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**ENVIRONMENTAL AND SOCIO-ECONOMIC
EFFECTS ASSOCIATED WITH THE
PLANTING OF Atriplex nummularia Lindl.
(OLDMAN SALTBUSH) IN THE KAROO**

THESIS

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ABSTRACT

This study examines the environmental and socio-economic effects associated with the planting of *Atriplex nummularia* Lindl. (Oldman saltbush) in the karoo. This is the first study of its kind on oldman saltbush and serves as an important scoping exercise in assessing the impact of saltbush on its surrounds and in identifying additional aspects which require investigation. The environmental parameters investigated include microclimatic effects, soil induced changes, salinity effects on the germination of selected karoo species and compositional changes in the indigenous plant community within a saltbush plantation. When compared to indigenous karoo plant species oldman saltbush is found to ameliorate soil temperatures and increase surface soil salinity (specifically sodium chloride), on an individual plant basis. Salinity is shown to have a differential effect on the germination of selected karoo shrubs. The indigenous plant community within a forty year old saltbush plantation is impoverished with both density of individuals and species richness being markedly reduced. Saltbush is identified as an unsuitable nurse plant for the majority of karoo shrubs. Farm size in relation to both actual and intended area established to saltbush is considered. The area of saltbush already established in the karoo is considered too insignificant to have any wide socio-economic impact. Farmers who intend planting large areas of their farms to saltbush are in the minority. It is those farmers who already have some saltbush planted, who intend planting more. Ecologically based management guidelines are presented, suggesting practices which minimize the detrimental effects of saltbush on soil salinity and the indigenous plant community. These guidelines are practical and in keeping with the overall objectives of optimum resource utilisation and the national grazing strategy for South Africa.

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CHAPTER 1

INTRODUCTION

1.1 Background

Drought is a regular phenomenon in South Africa (Tyson and Dyer, 1975; van Rooy, 1980; Roux, 1980) which impacts on the country and its people in many ways. The South African livestock industry has long been subject to regular losses of stock and reductions in livestock production due to the lack of sufficient fodder during dry periods (Drought Commission, 1923). Approximately 65% of the surface area of the natural pasture of South Africa is semi-arid or arid (Tidmarsh, 1966; Anon, 1989) while the rainfall is unreliable with drought being the norm not the exception (de Villiers, 1958). *Atriplex nummularia* Lindl., commonly known as oldman saltbush, is used extensively for fodder production in the arid areas of many countries. It is native to Australia (Black, 1948) where it is widely used for fodder and is particularly suited to arid and semi-arid regions. It is a highly adapted drought resistant plant which has the ability to maintain relatively high rates of biomass production under severe environmental conditions (Leigh and Wilson, 1970). Reports of the use of saltbush in South Africa date from the late 1880's. Alston (1889, 1890, 1891) conducted acclimatisation and productivity tests in the Cape Province on two Australian *Atriplex* species, one of which was *Atriplex nummularia*. Another source records the importation of seeds of oldman saltbush to South Africa from Australia as one of seven *Atriplex* species in 1893 (Rubidge *pers comm.*, 1984).

Oldman saltbush, spineless cactus (*Opuntia spp.*) and American aloe (*Agave americana*) are the three main types of drought resistant plants which have been used in South Africa (de Kock, 1980). Early work in South Africa on the use of saltbush as a source of fodder in dry periods was reported on by Turpin and Smuts (1925), Turpin and Gill (1928), Marais and Bonsma (1941) and Bonsma and Mare (1942). The Department of Agriculture and Water Supply has recommended the planting of saltbush in the karoo region for more than 20 years (Moodie, 1961; de Kock, 1967). The latest Government agricultural development plan for the karoo (Anon, 1987) identifies the use of drought resistant plants as important. The aims of research and extension toward furthering the use of drought resistant plants are specifically stated in the plan. Oldman saltbush is recommended as a drought reserve to enable farmers in the karoo to maintain their stock numbers during dry periods (Moodie, 1961). The extra fodder provided by saltbush plantations is also a possible way of improving the natural pasture by preventing over utilization during adverse periods (Aucamp, 1973a).

Saltbush can be utilized directly by small and large stock and some work has been done on the utilization of saltbush by ostriches (Agricultural News, 1987). There is no accurate figure, but it is estimated that an area of some 50 000 ha is already established to oldman saltbush in the karoo (Steynberg and de Kock, 1987). In recent times the plant has been seen by some farmers as a means of boosting the carrying capacity of their land by providing additional grazing (Turner, 1986). The long and short term impacts of planting *Atriplex nummularia*, a naturalized exotic (Gibbs Russell *et al.*, 1987), on the surrounding ecosystem are unknown in South Africa. This study arose from the realization that there may be long term detrimental environmental effects associated with saltbush cultivation in South Africa. Saltbush is not an aggressive invader and can be removed by overgrazing (le Houerou, 1986). *Atriplex nummularia* was originally the dominant perennial species over much of the south-eastern riverine plain of New South Wales, Australia, but as a result of stocking its presence now is confined to areas protected from stock grazing (Moore, 1953). Brown and Gubb (1986) list oldman saltbush as being moderately invasive in the arid and semi-arid habitats of southern Africa, while Geldenhuys (1986) and Poynton (1984) see *Atriplex nummularia* as a useful alien for which there is no indigenous substitute.

Most studies on introduced species in arid and semi-arid environments have been concerned with the survival and production of the introduced species (Forti, 1971; El Hamitouni and Sarson, 1975; le Houerou, 1986). The impact of the alien species on the environment is often not considered. Work on how alien species affect the indigenous habitat into which they are or have been introduced is mainly concerned with species which have become aggressively invasive (Macdonald *et al.*, 1986) and/or which have a detrimental effect on agricultural activities (Mooney and Drake, 1986). Furthermore, most efforts are concerned with the identification of invasive aliens (Bruton and Merron, 1985) and the ecology of the invasions (Co-operative Scientific Programmes, 1983; Brown *et al.*, 1985; MacDonald, *et al.*, 1986). It appears that to date, little research has been undertaken in South Africa on the effect of saltbush on its environment. Although saltbush has not yet become a threat to natural habitats in South Africa the more subtle longer term effects which it may have on its surrounds in southern Africa are unknown. This study considers a broad variety of possible effects and is of necessity a multidisciplinary one as it is essentially a scoping exercise. As the spread of saltbush in southern Africa is directly related to farming activities some socio-economic aspects are considered along with environmental ones. This study broadly follows the scientific method in as much as questions are researched through careful observation, analysis and synthesis and answered objectively on the basis of evidence gathered (Haring and Lounsbury, 1983). The study is focused by using key questions, this being "...the guiding impulse...and the beginning point (of science)" (Haring and Lounsbury, 1983, p. 2, brackets, authors own). The experimental and normative methods are both employed in answering the many questions raised in the various chapters.

Each chapter is a scientific study in its own right, examining separate issues and thus has its own specific key questions, theoretical background, methodology and conclusion. Each of these, essentially separate issues, is considered and presented in this study to provide a broad understanding of the ways in which oldman saltbush effects its surrounding micro-environment. The term micro-environment is used to indicate a broader perspective incorporating more than just the microclimate (e.g. soils and plant communities). The results of this study will possibly prove to be invaluable in the development of guidelines controlling the establishment, management and utilization of oldman saltbush in South Africa.

1.2 Aims and key questions

This study was funded by the Karoo Biome Project, one of the CSIR's Biome projects and part of the National Programme for Ecosystem Research. The goal of these projects is to develop a predictive understanding of the structure and functioning of ecosystems as a basis for their optimal management (Cowling, 1986). The principal objective of the Karoo Biome Project is "...to provide the fundamental understanding necessary for the optimal management of the karoo" (Cowling, 1986, p. 14). The general aim of this study is to assess potentially important biotic and abiotic factors and to gain an understanding of the ways in which oldman saltbush affects the ecosystem with the view to the development of ecologically acceptable management guidelines. This general aim places the study well within the objective of the Karoo Biome Project.

As this is the first study of its kind on oldman saltbush it is not possible that all of the potentially important ecological factors are examined nor may the management guidelines developed be complete but those recommendations that can be made will be based on sound ecological research. Other factors which may be important will also be identified for further research, which is important in any scoping exercise. There are two broad aspects which are examined. The first broad aspect examined is the possible effect of oldman saltbush on the surrounding soils, plants and microclimate. Oldman saltbush plants can grow to be 3 m in height and 10 m in diameter (le Houerou, 1986) and as such, will provide shade and protection, and may be significant as nurse plants for the indigenous low-growing karoo bushes. These associated effects may be important for the establishment and growth of karoo plants. Conversely, saltbushes are halophytes with a high salt concentration in their cell sap. This contributes to a high salt content in the leaf litter which, on decomposition, may be important in seed germination and favour the growth of some indigenous plants at the expense of others. The major thrust of this study is to assess the impact of saltbush on the microclimate, soils, germination rates and on the associated karroid plant community.

The second broad aspect and smaller part of this study is of a more socio-economic nature. Essentially, this section assesses the magnitude of the environmental problems, if there are any, by determining the areas typically planted to saltbush and the amount of planting which can be expected on farms in the karoo in the future. The amount of saltbush already planted and the intended future planting of saltbush is important as this provides a perspective regarding the magnitude of any possible environmental effects associated with oldman saltbush which are deemed detrimental. Furthermore, implications concerning farm size and the use of saltbush are also investigated which should provide insight into the actions of farmers on small farms to dry conditions and a harsher economic climate.

The two broad aims of this study can be summarized as:

- A. to examine the effect oldman saltbush has on the micro-environment and how these effects influence the surrounding karoo vegetation communities, and
- B. to assess the amount of saltbush planted in the karoo, the dynamics of farm size and the intentions of farmers to plant more saltbush.

1.2.1 Summary of key questions

Many questions have been identified in an attempt to consider a broad variety of potential long term influences which saltbush may have in the karoo. The specific key questions which this study focuses on are stated in each chapter but listed together here to provide an overall perspective. The key questions are divided into two groups according to the two broad aspects of the study:

A Key questions concerning the ecological aspects of the study.

- Are there gross differences in microclimate within saltbush plantations as compared to the adjacent natural karoo vegetation (unplanted) or are the effects of saltbush on microclimate restricted to each bush individually? (Chapter 2)
- What is the quantitative extent of the differences, if any, identified in the previous question, specifically soil temperatures, light intensity and relative humidity? (Chapter 2)
- Is the presence of *Atriplex nummularia* associated with changes in root densities? (Chapter 3)
- How does *Atriplex nummularia* affect soil chemistry and texture? (Chapter 3)
- What effect does increased salinity have on the germination rates of selected karroid species commonly found in areas planted to oldman saltbush? (Chapter 4)
- Do *Atriplex nummularia* plantations change the density of indigenous dwarf shrub

species ? (Chapter 5)

- Do *Atriplex nummularia* plantations change the species diversity of perennial indigenous dwarf shrub communities? (Chapter 5)
- Which indigenous shrub species are affected by the establishment of an *Atriplex nummularia* plantation? (Chapter 5)
- How effective is *Atriplex nummularia* as a nurse plant? (Chapter 8)
- Of what magnitude are the micro-environmental effects associated with *Atriplex nummularia* likely to be for the Karoo Region as a whole? (Chapter 8)
- How can any detrimental effects be kept to a minimum? (Chapters 7 and 8)

B Key questions concerning the socio-economic aspects of the study.

- What area of saltbush, on average, is presently established on farms in the karoo? (Chapter 6)
- What area, on average, do karoo farmers intend planting to oldman saltbush in the five year period 1984-1989? (Chapter 6)
- What is the extent of the spatial variation in the amount of *Atriplex nummularia* established and the amount farmers intend establishing in each of the four sub-regions of the karoo? (Chapter 6)
- Do smaller farms have a greater proportional area planted to oldman saltbush than larger farms? (Chapter 6)
- Do farmers on smaller farms intend establishing a greater proportion of their farms to oldman saltbush than farmers on larger farms? (Chapter 6)
- Will there be any significant economic benefit in the karoo as a result of increased agricultural production by utilizing *Atriplex nummularia*? (Chapter 8)

1.3 Choice of study areas

A different set of study areas was used for each of the two broad aspects of this study. In the case of the micro-environmental aspects associated with oldman saltbush, two sites were chosen. Both sites having well established *Atriplex nummularia* plantations with an adjacent area of natural vegetation. The two sites were both on near level plains and the boundary between karoo vegetation and saltbush plantation was reasonably well defined. In each case, both the sample and control areas were on the same soil type and soil depth. The location of the two study sites is illustrated in Figure 1.1.

The first site of completely enclosed and ungrazed 24 year old saltbush plants is situated near Middelburg (Cape Province, South Africa). The site is in one of the experimental areas of the

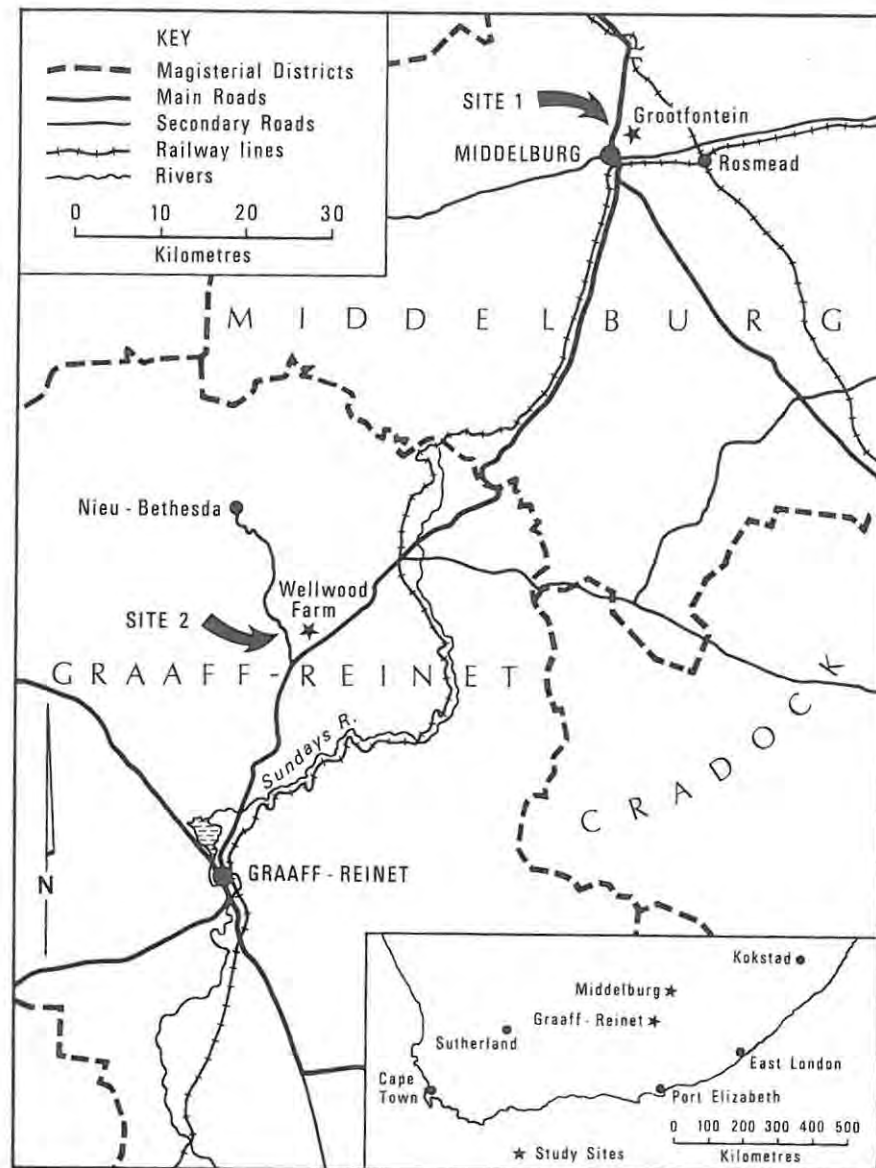


Figure 1.1: Location of both study sites

Grootfontein College of Agriculture. The second site of 40 year old saltbush plants is on the farm Wellwood, situated approximately 30 km from Graaff-Reinet on the Middelburg road (Figure 1.1). The second site has been subject to grazing within the normal rotational system of the farmer (see Plates 1&2, p.7). The veld type associated with the Grootfontein site (Site 1) is classified as False upper Karoo (Acocks, 1975, Type No. 36) while the veld type at Wellwood (Site 2) is False karroid broken veld (Acocks, 1975, Type No. 37). The climate of the study region is semi-arid continental with a mean annual precipitation of 350 mm, Grootfontein receiving approximately 37% of its precipitation in summer compared with 67% at Wellwood (Badenhorst, 1970). Mean annual temperatures are 15°C and 17°C for Grootfontein and Wellwood respectively. Grootfontein has a greater temperature range and extreme cold temperatures in the region of -10°C while Wellwood has a more restricted temperature range and less extreme minimum temperatures (in the order of



Plate 1: The 40 year old saltbush plantation at Wellwood (Site 2) where environmental parameters were investigated. Note the contrast between the open karoo vegetation (control) and the saltbush plantation (control). The cup anemometer in the foreground is 0,6m above ground and illustrates the general characteristics of the area in which the sensors were situated for microclimatic monitoring (period one).



Plate 2: A 2m tall saltbush plant in the 40 year old saltbush plantation at Wellwood (Site 2). Note the accumulation of litter around the base of the plant and the sparse karoo vegetation between saltbush plants.

-6°C). At Grootfontein the average absolute minimum temperature of the coldest month, July, is 0,4°C and the average absolute maximum temperature of the warmest month, January, is 30,7°C (Smit and Jacobs, 1978). Both sites experience regular frost during the coldest period of the winter (June to August).

The soil at the Grootfontein site is classified as Loskop series (Mispah form) (MacVicar *et al.*, 1977), underlain by a calcium carbonate layer and is between 25 and 50 cm deep. The soil can be classified as a loamy sand consisting of 4% clay, 12% silt and 84% sand from a bulked sample of the top 20cm of soil. The soil at Wellwood, characterized by a red structured (Blocky) B horizon, is classified as Glendale series (Shortland form) (MacVicar *et al.*, 1977) and has a sandy clay loam texture consisting of 32% clay, 22% silt and 46% sand in the A horizon. It is also underlain by a calcium carbonate layer.

The second broad aspect of this study is based on the 1984 postal return questionnaire survey conducted by the Department of Agriculture and Water Supply : Karoo Region. This component of the study therefore covers the Karoo Region as defined by the Department of Agriculture (Anon, 1987) and incorporates the North-west Karoo, Great Karoo, Karoo Midlands and the North-east Karoo regions.

1.4 Characteristics and utilization of *Atriplex nummularia*

The genus *Atriplex* has been extensively studied for its physiological attributes (Osmond, 1965, 1976; Slatyer, 1970; Osmond and Greenway, 1973; Mooney *et al.*, 1977) taxonomic peculiarities (Hall and Clements, 1923; Ulbrich, 1934; Nobs, 1978) and ecological significance in arid and psammospheric communities (Jessup, 1969; Jones and Hodgkinson, 1970; Barker and Lange, 1970). *Atriplex nummularia* in particular has been extensively studied and is utilized for agricultural purposes in the following countries, California, U.S.A. (Jones, 1970), Israel (Forti, 1971), Tunisia (El Hamitouni and Sarson, 1975), Egypt (Hassan *et al.*, 1978), South Africa (de Kock, 1980), Saudi Arabia (Hyder, 1981), Libya (Le Houerou *et al.*, 1983), Algeria, Morocco and Syria (le Houerou, 1986), Chile (Correal, 1987) and Ciskei (van Heerden, 1987).

Oldman saltbush is an exceptional plant in many ways, combining many peculiar characteristics. An understanding of these many characteristics is essential background knowledge for this study. The way in which saltbush is utilized is also important as there are various techniques for the establishment and approaches to the management and grazing of saltbush. *Atriplex nummularia* is a halophyte and is able to maintain high production rates in adverse conditions. In Israel it was

found to produce 1,53 kg of dry matter per square meter annually when watered with undiluted sea water (Pasternak *et al.*, 1985, 1986). *Atriplex* has been regarded as the mainstay of the pastoral industry in the drier parts of Australia (Trumble, 1932; Jackson, 1958). *Atriplex nummularia* has been noted in South Africa for its drought resistance and productivity (Burger, 1927; de Kock, 1967). Aucamp (1973a) obtained an equivalent carrying capacity of between 6 and 8 sheep per hectare per year over a six year period in trials at the Grootfontein College of Agriculture. The feed value of saltbush alone is sufficient for sheep to maintain their condition (Wilson, 1966a). Oldman saltbush is relatively water efficient, requiring 304 kilograms of water to produce one kilogram of dry material as compared to lucerne (alfalfa) which requires 750 kilograms of water (de Kock, 1967). Steynberg and de Kock (1987) calculated that there is an estimated area of 2,5 million ha in the Karoo Region which is suitable for saltbush cultivation. They estimate that an area of 451 200 ha of saltbush could carry all the stock, for a period of two months, that the natural karoo pasture can carry.

Oldman saltbush is a hardy shrub which can grow to be 3 m in height and 10 m in diameter (see Plate 2, p. 7) (le Houerou, 1986) and live for 100 years (Osmond *et al.*, 1980). Saltbush is resistant to cold and frost and can be established on a wide range of alkaline soils (Aucamp, 1973b). Saltbush can survive on as little as 150 mm of rainfall per annum (Aucamp, 1973b) but production is greatly increased by periodic irrigation. The optimum temperature range for the germination of oldman saltbush in the laboratory is 20-25° C (Beadle, 1952). The seeds of saltbush are also highly viable with germination percentages of 80% being common. Longevity of the seeds is however not very good. Edwards (1974) only obtained a 2% germination of saltbush seeds which were 8 years old. He also found that different batches of seeds had different longevities. The establishment of saltbush is best achieved by growing seedlings and then transplanting these. Seedlings can be grown using seed beds, plastic bags or seedling trays (de Kock, 1987). Hobson (1985) attributed the lack of saltbush planting in the karoo to poor nursery techniques. Establishing a saltbush plantation requires a certain amount of knowledge and careful planning. Oldman saltbush is not an active invader and there appears to be little danger of it becoming widespread by natural means. The fact that saltbush is not easy to establish probably explains why it is not more intensively used in the karoo. Saltbush can be grazed directly by livestock but should be allowed two years after transplanting before being grazed. The plants should however not be allowed to grow too tall as they can become inaccessible to livestock. Tall bushes can be severely cut back as this causes vigorous regrowth which is available and preferred by stock.

1.5 Factors investigated and structure of the study

Chapter 1 serves as the introduction to the study and presents the aims and overall strategy for the

study as well as providing necessary background information. Chapters 2 to 5 are concerned with the different ecological aspects considered in the study. Figure 1.2 illustrates the "factors" investigated schematically, showing how these form an integral unit of study on the long term impact of saltbush on the environment. Chapter 2 examines the microclimatic effects associated with oldman saltbush. Microclimates are examined at two different spatial scales. In the first instance by comparing conditions in the adjacent karoo dwarf shrubland (the natural vegetation) with those in the saltbush plantation. Secondly, within the saltbush plantation, by comparing the microclimate in the immediate proximity of a single saltbush plant with conditions between saltbush plants. Wind

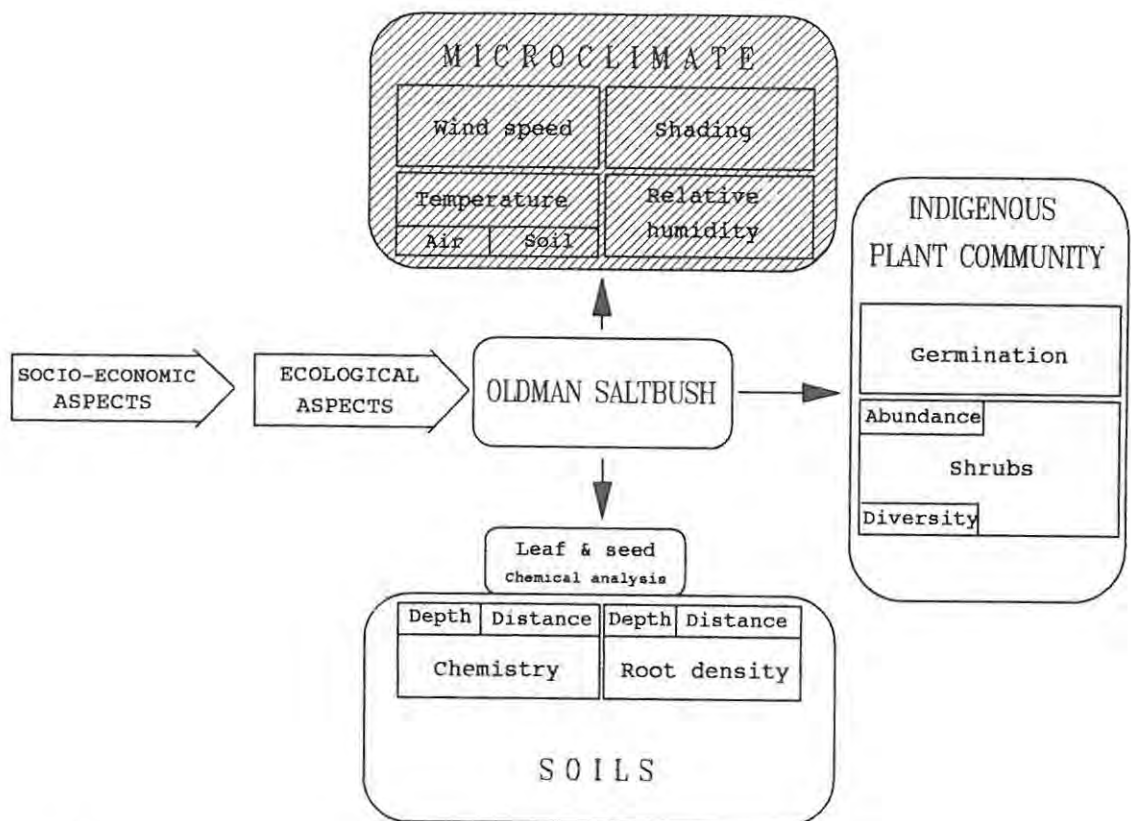


Figure 1.2: Schematic diagram of the "factors" investigated in the ecological aspects of the study (Chapters 2 to 5).

speed, shading, air temperature, soil temperature and relative humidity are compared at both spatial scales. Chapter 3 considers soil induced changes at different depths and distances associated with oldman saltbush. Root density surrounding a saltbush was also measured, quantified and reported on in Chapter 3. Soil samples are also compared at two scales: in the first instance, random samples

from within the saltbush plantation are compared to samples from the adjacent karoo dwarf shrubland. Secondly, a gradient analysis technique was employed which considered changes in soil chemistry associated with the dominant karoo dwarf shrub *Pentzia incana* with those surrounding oldman saltbush individuals.

Species of *Atriplex* have been reported to cause an increase in soil salinity (Roberts, 1950; Fireman and Hayward, 1952; Jessup, 1969; Sharma, 1973a; Sharma and Tongway, 1973). The effects of salinity on the germination of selected karroid species is examined in the laboratory and documented in Chapter 4. If oldman saltbush has a significant effect on the microclimate and soils in its proximity then the nature of this effect will be reflected in the plant community found in mature saltbush plantations. The plant community characteristics of species diversity and abundance are assessed in Chapter 5 in a comparison of unplanted areas with areas planted to saltbush.

Chapters 6 and 7 concern the socio-economic aspects of the study. The spread of saltbush, like many other alien species (Shaughnessy 1986), is largely determined by its history of use by man rather than by ecological factors. Chapter 6 considers the planting of oldman saltbush and farm size in the karoo. This analysis is based on an extensive questionnaire survey and is included as an essential part of this study as it determines the extent of the planting of saltbush. It concerns the dynamics of the planting of saltbush by farmers, without which there would be no need for the entire study. Some insight into the amount of saltbush planted and the likely planting of saltbush in the karoo is essential as it places detrimental and/or advantageous effects associated with oldman saltbush in the karoo into perspective by indicating the spatial and temporal magnitude of the cumulative effect of this management option. Insight should also be gained into which farmers in which regions of the karoo have and/or intend planting saltbush. In Chapter 7 management guidelines for the planting of saltbush in the karoo are developed. These guidelines constitute the first guidelines based on ecological research for the planting of saltbush. Chapter 8 concludes the study in the form of a general discussion by addressing broader questions which require a combination of the results of more than one chapter to answer. Aspects requiring further research are identified and the limitations of this study are discussed.

CHAPTER 2

MICROCLIMATIC EFFECTS ASSOCIATED WITH Atriplex nummularia

2.1 Introduction

Research into microclimates is detailed and extensive with the focus being on thermodynamics, physiology, modelling and the development of measuring techniques (Rosenberg, 1974; Oke, 1978; Jones, 1983). Limited work has been conducted on microclimates within natural plant communities. Research on microclimates associated with plants has mostly been concerned with agricultural applications (Denmeed, 1969). In the karoo "practically no information exists on the rate and magnitude of change ... in microclimates" (Roux and Theron, 1987, p 60).

Farrell (1990) in studying the role of trees in selected agroecosystems in Mexico states that;

"Trees are unique in their influence on agroecosystem properties because of their inherent structural characteristics and perennial growth habit. Large canopies intercept wind, precipitation and solar radiation, as well as contribute organic matter and nutrients to the soil surface" (Farrell, 1990, p 180-181).

Atriplex nummularia, being a large perennial shrub (up to 3m tall) may have similar influences on the dwarf shrub communities of the karoo. Microclimatic influences found by Farrell (1990) to be associated with trees were, decreases in radiant energy, air movement, evapotranspiration and maximum air temperatures and an increase in minimum air temperatures. The establishment of perennial shrubs in desert plant communities represents an important change and the development of a mosaic of considerably different microhabitats (McAuliffe, 1988). Plates 1 and 2 illustrate the difference in size of oldman saltbush as compared to the surrounding indigenous vegetation in the south eastern karoo. Large shrubs can be important in providing protection from damaging frosts as well as protection from heat stress in desert and semi-desert environments (Steenbergh and Lowe, 1977, 1983; Nobel, 1980). Open microhabitats have shown complete mortality of *Agave deserti* seedlings exposed to high temperatures, even when water was abundant (Jordan and Nobel, 1979).

Henrici (1955,1958) measured the temperature of various parts of many karoo species and found that the temperatures of plants were more extreme than air temperatures with many plants reaching

temperatures of over 40° C during the day. Temperature is an important factor in the germination of seeds of semi-arid plant species (Sharma, 1976; Potter *et al.*, 1986). This chapter examines the microclimatic effects associated with oldman saltbush. Saltbush plants, being large shrubs, could change air temperatures and soil temperatures as well as reduce the occurrence and severity of frost in their immediate micro-environments in the karoo. Litter on the soil surface associated with saltbush will change the flux of soil temperatures (Shmida and Whittaker, 1981; Ghuman and Lal, 1982).

As this study is largely a scoping exercise, the microclimate associated with oldman saltbush is examined at two different spatial scales. In the first instance by comparing conditions in the adjacent karoo dwarf shrubland (the natural vegetation) with those in the saltbush plantation. Secondly, within the saltbush plantation, by comparing the microclimate in immediate proximity of a single saltbush plant (under the bush) with conditions between saltbush plants. Conditions under an individual saltbush are also compared to conditions under an individual karoo bush (*Pentzia incana*) in an attempt to assess the magnitude of the influence of saltbush, if any, on the microclimate. Microclimatic parameters are measured during four monitoring periods. Relative humidity, wind speed, light intensity, air temperature, soil surface temperature and soil temperature at depth were all recorded during each monitoring period. These parameters were selected as they are the major factors determining microclimatic conditions (Oke, 1978) and are important in desert plant community dynamics (McAuliffe, 1988).

2.2 Key Questions

For the purposes of the overall study on how saltbush effects the environment, two specific key questions concerning the microclimate are identified.

- (i) Are there gross differences in microclimate within the saltbush plantations as compared to the adjacent natural karoo vegetation (unplanted) or are the effects of saltbush on microclimate restricted to each individual bush?
- (ii) What is the quantitative extent of the differences, if any, identified in the previous question (i), specifically soil temperatures, light intensity and relative humidity?

2.3 Methodology

Microclimatic parameters were measured using a MCS-120 electronic data logger with six temperature sensors, two relative humidity sensors, two light intensity meters, two cup anemometers

and one wind direction sensor (details of each sensor and its installation are discussed in Section 2.3.1). All sensors were calibrated and checked in the laboratory. The sensors were arranged into two sets, one for the sample area (oldman saltbush plantation) and the other for the control area (natural karoo vegetation adjacent to the saltbush plantation). Plates 1 and 2 present a visual impression of the situation at Site 2. Each set of sensors thus consisted of three temperature sensors, one relative humidity sensor, one light intensity meter and one anemometer (Figure 2.1). The distance between the sets of sensors was 25 meters with the logger situated in the middle. The wind direction sensor was used to monitor the overall wind direction and was placed near the data logger 2,5 m above ground (Figure 2.1).

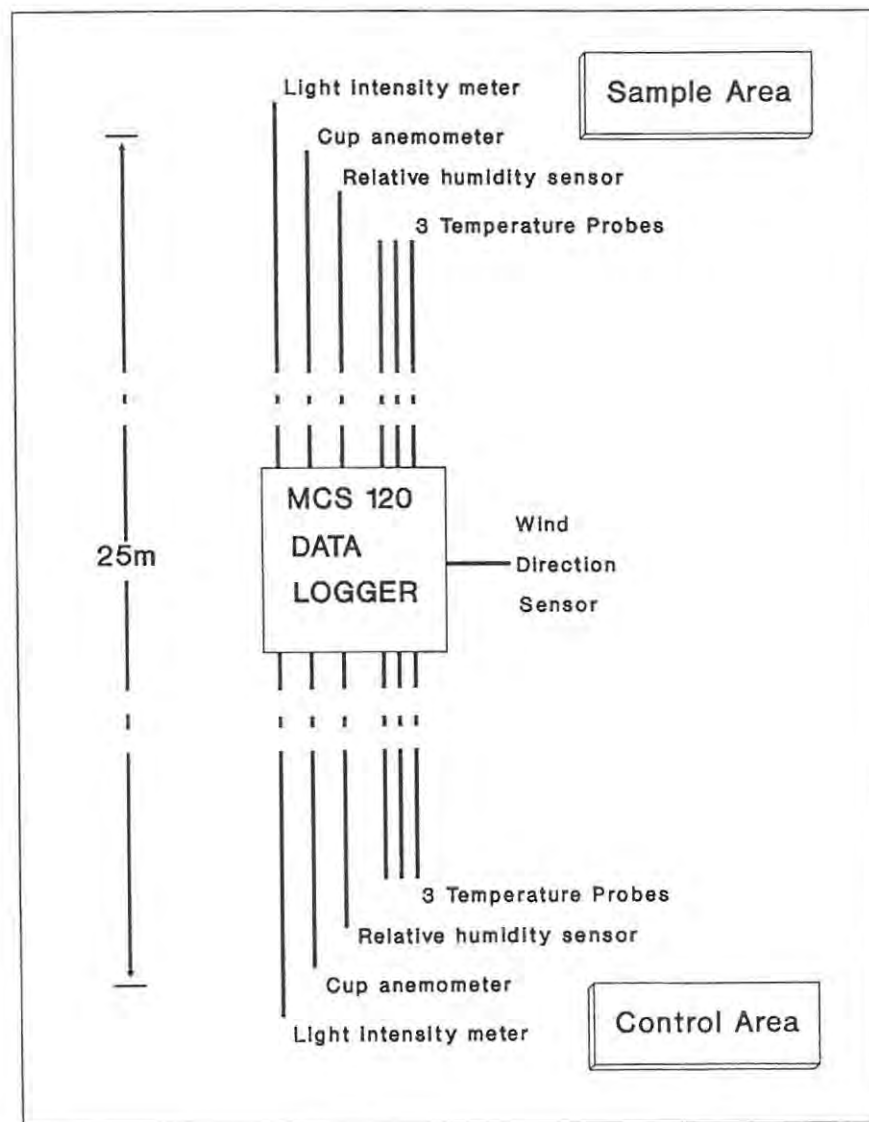


Figure 2.1: Schematic diagram of the layout of the data logger and sensors for microclimatic investigations in the sample and control areas.

The arrangement of sensors outlined above allowed for the simultaneous recording of microclimatic conditions in both the sample and the control sites. The data logger was programmed to scan all channels at half hourly intervals and save a mean value onto a microchip. These half hourly readings are the mean value of thirty internal scans (one each minute) done by the logger on each channel and stored in the memory of the logger. Four monitoring periods of one month each were completed: two months at Site 1 and two months at Site 2. Initially, the intention was to monitor microclimatic conditions for one month in winter and one month in summer at each site. Monitoring one month in summer and one in winter at each site was not achieved due to failure of the data logger on two occasions. The first two monitoring periods were completed at Site 2 the dates being 8/9/87 to 2/10/87 (spring) and 2/10/87 to 1/11/87 (early summer). The two monitoring periods at Site 1 ran during the periods 1/3/88 to 30/3/88 (summer) and 27/7/88 to 24/8/88 (winter). The positioning of the sensors was varied slightly for each of the months, as better insight of the microclimates was gained. The rearranging of the monitoring positions was deemed acceptable as all subsequent comparisons are limited to the comparison of sample and control readings only and no quantitative comparison is made between monitoring periods or sites. The precise arrangement of sensors for each monitoring period is summarized by Tables 2.1, 2.2, 2.3 and 2.4.

Table 2.1: Arrangement of sensors for monitoring period one 8/9/87 to 2/10/87 (spring) at Site 2, Wellwood.

Details	Location	Sensor	Position
Comparison of 40 year old saltbush plantation (sample) with adjacent karoo vegetation (control)	sample	temperature	50cm above ground between saltbush
	control	temperature	50cm above ground between bushes
	sample	temperature	soil surface between saltbush
	control	temperature	soil surface between bushes
	sample	temperature	10cm deep between saltbush
	control	temperature	10cm deep between bushes
	sample	relative humidity	5cm above ground between saltbush
	control	relative humidity	5cm above ground between bushes
	sample	light intensity	on soil surface between saltbush
	control	light intensity	on soil surface between bushes
	sample	wind speed	60cm above soil surface
	control	wind speed	60cm above soil surface

Table 2.2: Arrangement of sensors for monitoring period two 2/10/87 to 1/11/87 (early summer) at Site 2, Wellwood (Wind speed was not recorded).

Details	Location	Sensor	Position
Comparison of conditions within a 40 year old saltbush plantation. Under a saltbush (sample) as compared to between saltbush (control)	sample	temperature	soil surface under saltbush
	control	temperature	soil surface between saltbush
	sample	temperature	5cm deep under saltbush
	control	temperature	5cm deep between saltbush
	sample	temperature	10cm deep under saltbush
	control	temperature	10cm deep between saltbush
	sample	relative humidity	5cm above ground under saltbush
	control	relative humidity	5cm above ground between saltbush
	sample	light intensity	on soil surface under saltbush
	control	light intensity	on soil surface between saltbush

Table 2.3: Arrangement of sensors for monitoring period three 1/3/88 to 30/3/88 (summer) at Site 1, Grootfontein.

Details	Location	Sensor	Position
Comparison of conditions within and adjacent to a 24 year old saltbush plantation. The plantation is the sample while the adjacent karoo vegetation is the control	sample	temperature	soil surface under saltbush
	control	temperature	soil surface under <u>Pentzia</u> sp.
	sample	temperature	soil surface between saltbush
	control	temperature	soil surface between bushes
	sample	temperature	5cm deep between saltbush
	control	temperature	5cm deep between bushes
	sample	relative humidity	5cm above ground between saltbush
	control	relative humidity	5cm above ground between bushes
	sample	light intensity	on soil surface between saltbush
	control	light intensity	on soil surface between bushes
	sample and control	wind speed	Faulty sensor (readings incomplete)

Table 2.4: Arrangement of sensors for monitoring period four 27/7/88 to 24/8/88 (winter) at Site 1, Grootfontein (wind speed was not recorded).

Details	Location	Sensor	Position
Comparison of conditions 75cm from a 24 year old saltbush (sample) as compared to conditions between karoo bushes (control)	sample	temperature	20cm above ground 75cm from saltbush
	control	temperature	20cm above ground between bushes
	sample	temperature	soil surface 75cm from saltbush
	control	temperature	soil surface between bushes
	sample	temperature	5cm deep 75cm from saltbush
	control	temperature	5cm deep between bushes
	sample and control	relative humidity	Faulty sensor (No Readings Possible)
	sample	light intensity	on soil surface 75cm from saltbush
	control	light intensity	on soil surface between bushes

The readings recorded by the electronic data logger were read off the micro-chip into a personal computer and manipulated using a spreadsheet package (SuperCalc 5). Subsequent statistical analysis was undertaken using the Statgraphics statistical package (Statgraphics, 1986). The data collected for each of the four monitoring periods were all analyzed using the same procedures. Initially the mean value of each half hourly recording was calculated using the readings at that time of day for all of the thirty days. Standard deviations were calculated for each time period in order to provide insight into the daily variability of the different parameters. Graphs of the mean values for pairs of sample and control values were produced for comparative purposes. In this way curves of mean values of each parameter for the entire month are presented in one graph spanning a 24 hour period. This was done to provide an indication of gross differences between pairs of sample and control sensors for each parameter. The graphs are all presented using the same scales to prevent undue exaggeration and to facilitate easy visual comparison. In the case of the wind speed the average daily run was calculated for sample and control positions for the entire month.

Testing to determine whether the differences depicted by the graphs were statistically significant proved to be more complex than was initially expected. The raw data could not be analyzed using probability techniques as conditions from one day or one time to the next are clearly not independent. All that is required for this study is to be able to state with some certainty whether

conditions in the sample areas are different to conditions in control areas. To this end the area under the curve of each sensor for each day was calculated using the trapezoidal rule (Britton *et al.*, 1965). Calculating the area under the curve provided a gross measure in the form of a single figure of the quantitative extent of each parameter. This single figure (area under the curve) representation of each parameter allowed for a simple student's *t* test to be performed and the acceptance or rejection of the null hypothesis that: there is no difference between sample and control values. As each day was represented by a single value the sample size for statistical purposes (student's *t* test) was thirty.

2.3.1 The sensors and their installation

All six temperature sensors were of the MCS 151 series, where the sensor is fitted to an anodised aluminium tube. The operating temperatures of these thermocouple sensors is in the range -20°C to $+70^{\circ}\text{C}$ with an accuracy of $\pm 0,2^{\circ}\text{C}$ at 25°C and a resolution of $\pm 0,1^{\circ}\text{C}$ (MC Systems, 1986). Installation for measuring soil temperatures was done by excavating on one side and inserting the sensors horizontally. This was done to minimise heat conduction along the leads and to ensure a minimum of soil disturbance as well as good contact between sensor and soil. Soil surface temperatures were measured just below the soil surface by ensuring that a thin (less than 3mm) layer of soil covered the sensor. In all cases care was taken to ensure that sample and control sensors were installed in exactly the same way, to allow for valid comparison of the results. The sensors were allowed to equilibrate for a minimum of 18 hours.

Wind speed was measured using MCS 177 wind speed sensors mounted vertically 0,6m above the ground surface. The sensors were not placed at the standard meteorological measuring height of 10m (Jones, 1983) as this height is used to avoid turbulence from the ground or aerodynamic surface, which would defeat the purpose of measuring wind speeds in this instance. The height of 0,6m was chosen as this was higher than the karoo vegetation but lower than the saltbush. The wind speed sensors are of a standard 3 cup anemometer design (150mm turning radius with cups of 70mm diameter) where rotation is directly proportional to the wind speed. The data logger registers the number of rotations and was programmed to return a wind speed value in meters per second. The anemometers have a measuring range of 0 to 45ms^{-1} and a minimum threshold of $0,5\text{ms}^{-1}$. Wind direction was recorded using a MCS 176 wind direction sensor which has a wind threshold of $0,3\text{ms}^{-1}$ and an accuracy of $\pm 1,5\%$ from 0 to 360° .

Relative humidity was recorded using MCS 174-01 sensors which consist of a capacitive sensing element and electronic interface giving direct output of relative humidity. The sensor is mounted on a P.T.F.E. header which results in low capacitive change due to hygroscopic absorption in the

header. This reduces drift and apparent hysteresis. The humidity sensor is protected from contamination from the atmosphere by a bronze sintered filter. The sensors are accurate to within $\pm 2\%$ and deviate by less than 2% in the temperature range -10°C to 50°C . Their response time is 10 seconds. In the field the sensors were housed in ventilated wooden structures which provided shelter from direct radiation and from precipitation. The sensors in their wooden structures were placed on the ground such that the sensor was 5cm above the soil surface. This position was chosen to provide some insight into the range of relative humidities that young seedlings would be exposed to and done in such a way that the values of sample and control areas could be compared with each other.

Light intensity was measured using SKYE Photosynthetic Active Radiation (PAR) sensors. These are of the semiconductor variety producing a voltage which is proportional to radiation in the range 400 to 700nm. PAR was measured in order to consider the extent of shading, specifically of radiation in the general photosynthetic range (Jones, 1983). The PAR sensors were placed horizontally on the ground surface and allowed for comparison of radiation in the photosynthetic range between sample and control in each case.

2.4 Results and Discussion

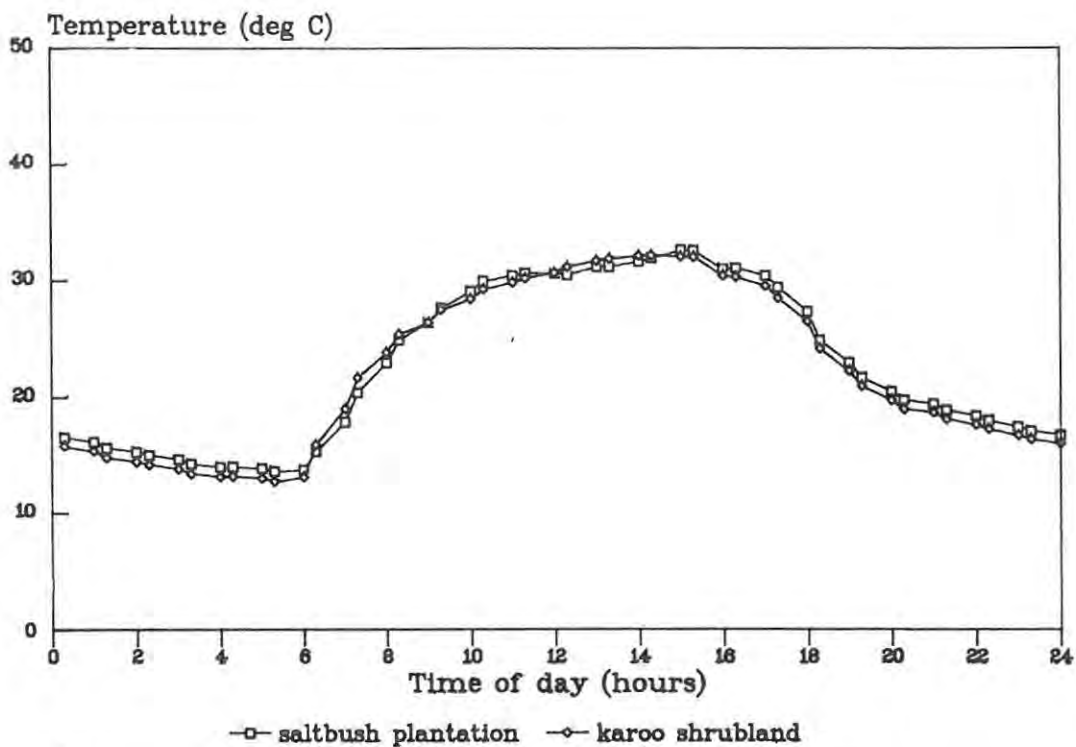
Variations and differences between mean values of each parameter for pairs of sample and control sensors are presented in Figures 2.2 through to 2.12. The graphs presented in these figures provide a visual impression of the extent of variations in microclimatic parameters associated with saltbush. Each of the four monitoring periods is presented and discussed separately to avoid confusion.

2.4.1 Monitoring period one, from 8/9/87 to 2/10/87, (spring) at Site 2, Wellwood

Details of the precise positioning of sensors are provided in Table 2.1. This monitoring period essentially compared microclimatic conditions within a 40 year old saltbush plantation (sample area) with those in the adjacent *Pentzia incana* dominated dwarf shrubland (control area). Figures 2.2 to 2.4 present the mean values for the period for each pair of sensors. The sensors placed within the saltbush plantation were placed between individual saltbush as opposed to under or near saltbush.

Referring to Figures 2.2a and 2.2b, there appears to be little difference in air temperature and soil surface temperature. Soil temperatures at a depth of 10cm (Figure 2.3a) appear to be more extreme in the saltbush plantation than in the karoo shrubland, although the differences are not more than

(a)



(b)

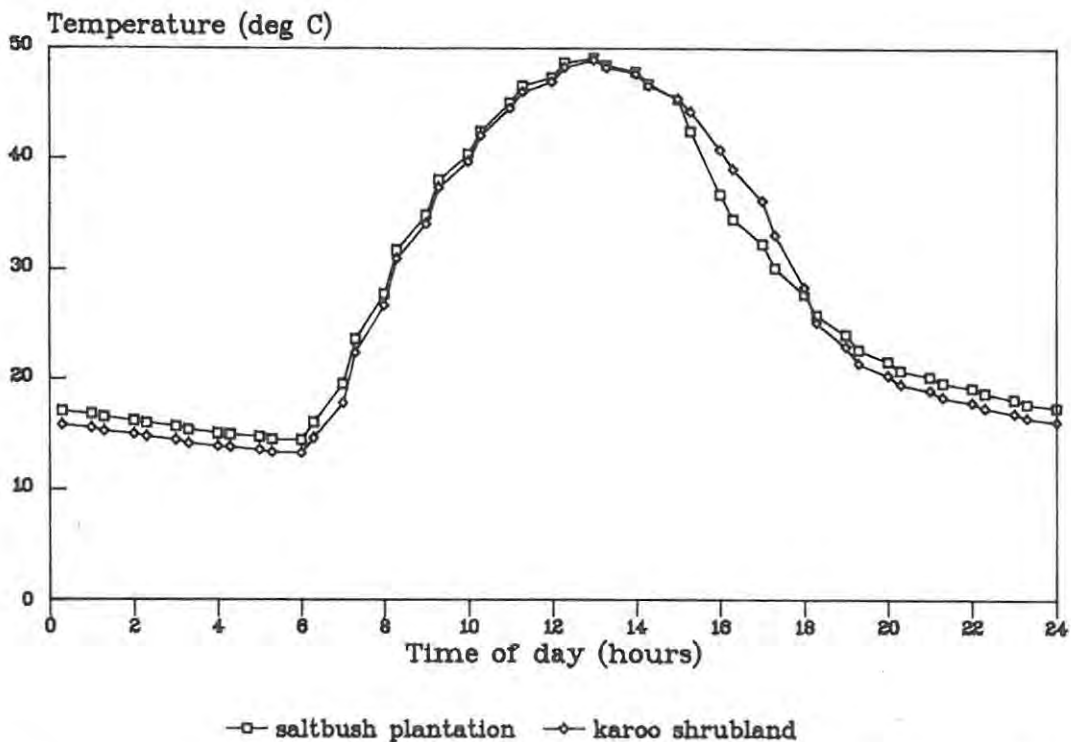


Figure 2.2: Comparative temperature profiles of a 40 year old saltbush plantation and the adjacent karoo shrubland (monitoring period one), (a) mean daily air temperature and (b) mean daily soil surface temperature.

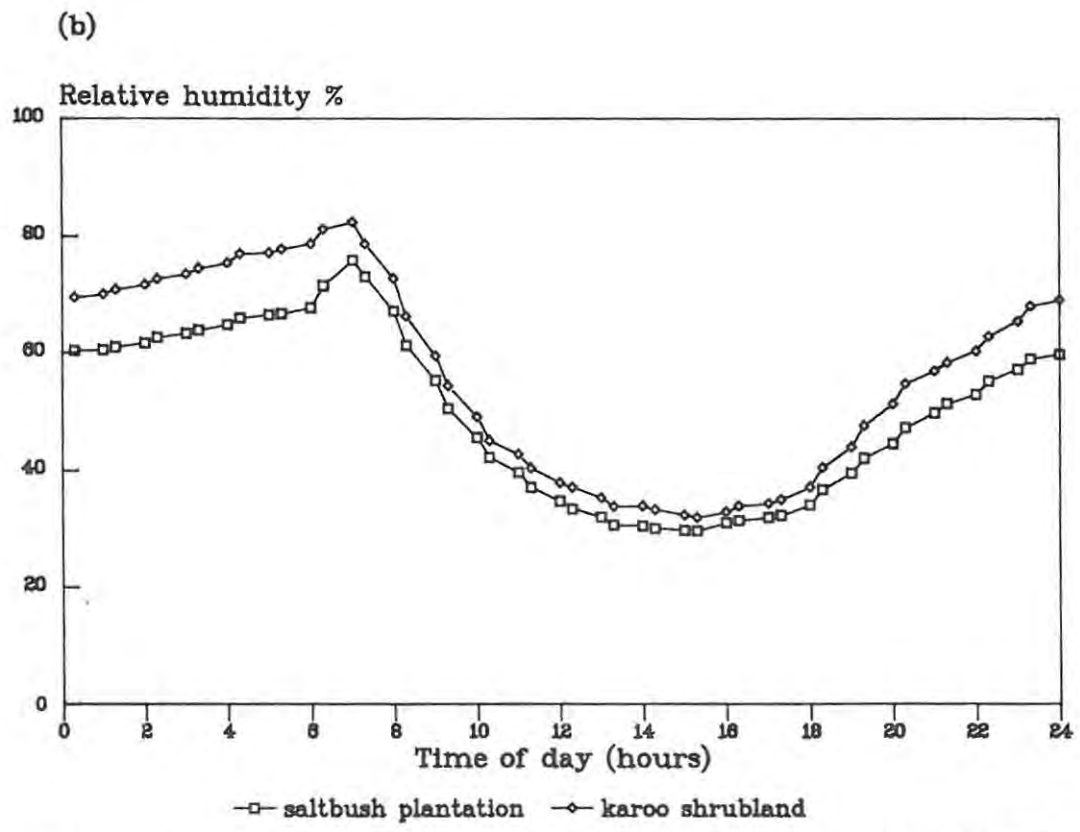
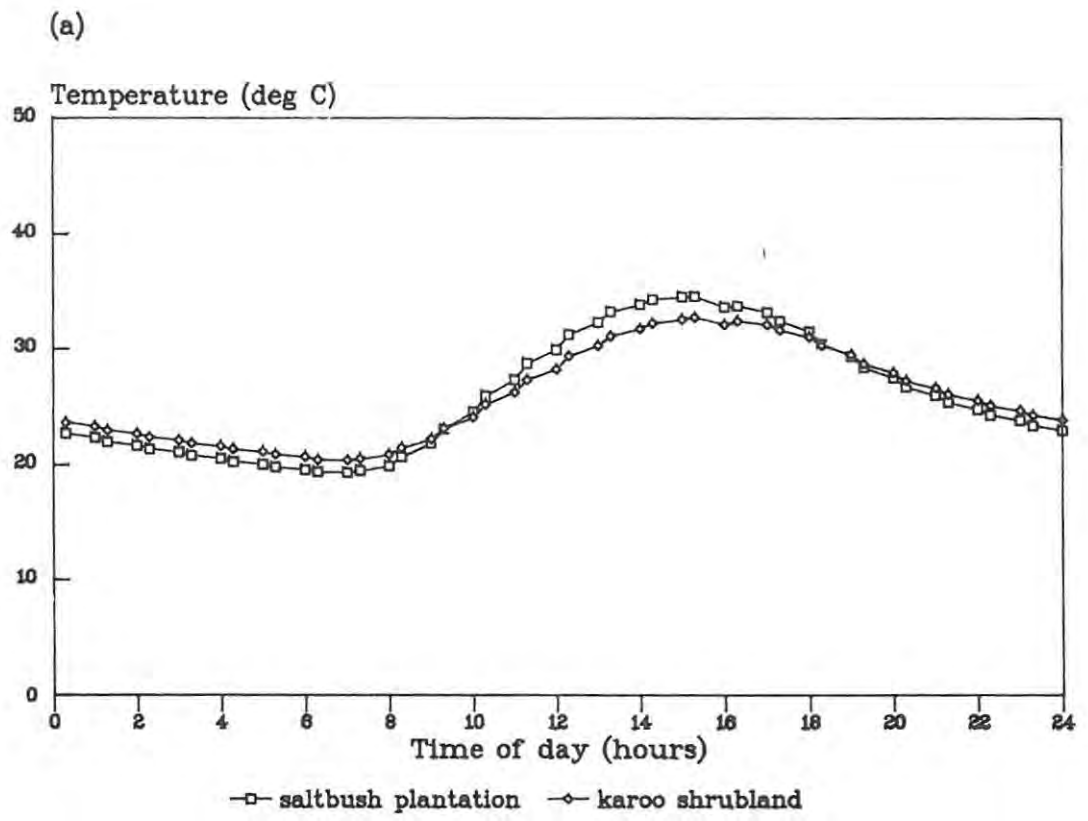


Figure 2.3: Comparative profiles of a 40 year old saltbush plantation and the adjacent karoo shrubland (monitoring period one), (a) mean daily soil temperature at a depth of 10cm and (b) mean daily relative humidity.

2 °C either way. Both relative humidity (Figure 2.3b) and light intensity values (Figure 2.4) are lower in the saltbush plantation. The light intensity measured was within the PAR (Photosynthetic Active Radiation) wavelengths and can be used as an indication of the intensity of radiation in the general photosynthetic range. There is a marked reduction in light reaching the soil surface in the saltbush plantation (Figure 2.4). The mean wind speed in the saltbush was $2,04\text{ms}^{-1}$ with a standard deviation of 0,78 as compared to $2,72\text{ms}^{-1}$ and 1,29 respectively in the karoo.

Comparing the area under the curve, for each day's readings, using the student's *t* test the assumption can be made with 98% certainty, that there is no difference between the sample and controls for all the parameters measured except light intensity (Table 2.5). The results of monitoring period one illustrate that there is very little difference in microclimatic conditions between saltbush in a 40 year old plantation as compared to conditions in the adjacent karoo vegetation (key question 2.1(i)).

Table 2.5: Comparison of area under the curve using mean monthly values of the microclimatic parameters measured at Site 2 for monitoring period one using student's *t* test. Note: The null hypothesis is that there is no difference between sample and control.

Sample and Control parameters	<i>t</i> value *	critical value $p = 0,02$	Accept or Reject the null hypothesis
Air temperature	0,396	2,39	accept
Soil surface temperature	0,438	2,39	accept
Soil temperature 10cm deep	0,046	2,39	accept
Relative humidity	-1,285	-2,39	accept
Light intensity	-5,191	-2,39	reject

* negative value indicates control values are greater than sample values

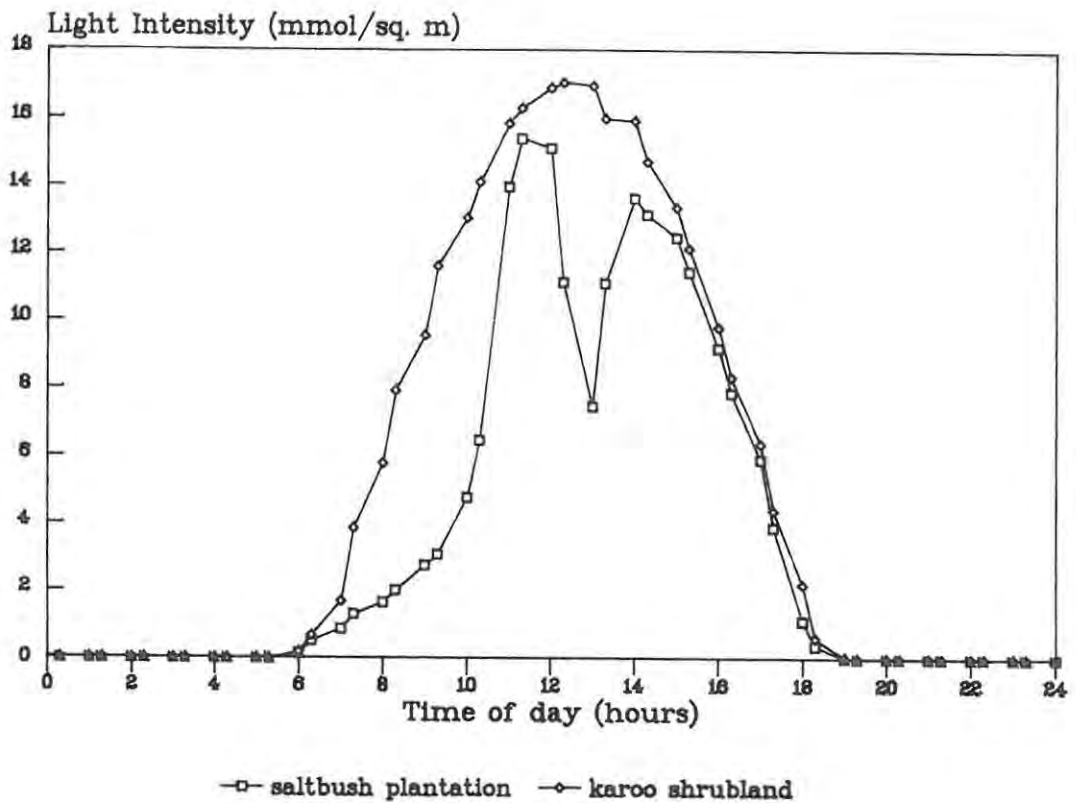


Figure 2.4: Comparative profiles of mean daily light intensities of a 40 year old saltbush plantation and the adjacent karoo shrubland (monitoring period one).

2.4.2 Monitoring period two, from 2/10/87 to 1/11/87, (early summer) at Site 2, Wellwood

Details of the precise positioning of sensors are provided in Table 2.2. For this monitoring period, all sensors were arranged within the 40 year old saltbush plantation so as to compare microclimatic conditions in immediate proximity of an individual saltbush (sample) with conditions in between saltbush (control). The saltbush were spaced fairly regularly apart (approximately 4m between plants) and the total distance between sets of sensors was only 2,5 m.

Referring to Figures 2.5 and 2.6a, soil temperatures are clearly different in the sample (under the saltbush) and control (between the saltbush) sites in all three cases. Soil surface temperatures (Figure 2.5a) under the saltbush peak at 11h30, some 3 hours before and 5° C less than soil surface

temperatures between saltbush. The difference between sample and control soil temperatures at a depth of 5cm (Figure 2.5b) is similar with a difference in peak temperatures of 5° C while the time lag between peaks is 4 hours. In the case of the values obtained for soil temperatures at a depth of 10cm (Figure 2.6a) the difference in peak temperatures is 5,5° C while the time lag is 4½ hours. Comparing the values obtained for relative humidity at the sample and control positions (Figure 2.6b) reveals that there is little overall difference. Relative humidity is however lower between saltbush during the day than under saltbush, while the situation is reversed at night. This is as expected due to the shade provided by the saltbush during the day. Differences in light intensity (Figure 2.7) are marked.

Comparisons of the area under the curve for each pair of sensors using the student's *t* test confirms that it can be assumed with 98% certainty that there is a difference between samples and controls in all cases except relative humidity (Table 2.6). Monitoring period two shows that there is a significant difference in soil temperatures and light intensity when comparing conditions under saltbush with those between saltbush within a 40 year old plantation. The results of monitoring period one and two in the same 40 year old plantation suggest that the effects of saltbush plantations on microclimate should not be explained on the basis of the entire plantation but that the changes caused by the plants are on an individual basis with minimal cumulative effect at a spatial scale of the entire plantation.

Table 2.6: Comparison of area under the curve using mean monthly values of the microclimatic parameters measured at Site 2 for monitoring period two using student's *t* test. Note: The null hypothesis is that there is no difference between sample and control.

Sample and Control parameters	<i>t</i> value *	critical value p = 0,02	Accept or Reject the null hypothesis
Soil surface temperature	-4,735	-2,39	reject
Soil temperature 5cm deep	-7,923	-2,39	reject
Soil temperature 10cm deep	-9,438	-2,39	reject
Relative humidity	-0,761	-2,39	accept
Light intensity	-10,793	-2,39	reject

* negative value indicates control values are greater than sample values

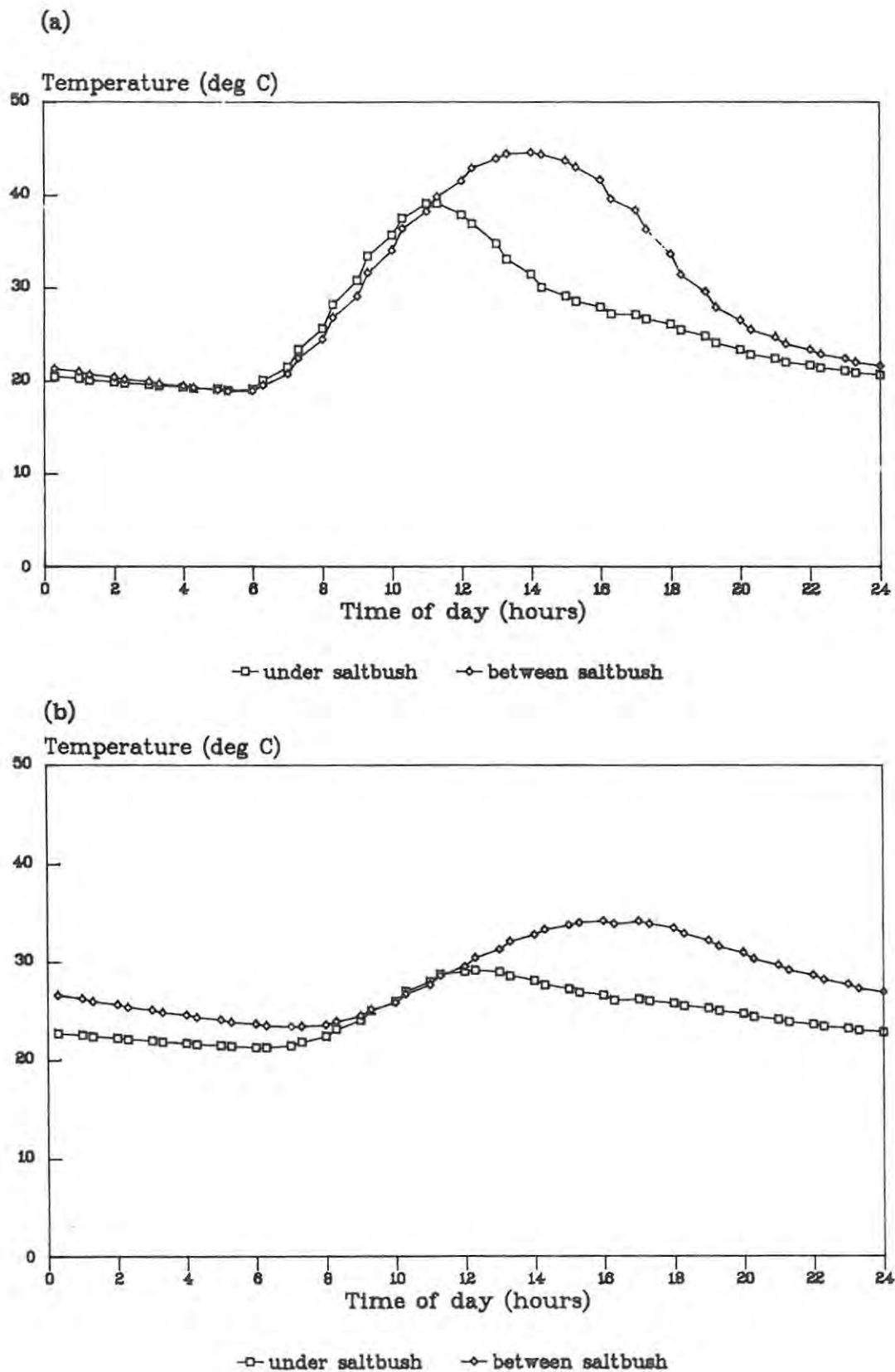


Figure 2.5: Comparative profiles of temperatures between and under an individual saltbush in a 40 year old saltbush plantation (monitoring period two), (a) mean daily soil surface temperature and (b) mean daily soil temperature at a depth of 5cm.

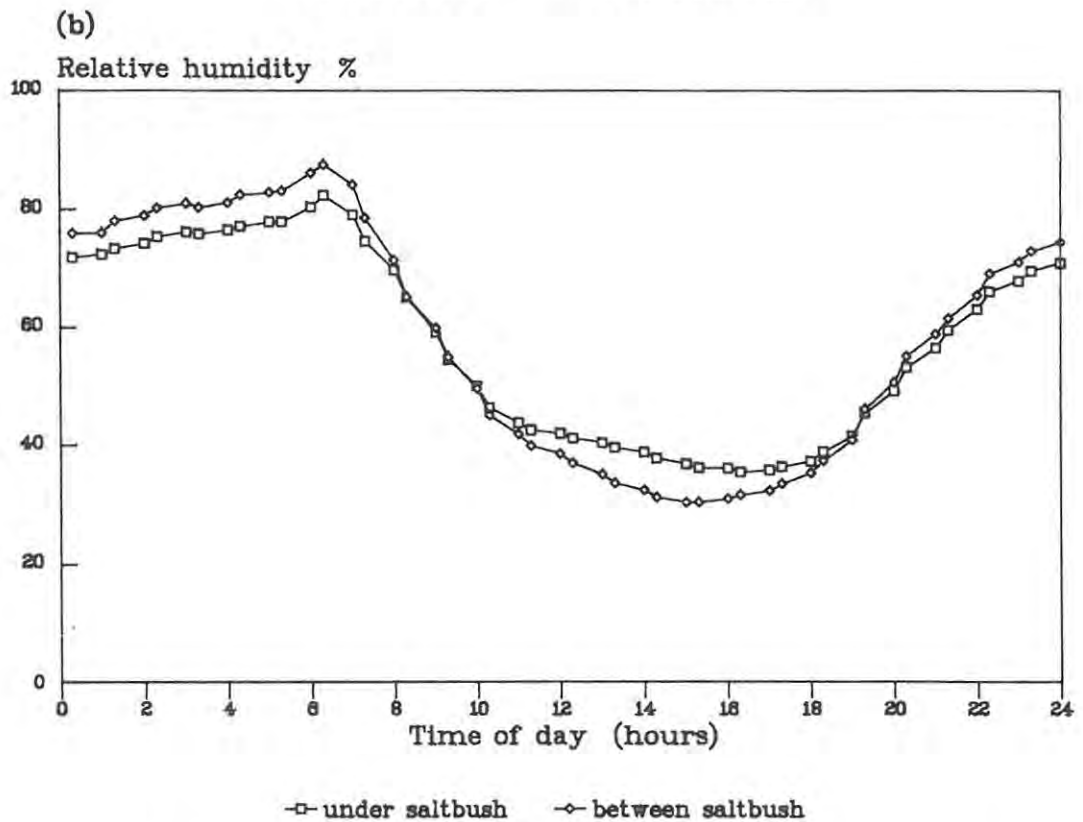
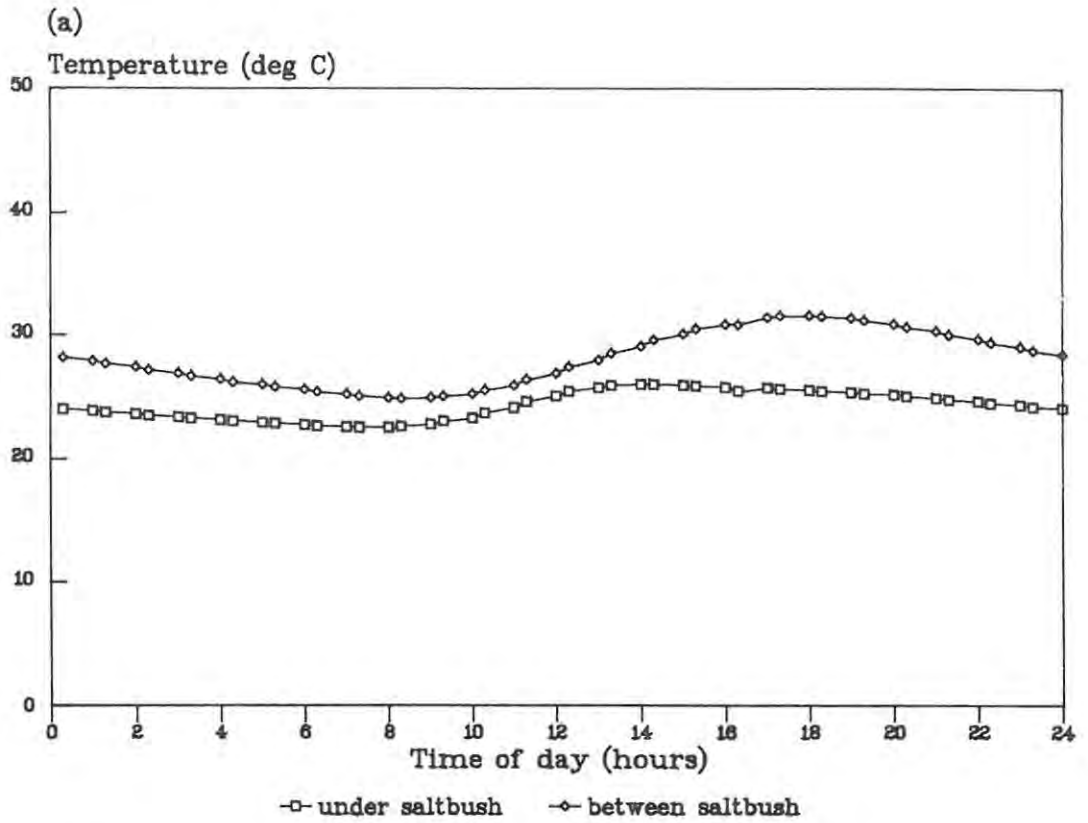


Figure 2.6: Comparative profiles from between and under an individual saltbush in a 40 year old saltbush plantation (monitoring period two), (a) mean daily soil temperature at a depth of 10cm and (b) relative humidity.

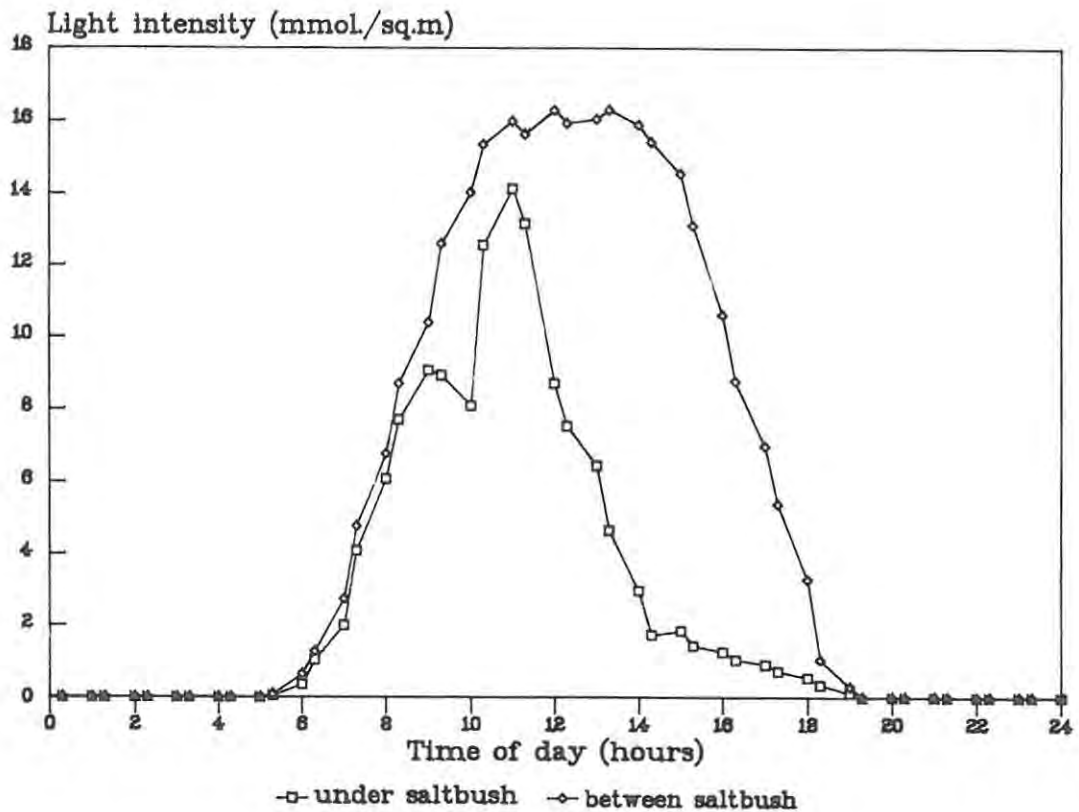


Figure 2.7: Comparative profiles of light intensity from between and under an individual saltbush in a 40 year old saltbush plantation (monitoring period two).

2.4.3 Monitoring period three, from 1/3/88 to 30/3/88, (summer) at Site 1, Grootfontein

Table 2.3 provides details of the precise positioning of sensors for this monitoring period at Site 1 (the saltbush plantation consisting of 24 year old plants). Comparisons of microclimatic conditions are at both the plantation and the individual bush scale. Soil surface temperatures under a saltbush are compared with soil surface temperatures under a karoo bush (*Pentzia incana*). The results of the readings obtained for each set of sensors are presented in Figures 2.8 to 2.10.

Figures 2.8a and 2.8b illustrate the trends observed for soil surface temperature. Soil surface temperatures under a saltbush are lower than those under a karoo bush (*Pentzia incana*), the

difference between the peak temperatures being 5,5°C, while there is a 4 hour lag for the peak temperature (Figure 2.8a). There is little difference in soil surface temperature between saltbush as compared to between karoo bushes (Figure 2.8b). Soil temperatures at a depth of 5cm are markedly different (Figure 2.10) in the saltbush plantation as compared to the karoo shrubland with a difference in average peak temperatures of 8,5°C showing that saltbush is a much more efficient ameliorator of soil temperature than the karoo bush. Mean daily relative humidity profiles for the saltbush plantation and the karoo shrubland (Figure 2.9b) exhibit very similar trends to those encountered for monitoring period two (Figure 2.6b) with the karoo shrubland having greater extremes. Mean daily light intensity recorded in the saltbush plantation is approximately half of that recorded in the karoo shrubland (Figure 2.10). Statistically, using the student's *t* test as before, it can be accepted that there is a difference between sample and control (at $p = 0,02$) for all comparisons except relative humidity (Table 2.7).

Table 2.7: Comparison of area under the curve using mean monthly values of the microclimatic parameters measured at Site 1 for monitoring period three using student's *t* test. Note: The null hypothesis is that there is no difference between sample and control.

Sample and Control parameters	<i>t</i> value *	critical value $p = 0,02$	Accept or Reject the null hypothesis
Soil surface temperature under bushes	-2,783	-2,39	reject
Soil surface temperature between bushes	-2,241	-2,39	reject
Soil temperature 5cm deep between bushes	-7,871	-2,39	reject
Relative humidity	1,791	2,39	accept
Light intensity	-15,145	-2,39	reject

* negative value indicates control values are greater than sample values

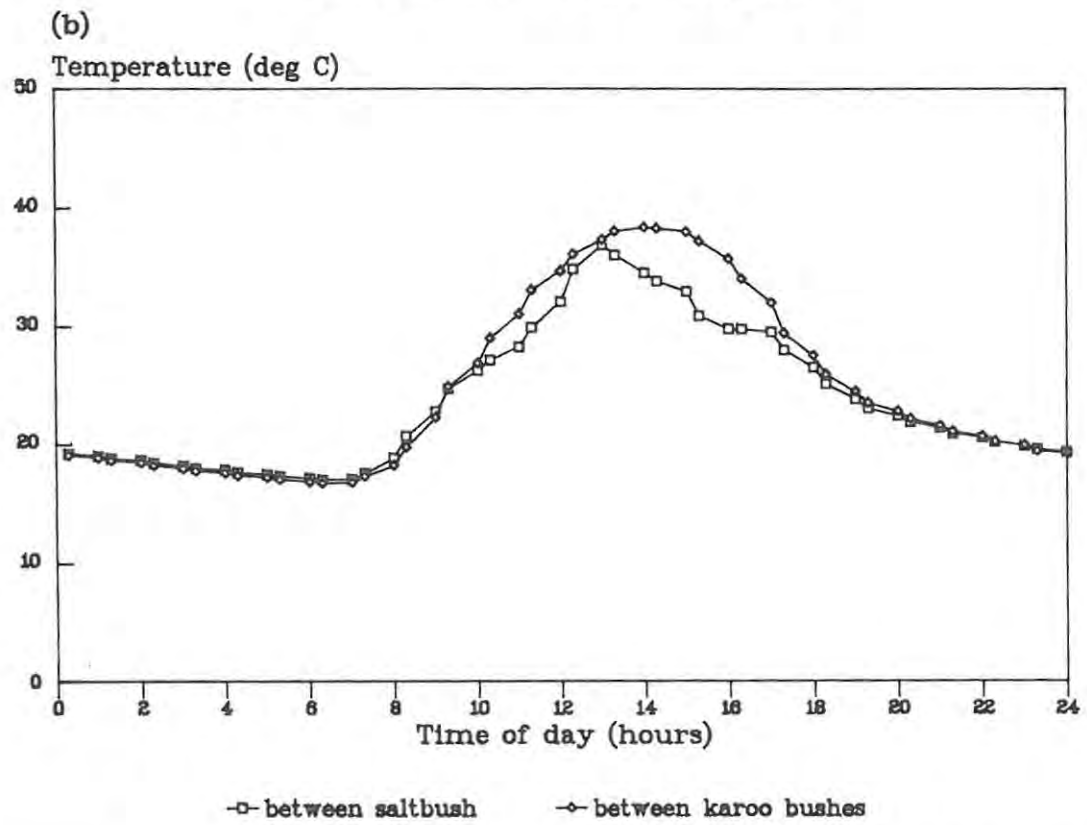
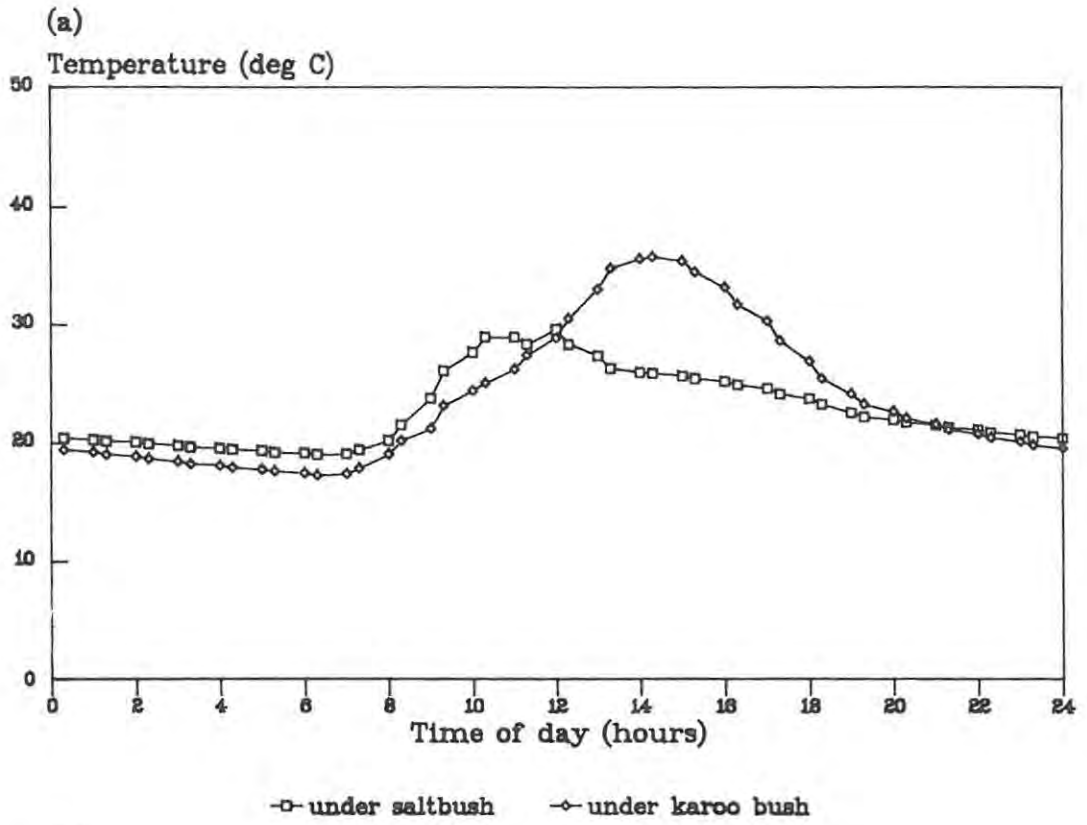


Figure 2.8: Comparative profiles of mean daily soil temperatures from a 24 year old saltbush plantation and the adjacent karoo vegetation for monitoring period three, (a) soil surface temperatures under a saltbush plant and a *Pentzia incana* plant and (b) soil surface temperatures between saltbush plants and karoo plants.

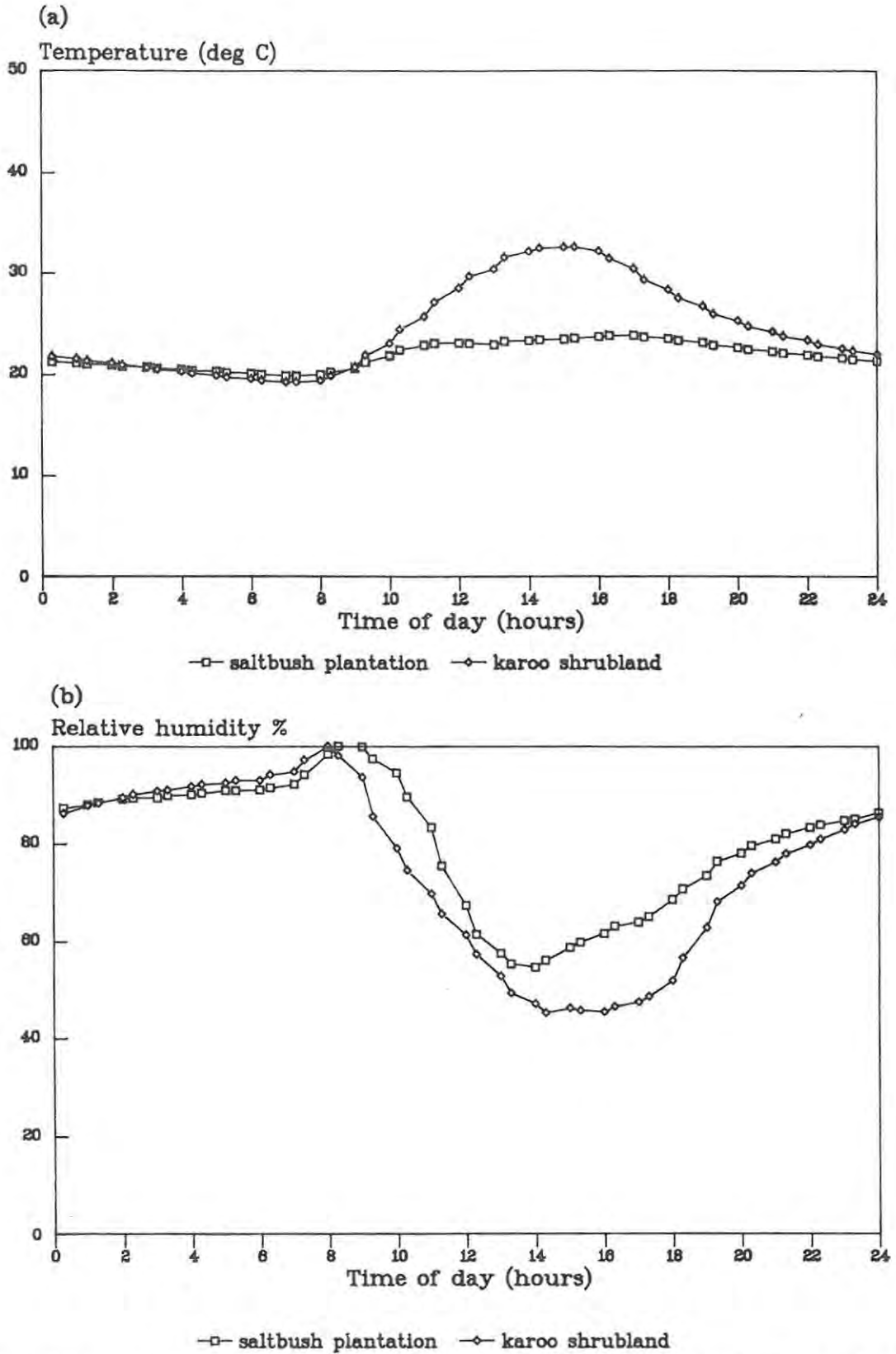


Figure 2.9: Comparative profiles of (a) mean daily soil temperature at a depth of 5cm and (b) mean daily relative humidity, from between bushes in a 24 year old saltbush plantation and between karoo bushes in the adjacent shrubland for monitoring period three.

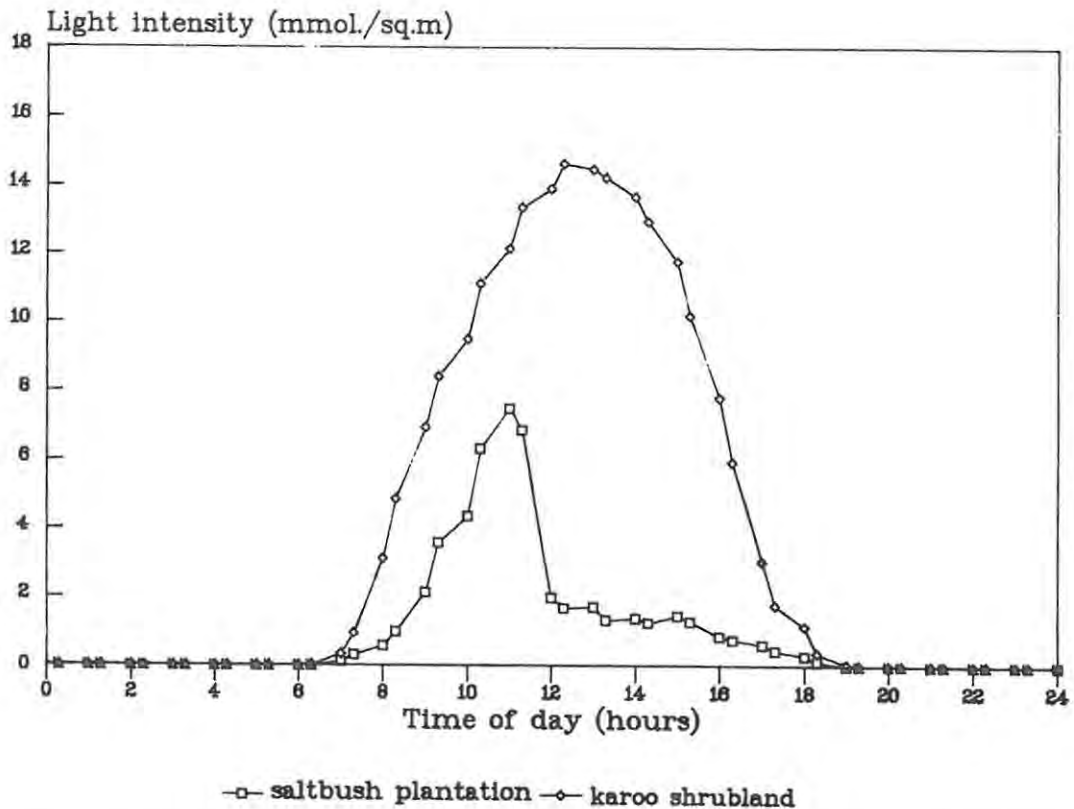


Figure 2.10: Comparative profiles of mean daily light intensity from between bushes in a 24 year old saltbush plantation and between karoo bushes in the adjacent shrubland for monitoring period three.

2.4.4 Monitoring period four, from 27/7/88 to 24/8/88, (winter) at Site 1, Grootfontein

This monitoring period is the only one of the four to be in winter and considers the difference in microclimatic conditions 75cm from one saltbush (sample) in a 24 year old plantation with conditions between bushes in the adjacent karoo shrubland (control). The saltbush used had a crown radius of 1,1m, meaning that the sensors were well under, but not at the base of the plant. The positioning of sensors is listed in Table 2.4, however one of the relative humidity sensors was faulty and so no comparison could be made for this monitoring period. Figures 2.11 to 2.12 illustrate the trends recorded.

Referring to Figure 2.11a, air temperatures are very similar with no clearly observable difference between sample and control sites. Soil temperatures on the other hand are markedly different (Figures 2.11b and 2.12a). Soil surface temperature 75cm from the saltbush peaks 8° C lower than

soil surface temperature between bushes in the karoo shrubland. The time lag between peaks is 2½ hours in this case. Similarly soil temperatures at a depth of 5cm peak at 3,7° C lower 75cm from the saltbush as compared to between bushes in the karoo shrubland with a time lag of 3½ hours (Figure 2.12a). Figure 2.12b illustrates differences in light intensities, showing that the saltbush has a noticeable shading effect 75cm from its base which is as could be expected. Table 2.8 summarizes the results of the student's *t* test analyses on the area under the curve as presented in Figures 2.11 and 2.12. The results shown on Table 2.8 indicate that there is a difference between all sample and control comparisons (at $p = 0,02$) except in the case of air temperatures.

Table 2.8: Comparison of area under the curve using mean monthly values of the microclimatic parameters measured at Site 2 for monitoring period four using student's *t* test. Note: The null hypothesis is that there is no difference between sample and control.

Sample and Control parameters	<i>t</i> value *	critical value $p = 0,02$	Accept or Reject the null hypothesis
Air temperature	0,023	2,39	accept
Soil surface temperature	-3,101	-2,39	reject
Soil temperature 5cm deep between bushes	-3,276	-2,39	reject
Relative humidity	-----	-----	no readings recorded
Light intensity	-7,821	-2,39	reject

* negative value indicates control values are greater than sample values

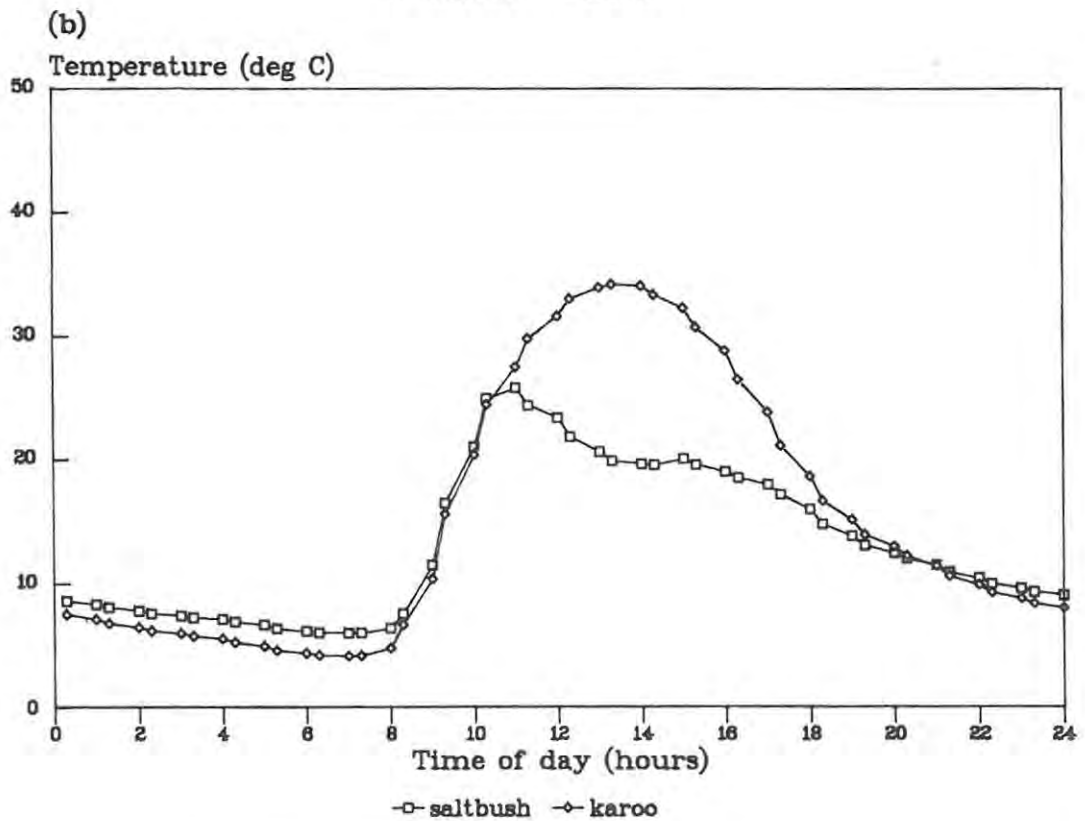
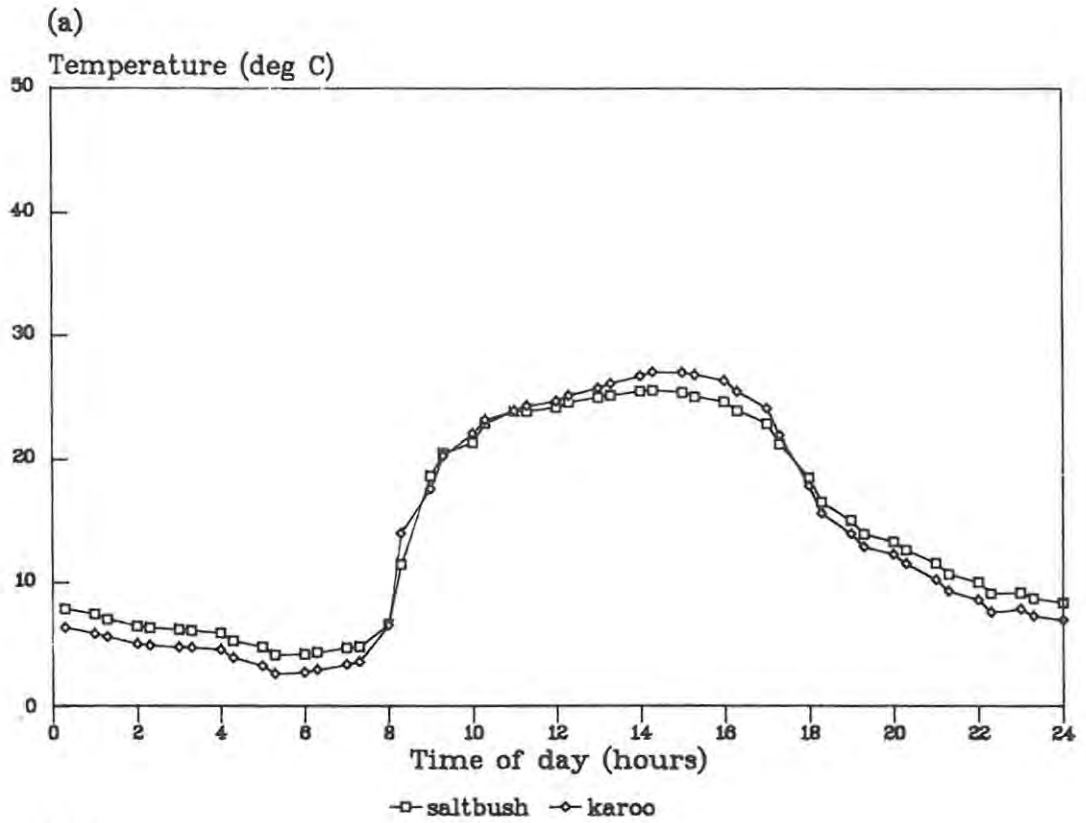


Figure 2.11: Comparative temperature profiles of readings taken 75cm from the base of a 24 year old saltbush plant and between karoo bushes (monitoring period four), (a) air temperature and (b) soil surface temperature.

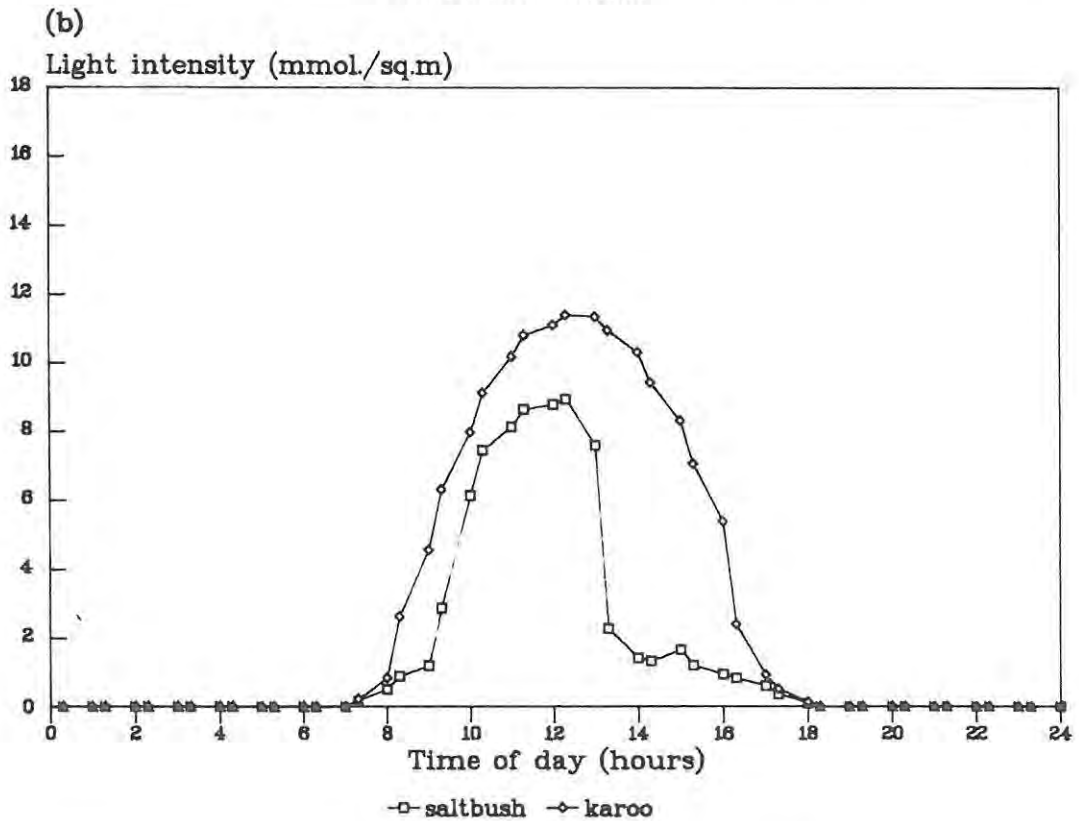
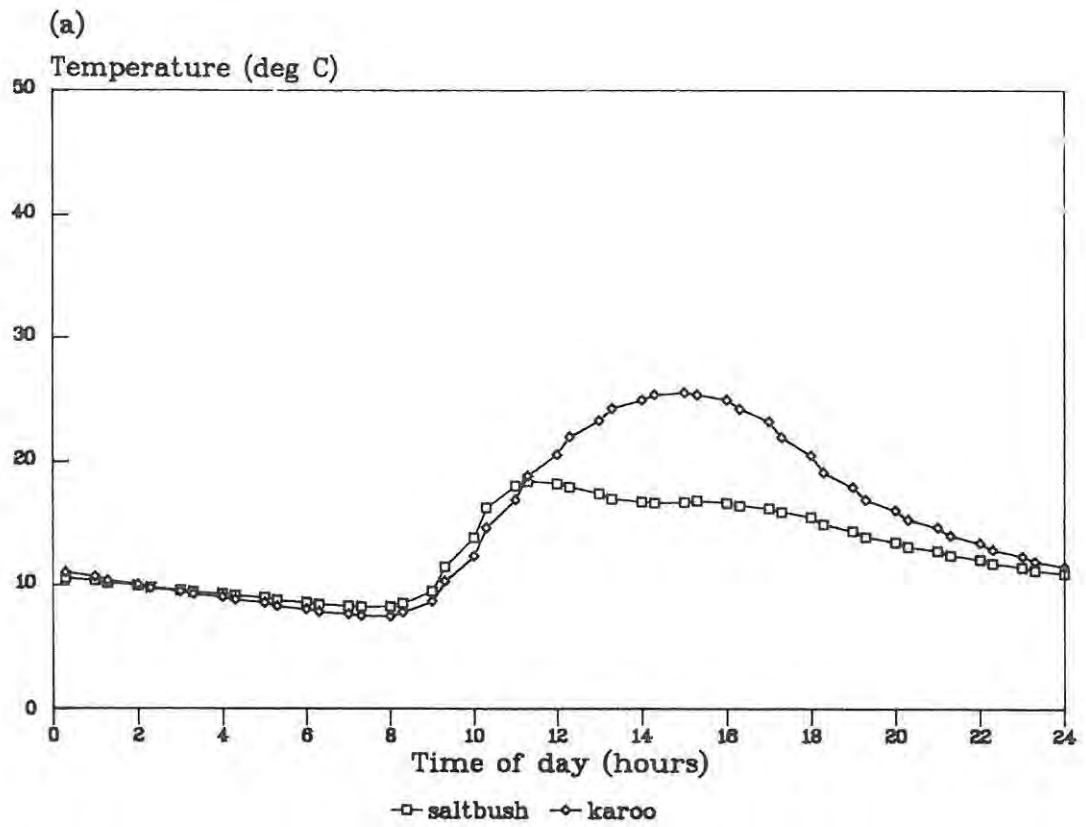


Figure 2.12: Comparative profiles of readings taken 75cm from the base of a 24 year old saltbush plant and between karoo bushes (monitoring period four), (a) mean daily soil temperature at a depth of 5cm and (b) mean daily light intensity.

Oldman saltbush affects the microclimate significantly on an individual plant basis. Microclimatic conditions between saltbush plants in a plantation are not very different to conditions in the adjacent karoo dwarf shrubland. Figure 2.13 summarizes the results of the microclimatic parameters investigated. The microclimate was found to be significantly modified within 75cm of the base of a 24 year old saltbush. Microclimatic parameters which were most noticeably affected by the presence of oldman saltbush were soil surface temperatures and soil temperatures at depths of 5cm and 10cm.

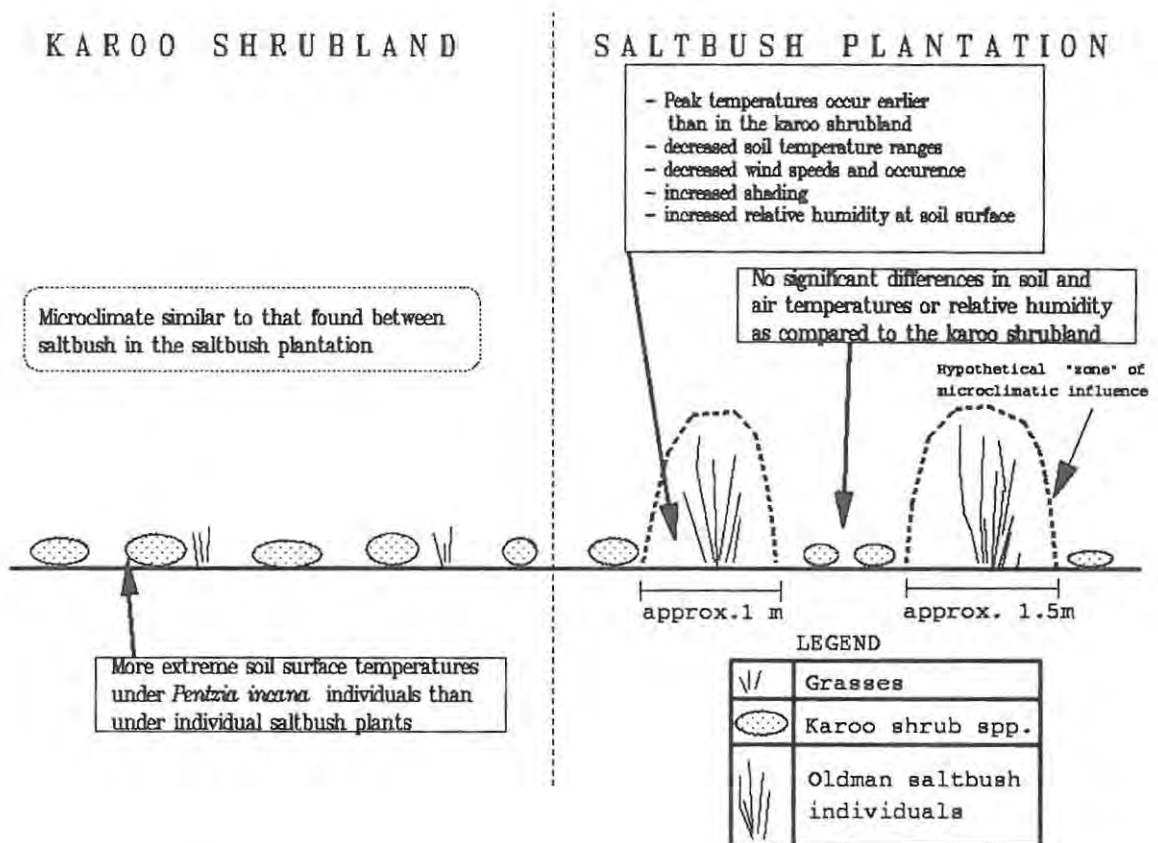


Figure 2.13:

Schematic diagram showing the influence of oldman saltbush on selected microclimatic parameters in the karoo. Conditions in the saltbush plantation (sample) are compared to those in the adjacent karoo dwarf shrubland.

Saltbush reduced soil temperatures greatly in comparison to *Pentzia incana*. The hottest temperature recorded (54° C) was the soil surface temperature in the karoo shrubland at Site 2. The coldest temperature (-8° C) also at the soil surface was recorded at Site 1. Peak temperatures and

the lag time between peak temperatures are greater during summer than in winter. The soil temperatures recorded at both study sites are of similar magnitude and variation to those presented by Watson (1980) for south eastern Australia. The study area used by Watson (1980) includes the region where *Atriplex nummularia* is one of the dominant climax community shrubs. The temperature ranges recorded for all four of the monitoring periods are close to the optimum temperatures for saltbush.

The microclimatic influences found to be associated with saltbush are similar in nature to those found by Farrell (1990) for trees. There are gross differences in microclimate within saltbush plantations but these differences are on an individual plant basis only and not for the plantation as a whole (key question 2.1(i)). This is important as saltbush plants represent an important change to and the development of a mosaic of considerably different microhabitats (McAuliffe, 1988). Quantitative differences in microclimatic conditions in as opposed to adjacent to saltbush plantations are variable depending on the site and time of the year (key question 2.1(ii)). The amelioration of the microclimate in the immediate proximity of saltbush suggests that they may be good nurse plants encouraging the germination and establishment of natural karoo plants. Changes in the amount of litter associated with oldman saltbush could also be important in determining the final characteristics of the microhabitat. These positive effects may however be countered by other ways in which saltbush effects its immediate environment. Oldman saltbush has been shown to increase soil salinities around each plant (Sharma and Tongway, 1973) and to change soil physical properties (Sharma, 1973a). This is investigated and discussed in Chapter 3.

CHAPTER 3

SOIL INDUCED CHANGES ASSOCIATED WITH *Atriplex nummularia*

3.1 Introduction

"The nutrient system is closely associated with plant production, litter fall and the accumulation and transformation of organic matter in the underlying soil" (Rixon, 1970, p. 90). Oldman saltbush is known to effect the soils and the plant community within which it occurs (Roberts, 1950; Sharma, 1973a; Sharma and Tongway, 1973) and is highly tolerant of extreme saline and drought conditions (Gates and Muirhead, 1967; Wallace *et al.*, 1973).

Various arid plants are known to significantly affect soil properties and plant growth (Fireman and Hayward, 1952; Romney *et al.*, 1980; Lailhacar-Kind, 1986) and hence patterning within the plant community (Malik *et al.*, 1976). Noy-Meir (1985) for example supports the notion that nutrients in desert ecosystems are concentrated around shrubs in the top soil layer. Rixon (1970, p. 94) states that "...the surface soil under saltbush plants has twice the potential capacity to supply mineral nitrogen as has the soil from the interbush areas". Species of *Atriplex* have been reported to have increased soil salinity and pH under the plants compared to between them (Roberts, 1950; Fireman and Hayward, 1952; Jessup, 1969; Sharma and Tongway, 1973). Associated with these salinity increases is an increase in exchangeable sodium (Roberts, 1950; Fireman and Hayward, 1952; Sharma, 1973a; Sharma and Tongway, 1973). Sharma and Tongway (1973) found that both *Atriplex nummularia* and *A. vesicaria* induced significantly higher salinity in the 0-15 cm soil horizon beneath the bush canopies as compared to between the bushes. Sharma (1973a) reported that the presence of *Atriplex nummularia* resulted in increased electrolyte concentration, higher sodium adsorption ratio and higher levels of exchangeable sodium and organic matter in the surface soil (0-7,5 cm). These changes were shown to reduce aggregate stability, decrease drainage and lower hydraulic conductivity in association with saltbush in Australia. Oldman saltbush is not significantly effected by high levels of chloride or calcium (Osmond, 1966; Wallace *et al.*, 1982). El-Ghonemy *et al.* (1980), found significant differences among plant groupings with respect to absolute and relative amounts of soil Na and K and cation exchange capacity in the northern Mojave desert, U.S.A. Any changes found in the soils associated with *Atriplex nummularia* in the karoo could also be expected to impact on the indigenous plant community. The changes in plant community composition is considered in Chapter 5.

The aim of this section is to gain some understanding of the way in which oldman saltbush affects the soil associated with individual plants in an ungrazed and grazed situation. It is hoped that this understanding will contribute toward the development of management strategies for the planting of saltbush in the karoo.

Induced changes in soil chemical properties associated with oldman saltbush at both study sites are investigated using a gradient analysis technique. The results are compared to the chemical properties of the soils found in the adjacent karroid dwarf shrubland. Root density in association with a 40 year old saltbush plant is examined using a trench excavation technique to determine if roots are responsible for possible changes in soil chemistry with increasing distance from the saltbush plants. Leaf and seed chemical analyses are also done in order to ascertain if recorded changes in soil chemistry associated with saltbush can be attributed to the decomposition of litter produced by saltbush. The chemical composition of leaves from 24 year old saltbush plants is compared with values found by other researchers, while the chemical composition of selected karroid plants are also listed for comparative purposes. This study considers variations in sodium, chloride, potassium, calcium, magnesium, electrical conductivity, sodium adsorption ratio and exchangeable percentage sodium for two saltbush plantations (different age and grazing treatments) and the adjacent karoo dwarf shrubland.

3.2 Key questions

- (i) Is the presence of *Atriplex nummularia* associated with changes in root densities?
- (ii) How does *Atriplex nummularia* affect soil chemistry and texture?

3.3 Methodology

3.3.1 Root Density assessment

A trench 3 m long was excavated down to bedrock (0,6 m) to expose a vertical face (soil profile) orientated in a southerly direction at Wellwood (Site 2), in order to expose a section of the roots surrounding an individual oldman saltbush. The face was smoothed with a shovel and the roots exposed with a fine spray of water under pressure (method modified after Levin *et al.*, 1973). Actual root positions and relative sizes (diameter) were recorded directly on a large sheet of transparent plastic spanned across the vertical face. All roots were recorded in three diameter classes namely, large roots (>10 mm), medium sized roots (5-10 mm) and small roots (<5 mm) (Bohm, 1979).

Root densities were subsequently plotted, illustrating root distribution with both depth and distance from the saltbush. Roots of all plants were recorded and no type (taxonomic) differentiation was attempted. The plotted positions of the various root classes were scaled down in the laboratory from the transparent sheet to a manageable diagrammatic representation. Analysis of the density of all the roots (all diameter classes) was done for both depth and distance from the saltbush by calculating their proportional representation in 20cm sections along each axis.

3.3.2 Leaf and seed chemical analysis

Mature *Atriplex nummularia* leaves were collected from ten 24 year old individuals and bulked. A sample of mature, viable, sifted seeds was obtained from the Grootfontein College of Agriculture. The leaf and seed samples were analysed using a dry ashing procedure (Hasses, 1971). The extracts were analysed for K, Ca, Mg, Fe, Mn, Zn, Cu and Na using an Atomic Absorption Spectrophotometer. Chlorides were measured using a standard silver nitrate titration (argentometric method), nitrogen concentrations with the Kjeldahl method and Phosphorus using the vanado-molybdenate yellow method (after Hasses, 1971).

3.3.3 Soil sampling technique

Single bulked soil samples were collected using a bucket type hand auger at two levels, surface (0-15 cm, bulked) and at depth (20-30 cm, bulked) at each of five sampling points on each transect. Sampling and analysis was completed at Grootfontein (Site 1) and on the basis of these results the number of transects and sampling points was reduced for Wellwood (Site 2). Five transects were sampled at Grootfontein (Site 1) and four transects at Wellwood (Site 2). The plants used for each transect were located randomly. A stratified random sampling was used as saltbush have been shown by Sharma and Tongway (1973) to cause localised increases in soil salinity. Each transect at Grootfontein consisted of five proportionately spaced (relative distance from plant) sampling points, starting from the midpoint between plants of either saltbush or *Pentzia incana* individuals. At Wellwood only three proportionately spaced points were sampled along each transect as the samples at the end points and midpoint taken at Grootfontein were markedly different. Three sampling positions were thought to be acceptable in assessing if the gross variations observed at Grootfontein also occurred at Wellwood. A diagrammatic representation of the gradient analysis technique is presented by Figure 3.1. The transects were all taken in a northerly direction and were an average length of 0,75 m in the case of the two transects in the *Pentzia incana* dwarf shrubland at Grootfontein and 2,0 m for both saltbush plantations (Sites 1 and 2). In order to compare overall (average) soil chemistry in a saltbush plantation (sample) with soil from the adjacent karoo (control)

shrubland ten random sample points were located in the sample and control areas at Wellwood (Site 2).

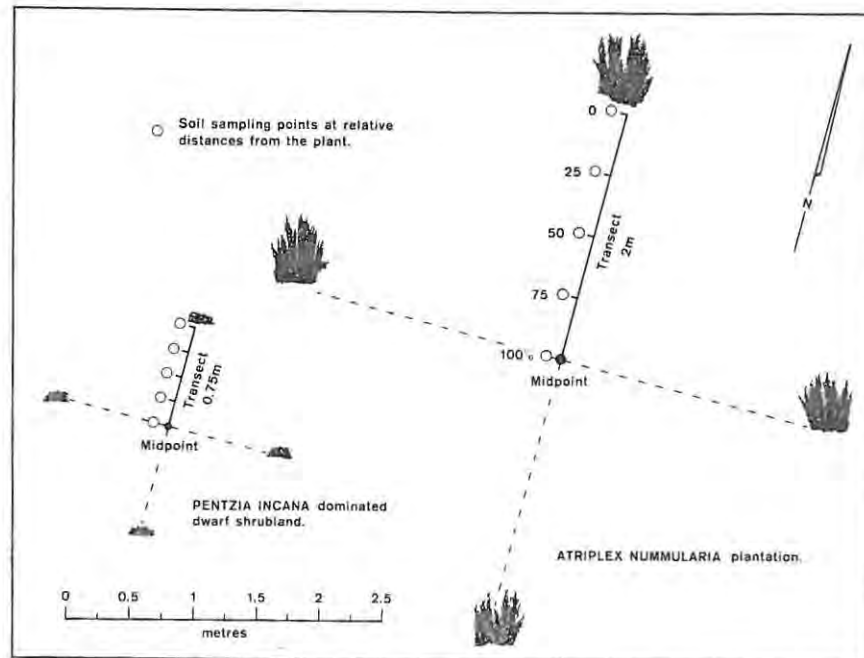


Figure 3.1: Sampling technique for soil chemistry gradient analysis

3.3.4 Soil chemical analysis

The surface (0-15 cm) and depth (20-30 cm) soil samples at the five relative distances from the plants of each of the transects were extracted and analysed for chemical composition using duplicate sub-samples as described in the next paragraph.

All samples were air dried, ground and passed through a 2 mm sieve. Saturation extracts were obtained from 100 g of ground air dried soil by placing in filter-paper cups on a capillary rise water bath for 16 hours (U.S. Department of Agriculture, 1972). The saturation extracts for chemical analysis were removed from the soil samples under vacuum. Electrical conductivity was measured, while quantitative analyses of the cations Na^+ , K^+ , Mg^{++} and Ca^{++} were conducted using an Atomic Absorption Spectrophotometer. The argentometric method was used to assess the chloride content

of the saturation extracts. The sodium adsorption ratio (S.A.R.)¹ and exchangeable sodium percentage (E.S.P.)² were calculated for each of the samples.

$$^1 \text{ S.A.R.} = \sqrt{\frac{\text{Na}}{\frac{(\text{Ca} + \text{Mg})}{2}}}$$

$$^2 \text{ E.S.P.} = -0,42 + 1,56(\text{S.A.R.}) \quad (\text{Moolman and Weber, 1979}).$$

3.4 Results and discussion

3.3.1 Root density assessment

The spatial distribution of all roots (all species together and all diameter classes) surrounding the 40 year old saltbush plant excavated is illustrated by Figure 3.2. The proportion of roots of different diameter classes with depth and distance is presented in Tables 3.1 and 3.2 respectively. The 20-40 cm zone contains the highest proportion of roots (46%) with depth, these consisting predominantly (80%) of small roots (< 5 mm). This accords with the results of Wallace *et al.*, (1980) who found that in the northern Mojave desert, U.S.A. the majority of the roots of the species investigated were in the 10 to 30 cm zone. The surface zone (0-20 cm) has a higher proportion (34%) of all roots in comparison to the deepest zone (40-60 cm), while both the surface and deepest zones have a lower proportion of small roots (< 5 mm diameter) as compared to medium (5-10 mm diameter) and large (> 10 mm diameter) roots. With distance from the saltbush there appears to be a fairly constant density of roots for the first 1,4 m. The uniform density of roots is in agreement with the ideas of Walter and Stadelmann (1974) that the roots of plants in semi-arid and arid areas exploit most of the soil. The two outer 20 cm zones are the only areas where there is an appreciable decline in the number of roots. The total number of roots do possibly exhibit an indistinct decrease with distance away from the saltbush. Similarly the proportion of small roots (< 5 mm diameter) increases slightly with distance from the saltbush. Interpretations of these "trends" on the basis of the contribution of different species is not possible as the methodology simply records the roots of all species, further, only one transect was studied. The roots recorded could either be from the dwarf shrubs occurring in the vicinity of the profile or from the saltbush, each having different root systems. Roots of *Pentzia incana* have been recorded at depths of 3 m in the deep soils of the Worcester-Robertson Karoo (Scott and van Breda, 1983) while Hoffman (in Hoffman and Cowling, 1987) reports that in the shallow soils of the Beaufort series rocks of the eastern karoo (as in this case) the roots of all shrubs seldom penetrate below 0,5 m. The recorded distribution of roots in the profile (Figure 3) corresponds closely with those observed by Hoffman (in Hoffman and Cowling, 1987).

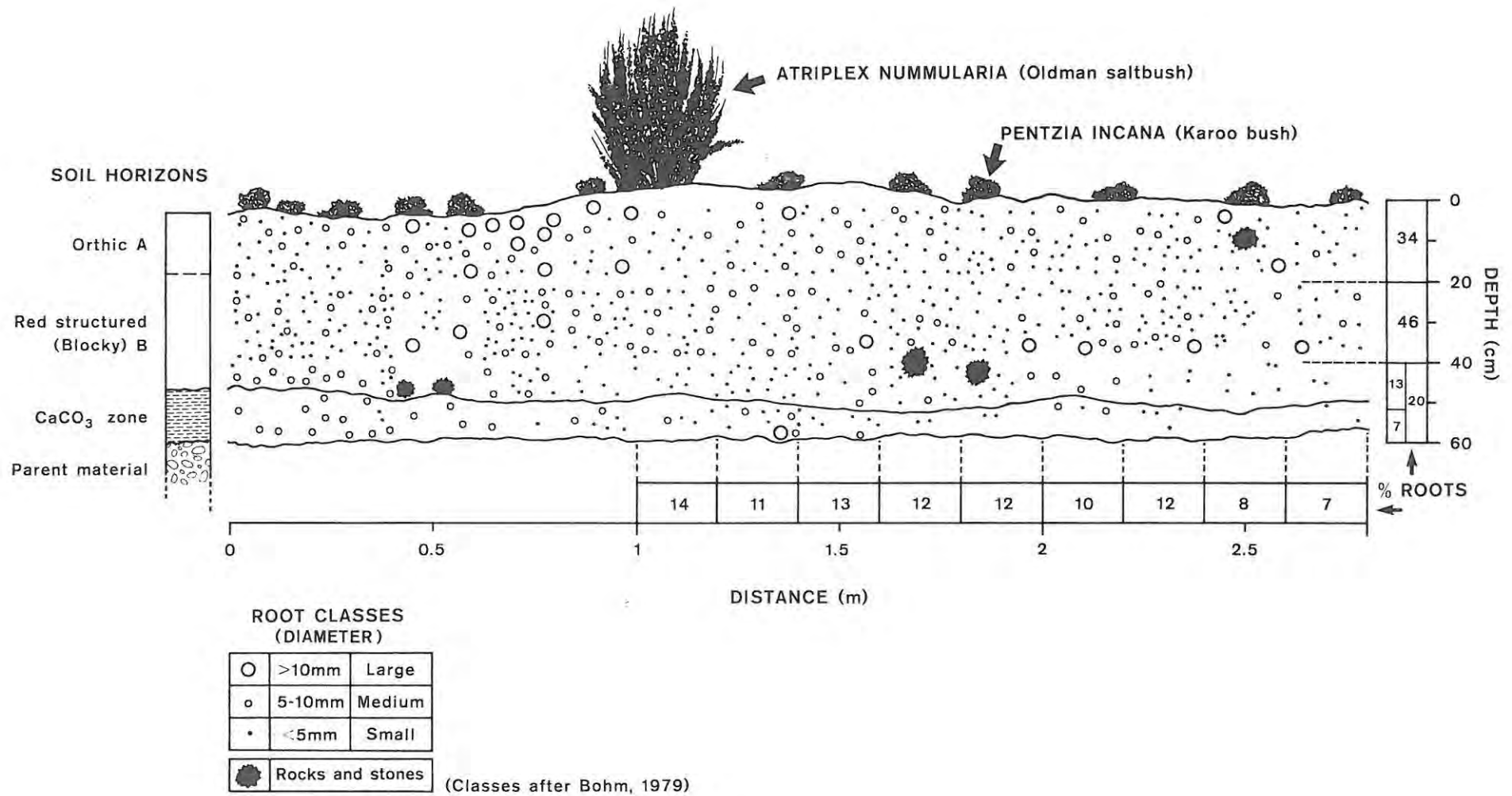


Figure 3.2: Root density profile showing the relative proportion of roots of all diameter classes with soil depth and with distance from a 40 year old *Atriplex nummularia* plant (Site 2).

Table 3.1: Proportional composition of roots in 3 diameter classes with distance from an *Atriplex nummularia* plant.

Diameter	Distance from saltbush								Total	%	
	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160			160-180
> 10 mm	2	1	0	1	1	1	1	2	1	10	2.5
5-10 mm	16	14	10	4	5	12	7	2	2	72	17.7
< 5 mm	40	31	44	44	41	29	39	29	27	324	79.8
Total	58	46	54	49	47	42	47	33	30	406	
%	14.3	11.3	13.3	12.1	11.6	10.3	11.6	8.1	7.4		100

Table 3.2: Proportional composition of roots in 3 diameter classes in 3 zones of increasing soil depth, within 1.8m of an *Atriplex nummularia* plant.

Soil depth cm	Root diameter classes (mm)			Total	%
	> 10 mm	5 - 10 mm	< 5 mm		
0 - 20	3	25	110	138	34.0
20 - 40	5	33	149	187	46.1
40 - 60	2	14	65	81	19.9
Total	10	72	324	406	
%	2.5	17.7	79.8		100

Atriplex nummularia has an extensive root system and Jones and Hodgkinson (1970) traced lateral roots for 10 m and vertical roots to a depth of 3,5 m. The root system has been described as having three zones (Jones and Hodgkinson, 1970): (1) a very shallow zone (top 5 cm) of extremely fine, probably ephemeral roots; (2) a zone of greatest root concentration (50-100 cm) which may coincide with the depth of cracking in the soil; (3) a deeper zone of vertically exploring roots. Jones and Hodgkinson (1970, p. 84) conclude that "... *Atriplex nummularia* is deep rooted and displays an extensive flat root system at some depth". Presumably this "extensive flat root system" corresponds with zone (2) and the soil horizon of most cracking, in the case of this study, zone (2) corresponds with the 20-40 cm root zone which is the blocky red B horizon.

Cursory investigation of the roots recorded in the large category revealed that these roots were those of *Atriplex nummularia*. The distribution of these large roots in the profile support the notion of an extensive flat root system in combination with some vertically exploring roots. One of the large vertically exploring roots was recorded well within the hard calcium carbonate zone beyond which excavation was impossible. The root profile diagram (Figure 3.2) does not show any marked changes in root density associated with the saltbush plant examined (key question 3.1(i)).

Although, "...overall the roots (of saltbush) do not accumulate salts" (Greenway, in Jones and Hodgkinson, 1970, p. 70) they do contain some salts, meaning that any study considering the redistribution and/or accumulation of salts in the soil must account for rooting patterns. In this study, the fact that (i) the root densities remain fairly constant for 1,4 m from the saltbush and (ii) that the relative proportion of roots between the surface (0-20 cm) and depth (20-40 cm) remains similar over the same distance allows for the following assumption. Chemical composition of soil samples taken within 1,4 m of the saltbush will not be adversely affected by salts contained in the roots in the soil sample. Although this has only been tested for one individual saltbush in this case (due to the amount of work involved in excavation) this assumption has been made implicitly by other workers (Charley and McGarity, 1964; Sharma, 1973a; Sharma and Tongway, 1973).

3.4.2 Leaf and seed chemical analysis

Mineral element composition of fresh mature leaves and seeds of oldman saltbush are listed in Table 3.3 along with values obtained by other researchers. For comparative purposes, the chemical composition of leaves of six selected karroid plants are listed in Table 3.4. Although it is not the purpose of this study to conduct a comparative analysis of the chemical composition of *Atriplex nummularia* leaves from different parts of the world it is useful to consider the results obtained in this study in the light of those values obtained by other researchers. The chemical composition of

saltbush leaves is not constant and varies with drought, age, substrate (Beadle *et al.*, 1957; Sharma *et al.*, 1972) and season (Beadle *et al.*, 1957; Chatterton *et al.*, 1971; Smit and Jacobs, 1978). The values obtained by the different studies including this one as shown in Table 3.3 are all of comparable magnitude and proportion. The salt-accumulating nature of *Atriplex nummularia* (Fireman and Hayward, 1952; Sharma and Tongway, 1973) is illustrated by the high Na and Cl

Table 3.3: Mineral element content of *Atriplex nummularia* leaves and seeds, * grown in Hoaglands solution $\pm 50 \text{ m.eq.l}^{-1}$ NaCl (Hoagland and Arnon, 1950), ** % Dry weight.

Element	This study		Khalil <i>et al.</i> , 1986	Smit & Jacobs, 1978	Sharma <i>et al.</i> , 1972	Ashby & Beadle, 1957 *	Beadle <i>et al.</i> , 1957	Wood, 1925
	fresh leaves	seeds						
Cl % **	4,3	4,56	---	---	8,2-0,6	6,37	9,9-12,9	7,8-10,3
Na % **	3,57	3,76	4,85	4,2-1,2	7,1-0,4	---	4,5-7,9	---
K % **	2,12	2,1	2,49	2,8-0,9	---	3,08	2,6-5,6	---
Ca % **	1,48	0,72	1,44	1,1-0,3	---	---	0,3-0,8	---
P % **	0,97	0,173	0,24	0,3-0,1	---	---	0,1-0,2	---
Mg % **	1,34	1,34	0,55	0,76	1,2-0,2	---	---	---
Fe ppm	620	13,2	420	---	---	---	---	---
Mn ppm	120	183	74	---	---	---	---	---
Zn ppm	8,8	63	54	---	---	---	---	---
Cu ppm	6,7	4,9	24	---	---	---	---	---

Table 3.4: Mineral element content of leaves of selected karroid species (from Loum *et al.*, 1968). (** % Dry weight)

Element	<i>Drosanthemum</i> spp.	<i>Rhigozum trichotomum</i>	<i>Pentzia incana</i>	<i>Erioccephalus ericooides</i>	<i>Rosenia humilis</i>	<i>Salsola geminiflora</i>
Na % **	3,12-6,32	2,65-2,78	0,34-0,48	0,63-0,82	0,17-0,59	5,07-7,87
K % **	2,65-2,78	0,81-1,14	1,15-1,51	0,92-1,25	1,28-1,66	1,72-1,75
Ca % **	0,61-0,95	0,86-1,35	0,44-0,74	0,44-0,63	0,61-0,7	0,56-0,6
P % **	0,1-0,12	0,17-0,31	0,09-0,23	0,12-0,14	0,09-0,12	0,14-0,21
Mg % **	1,1-1,13	0,3-0,45	0,22-0,33	0,18-0,26	0,3-0,36	1,05-1,12
Fe ppm	150-172	55-72	28-63	17-28	74-95	150-156
Mn ppm	1908-3720	871-1404	818-2351	514-260	2144-2181	965-5121
Cu ppm	5,55-7,74	13,92-15,31	6,6-11,31	5,1-7,08	10,8-12,54	11,92-11,93

values found within the leaves. In comparison to karroid shrubs *Atriplex nummularia* leaves contain excessive quantities of Cl, Na and K and to some extent Ca, P and Mg. Of the fifty-six different karroid plants analysed by Louw *et al.* (1968) the highest values of Na content were encountered in the leaves of *Salsola geminiflora* and are of the same order of magnitude as those values obtained in this study for oldman saltbush leaves (see Table 3.4).

In comparison to the values obtained by the other studies of *Atriplex* leaves shown in Table 3.3 the quantities of the three main chemical constituents measured for this study fall at the lower end of the range. The principal mineral constituents which are contained in saltbush leaves, and are hence available for release on decomposition, are Na, Cl, K, P, Ca and Mg, a portion of which may become incorporated and redistributed within the soil. The main mineral components of oldman saltbush seeds are Na, Cl and K and these may also be an important source of additional minerals to the soil by leaching from seed mats. These salts are thought to be involved in the dormancy mechanism of the seed and need to be leached out before germination will occur. Various *Atriplex* species have been known to increase soil nitrate levels around them as noted by Rixon (1971).

3.4.3 Soil chemical analysis

The soil samples collected for gradient analysis of changes in soil chemistry with distance from *Pentzia incana* and saltbush were analysed. The results of the two transects in the adjacent karoo vegetation (*Pentzia incana* dominated dwarf shrubland) at Site 1 (Grootfontein) are presented in Table 3.5.

Table 3.5: Soil chemistry associated with a *Pentzia incana* shrubland at two depths and with distance at Site 1 (Grootfontein). (Values are means of replicates of samples from two transects).

		Relative distance from <i>Pentzia incana</i> %				
		100	75	50	25	0
E.C mS/m	surface	148	128	116,5	108	179
	depth	226	130	139,5	106	111
Cl mg/l	surface	134	92	91	100,5	143,5
	depth	259	117	101,5	64	68
Na mg/l	surface	35,5	22	26,5	36,5	45,5
	depth	102	52,5	52,5	50	30
K mg/l	surface	46,5	43,5	47	24	61,5
	depth	12	21	9,5	10,5	13
Ca mg/l	surface	99,5	88	81	66,5	93
	depth	138,5	102,5	83,5	69,5	59
Mg mg/l	surface	69	61,5	63	48	69,5
	depth	74	59,5	42,5	37	31

The average transect length in the karoo vegetation was 0,75 m from the midpoint between karoo bushes (*Pentzia incana*) to under the bushes. In general the values obtained for electrical conductivity and individual mineral constituents do not exhibit any clear or marked gradients along the transect (see Table 3.5). Electrical conductivity values range between 106 mS/m and 226 mS/m for the samples at depth and 108 mS/m to 179 mS/m for the surface samples. In the case of the surface samples the two extreme values are from sampling positions immediately adjacent to each other. In general the electrical conductivity values at depth are greater than surface sample values. Individual mineral constituents (Cl, Na, K, Ca and Mg) likewise show no clear gradients with distance between plants.

Comparing the values obtained for each mineral at depth and surface there is also little difference except for sodium, which are generally lower at the surface, while potassium values are clearly lower at depth than surface sample values. Referring back to Table 3.4, the potassium content of the leaves of *Pentzia incana* can be ascertained as being in the range 1,15 to 1,51%. It must be pointed out that there is very little litter accumulation in the karroid dwarf shrublands and so it may be meaningless to correlate leaf constituents directly with mineral accumulations in the soil in this case. Furthermore, although the vegetation is dominated by *Pentzia incana* any litter accumulated on which decomposition could occur may be from many other species which will have different chemical composition. There is however no spatial trend observable in either sodium or potassium content in association with *Pentzia incana* individuals along the transect. The values obtained for the *Pentzia incana* dominated dwarf shrubland serve as a control against which similar gradient analyses associated with *Atriplex nummularia*, where there is a build up of litter, can be compared.

Figures 3.3 to 3.6 illustrate soil gradients in selected chemical elements found in association with 24 year old saltbush plants which have never been grazed (Site 2). Sodium, chloride (Figure 3.3), potassium and electrical conductivity (Figure 3.4) all increase dramatically in both surface and depth samples at 25% (approximately 0,5 m) from the saltbush and peak with the highest values occurring at the base of the saltbush (0% from the saltbush). Calcium and magnesium (Figure 3.5) values remain relatively constant in both the surface and depth samples with distance from saltbush. Both these mineral elements do increase slightly in the surface sample 25% from the saltbush. As may be expected from the changes observed in Ca, Mg and Na, the sodium adsorption ratio (S.A.R.) and the exchangeable sodium percentage (E.S.P.) both increase in the proximity of the saltbush (Figure 3.6) in a similar fashion as the sodium and chloride content of the soil. In all cases the values obtained for the depth (20 - 30 cm) samples are greater than those obtained for the surface (0 -15 cm) samples at similar positions. This is in direct contrast to Sharma (1973a) and Sharma and Tongway (1973) who reported finding that soil chemistry changes associated with saltbush only occur in the top 0 - 15 cm of the soil. The changes in soil chemistry at a greater depth tends to suggest

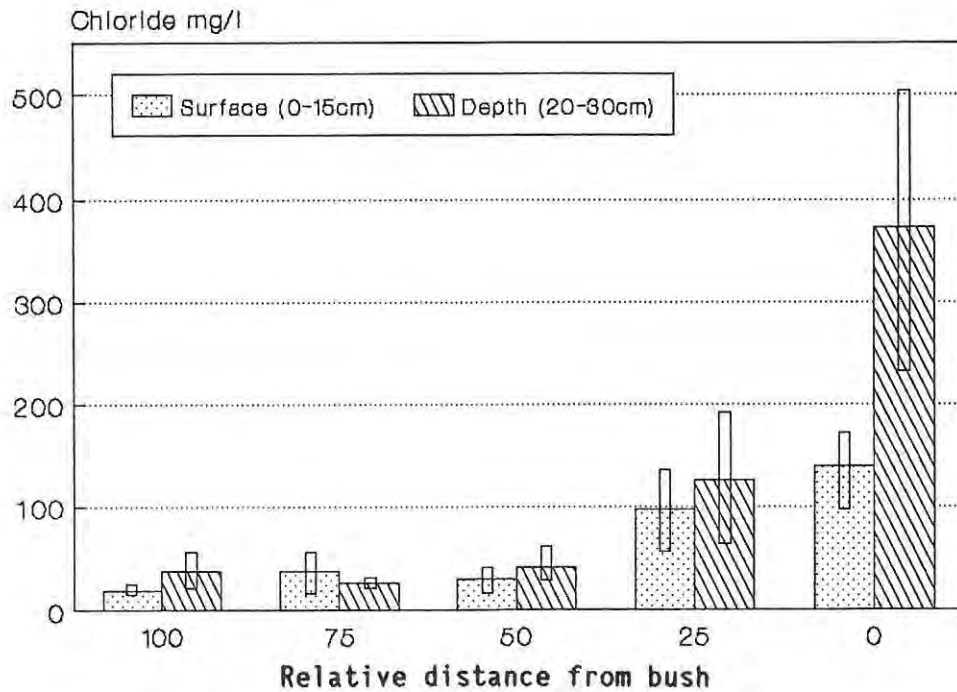
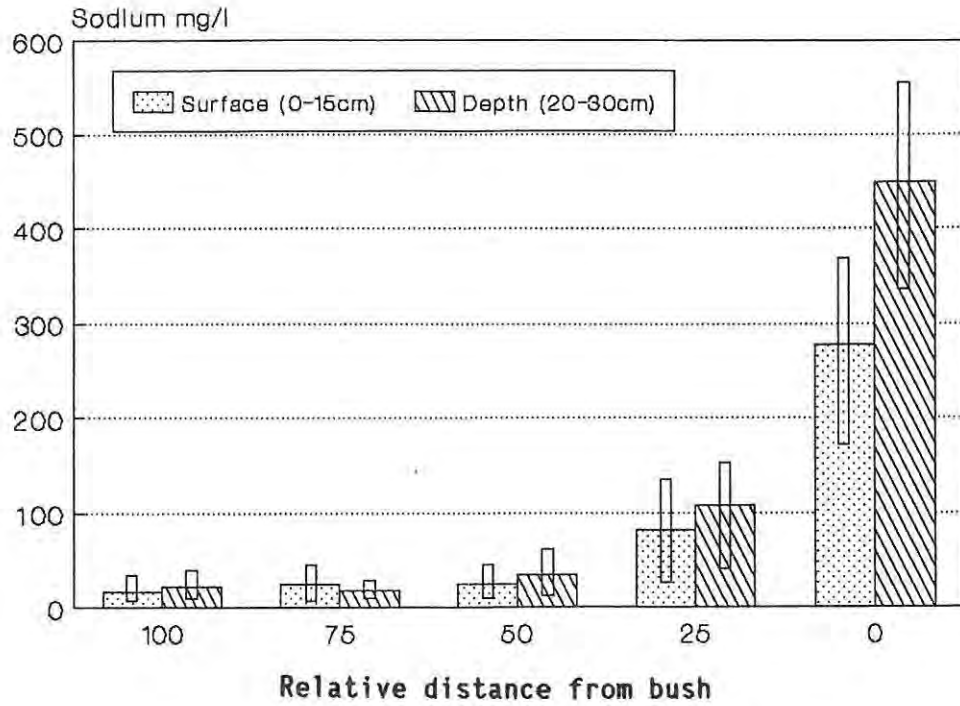


Figure 3.3:

Variation in sodium and chloride content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 24 year old saltbush plantation (Site 1, Grootfontein). Values are means of replicates of five samples each, standard error bars are included.

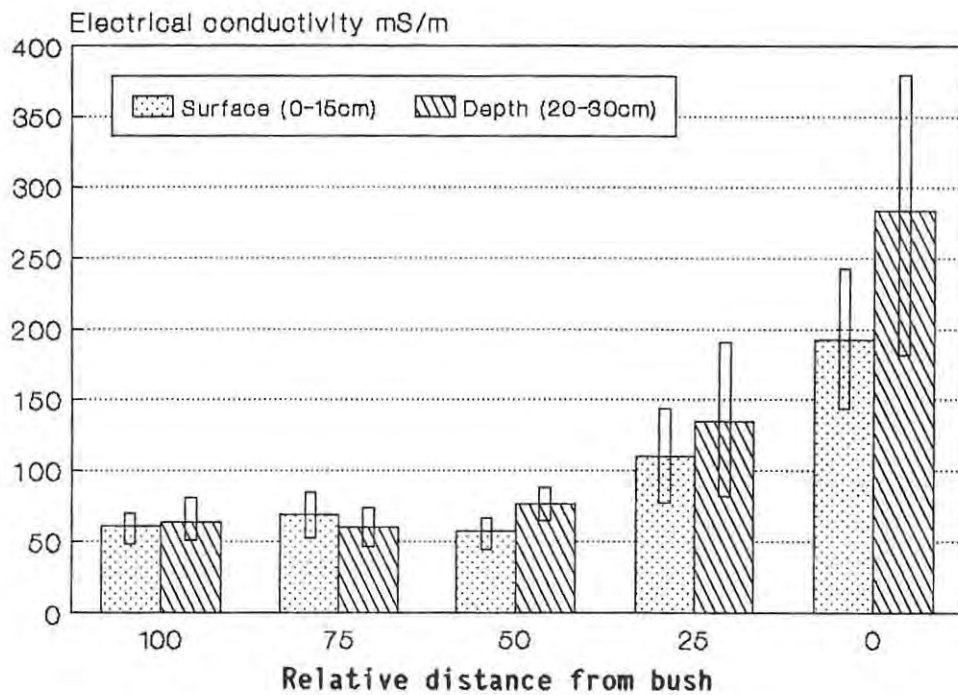
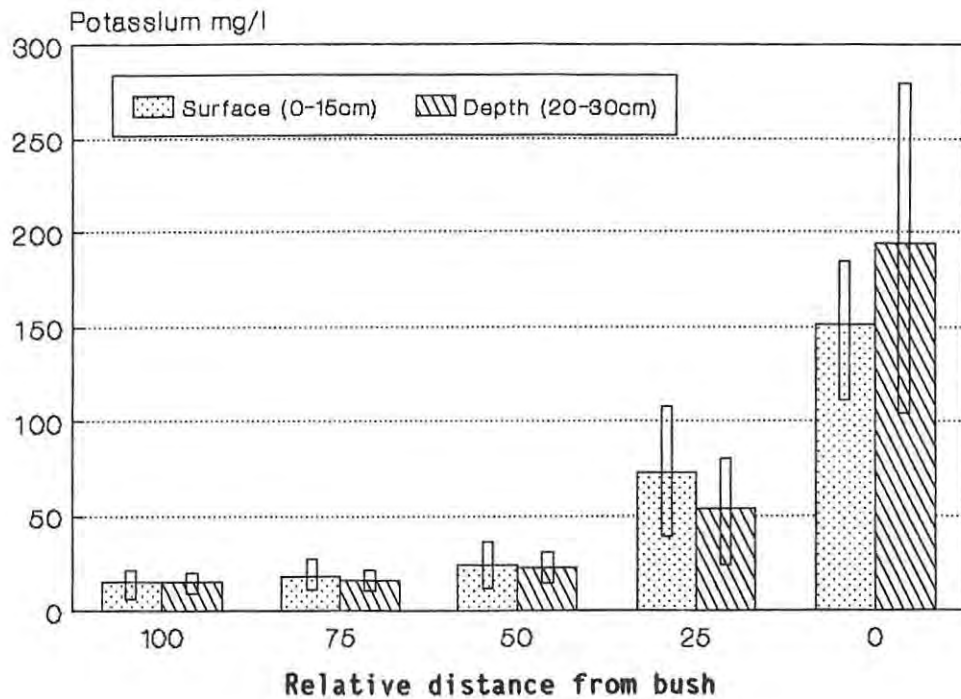


Figure 3.4: Variation in potassium content and electrical conductivity of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 24 year old saltbush plantation (Site 1, Grootfontein). Values are means of replicates of five samples each, standard error bars are included.

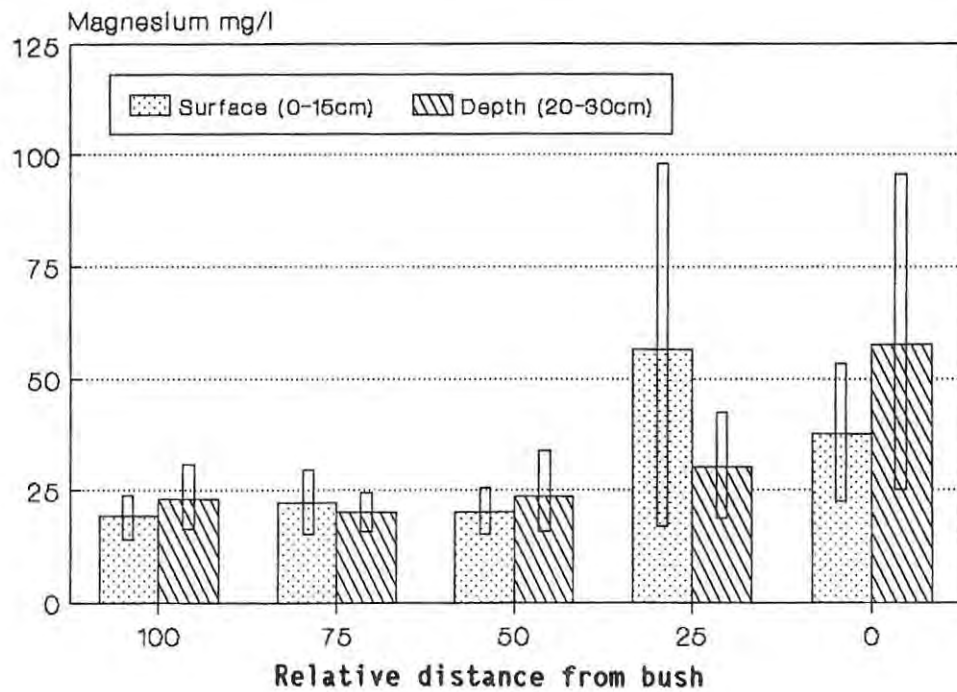
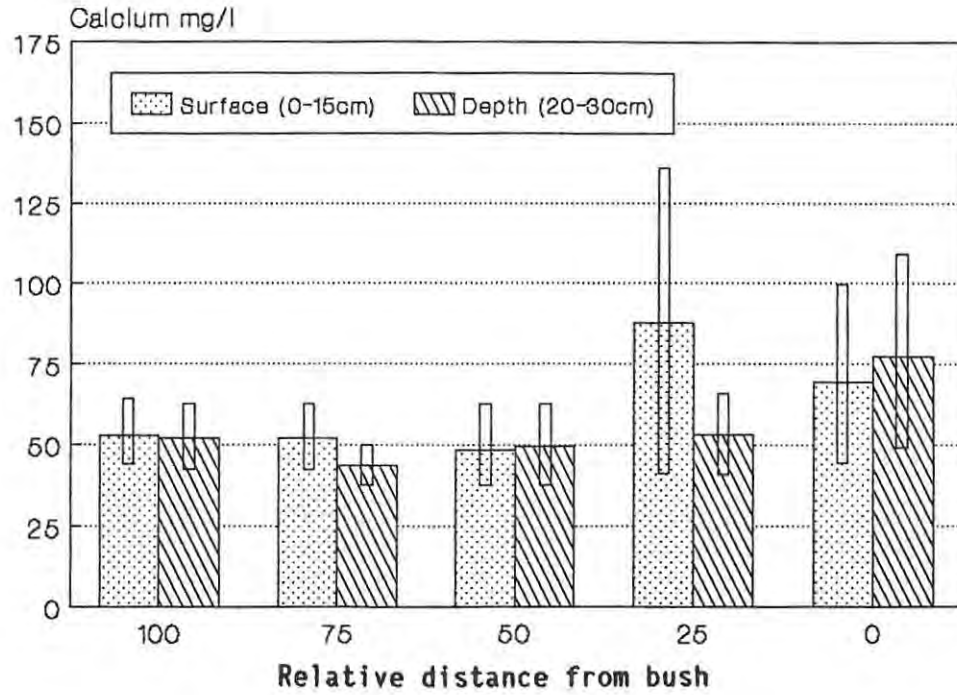


Figure 3.5: Variation in calcium and magnesium content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 24 year old saltbush plantation (Site 1, Grootfontein). Values are means of replicates of five samples each, standard error bars are included.

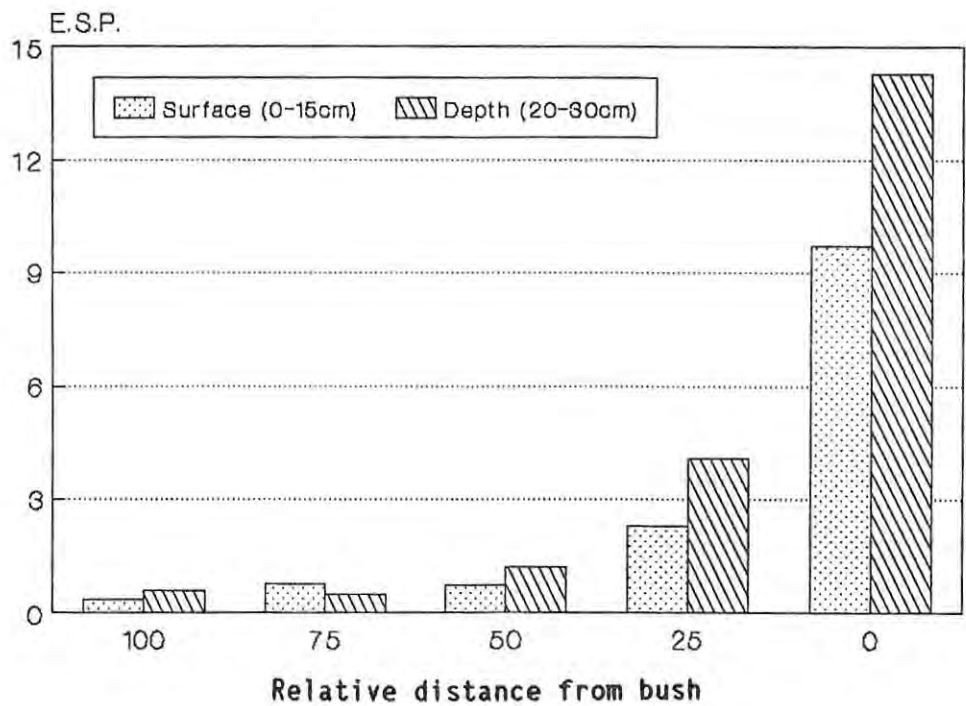
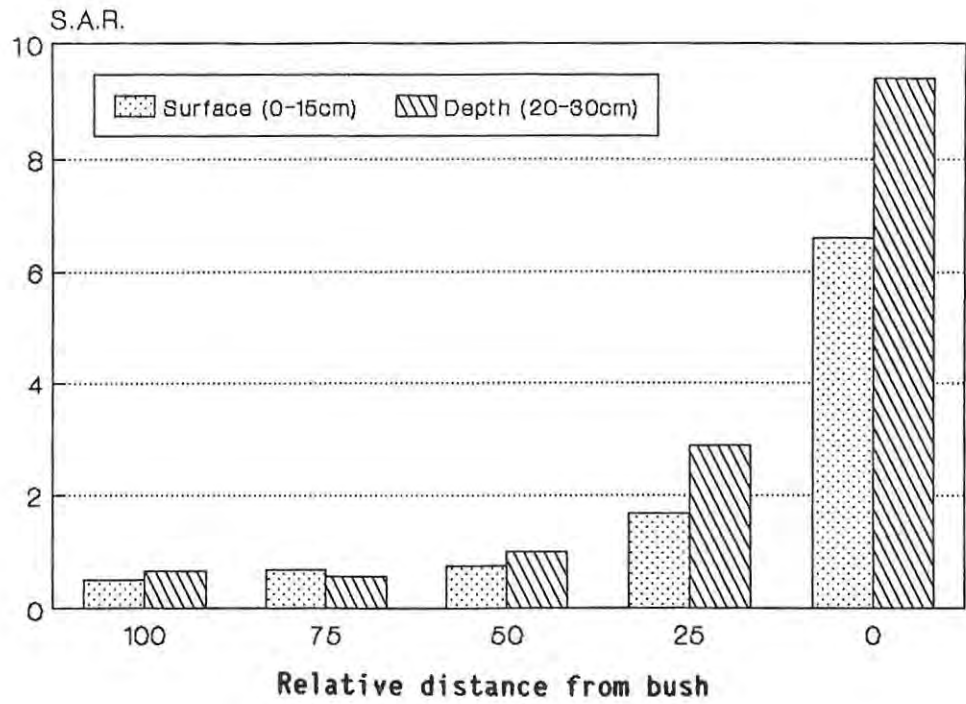


Figure 3.6: Variation in S.A.R. and E.S.P. content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 24 year old saltbush plantation (Site 1, Grootfontein). Values are means of replicates of five samples each, standard error bars are included.

a net downward movement of minerals. The difference between surface and depth samples associated with saltbush is also different to the distribution of minerals in the soil associated with *Pentzia incana* in the adjacent natural vegetation.

The variation and values obtained for all mineral constituents at both surface and depth (except magnesium at depth) increase considerably as the saltbush is approached (standard error bars are included in all figures where applicable). Extremely high values of the standard error of the best estimate of the mean were obtained, for all parameters analysed, at the saltbushes (0% from the plant). By way of illustration, electrical conductivity at the saltbush for both surface and depth samples is considered. The mean value for electrical conductivity of ten subsamples (two replicates in five transects) at the saltbush is 193 mS/m for surface and 283 mS/m for depth, with standard errors of ± 51 and ± 91 respectively. Chloride had the highest standard error recorded of ± 141 about a mean value of 373 mg/l at depth, under the saltbush (0% from the saltbush). For all minerals the standard error of the values obtained from the two sampling positions furthest from the saltbush (100% and 75% from saltbush), were of the order of ± 9 for chloride, ± 8 for calcium, ± 9 for electrical conductivity and ± 5 for sodium. Despite the high variability of the values recorded for the mineral constituents the increases of Cl, Na and K associated with the saltbush are of such magnitude that it can be accepted that these minerals generally increase within 0,5 m of saltbush plants at Grootfontein (Site 1). This finding is further validated by the consistent trends in all of the five transects.

The sodium adsorption ratio (S.A.R.) and exchangeable sodium percentage (E.S.P.) both increase in the proximity of saltbush, especially at the 25% and 0% relative distances from the plant (see Figure 3.6). The highest values encountered for both S.A.R. and E.S.P. are at depth at the saltbush. The addition of potassium to the denominator of the S.A.R. equation, as is sometimes done in semi-arid areas, results in a near identical trend although the extreme values were between 1,5 and 2 units lower than those obtained using the standard S.A.R. equation. All values of S.A.R. and E.S.P. from between saltbush are either of similar magnitude or lower, as compared to those obtained from the samples taken in the adjacent karoo vegetation.

Similar analyses were conducted at Wellwood (Site 2) in a 40 year old saltbush plantation. The plantation has been regularly grazed by sheep for the 40 year period as it occupies part of a camp within a rotational grazing system and is not fenced separately. Initially ten soil samples, each having two depths, were collected randomly in the karoo vegetation adjacent to the saltbush and 10 samples from between the saltbush plants in the plantation. These samples were collected to assess if the soils of the saltbush plantation as a whole were grossly more saline than the soils in the adjacent karoo vegetation. The soil samples were analysed using the saturation technique, as already outlined, for sodium and calcium content. Electrical conductivity was also measured. Two replicates

were analysed from each sample and the mean values and standard errors of each are summarized in Table 3.6.

Table 3.6: Comparative study of soils from a 40 year old saltbush plantation (Site 2) and the adjacent karoo vegetation. Samples in the plantation are from between saltbush plants while those in the karoo vegetation were random.

		karoo*	saltbush*
Electrical conductivity mS/m	surface	70 ± 10	56,6 ± 7,0
	depth	58 ± 3,4	61,8 ± 5,1
Na mg/l	surface	33 ± 2,3	34 ± 4,9
	depth	37 ± 4,8	37,6 ± 3,2
Ca mg/l	surface	35,5 ± 6,0	25,8 ± 4,1
	depth	37,9 ± 2,4	31,9 ± 3,3

* Values are means of ten samples (two replicates were done for each sample)

The mean values of the ten soil samples (Table 3.6) show that electrical conductivity is generally slightly higher in the surface layer (0 - 15 cm) of the soils in the karoo vegetation as compared to between saltbush in the saltbush plantation. The situation is reversed for the samples at depth (20 - 30 cm) such that conductivity is higher in the saltbush plantation (between bushes) than in the karoo vegetation. Sodium content of both surface and depth samples is similar for each of the sampling positions although all sodium values recorded are higher at depth than at the soil surface. The calcium content of the soil in the karoo vegetation appears to be greater than that in the saltbush plantation and also greater at depth than at the soil surface. Generally, it appears that there is little difference between the soil of the adjacent karoo vegetation and the soil between saltbushes in the 40 year old plantation. Using the same sampling procedure as at Grootfontein except that samples were only taken from only three relative distances from the saltbush (100%, 50% and 0%), chemical analysis of selected elements was conducted at Wellwood (Site 2). The average transect length was 2 meters. Mean values obtained for the parameters measured along the transects, using replicate subsamples of each sample, are illustrated in Figures 3.7 to 3.10. Standard error bars are included where relevant.

Sodium and chloride both increase in the surface soil layers and at depth in the proximity of 40 year old saltbush plants (Figure 3.7). The highest values recorded for sodium and chloride being in the soil surface under or at the saltbush plants, these positions also have the highest standard error about the mean. As in the case of Site 1 (Grootfontein) the variability of the values measured tends to increase as a saltbush is approached. The highest standard error of ± 218 is for the values of chloride measured at the saltbush from surface samples (a mean value of 881 mg/l). The soil surface samples in general exhibit a greater content of both sodium and chloride at all distances

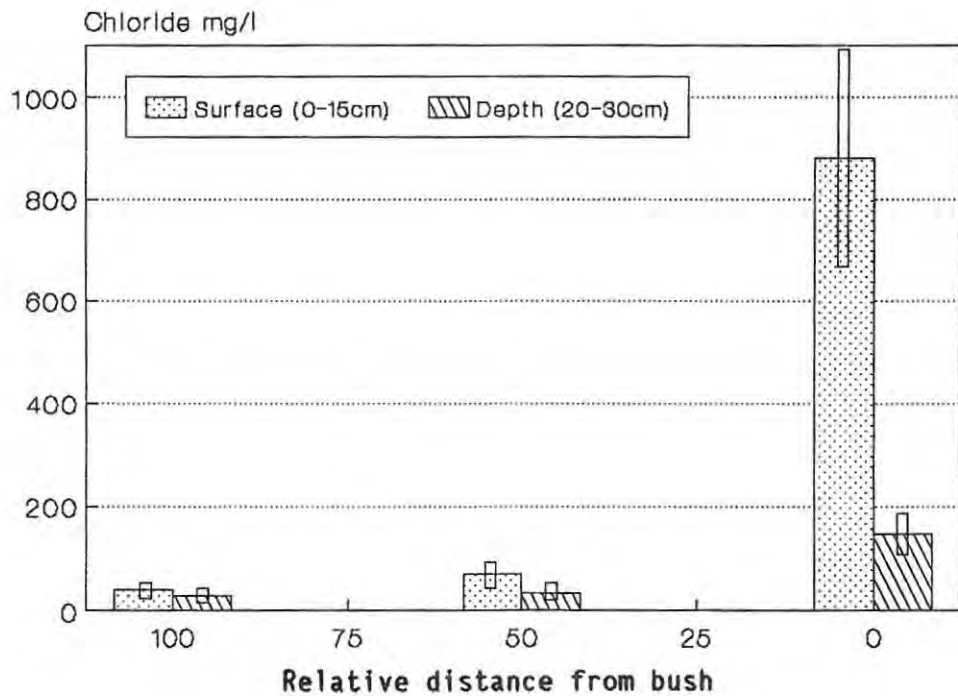
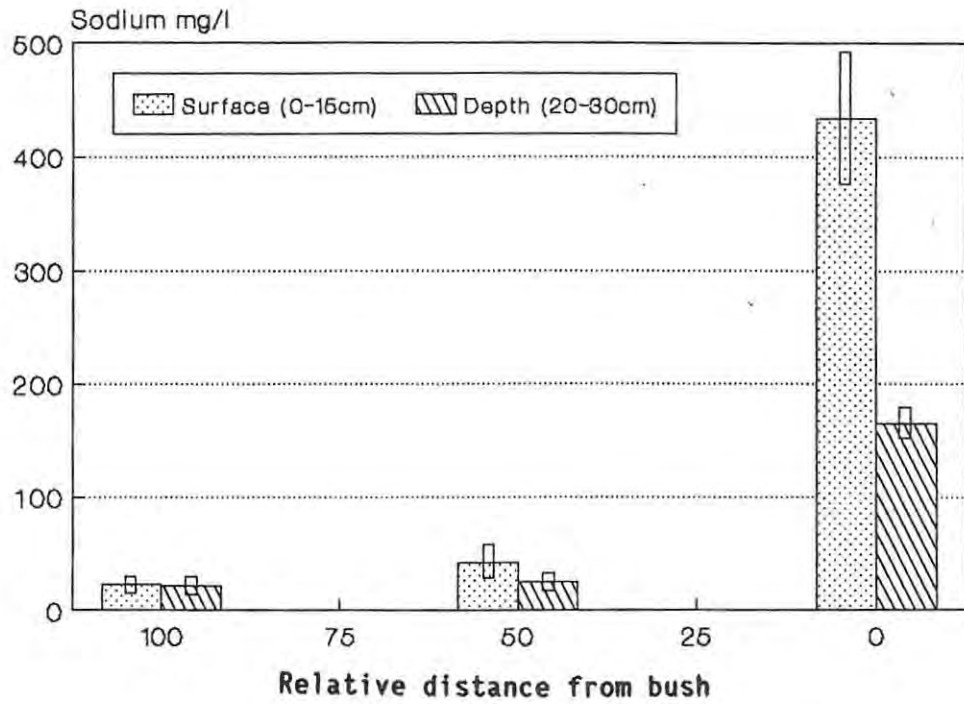


Figure 3.7: Variation in sodium and chloride content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 40 year old saltbush plantation (Site 2, Wellwood). Values are means of replicates of ten samples each, standard error bars are included.

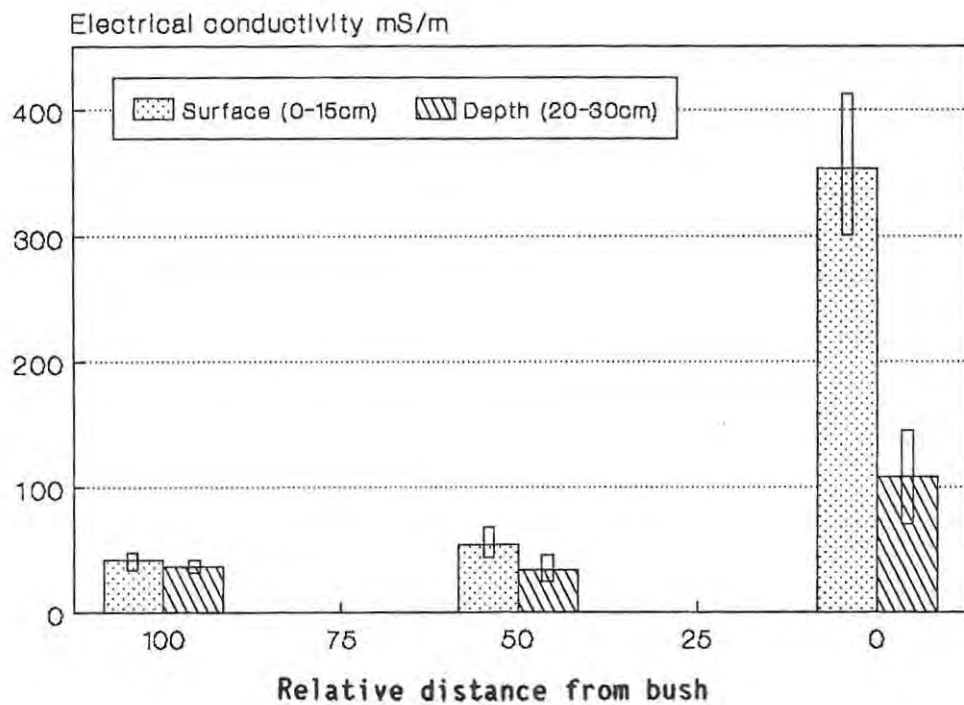
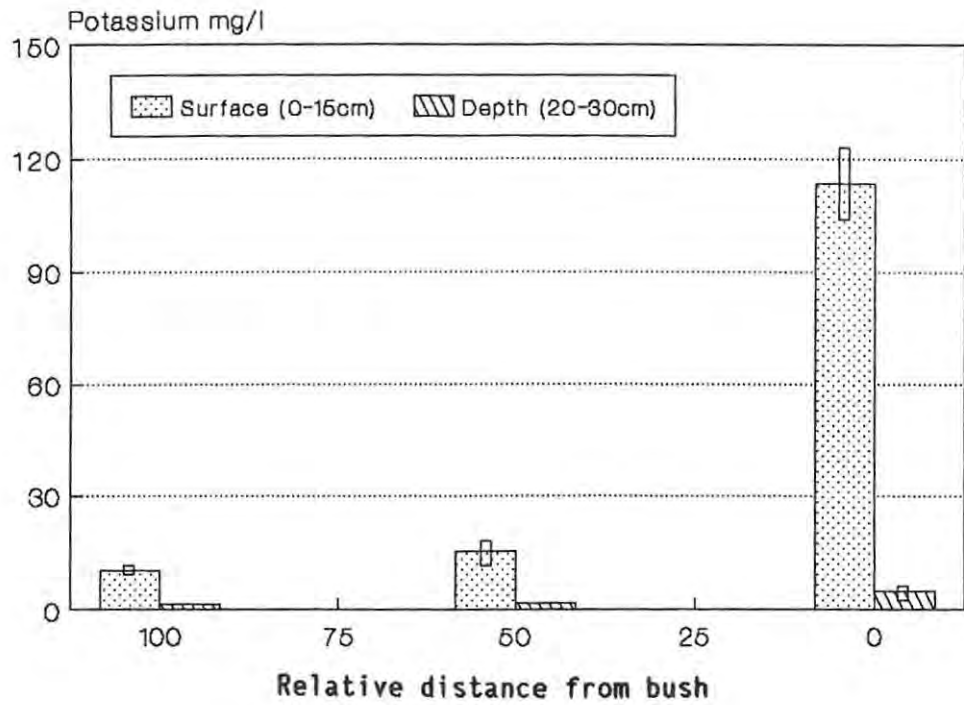


Figure 3.8: Variation in potassium content and electrical conductivity of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 40 year old saltbush plantation (Site 2, Wellwood). Values are means of replicates of ten samples each, standard error bars are included.

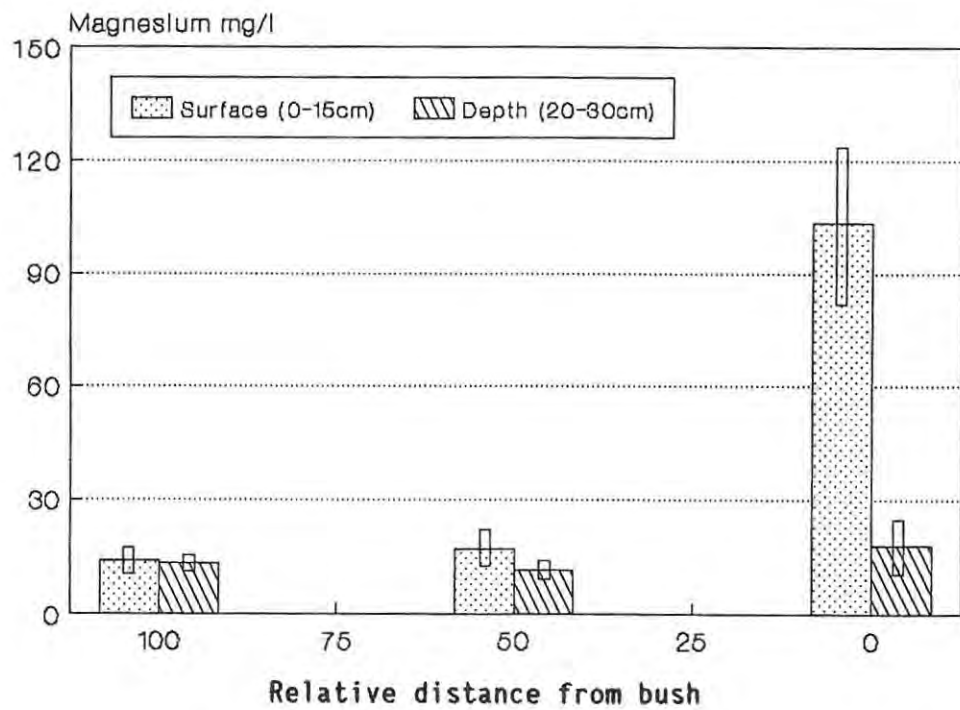
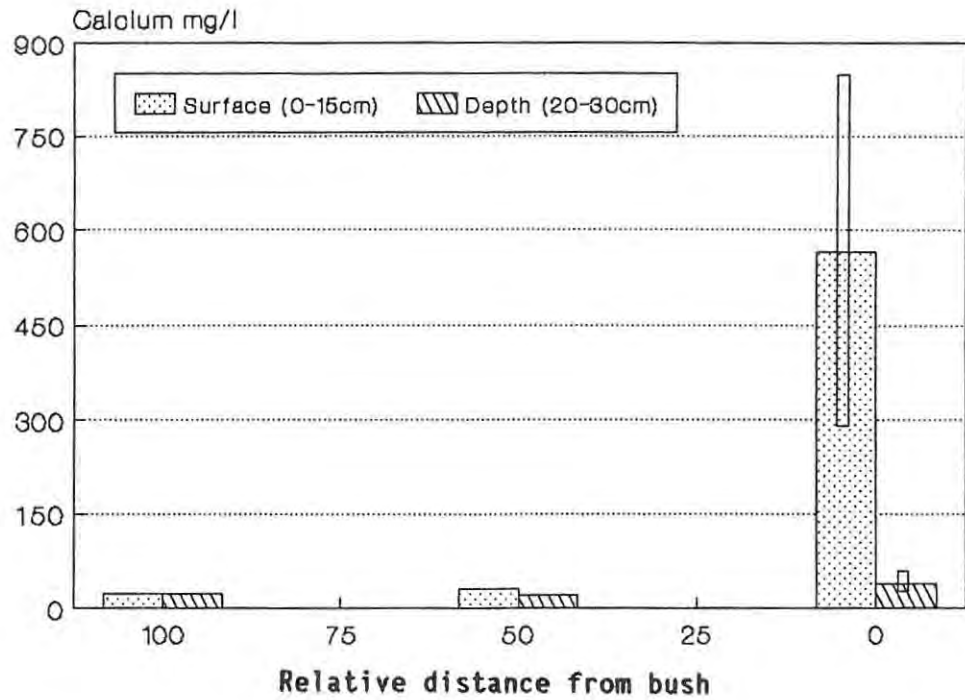


Figure 3.9: Variation in calcium and magnesium content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 40 year old saltbush plantation (Site 2, Wellwood). Values are means of replicates of ten samples each, standard error bars are included.

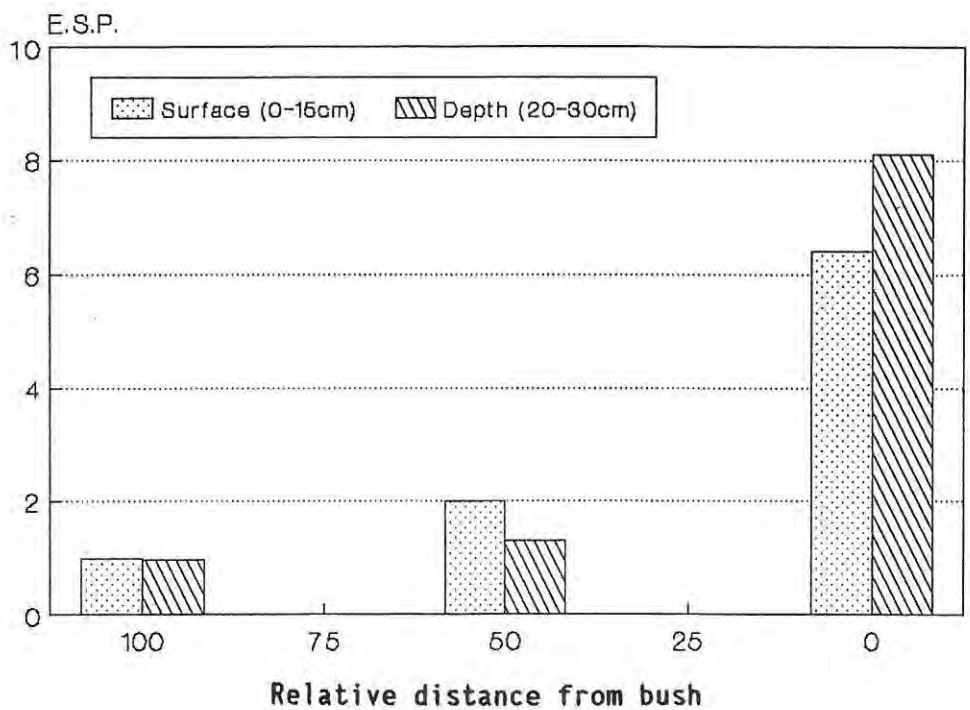
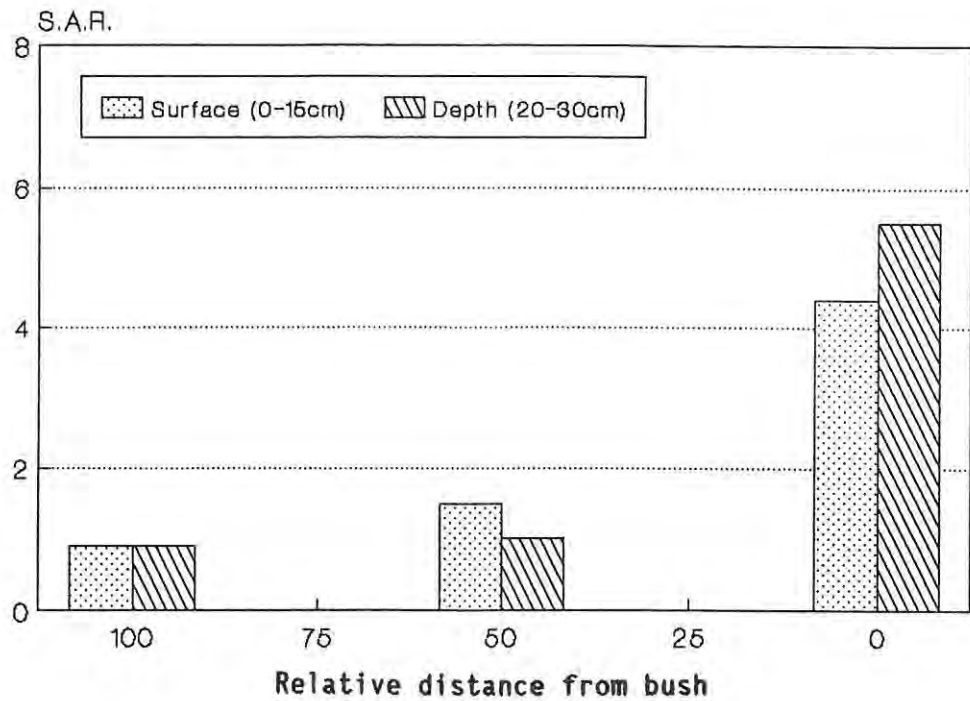


Figure 3.10: Variation in S.A.R. and E.S.P. content of the soil with relative distance from saltbush plants (see Figure 3.1) at surface (0-15 cm) and depth (20-30 cm) in a 40 year old saltbush plantation (Site 2, Wellwood). Values are means of replicates of ten samples each, standard error bars are included.

from saltbushes than the soil samples at depth. This is converse to the situation at Site 1 (Grootfontein) where the depth samples had greater concentrations of sodium and chloride than the surface samples. Causal factors for this phenomenon have not been addressed but could be due soil type, texture and/or hydrological conditions.

Potassium and electrical conductivity both increase in association with saltbush (Figure 3.8) with the surface soil samples once again having higher values than the samples taken at depth. Standard error values are low except for the surface samples at the saltbush. Calcium and magnesium exhibit marked increases in the surface samples as the saltbushes are approached (Figure 3.9), however, the samples at depth show very slight changes relative to the proximity of saltbush and are an order of magnitude less at the saltbush. This differs from the consistent values recorded for calcium and magnesium in both surface and depth samples from the 24 year old plantation. S.A.R. and E.S.P. both increase dramatically in association with saltbush from the 40 year old plantation (Figure 3.10). S.A.R. values range from 0,9 to 4,4 for surface and 0,9 to 5,5 for depth samples while E.S.P. values for surface and depth samples range from 0,9 to 6,4% and 0,9 to 8,1% respectively. The trends in S.A.R. and E.S.P. are very similar to those observed in the 24 year old plantation (Figure 3.6) but the extreme values are lower in the case of the 40 year old plantation.

3.5 Conclusion

The soil chemistry changes considerably in the proximity of *Atriplex nummularia* (saltbush) plants at both study sites (key question 3.1(ii)). Associated with saltbush plants in both cases is an increase in sodium, chloride, potassium and electrical conductivity detectable at about 0,5 m on average from the plant, reaching maximum values at the saltbush. Calcium and magnesium content in the soil both increase in association with saltbush in the 40 year old plantation (Site 2) at the soil surface but not at depth. Calcium and magnesium however do not show any trends in association with saltbush in the 24 year old saltbush plantation (Site 1). S.A.R. and E.S.P. increase in association with saltbush at both Sites (1 and 2). The changes in soil chemistry occur within 0,5 m of the saltbush and hence do not seem to be attributable to the presence of roots, as the density of roots surrounding the saltbush excavated remains fairly consistent for 1,4 m from the saltbush.

The increases in sodium, chloride and potassium in particular are attributed to the decomposition of the litter of saltbush leaves and seeds found surrounding the base of saltbush plants. This was confirmed by chemical analysis of saltbush leaves and seed. These findings are similar to those observed by Sharma and Tongway (1973). Similar changes in soil chemistry from the decomposition of leaves of *Atriplex torreyi* have been reported by Vasek and Lund (1980). The soil between

saltbush at both sites appears to be similar to that found in the adjacent karoo dwarf shrubland. This situation may change as the density of the plantation varies although no inference can be made here as both plantations had plants spaced 4 m apart (on average). Comparing the induced soil chemical variations associated with saltbush for each of the sites shows that there is little difference between the trends despite the fact that the plantations are of different age and that one has been grazed and the other not. Grazing by sheep could be expected to reduce the litter and possibly redistribute the salts within the plantations in the form of urine (Wilson, 1966b). This did not seem to be important in effecting the trends observed at both sites. The soils at each site are also different which may explain why the sodium, chloride, potassium and electrical conductivity values were higher at greater depth at Site 1 (loamy sand) while at Site 2 (sand clay loam) the values were higher in the surface soil samples.

Further studies are needed to understand (i) temporal changes in soil chemistry associated with saltbush (Beadle *et al.*, 1957), (ii) nutrient cycling in saltbush plantations, (iii) the effects of soil salinity changes on other plants in the dwarf shrubland community, (iv) the effect of increased salinity on soil texture in saltbush plantations and (v) soil chemistry changes in areas where saltbush plants have been removed.

CHAPTER 4

SALINITY EFFECTS ON THE GERMINATION OF SELECTED KARROID SPECIES

4.1 Introduction

"Soil salinity may affect the germination of seeds in two ways: a) by decreasing the ease with which seeds may take up water and thereby decreasing the rate of water entry; and b) by facilitating the entry of ions in sufficient amounts to be toxic" (Ayers, 1952, p. 82). These two effects have been shown by Urvits (1946) and Ayers and Hayward (1948) to slow the emergence rate of seeds that germinate and to decrease the percentage of germination. The aforementioned work was conducted using seeds of alfalfa and sugar beet, respectively. Sharma (1973b) simulated the effect of drought in examining its effect on germination by using increased concentrations of NaCl. Potter *et al.* (1986) found that the germination of *Atriplex canescens* is significantly altered by temperature, osmotic potential and pH.

Atriplex nummularia causes an increase in soil salinities within 0,5 m of individual plants (Chapter 3). This increased salinity may cause changes in the species composition of areas planted to oldman saltbush in the long term by changing both germination and establishment rates of new seedlings on a species selective basis. Germination tests of *Atriplex nummularia* seeds were conducted by Beadle (1952) who found that light and pH had little effect on germination percentage or time taken to germinate. Work on the germination of karoo plants is limited, early studies were undertaken by Henrici (1933, 1935, 1939) and van Breda (1939). This work revealed that each batch of seeds should be treated separately as age, harvesting time and germination season are important. Furthermore germination cues for the germination of karoo shrub seeds are both complex and varied.

This chapter outlines the methods used and describes the results of experiments to determine the effect of salinity on germination rate for selected karroid species. The range of salinities used was determined by the increase in soil surface salinity associated with saltbush measured and documented in Chapter 3. Establishment rates are not examined as these are dependent on a number of variables. The impact of differential establishment of karoo plants in saltbush plantations is incorporated in the examination of the indigenous plant community found within a 40 year old saltbush plantation in Chapter 5.

4.2 Key question

- (i) What effect does increased salinity have on the germination rates of selected karroid species commonly found in areas planted to oldman saltbush?

4.3 Methodology

4.3.1 Collection, selection and testing of seeds

Species were initially selected as being suitable for germination tests on the basis of three criteria, namely; (i) if they had been observed in saltbush plantations, (ii) if seeds were available in the field and (iii) if they were common karoo species and/or good grazing plants. Seeds of the following species were collected: *Aristida diffusa*, *Tragus koelerioides*, *Eragrostis curvula*, *E. lehmanniana*, *E. obtusa*, *Cynodon dactylon*, *Limeum aethiopicum*, *Pharpaceum verrucosum*, *Drosanthemum* sp., *Felicia ovata*, *Rosenia humilis*, *Pentzia incana*, and *P. sphaerocephala*. Seeds of *Atriplex nummularia* were supplied by Grootfontein College of Agriculture.

Ripe seeds of each species were carefully picked by hand from many individual plants in the magisterial districts of Pearston and Graaff-Reinet. All seeds for each species were bulked and germination experiments were conducted using seeds from these bulked samples. In order to obtain some preliminary indication of the viability of the bulked samples, 50 seeds of each species were placed on filter paper in a petri dish. The filter paper was kept uniformly moist with distilled water. The petri dishes were exposed to natural light and temperature conditions in the laboratory. Germinated seeds were counted and removed on a daily basis for a period of 20 days. The germination percentage obtained in each case is listed in Table 4.1. All species which did not germinate, namely *Eragrostis curvula*, *E. lehmanniana*, *Cynodon dactylon* and *Limeum aethiopicum* were omitted from further germination tests. Lack of germination could be due to various reasons some possibilities being immature seeds, incorrect germination cues, season of germination and insufficient after-ripening period (Henrici, 1939). The specific reasons for the selection of each species finally used are indicated in Table 4.2. It was unfortunate that viable seeds of *Eragrostis curvula*, *E. lehmanniana* and *Cynodon dactylon* were not obtained as these species are common grass species in the karoo. In an attempt to obtain viable seeds for these three grasses batches of seeds were collected from Cradock, Grootfontein (Site 1), Wellwood (Site 2) and Pearston.

In order to determine the minimum number of seeds required for a representative sample further preliminary tests were conducted. For each species, samples containing 5, 10, 20, 40, 80, 160 and 320 seeds were counted. Each batch of seeds was washed in a 5% solution of sodium hypochlorite in order to prevent fungal growth. The seeds were then placed on filter paper in separate petri

Table 4.1: Germination percentages of initial tests done at room temperature with natural light and dark regimes of 50 seeds for each of the species listed.

Species	Percentage germination (%)
<u>Aristida diffusa</u>	38
<u>Tragus koelerioides</u>	40
<u>Eragrostis curvula</u>	0
<u>E. lehmanniana</u>	0
<u>E. obtusa</u>	8
<u>Cynodon dactylon</u>	0
<u>Limeum aethiopicum</u>	0
<u>Pharnaceum verrucosum</u>	14
<u>Drosanthemum sp.</u>	64
<u>Felicia ovata</u>	82
<u>Rosenia humilis</u>	68
<u>Pentzia incana</u>	36
<u>P. sphaerocephala</u>	78
<u>Atriplex nummularia</u>	52

Table 4.2: Species selected for germination tests, reason selected and the number of seeds used in replicate samples at different salinities.

Species selected	Reason selected	Number of seeds used
<u>Aristida diffusa</u>	common species	50
<u>Tragus koelerioides</u>	common species	50
<u>Eragrostis obtusa</u>	common species	100
<u>Pharnaceum verrucosum</u>	common species	100
<u>Drosanthemum sp.</u>	common species	50
<u>Felicia ovata</u>	good for grazing	100
<u>Rosenia humilis</u>	common species	100
<u>Pentzia incana</u>	common species	100
<u>P. sphaerocephala</u>	common species	100
<u>Atriplex nummularia</u>	-----	50

dishes. The petri dishes were kept moist with distilled water and placed in a constant environment room at 20°C and exposed to 12 hours of light and 12 hours of dark. Henrici (1939) found germination of most shrubs to be relatively good at 20°C and that alternating light and dark regimes in general produced the best germination response. The method used is similar to that used by Holmes and Rebelo (1988) for the germination of *Acacia cyclops* seeds. Germinated seeds were counted and removed daily for a period of 16 days. Seeds were classified as "germinated" when the radicals were extended 1-2 mm beyond the seed coat (Pieterse and Cairns, 1986). No further seeds germinated after 13 days. The results of percentage germination with increased sample size (number of seeds) are presented in Figures 4.1 to 4.6. Figure 4.6 illustrates the retarding effect of the seed testa on the germination of *Atriplex nummularia* (Beadle, 1952). For the purpose of these germination tests the seed testa of saltbush seeds were removed and only 50 seeds were used in each petri dish. The retarding effect of the testa may either be due to high osmotic potentials in the testa or the presence of some inhibitor as found in the case of the desert saltbush, *Atriplex polycarpa* by Askham and Cornelius (1971). Based on Figures 4.1 and 4.2 the minimum representative sample size (number of seeds) was decided on for each species. The number of seeds used for each replicate is indicated in Table 4.2, these are of the same order of magnitude as used by Henrici (1939).

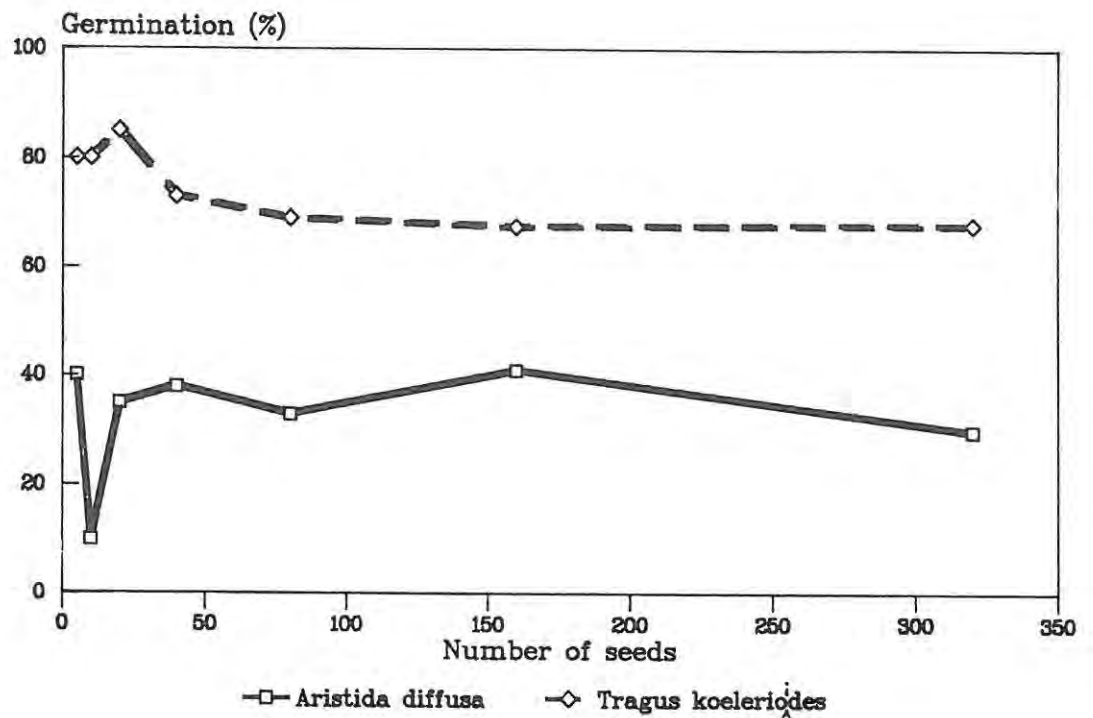


Figure 4.1: Percentage germination with increased sample size for *Aristida diffusa* and *Tragus koelerioides*

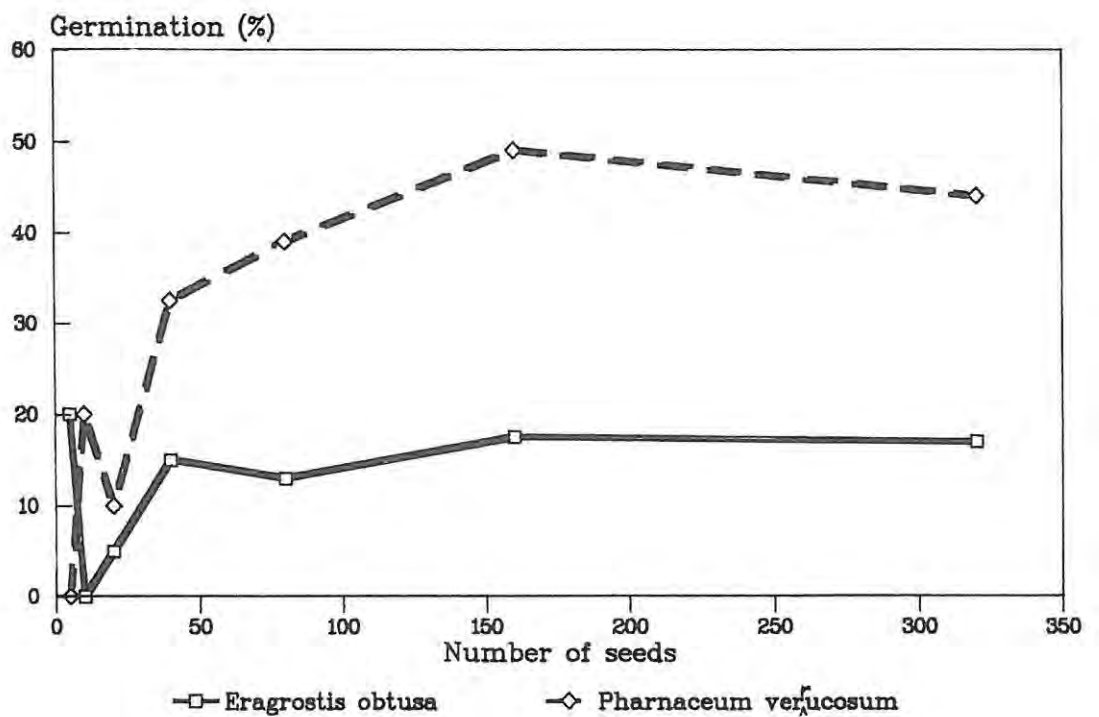


Figure 4.2: Percentage germination with increased sample size for *Eragrostis obtusa* and *Pharnaceum verrucosum*

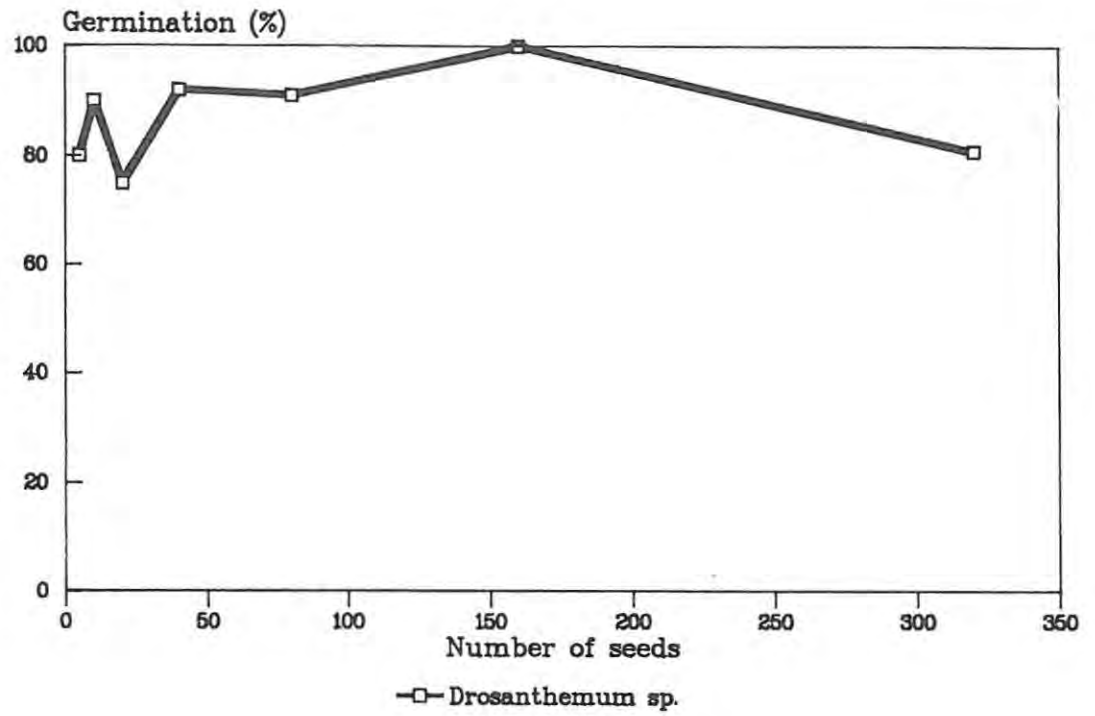


Figure 4.3: Percentage germination with increased sample size for *Drosanthemum sp.*

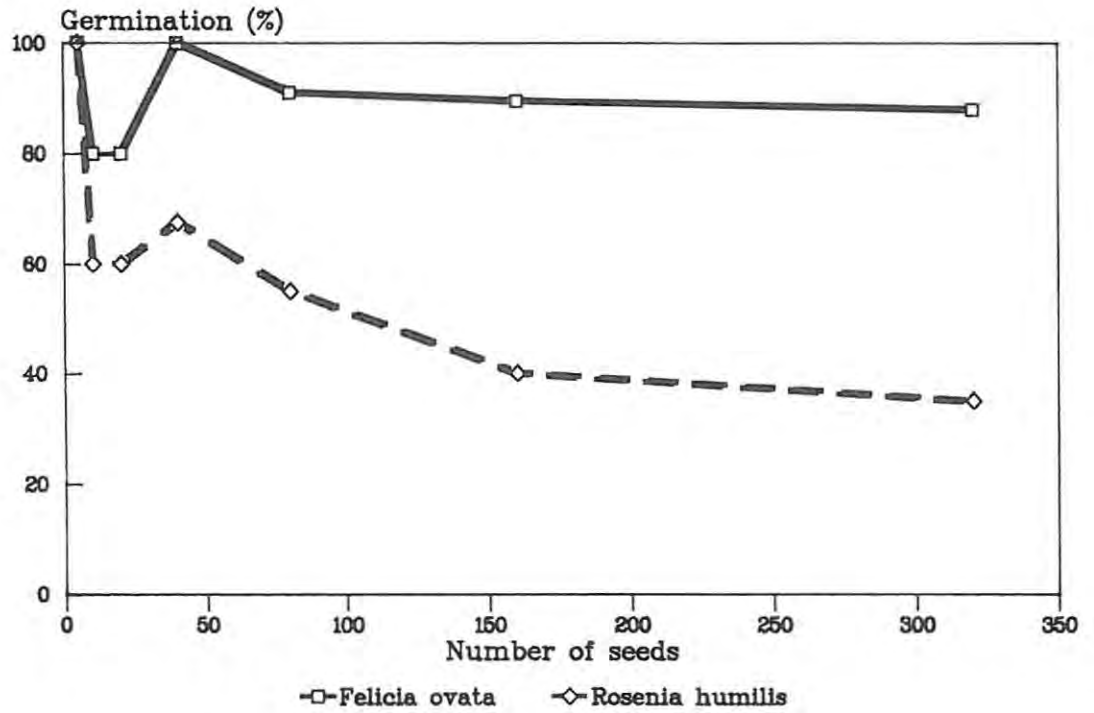


Figure 4.4: Percentage germination with increased sample size for *Felicia ovata* and *Rosenia humilis*

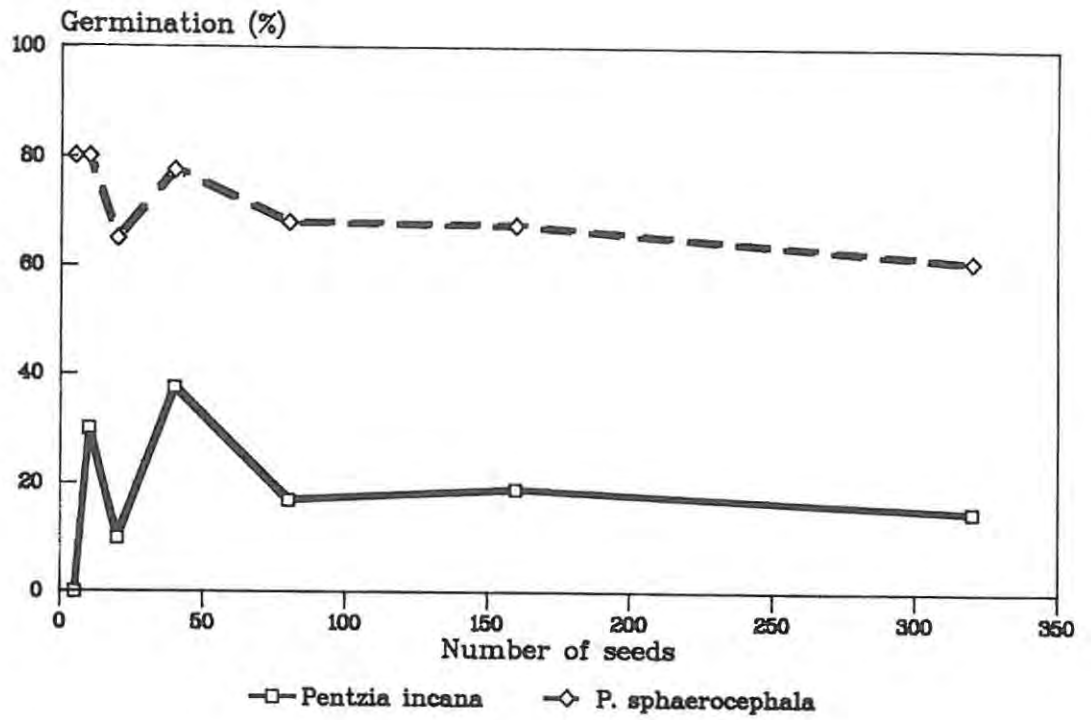


Figure 4.5: Percentage germination with increased sample size for *Pentzia incana* and *P. sphaerocephala*

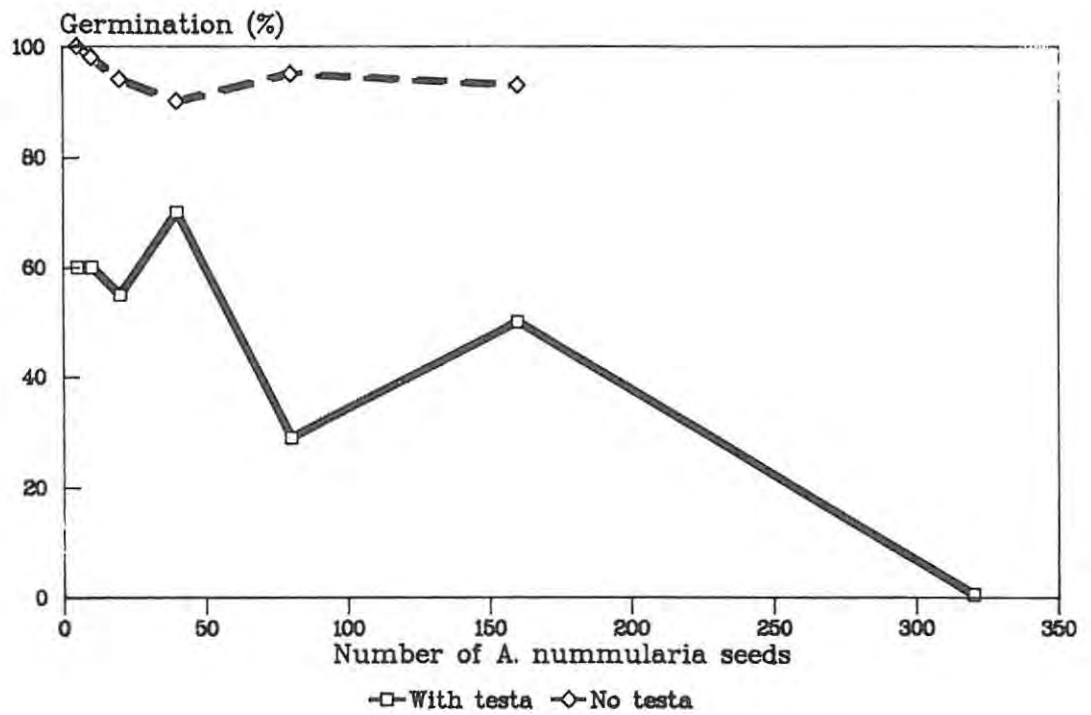


Figure 4.6: Percentage germination with increased sample size for *Atriplex nummularia*

Having determined the number of seeds required for replicate samples of germination tests for each batch of seeds collected, the germination tests proper were conducted using the following method. Seeds were counted into samples and washed in a 5% solution of sodium hypochlorite before being placed on filter paper in petri dishes. Five levels of salinity were used for each of the species, namely (i) distilled water, (ii) 30 mg/l NaCl, (iii) 500 mg/l NaCl, (iv) 1000 mg/l NaCl and 2000 mg/l NaCl, the upper limit was determined by the highest salinity recorded in the soils associated with saltbush plants (Chapter 3). Three replicates of each species were prepared for each salinity treatment. Initially 10 ml of the appropriate saline solution was added to the petri dishes. The petri dishes were placed in a constant environment room, at 20° C, with 12 hours of light alternated with 12 hours of dark. Germinated seeds were counted and removed daily. The filter paper was kept moist with additional amounts (3 ml) of the specific saline solution used in each case. Additional saline solutions were added to all petri dishes on days five and eleven. No further germinations were recorded after day 13 and the treatments were terminated after 16 days.

4.4

Results

The germination response of each of the selected species with increased salinity is illustrated in Figures 4.7 to 4.16. Both *Aristida diffusa* (Figure 4.7) and *Tragus koelerioides* (Figure 4.8) germinated best at the 30 mg/l NaCl treatment, while germination percent decreased with further increases in salinity. High salinity levels also caused a delay in germination response, meaning that at higher salinity levels germination was not only reduced but also took longer. *Eragrostis obtusa* (Figure 4.9) and *Pharnaceum verrucosum* (Figure 4.10) both recorded low germination percentages (all below 10% in all five treatments) with no observable trends exhibited at the various salinity levels. The germination of *Drosanthemum* sp. (Figure 4.11) increased with increased salinity up to a NaCl concentration of 1000 mg/l. At 2000 mg/l NaCl germination of *Drosanthemum* sp. was at its lowest.

Increased salinity has no noticeable effect on the time taken for *Drosanthemum* sp. seeds to germinate. Referring to Figure 4.12, the germination percentage of *Felicia ovata* is not adversely affected by increased salinity. The highest germination percentages are recorded at NaCl concentrations of 500 and 2000 mg/l. The time taken to germinate is also not delayed by increased salinity. The germination of *Rosenia humilis* appears not to be affected by changes in salinity (Figure 4.13). The difference between the highest and lowest germination percentage recorded is only 10% and there are no discernable trends in germination percentage with increased salinity.

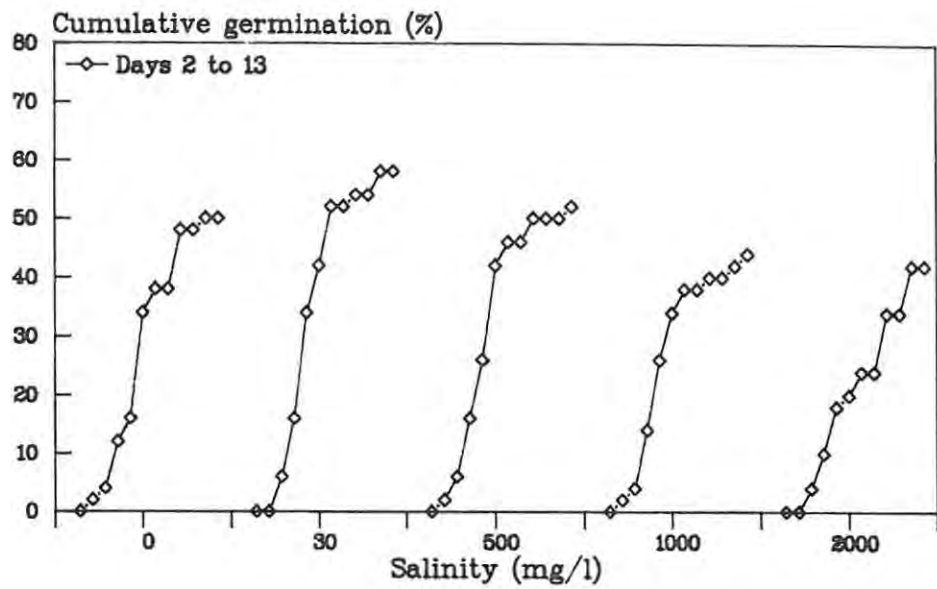


Figure 4.7: Germination response of *Aristida diffusa* with time at different salinities

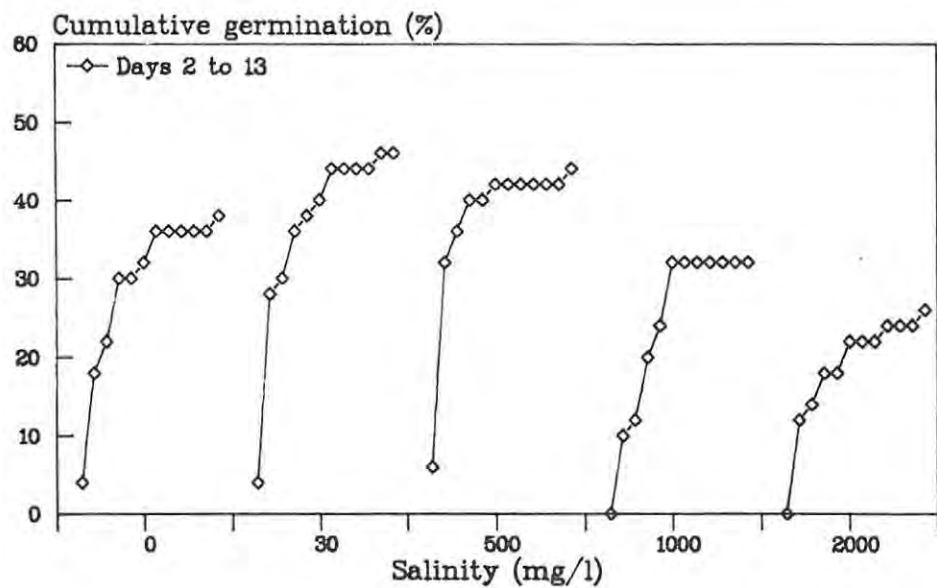


Figure 4.8: Germination response of *Tragus koelerioides* with time at different salinities

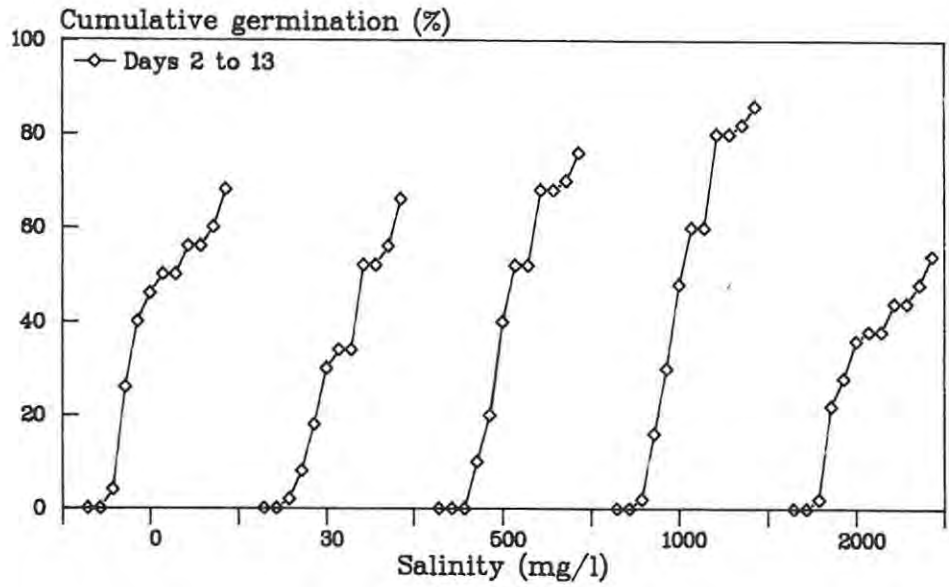


Figure 4.11: Germination response of *Drosanthemum* sp. with time at different salinities

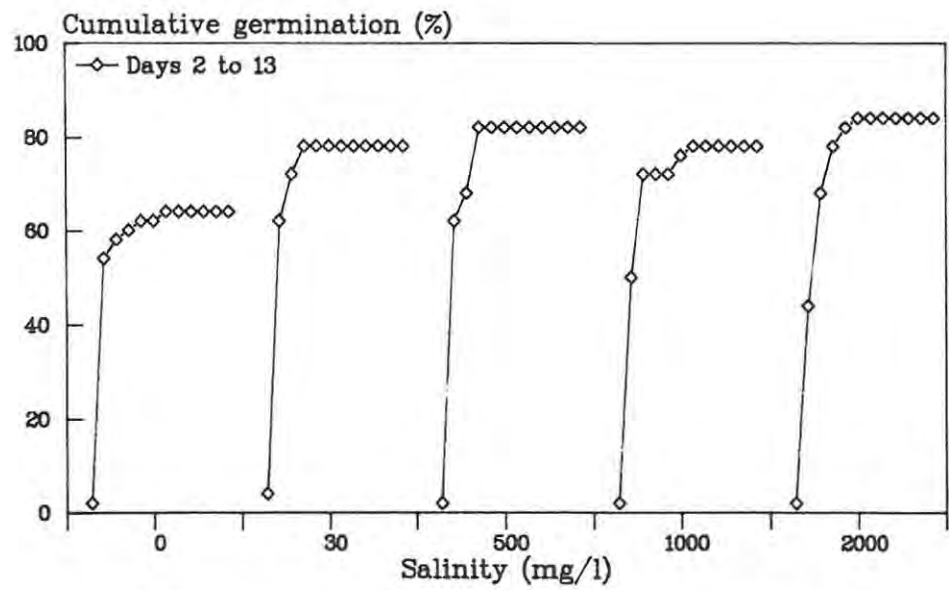


Figure 4.12: Germination response of *Felicia ovata* with time at different salinities

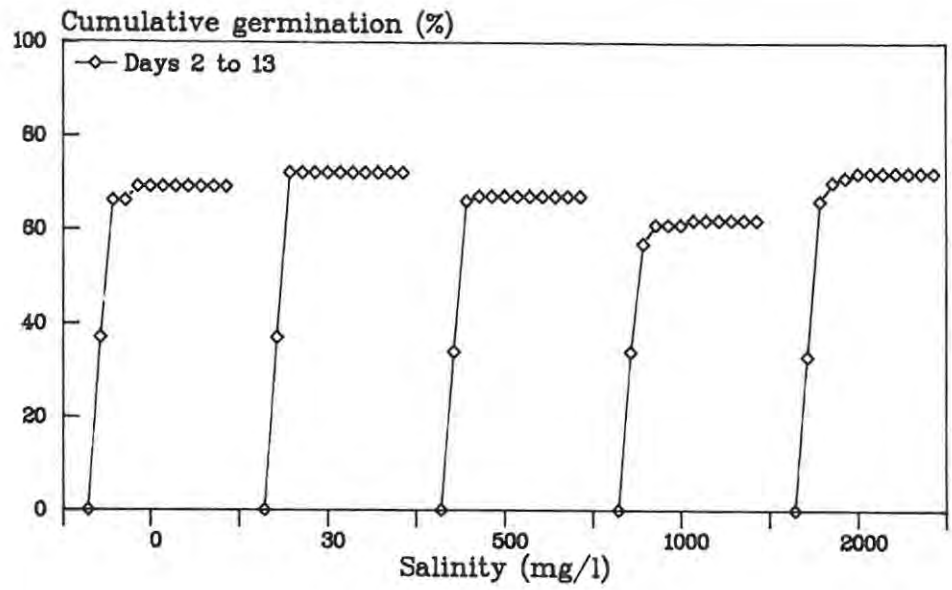


Figure 4.13: Germination response of *Rosenia humilis* with time at different salinities

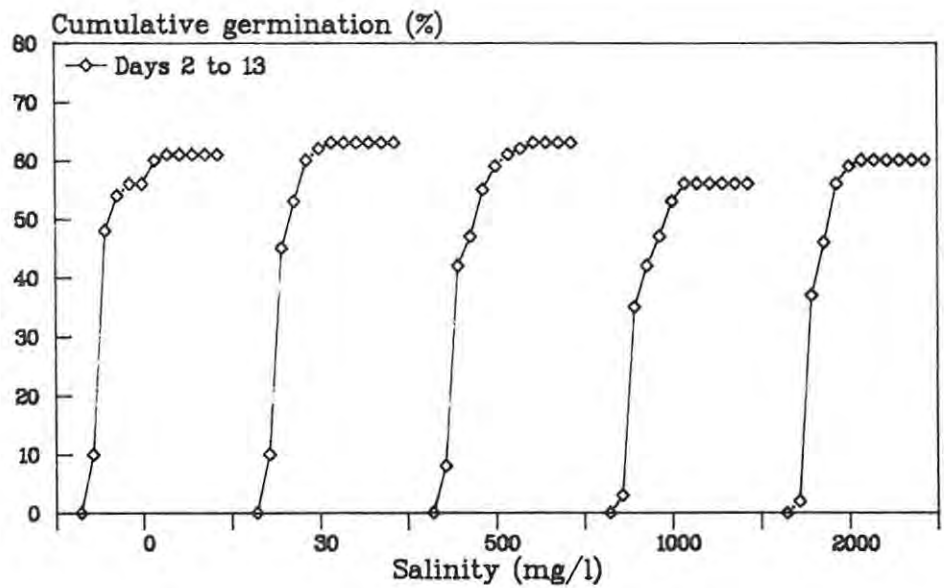


Figure 4.14: Germination response of *Pentzia incana* with time at different salinities

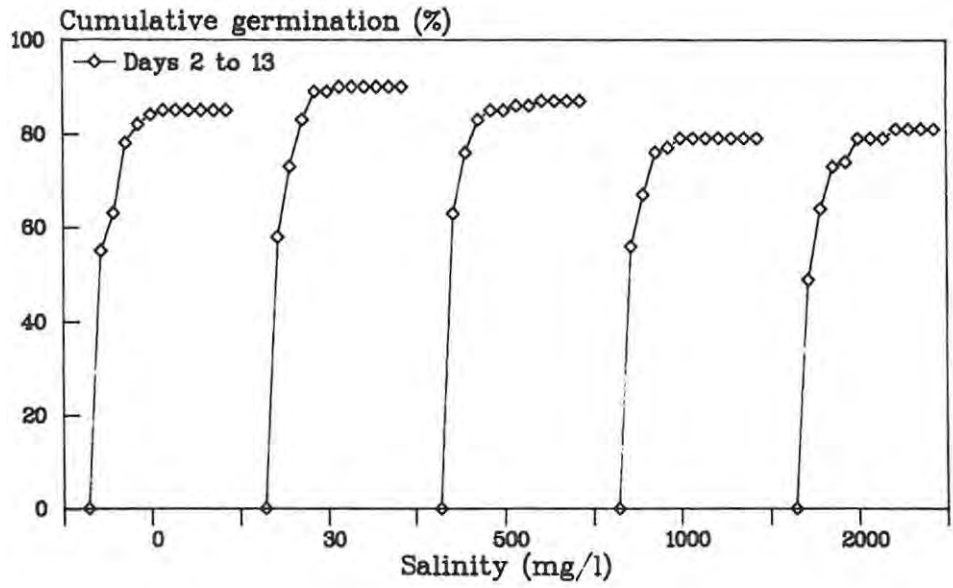


Figure 4.15:

Germination response of *Pentzia sphaerocephala* with time at different salinities

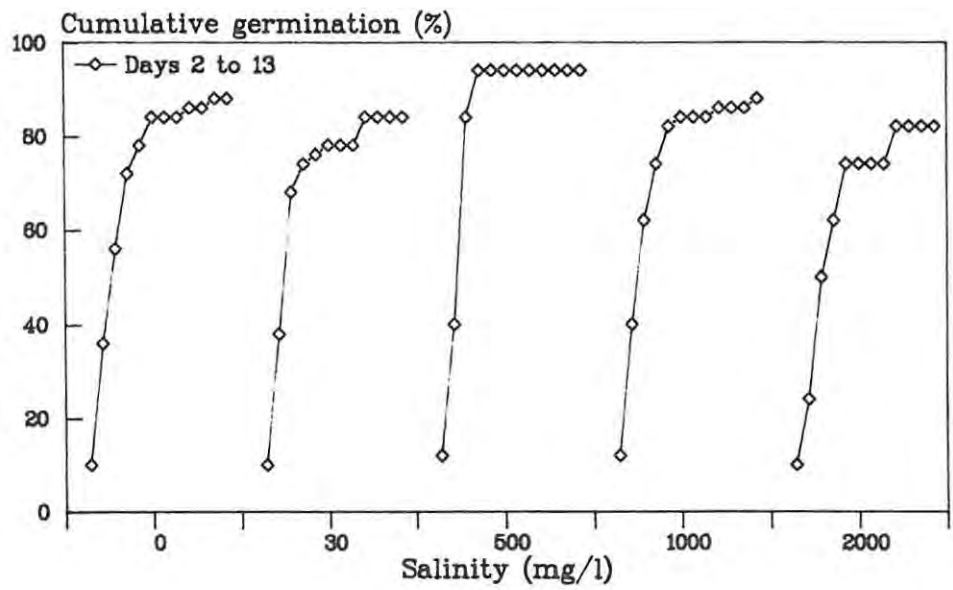


Figure 4.16:

Germination response of *Atriplex nummularia* with time at different salinities (The testa was removed from the seeds)

The germination of both *Pentzia incana* (Figure 4.14) and *Pentzia sphaerocephala* (Figure 4.15) was minimally effected by increased salinity. The only observable trend is that germination is slightly lower with increased salinity for the first two days in the case of *Pentzia incana* and the first six days in the case of *P. sphaerocephala*. The germination of *Atriplex nummularia* (Figure 4.16) is greater at intermediate salinity levels of 500 mg/l NaCl and is less at both lower and higher salinity treatments. Table 4.3 summarizes the results of the germination response of each species studied at each of the five salinity treatments.

Table 4.3: Summary of the germination response of selected karroid species with increased salinity.

Species	Germination response with increased salinity	Concentrations of NaCl at which extremes of germination response occurred	
		Highest germination	Lowest germination
<u><i>Aristida diffusa</i></u>	reduced by 10%	30 mg/l	2000 mg/l
<u><i>Tragus koelerioides</i></u>	reduced by 20%	30 mg/l	2000 mg/l
<u><i>Eragrostis obtusa</i></u>	no noticeable effect	30 mg/l	500-1000 mg/l
<u><i>Pharnaceum verrucosum</i></u>	no noticeable effect	distilled water	500 mg/l
<u><i>Drosantheum</i> sp.</u>	increased up to 1000 mg/l NaCl	1000 mg/l	2000 mg/l
<u><i>Felicia ovata</i></u>	no marked effect	500-2000 mg/l	dist. water
<u><i>Rosenia humilis</i></u>	no noticeable effect	30 mg/l	1000 mg/l
<u><i>Pentzia incana</i></u>	no noticeable effect	30 mg/l	1000 mg/l
<u><i>P. sphaerocephala</i></u>	no noticeable effect	30 mg/l	1000 mg/l
<u><i>Atriplex nummularia</i></u>	slightly higher at intermediate salinity	500 mg/l	2000 mg/l

4.5 Discussion and Conclusions

As expected the germination of different species was differentially affected at the various sodium chloride concentrations. Of the nine selected karroid species the germination of six were not affected in any noticeable way, two were reduced while one species actually recorded a higher germination percentage with increased salinity (Table 4.3). The germination of *Eragrostis obtusa*, *Pharnaceum verrucosum*, *Felicia ovata*, *Rosenia humilis*, *Pentzia incana* and *P. sphaerocephala* was not noticeably

affected. While the germination of *Aristida diffusa* and *Tragus koelerioides* was reduced and the germination of *Drosanthemum* sp. stimulated with increased salinity. In general the highest germination percentages were recorded at a sodium chloride concentration of 30mg/l and the lowest percentages at concentrations of 1000 and 2000 mg/l NaCl. The germination of *Atriplex nummularia* was highest at 500 mg/l NaCl although reduction in germination percentage was not more than 20 percent. Germination was however slower at higher salinities with 80 percent germination occurring after 4 days at 500 mg/l NaCl as compared to 10 days at 2000 mg/l NaCl. The testa was removed from the *Atriplex nummularia* seeds used which, due to the relatively limited effect of increased salinity on germination, lends support to the role of the testa in seed germination.

Germination is but one factor which determines the final composition of a plant community. Other important factors include establishment, recruitment, competition, microhabitat heterogeneity and grazing. Germination is however a critical process in the plant life cycle which if reduced, delayed or prevented will certainly change the structure of the plant community. This study is obviously limited in that germination tests at different salinity concentrations were conducted using only nine species. Other limitations are that germination tests should be conducted through a range of temperatures and a variety of light and dark regimes as the germination cues for some species are complex (Henrici 1935, 1939). On the basis of the results of these experiments it is suggested that presence of saltbush plants is only favourable for the germination of a few karroid species. High concentrations of salinity only has a negligible affect on the germination of the majority of the species tested. The germination of some species is however detrimentally affected by increased concentrations of salinity and so will be detrimentally affected by the presence of saltbush. Further research is required to determine the effect of saltbush on the germination of specific key species in the natural plant community.

CHAPTER 5

Atriplex nummularia AND INDIGENOUS PLANT COMMUNITY INTERACTIONS

5.1 Introduction

Research relating to patterning of plants in semi-arid and arid environments is widespread in the literature (Greig-Smith, 1961; Beals, 1968; Anderson *et al.*, 1969; Anderson, 1971; Gulmon and Mooney, 1977). Plant patterning in association with various *Atriplex* species has also had its share of attention (Anderson, 1967, 1970; Malik and Anderson, 1971). Most of this work is however aimed at understanding the natural vectors and processes controlling the spacing and clumping of indigenous plants in these extreme environments. The soil associated with *Atriplex nummularia* plants in the karoo was found to have increased concentrations of sodium (Na), chloride (Cl) and potassium (K) (Chapter 3). The germination experiments conducted in Chapter 4 on selected indigenous plants revealed that the germination of some species is detrimentally effected while others are not effected by increased salinity concentrations. As mentioned in Chapter 3, El-Ghonemy *et al.* (1980) found a significant difference among plant groupings with respect to absolute and relative amounts of soil Na and K in the northern Mojave desert, U.S.A. This study assesses the impact, after a period of 40 years, of *Atriplex nummularia* on the indigenous perennial dwarf shrubs of a site in the karoo (Site 2). The focus is not specifically to elucidate causal factors of any change in the natural plant community but to note what changes there have been.

Saltbush plants have the potential to exert either a beneficial or adverse effect on the smaller dwarf shrubs of the karoo. On the one hand the amelioration of the microclimate within the immediate vicinity of saltbush individuals causes temperatures to be less extreme (Chapter 2) which possibly means that saltbush plants are good nurse plants. On the other hand, increases in soil salinity (Chapter 3) and root competition for moisture and nutrients around saltbush individuals could have an adverse effect on indigenous perennial dwarf shrubs. Osmond *et al.* (1980, p. 400), based on experiments using culture solutions of NaCl found that "The growth of non-halophytes is inhibited by all concentrations of NaCl and the inhibition of growth is greater in dry than humid atmospheres". A further factor which may influence the indigenous species occurring in a saltbush plantation is livestock, both directly by grazing and indirectly by trampling, soil compaction, hoof chipping and urination (Wilson, 1966b).

The specific changes in the indigenous plant community considered are species richness and plant density. Of particular interest is to observe which species are affected most as species composition and plant density influence the carrying capacity of the natural pasture. The plant community occurring within a 40 year old saltbush plantation (sample) is compared with the community of the adjacent karoo dwarf shrubland (control). The sample and control areas constituted one continuous plant community on a near level karoo plain before the saltbush plantation was established and so were considered to have been identical before the establishment of the saltbush plantation.

5.2 Key Questions

The specific key questions examined with respect to saltbush plantations and interaction with the indigenous plant community are listed in Table 5.1.

Table 5.1 Summary of key questions considered in looking at *Atriplex nummularia* and the indigenous plant community interactions.

- a) Do *Atriplex nummularia* plantations change the density of indigenous dwarf shrub species?
- b) Do *Atriplex nummularia* plantations change the species diversity of perennial indigenous dwarf shrubs?
- c) Which indigenous shrub species are affected by the establishment of an *Atriplex nummularia* plantation?

5.3 Methodology

The oldest saltbush plantation of 40 years (Site 2) was selected as the best site to compare the indigenous plant community found within the saltbush plantation with that of the adjacent karoo dwarf shrubland. This site has been influenced the longest by the impact of oldman saltbush, allowing changes in the plant community, if any, to be apparent. As the purpose of this aspect of the study was to identify any long term changes in the plant community associated with a saltbush plantation, it was decided that only indigenous perennial dwarf shrubs would be recorded. The percentage cover of *Cynodon dactylon* per square meter was also recorded as this sward-forming perennial, rhizotomous and stoloniferous grass plays an important role in binding the soil and

providing grazing in areas that suffer from overstocking (Gibbs Russell, *et al.*, 1990). Many of the dwarf shrubs are thought to be long lived (although little work has been done to determine their lifespans) and hence represent one of the major dominants of the vegetation. The dwarf shrubs, due to their longevity and drought resistant characteristics, are dominant in determining microclimatic and microhabitat characteristics and are concentrated on in this study. Grasses, annuals and geophytes were not recorded for the following reasons. Due to the lack of rain, the grass and annual components of the vegetation were limited for the duration of the study. Distinguishing between dead and living grass tufts was too unreliable. To study the impact of saltbush on the grass and annual components would require consideration of both spatial and temporal changes (including various amounts of rain at different times of the year). Geophytes were omitted as locating them during dry/dormant periods is difficult, they are nevertheless important and would need to be considered in future studies. The saltbush plantation was considered as the sample area while the adjacent karoo dwarf shrubland as the control area.

Using an eight meter wide swath in the control area working in a southerly direction, contiguous one meter by one meter quadrats were sampled to build up a consecutively larger sampling area. The different species and their abundance in each quadrat were recorded as well as the percentage cover of *Cynodon dactylon* using the Domin scale. The Domin scale was used to avoid the problem of over estimation (Wratten and Fry, 1980). Species-area curves were constructed for the dwarf shrubs in the field as sampling progressed, in order to determine when the sample area had become optimal. This procedure was employed for both the sample and control areas and it was decided that a sample area of 160 m² (i.e. 8 x 20 m) was large enough in each case (Figure 5.1). The sample areas were standardized at the same size to facilitate comparison. Plant specimens were collected, pressed and identified at the herbaria of the Albany Museum, Rhodes University and Grootfontein College of Agriculture. Some specimens, which were difficult to identify with certainty, were sent to the Botanical Research Institute, Pretoria (PRE), for positive identification. Two unidentifiable species were encountered and the voucher samples have been sent to Hamburg by PRE. These two species have been provisionally classified as representatives of the genera; *Delosperma* (collectors No., 302) and *Drosanthemum* (collectors No., 304).

The whole data set was initially summarized for the sample and control areas in the form of the number of species found, the density of shrubs (number per square meter) and the mean number of species per square meter. Frequency histograms were constructed using the number of species per square meter as classes and the number of occurrences as frequencies for the sample and control areas. In order to highlight changes in the abundance of individual species the abundance of each species in the control and sample areas was compared. By subtracting the abundance of each species occurring in the saltbush (sample) area from that occurring in the adjacent karoo

shrubland, changes in the abundance of each species were highlighted. Species with a negative value had thus decreased in the saltbush plantation while any species with a positive value had increased. It must be remembered that the purpose of doing this is merely to highlight major changes in abundances of individual species and minor differences should be ignored.

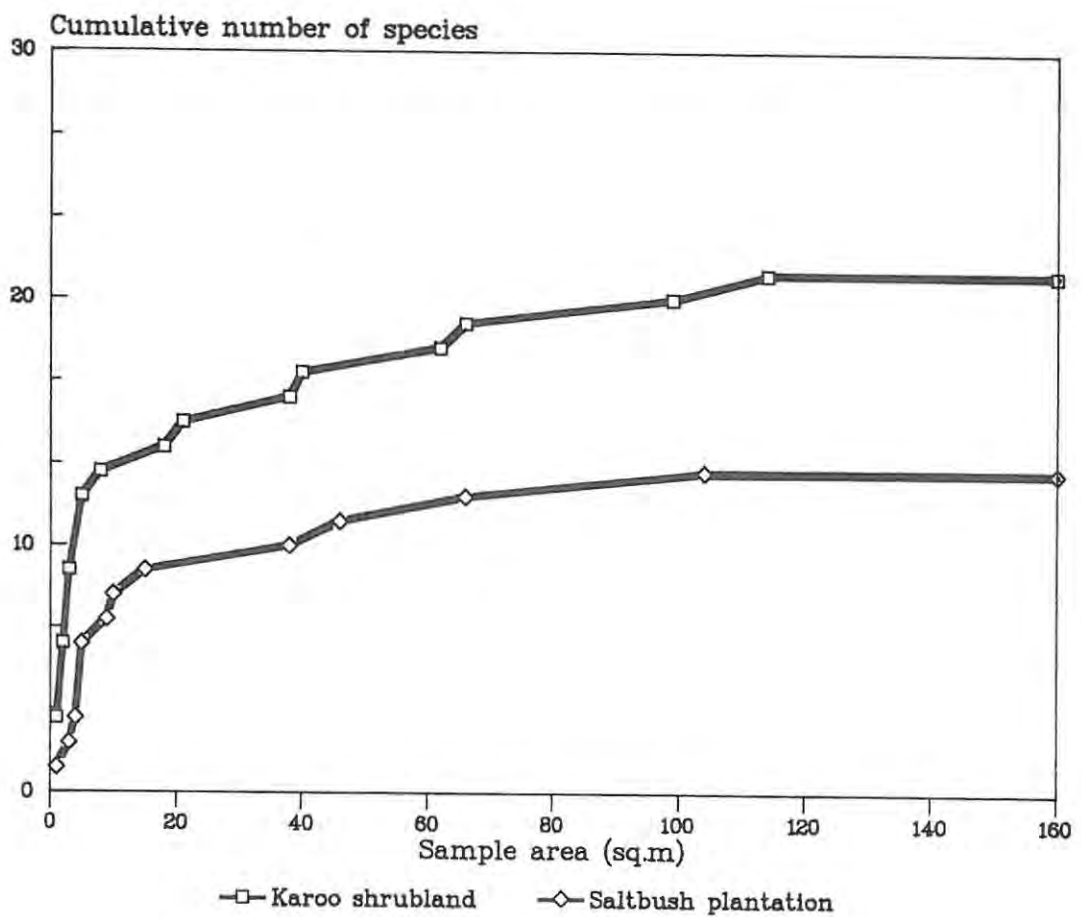


Figure 5.1: Species area curves of the indigenous shrubs for the sample and control areas at Site 2, Wellwood

Species diversity was examined in a more traditional manner using Simpson's diversity index (D) and equitability index (E). This index and its associated equitability takes into account not only the number of species but also their relative abundance. The Shannon-Wiener formulae for diversity

and equitability could not be applied in this situation as the samples were contiguous (Pielou, 1966) and fully censused (Pielou, 1974). The complexity of each community is also presented by means of a rank abundance diagram. Lastly, the spatial distribution of the density of *Cynodon dactylon* and those dwarf shrub species which had a difference in abundance (between sample and control areas) of more than 25 individuals are presented in a series of three dimensional profile diagrams for both sample and control areas. The cut off level of 25 individuals was chosen once the data had been collected and includes the species which were most different.

5.4 Results

Referring back to Figure 5.1, the karoo dwarf shrubland (control) clearly has a greater diversity of shrubs than the saltbush plantation (sample area). A total of 21 indigenous perennial dwarf shrub species were recorded in the karoo shrubland while only 13 were recorded in the saltbush plantation. The density of all indigenous dwarf shrub species and individuals of the sample and control areas is presented on Table 5.2.

Table 5.2 Summary of the plant community characteristics of the indigenous perennial dwarf shrubs in the saltbush plantation (sample) and those in the adjacent karoo dwarf shrubland (control).

	Karoo dwarf shrubland (Control)	Saltbush plantation (Sample)
No. of indigenous perennial dwarf shrub species	21	13
No. of individuals per square meter (Density)	9,98	6,27
Mean No. of species per square meter	3,85	2,49

The frequency distribution of the number of shrub species per square meter is illustrated in Figure 5.2. Although both the sample and control areas have the same modal class of 3 species per square meter and are positively skewed, the distribution within the classes (kurtosis) is noticeably different. The kurtosis value for the karoo (control) being -1,6 and the saltbush plantation (sample) -2,2. The class with the second highest frequency shows the major difference between the sample and control areas. The second highest frequency class for the sample area was two species per square meter while for the control areas it was four species. The saltbush plantation had less species of indigenous dwarf shrubs as well as there being a lower density of individual dwarf shrubs. This reduction in species and plant density has important implications which will be discussed later and be borne in mind in the presentation of management guidelines.

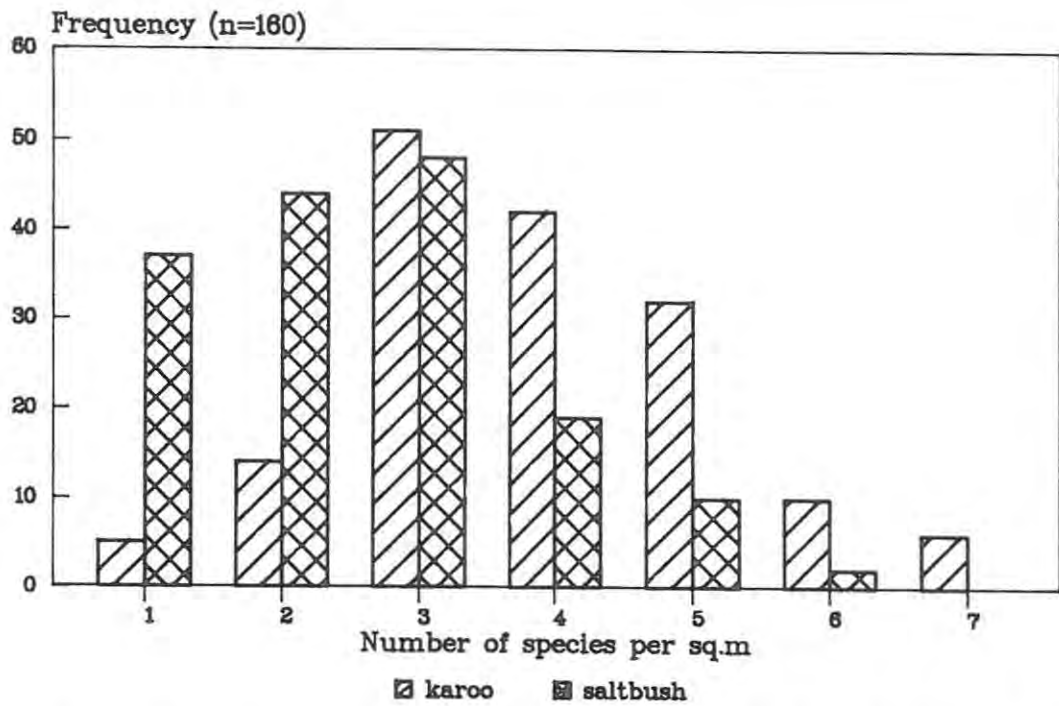


Figure 5.2 Frequency distribution of the number of shrub species per square meter for a 40 year old saltbush plantation and the adjacent karoo dwarf shrubland

Changes in the abundances of dwarf shrub species found in the saltbush plantation were identified by examining the absolute difference in the number of individuals of each species. Species with a negative difference have declined in absolute abundance while species with positive differences have increased in the saltbush plantation. The results of this comparison are presented in Figure 5.3. Species which are noticeably reduced in number in the saltbush plantation are (in order of magnitude) *Delosperma* sp., *Salsola glabrescens*, *Pentzia incana* and *Felicia ovata*. These four species all have a negative abundance difference (i.e. reduction) of more than 50 individuals in the 160 square meter sample area. Other species which are reduced in number in the saltbush plantation are *Argyrolobium pauciflorum* (-21 individuals), *Euryops anthemoides* (-20), *Limeum aethiopicum* (-16), *Trichodiadema setulifera* (-15) and *Hermannia cuneifolia* var. *cuneifolia* (-15).

Species which had an increased absolute abundance in the saltbush plantation were, in order of magnitude, *Atriplex nummularia* itself (40), *Felicia muricata* (25), *Drosanthemum lique* (14) and marginally *Rosenia humilis* (3). *Atriplex nummularia* is included for reference purposes. The density of 40 saltbush plants in 160 square meters corresponds to a planting density of 2 500 plants per hectare. This approximates the recommendations of the Department of Agriculture and Water Supply. Turning to the plant community as a complex unit and considering both the number of species and their proportional abundance, diversity indices were calculated for sample and control areas and are listed in Table 5.3.

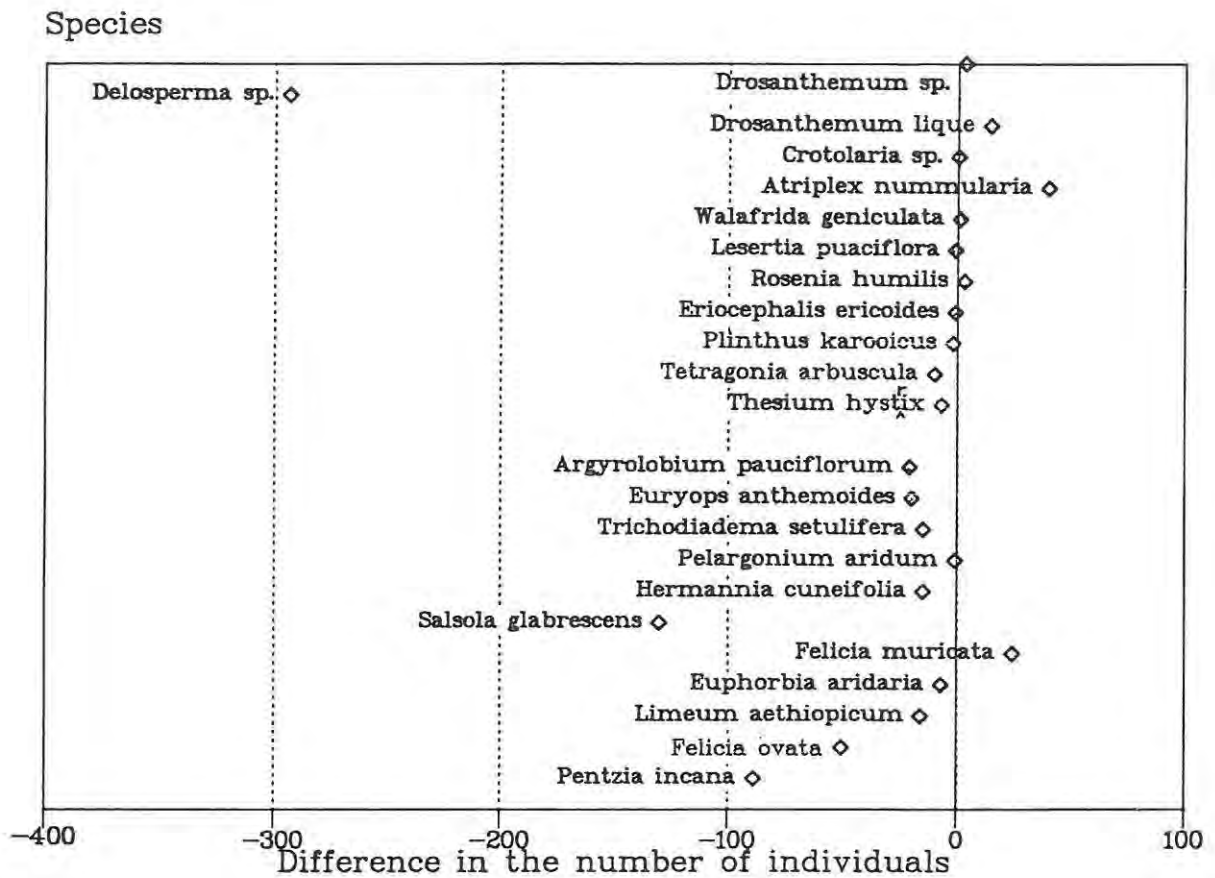


Figure 5.3 Absolute difference in the number of individuals of each shrub species, 40 years after the establishment. Sample and control areas are compared such that a negative value indicates a decrease in number of individuals for that species in the sample area

Table 5.3 Diversity indices for the perennial plant community of a 40 year old saltbush plantation (sample) and the adjacent karoo shrubland (control). Where S is the number of species and P_i is the proportion of total individuals in the ith species.

		SAMPLE	CONTROL
Number of species	S	21	13
Simpson's diversity index	$D = \frac{1}{\sum p_i^2}$	3,887	2,823
Equitability	$E = \frac{D}{S}$	0,185	0,235

Comparing the values obtained for both diversity indices the sample area has a higher value and a lower equitability value indicating that the sample area is less diverse and more equitable. The number of species does affect the values obtained for both the diversity indices and the equitability

values and so direct comparison is not strictly speaking correct. However, as the sample area is assumed to have been the same as the control area, comparison of the trends is in order. The rank-abundance diagram (Figure 5.4) provides a more accurate and complete picture of the distribution of species abundances in the two areas. The indigenous plant community of the saltbush plantation is dominated by a few common species, more so than in the adjacent karoo shrubland (Figure 5.4). Referring back to Figure 5.3 the common indigenous plants which have survived in the saltbush plantation are *Felicia muricata* and *Drosanthemum lique*. The karoo shrubland on the other hand while having some common dominants is markedly different in that there are numerous species which have low proportional abundances.

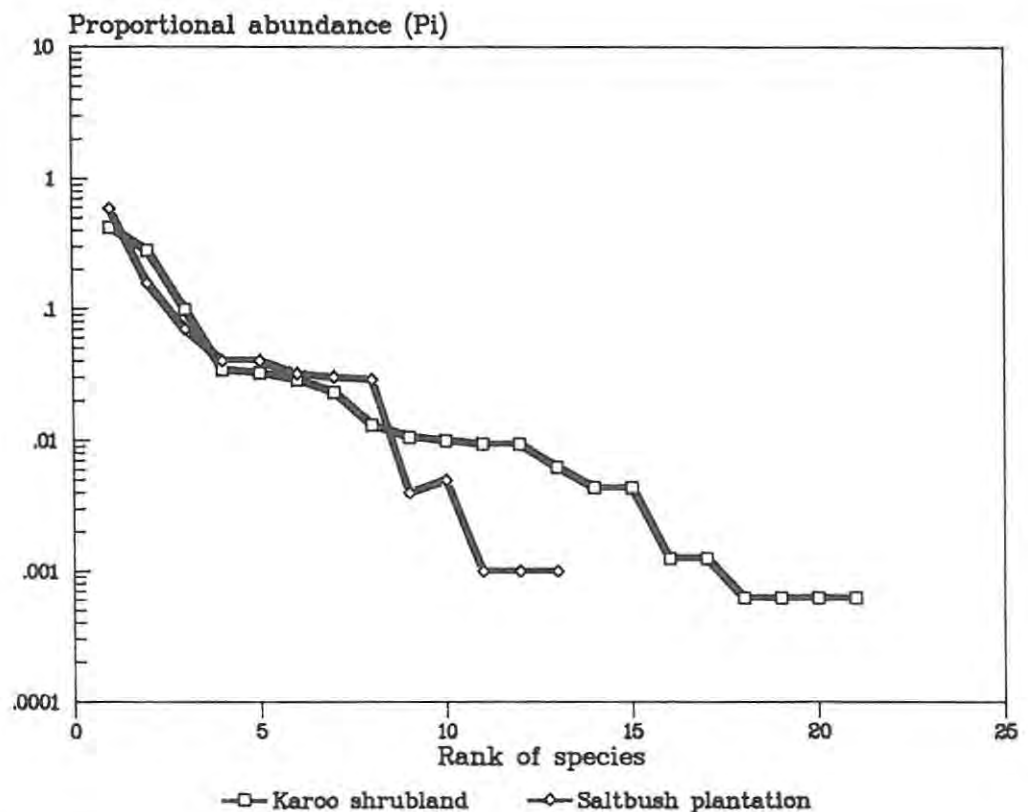


Figure 5.4 Rank abundance diagram of the indigenous shrub communities of the karoo shrubland (control) and saltbush plantation (sample)

Figures 5.5 to 5.10 illustrate the spatial distribution of *Cynodon dactylon* and those dwarf shrub species which had a difference in relative abundance of more than 25 individuals, in the order of the differences. In all cases the distribution of oldman saltbush in the sample area is presented together with the distribution of each species in the sample and control areas. All the profile diagrams are

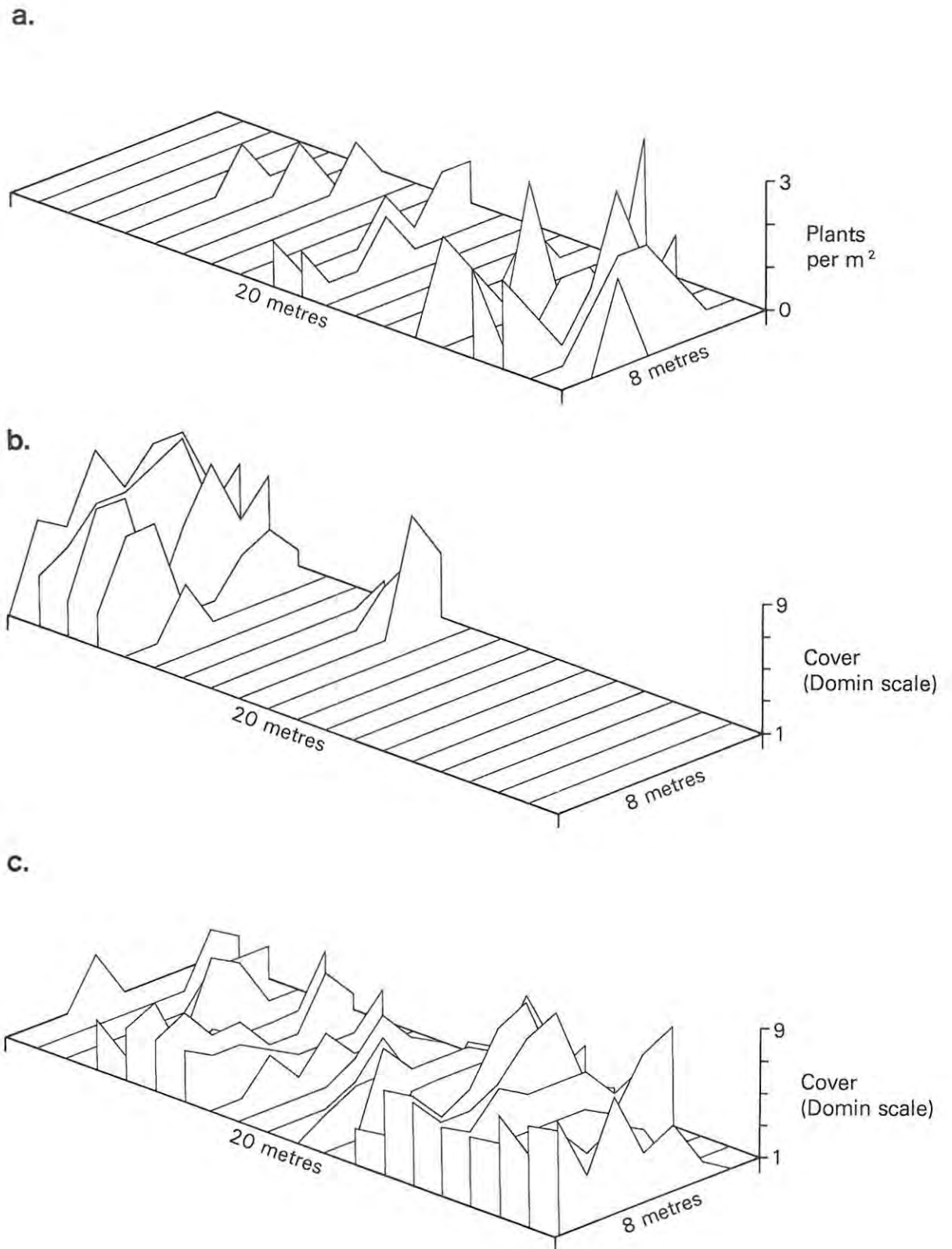


Figure 5.5: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Cynodon dactylon* in b) the sample area and c) control area. All the profile diagrams are viewed from the north east corner (ie looking south west).

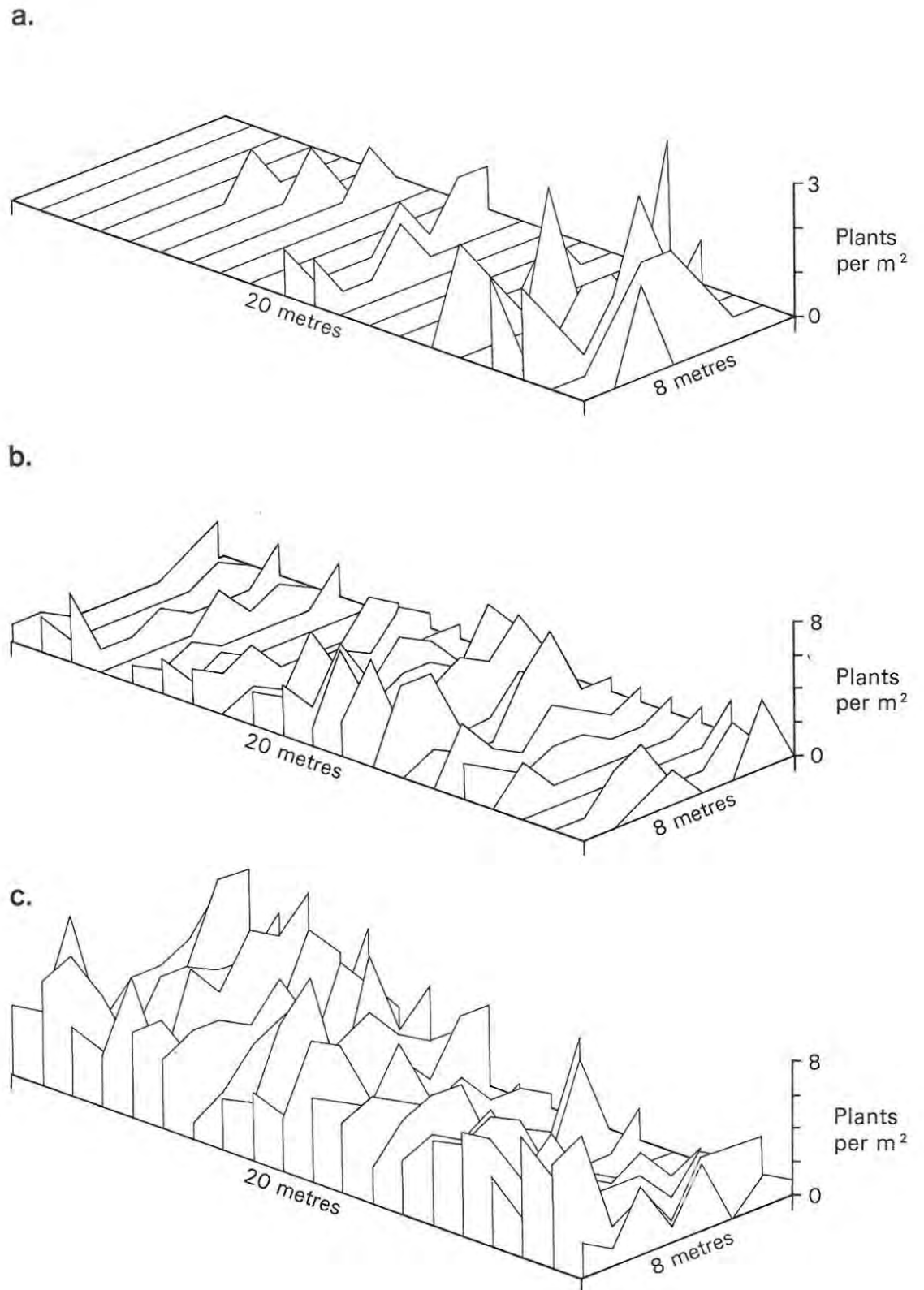
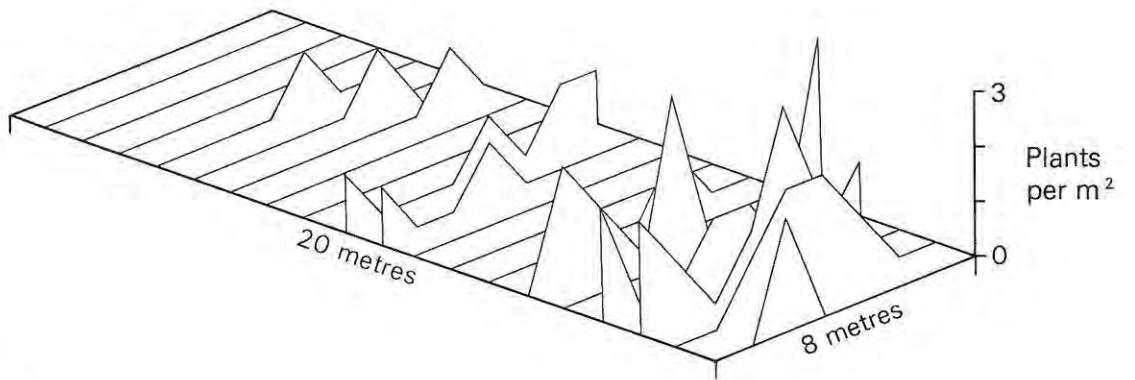
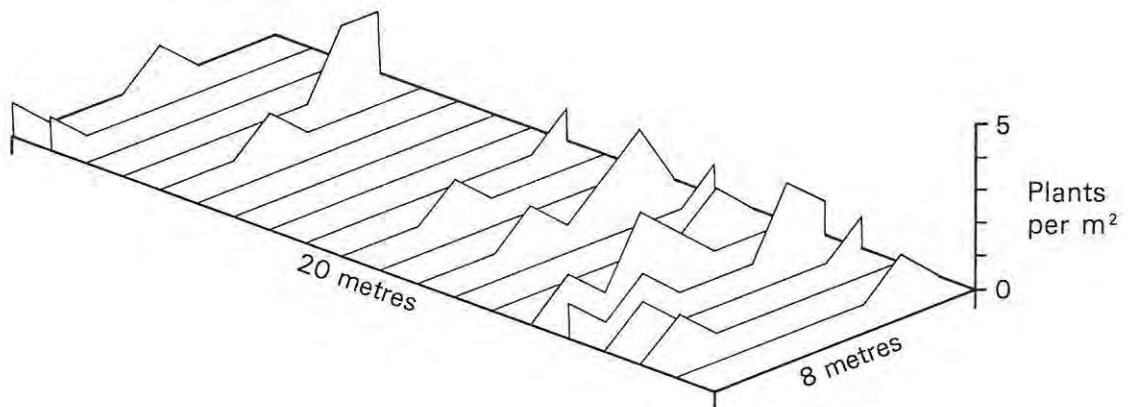


Figure 5.6: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Delosperma* sp. in b) the sample area and c) control area. All the profile diagrams are viewed from the north east corner (ie looking south west).

a.



b.



c.

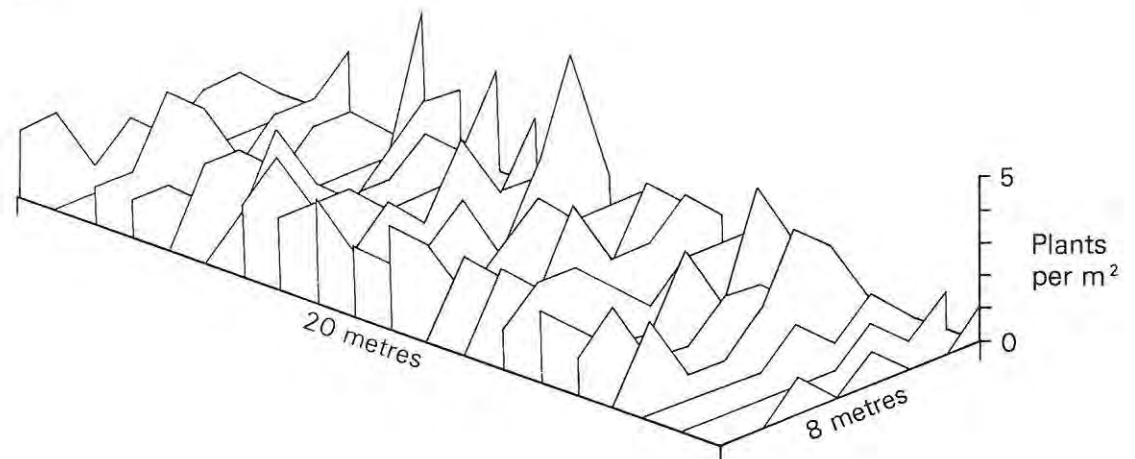


Figure 5.7: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Salsola glabrescens* in b) the sample area and c) control area. The profile diagrams are viewed from the north east corner (ie looking south west).

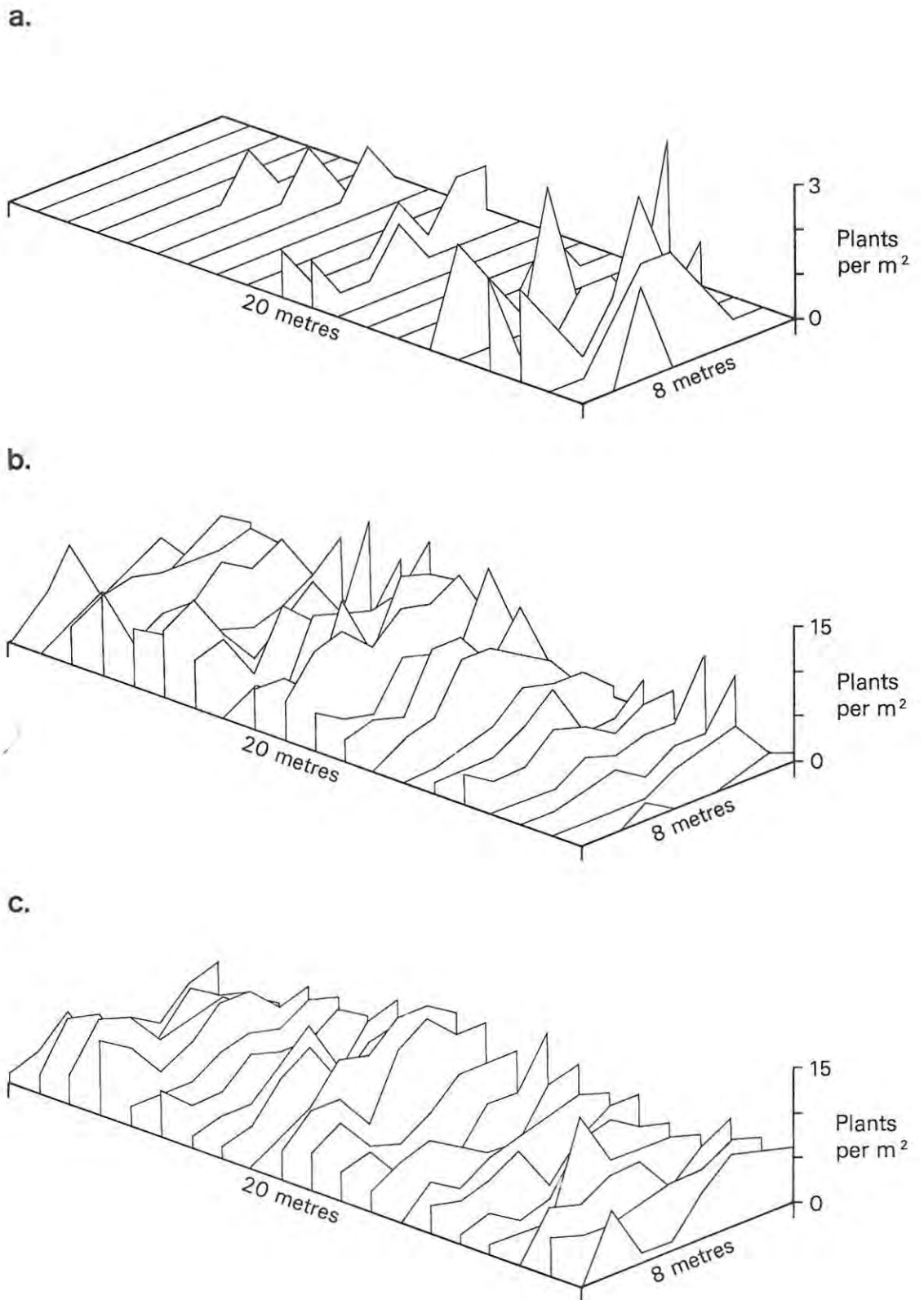


Figure 5.8: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Pentzia incana* in b) the sample area and c) control area. All the profile diagrams are viewed from the north east corner (ie looking south west).

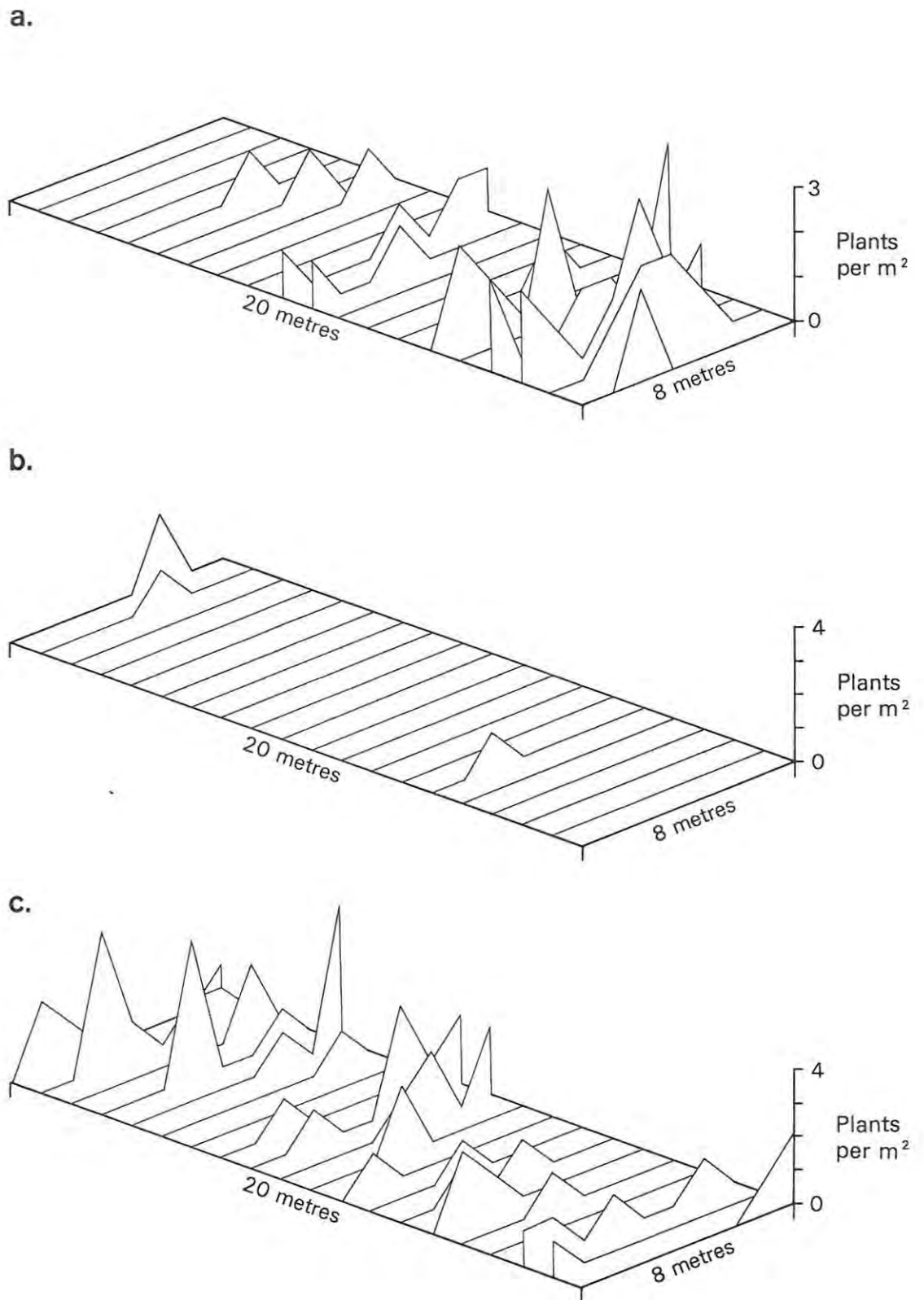
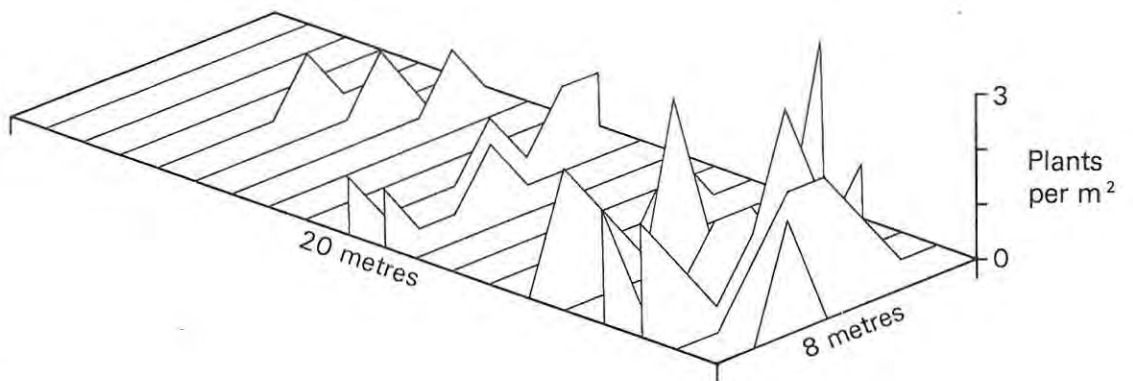
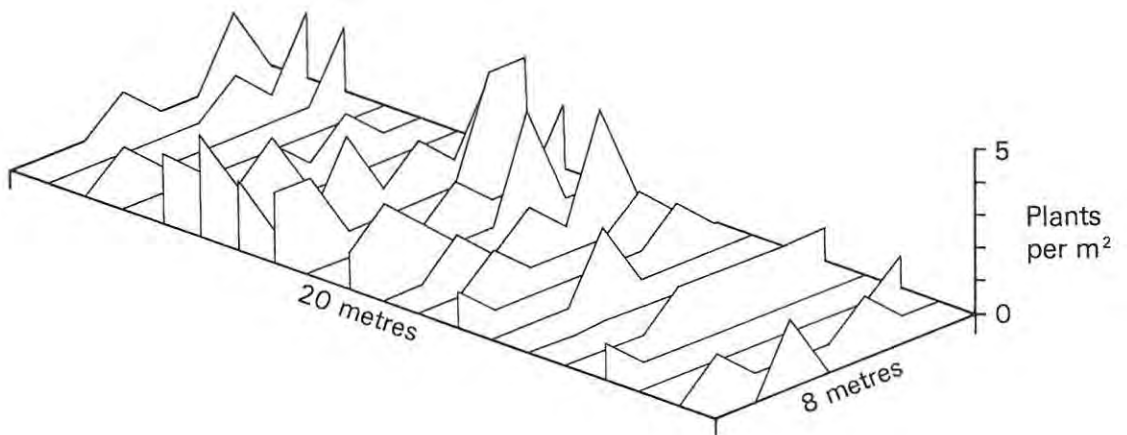


Figure 5.9: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Felicia ovata* in b) the sample area and c) control area. All the profile diagrams are viewed from the north east corner (ie looking south west).

a.



b.



c.

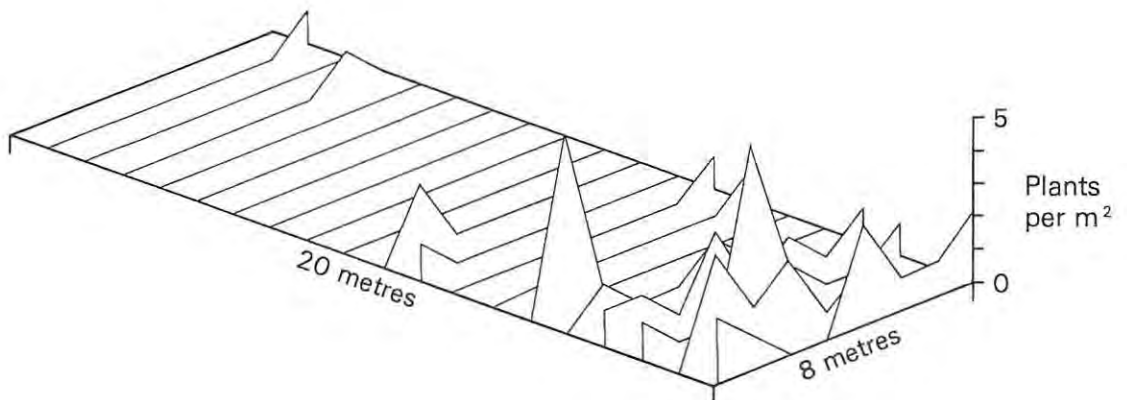


Figure 5.10: Spatial distribution of a) *Atriplex nummularia* in the sample area and *Felicia muricata* in b) the sample area and c) control area. All the profile diagrams are viewed from the north east corner (ie looking south west).

viewed from the north east corner (ie looking south west). Referring to Figure 5.5a, the highest density of saltbush individuals is in the northern end of the sample area with some individuals in the mid regions and no saltbush in the southern most parts of the plot. The distribution of *Cynodon dactylon* is the inverse of saltbush in the sample area (Figure 5.5b) while it is fairly evenly spread in the control area (adjacent karoo shrubland) (Figure 5.5c).

Delosperma sp. is the dwarf shrub species whose relative abundance is reduced the most in the saltbush plantation (sample area) as compared to the karoo shrubland (control area). While the density of *Delosperma* sp. is reduced its spatial distribution in the saltbush plantation (Figure 5.6b) is not clearly related to the distribution of saltbush (Figure 5.6a). *Delosperma* sp. is well distributed in the karoo shrubland plot (Figure 5.6c) with the north west corner having fewer plants per square meter. The density of *Salsola glabrescens* is reduced in the saltbush plantation and once again there is no visually clear relationship between the density of saltbush and the density of *S. glabrescens* in the sample area. *S. glabrescens* is evenly distributed and denser in the karoo shrubland (control area). *Pentzia incana* is evenly distributed in both the sample and control areas except for the northerly extreme of the sample area where the density of saltbush is greatest (Figure 5.8).

Felicia ovata, the only other dwarf shrub species to be decreased by more than 25 individuals in the saltbush plantation, is reasonably consistently distributed over the karoo shrubland plot (Figure 5.9c). Only four *F. ovata* individuals were found in the saltbush plantation (sample area) and these are predominantly found away from saltbush plants (Figure 5.9a and b). There were 25 more *Felicia muricata* in the saltbush plantation than in the karoo shrubland. *F. muricata* is densest in areas of intermediate saltbush density (Figure 5.10a and b). The distribution of *F. muricata* in the karoo shrubland (Figure 5.10c) is anomalous in that individuals are not evenly spread throughout the plot but are concentrated in the northerly end. This will be discussed in section 5.5 (Discussion and conclusions).

5.5 Discussion and conclusions

The direct comparison of indigenous shrub species found in a 40 year old saltbush plantation as compared to the adjacent karoo shrubland revealed that there are marked differences in the shrub component of the two plant communities. No attempt has been made to identify causal factors for these differences apart from relating spatial distributions with changes in abundance of saltbush, the focus being on whether or not there are differences and what those differences are. Soil salinity is however an obvious factor which could be important in determining changes in the plant community while other less obvious factors like the allelopathic effects of shrubs in *Atriplex* plant communities

suggested by Klubek and Skujins (1980) may also be important. More specifically, the 40 year old saltbush plantation had a reduced density of indigenous shrub species, approximately a third less (key question 5.1 (a)). The species richness in the saltbush plantation was reduced by as much as half that of the adjacent karoo shrubland (key question 5.1 (b)). Species most detrimentally affected by the presence of the saltbush plantation were *Delosperma* sp. (Collectors no. 302), *Salsola glabrescens*, *Pentzia incana* and *Felicia ovata*, while *Felicia muricata* and *Drosanthemum lique* increased in abundance (key question 5.1 (c)).

The percentage cover of *Cynodon dactylon* (Figure 5.5) at Site 1 is extremely reduced in the saltbush plantation, suggesting that either microclimatic conditions, soil salinity or some other factor associated with the presence of *Atriplex nummularia* is detrimental to the establishment and or growth of *C. dactylon*. Unfortunately, attempts at germinating *C. dactylon* seeds were unsuccessful (Chapter 4) and so the impact of salinity on germination could not be assessed. The abundance of both *Delosperma* sp. and *Salsola glabrescens* is reduced in the saltbush plantation (Figures 5.6 and 5.7 respectively). However, the spatial distribution of neither species in the saltbush plantation appears to relate to the distribution of saltbush individuals. The role of soil salinity as a causal factor could not be assessed for either species as germination tests were not conducted (no viable seeds were obtained).

The reduction in the abundance of *Pentzia incana* in the densely populated parts of the saltbush plot suggests that *P. incana* is adversely affected by the presence of saltbush. This finding needs to be investigated in more depth as the sample area which is being referred to is only six meters wide and eight meters long and it is felt that a larger sample area than this is required for confirmation of this trend. Germination of *P. incana* seeds was not noticeably affected by high concentrations, up to 2000 mg/l, of NaCl (Chapter 4). The marked decrease in abundance of *Felicia ovata* in the saltbush plantation is also not attributable to the influence of increased soil salinity on germination (Chapter 4). *F. ovata* is a very readily grazed species which is usually found growing in the protection of other plants (Hobson *et al.*, 1970) which could partly account for its scarcity in the saltbush plantation, as the density of plants is on average 9,98 individuals per square meter in the karoo shrubland as opposed to 6,27 in the saltbush plantation (Table 5.2).

Felicia muricata increased in abundance in the saltbush plantation (Figure 5.10) especially in areas of intermediate saltbush density, which could possibly be due to this pioneer species (Roux and Theron, 1987) being able to grow in the less vegetated areas with higher soil salinities. The distribution of *F. muricata* in the northern end of the karoo shrubland plot suggests that this area is or has been disturbed in some way, although this trend is not shown by any of the other species whose spatial distribution was plotted.

Considering all the species investigated together, the dwarf shrubs found in the 40 year old saltbush plantation are impoverished, not only in terms of species diversity but also in terms of shrub density. Due to the decrease in density and diversity it is likely that the grazing potential of the shrubs in the saltbush plantation is less than that of the equivalent area without saltbush. In calculating the grazing capacity of saltbush plantations it follows that one must allow for a reduction in the fodder production from the natural pasture even if it is in a reasonable condition. Furthermore, areas which have a high species diversity and or good grazing potential should be avoided as potential sites for the establishment of saltbush plantations. The practice of planting saltbush in the natural pasture to increase normal forage production should not be undertaken as the findings of this study indicate that this will be detrimental to the natural pasture.

This study is limited in that the grasses, annuals and geophytes not considered could play a major role in providing grazing within saltbush plantations and the abundance and vigour of some of these species will also be influenced by changes in microclimate and soil salinity. The grasses and annuals are however unlikely to be valuable sources of fodder during extremely dry periods in the karoo. The indigenous plant community at only one site was examined and so it may be extremely dangerous to imply that the trends observed are indeed general ones. In other regions of the karoo, where the plant community and soils are different, saltbush plantations may cause dissimilar changes. This should be examined in order gain a comprehensive understanding of the impact of saltbush in the karoo. Studies of plant patterning within saltbush plantations could reveal causal factors explaining the distribution (King and Woodell, 1973; Olsvig-Whitaker *et al.*, 1983) and ecological preferences of indigenous species. Competition and spacing studies should also be considered (Yeaton and Cody, 1976; Yeaton *et al.*, 1977).

CHAPTER 6

THE PLANTING OF *Atriplex nummularia* AND FARM SIZE IN THE KAROO

6.1 Introduction

This chapter focuses on some of the socio-economic aspects of the planting of *Atriplex nummularia* (oldman saltbush) in the karoo. Oldman saltbush, a shrub which is both highly productive and drought resistant, can be used in two principle ways in the extensive farming industry in the semi-arid and arid regions of southern Africa. Saltbush can be used either as a drought reserve or as a supplement to the natural pasture. Using saltbush as a drought reserve allows farmers to maintain stock numbers during dry periods by using the accumulated reserves to make up feed requirements. The Department of Agriculture recommends that between 2 and 4% of a farm be established to some sort of drought reserve (Steynberg and de Kock, 1987). The second less common way of using saltbush is to plant large areas of natural pasture to saltbush and utilize the saltbush along with the natural pasture for regular grazing. The purpose of planting the saltbush is to increase the carrying capacity of the land by growing more natural fodder. In both cases, the amount of saltbush on the farm as a proportional area is important in determining the effectiveness of the practice.

This portion of the study focuses on the amount of saltbush already established on farms in the karoo and on how much saltbush farmers intend planting within the next five years. The size of each farm is seen as being an important factor due to the adverse economic climate that has faced karoo farmers in recent years. Daniel (1975) found that farm size was strongly related to income in the Cape Midlands and Karoo regions. Economic pressures may be a potential factor causing farmers on smaller farms (and presumably less productive ones on average) in the karoo to look for alternate means of maintaining productivity, like planting saltbush. It is expected that farmers on smaller farms may have established, or intend establishing, a greater proportion of their farms to saltbush. Farmers on larger farms on the other hand are assumed to be under less economic pressure and hence to have planted less saltbush. Of course, planting drought reserves is only one way in which farmers can respond to economic pressures, while economic pressures *per se* may not be the primary factor responsible for prompting farmers to plant drought resistant shrubs. However, it is potentially useful to know whether farms of differing size have disparate proportional areas of saltbush. This type of knowledge is important for extension activities and for agricultural policy-making.

6.2 Key questions

Table 6.1 summarizes the key questions for this portion of the study. The key questions set out are important in that, if saltbush has a long-term detrimental effect on the karoo vegetation, some idea of the magnitude of the impact can be gained. While if saltbush is seen as a favourable agricultural option in the karoo then in the policy-making for the control of the use of saltbush it will be important to know which farmers are using saltbush already and which farmers intend using more saltbush.

Table 6.1: Summary of key questions.

- | | |
|-------|--|
| (i) | What is the mean area of saltbush established on farms in the karoo? |
| (ii) | What is the mean area karoo farmers intend planting to oldman saltbush in the next five years? |
| (iii) | What is the extent of spatial variation of the amount of saltbush established and the amount farmers intend establishing in each of the four regions of the karoo? |
| (iv) | Do smaller farms have a greater proportional area planted to oldman saltbush than larger farms? |
| (v) | Do farmers on smaller farms intend establishing a greater proportion of their farms to saltbush within the next five years than farmers on larger farms? |

6.3 Methodology

The data used in assessing the key questions in this chapter was provided by the Department of Agriculture and Water Supply, Karoo Region. The data was collected by a questionnaire survey conducted in 1984 by the Department, involving some 1200 questionnaires in the karoo and a percentage return of 32% (i.e. 384 questionnaires were returned). A copy of the questionnaire is included in Appendix A. Only the responses for question seven (farm size) and question eight (area planted and intended area planted to saltbush in the next five years) were supplied. Both questions seven and eight used categories to determine the quantity of each parameter.

Farms were grouped into eight categories based on size namely, 0-100 ha; 101-500 ha; 501-1000 ha;

1001-2000 ha; 2001-3000 ha; 3001-5000 ha; 5001-10 000 ha and >10 000 ha. The existing and proposed areas established to saltbush was specified using ten categories namely 0-1 ha; 2-5 ha; 6-10 ha; 11-20 ha; 21-30 ha; 31-50 ha; 51-100 ha; 101-200 ha; 201-500 ha and >500 ha. In all cases the interval of the categories was not equal. The first of the ten categories in question is 0-1 ha meaning that it is impossible to distinguish farms with no saltbush from those with up to 1 ha of saltbush. These two points and the nominal scale of the data are major restrictions to the analysis of the data and should be borne in mind. Using the original categories, relative frequency histograms were constructed for farm size, area of saltbush established and intended area to be established within five years for the entire data set and for each of the four sub-regions.

Various attempts were made to assess if the differences between farm size, the area established, and intended area of saltbush established were due to chance. Chi-square tests using eight by ten and ten by ten contingency tables were attempted, however, this was not valid due to the low number of occurrences in too many of the cells of the contingency tables (Siegel, 1956). Classes were combined successively and final Chi-square analyses were conducted with two by three and three by three contingency tables. Further data analysis was conducted using a qualitative approach in order to identify general trends. General trends were identified by means of the line of best fit. In this way using the raw data, farm size can be compared with either area of established saltbush or intended area to establish to saltbush. Plotting the scatter of the points was not done, as both the axes were for nominal data, making it impossible to distinguish one occurrence from many occurrences. The slope of the line of best fit indicates the general relationship between the variables. Qualitative comparison of trends is also possible.

Lastly, the midpoint of each class was used to determine the area of saltbush and the intended area as a proportion of the farm size. The results of proportional areas are also presented as lines of best fit. No further analysis was conducted as it was felt that the data, due to it being at the nominal scale of measurement and due to the split of the categories, was not robust enough.

6.4 Results

The frequency distribution of farm sizes for the Karoo region, as sampled by the questionnaire survey, is negatively skewed (Figure 6.1). The modal farm size class is 5001 - 10 000 ha and 57,2% of the farms are between 3000 and 10 000 ha. There are a few farms which are less than 1000 ha

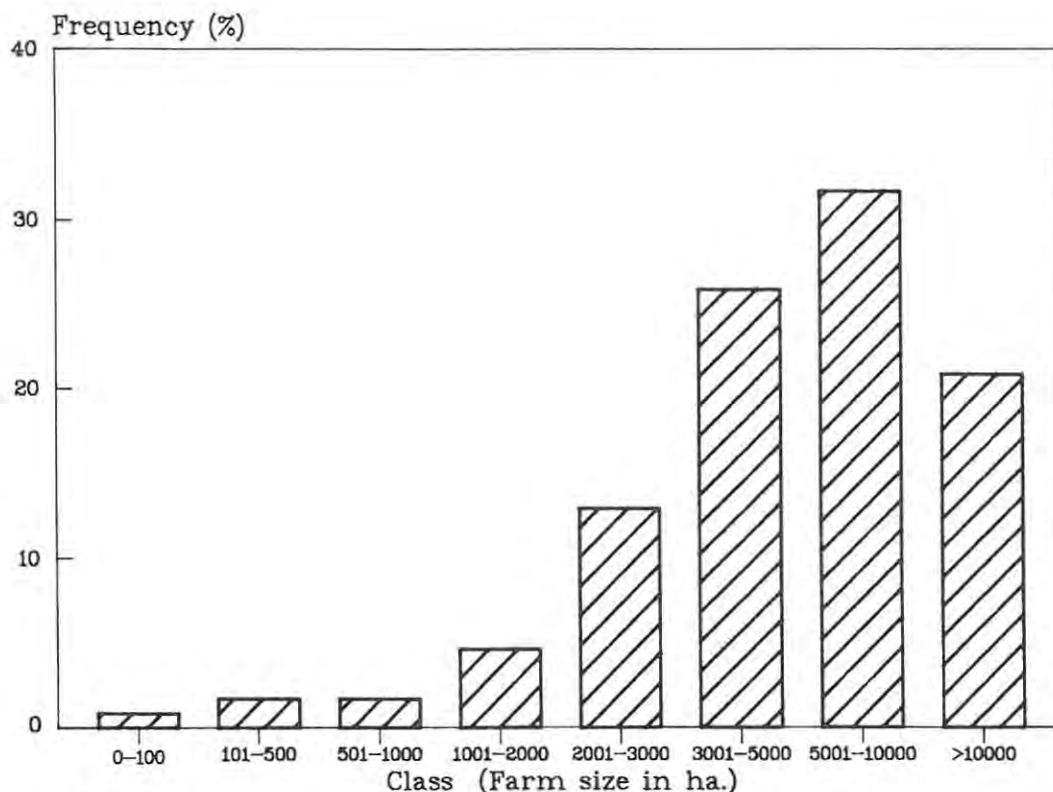


Figure 6.1: Farm size distribution for the whole Karoo region

while 21% of the farms are over 10 000 ha. The amount of saltbush already established in the Karoo region (key question (i)) is negligible as most farms (51%) have between 0 and 1 ha (Figure 6.2). Many farms (35%) have between 2 and 5 ha of saltbush established meaning that 85% of the farms have less than 5 ha of saltbush established (key question (i)). As a proportion of the farm size (modal class 5001 - 10 000 ha), 5 ha is extremely little. However, there are some farms (3,2%) which have a sufficiently large area (>101 ha) established to saltbush to be agriculturally, economically and ecologically significant.

Referring to Figure 6.3 it is clear that on the whole in the Karoo region, farmers do intend planting more saltbush. Combining the two classes with the highest relative frequency indicates that 48% of the farmers intend establishing between 2 and 10 ha of saltbush (key question (ii)). This still represents a low proportion of the farm area. However, 6% of the farmers intend planting large areas (>101 ha) to saltbush, which would be significant in changing their management practices and production capabilities. If one takes the midpoint of the modal class for farm size (i.e. 7500) then an area of saltbush some 225 ha in extent would only represent 3% of the area of the farm while 100 ha of saltbush would only be 1,3% of the farm area. The spatial variation of the area of saltbush and the intended area between the four sub-regions of the karoo is considered by comparing Figures 6.4, 6.5, 6.6 and 6.7. All four regions have similar distributions of frequencies in each class for both the area of saltbush established and the intended area (key question (iii)).

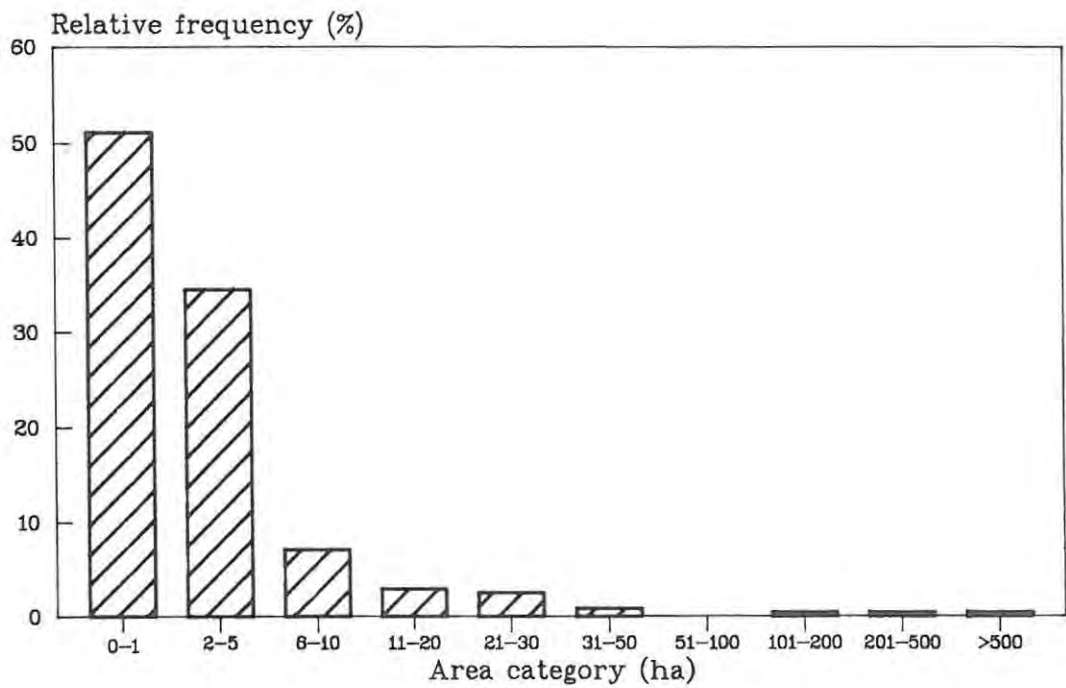


Figure 6.2: The amount of saltbush already established in the karoo

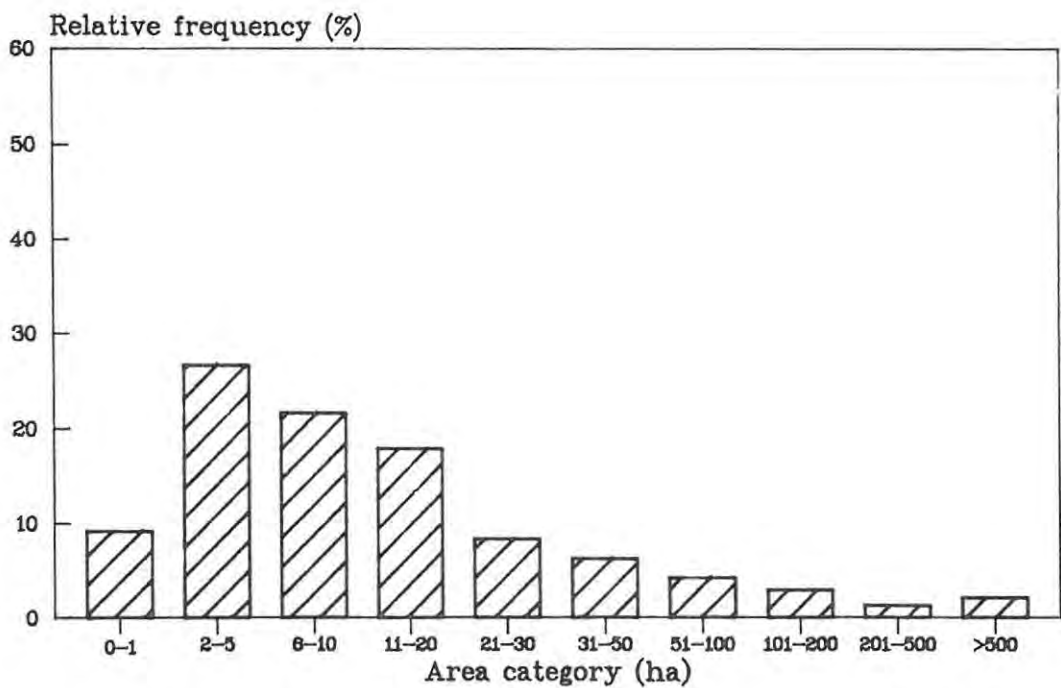


Figure 6.3: Frequency distribution of the area farmers intend planting to saltbush on their farms in the karoo

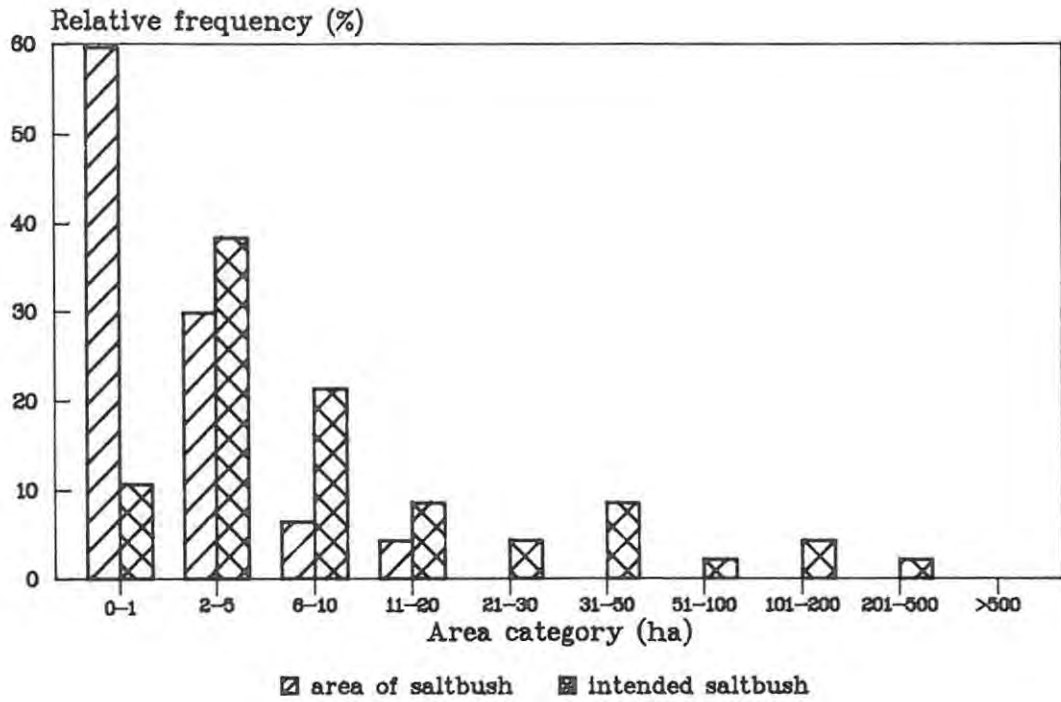


Figure 6.4: Area established to saltbush and intended area to be established by farmers in the North West sub-region of the Karoo

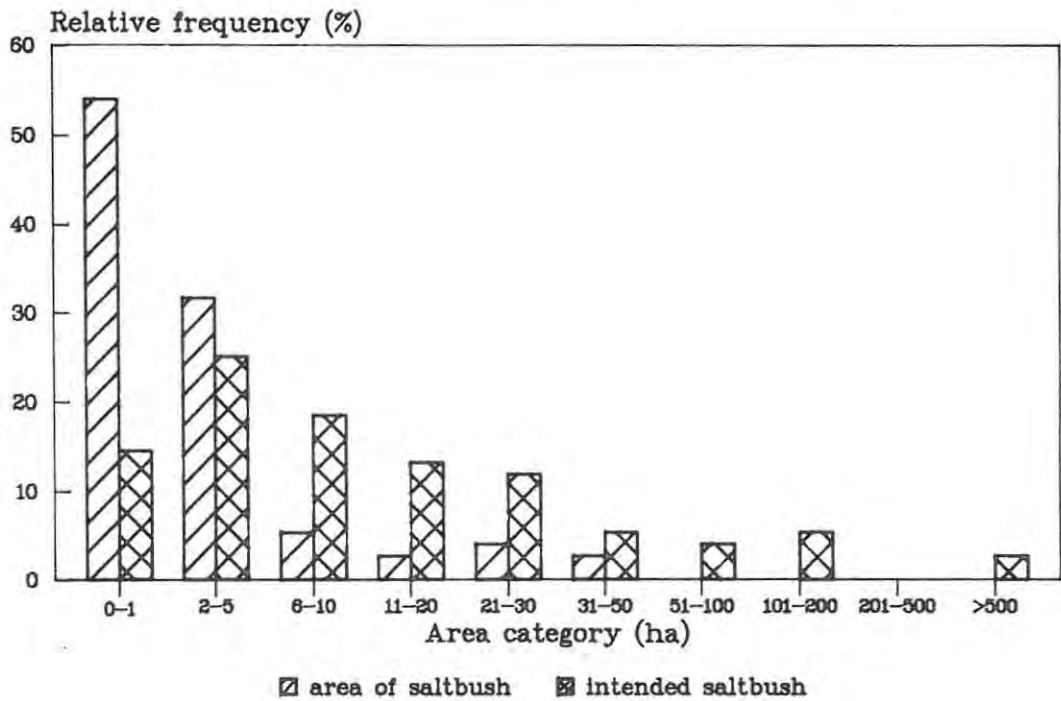


Figure 6.5: Area established to saltbush and intended area to be established by farmers in the North East sub-region of the Karoo

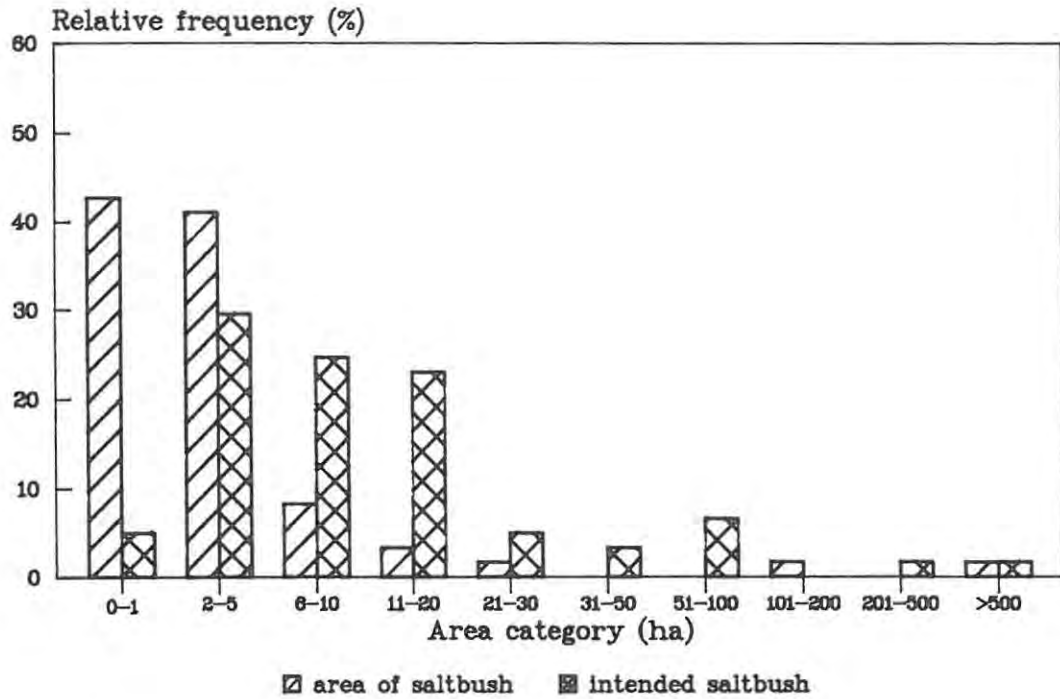


Figure 6.6: Area established to saltbush and intended area to be established by farmers in the Great Karoo sub-region of the Karoo

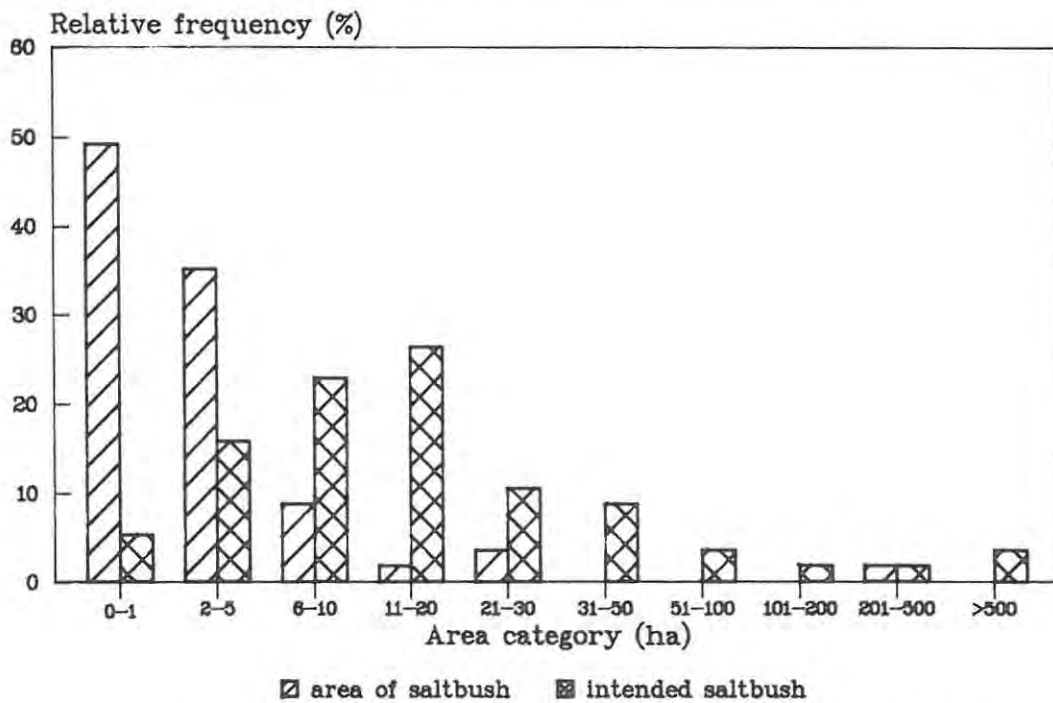


Figure 6.7: Area established to saltbush and intended area to be established by farmers in the Karoo Midlands sub-region of the Karoo

The Chi-square test, was used to determine whether the difference between observed and expected frequencies for farm size, the area of saltbush established and the intended area to establish were due to chance or not, at the 2,5% significance level. Table 6.2 summarizes the results of all three cross-tabulations. In cross-tabulating farm size against the area already established to saltbush (Table 6.2) the calculated Chi-square value is 4,65 with 2 degrees of freedom as compared to a critical value of 5,99 at the 5% significance level. The null hypothesis, that there is no difference, cannot be rejected as the critical value is greater than the calculated value. The differences in the amount of saltbush established hence appears to be due to chance and cannot be attributed to farm size (key question (iv)). In the case of farm size cross-tabulated with the intended area of saltbush to be established (Table 6.2) the calculated Chi-square value is 7,46 while the critical value is 7,38 at the 2,5% significance level. The null hypothesis can be rejected and it can be assumed that the differences in the intended area of saltbush to be established and farm size are not due to chance (key question (v)).

Table 6.2: Chi-square analysis of farm size, area of salt bush established, and intended area to be established to saltbush. (*Ho = no difference)

Variables	Calculated value	Critical value	df	sig. level (%)	Accept/Reject Ho*
Farm size vs area of saltbush	4,65	5,99	2	5%	Accept
Farm size vs intended area of saltbush	7,46	7,38	2	2,5%	Reject
Area of saltbush vs intended area	81,2	18,47	4	0,1%	Reject

The third cross-tabulation of area of saltbush established against intended area (Table 6.2) yielded a calculated value of 81,2 and a critical value of 18,47 at the 0,1% significance level. The null hypothesis of no difference can be rejected and it can be assumed that those farmers who have some saltbush intend planting more while those with very little saltbush do not intend planting much more saltbush.

The last technique of data analysis used, aims at determining, qualitatively, the direction of the relationships identified using Chi-square analysis. Using the raw categorical data in the original classes the lines of best fit for the scattergram are presented in Figure 6.8. The fact that the line

of best fit for the intended area (dashed line) is above that for the actual area established, illustrates that farmers of all farm size categories intend planting more saltbush. This is in agreement with Figure 6.3. The slope of the line of best fit for the intended area is slightly steeper than that for the actual area, meaning it is the farmers on larger farms who intend establishing more hectares of saltbush than farmers on smaller farms.

Using the same 'line of best fit' technique a qualitative assessment was made of the proportional area (as a percentage) of the farm planted to saltbush and intended proportion to be established to saltbush (Figure 6.9). Referring to Figure 6.9, it appears that farms of all size categories have approximately the same proportional area already established to saltbush (approximately 0,2%). Farmers on smaller farms however, do intend planting a greater proportion (approximately 1%) of their farms than farmers on larger farms (approximately 0,4%).

6.5 Discussion and Conclusions

The amount of saltbush established on the farms sampled in the questionnaire survey (key question (i)) can only be estimated due to the nature of the data collected. Most of the farms sampled were between 5001 and 10 000 ha in extent and of these 51% have between 0 and 1 ha of saltbush established while 85% of all the farms sampled have <5 ha of saltbush established. While no estimation of the actual amount of saltbush established can be made it appears that there is in fact very little saltbush established at present (in the region of 0,2% of the farm area). There appears to be no relationship between farm size and the proportional amount of saltbush established on the farm (key question (iv)) or any discernable spatial variations in either intended area or area established to saltbush (key question (iii)). The amount of saltbush already established in the karoo is on the whole unlikely to have been significant agriculturally, economically or ecologically. There are however some farms which have significantly large areas (>101 ha) established to saltbush and these areas are likely to be important in the production potential and management of the farms. Most farmers do intend planting more saltbush. Farmers on large farms intend planting slightly more saltbush than farmers on small farms, in absolute terms. Although, as a proportion of the farm size, farmers on small farms intend planting a greater proportional area (approximately 1%) of saltbush than farmers on larger farms (approximately 0,4%), referring to key question (v). Farmers on the whole for the karoo region intend establishing between 2 and 10 ha of saltbush (key question (ii)) however 6% of the farmers intend planting large areas of saltbush (>101 ha).

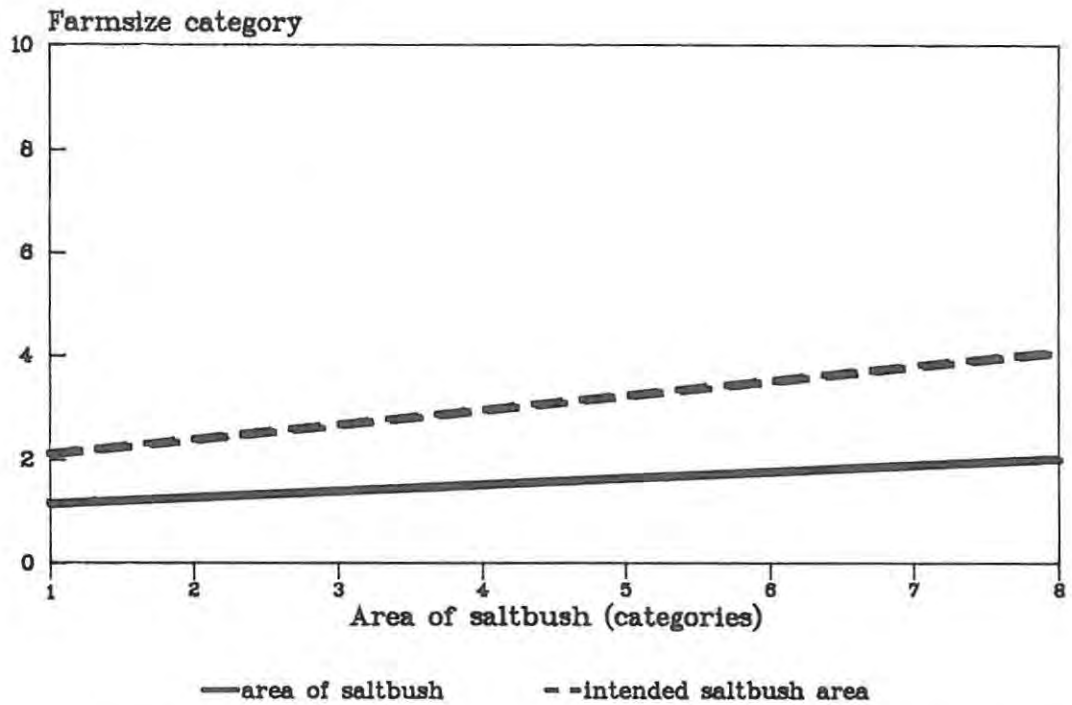


Figure 6.8: Lines of best fit for the scattergram of the area of saltbush and farm size using the actual categories. Points are not plotted as

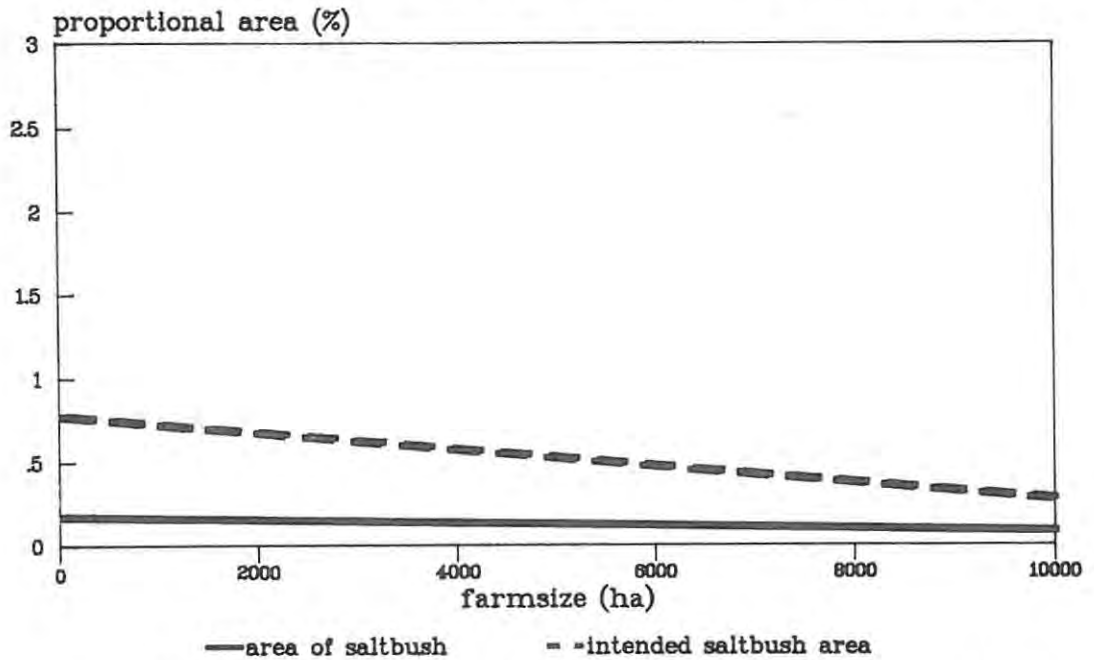


Figure 6.9: Lines of best fit for the scattergram of the area of saltbush as a proportion of farm size using the midpoint of the categories to calculate the proportions. Points are not plotted as they cover each other and mask the scatter.

The strongest trend observed is that farmers who already have some saltbush established intend planting more. These farmers have, in all likelihood, started benefitting financially from the added fodder and increased management flexibility. Further research on the motivation and intentions of those farmers who have substantial areas of saltbush is required. The question as to why some farmers don't have any saltbush and no intention of planting any also needs to be investigated. On the whole the planting of saltbush, due to the small areas established, is likely to have had little socio-economic impact in the karoo. It can certainly be expected that there can have been no major managerial and farm size changes nor any significant change in employment opportunities. It is proposed that the area established to saltbush in the karoo is too insignificant to have had any mentionable economic impact.

CHAPTER 7

MANAGEMENT GUIDELINES AND RECOMMENDATIONS FOR PLANTING SALTBUSH

7.1 Introduction

Criticism is often levelled against researchers for not conveying the results of their work to user agencies. This chapter is included to present the major findings of this study in an applied way such that they are useful to farmers and other interested parties. Hoffman and Cowling (1987) stress the complexity of the response of karoo plants to the stochastic rainfall and disturbance events in the karoo. They discuss how management guidelines have been too simplistic and based on insufficient data. They suggest that this situation has arisen due to the lack of a predictive understanding of a complex ecosystem. The management guidelines presented in this study are in danger of qualifying for similar criticisms. They are, however, based on broad multidisciplinary investigations into what were considered to be key issues.

The most significant detrimental effects associated with saltbush which have been identified in this study are, an increase in soil surface salinity and an impoverishment of the indigenous plant community within saltbush plantations. This chapter considers how these detrimental effects can be kept to a minimum. Controlled management and the implementation of legislation which encourages the sensible utilization of saltbush are briefly examined and guidelines are presented. Farmers should be informed about the impact that saltbush has on the micro-environment (including soils, plant communities, etc.) so that an ethic of sensible land management is encouraged by positive means rather than by legislation.

Land management in the karoo is undertaken by various groups and organisations. The most important group, due to their numbers and direct control of the land, is the farmers while the principal organization is the Department of Agriculture and Water Supply. The management guidelines presented here focus upon two categories, the farmer level and the institutional level. It should be borne in mind that those guidelines presented for farmers (farmer level) are also relevant at the institutional level. There are also some general requirements for growing saltbush of importance for the planting and utilization of saltbush which have not been addressed by the research of this study but which can be drawn from the literature (Bonsma and Mare, 1942; Aucamp, 1973a, 1973b; de Kock, 1967, 1980, 1987; Hobson, 1985; Steynberg and de Kock, 1987; van

Heerden, 1987). The most fundamental of these general requirements derived from the literature, are included in the guidelines applicable at the farmer level. Lastly, those guidelines applicable at the institutional level are presented.

7.2 Guidelines for farmers (farmer level)

General requirements for the planting of saltbush, although they have not been specifically researched are mentioned before the guidelines for farmers are discussed. Saltbush requires considerable effort on the part of the farmer to establish and so knowledge of those is necessary. The effort required to establish saltbush is a possible factor which explains why saltbush plantations are not more widespread in the karoo.

Saltbush can grow on a wide range of soils but should, preferably, be planted on soils which are alkaline and at least 0,5 m deep. Deep fertile soils will allow saltbush to grow vigorously once established. Sufficient drinking water of a fairly good quality should be available for livestock to drink as livestock will not forage well on saltbush if little and/or poor quality water is available (Wilson, 1974; Pasternak *et al.*, 1986). Saltbush plantations should be allowed sufficient time for establishment, normally two years, but once established should be grazed at least annually. Watering saltbush plantations periodically, even if infrequent, stimulates growth and should be done whenever possible care should, however, be taken on saline and clay/silt soils which are prone to become 'brak'. Although saltbush provides sufficient fodder for small stock to maintain their body weight (le Houerou, 1986), it should not be used as the sole dietary intake for sheep, for extended periods of more than four months (Pasternak *et al.*, 1986).

The guidelines, at the farmer level, for the establishment of saltbush presented here are not definitive or prescriptive but are presented as a result of the research work done for this study. These guidelines were also developed to suggest practicable ways of keeping the detrimental effects associated with saltbush plantations to a minimum. It should be noted that most guidelines presented in this section are also of relevance at the institutional level.

The plantation density of saltbush is important, as individual plants do change the micro-environment significantly. The major finding of this study was that soil surface salinity increases within 0,5 m of individual saltbush plants. It is therefore suggested that plantations not be established at densities of more than 3 500 plants per hectare to ensure that the cumulative changes of individual plants do not affect the entire area. Planting densities of between 2000 and 3500 plants per ha were found by Forti *et al.* (1986) to be optimal in terms of yield per unit area

and yield per unit shrub. Furthermore at high planting densities saltbush plants tend to grow taller, while at lower densities the shrubs tend to increase more in diameter (Forti *et al.*, 1986) allowing better accessibility for livestock. Detailed research into the optimum planting densities for saltbush in the karoo is therefore required.

It is suggested that plantations not be too sparse (less than 1 500 plants per hectare) as they would have to cover a large area to be of any use as drought reserves. This study is in agreement with the planting densities advocated by de Kock (1980) and Forti *et al.* (1986) of between 2000 and 3000 plants per ha. Plantations in the karoo should be fenced off separately to facilitate better control of grazing pressure and stock density as suggested by le Houerou (1986) for the Mediterranean basin. Fencing areas off separately also allows the plantations to be set aside as drought reserve areas. If saltbush plantations are not set aside but are used as part of normal grazing they are likely to be of little use during drought periods.

Saltbush should, however be browsed from time to time (at least once every 18 months) to prevent leaf litter accumulation and to keep the plants in an actively growing state so that suitable shoots are available. Saltbush seed should be collected or grazed before the seeds are mature as it is the development of seed and leaf litter mats which contributes to the increase in soil salinity. This study found that the seeds and leaves of saltbush had high salt contents. Selecting the area to establish as a drought reserve using oldman saltbush needs to be done carefully. The local extension officer could help in this task. Areas of low species richness and/or poor natural grazing potential should be selected in preference to diverse, good quality natural pasture. This will probably be done by most farmers because of their knowledge of the veld. Areas which have the potential to be rehabilitated to good natural grazing should be identified so as to avoid using these areas for saltbush plantations.

Ideal sites for planting saltbush which are easily identifiable are areas which have already been extensively disturbed, are fenced off and which are on fairly deep soils (but which don't have a potential for rehabilitation to natural pasture of a reasonable quality). These types of sites are typically found on abandoned cultivated lands and areas near sheds, kraals and near watering points. These "disturbed" areas should be planted before any natural pasture is disturbed on the farm. Farmers should establish a significant proportion of their farms as some form of drought reserve, in the region of 3% of farm size but no more than 10% of any farm should be established to saltbush.

Oldman saltbush has great potential for providing supplementary fodder during dry periods in the Karoo Region. If saltbush was planted on a large scale in the karoo it is possible that drought aid would not be necessary as farmers would be able to maintain their stock numbers at little extra cost. With this in mind, farmers should be actively encouraged to establish saltbush plantations within the guidelines already discussed. Due to the many aspects of the environment which saltbush affects, as highlighted by this study, it is suggested that the Department of Agriculture and Water Supply should only recommend that farmers plant saltbush once sufficient research has been conducted into the full impact which saltbush has on the ecosystem. The problem of privately owned land and the control of alien species invasions (Trainor *et al.*, 1985) is also relevant as most areas on which saltbush is established will be on privately owned farms and difficult to control according to centralised guidelines, with or without legislation.

At the institutional level, the area planted to saltbush and the saltbush plantation density should be monitored in order to control long term detrimental effects to the environment (soils and plant communities). When encouraging farmers to plant saltbush, definite advice should be given as to suitable areas, thereby controlling where saltbush plantations are established on an individual farm basis. Small farms should be focused on as a priority for the establishment of drought reserves in agricultural extension activities as these units are the first to be effected by drought (Daniel, 1975). Successful implementation of *Atriplex nummularia* on a few small farms could serve as a stimulus for other small farmers as many farmers are reluctant to accept new ideas until they have been shown to be reliable and worthwhile (Siepker, 1987). If an organization is committed to subsidizing farmers (albeit because of reasons other than good agricultural practice) then some form of subsidy structure should be considered which encourages the farmers to implement the use of drought reserves rather than relying on direct financial subsidy during droughts. This will benefit those farmers who are making an effort to survive droughts without Governmental help. Finally, research by Government Departments, as well as by Universities, should be encouraged through the provision of finance and the identification of research priorities among the many topics identified by this and other studies.

CHAPTER 8

GENERAL DISCUSSION

8.1 Introduction

Many different aspects need to be considered in studying the impact of a plant which has been widely introduced and established for agricultural purposes. A multidisciplinary study is required as there are many different aspects which need to be examined. Also, a number of the aspects are interrelated and it is these that are considered in this Chapter. The discussion and conclusions of each individual chapter should be referred to for any detailed findings of a specific aspect. The physiology, life cycle and other specific peculiarities of the plant need to be understood. Their effects on the particular environment/s in which the plant is established need to be assessed. The farmers themselves and their reasons for using the plant are also essential factors to be examined in assessing the impact of a plant on the environments of a certain region, as these are the people who determine the sites and magnitude of saltbush planting as well as their management. It was the diversity of aspects involved and the lack of knowledge in the South African context which led to the development of this multidisciplinary study, largely of a scoping nature. Each research chapter examines a different aspect and has its own conclusions. The purpose of this final chapter is not to re-iterate those conclusions but to use them together to answer questions of a more general nature.

In concluding and linking the various chapters together the two broad aspects of the research study that are considered are the impact of oldman saltbush on the micro-environment and the socio-economic aspects of planting saltbush in the karoo. In keeping with the rest of the study, assessments of the two broad aims are focused by means of key questions.

8.2 Key Questions

The key questions for this, the final chapter are questions which are answered from the results of more than one chapter in the study. The questions are of a wide nature and include both ecological and socio-economic aspects. These key questions are presented in Table 8.1.

Table 8.1 Summary of key questions

- i) How good is *Atriplex nummularia* as a nurse plant?
- ii) Of what magnitude are the micro-environmental effects associated with *Atriplex nummularia* likely to be for the Karoo Region as a whole?
- iii) How can any detrimental effects be kept to a minimum?
- iv) Will there be any significant economic benefit in the karoo as a result of increased agricultural production by utilizing *Atriplex nummularia*?

8.3 The impact of oldman saltbush on the environment

Chapters two, three, four and five considered four of the potential impacts which saltbush could have on its immediate environment. The aspects examined were the microclimatic effects (Chapter 2), soil induced changes (Chapter 3), salinity effects of germination (Chapter 4) and plant community interactions (Chapter 5) associated with saltbush. The results of each of these aspects are considered here in one overall synthesis.

How good is saltbush as a nurse plant (key question 8(i))? Individual saltbush plants do cause an amelioration of the microclimate in the immediate vicinity (within 0,75 m) of each bush (Chapter 2). The changes in microclimate could possibly be expected to favour the germination and establishment of indigenous species. However there is an increase in soil surface salinity, specifically NaCl, around each individual saltbush (Chapter 3) which does affect the germination rate of some species (Chapter 4). More indigenous shrub species had lower abundances, while only two shrub species increased in abundance in the saltbush plantation assessed (Chapter 4). The ground cover of *Cynodon dactylon* was markedly reduced in association with saltbush. Both microclimatic and soil induced changes can be expected to affect different indigenous plant species differentially. Salinity has been shown to have a differential effect on the germination of some indigenous dwarf shrubs (Chapter 4) although salinity was not a causal factor in the reduction of *Pentzia incana* and *Felicia ovata* in the saltbush plantation. The combined effects of salinity and microclimatic changes on the recruitment rate of indigenous shrubs have not been assessed nor have allelopathic interactions. Their effects would be expected to be species specific.

On the basis of the research conducted in this study, a broad preliminary insight can be provided as to the suitability of oldman saltbush as a nurse plant. It is postulated that the increased salinity and competition will not be beneficial for the establishment of the majority of indigenous karoo

shrubs. Although no specific causal factors have been identified, the plant density of indigenous shrubs in a 40 year old saltbush plantation was found to be reduced by approximately one third (Chapter 5). Only two indigenous shrub species (*Felicia muricata* and *Drosanthemum ligue*) increased in abundance and the number of species was reduced by 38% (Chapter 5) suggesting that oldman saltbush is not a suitable nurse plant for most of the shrubs encountered at study Site 2, namely Wellwood farm. *Cynodon dactylon*, the only grass assessed, was detrimentally affected by the presence of saltbush.

It is quite clear that a saltbush plantation has a substantial impact on the indigenous plant community in the medium to long term. This impact is of both ecological and managerial importance. The ecological implications include the reduction in species richness and plant diversity of the indigenous dwarf shrubs of the karoo wherever saltbush plantations are established. Apart from ecological considerations the impoverishment of the indigenous plant community may lead to a decrease in the fodder production of the natural plant community. Further, changes in soil salinity may also cause the soil to become dispersive in some places (around individual saltbush plants). For example, dispersive clays within the soil can then be relocated further down the soil profile in areas of the karoo where there is sufficient infiltration for eluviation and illuviation to occur. An increase in surface soil dispersivity could result in increased soil erodibility. There was however no convincing visual evidence at either study site of excessive soil erosion or of the redistribution of clays in the soil profile.

The magnitude of micro-environmental effects associated with *Atriplex nummularia* in the karoo region as a whole (key question 8 (ii)) depends on the effects themselves and on the extent of the area on which saltbush is established. The extent of the effects has been mentioned already but may be summarized as being mostly on an individual saltbush plant basis and hence dependant on the density of each saltbush plantation (guidelines for plantation density are given in Chapter 7). The regional magnitude of these effects is also dependant on the quantity of saltbush established. Both the density of plantations and the amount of saltbush planted is dependant on the attitudes and activities of the farmers themselves. Eighty five percent of the farms in the questionnaire survey had less than 5 ha of saltbush (Chapter 6). The fact that so little saltbush has been planted and that saltbush has a limited effect on its micro-environment suggests that for the karoo region as a whole the impact of saltbush is limited and that saltbush planting presents no immediate ecological threat (key question 8 (ii)). This suggestion is strengthened by the relatively short longevity of saltbush seed (Edwards, 1974) and hence the unlikelihood of the development of extensive seed banks, which has been an important factor in the case of *Acacia cyclops* (Holmes and Rebelo, 1988). The area which farmers intend establishing to saltbush is also small, ranging for the majority of farms from two to ten hectares. However six percent of the farmers who responded to the questionnaire survey

intend establishing areas of greater than 100 ha. These large areas of saltbush will no doubt have a significant effect on the soils and indigenous plant communities (not to mention insect and micromammal populations). In this instance there is a need for controlled development, development guidelines and legislation for planting saltbush in the Karoo Region.

8.4 Socio-economic aspects of saltbush planting in the karoo

Farm size, in relation to the amount of saltbush established and the intended area to establish to saltbush was discussed in Chapter 6. Socio-economic aspects are considered here in order to make an assessment of the possible financial contribution oldman saltbush is making in the karoo region by increasing production (key question 8 (iv)). The actual area occupied by saltbush plantations in the karoo, at present, is so small that it is certain to have little impact as a supplementary fodder source or drought reserve. Economically, although saltbush has the potential to increase production tremendously, saltbush planting in the karoo is of such insignificant magnitude that no noteworthy impact is likely to have occurred. The area which farmers intend establishing with saltbush is also so small that it will have a negligible economic impact. However, those farmers who do establish over 100 ha of saltbush will undoubtedly benefit economically by being able to maintain higher production levels. Only 6% of the farmers who responded to the questionnaire survey intend planting more than 100 ha. The fact that those farmers who already have some saltbush established are the ones who intend planting more suggests that saltbush does provide a significant benefit to the farmer.

8.5 Limitations of this study and suggestions for further research

This study has two major limitations: in the first instance there are a limited number of aspects considered and secondly only two sample sites in the eastern karoo were examined. The limited scope of the research done in this study is due to the practical limitations of time and money and the fact that this is the first study of its kind on oldman saltbush. Further, this study, being a first in South Africa, has focused on what were considered to be the major ways in which the planting of saltbush could have an impact on the ecosystem (the study is largely a scoping exercise). The aspects examined were thought to be the most important and to constitute a well rounded set of inter-related and relevant factors which would also serve to identify other aspects requiring research.

As far as micro-environmental factors are concerned, the microclimate, soils, root densities, salinity effects on germination and plant community interactions have been considered. All of these studies

were site specific and so the application of the results obtained to the karoo as a whole must be done with extreme caution. Different soils and plant communities may have a strong influence on the way in which saltbush affects its surrounds. For the findings and recommendations to be extended to the karoo as a whole, more experimental areas need to be examined. The localised salinity increases found in association with saltbush need to be examined more intensively. Aspects such as the mobilization of clays and nutrient cycling require further research. The impact of saltbush on the plant community also needs to be the subject of further intensive study, including investigations in different plant communities and the impact on grasses, annuals and geophytes. Species (plant and animal) detrimentally affected in saltbush plantations by salinity, competition or any other factor, need to be identified. Annuals and grasses have not been considered in this study yet they are important in the production of fodder in the karoo. Plant-water relations within saltbush plantations require attention as this may be one of the major impacts that saltbush has on the indigenous plants (Yair and Danin, 1980). *Atriplex* sp. have the ability for extremely fast root growth (Hodgkinson and Baas Becking, 1977) and more work is required in assessing the competition between *Atriplex nummularia* and indigenous plant species.

Another aspect not considered in this study is the impact which saltbush, as a large shrub, has on the insect and animal populations of the open karoo areas. Saltbush plants, directly and indirectly by their influence on the plant community, may have an impact on the pollinators and other insects (e.g. ants) in the karoo which may be crucial in ecosystem functioning. *Atriplex tartarica* has been noted to be adversely affected by *Foricula tomis* in the U.S.S.R. (Kaldey, 1978). Small mammal populations may also change due to the provision of shelter by saltbush plantations and this should be researched as small mammals can have a dramatic impact on the carrying capacity for domestic stock.

This study is limited as far as the socio-economic aspects of saltbush planting in the karoo is concerned. The limited amount of saltbush established in the region, however, means that the impact is as yet very localised and so makes this deficiency more acceptable. If saltbush plantations become widespread in the karoo and higher levels of sustained productivity are realized then there will be tremendous scope for socio-economic studies concerning how this innovation changes farm size, employment and income in the karoo. Changes in the economic situation of farmers will also have the potential to affect the population and population structure of the karoo. The lack of a younger generation of farmers (under 30 years of age) identified by Daniel (1975) and the depopulation of the karoo could possibly be reversed if higher agricultural production was realized. The size of the economic farming unit in the karoo may be reduced if farmers can maintain their livestock numbers through drought periods and ensure continued production. Those farmers who successfully increase production by using saltbush could expand their activities and develop large

estates and farming operations.

All these aspects will need to be studied if the overall objective of the National Grazing Strategy (1985) is to be realized, namely;

To use, develop and manage the natural and cultivated pastures in the Republic of South Africa in such a way that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations (National Grazing Strategy, 1985, p. 4).

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VRAELYS : OUMAN SOUTBOS
 QUESTIONNAIRE: OLDMAN SALTBUSH

Distrik / District :

Beantwoord asseblief die vraelys deur die toepaslike blokkies te voltooi of kortliks kommentaar te lewer.

Please complete the questionnaire by marking the blocks and commenting briefly where requested.

1. Het die Ouman soutbossaad u in 'n goeie toestand bereik?
 Did you receive the Oldman saltbush seed in a good condition?

Ja / Yes	<input type="checkbox"/>
Nee / No	<input type="checkbox"/>

2. Was die plant instruksies wat u met die saad ontvang het ?
 Were the planting instructions received with the seed ?

Volledig / Complete	<input type="checkbox"/>
Onvolledig / Incomplete	<input type="checkbox"/>
Langdradig / Tedious	<input type="checkbox"/>
Verwarrend / Confusing	<input type="checkbox"/>

3. Hoe het u die saad gesaai ?
 How did you sow the seed ?

Saadbeddings / Seedbeds	<input type="checkbox"/>
Plastiekplantsakkies / Nursery planting bags	<input type="checkbox"/>
Saailinghouers / Speedling seedling trays	<input type="checkbox"/>
Direk in veld / Direct in veld	<input type="checkbox"/>

4. Hoe het die saad ontkiem ?
 How did the seed germinate ?

Swak / Poorly	<input type="checkbox"/>
Goed / Well	<input type="checkbox"/>
Baie goed / Very well	<input type="checkbox"/>

5. Hoe het die plante gevestig ?
How did the plant establish ?

Swak / Poorly
Goed / Well
Baie goed / Very well

6. Waar het u die plante geplant ?
Where did you plant the plants ?

Ou lande / Old lands
In die veld / in the veld
Waterbane / Watercourses
Voorskoot / Apronveld
Bergveld / Mountainveld

7. Die oppervlakte waarop u boer ?
The area you are farming on?

0 - 100 ha
101 - 500 ha
501 - 1 000 ha
1 001 - 2 000 ha
2 001 - 3 000 ha
3 001 - 5 000 ha
5 001 - 10 000 ha
Meer / more 10 000 ha

3/....

8. Die oppervlakte soutbos waaroor u tans beskik en die verwagte oppervlakte oor 5 jaar ?

Area under saltbush at present on your farm and the estimated area in 5 years time ?

	Tans / Present	oor 5 jaar / 5 years	next 5 years
0 - 1 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
2 - 5 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
6 - 10 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
11 - 20 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
21 - 30 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
31 - 50 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
51 - 100 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
101 - 200 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
201 - 500 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>
Meer/more 500 ha	<input type="text"/>	<input type="text"/>	<input type="text"/>

9. Vreet diere die plante ?
Do the animals eat the plants ?

Swak / Poorly	<input type="text"/>
Redelik / Reasonably	<input type="text"/>
Goed / Well	<input type="text"/>
Baie goed / Very well	<input type="text"/>

9.1 Watter soort diere ?
What kind of animals ?

Wolskape / Woolled sheep	<input type="text"/>
Vleisskape / Mutton sheep	<input type="text"/>
Boerbokke / Boer Goats	<input type="text"/>
Vleisbeeste / Beef Cattle	<input type="text"/>
Melkbeeste / Dairy Cattle	<input type="text"/>

4/....

10. Waar het u die meeste probleme ondervind ?
Where did you experience the most problems ?

Ontkieming / Germination
Vestiging / Establishment
Beweiding / Grazing

11. Sal u meer soutbossaad wil aankoop ?
Would you like to buy more saltbush seed ?

Ja / Yes
Nee / No

12. Is die aanplant van ouman soutbos ekonomies geregverdig ?
Is the planting of oldman saltbush economically justified ?

Ja / Yes
Nee / No

13. Dink u dit is die moeitewerd om ouman soutbos aan te plant ?
Do you think it is worth while to plant oldman saltbush ?

Ja / Yes
Nee / No
Onseker / Uncertain

14. Indien nee, wat is u redes ?
If no, please give reasons.

.....
.....
.....
.....
.....

15. Kan u 'n alternatiewe droogtevoer voorsorgmaatreël voorstel ?
Can you suggest an alternative drought fodder measure ?

Ja / Yes

Nee / No

16. Verstrek alternatief en gee redes vir antwoord.
Give alternative and reasons for answer.

.....
.....
.....
.....
.....

Baie dankie vir u samewerking.
Thank you for your co-operation.

Pos asseblief in die ingeslote gefrankeerde koevert.
Please mail in the enclosed envelope.

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