initially cleared from invasive alien vegetation (~1/3 of the park). The plans are to clear all seed-bearing alien species from the park by the end of 2003.

South Peninsula Municipality
SPM oversees both clearing of alien and prevention of erosion and discusses methods concerning these issues. They advice that clearing of alien vegetation is more cost-effective if clearing is done in blocks compared to clearing in rows. (Though, one implication of this is that the soil erosion effect due to water repellency will be more severe in big blocks than in rows.) SPM also advice that stacking of cut vegetation should preferably take place in rocky areas (granite bedrock) instead of sandy areas (TMS) which have less water repellency and less erosion.

4.2.4 Alien clearing - human resources

Most of the studied organisations/authorities in the Cape metropole area employ large numbers of people in the alien clearing work. Generally, they try to give the jobs to disadvantaged people in rural areas.

The Cape Peninsula National Park works with an alien clearance programme, which provides employment for nearly 1500 people. At the moment (July 2002) the workers are in teams of 10-15 persons lead by 100 different contractors. The people are from nearby, historically disadvantaged communities. The CPNP also support initiatives from volunteers. Volunteers have been trained to provide an informational/educational service to visitors at Boulders and a volunteer programme has been introduced on Table Mountain. Some volunteer groups are also actively involved in fire fighting and alien vegetation clearance.

The Ukuvuka campaign team consists of 10 people: management, communication, administration and technological staff. Ukuvuka has a strong focus on employment. Jobs preferably go to disadvantaged people and they mostly work with the clearing of aliens. All of the actual clearing and rehabilitation work (done by CPNP and Ukuvuka) is done by independent contracting teams. The number of people gaining employment on the peninsula in alien clearing varies with the work available, season, funding, etc.

Ukuvuka sponsors 68-70 volunteering fire fighters. Some volunteers have adopted parts of the mountain that they will keep cleared from alien vegetation. Ukuvuka thinks that there is plenty of room for expanding the volunteering side. During the fieldtrip with Douglas Euston-Brown, we visited Misty Cliffs, near Scarborough. People employed by CPNP worked there with alien clearing. They used "tree-poppers" to remove the alien vegetation (Figure 11). These tools will take the whole plant away, but it doesn't work on bigger plants. Big plants are additionally sprayed with poison after cutting. It's easier to clear rooikrants (*Acacia cyclops)* because it doesn't

re-sprout that fast (it takes 5-10 years). Contrary to rooikrants, Port Jackson (*Acacia saligna*) will re-sprout quickly and grows easily in all kinds of environments. According to Euston-Brown, Port Jackson will quickly re-emerge if the clearing people don't take away all the small plants. The Cape Nature Conservation involves about 3500 people in alien clearing on different levels. According to CNC, there is also a large potential to do work through volunteers. Volunteers could be of assistance in the alien clearing and erosion control work. At the moment (July 2002), they have a couple of groups (not a huge basis) of volunteers assisting in general conservation work. In Cederberg, volunteers have helped out with management work when extra people were needed.

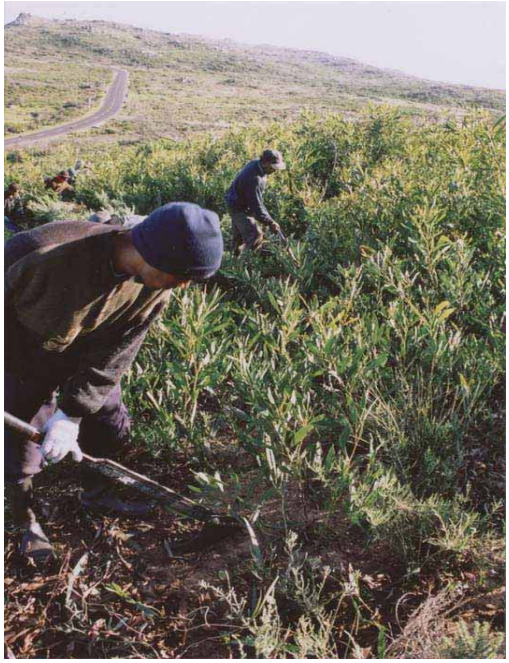

Figure 11. Clearing of Port Jackson with tree-poppers, Misty Cliffs. (Photo. I. Florberger)

CNC finds that volunteering is a way to get people involved in the conservation management. To improve and develop the volunteering work, CNC have sent some people to the USA to study their organisation of volunteers. Also, the secondary industry that comes with alien plant clearing is an important activity. Products made of alien wood, e.g. furniture, contribute to the uplifting of people, encouraging their social and economical situation.

Working for Water programme involves people in the rural areas in alien clearing. Currently, (June 2002) 20000 people are working with clearing of alien vegetation throughout the country.

SPM is a local council that oversees and supervises alien clearing activities. They don't have the capacity to employ people working with alien vegetation clearing and similar. Occasionally, they employ supervised labour-based teams from private contractors, with a minimum of 30% local labour content.

4.2.5 Prevention of fires – information and public awareness

There are different approaches in ways of making people more aware of the fire risks. In the Cederberg Wilderness area, Cape Nature Conservation (CNC) hands out pamphlets. CNC also have people working with information, e.g. to farmers. They believe that people in general have a good knowledge about fires and its implications. At the moment, CNC thinks that there is a higher level of awareness compared to three years ago, especially after the Cape Peninsula fires in 2000.

The Ukuvuka firestop campaign has a fire protection education and they help landowners to co-operate in this issue. Ukuvuka informs about fires in newspapers and in the radio. In co-operation with its partners, they have also produced some awareness materials. Ukuvuka support a "fire and life safety organisation" that travels around to schools and other groups to educate on the fire-issue. More than 15000 people have received this information. There has also been some targeted information to landowners on the mountain slopes and to people living at the urban edge.

4.2.6 Prevention of post-fire soil erosion methods

Ukuvuka has used silt curtains (Appendix 6) to catch soil erosion material. These are built on steep, vulnerable slopes. Stone gabions (Appendix 7) have been used along roads and storm water outlets. The usage of sandbags and sandgabions (baskets filled with bags of sand) has shown to be successful.

Another way of preventing post-fire soil erosion is by using "Geofabric"(Appendix 6). The Geofabric is part woven and part heat-sealed. This type of composition allows the free flow of water but prevents any solid granules to pass through. The Geofabric curtains are draped across the burned slopes to trap the soil particles until natural re-growth occurs and bind the soil. In order to minimise the environmental impact; the geofabric curtains are fastened to the ground with ungalvanized wires and untreated wood stakes. These products will eventually decompose naturally. When there is enough natural regrowth, remaining parts of the geofabric could be removed without damaging the seedlings. The geofabric is made locally and has proved to be worth using in previous rehabilitation work in locally burnt areas on the Peninsula.

4.2.7 Research issues and management implications

Cape Peninsula National Park
Management of the park is complicated by its location within the metropolitan area. The management problems include the spreading of alien invasive vegetation, unwanted wild fires, increasing urban development and increasing tourist numbers. The fire frequency in the park has increased to an unacceptable level. The dense stands of alien vegetation in the park significantly contribute to the intensity of fires and the ability to manage the fire regime appropriately.

Firebreaks are put behind the urban edge, mainly to protect people's houses and to enable access for fire fighting. Though, when there are windspread fires, the firebreaks won't work.

South Peninsula Municipality
SPM holds the following topics as important future research issues:
- More detailed studies of appropriate clearing methods for specific alien plant species
- Experiments concerning methods of doing the re-vegetation
- More information is needed concerning fire modeling, e.g. impacts/effects of hot or cold fires and the optimum time for controlled management fires

- The effects of burning of stackpiles and its implications, e.g. how much of a hazard is it to burn standing vegetation compared to burn stackpiles

Where the cut trees are stacked could be of importance. (E.g. soiltype, bedrock, slope angle could influence.) Considering the water repellency effect, it's better to stack the cut trees in rocky areas. Right now, the trees are often stacked in sandy areas where water repellency could influence soil erosion.

Another possibility to prevent alien re-vegetation is by leaving the stackpiles unburnt for a year. During this time, mice will eat the alien plant seeds, which would result in decreased re-spreading of the alien vegetation.

The indigenous vegetation is less of a problem concerning soil erosion compared to the alien vegetation. E.g. in Scarborough, where there is sandy soil and fynbos vegetation, there haven't been any problems with soil erosion.

The expanding development in the mountain area also contributes to management implications. The urban edge moves higher up in the mountains. SPM believes that the fire-parameter should be included when planning for these mountain areas. Fires and storm water drainage causes more problems than before. Along with the storm water drainage, the fire access point of view needs to be considered in the planning.

Douglas Euston-Brown
Controlled fires of fynbos are done (~ every 5 years), to avoid runaway wildfires. This is managed by the CPNP (on the Cape Peninsula). At some occasions, they have burnt in the winter, which is not the ecologically right season for the burning of fynbos. The burning of fynbos should take place in the summer when it's warm and dry. There could be negative effects when it burns in the winter; e.g., the fires will not be hot enough to enable the fynbos to germinate. Wildfires, on the other hand, could sometimes get too hot and therefore cause problems with the fynbos germination.

In May 2002, there was a fire above Simons Town. The fire started when the burning of stackpiles got out of hand. There is always a risk of accidental fires when stacking in piles. Though, a positive effect is that stackpiles overgrown by fynbos will decompose when the natural fynbos fire-cycle occurs.

According to Euston-Brown the clearing of alien vegetation could be more cost-effective if there were smaller teams of workers. One of the methods Ukuvuka used involved large clearing teams and resulted in a rapid re-spreading at one specific site, (wetland near Chapman´s Bay) probably with ~ 75%. The method used here involved one worker cutting the alien plants to ground level and the next worker spraying poison on the stumps. This resulted in rapid re-growth since the sprayers probably didn't spray all of the stumps.

The main research issues that need to be prioritised according to Euston-Brown concern methods of alien clearing. He suggests that the following issues should be studied:
- Is it better to clear alien vegetation and remove it physically? (an expensive method)

- Or, is it better to clear the alien vegetation, pile it and then burn it?

Additionally, more research is needed to inform the management workers and planning of management is needed. The first priority of Working for Water programmes activities is to create jobs through the clearing of alien vegetation. Though, at the moment they are not sure of the best way of doing it. Douglas suggests a clearing method involving cutting the alien vegetation and then remove it physically.

5. Discussion and conclusion

The invasive alien vegetation has brought and is still bringing problems to the Western Cape region. The alien species demand a lot of water that decreases the water supply in important mountain catchments. Fires in areas of alien vegetation are known to be more intensive and could enhance the post-fire soil erosion. Additionally, the invasive alien vegetation is threatening the region's biodiversity.

The awareness of fire-related problems seems to be relatively high, both on public and institutional level. The local government has given the issue more attention since the Cape Peninsula fire event in January 2000. This has resulted in more money to the organisations/authorities of interest. There is a general interest in informing the public of the risks and dangers of fires, e.g. Ukuvuka supports the "Fire and life safety organisation". Also, most of the studied organisations/authorities involve volunteers in their work in some way. With an even higher public awareness of the complications of fires, future accidental fires could be minimised.

Different approaches are used by the studied organisations/authorities and they are concerned with the fire-related issues on different levels, which leads to different priorities. Generally, they focus on the fire prevention and clearing of alien vegetation. The post-fire soil erosion issues are dealt with on an ad hoc basis, using short-term engineering solutions.

The results show similarities and common features between the studied organisations and authorities. It's consistent that they all work with alien vegetation clearing, some of them also use the same methods to do this, e.g. Ukuvuka and CPNP. Most of the organisations/authorities focus on employment, particularly giving the jobs to people from disadvantaged communities. The employment issue is also a common feature for Ukuvuka and CPNP.

The natural fynbos vegetation is dependent on fires for its re-germination. The ecologically correct season of burning is in the summer, there could be negative effects if the controlled burning is done in the winter. There is e.g. a risk that the fire doesn't get hot enough for fynbos re-germination. On the other hand, if the burning is done in the summer, there is a risk for the fire to get too hot and damaging to the fynbos seedbank. This especially happens in areas impacted by alien vegetation that intensifies fires. Also, there is a bigger risk for spreading of the fire when it's hot and dry, which could be a hazard for the people living nearby.

There are currently some problems with re-spreading after alien vegetation clearing work. This is probably a combination of different factors. The methods used are not always specific and effective for the particular alien species. E.g., at one occasion (wetland, Chapman's Bay), when the "cut and spraying" method was used, the sprayers didn't spray careful enough. This resulted in a rapid re-grow of alien vegetation. Additional research and information is needed to obtain better and more effective clearing methods for specific alien plants. Also, the "cut and spraying" method involves the usage of poison and could be questioned from an environmental point of view. Along this come

problems with large clearing teams. The studied organisations/authorities all have a strong focus on employment. This has resulted in employment of a lot of people working with alien vegetation clearing. The working teams usually consist of 10-15 people. It could be easier to organise and supervise smaller groups and could result in more cost-effective clearing.

A major, consistent issue that the organisations/authorities deal with is the removal of the stack piles. Generally, removal through burning takes place under controlled situations. Occasionally, physical removal of the stack piles takes place. This is a very expensive method, which could be further developed. Euston-Brown suggests that people from nearby communities could take the wood away and use it for energy (as firewood) and production purposes (secondary industries). This will benefit both the organisations/authorities doing clearing work and people living under disadvantaged conditions.

The most effective clearing methods are mainly the most expensive ones. Although, if soil erosion could be avoided with the use of a more expensive, but also more effective clearing method, it would probably be cheaper in the long-term.

The above problems/issues need a more complete scientific understanding. Prioritised studies will be those concerning fires in alien vegetation: burning regime/intensity, the impact of fire considering season of the year and the significance of soil type. Related to this, are the issues of water repellency and soil erosion. The spatial and temporal distribution of natural and fire-induced water repellency needs to be further examined. The post-fire soil erosion risk needs to be anticipated and mapped for areas of concern.

The results indicate that the communication between scientists and management organisations could be improved. More exchange of information would help both parts to do their work more efficiently. This could also help to achieve a better understanding of the fire-related problems.

Along with the difficulties of working with fire-related issues comes the fact that the areas of concern have many different landowners. E.g. on the Cape Peninsula, there are many private landowners. It's very important for them to be aware of the fire risk in alien vegetation. Private landowners should try to keep their land cleared of alien vegetation, either themselves or by help from specialised clearing teams. Common guidelines for all the landowners could help to improve alien clearing work and decrease to fire risk.

In general, a more complete understanding of the fire-erosion cycle is asked for. At the moment, short-term solutions are used. With a better knowledge of the fire-related issues, long-term solutions could be developed. Using long-term, environmental approaches rather then short-term engineering approaches could be a sustainable way of dealing with the fire-erosion event.

If a better scientific understanding of the fire-related issues could be achieved, the above problems could be dealt with and mismanagement avoided. In such case, common

management guidelines for the organisations/authorities could be developed to decrease and prevent the fire-related problems in the Western Cape region.

The discussion brings out the following conclusions and recommendations:

- There is a relatively high awareness of the fire-related problems in the Western Cape and the involvement of volunteers is increasing.

- The studied organisations/authorities focus on the prevention and clearing of alien vegetation. The post-fire soil erosion issues are dealt with on an ad hoc basis.

- The studied organisations/authorities have a strong focus on employment. This has resulted in employment of lots of people working with alien clearing in rather large teams. Though, smaller groups might be easier to organise and supervise and could result in more cost-effective clearing.

- The method involving physical removal of stackpiles would be more efficient and less expensive if the people from nearby disadvantaged communities could make use of the wood (as firewood and for secondary industry purposes).

- The fire-related issues need additional research for a more complete scientific understanding. The communication between the studied organisations/authorities and scientists could also be improved.

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