A GRADIENT ANALYSIS ALONG TWO PARALLEL ELEVATIONAL TRANSECTS ON DIFFERENT SOILS, NEAR ROBERTSON IN THE S.W.CAPE

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ABSTRACT. Within the S.W.Cape are many distinct vegetation types including the dominant sclerophyllous-type, Fynbos. This project investigates the vegetation in two adjacent areas with the same macro-climate and both being equally undisturbed but having different substrates. Fynbos tends to occur on sandy,nutrient-poor soil in dry areas.

INTRODUCTION.

The S.W.Cape, despite it's small size, is classified as a distinct phyto-geographic region (e.g. 'The Cape-Region' of White(1976). Within this region are many vegetation-types e.g. Macchia, Coastal-Macchia and Coastal-Renosterveld (Acocks 1953). Also within the S.W.Cape there are smaller areas containing elements from other phyto-geographic areas of Africa e.g. Afro-montane elements (Goldblatt 1978) and Karroo-Namib elements (Werger 1978).

There are many untested hypotheses as to how and why each vegetation-type exists in each area. For example Afro-Montane elements may have migrated down the mountain-chains and exist in the moist areas of the S.W.Cape (Axelrod and Raven 1978) and that the Renosterbos exists and spreads in the Fynbos as an invasive fire-weed (Levyns 1929).

It would appear that today the position of each vegetation-type is determined by the relationship between the local climate, the disturbance regime and the soil-types.

The dominant vegetation-type of the S.W.Cape is the broad category of sclerophyllous heathland, Fynbos (see Kruger 1979 and Taylor 1978 , for a detailed description).

The hypothesis that 'Fynbos tends to occur on sandy-soils in arid regions ' was tested in this survey by the use of a parralel gradient in which the climate-type and disturbance-regime were equal and the soil-type was different.

Further research will eluciadate whether the differences in vegetation-types is due to the nutrient-status or the water-related properties of the different soils.
The parallel gradient used also facilitated an investigation into differences in the two different communities organization and structure.
Causes of patterns of plant species diversity is a primary aim of most ecological surveys, whether the survey is for management or for a general understanding of community dynamics. Approaches to interpreting diversity are numerous and in this survey the emphasis is placed on the possible enviromental causes for changes in diversity.
Structural characteristics are an important feature of a community and in this survey various structural characteristics were measured,compared and interpreted.

METHOD.

Each 300m. altitude transect was divided into 4 stations. Each station was 100m. apart and at each station, 4 random 5m. x 5m. plots were laid. Therefore each gradient contained 16 plots and the whole survey 32plots.
Each plot was sampled for total floristics and the cover-abundance of each species was recorded. The growth-form, height, leaf-size-class, periodicity and spinescence of each species was also recorded as done by Parsons and Moldenke (1975).
Considerable enviromental-data was also collected at each quadrat such as aspect, altitude, slope, soil-depth, abundance of rock-cover, litter and humus. In addition a soil sample from each station was analysed by the Dept. of Agricultural Technical Services at Stellenbosch, see Soil Data graphs.
Information pertaining to the condition of each site was also noted. In both cases the vegetation had not been disturbed for at least 20years and was not used for agriculture.
The survey took place in April, 1981 and due to the significant amounts of geophytes in the Karroo but naturally absent in summer the data presented here is incomplete. Similarly, one would expect an increase in the herb cover-abundance and number of species in the Fynbos in spring and thus this survey would be complimented by one performed in winter-spring, to obtain a more comprehensive floristic data for those members of each community which survive the severe summers of this region as seeds or from underground storage or by shedding their leaves.

SITE DESCRIPTION.

Two mountain sites,five miles apart, were specifically selected for having the same slope , aspect,altitude, lack of disturbance and climate but different soils.

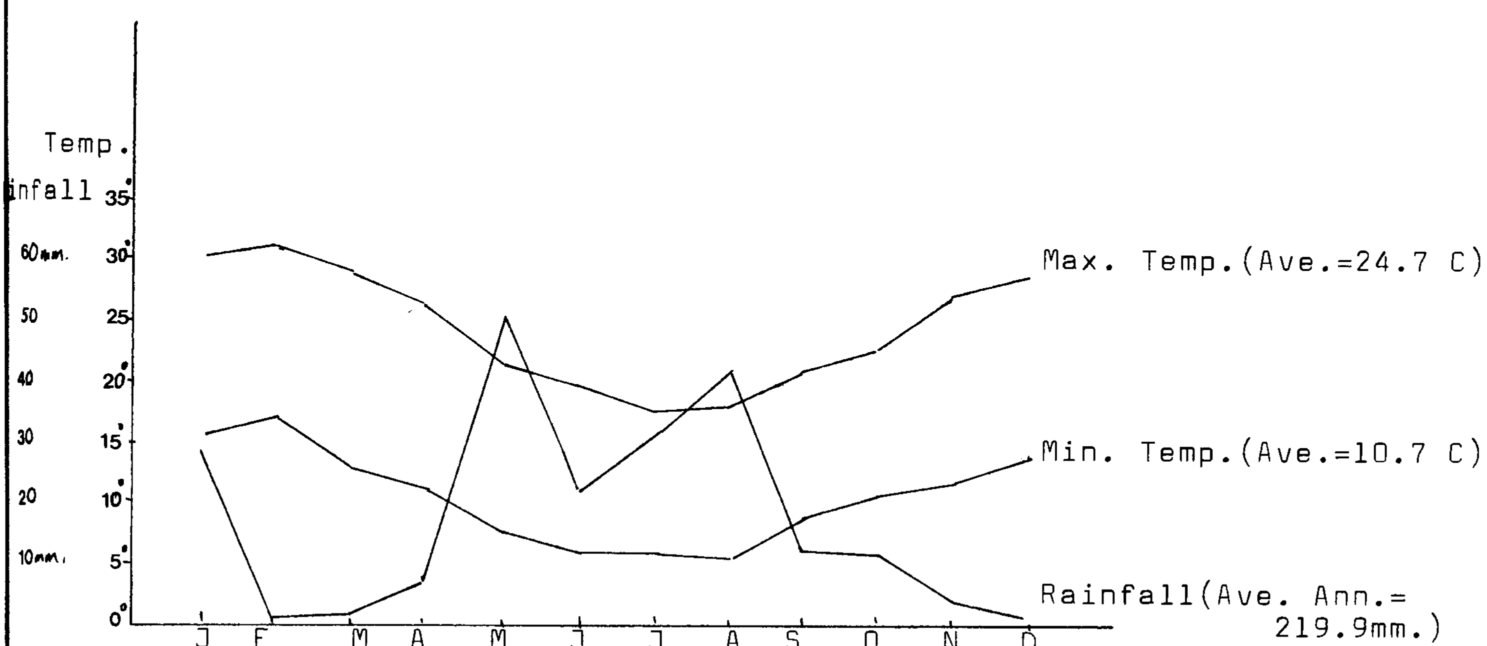
Site A is at 19 48 E and 33 48 S and is referred to as Karroo in this report.

Site B is situated at 19 48 E and 33 51 S and is referred to as Fynbos .

Both transects begin at 240m and go up in steps of 100m, a total rise in elevation of 300m. Each transect is about 1km in distance.

CLIMATE.

Climate data is from Robertson, 19 48 e and 33 50 S, at an altitude of 156m.(Report on Meterlogical Data of the year 1975) The climate is basically Mediterranean and generally has extreme temperatures and low annual rainfall.



Brief site description.

Shale substrate supporting a community reffered to as Succulent (due to presence of members of the Crassulaceae and Euphorbiaceae), Renoster (Elytropappus sp.) Karroo.

S.E. facing.

540m Station 4 (plots 13,14;15,16.)

Rocky mountain Top. Heeria, Phyllica, and Maytenus in protected sites.

440m Station 3 (plots 9,10,11,12.)

Mainly Renosterveld.

330m Station 2 (plots 5,6,7,8.)

Renosterveld with scattered clumps of trees e.g. Euclea undulata, Carissa haematocarpa, Olea africana associated with termitary.

240m Station 1 (plots 1,2,3,4.)

Mature undisturbed Dry Succulent/Renoster/Karroo.

Characterised by Ralhenia,Euphorbia species. Scattered trees e,g. Euclea,Dodonea which did not appear on the random plots.

Brief site description.

Sand,quartzite substrate supporting a community referred to as Fynbos (due to the prescence of members of the Restionaceae,Ericac eae and Proteaceae.)

540m Station 4 (plots 13,14,15,16.)
Mature Arid Mountain Fynbos.
Unburnt for a long time(Protea > 4m)

S.E. facing.

440m Station 3 (plots 9,10,11,12,)
Very senescent. Mainly Restionaceae.

340m Station 2 (plots 5,6,7,8.)
Similar Fynbos to sand-veld i.e much litter and mainly Restionaceae with occasional Proteaceae.

230m Station 1 (plots 1,2,3,4.)
Mature un-disturbed Arid Fynbos.

CLASSIFICATION and ORDINATION.

Using the species and their abundance ratings a classification and an ordination was performed using the Cornell Ecology Programs Decorana and Twinspan (Hill 1979).

The classification and ordination was performed on each gradient to see whether each station represented homogenous alliances so that the four plots making up each station could be grouped grouped together for further comparisons between stations. The classification and ordination reveal many trends.

In the Karroo ordination (Fig. 1), plots 1-4 (Station 1) form a distinct group and the other 12 plots are closely situated next to each other. Although the similarity is high between these plots, they do group together as stations.

The four Karroo stations form a gradient with station 1, the lowest in altitude furtherest from the X-axis and station 4, the highest in altitude closest to the X-axis. This means that axis 1 could be replaced by decreasing altitude.

The Karroo dendrogram (Fig. 2), also shows that station 1 is most distinct from the other relatively similar remaining plots. This dendrogram is derived from a completely different numerical procedure to the ordination and it also shows it is legitimate to clump the plots together as stations.

The shortness of the Karroo dendrograms arms, which corresponds to similarity, indicates a gradual change in vegetation up the gradient which mirrors the trend observed in the field where there was no abrupt change in the vegetation, up the Karroo slope.

In the Fynbos however, each station was more distinct from the others than was the case in the Karroo and axis 1 does not correspond to altitude.
The total dissimalarity between stations in the Fynbos is 62% than that in the Karroo, which is shown by the longer arms of the Fynbos dendrogram and reflects the vegetation discontinuities observed in the field.
It will be noted later in the discussion on diversity that axis 1 in the Fynbos may replaced by soil-factors (e,g. nutrients or depth).

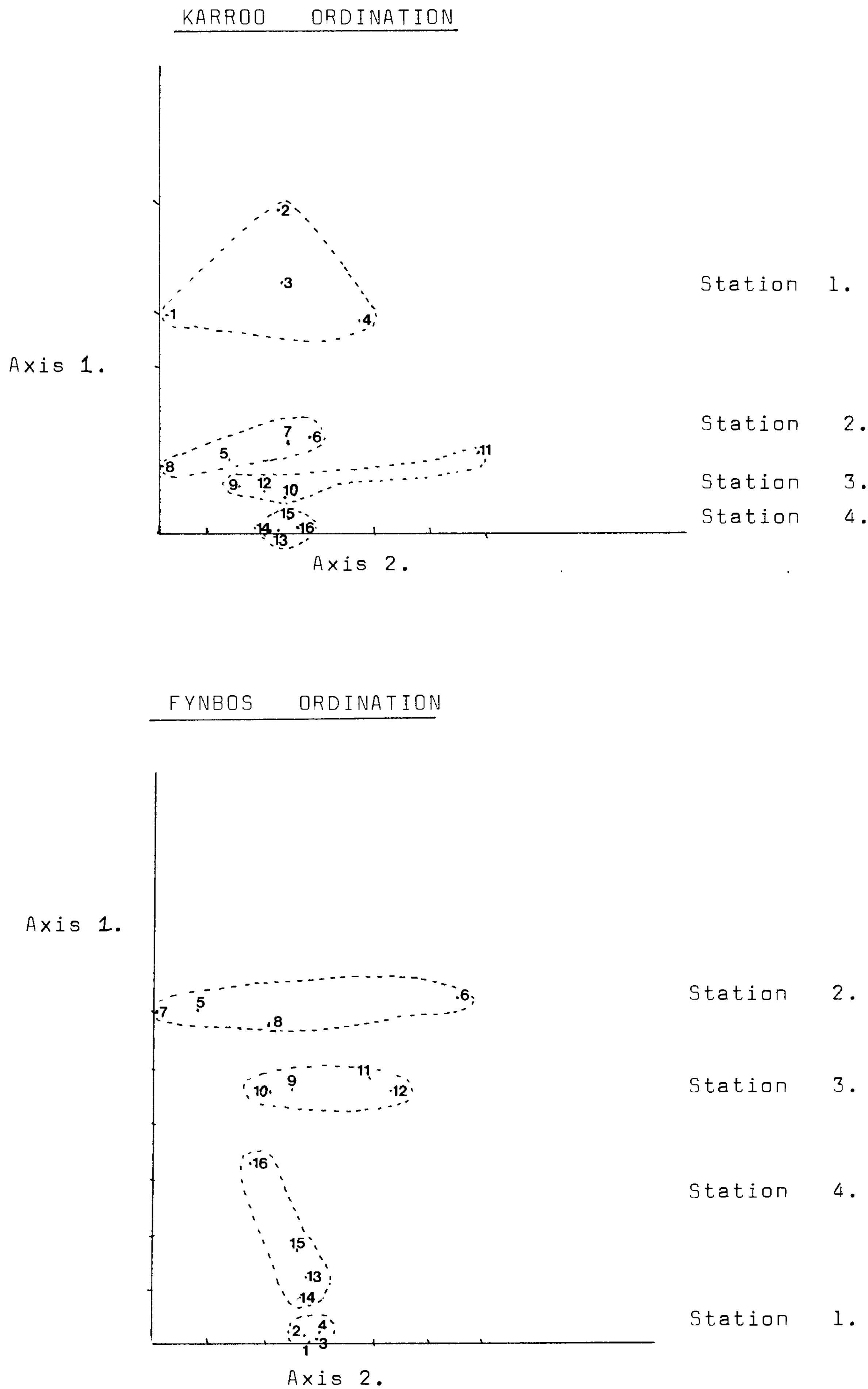


Figure 1. Ordination Diagrams.

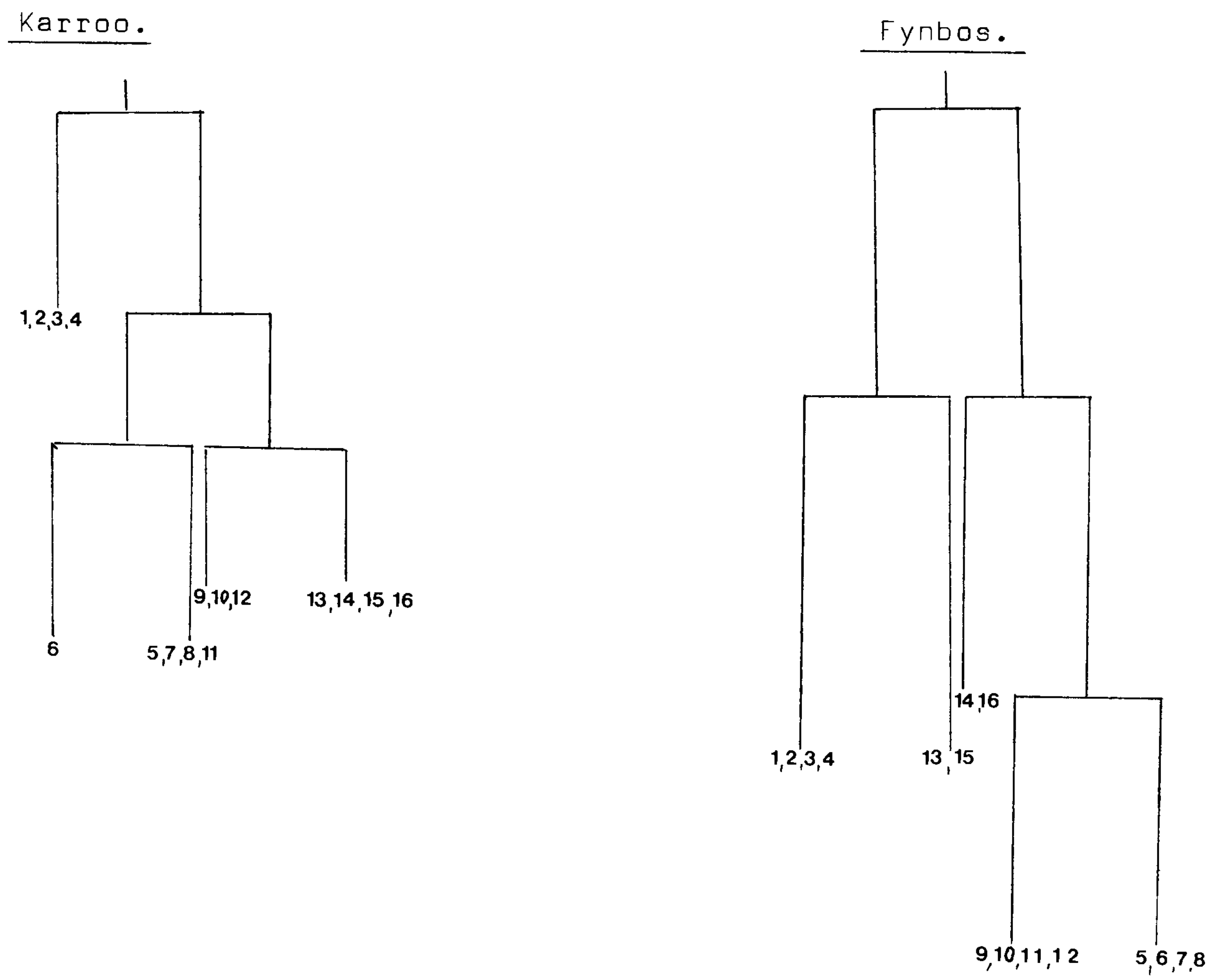
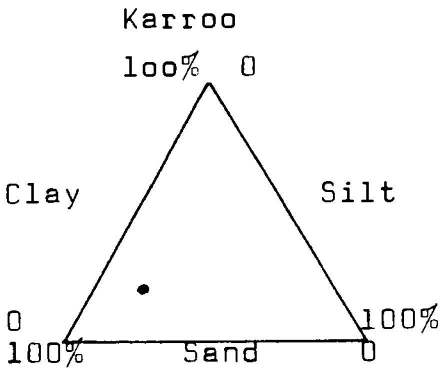
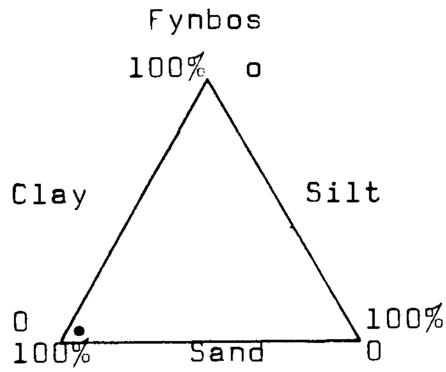


Figure 2. Classifactory Dendrograms.

(Numbers represent plots and both diagrams are drawn to the same scale which is derived from the Twinspan Eigen-vectors.)

SOIL DATA. Using the triangulation and classification of the Soils Analysis Methods (1974) the following triangles were obtained.



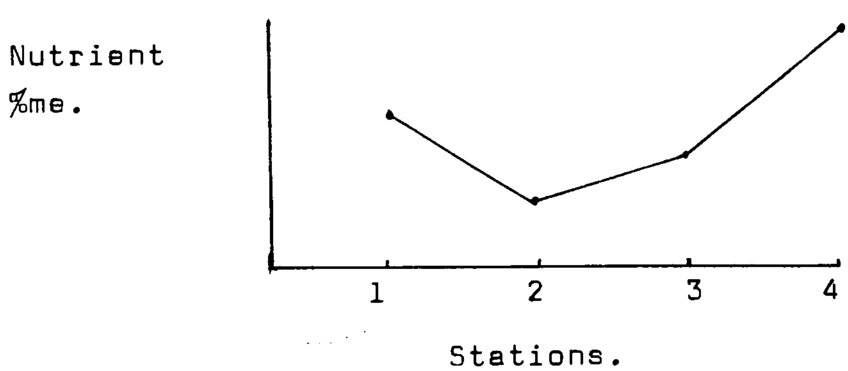


The Karroo soil has considerably more clay and silt than the Fynbos soil which is predominantly sand. The Karroo soil is classified as sandy-loam and the Fynbos soil, sand.

Important features of the six soil nutrient data graphs is ;

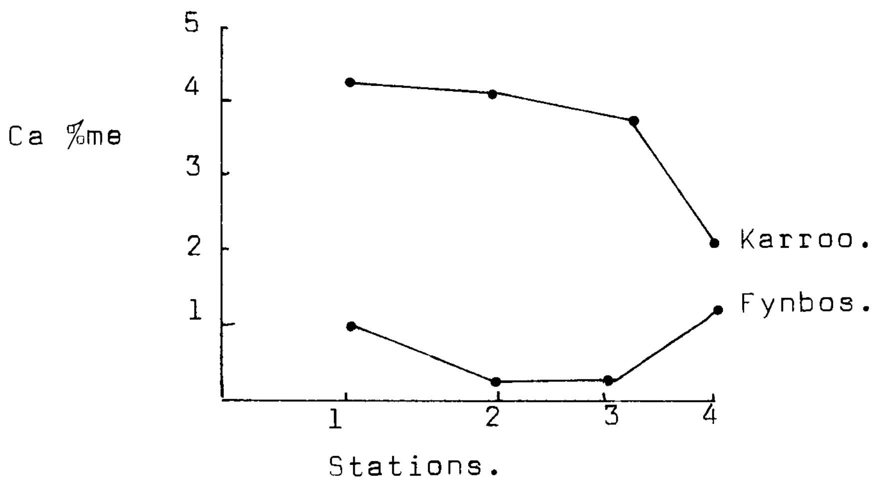
1.) The shale soils of the Karroo are considerably richer in all nutrients than the very oligotrophic sandy soils which support the Fynbos. This prevents premature hypotheses as to whether N or C (or any of the other nutrients) are the the most important nutrients in determining the resulting community on the different soils.

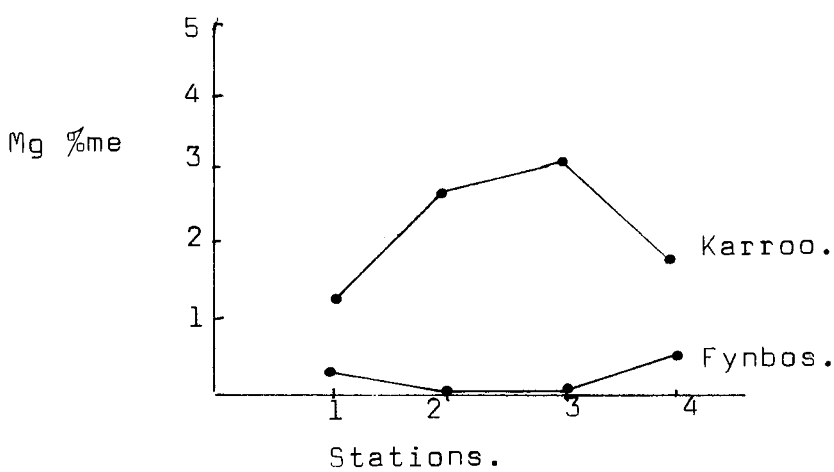
2.) There does not appear to be a generalised curve for the change in nutrient concentration up the Karroo gradient. In the Fynbos the following is a generalised nutrient conc. curve,

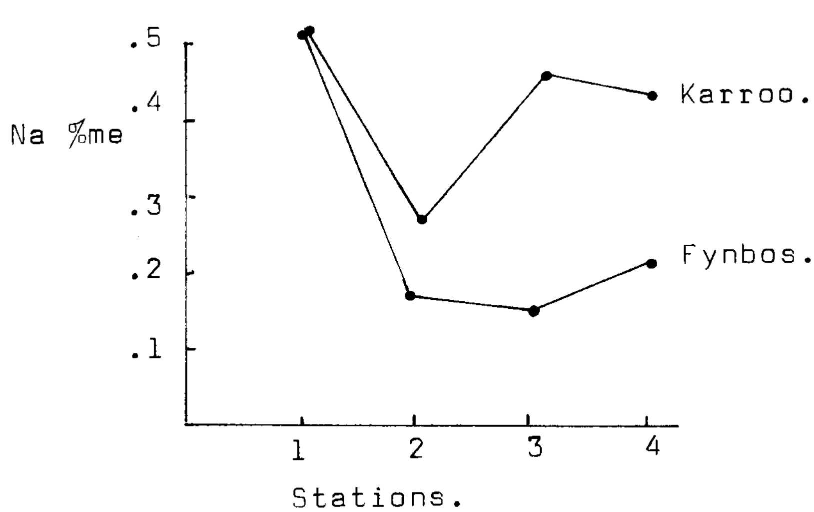


The rock-cover of the Fynbos has the same basic curve and so does the alpha-diversity graph(see Graph 1)indicating the crucial determining factor that nutrients are in the positioning of the different types of Fynbos. Unfortunately, because most of the nutrients of the sandy soil up the Fynbos gradient vary in the same way it can-not be speculated from this data which is the fundamental differential nutrient. The alpha-diversity of the Karroo is best correlated to changes in N and C concentration.

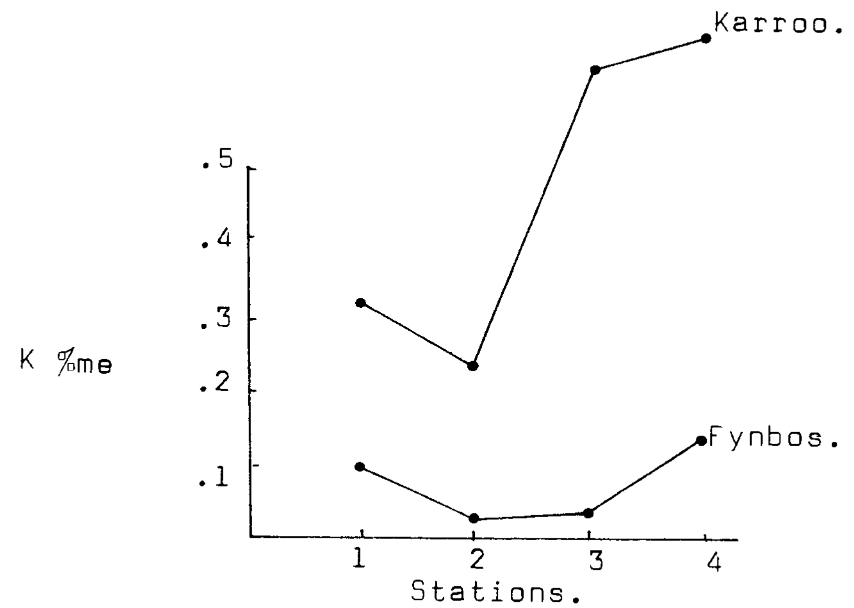
SOIL NUTRIENT DATA.

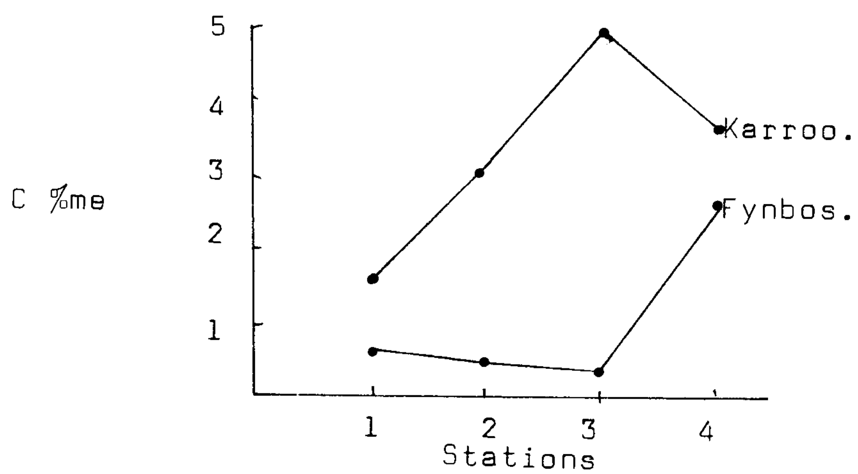


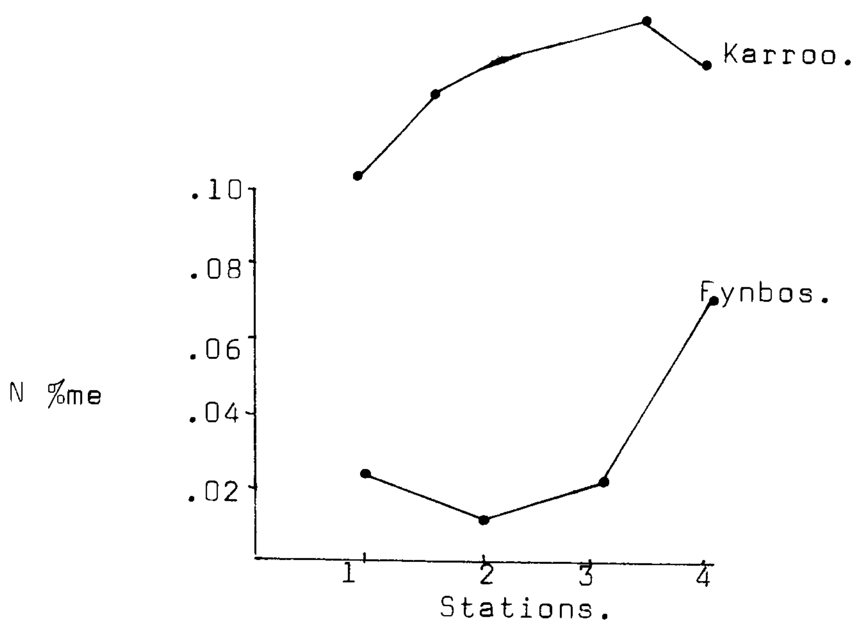




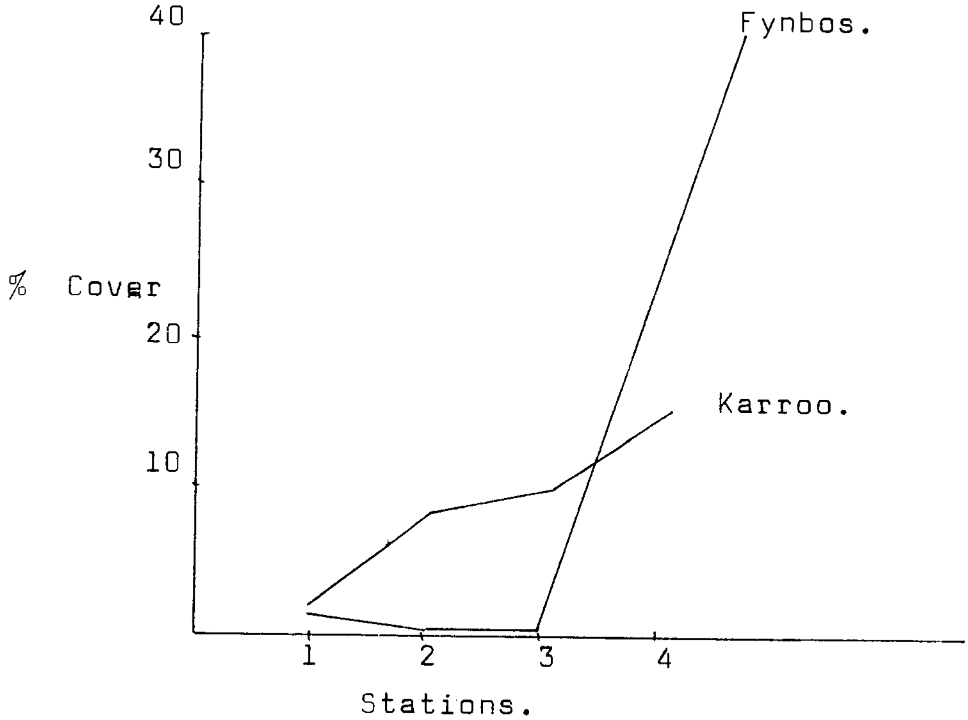
Soil nutrient data.



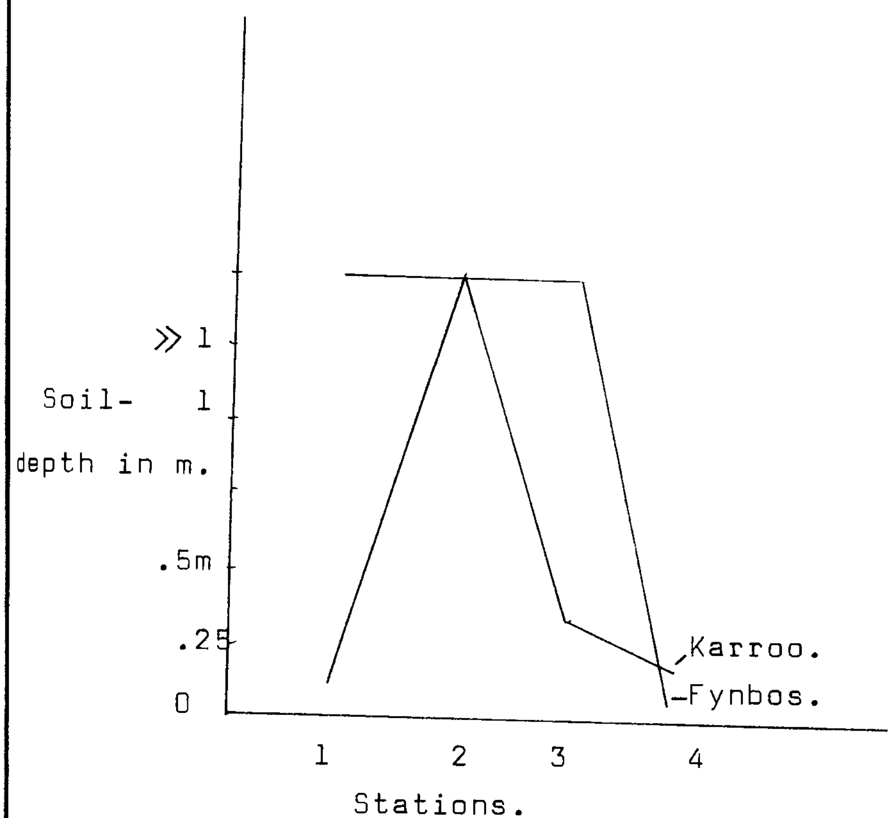




% ROCK) COVER.



SOIL DEPTH.



COMPARISONS RELATING TO FLORISTICS.

1. DIVERSITY (Using Whittaker's Indices (1977).

1.1 Community (Gamma) Diversity.

Total number of species in the Fynbos	113
Total number of species in the Karroo	94
Total number of species	189

There are less than 10% of the species in common (see Venn-diagrams 5,6) indicating that most species must be specialised to compete on only one of the soil-types. Fynbos is well known to have a high community diversity (Taylor 1978). Even in this arid region where only 16 plots each of only $25m^2$ up the 300m gradient were taken, a high number of species were recorded. Surprisingly the Karroo also has a high gamma-diversity.

The Venn-diagrams show how the diversity of the Fynbos drops in comparison to that of the Karroo as the taxa level rises from species to genus to family. The diagrams also show how the groups in common increase relatively as the taxa level rises.

1.2 Alpha (Within plot) Diversity.

Mean number of species per plot,in the Karroo was 25.5 (S.D=5.2) and in the Fynbos was 19.0 (S.D.=7.7).

A Chi-squared Test shows this difference to be significant at the 95% level. This is surprising because Fynbos is well documented in the litterature for having a high alpha-diversity (Taylor 1978) but little is mentioned about the high diversity of the succulent Karroo.

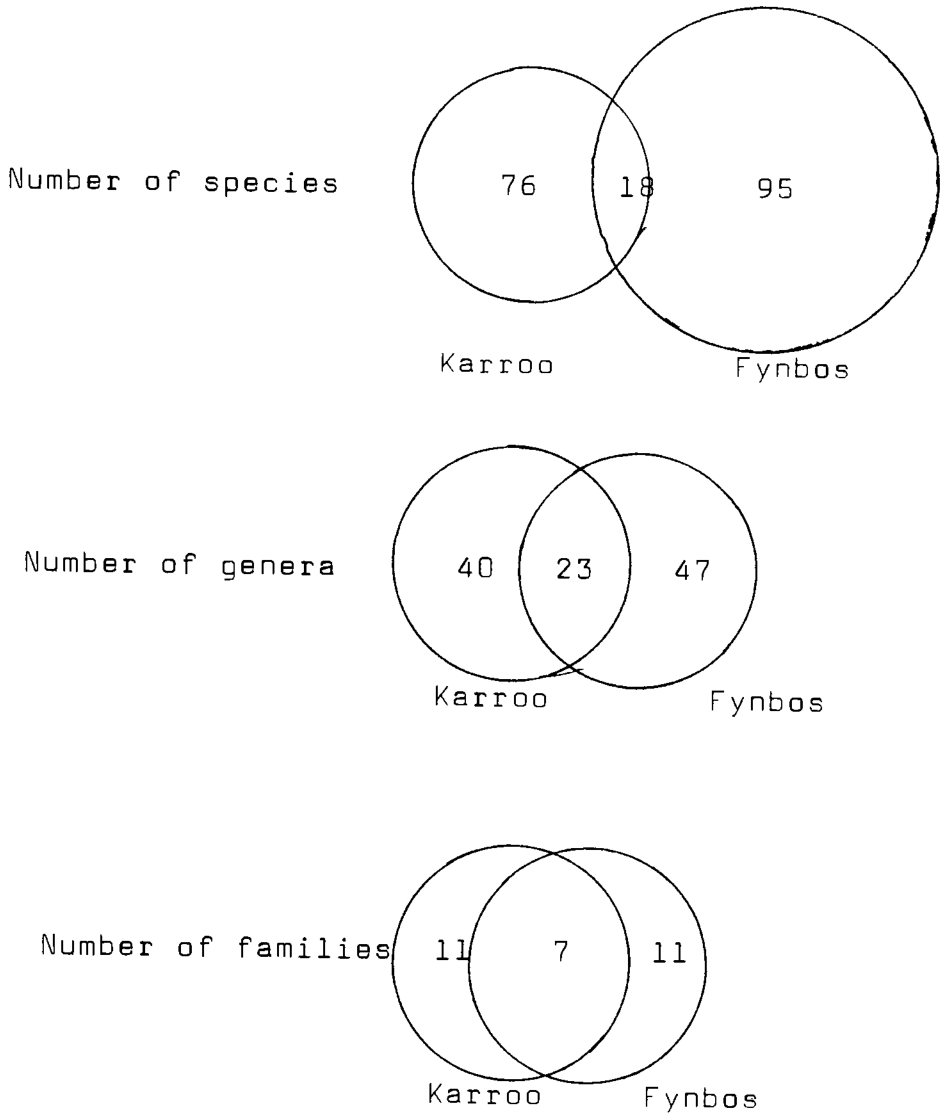
1.3 Beta (Between plot) Diversity.(Graph 1)

As can be seen from the graph most of the Fynbos species occur in only one station (often only one plot).

Comparisons relating to Floristics.

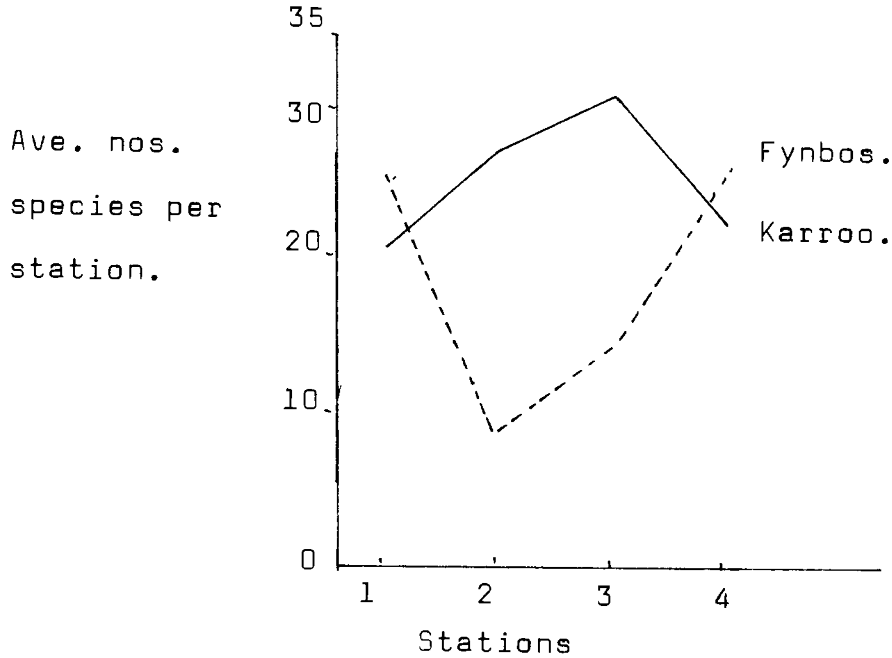
Total number of species = 189

Total number of species in common= 18 =9.5%

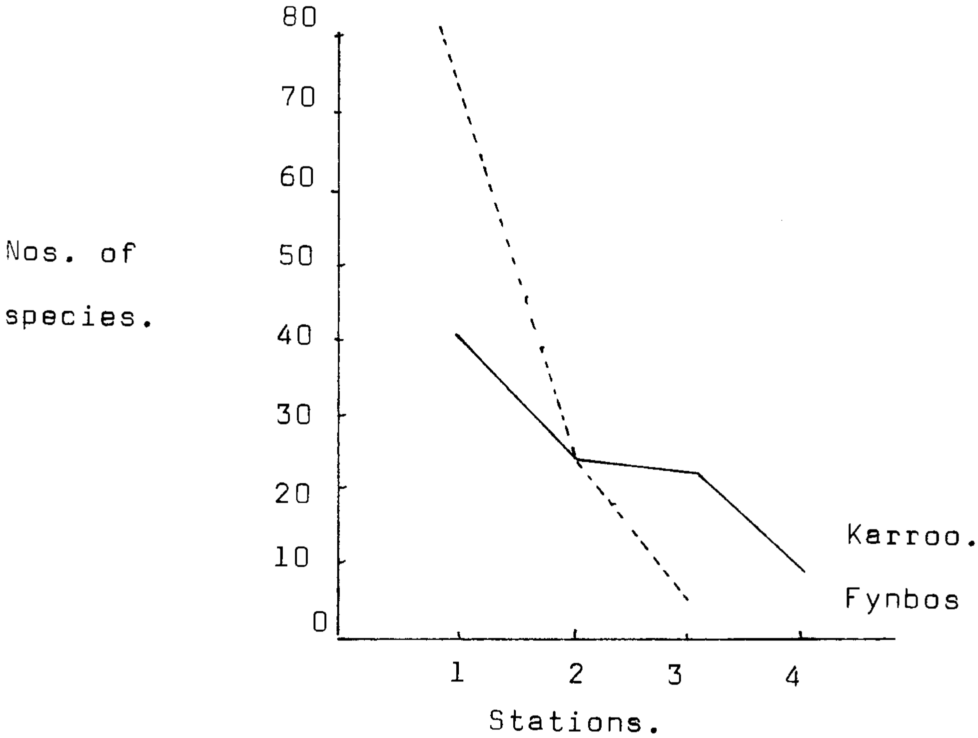


Venn Diagrams Showing GAMMA-DIVERSITY.

COMPARISONS OF DIVERSITY.



Graph 1. Showing Alpha-diversity per station per gradient.



Graph 2. Showing the number of species occurring in 1,2,3,4 stations.

Replacement of species from station to station in the Karroo is more gradual. This is in line with the hypothesis that the Fynbos is an old flora (Axelrod and Raven 1978) and therefore has had a long time to speciate into all the available niches.

If there are ' as many species as limiting factors ' (Williamson 1967, cited in Whittaker 1977) in an area, then the sandy soil of the Fynbos must have many limiting factors. The soil-nutrient data indicates that most nutrients in the sandy soil are present in very low concentrations.

More than 10 species in the Karroo were found in all 4 stations, whereas none were found to do this in the Fynbos. The Fynbos has fewer species per plot than the Karroo but has a greater replacement of species than the Karroo.

The Fynbos seems to have a distinct group of species for each soil (and climate) situation. From the soil-depth data it will be noticed that there is a strong negative correlation between soil-depth and alpha-diversity in the Fynbos. The deep sandy soil cuts the diversity down to a few Restionaceae species. Presumably the deep sandy soil reduces the heterogeniety of the enviroment thus reducing the diversity.

In the Karroo the opposite was noted. The pattern there is, the deeper the soil the higher the diversity. I think this has to do with the water-properties of the shale soils of the Karroo. Deep soil in the shale will facilitate deeper rooting-systems which will improve the plants water absorbing potential.

The deep sandy soil will cause rapid penetration of rain-water which will therefore quickly be lost to the Fynbos system. The rock-cover data shows that in the Fynbos high rock-cover is associated with high alpha-diversity, whereas this effect is not noted in the Karroo.

GROWTH-FORMS.

It has been previously shown that floristically and diversity-wise the vegetation on the two soils is different. Similarly, it will be shown that the growth forms of these species is also very different.

The total-cover(Fig 1) is always higher in the Karroo than the Fynbos, indicating that the Karroo is a more hospitable enviroment. Since the only difference between the two sites is the soil, either the shale soil has a higher water-status or mineral-status, or both. The soil nutrient data shows the shale soil to be far richer in every nutrient than is the sandy soil of the Fynbos. Further analysis is needed to resolve the problem of whether the critical difference between the two soil-types is to do with nutrients or water, as far as the plants are conserned.

Despite the always lower total-cover of the Fynbos it still manages to have the higher gamma-diversity.

The graph(Graph 2) of relative % cover per growth form shows the entirely different strategies of the two vegetation-types. The dominant growth-form in the Karroo is woody-plants (e,g, Elytropappus sp.,Euryops, Relhania) whereas herbs dominate the Fynbos. There is always a succulent and a deciduous element in the Karroo whereas these elements are hardly present in the Fynbos.

Succulence is interpreted as a response to aridity (Ting and Szarek 1975) and deciduousness usually only occurs as a response to an unfavourable season on nutrient rich soils(Monk 1966, Small 1973).

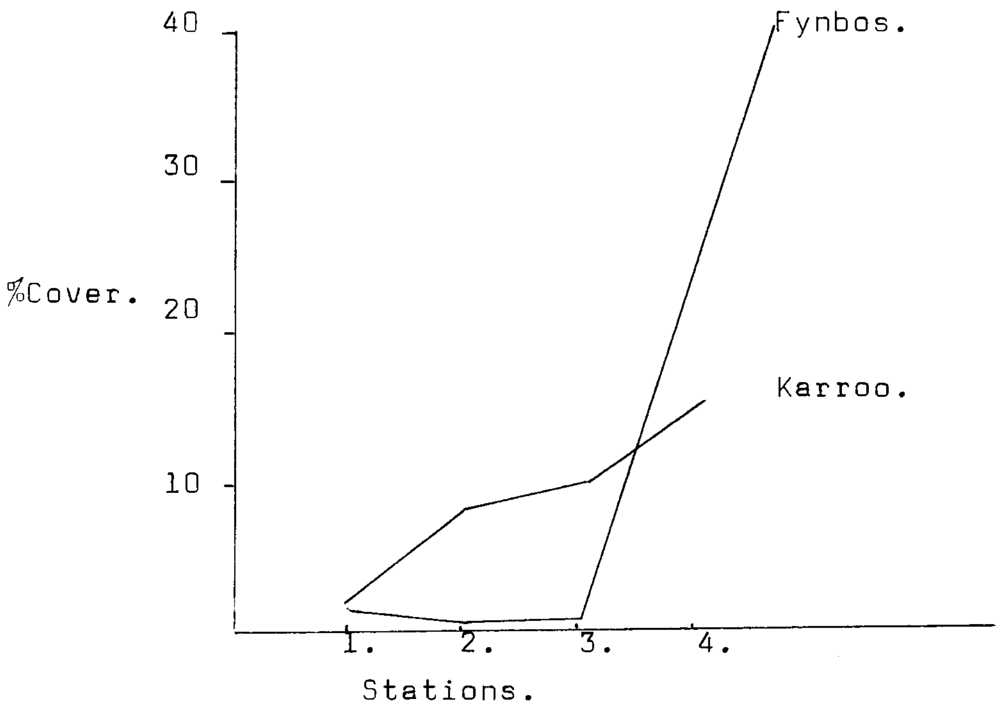


Figure 1. Showing % cover per Station.

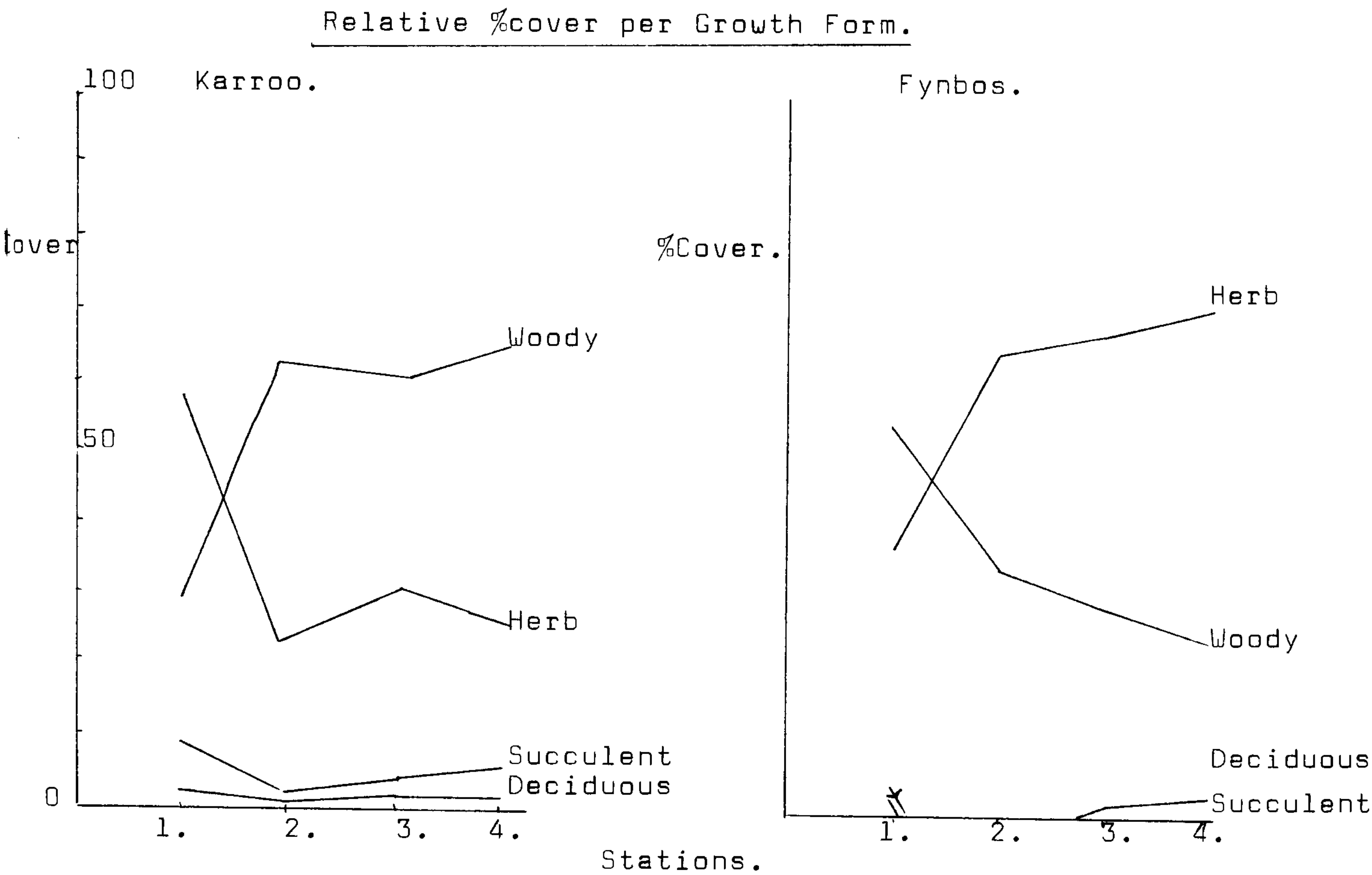


Figure 2. Showing Relative % cover per Growth Form per Station.

These two factors point to water being the critical limiting factor in the shale-soils. This is further emphasised by the trend of increasing total-cover and diversity up the altitudinal gradient, which would match the increase in precipitation one would expect up a slope.

Moore (1980) maintains that the cost of finding and absorbing nutrients for the plant in nutrient poor areas is not competitive for deciduous plants. This could explain why the Fynbos is predominantly evergreen and that the summer deciduous plants only occur on the nutrient-rich shale soils. Beadle (1968) notes that sclerophylly in Australia is associated with nutrient poor soils and that sclerophylly pre-adapts plants to aridity. This theory would explain why sclerophylly is a common attribute of plants in the basically nutrient-poor and dry S.W.Cape.

LEAF-SIZES.

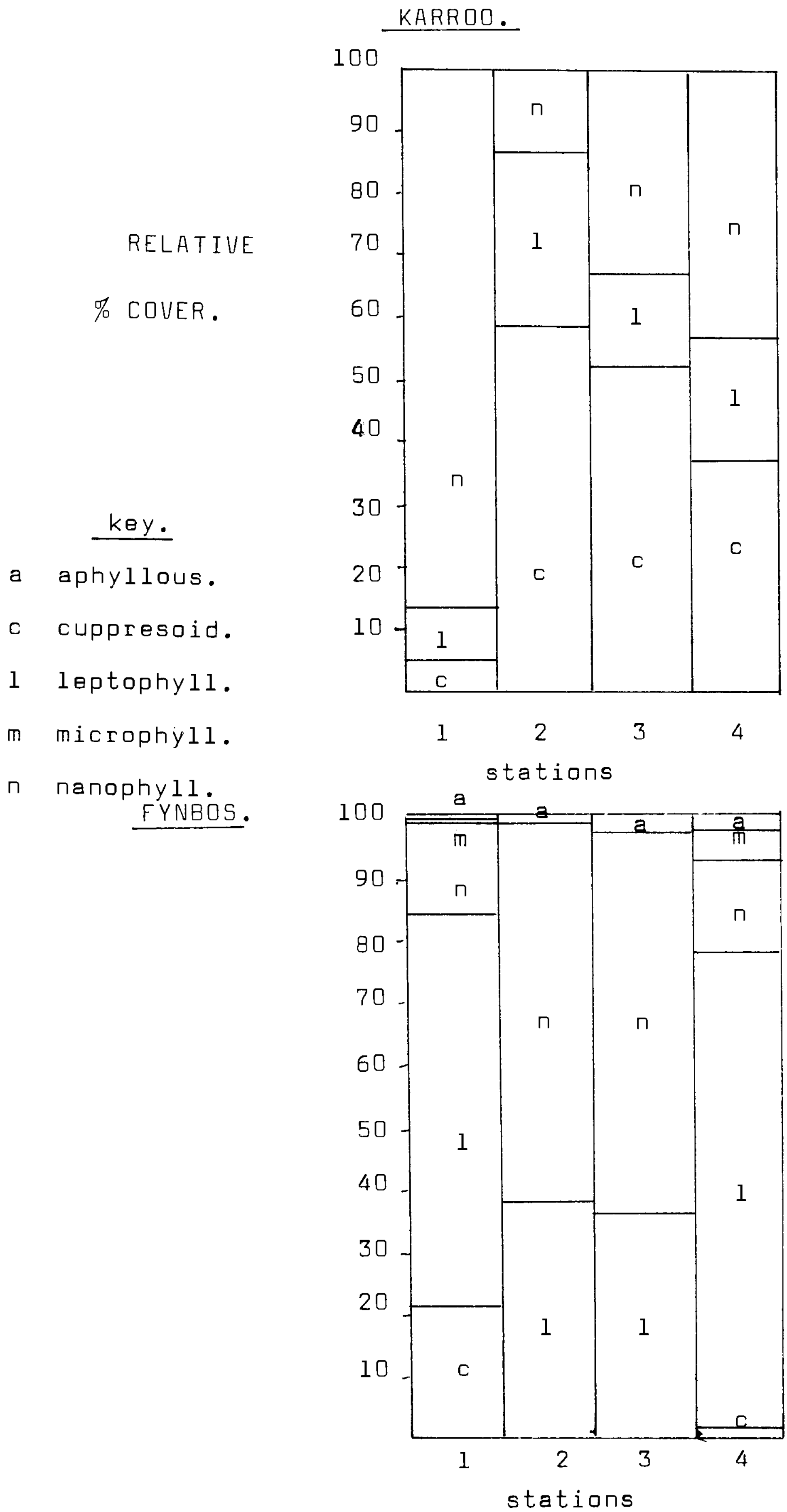
There is a high relative amount of cuppresoid leaves in the Karroo(e.g. Elytropappus sp.). This leaf-structure is associated with restricting transpirational water-loss. Graph 7 shows that leaf-size is generally larger in the Fynbos than in the Karroo. Sclerophyllous leaves (from leptophyllous to micro-phyllous) characteristic f the Fynbos as already mentioned are associated with nutrient-poor soils.

Thus leaf-size classes also point to the fact that in the Karroo competition is associated water-relations whereas in the Fynbos competition is centred around nutrients.

There is a small but always present aphyllous element(usually members of the Fabaceae) element in the Fynbos but not in the Karroo.

There is only a small developement of spinescence in botn sites (e.g. Carissa haematocarpa and Putterlickia pyracantha in the Karroo and Muraltia sp. in the Fynbos)

RELATIVE % COVER PER LEAF CLASS OF THE WOODY ELEMENT.



Graph 3. Showing the relative % cover per leaf-size-class.

CONCLUSIONS.

1.) Fynbos tends to occur on sandy, nutrient-poor soils in arid regions. Succulent-Renoster-Karroo vegetation occurs on the richer shale-soils. Fynbos does occur on shale-bands but usually only in wet areas where presumably the soil is leached of its nutrients.

2.) The vegetation on the two different soils is widely divergent in terms of floristics, diversity and structure. Fynbos has the greater Beta-diversity and Gamma-diversity, whereas the Karroo has the greatest Alpha-diversity.

3.) It is tentatively hypothesized that competition in the Fynbos is centred around nutrients not water and in the Karroo competition is centred around better water-relations-management.

4.) This investigation shows that the communities on the two different substrates are distinct indicating different adaptive strategies to different sets of limiting factors.

ACKNOWLEDGEMENTS.

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APPENDIX.

Species found on the sandy soils (Fynbos.)

Anthospermum

Agothosma capensis

Aspalathus F1

Aspalathus F2

Aspalathus small leaf

Arctotus

Asparagus

Berkheya

Stoebe aethiopica

Cotyledon

Crassula 1

Crassula 2

Lightfootia

Carpochoe 1

Carpochoe vaginata

Cynodon

Disparigo 1

Danthonia diastycha

Diosma hirsuta

Danthonia stricta

Disparigo 2

Digiteria

Deciduous shrub

Decumbent shrub

Dodonea

Dianthus

Danthonia 3

Euchaetis

Eriospermum

Erica pink

Erica 1

Eroeda

Erepsia

Ehrharta wavy leaf

Ehrharta aphylla

Euphorbia burmanii

Erica small

Ficinia 1

Ficinia 2

Felicia

Gazania

Hypodiscus 1

Hypodiscus striatus

Hypodiscus wildenovia

Helichrysum zeyheri

Hermannia

Ifloga

Lightfootia 2

Lasiochloa

Leucospermum

Leptocarpus

Legume 1

Leucodendron saligna
Leucodendron sp.
Legume leaf succulent
Legume stem succulent
Microloma tenuifolia
Metalasia
Gallium
Mesem F2
Mesem F3
Muraltia
Pteronia
Rafnia
Phyllica stipularis
Protea laurifolia
Pentachustus F1
Pentachustus F2
Pentachustus open panicle
Phyllica
Pharnaceum
Prismatocarpus
Rowella
Dimorphotheca
Ruschia F1
Relhania squarosa
Restio fructicosus
Restio curvy small
Ruschia 1
Ruschia 2
Leptocarpus
Restio wavy leaf
Wildenowia striata
Rhus dissecta
Wildenowia arescens
Restio cuspidatus
Restio F1
Restio F2
Restio F3
Centella
Limonium
Selago
Sporobilis
Seururia
Stritholia
Diospyros
Thamnochortus
Thamnochortus F2
Thamnochortus F3
Thamnochortus dichotomous
Tetraria spike
Tetraria cuspidata
Thecium
Tetraria white base
Tetraria tall
Leysera
Chamaraea
Species 1-6

Species found on shale soils.

Anthospermum

Asparagus capensis

Asparagus 1

Aspalathus

Berkheya

Bulbine

Carissa

Cheilanthes

Chrysocoma tenuifolia

Chironia backsifera

Clutia

Cotula

Cotyledon finger

Cotyledon paniculatum

Adromischus

Crassula coltrata

Crassula intermedia

Crassula intermedia 1

Crassula molus

Crassula mucosa

Asparagus africanus

Crassula ciliaris

Crassula perforata

Danthonia

Dodonea

Drosanthemum

Drosanthemum 2

Ehrharta K1

Ehrharta K2

Ehrharta hairy ligule

Euphorbia burmanii

Euphorbia mauritanica

Elytropappus rhinocerotis

Eriospermum

Euclea undulata

Euryops

Ficinia

Felicia

Ficinia ramocysima

Gorteria

Gallenia africana

Grass Broad leaf

Gallium

Geophyte lily

Gasteria

Herb 1

Helichrysum k1

Herb climber

Hermania

Helichrysum teretifolia

Herb wavy leaf

Indigofera

Kedostris

Eriocephalathus

Lasiochloa
Lasiochloa long
Legume shrub
Tulbaghia
Drosanthemum
Mesem small leaf
Muraltia
Melisa
Montinia
Oxalis polyfilla
Oxalis long
Oxalis round
Oxalis purple
Peucedanum
Pteronia
Putterlickia pyrancanthese
Polygala
Pelargonium 1
Pelargonium 2
Pelargonium ring
Pteronia 1
Phyllica
Restio gaudichaudianus
Rosette shrub
Relhania genistifolia
Relhania terete leaf
Relhania sp
Ruschia long leaf
Ruschia cushion
Ruschia small leaf
Relhania squarosa
Ruschia 1
Rhus glauca
Aptosimum
Senecio radicans
Sutera
Urginea
Thecium
Umbel geophyte
Zygophyllum morgzana