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9. RESULTS AND DISCUSSION

9.1 TAXONOMIC OVERVIEW OF SPECIES RECORDED DURING THE SURVEY

During surveys conducted for this study, a total of 457 plant species were recorded. An overview of the number of species per recorded vegetation layer, as well as taxonomic groupings are given in Tables 2 and 3 respectively. A fully annotated species list is given in Appendix 2.

Table 2: Number of species per recorded layer, based on fully-grown specimens (e.g. *Albizia anthelmintica* is calculated as tree, although it may often appear as low shrub).

Layer recorded	***Number of plant species per layer***
Herbs	218
Annual grasses	33
Perennial grasses	52
High shrubs (nano-phanerophytes)	52
Low shrubs (chamaephytes/hemicryptophytes)	84
Trees (micro- and meso-phanerophytes)	18
Total	*457*

It should be noted here that throughout the analysis of data species names, as they are represented in the last update of TURBOVEG, have been kept to avoid potential errors and omissions whilst running various PC-programs. The latest name changes (Craven and Kolberg 1999) are indicated on the species list in Appendix I. Further, based on available literature (Ross 1979, Coates Palgrave 1984, Van Wyk and Van Wyk 1997) as well as identifications by taxonomists of the National Botanical Research Institute in Windhoek, no distinction could be made between the species *Acacia reficiens* Wawra ssp. *reficiens* and *Acacia luederitzii* Engl. var. *luederitzii*. Hence, these two species were treated throughout the study as *A. reficiens*.

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Table 3: Taxonomic grouping of recorded plant species of the study area, indicating number of species per genera in the various families

Family	Number of genera (Species)	Genera (species)
Ophioglossaceae	1 genus (1 species)	*Ophioglossum* (1)
Pteridaceae	1 genus (1 species)	*Cheilanthes* (1)
Marsileaceae	1 genus (1 species)	*Marsilea* (1)
Poaceae	36 genera (84 species)	*Andropogon* (2), *Anthephora* (2), *Aristida* (8), *Bothriochloa* (1), *Brachiaria* (6), *Cenchrus* (1), *Chloris* (1), *Coelachyrum* (1), *Craspedorhachis* (1), *Cymbopogon* (1), *Cynodon* (1), *Dactyloctenium* (2), *Dichanthium* (1), *Digitaria* (3), *Diplachne* (1), *Eleusine* (1), *Enneapogon* (3), *Eragrostis* (16), *Fingerhuthia* (1), *Heteropogon* (2), *Melinis* (3), *Microchloa* (1), *Monelytrum* (1), *Oropetium* (1), *Panicum* (3), *Pogonarthria* (2), *Schmidtia* (2), *Setaria* (2), *Sorghum* (1), *Sporobolus* (3), *Stipagrostis* (2), *Tragus* (2), *Tricholaena* (1), *Triraphis* (1), *Urochloa* (3), *Willkommia* (1)
Cyperaceae	6 genera (9 species)	*Bulbostylis* (1), *Cyperus* (4), *Kyllinga* (1), *Kyllingiella* (1), *Mariscus* (1), *Monandrus* (1)
Commelinaceae	1 genus (3)	*Commelina* (3)
Colchicaceae	2 genera (2 species)	*Gloriosa* (1), *Ornithoglossum* (1)
Asphodelaceae	1 genus (2 species)	*Aloe* (2)
Hyacinthaceae	2 genera (2 species)	*Urginea* (1), *Lindneria* (1)
Asparagaceae	1 genus (3 species)	*Asparagus* (3)
Amaryllidaceae	2 genera (2 species)	*Boophane* (1), *Nerine* (1)
Velloziaceae	1 genus (1 species)	*Xerophyta* (1)
Iridaceae	2 genera (3 species)	*Gladiolus* (1), *Lapeirousia* (2)
Santalaceae	1 genus (1 species)	*Thesium* (1)
Olacaceae	1 genus (2 species)	*Ximenia* (2)
Polygonaceae	1 genus (2 species)	*Oxygonum* (2)
Chenopodiaceae	1 genus (2 species)	*Chenopodium* (2)
Amaranthaceae	10 genera (12 species)	*Achyranthes* (2), *Aerva* (1), *Alternanthera* (1), *Amaranthus* (1), *Hermbstaedtia* (2), *Kyphocarpa* (1), *Leucosphaera* (1), *Nelsia* (1), *Pupalia* (1), *Sericorema* (1)
Nyctaginaceae	3 genera (4 species)	*Boerhavia* (2), *Commicarpus* (1), *Phaeoptilum* (1)
Gisekiaceae	1 genus (2 species)	*Gisekia* (2)
Molluginaceae	2 genera (5 species)	*Limeum* (4), *Mollugo* (1)
Aizoaceae	3 genera (3 species)	*Aizoon* (1), *Tetragonia* (1), *Trianthema* (1)
Portulacaceae	2 genera (6 species)	*Portulaca* (2), *Talinum* (4)
Caryophyllaceae	1 genus (1 species)	*Polycarpaea* (1)
Illecebraceae	1 genus (1 species)	*Pollichia* (1)
Brassicaceae	2 genera (2 species)	*Erucastrum* (1), *Lepidium* (1)
Capparaceae	3 genera (11 species)	*Boscia* (2), *Cleome* (6), *Maerua* (3)
Crassulaceae	2 genera (3 species)	*Crassula* (1), *Kalanchoe* (2)
Vahliaceae	1 genus (1 species)	*Vahlia* (1)
Fabaceae	28 genera (57 species)	*Acacia* (12), *Albizia* (1), *Chamaecrista* (2), *Crotalaria* (6), *Cullen* (1), *Dichrostachys* (1), *Dolichos* (1), *Elephantorrhiza* (1), *Indigastrum* (1), *Indigofera* (7), *Lablab* (1), *Lessertia* (1), *Lonchocarpus* (1), *Lotononis* (2), *Macrotyloma* (1), *Mundulea* (1), *Neorautanenia* (1), *Otoptera* (1), *Peltophorum* (1), *Ptycholobium* (1), *Requienia* (1), *Rhynchosia* (3), *Rothia* (1), *Senna* (1), *Sesbania* (1), *Tephrosia* (4), *Tylosema* (1), *Zornia* (1)
Geraniaceae	1 genus (1 species)	*Monsonia* (1)
Oxalidaceae	1 genus (1 species)	*Oxalis* (1)
Zygophyllaceae	1 genus (1 species)	*Tribulus* (1)
Simaroubaceae	1 genus (1 species)	*Kirkia* (1)
Burseraceae	1 genus (6 species)	*Commiphora* (6)
Malpighiaceae	1 genus (1 species)	*Triaspis* (1)
Polygalaceae	1 genus (1 species)	*Polygala* (1)
Euphorbiaceae	7 genera (10 species)	*Acalypha* (2), *Cephalocroton* (1), *Chamaesyce* (2), *Croton* (1), *Euphorbia* (1), *Jatropha* (1), *Phyllanthus* (2)
Anacardiaceae	3 genera (5 species)	*Lannea* (1), *Ozoroa* (2), *Rhus* (2)

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Family	Number of genera (Species)	Genera (species)
Celastraceae	1 genus (1 species)	*Maytenus* (1)
Rhamnaceae	2 genera (3 species)	*Helinus* (2), Ziziphus (1)
Vitaceae	1 genus (4 species)	*Cyphostemma* (4)
Tiliaceae	2 genera (7 species)	*Corchorus* (1), *Grewia* (6)
Malvaceae	5 genera (12 species)	*Abutilon* (1), *Gossypium* (1), *Hibiscus* (7), *Pavonia* (1), *Sida* (2)
Sterculiaceae	4 genera (9 species)	*Dombeya* (1), *Hermannia* (5), *Melhania* (2), *Waltheria* (1)
Cactaceae (alien invasive)	1 genus (1 species)	*Opuntia* (1)
Thymelaeaceae	1 genus (1 species)	*Gnidia* (1)
Combretaceae	2 genera (5 species)	*Combretum* (3), *Terminalia* (2)
Ebenaceae	1 genus (1 species)	*Euclea* (1)
Oleaceae	1 genus (1 species)	*Olea* (1)
Periplocaceae	1 genus (2 species)	*Raphionacme* (2)
Asclepiadaceae	6 genera (9 species)	*Gomphocarpus* (1), *Marsdenia* (2), *Pentarrhinum* (2), *Pergularia* (1), *Sarcostemma* (1), *Stapelia* (2)
Convolvulaceae	7 genera (18 species)	*Convolvulus* (1), *Evolvulus* (1), *Ipomoea* (12), *Jacquemontia* (1), *Merremia* (1), *Seddera* (1), *Xenostegia* (1)
Boraginaceae	3 genera (7 species)	*Cordia* (1), *Ehretia* (1), *Heliotropium* (5)
Verbeneceae	3 genera (5 species)	*Chascanum* (1), *Lantana* (3), *Priva* (1)
Lamiaceae	8 genera (11 species)	*Acrotome* (2), *Becium* (1), *Clerodendrum* (2), *Hemizygia* (1), *Leucas* (2), *Ocimum* (1), *Plectranthus* (1), *Tinnea* (1)
Solanaceae	3 genera (13 species)	*Lycium* (3), *Solanum* (9), *Withania* (1)
Scrophulariaceae	8 genera (10 species)	*Aptosimum* (3), *Craterostigma* (1), *Hebenstretia* (1), *Hiernia* (1), *Lindernia* (1), *Peliostomum* (1), *Selago* (1), *Striga* (1)
Bignoniaceae	3 genera (3 species)	*Catophractes* (1), *Kigelia* (1), *Rhigozum* (1)
Pedaliaceae	3 genera (4 species)	*Harpagophytum* (1), *Pterodiscus* (1), *Sesamum* (2)
Acanthaceae	11 genera (20 species)	*Barleria* (3), *Blepharis* (4), *Dicliptera* (1), *Hypoestes* (1), *Justicia* (1), *Megalochlamys* (1), *Monechma* (4), *Peristrophe* (1), *Petalidium* (2), *Ruellia* (1), *Ruelliopsis* (1)
Rubiaceae	3 genera (5 species)	*Ancylanthos* (1), *Kohautia* (3), *Oldenlandia* (1)
Cucurbitaceae	8 genera (11 species)	*Acanthosicyos* (1), *Citrullus* (1), *Corallocarpus* (1), *Cucumis* (4), *Dactyliandra* (1), *Momordica* (1), *Trochomeria* (1), *Zehneria* (1)
Asteraceae	27 genera (38 species)	*Artemisia* (1), *Bidens* (1), *Calostephane* (1), *Dicoma* (3), *Eriocephalus* (1), *Felicia* (3), *Flaveria* (1), *Geigeria* (3), *Helichrysum* (3), *Hirpicium* (1), *Kleinia* (1), *Laggera* (1), *Launaea* (1), *Melanthera* (1), *Nidorella* (1), *Ondetia* (1), *Osteospermum* (1), *Pechuel-Loeschea* (1), *Pegolettia* (2), *Platycarpha* (1), *Schkuhria* (1), *Senecio* (1), *Tagetes* (1), *Tarchonanthus* (1), *Ursinia* (1), *Vernonia* (2), *Xanthium* (2)

9.2. PHYTOSOCIOLOGICAL ANALYSES

A classification with TWINSPAN (on MEGATAB) of the entire data set (467 relevés and 457 species) resulted in 53 subdivisions, which were, on inspection and re-arrangement of species sequences on the table, grouped together into 14 definable vegetation associations (Tables 26 to 29 in Appendix 1.2.). These associations, grouped according to the first TWINSPAN division, were further analysed using PCA (Figures 12 and 13) and DCA (Figures 14 and 15) (with PC-ORD), to detect the main underlying environmental factors influencing these vegetation units. These appeared to be primarily soil types, with rainfall gradients and geology playing a relatively strong role as well.

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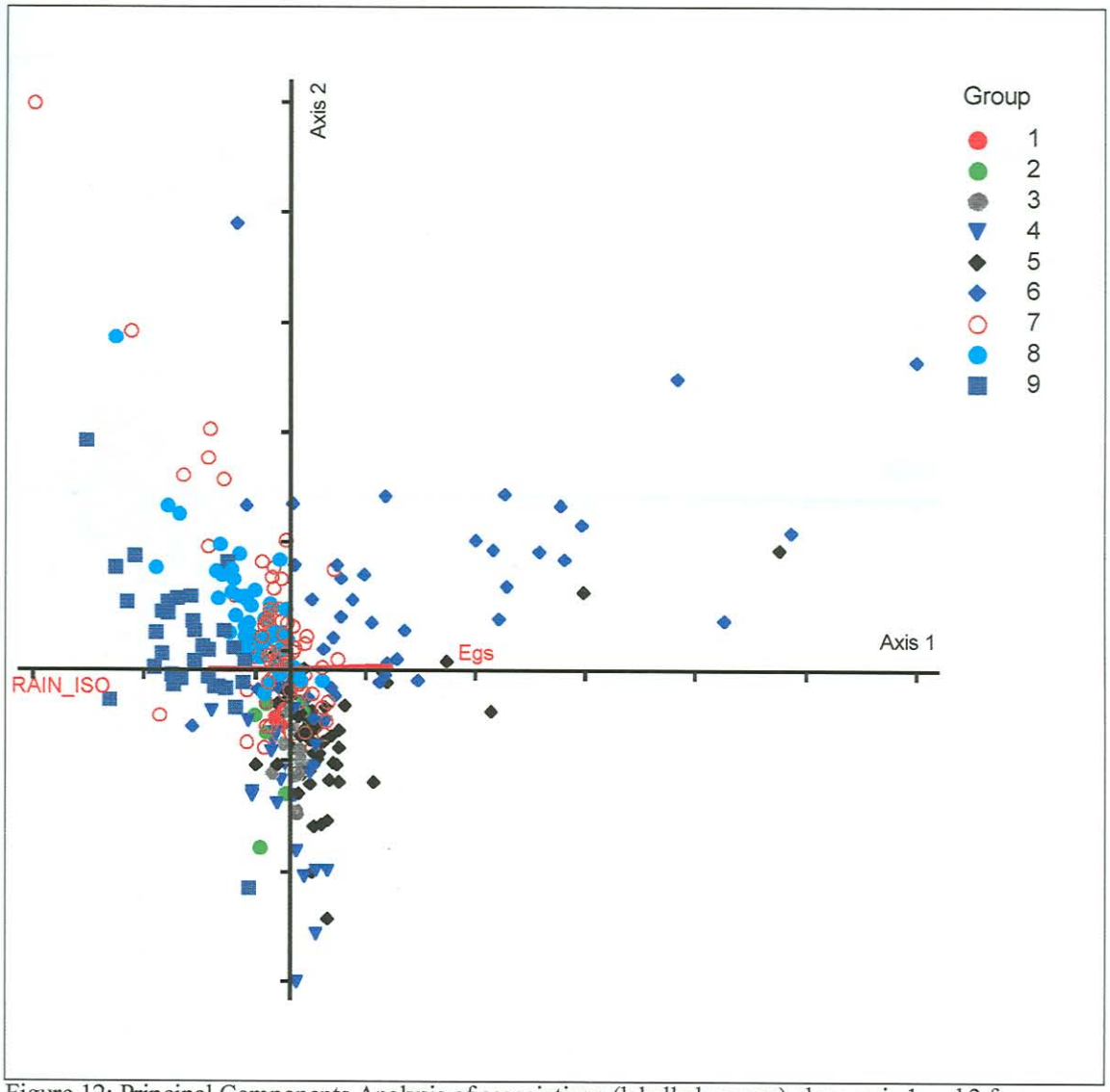

Figure 12: Principal Components Analysis of associations (labelled groups) along axis 1 and 2 for Associations 1 to 9. Egs refers to the geology of the Damara Sequence; RAIN_ISO refers to the long-term mean annual rainfall.

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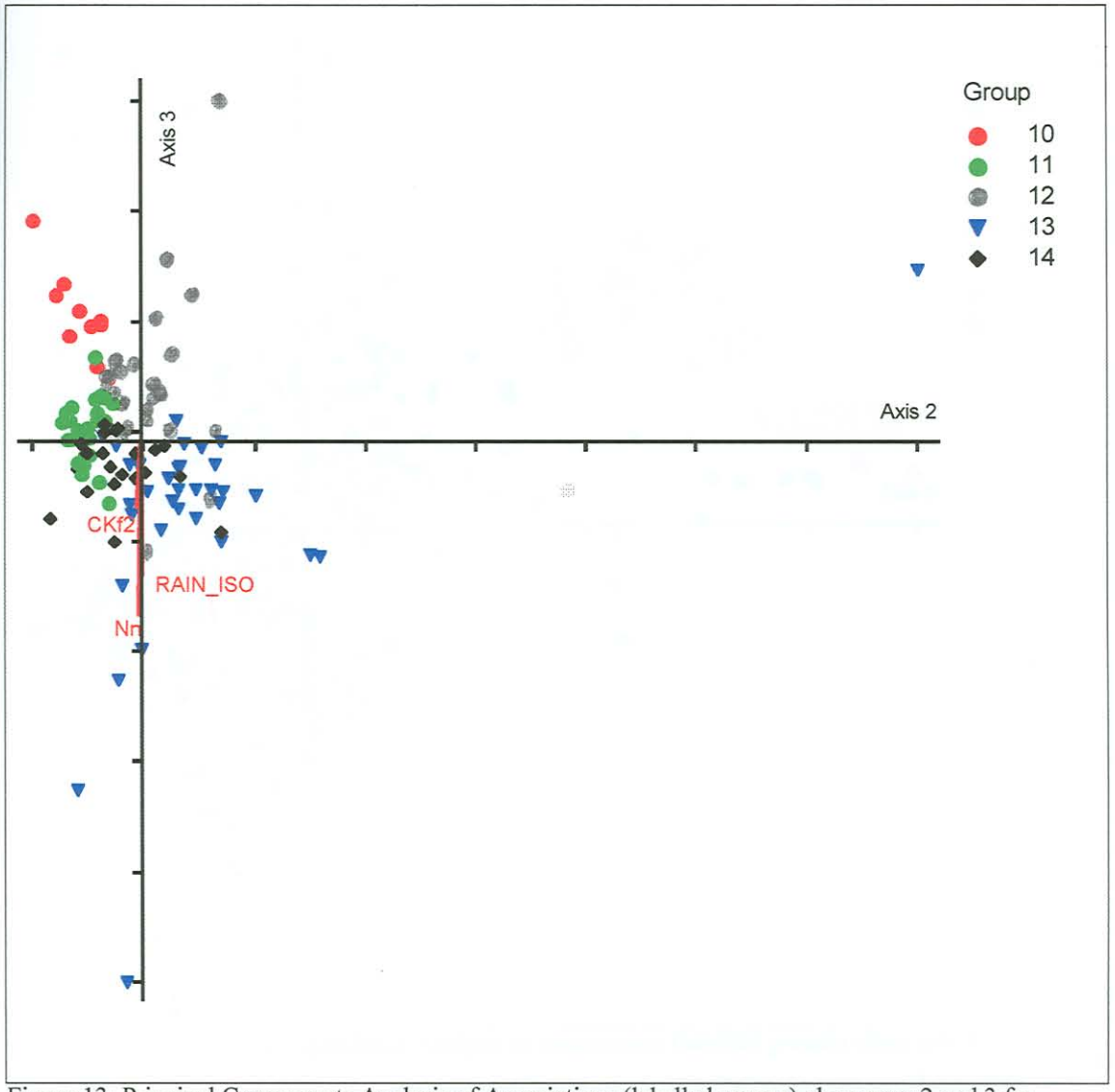

Figure 13: Principal Components Analysis of Associations (labelled groups) along axes 2 and 3 for Associations 10 to 14. CKf2 are leptic Regosols, Nn is part of the Damara Sequence, and RAIN_ISO refers to mean long-term annual rainfall.

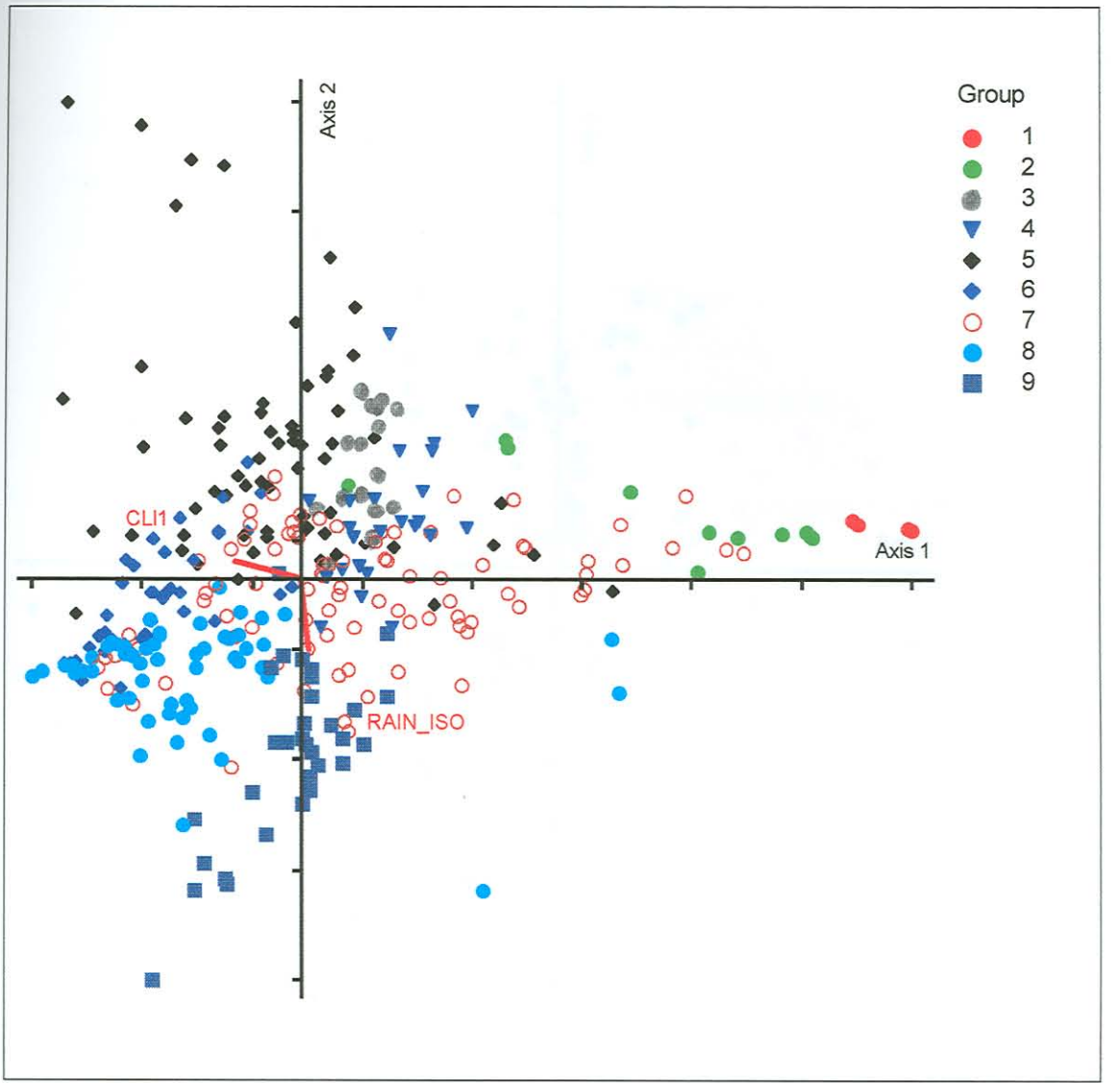

Figure 14: Detrended Correspondence Analysis of associations (labelled groups) along axis 1 and 2 for Associations 1 to 9. CL11 are chromic Cambisols, RAIN_ISO refers to mean long-term annual rainfall.

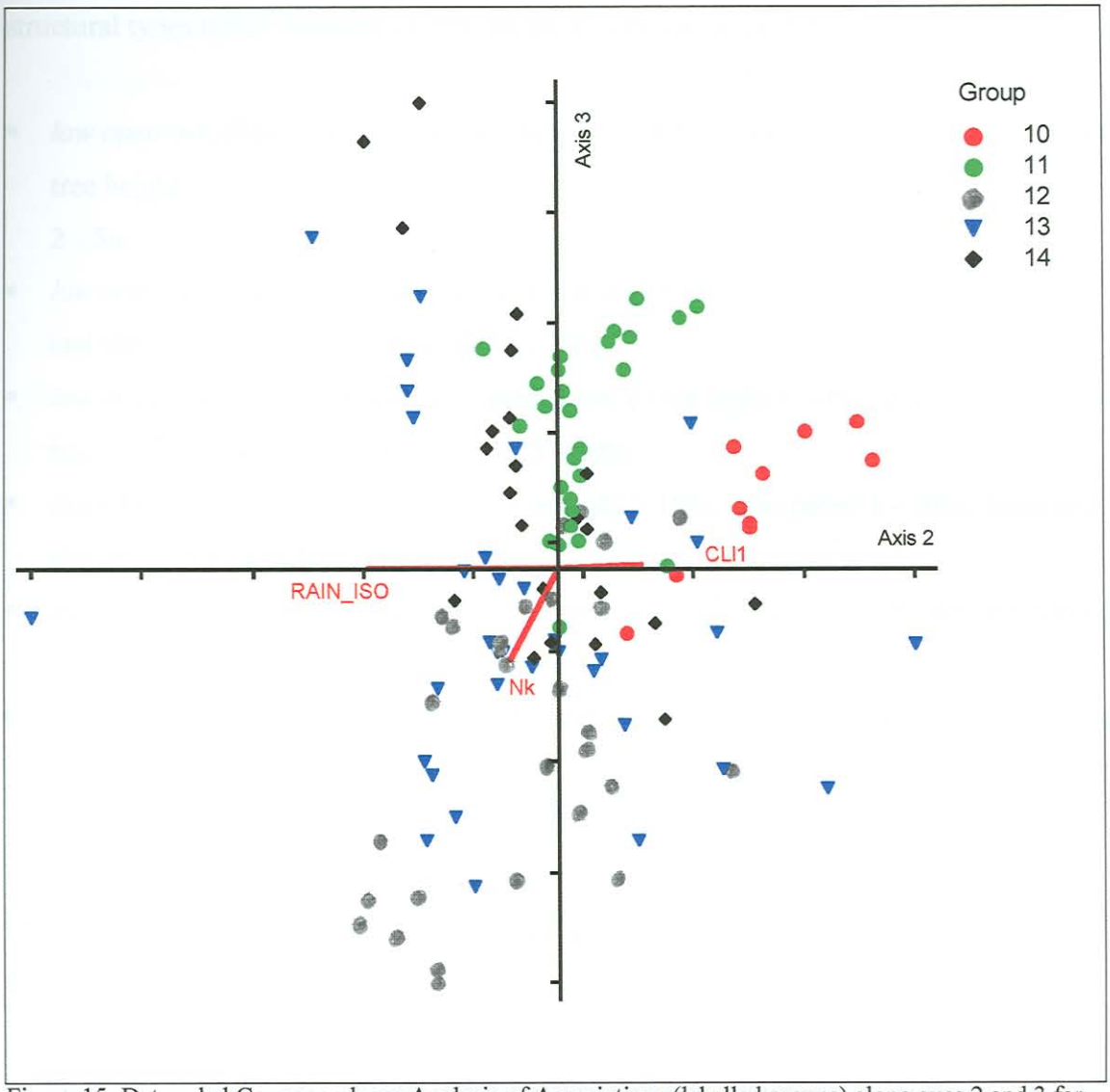

Figure 15: Detrended Correspondence Analysis of Associations (labelled groups) along axes 2 and 3 for Associations 10 to 14. RAIN_ISO refers to mean long-term annual rainfall, Nk is part of the Damara sequence, CLl1 are chromic Cambisols.

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Vegetation associations were additionally characterised according to the following structural types (after Strohbach 1998, adapted from Edwards 1983):

- *low open woodland* : shrub cover (>1m high) < 10%; tree cover 0.1 - 1%; dominant tree height 2 - 5m
- *low semi-open bushland*: shrub cover (>1m high) > 10%; tree cover 1 - 10%; trees and shrubs 2 - 5m; shrub cover 10 - 25%
- *low moderately closed bushland:* shrub cover (>1m high) > 10%; tree cover 1 - 10%; trees and shrubs 2 - 5m; shrub cover 25 - 50%
- *low closed bushland:* shrub cover (>1m high) > 10%; tree cover 1 - 10%; trees and shrubs 2 - 5m; shrub cover 50 - 75%
- *low closed shrubland:* tree cover < 1%; shrub cover 10 - 100%; dominant shrub height < 0.5m
- *tall sparse shrubland:* tree cover < 1%; shrub cover 0.1 - 10%; dominant shrub height 1 - 2m

Following the TWINSPAN Classification (Figure 16), the savanna of the study area can be divided into:

1. The *Acacia mellifera - Boscia albitrunca* bushlands, which occur largely on soils of the Omingonde Formation, with smaller inclusions of granites and quartzes as well as localised areas of undifferentiated metamorphic rocks and calcretes of the Damara Sequence. Long-term average rainfall ranges from 350 - 490 mm p.a., with the predominant part of this vegetation group at a rainfall below 400 mm.

Within this vegetation group, 9 vegetation associations have been identified, viz.:

- Association 1: *Catophractes alexandri - Willkommia sarmentosa* tall sparse shrubland
- Association 2: *Boscia albitrunca - Eragrostis cylindriflora* low open woodland
- Association 3: *Acacia mellifera - Leucosphaera bainesii* low closed shrubland with patches of low open woodland
- Association 4: *Acacia mellifera - Eragrostis rotifer* low moderately closed bushland

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- Association 5: *Acacia mellifera - Monechma genistifolium* low semi-open bushland
- Association 6: *Albizia anthelmintica - Stipagrostis uniplumis* low open woodland
- Association 7: *Acacia mellifera - Aristida congesta* low semi-open bushland
- Association 8: *Acacia erioloba - Stipagrostis uniplumis* low semi-open bushland
- Association 9: *Lonchocarpus nelsii - Eragrostis rigidior* low moderately closed bushland and transitional to vegetation group 2

2. The *Acacia mellifera - Dichrostachys cinerea* bushlands, occurring mostly on undifferentiated limestone, dolomite and calcrete of the Damara Sequence, with small inclusions of deeper Kalahari sands. Long-term average rainfall ranges from 410 to 560 mm p.a., with the exception of the *Boscia foetida - Leucosphaera bainesii* bushland, which occurs at a lower rainfall of 350 - 370 mm on patches of surface calcrete.

This vegetation group consists of following 5 vegetation associations:

- Association 10: *Boscia foetida - Leucosphaera bainesii* low semi-open bushland
- Association 11: *Acacia mellifera - Stipagrostis hirtigluma* low moderately closed bushland
- Association 12: *Acacia mellifera - Cenchrus ciliaris* low moderately closed bushland
- Association 13: *Dichrostachys cinerea - Cenchrus ciliaris* low moderately closed bushland
- Association 14: *Terminalia prunioides - Croton gratissimus* low closed bushland

The different vegetation associations and their main environmental attributes are summarised below in Tables 4-6:

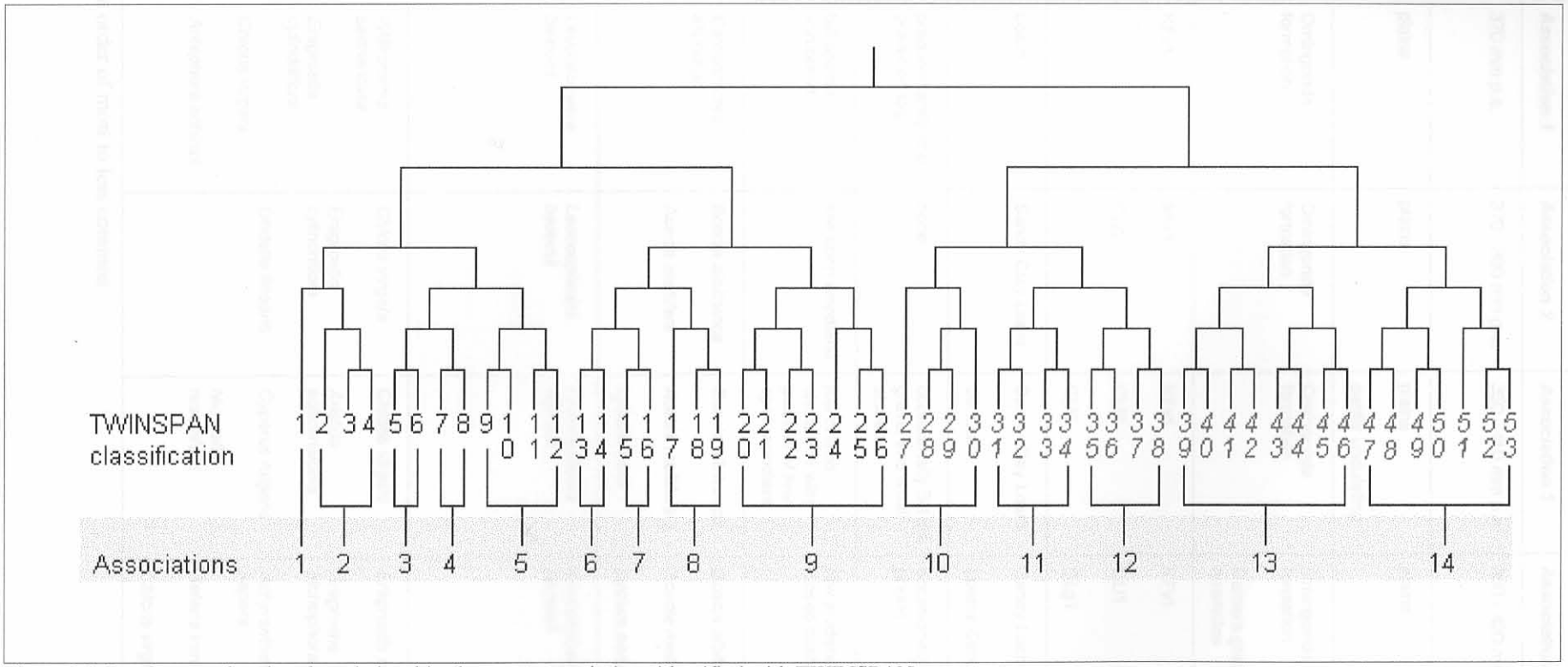

Figure 16: Dendogram showing the relationships between associations identified with TWINSPAN

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Table 4: Overview of Vegetation Associations 1-5:

Criteria	*Association 1*	*Association 2*	*Association 3*	*Association 4*	*Association 5*
Long-term average rainfall	370 mm p.a.	370 - 380 mm p.a.	350 - 410 mm p.a.	360 - 420 mm p.a.	350 - 450 mm p.a.
Landform *	plains	plains	plains gently undulating	plains	plains
Geology *	Omingonde formation	Omingonde formation	Omingonde formation	Omingonde formation Damara granites & quartzites	Omingonde formation Damara granites
Soil types *	KFv1	KFv1 CLI2	KFv1 CLI2 CLI1	KFv1 CLI1 CLg1	CLI1 CLI2
Soil surface texture *	Loam	Sandy Clay Loam	Sandy Clay Loam Silt Loam	Sandy Loam Loamy Sand	Sandy Loam Loamy Sand
Gravel, stoniness & rockiness	predominantly fine gravel on top	none	occasionally 5-15% gravel and small stones	occasionally 2-5% gravel	occasionally 5-15% gravel to large stones
Vegetation structure	tall sparse shrubland	low open woodland	low closed shrubland with patches of low open woodland	low moderately closed bushland	low semi-open bushland
Most consistent trees and high shrubs	*Catophractes alexandri*	*Boscia albitrunca* *Acacia mellifera*	*Boscia albitrunca* *Acacia mellifera* *Lycium eenii*	*Boscia albitrunca* *Acacia mellifera* *Lycium eenii*	*Acacia mellifera* *Lycium eenii*
Most consistent low shrubs	*Leucosphaera bainesii*	*Leucosphaera bainesii*	*Leucosphaera bainesii*	*Leucosphaera bainesii*	*Monechma genistifolium* *Leucosphaera bainesii*
Most consistent grasses and herbs	*Willkommia sarmentosa* *Eragrostis cylindriflora* *Chloris virgata* *Antephora schinzii*	*Chloris virgata* *Eragrostis cylindriflora* *Ondetia linearis*	*Chloris virgata* *Aristida adscensionis* *Cyperus fulgens* *Nidorella resedifolia*	*Eragrostis rotifer* *Eragrostis trichophora* *Achyranthes aspera* *Setaria verticillata* *Chloris virgata*	*Enneapogon cenchroides* *Aristida adscensionis* *Cenchrus ciliaris* *Stipagrostis uniplumis*

* Criteria in order of most to less common

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Table 5: Overview of Vegetation Associations 6-9:

Criteria	*Association 6*	*Association 7*	*Association 8*	*Association 9*
Long-term average rainfall	350 - 440 mm p.a.	350 - 410 mm p.a.	360 - 440 mm p.a.	400 - 490 mm p.a.
Landform *	plains	plains	plains	plains low gradient footslopes
Geology *	Omingonde formation Damara granites	Omingonde formation Damara granites & quartzites	Omingonde formation	Damara calcrete and undifferentiated metamorphic rock Damara quartzites
Soil types *	CLl1	CLl1 CLl2	CLl1 KFv1	CKg1 CLl2 CLg1
Soil surface texture *	Sandy Loam Loam	Sandy Clay Loam Loamy Sand	Loamy Sand Sandy Loam	Loamy Sand Sandy Loam
Gravel, stoniness & rockiness	often 5-15% gravel, occasionally 2-5% stones & rock	often 5-15% gravel, seldom 2-5% stones	occasionally 2-5% gravel and small stones	occasionally 2-5% gravel and small stones
Vegetation structure	low open woodland	low semi-open bushland	low semi-open bushland	low moderately closed bushland
Most consistent trees and high shrubs	*Acacia mellifera* *Albizia anthelmintica* *Lycium eenii*	*Lycium eenii* *Acacia mellifera* *Boscia albitrunca*	*Acacia mellifera* *Acacia erioloba* *Boscia albitrunca* *Grewia flava*	*Dichrostachys cinerea* *Acacia mellifera* *Grewia flava* *Grewia bicolor* *Lonchocarpus nelsii*
Most consistent low shrubs	*Monechma genistifolium* *Pupalia lappacea* *Ptycholobium biflorum*	*Ptycholobium biflorum* *Barleria lanceolata* *Leucosphaera bainesii* *Indigofera rautanenii*	*Otoptera burchellii*	*Hibiscus elliottiae* *Pupalia lappacea*
Most consistent grasses and herbs	*Stipagrostis uniplumis* *Enneapogon cenchroides* *Evolvolus alsinoides*	*Stipagrostis uniplumis* *Aristida congesta* *Enneapogon cenchroides* *Talinum arnotii* *Evolvolus alsinoides*	*Stipagrostis uniplumis* *Talinum arnotii* *Melinis repens ssp grandiflora* *Pogonarthria fleckii* *Urochloa brachyura*	*Eragrostis rigidior* *Pogonarthria fleckii* *Eragrostis trichophora* *Evolvolus alsinoides* *Aristida congesta*

* Criteria in order of most to less common

Table 6: Overview of Vegetation Associations 10-14:

Criteria	*Association 10*	*Association 11*	*Association 12*	*Association 13*	*Association 14*
Long-term average rainfall	350 - 370 mm p.a.	470 - 530 mm p.a.	410 - 530 mm p.a.	420 - 560 mm p.a.	420 - 530 mm p.a.
Landform *	plains gently undulating to undulating plains	plains	plains gently undulating to undulating ridges	plains gently undulating to undulating ridges	gently undulating ridges low gradient footslopes
Geology *	Damara calcrete and undifferentiated metamorphic rock Omingonde formation	Damara calcrete and undifferentiated metamorphic rock Kalahari sands on calcareous horizon	Damara calcrete and undifferentiated metamorphic rock Damara quartzites Kalahari sands on calcareous horizon	Damara calcrete and undifferentiated metamorphic rock Damara quartzites Damara limestone & dolomite	Damara quartzites Damara calcrete and undifferentiated metamorphic rock
Soil types *	CLl1	CKl1 CKg1	CKg1 CKl1	CKg1 CKf2 CKl1	CKg1 CKf2 CKl1 CLg1
Soil surface texture *	Loam Sandy Clay Loam	Sandy Loam Sandy Clay Loam	Sandy Loam Sandy Clay Loam	Sandy Loam Sandy Clay Loam	Sandy Clay Loam Sand
Gravel, stoniness & rockiness	predominantly 15-40% gravel, 2-40% small to large stones	predominantly 5-15% small to large stones, often 5-15% rock	sometimes 2-5% gravel and small to large stones	predominantly 2-15% medium to large stones, often 2-40% small stones and rock	predominantly 2 - 40% each of small to large stones as well as rock
Vegetation structure	low semi-open bushland	low moderately closed bushland	low moderately closed bushland	low moderately closed bushland	low closed bushland
Most consistent trees and high shrubs	*Catophractes alexandri* *Acacia mellifera* *Boscia foetida* *Grewia flava*	*Acacia mellifera* *Acacia reficiens* *Catophractes alexandri* *Dichrostachys cinerea*	*Acacia mellifera* *Acacia reficiens* *Dichrostachys cinerea*	*Dichrostachys cinerea* *Acacia mellifera* *Grewia flavescens ssp. flavescens*	*Terminalia prunioides* *Dichrostachys cinerea* *Croton gratissimus* *Combretum apiculatum* *Acacia mellifera* *Acacia reficiens* *Rhus marlothii*

* Criteria in order of most to less common

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Table 6 continued

Criteria	Association 10	Association 11	Association 12	Association 13	Association 14
Most consistent low shrubs	*Leucosphaera bainesii* *Eriocephalus pubescens* *Melhania virescens* *Seddera suffruticosa* *Aizoon virgatum*	*Melhania virescens* *Eriocephalus pubescens* *Clerodendrum ternatum* *Lantana angolensis* *Seddera suffruticosa*	*Melhania virescens* *Leucosphaera bainesii* *Leucas pechuelii*	*Melhania virescens* *Lantana angolensis*	*Melhania virescens* *Seddera suffruticosa*
Most consistent grasses and herbs	*Enneapogon desvauxii* *Stipagrostis uniplumis* *Enneapogon cenchroides* *Cenchrus ciliaris*	*Stipagrostis hirtigluma* *Eragrostis echinochloidea* *Eragrostis trichophora* *Cenchrus ciliaris* *Enneapogon scoparius*	*Cenchrus ciliaris* *Eragrostis trichophora* *Eragrostis echinochloidea* *Corchorus tridens*	*Eragrostis echinochloidea* *Melinis repens ssp grandiflora* *Enneapogon cenchroides* *Eragrostis trichophora*	*Stipagrostis hirtigluma* *Enneapogon cenchroides* *Melinis repens ssp grandiflora* *Heteropogon contortus*