PHYTOSOCIOLOGICAL STUDY OF THE RIPARIAN AND ASSOCIATED WETLAND VEGETATION ALONG THE VET RIVER, FREE STATE PROVINCE, SOUTH AFRICA.

By

ANDRI CORNé VAN AARDT

Submitted in fulfilment of the requirements for the degree

MAGISTERS SCIENTIAE

In the Faculty of Natural & Agricultural Sciences
Department of Plant Sciences
University of the Free State
Bloemfontein
South Africa

May 2010

Supervisor: Prof. P.J. du Preez
Department of Plant Sciences, UFS, Bloemfontein

Co-supervisor: Dr. E.J.J. Sieben
Department of Plant Sciences, UFS, Qwaqwa Campus




I dedicate this thesis to my parents, Hans & Cila,

and my sister Marga




AKNOWLEDGEMENTS

I wish to thank the following:

- # My Lord, Jesus Christ, for the strength, ability and insight to complete this study.
- # Prof. Johann du Preez (supervisor), for his guidance and insights.
- # Dr. Erwin Sieben (co-supervisor), for his guidance and insights.
- # Nacelle Collins for his assistance.
- # The Water Cluster at the University of the Free State for funding this project.
- # All the farmers along the Vet River who allowed me onto their farms. Mr Frans Nel, Henk Victor, Michael de Villiers, Fanie Els, Wessel Wessels, Johan Slabbert, Rassie Smit, Martiens Prinsloo, Albertus Brink, Paul Maas, Maarten Ras, Johan Otto, Mrs Mitchell and the people from Korannaberg Adventures.
- # Mariska Labuschagne, Hans and Marga van Aardt for their assistance during the field analysis.
- # Beanelri Janecke for her encouragement.
- # Tasha Vos for her help with the interpretation of the water analysis.
- # Darius van Rensburg for assistance with the drawing of the maps.
- # My parents, Hans and Cila, and sister Marga for all the love, support and encouragement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

The Free State is often seen as a flat, dry and sometimes boring region of South Africa. However when looking carefully, this is a region with very interesting vegetation, geology and landscapes. The geology of the Free State is mainly dominated by the Karoo Supergroup. The topography of the Free State shows a definite westward slope. The highest point is situated in QwaQwa, eastern Free State (3 274m a.s.l.). The lowest point of 1 114m a.s.l. is near the confluence of the Modder and Riet Rivers in fhe West Free State. In the north-eastern parts of the Free State where it is more humid, large wetlands develop on flood plains along rivers and streams. These wetlands play an important role as a habitat for wetland birds that migrate through the province. Furthermore these areas are also an important source of groundwater for the agricultural industry (Van Rensburg 1997).

There are over 3 000 plant species in the Free State. Sometimes the vegetation is seen as an undulating grass dominated landscape. However, river courses with their tangled growth of thorny trees can be easily distinguished from a distance. The plants on the Highveld have several adaptations to survive in the harsh environment which might sometimes include excessive moisture loss, very cold conditions and frequent fires. Although the grass covered plains of the Free State is simple in structure they have supported large herds of herbivores in the past (Van Rensburg 1997) and today they are supporting an important game and domestic stock industry.

The relationship between man and the environmental in southern Africa can be traced as far back as 3 million years ago (Klein 1977). Early inhabitants of the Free State were mostly hunter-gatherers such as the San. Later the nomadic herders, such as the KhoiKhoi, arrived. The San were the earliest human inhabitants and their works of art can be seen throughout the region in protected caves and cliffs. The caves in which their works are present also performed an important function as shelter for the mountaineers and the domestic animals during the very cold winters (Van Rensburg 1997). Neither the San nor the Khoikhoi left much of an imprint on the environment. The tranquillity of this rural area was interrupted in the 19^{th} century by inter-tribal warfare called the Defahane, as well as the arrival of the Voortrekkers who were trying to escape the British rule in the Cape Province (River Health Programme 2003).

The name of the Vet River was given by the Voortrekkers. The reason: These people moved through the country and found that during the winter months different game species along the, then unknown river, would be fat, the reason being the floodplains along the river with their lush vegetation. The Voortrekkers then named this river the Vet River (Prinsloo, *pers comm.* 2009).[1]

Humans have several effects on the ecological processes that create and maintain the plant communities. These effects include overgrazing of arid grasslands, the introduction of alien invasive species or fertilizing infertile soils. It is not only certain individual plants that are affected, sometimes entire vegetation types and ecosystems, disappear (Keddy 2007). In South Africa there are four species of alien aquatic plants which are causing major economic impacts (Fuggle & Rabie 1992). Two of these species are present in this area of study.

The Vet River has it`s origin on the eastern highlands of the Free State namely the Koranna Mountains, from where it flows over plains until it joins the Vaal River west of Hoopstad (Els 1952). The Free State also has a relatively high tourism potential. There are various tourist destinations to visit. The study area includes the Korannaberg Hiking Trail at Excelsior and the Erfenis Dam Nature Reserve near Theunissen and the Sandveld Nature Reserve near Hoopstad (Van Rensburg 1997).

Agriculture is an important source of revenue in the province. The rivers present in the province are mostly used for irrigation (Van Rensburg 1997). The plains around the Vet and Sand Rivers are mainly used for agriculture. Dryland crops cover 31% of the upper and 63% of the lower catchment, while irrigation comprises only 1%.

[1] Mr Martiens Prinsloo, Theronshoop, Hoopstad.

The dams (Erfenis Dam, Allemanskraal Dam and Bloemhof Dam) comprise 3% of the total catchment of the Vet River (River Health Programme 2003).

Rivers are seen as the brown gods of continents as these ecosystems have the ability to cleanse and renew, destroy and create as well as sculpture the landscape. They take and give lives. Furthermore rivers can be seen as a string of pearls with each pearl being separate ecosystems as no two sections of the river are the same (Davies & Day 1998).

The term wetland is difficult to define, however these unique ecosystems perform certain functions in the landscape and have various values to humans, which include the control of hydrological stream flow, purify water and can be seen as some of the most productive landscapes on earth as they provide nutrients and water in a stable environment which leads to the rapid growth of plants. Furthermore wetlands are also some of the most diverse ecosystems in terms of biodiversity on earth (Davies & Day 1998).

Although the Vet River catchment was assessed during the surveys to compile the State-of-Rivers report the riparian vegetation were not included in these surveys. Habitat integrity was assessed and found to be good in the upper areas of the Vet River. However for the lower-lying areas near Hoopstad there is no information available (River Health Programme 2003). It was for this reason that the vegetation of the Vet River was classified and described.

The study of the Vet River was restricted to the banks which included the riparian vegetation as well as the floodplain. The aim of the study was to:

- assess,
- classify and
- describe

the natural vegetation along the Vet River, Free State Province, South Africa.

Water samples were also taken at different sites along this river to assess the quality of the water. Farmers along the river make use of the water for irrigation and livestock watering. On the other hand municipalities and mines discharge effluent into the River.

REFERENCES: CHAPTER 1

DAVIES, B. & DAY, J. 1998. *Vanishing Waters*. University of Cape Town Press. Cape Town, South Africa.

ELS, W.C. 1952. Waterverbruik en Grondbenutting in die Vet- en Sandriviergebied. Unpublished M. Artium dissertation at the Faculty of Arts, University of the Orange Free State, Bloemfontein.

FUGGLE, R.F. & RABIE, M.A. 1992. *Environmental management in South Africa.* Juta & Co, Ltd. Cape Town, South Africa.

KEDDY, P.A. 2007. *Plants and Vegetation: origins, processes and consequences.* Cambridge University Press. United Kingdom.

KLEIN, R.G. 1977. The ecology of early man in Southern Africa. *Science*. 197: 115-126.

RIVER HEALTH PROGRAMME. 2003. State-of-Rivers Report. Free Sate Region River Systems. Department of Water Affairs and Forestry. Pretoria, South Africa.

VAN RENSBURG, C. 1997. *Free State the Winning Province.* Chris van Rensburg Publications (PTY) Limited. Johannesburg, South Africa.

CHAPTER 2

STUDY AREA

2.1 LOCATION

This phytosociological study was restricted to the banks and floodplains of the Vet River in the Free State Province, South Africa. The study area covers approximately 8 928 hectares including the surface area of the Erfenis Dam, which is situated downstream of the confluence of the Groot Vet and Klein Vet Rivers (Figure 2.1). Towns situated in the Vet River catchment are Excelsior, Winburg, Theunissen and Hoopstad. A number of conservation areas are also located in the vicinity of the Vet River. The provincial nature reserves are: Willem Pretorius Game Reserve along the Sand River (a tributary of the Vet River), the Erfenis Dam Nature Reserve near Theunissen and the Sandveld Nature Reserve downstream of Hoopstad at the Vet River and Vaal River confluence. Several private game reserves also fall within the Vet River Catchment.

2.2 ABIOTIC FACTORS

2.2.1 General Climatology

The biosphere is strongly influenced by soil, climate and vegetation (Schulze 1997). Climate is the principal dynamic component and the most independent variable which strongly influences the other two components. Vegetation development of a region is mostly affected by light, temperature and moisture present in a particular area, which are determined components of the local climate (Schulze 1997).

The climate of any place on earth is controlled by a number of factors, namely: Latitude, determining the amount of solar radiation received, position relative to the distance from the sea, height above sea level, circulation of the atmosphere, ocean currents, the nature of the underlying surface, vegetation cover, orientation relative to hills or mountains (Schulze 1965).

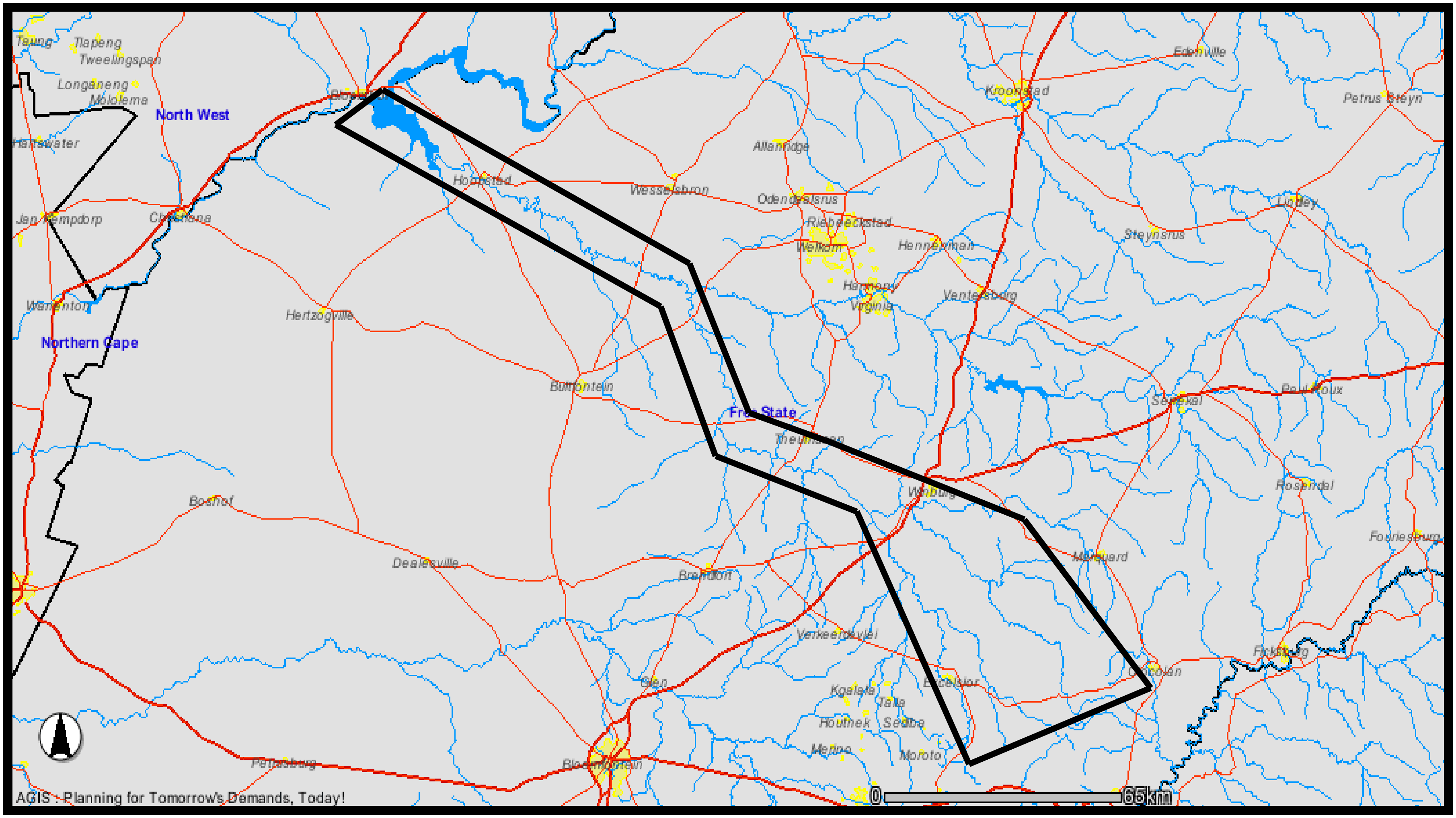


Figure 2.1: Map of the Vet River, Free State Province, South Africa (AGIS 2010). The black block indicates the study area.

South Africa can be divided into summer-, winter- and all-year rainfall regions (Figure 2.2). The summer rainfall area has warm summers and cold winters (Van Zyl 2003). The surface temperature of oceans is an important factor influencing the air masses that affect the climate of this sub-continent. Periods of drought are also common for countries that are situated in the 30^0 South and North latitude zones. Severe droughts may occur occasionally (Schulze 1965).

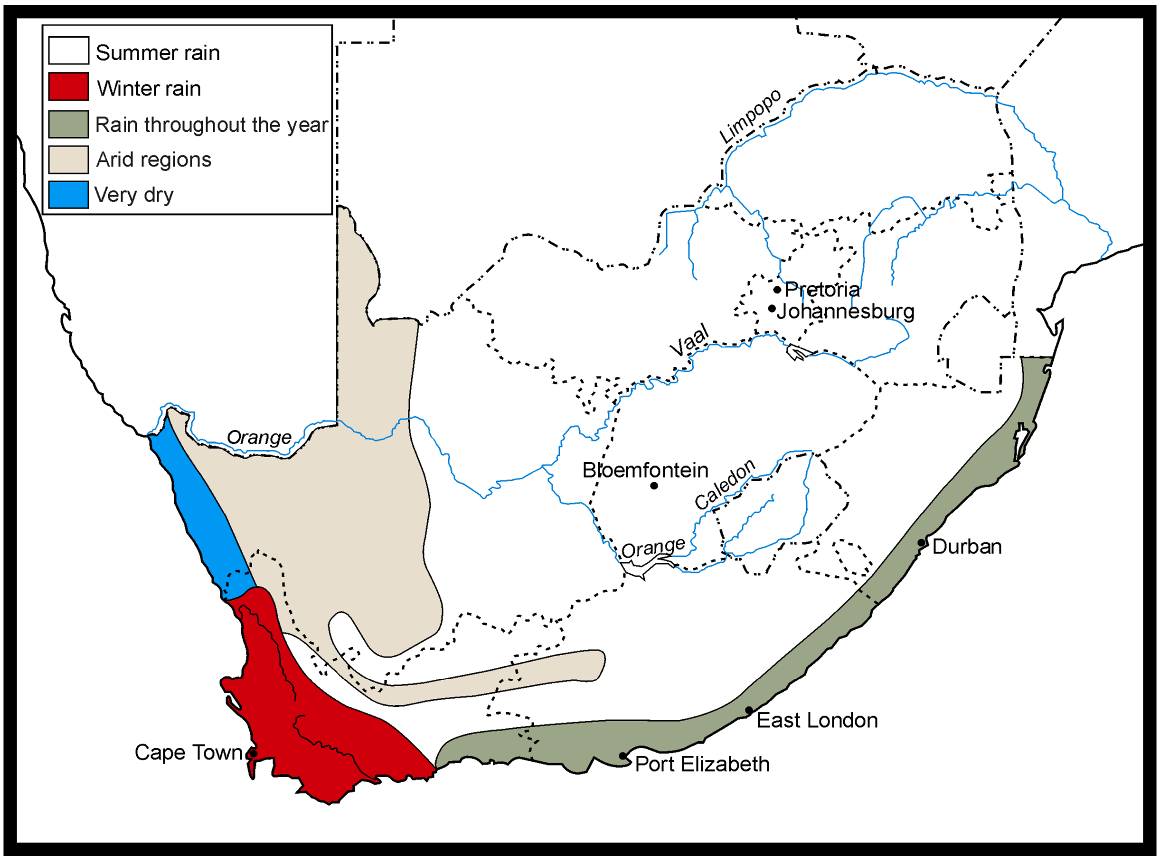


Figure 2.2: Map of the different rainfall regions in South Africa (Connexions 2010).

South Africa is situated in the subtropical belt of high pressure and therefore has plenty of sunshine and settled weather (Van Zyl 2003). This high-pressure belt has a significant influence on seasonal fluctuations. The weather in South Africa is largely dependent on the influence of a westerly circulation. Changes in the weather can be assigned to the cyclones/depressions and anti-cyclones that occasionally move around the coast (Schulze 1965).

The interior of South-Africa is situated on an elevated plateau with an altitude that ranges from 1 000 m above sea level, in the Kalahari, to 3 000 m above sea level, in the Lesotho highlands. There is a steep altitudinal gradient between the coast and the edge of the escarpment. This physical feature has a relatively strong influence on the climate of the sub-continent (Schulze 1965). South Africa is surrounded by oceans on two sides. This has a moderating influence on the climate of the country. The Agulhas/Mozambique Current on the east coast flows southwards from tropical latitudes. It is therefore a warm current. The Benguela Current on the other hand is a cold current and flows northwards from Antarctica along the west coast of South Africa (Van Zyl 2003).

The vegetation of southern Africa is affected both directly and indirectly by the climate: directly by factors such as solar radiation, temperature and moisture which determine the species presence in an area, and indirectly through the influence on soil conditions and fire regime. To vegetation, precipitation and temperature are important climatic factors, but other factors such as predominant wind direction, potential evaporation, light (solar radiation) and moisture availability are also of significance (Schulze 1997).

2.2.2 Precipitation

Vegetation growth and distribution is dependent upon the season in which precipitation falls as well as the frequency of occurrence (Schulze 1997). Of the various environmental parameters that have an influence on vegetation, the availability of water can be considered the most important. In regions where there is a limited rainfall, such as South Africa, primary production is often limited by water availability. Water is essential for the maintenance of physiological and chemical processes in the plant as well as the exchange of energy and the transport of nutrients. Precipitation is seen as the main source from which plants obtain their water. Precipitation can be either in the form of rain, fog or snow. Of these three, rain is the most important. Fog is restricted to the coastal and escarpment areas and snow is restricted to the high-lying areas in the Cape and along the eastern escarpment. Precipitation is not always directly available to plants as it might be intercepted by vegetation, form part of streams as runoff after a rain storm, percolates into deeper soil layers beyond the root zones or evaporates directly from the ground (Schulze 1997).

Moisture precipitates from clouds in the form of liquid droplets or ice particles (Van Zyl 2003). In general it may be stated that the summer rainfall zones receives the most of their precipitation in the form of thunderstorms and instable showers, especially in the eastern Highveld region. The intensity of some of these showers may lead to local floods which may cause damage to bridges, cultivated fields and crops (Schulze 1965).

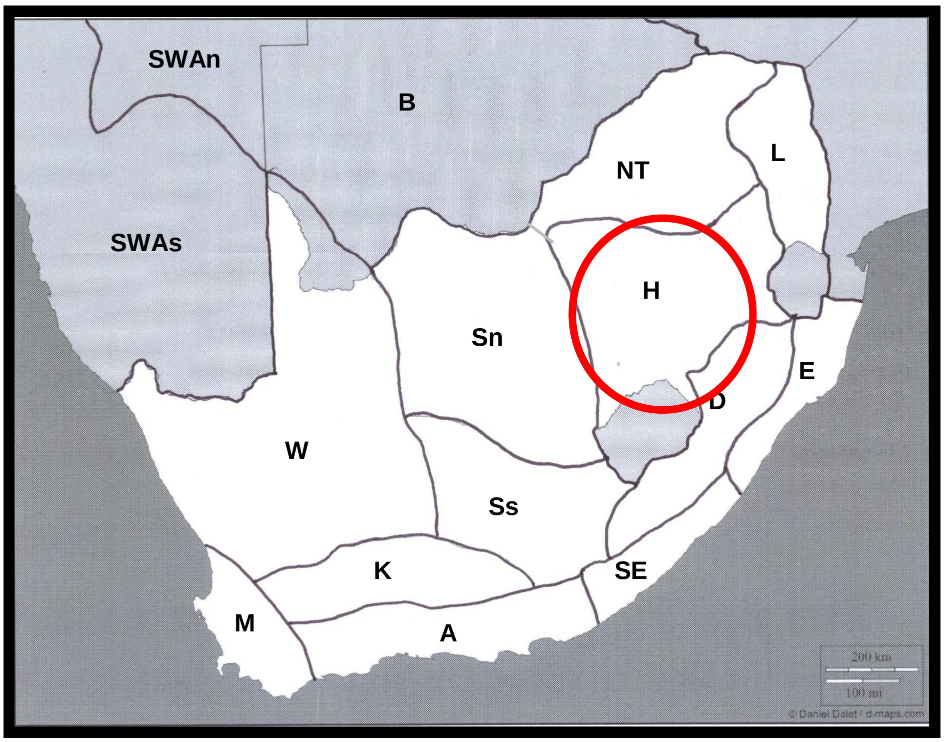


Figure 2.3: Map of the different climatic regions in South Africa as presented by Schulze (1965). M – Mediterranean climate, A – receives rain equally in all seasons, K – Little and Great Karoo, W and SWAs – rainfall is unreliable, Ss and Sn – southern and northern steppe, SE – southeastern coastal region, E – warm to hot and humid subtropical climate, D – Drakensberg region, L – Transvaal Lowveld, H – Highveld region, NT – Northern Transvaal region and SWAn and B – becomes more humid northwards (Map after Schulze 1965; d-maps 2010).

The study area is located in the Highveld climate region (H) (Figure 2.3) which is one of the climate regions in South Africa as identified by Schulze (1965) and Van Zyl

(2003). Mucina & Rutherford (2006) stated that the cold and dry conditions that occur in the Highveld region are a result of the high elevation and the inland continental aspect of these areas. This climate region is characterised by warm summers with strong summer rainfall patterns and mild winters with drought (Mucina & Rutherford 2006; Van Zyl 2003). The area is a typical summer rainfall area with a peak of precipitation in December to January. The average number of days of frost is relatively high (37 to 43 days in a year) (Mucina & Rutherford 2006). This region receives summer rainfall in the form of showers and thunderstorms during the months of October to March (Schulze 1965; Van Zyl 2003).

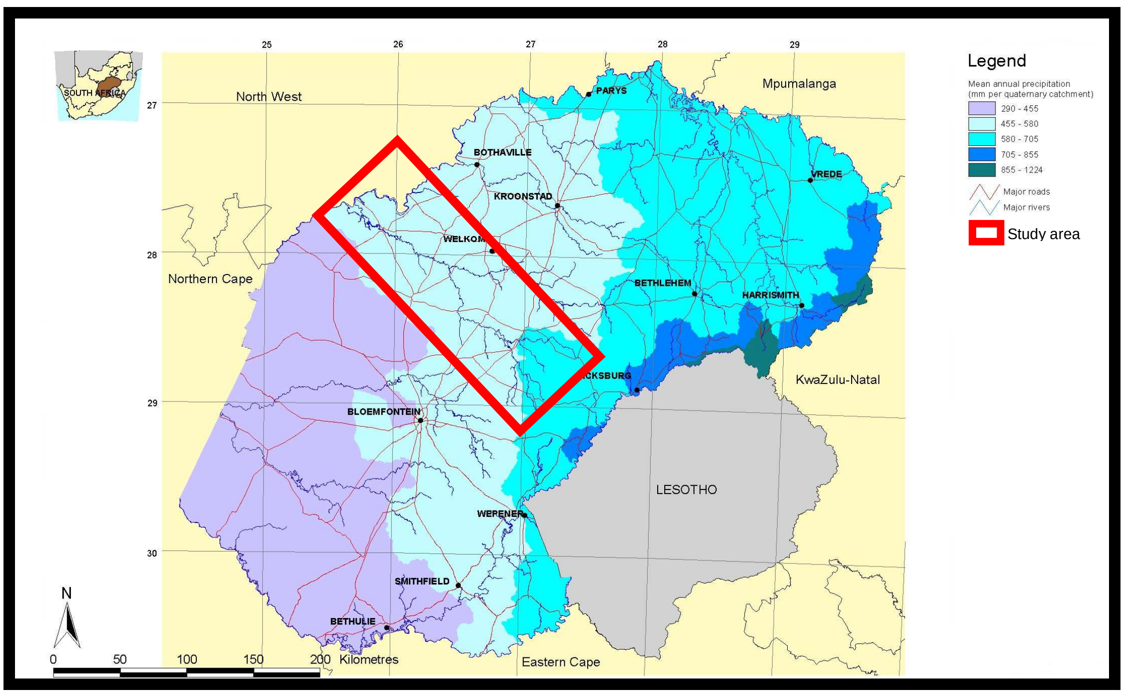


Figure 2.4: Map indicating the mean annual precipitation in the Free State, South Africa (Department of Environmental Affairs and Tourism 2009).

The occurrence of thunderstorms is more frequent in this biome than in other biomes. The average number of thunderstorms is about 70 per year in the grassland biome as defined by Rutherford & Westfall (1994). Hail, that sometimes accompanies thunderstorms on the Highveld occurs mostly in early summer (Schulze 1965). Hailstorms may sometimes be severe and potentially cause substantial damage to vegetation. The density of lightning flashes to the ground is also highest in this biome. The lightning events that occur during the summer thundershowers are regarded as the most significant natural cause of veld fires in South Africa (Schulze 1997). Rainfall varies between 400 and 2500 mm per year (Mucina & Rutherford 2006). Figure 2.4 indicates that the mean annual precipitation increases from the west to the east across the Free State province. The study area (red square) falls mainly between the 455 and 580 isohyets, except for the head waters of the Vet River where the rainfall exceeds 580mm/annum.

2.2.3 Wind

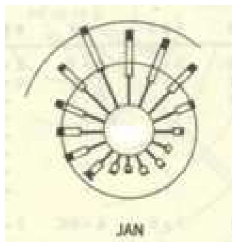
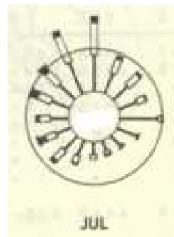
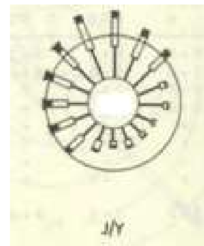
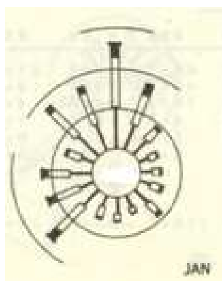
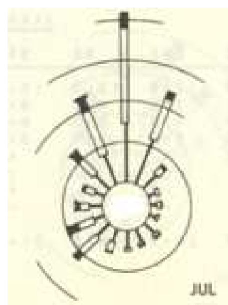
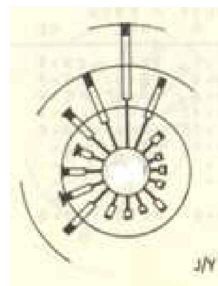
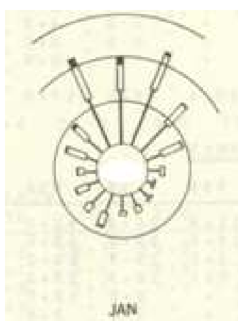
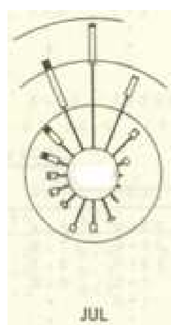
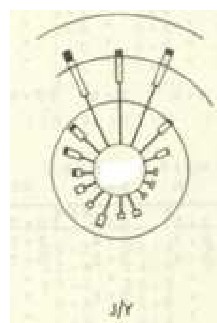
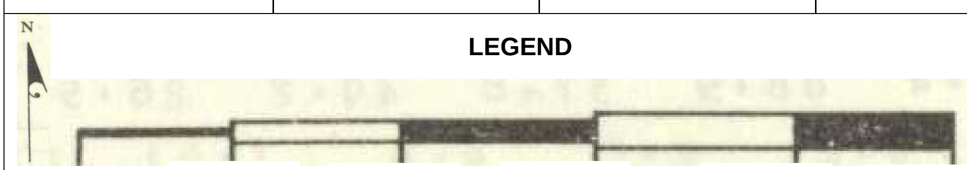
Few seasonal changes can be differentiated when looking at the wind in the central parts of South Africa. Winds from a northerly direction dominate. The presence of whirlwinds or dust-devils are common anywhere in the interior of South Africa during hot summer days. These whirlwinds are caused by strong convection and are more frequent over sandy or dusty veld. Winds in the Highveld region are light except for short periods during thunderstorms (Schulze 1965).

In the vicinity of Bloemfontein the dominant wind direction (Table 2.1) during the month of January, which mostly represents the middle of summer, is north north-west. In the Kimberley area the north north-west, north west and north north-easterly winds are dominant, while in Potchefstroom the dominating winds during the summer months are north north-west and north north-east. Wind is also more likely to occur during summer months than during winter.

During the winter, which is represented by July, the dominating winds in the Bloemfontein area are from the north north-west, Kimberley is dominated by north north-westerly and north north-easterly winds. In Potchefstroom the dominant wind direction is from the north north-west and north north-east.

The prevailing wind directions can be seen in Table 2.1. From Table 2.1 it is clear that the dominant wind directions through the year in the study area are mostly northerly. These wind directions range mostly from north north-easterly to north north-westerly.

Table 2.1: Windroses of Bloemfontein, Kimberley and Potchefstroom. These windroses represent the dominant wind directions for January, July and an average for the year (Weather Bureau 1960).

City	January	July	Average per year
Bloemfontein			
Kimberley			
Potchefstroom			
LEGEND  3-8 9-15 16-25 26-38 >38 MPH			

2.2.4 Solar radiation (Sunshine)

The western interior of the country receives more than 80% of the possible sunshine throughout the year. The areas that receive maximum sunlight shift to the south in summer and to the north in winter due to the seasonal movement of the sun and high pressure belt, which influences cloud formation. In winter the interior of the country receives around 70% of the possible sunshine duration. The areas with the lowest values for sunshine duration are mostly found around the eastern escarpment and those areas with a high altitude (Schulze 1965).

The escarpment of the continent plays an important role in the sunshine pattern over South Africa. In summer the eastern and south-eastern escarpments receive less than 50% of the possible sunshine and in winter the mountains of the south-western Cape are receiving less sunshine. During the dry season, which is winter on the interior plateau, there is abundant sunshine. During the summer months the sunlight intensity is the highest, when there is no cloud cover (Schulze 1965). The occurrence of sunshine in the Highveld climate region has duration of 60% in the summer and about 80% in winter of the possible sunshine (Schulze 1965).

All ecosystems are dependent on the quantity of incoming solar radiation intercepted as their primary source of energy and this radiation will show seasonal variation as the sun moves between the tropic of Cancer and the tropic of Capricorn. Therefore it is important to view the seasonal patterns of solar radiation as well as the effects of the varying topography (Schulze 1997). Schulze (1997) stated that a permanent difference in the amounts of radiant energy intercepted on different exposure levels may cause variations in the distribution of plant communities.

In the south-western interior of the country the air is dry with clear skies which lead to the transmitting of a large portion of solar energy. In contrast the eastern parts of the country are moist and cloudy which results in less total solar radiation reaching the earth`s surface. It is estimated that the clouds reflect 55% of the incoming radiation of the sun. The type of clouds and the presence of dust and vapour in the air also play a role in restricting radiation (Schulze 1965).

2.2.5 Temperature

Schulze (1997) stated that temperature is a basic variable in climatology which can be used as an index to assess the energy status of the environment. Temperature is a vital limiting factor which has an effect on the distribution of vegetation. The diurnal temperature ranges increase from the east of the country to the west in January (mid-summer) and thus reflects a correlation with altitude and cloud cover (longitudinal trend – western areas with less cloud cover than the eastern areas). This is in phase with the rainfall distribution and reflects the high humidities and high degrees of cloudiness, both of which suppress the temperature range. In July (mid winter) a latitudinal trend is followed where the highest range between maximum and minimum temperatures decreases from north to south (Schulze 1997).

In the summer rainfall areas the daily temperature range increases from summer to winter (Schulze 1965). Temperature on the Highveld is subjected to diurnal and seasonal variation with daily maxima (Figure 2.5) ranging between 27^{o}C in January and approximately 17^{0}C in July with extremes which can attain 38^{o}C and 26^{0}C. The average minimum (Figure 2.6) temperatures in this region range from 13^{o}C in January to below freezing point in July (Schulze 1965).

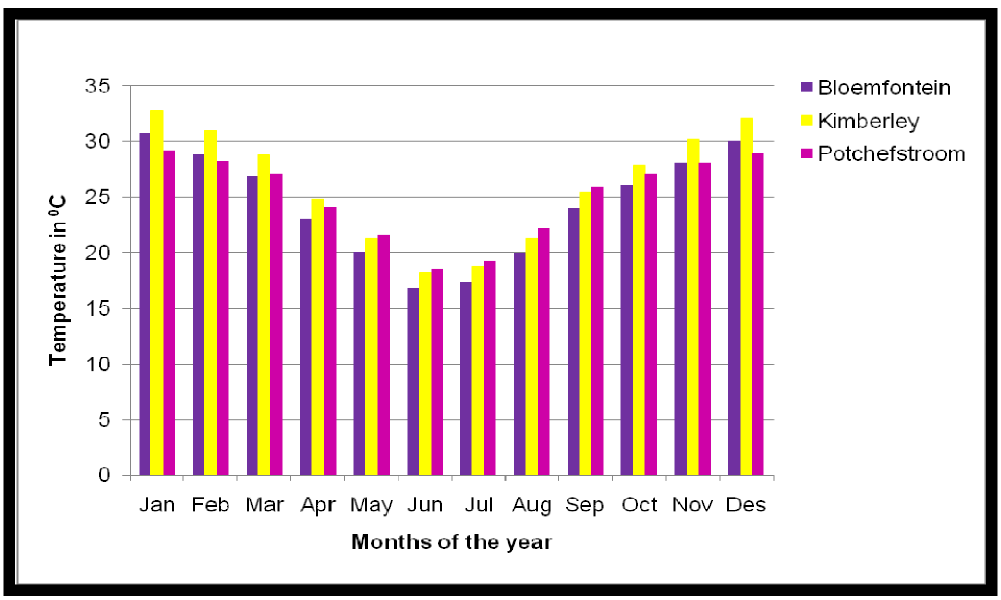


Figure 2.5: Graph of the average maximum temperatures for Bloemfontein, Kimberley and Potchefstroom (SAWS 2002).

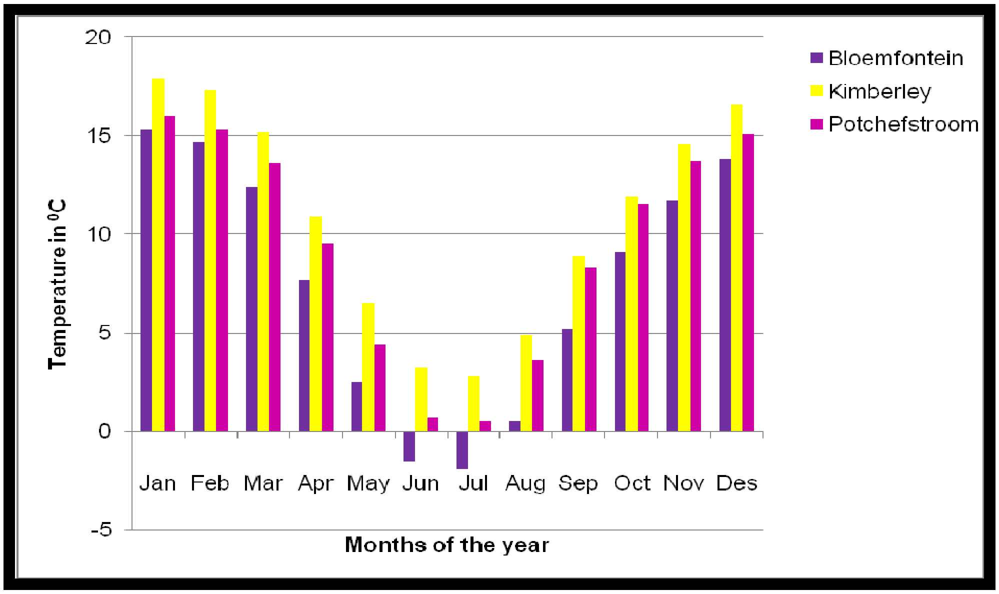


Figure 2.6: Graph of the average minimum temperatures for Bloemfontein, Kimberley and Potchefstroom (SAWS 2002).

Low temperatures and frost are critical in determining plant survival and are therefore important when looking at plant distribution. Although plants have a number of physical and biological mechanisms to avoid freezing, none are completely protected (Schulze 1997). Freezing of the plant will lead to the disruption of cell walls and other anatomical features (Salisbury & Ross 1992). Frost is a common phenomenon on the Highveld can be expected during the months of May to September for approximately 120 days, but this period is longer in the southern highlands of Lesotho (Schulze 1965; Mucina & Rutherford 2006). Frost occurs on clear nights when the ground temperature drops significantly due to radiation (Van Zyl 2003). Hoar frost is common in the Highveld region and occurs during the months of April to September. This type of frost is most severe in the high plateau and are least expected near the coast. Sometimes when severely cold dry air enters the country from the south, 'black frost' may occur. With this type of frost the moisture within the plant cells freezes and this causes the cells to rupture, which can result in significant damage to plant life (Schulze 1965).

2.2.6 Geology

The geology of an area is an important environmental factor and strongly influences the topography, soils and vegetation (Du Preez 1991).

During the period 310 to 182 million years ago the Karoo Supergroup has been deposited to cover two-thirds of South Africa (McCarthy & Rubidge 2005). The study area is also underlain by the geological strata of the Karoo Supergroup.

2.2.6.1 General overview

The Karoo Supergroup consists of the following layers: Dwyka (oldest), Ecca, Beaufort, Stormberg and Drakensberg (youngest) Groups. The sedimentation of the Karoo Supergroup was initiated by glaciation (Permo-Carboniferous glaciations) between 248 and 354 million years ago. The deposits from this period are known in South Africa as the Dwyka Group. It is also the oldest of the Groups (Truswell 1970; 1977; McCarthy & Rubidge 2005). Unlike the Dwyka sediments, the Ecca Group consists of sediments of fluvial origin (deposited by rivers into a shallow sea known as the Karoo Sea). The Beaufort Group consists of sand and muc deposits from rivers and floodplains (McCarthy & Rubidge 2005). On top of the Beaufort sediments occur the sediments of the Stormberg Group. The Stormberg Group consists of three subgroups namely the Molteno, Elliot and Clarens Formations. The Stormberg Group consists of fluvial and aeolian (wind-blown) sands. These sediments were deposited during more arid conditions (Truswell 1970; McCarthy & Rubidge 2005).

The youngest layer that still covers large parts of Lesotho, is the Drakensberg Group. Unlike the older groups it is of igneous origin and was fed by numerous dykes filled with basaltic lava. Today these dykes and sills form important topographical features in the landscape as dolerite dykes and dolerite capped hills and ridges (Truswell 1970; McCarthy & Rubidge 2005).

The geology generally consists of layers of sandstone and shales (Ecca, Beaufort, Stormberg Groups) which are underlain by glacial tillite (Dwyka Group) (Truswell 1970). In some areas these sediments are covered by basaltic lava with intrusions of sheets and dykes of dolerite (Truswell 1970). Dolerite intrusions are very common in the Karoo Supergroup. About 300 million years ago at the end of the period of sediment accumulation, erosion started to remove most of the lava sheets (McCarthy & Rubidge 2005). The total thickness of the combined Karoo Supergroup thins towards the north of the country (Truswell 1970; McCarthy & Rubidge 2005).

The headwaters of the Vet River originate in mountainous areas of Korannaberg and Viervoetberg. These mountains are capped by the thick sandstone deposits of the Clarens Formation. In the vicinity of this river, there are dolerite intrusions which were used to build bridges and dams. Towards the north-west the Vet River also flows through plains which are underlain by sediments of the Beaufort and Ecca Groups. In the area where the Vet and Sand Rivers join, outcrops of the Ventersdorp Supergroup can be found (Els 1952). The Ventersdorp Supergroup was formed during the Archaean eon more or less 3 000 to 2 500 million years ago (McCarthy & Rubidge 2005). Much of the exploratory drilling in search of gold passes through the Ventersdorp Supergroup. There is also evidence that portions of the crust moved relative to each other which led to the rising of positive elements and the sinking of negative elements (Truswell 1970).

The geological formation in the area has little to no direct influence on the sedimentary soil types along the river, as the soil types are very old and overlay the shales. The origin of the sandy soils towards the west (Hoopstad area) is not well understood, but they are likely to be deposited from elsewhere. There are two theories explaining the origin of these sand deposits. The sand can either be of the alluvial material from the Vaal River that are blown in by the north westerly winds or the sandy soil can be blown in from the Kalahari desert further to the west. The first theory is the more likely one as there are no sandy soils present on the northern side of the Vaal River. The sandy soils occur in more or less 50% of the study area. The sandy soils are mostly deposited on the left hand bank of the Vet River to the point where the Vet and Sand Rivers form a confluence. From the confluence downstream to Hoopstad the sand of the river are mostly deposited on the right hand bank of the Vet River (Els 1952).

2.2.6.2 Description of the geological groups present in the study area

2.2.6.2.1 The Ecca Group

As Gondwanna drifted northwards and moved out of the polar region, the glaciers finally melted and a large body of inland water was formed. This waterbody was however connected to the ocean although tidal ranges were small. The rivers present drained the region along the northern shoreline, forming large deltas – these depositions were known as the Ecca Group of rocks (McCarthy & Rubidge 2005). This difference is indicated by the directional structures in the rock as well as the differing nature of the rocks. Furthermore, it is possible to determine the type of sedimentation by looking at the thickness of sediment deposition which provides information on the environment of sedimentation, as well as the tectonic settings in which the sedimentation has taken place (Truswell 1970). The sediment also contains volcanic ash produced by violent volcanic eruptions which were carried by wind and deposited within the Karoo Supergroup strata (McCarthy & Rubidge 2005). This group contains very few fossils of animals (vertebrates and invertebrates) (Truswell 1977), however the earliest reptile from Gondwana which was a small aquatic animal (*Mesosaurus)* was found in this Group (McCarthy & Rubidge 2005). Fossils found in the Ecca Group are fossils of plants, small spores and pollen produced by the plants. The plants are mostly representatives of the *Glossopteris* flora (Truswell 1977).

2.2.6.2.2 The Beaufort Group

This group covers more of South Africa than any other stratigraphic unit. The composition is mainly shales and mudstone with interbedded lenticular sandstones (Truswell 1970; 1977). Most of the sediment was deposited in the form of large, northward-flowing, meandering rivers with extensive floodplains. Periodic floods deposited mud and sand (McCarthy & Rubidge 2005). Most of the fossils that were found are of reptiles and to lesser extent amphibians (Truswell 1970; 1977).

Two formations within the Beaufort Group can be recognized: the Katberg and the Burgersdorp Formations. The Katberg Formation is 1 000 m thick and consists of igneous and metamorphic pebbles, quartz pebbles and plant fossils (mainly petrified wood). This formation occurs from East London to Senekal in the central Free State.

The Burgersdorp Formation (1 000 m) contains gneiss and pegmatic, icrocline as well as quartz, red granite and quartzite. These formations recorded the recovery of life after the devastating Permian mass extinction (Truswell 1977; McCarthy & Rubidge 2005).

2.2.6.2.3 The Stormberg Group

The rocks of the Stormberg Group show a gradual change to increasingly more arid conditions (McCarthy & Rubidge 2005). This group consists of three different formations: the Molteno, Elliot and the Clarens respectively.

The *Molteno Formation* covers the area from the eastern Cape Province northwards into parts of the Free Sate, Lesotho and KwaZulu-Natal. This formation consists of different fluvial cycles (Truswell 1977):

- Shales, and some coal-bearing layers ;
- Fine-grained sandstone, siltstone and silty shale;
- Coarse, medium and fine-grained sandstone, and
- Pebbly conglomerate deposited on the slightly eroded Beaufort rocks

This formation has a maximum thickness of about 588 – 600 m. Throughout this formation, fossils of the *Dicroidium* flora (a seed fern) is preserved, while in the sandstone layers fossilized logs of the tree *Dadoxylon* sp. can be found. Although no preserved reptiles have been found in this formation, plant and insect fossils have been found in this formation (Truswell 1977; McCarthy & Rubidge 2005).

The *Elliot Formation* consists of red mudstones and shales as well as fine-grained yellowish, lenticular sandstones. The maximum thickness is about 500 m. The deposition of sediment took place on alluvial flats. The fossils present in this formation are mostly those of reptiles, mostly of primitive dinosaurs. The lower strata of the Elliot Formation contain the earliest fossils of dinosaurs in South Africa. The fauna became scattered and more gracile towards the top of the Elliot Formation. This can be attributed to climatic changes – the environment gradually became more arid (Truswell 1977; McCarthy & Rubidge 2005).

The *Clarens Formation* was deposited under extreme arid conditions. The base of the Formation show evidence of ephemeral salt pans and river activity, but the deposition of the upper Clarens Formation occurred in true desert conditions which lead to the development of an extensive sand sea. The Cargonian Highlands became submerged under the accumulated sediment, and the desert sands of the Clarence Formation formed an uninterrupted sand sea (Truswell 1977; McCarthy & Rubidge 2005).

2.2.7 Topography

The Vet River originates in Korannaberg in the highlands of the eastern Free State form where it flows through plains to the confluence with the Sand River. After the confluence the Vet River meanders through pediplains until it joins the Vaal River west of Hoopstad. Various small streams contribute to the main stream of the Vet River. Most of these small streams join the river before Winburg (Els 1952). The study done by Els (1952) is the only known detailed geomorphological study of the area.

The catchment area of the Vet River can be divided into three parts: the eastern highlands where the Sand and Vet Rivers originate, the middle reaches and the western pediplains through which the lower parts of the rivers flow until they join downstream of Welkom. Downstream of this confluence the Vet River flows through undulating plains with a relatively poor drainage until it joins the Vaal River at the Bloemhof Dam (Els 1952). The numerous pans on these undulating plains are proof of the poor drainage in the region.

From Figure 2.7 it is clear that the eastern parts of the Free State are mountainous, while the areas to the west are relatively flat. On these flat plains indorheic (inward-draining) pans are an important hydrological feature.

Eastern highlands

The entire area of origin of the Vet and Sand Rivers is located above an altitude of 1 515 meter above sea level Els (1952). All the tributaries that flow into these rivers in the middle reaches join the rivers above the 1 363 meter level. The rest of the area consists of scattered undulating plains with hills and ridges. The hills consist mainly of light-coloured sandstone. Sometimes these hills are intruded by dolerite dykes and sills. The relatively flat topography is suitable for crop farming which is practiced in about 50% of the area in the form of maize, sunflower and wheat production (Els 1952).

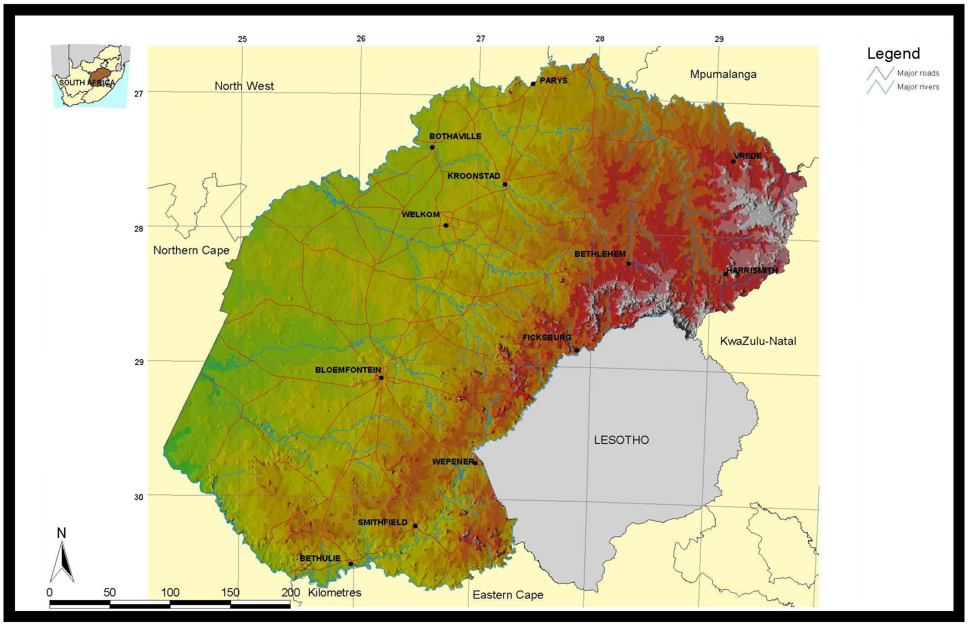


Figure 2.7: Map of the topography of the Free State (Department of Environmental Affairs and Tourism 2009).

Middle and western plains

Downstream of Winburg, the Vet River drains onto the undulating pediplains. The topography is very flat and the altitude above sea level gradually decrease from 1 363 meters to 1 212 meters at the confluence with the Sand River. Downstream of this confluence the Vet River starts to meander. This is an indication of the very flat topography of the area (Els 1952).

Stream erosion and deposition are controlled by the velocity, discharge and turbulence of a river. Of the three factors, velocity is the most important factor. The velocity of a stream is determined by the gradient of the stream, the channel shape and the roughness of the channel. The maximum velocity of a stream is reached in the middle of the channel. The friction of the water with the stream`s banks and bed slows down the water velocity (Plummer & McGeary 1979).

The velocity of a stream determines whether that stream will erode or deposit sediment. High velocities lead to erosion, while low velocities lead to the deposition of sediment. The deposition of material is due to the decrease in velocity or discharge. The heavier particles such as gravel and sand will be deposited first. Silt and clay will only be deposited once the river stops flowing. Therefore the coarsest sediment which includes sand and silt is deposited close to the river while the finer clay is carried further from the river into the lowlands as well as onto floodplains. The cycles of erosion and deposition are repeated as the sediment moves downstream and this deposition of sediment leads to the formation of floodplains. Near the end of a stream the finer sediment may be deposited more permanently and from a delta (Plummer & McGeary 1979).

During floods the floodplains may be covered by water that carries suspended load. Most of the time the sudden decrease in the velocity of the water lead to the deposition of most of the sediment near the main channel with less sediment being deposited away from the channel (Plummer & McGeary 1979).

The area upstream of Winburg is well drained and no large wetlands are present, but wetlands are extensive in the floodplains along the river downstream of Theunissen. During floods, the banks of the Sand River a tributary of the Vet River, erode and sandy sediment is transported downstream. The Vet River has a much less steep gradient and will deposit its sediment load on the banks so levees are formed on either side of the river (Els 1952).

2.2.8 Terrain types

A terrain unit can be identified as any part of the land surface with homogeneous form and slope. A terrain therefore consists of units which might represent the following: crest, scarp, midslope, footslope and a valley bottom or floodplain. A terrain type (Figure 2.8) is an area of land over which the marked uniformity of the surface form can be easily shown on a map with a 1: 250 000 scale. The terrain units present in the area of study is indicated in Table 2.2 (AGIS 2010a).

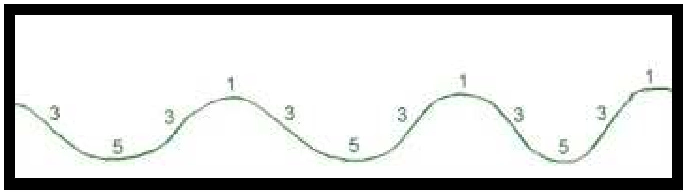


Figure 2.8: Figure of the different terrein types present in the study area (AGIS 2010a).

Table 2.2: Table of the numbers assigned to different terrain types present in the study area (AGIS 2010a).

Legend	**Terrain Type**
1	Crest
2	Scarp
3	Midslope
4	Footslope
5	Valley bottom

2.2.9 Land types

A land type is indicated by an area that can be shown on a map with a scale of 1:250 000. The delineation of land types is determined by a marked degree of uniformity represented by terrain form, soil pattern and climate. The different land types are numbered according to their convenience in a broad soil pattern. Therefore land type Ea39 is the thirty-ninth land type that qualified for inclusion into the broad Ea soil pattern (AGIS 2010a).

The following land types namely: Ae, Ah, Ai, Bd, Ca, Db, Dc and Ea were identified in the Vet River area (Figure 2.9). The land types and the dominant soils forms will be discussed briefly.

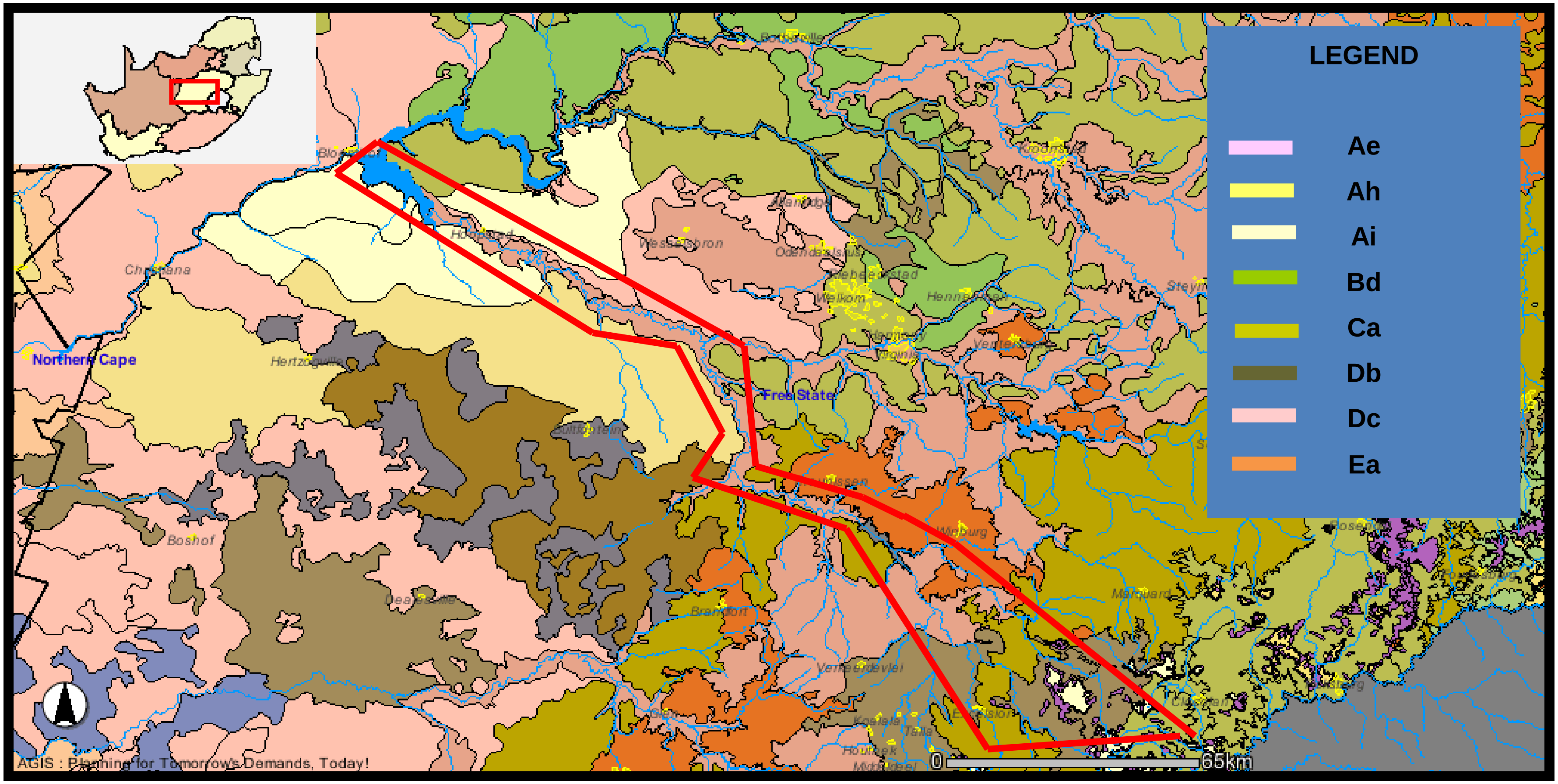


Figure 2.9 : Map of the different Land Types present in the study area (AGIS 2010). The red block demarcates the study area.

A Land Type (Ae, Ah and Ai)

This land type consists mainly of red-yellow apedal, freely drained soils which belong to one or more of the following soil forms: Inanda, Kranskop, Magwa, Hutton, Griffin or Clovelly. These units refer to land that does not qualify as a plinthic catena and where the above mentioned soil forms represents more or less 40% of the area. In the unit Ae yellow soils occupy less than 10% of the area, while dystrophic and/or mesotrophic soils occupy a larger area. The Ae land type further has a red, high base status, is more than 300mm deep, with no dunes. With Ai land type the same rule applies as in the case of Ae, however the Ai type has yellow soils with a high base status (AGIS 2010a).

Unit Ah is mostly dominated by red and yellow soils with a cover of higher than 10% of the area, while the dystrophic and/or mesotriphic soils cover a larger area than the high base status red and yellow apedal soils (AGIS 2010a).

The geology of the Ae land type is mostly characterised by Ecca sandstone, mudstone and shale with the sporadic occurrence of intrusive dolerite sills. The rocks are overlain by aeolian sands derived from the sandstone in the Ecca Group. Land type Ah consists also of sandstone, mudstone and shale with intrusions of dolerite sills, but in this land type calcrete also occurs sporadically. Land type Ai is mostly comprised of sandstone with the possible presence of mudstone and/or shale with the sporadic occurrence of dolerite sills from the Ecca Group (AGIS 2010a).

B Land Type (Bd)

This land type is a plinthic catena with an upland duplex and the rare occurrence of margalitic soils. Large parts of the interior of South Africa are covered by catenas. These catenas are represented by the following soil forms: Hutton, Bainsvlei, Avalon and Longlands. Valley bottom areas are occupied by one or other gley soil such as the Rensburg, Willowbrook, Katspruit and Champagne forms. The shallow water tables play a role in this land type. If the water tables extended far beyond the valley bottoms the landscape is dominatned by Longlands and Avalon with related gray and yellow soils, however it is possible that red soils are excluded. If the water table is maintained within the valley bottoms then red soils dominate with the plinthic soils restricted to narrow strips of land along the valley bottoms or pans. An area needs to have a cover of 10% or more plinthic soils to be included in the B Land Type (AGIS 2010a).

Unit Bd is mostly composed of red and/or yellow apedal soils of dystrophic and/or mesotriphic origin, which occur over red and/or yellow apedal soils (eutrophic soils) – where red soils occupy more than a third of the area. However this unit in the study area is dominated by dystrophic and/or mesotriphic soils and the red soils that occur are not wide spread (AGIS 2010a).

The geology of this land type is mostly shale, mudstone and sandstone from the Ecca and Beaufort Groups with aeolian and possibly colluvial sand that overlies the rocks (AGIS 2010a).

C Land Type (Ca)

Duplex and margalitic soils must occupy more than 10% of the area for the area to classify as a C Land Type. This unit can also be identified as a plinthic catena (AGIS 2010a).

The geology is mostly sandstone, mudstone and grit form the Molteno and Elliot Formations with dolerite sills and dykes in some areas. The crests and middle slopes are mainly on the Molteno and Elliot formations while the valley bottoms are dominated by mudstone (AGIS 2010a).

D Land Type (Db and Dc)

This is prismacutanic and/or pedocutanic dominated horizons. D Land Types dominate areas were the duplex soils are dominant. The soil forms present in the upland areas are Estcourt, Sterkspruit, Swartland, Valsrivier and Kroonstad forms. When rock, stones or boulders are removed more than half of the remaining land must consist of duplex soils. Db refers to areas of land where more than half of the area is covered by duplex soils with a non-red B horizon. Dc indicates land that, in addition to the duplex soils, also need to have more than 10% of the land type comprised of the following diagnostic horizons: vertic, melanic and red structured (AGIS 2010a).

The geology is mostly composed of sandstone, mudstone, shale and grit of the Molteno and Elliot Formations. In some areas dolerite intrusions are visible. The sporadic occurrence of Ventersdorp lawa is also present (AGIS 2010a).

E Land Type (Ea)

This unit consists of one or more of: vertic, melanic, red structured diagnostic horizons. This unit is indicated by high base status, dark coloured and/or red soils which are usually clayey and associated with basic parent materials. Areas that can be included into this land type, must include vertic, melanic and red structured diagnostic horizons in half of the area. However land types with less than half of the area covered by the above mentioned soils can also be included if (AGIS 2010a):

- duplex soils occur in non-rock areas where Ea covers a larger area than the duplex soils;
- areas where exposed rock covers more than half of the land type.

The geology is presented by shale, mudstone and sandstone of the Beaufort Group with dolerite intrusions (AGIS 2010a).

2.2.10 Soils

Winegardner (1996) defined soil as “an aggregate of unconsolidated mineral and organic particles produced by the combined physical, chemical and biological processes of water, wind and life activity”. Soil forms the interface between the atmosphere and lithosphere. Furthermore, soil is a living medium for a variety of soil organisms as well as the medium from which plants obtain their water and nutrients (Bardgett 2005). Therefore it can be said that all terrestrial life depends on soil for its existence (Winegardner 1996). The organisms that occur in the soil play an important part in soil formation as well as physical and chemical properties.

Soil texture (degree of coarseness or fineness of the mineral particles of soil (Courtney & Trudgill 1984)) refers to the proportions of various sized particles eg. sand, silt and clay. However a good soil structure (the binding of the various-sized mineral particles into larger aggregates or a ped) can be recognized as a key attribute of soil fertility because of the increase of the flow of water and gasses and therefore reducing the possible development of anaerobic conditions (Bardgett 2005). However Courtney & Trudgill (1984) stated that the soil texture also play an important role in the availability of water and nutrients.

Soil differs with respect to organic matter which differs in chemical composition and quantity. The organic matter in soil plays an important role by promoting soil stability and thereby preventing soil erosion (Bardgett 2005). Three layers of humus is present namely (Courtney & Trudgill 1984):

- Leaf litter – where leaves and other plant remains are recognizable.
- The fermentation or humification layer – where decay is active.
- The humus layer – plant remains are unrecognizable.

The living organisms in the soil contribute to the decomposition process and nutrient mineralization through the process of mixing and fragmenting organic matter and by feeding on the microbes that affect the growth of organisms (Bardgett 2005).

Soil is the medium in which plants grow and obtain water and minerals. There are five factors that play a role in the formation of soils. These factors are parent material, climate, topography, the interaction of biological factors over a period of time (Money 1972; Winegardner 1996; Hensley *et al*. 2006).

The parent rock present in the area is broken down into small inorganic particles by chemical or mechanical action which makes up the main part of the soil. These particles can remain in the local area or transported to another area by means of water or wind. The soils present in a particular area may be a mixture of material from various origins. The properties of soils are affected by the size of the soil particles. Water will drain quickly through sandy soils as it has a coarse texture and large pores, while clay soils retain water much longer as the particles are small and electrically charged and tiny pores do not allow adequate drainage (Money 1972).

Inorganic particles from the weathering of rock form the bulk of most soils, but some soils have a greater portion of undecomposed organic matter (Money 1972). Rocks are subjected to chemical or mechanical weathering, which forms the parent material of the soils. In cold or dry regions where the overlying soil is thin, mechanical weathering is the most prominent (Eyre 1968). In hot and wet regions with a thick layer of soil covering the rock, chemical weathering is more prominent (Eyre 1968). Organic matter present in the soils originates from decaying plant and animal matter. The composition of soils is also affected by the presence of living organisms, insects, worms, fungi and bacteria (Money 1972). Depletion of oxygen, cold and drought conditions can limit aerobic respiration in the soil and thereby the decomposition of organic matter. These conditions lead to a large component of undecomposed organic material in the soil which leads to the formation of peat and organic soils (Money 1972).

The Beaufort and Ecca Groups underlie most of the Free State Province, and the soils in the study area are derived from these substrates, which are mudstones and siltstones. The western part of the Free State which stretches from the Orange River south of Koffiefontein to north of Bothaville and north-eastwards to Sasolburg consists of wind-blown sand deposited on top of the Beaufort and Ecca Groups. Within the mentioned area between Bultfontein and the Vaal River, around Hoopstad and Wesselsbron the soils are deep and sandy soil with a water table which is valuable for the production of crops (Hensley *et al*. 2006).

The grasslands of South Africa cover a large portion of the Karoo Supergroup. Soils that are associated with the Grassland Biome are usually deep and fertile soils, but a wide variety of soil types is possible. Fifty percent of the soils that are found in the Grassland biome are from the red-yellow-grey latosol plinthic catena. On the rocky ridges, some very shallow soils can be found like undifferentiated rock and lithosols, lime-poor weakly developed soils on rock. Soil erosion in the biome occurs mostly in those areas that receive high rainfall and have a low vegetation cover or are located on steeper slopes (Rutherford & Westfall 1994; Mucina & Rutherford 2006).

A study of the water and soil use in the Vet and Sand River Basin was conducted by Els (1952). The soils present in the area are mainly sandy, loamy and alluvial soils. The sandy soils are suitable for agricultural irrigation, however the loamy alluvial soils are mostly low lying and therefore often inundated (Els 1952).

2.3 GENERAL VEGETATION

In the region a number of phytosociological studies were done in the past. A phytosociological study of the Willem Pretorius Nature Reserve was conducted by Müller (1986). The Sandveld Nature Reserve (between Bloemhof and Hoopstad) was done by Viljoen (1979). In 1991, a more extensive study was conducted by Du Preez. Müller (2002) did a study on the plant communities in the Central parts of the Free State.

A biome is a broad ecological spatial unit representing major life zones of large natural areas, they are defined mainly by vegetation structure, climate as well as major large-scale disturbance factors such as fire (Mucina & Rutherford 2006).

Four different biome typea cover the Free State province. They are: Forest, Grassland, Nama-Karoo and Savanna (Rutherford & Westfall 1994; Low & Rebelo 1996; Mucina & Rutherford 2006). The main biome in the study area is the Grassland biome, with a small part covered by Savanna to the west of Hoopstad.

The Grassland Biome is mainly present on the high central plateau of South Africa, the inland areas of the eastern seaboard as well as the mountainous areas of KwaZulu-Natal and the Eastern Cape (Rutherford & Westfall 1994; Low & Rebelo 1996; Mucina & Rutherford 2006). The topography of the area generally is flat to rolling, but the steep escarpment of the Drakensberg range is also included within the Grassland Biome. Altitudes range from near sea level to 2 850 m above sea level (Rutherford & Westfall 1994; Low & Rebelo 1996).

On a global scale the South African Grassland Biome forms part of the Temperate Grassland Biome which occurs between the latitudes 25^0 to 33^0S (Mucina & Rutherford 2006). However most of the grasslands are found at higher latitudes, while the grasslands of South Africa are found at lower latitudes, but higher altitudes.

2.3.1 Driving factors of the Grassland biome

In South Africa the vegetation structure as well as the environmental factors, the summer rainfall and the minimum temperature in winter help to define the extent of the biome (Mucina & Rutherford 2006). Therefore the Grassland biome is dominated by grasses with an absence of a shrub layer and karoo bushes because of the low temperatures reached during the winter months (Mucina & Rutherford 2006). This biome is located within the summer rainfall area. The mean annual rainfall varies between 400 and 2 500 mm (Rutherford & Westfall 1994; Mucina & Rutherford 2006). The minimum temperature for the coldest months is consistently below 1^oC. There is also a possibility for the occurrence of fog in the upper escarpment and seaward scarps where mist belt vegetation occurs (Rutherford & Westfall 1994).

The canopy cover in the biome is moisture dependent and decreases with mean annual rainfall (Rutherford & Westfall 1994; Mucina & Rutherford 2006). Based on the availability of moisture the Grassland biome can be divided into two classes: moist grassland and dry grassland. Moist grassland is dominated by sour grass species that can deal with leached and dystrophic soils (‘sour grasses’). These species occur with a high canopy cover and have a high production of biomass which leads to the high frequency of fires (Mucina & Rutherford 2006). The sour grasses have high fibre content and withdraw the nutrients from their leaves in winter (Low & Rebelo 1996). Dry grassland has palatable grass species that are adapted to less leached soils, and canopy cover, biomass productivity and fire frequency are lower than in the moist areas (Mucina & Rutherford 2006). These species, referred to as ‘sweet grasses’ have low fibre content and retain nutrients in their leaves during winter. This is the reason for their palatability (Low & Rebelo 1996).

In South Africa sour grasslands mostly occur at higher altitudes with a relatively high rainfall, and soils with a low base status. Sweet grasslands occur at lower altitudes with a lower relative rainfall and soils with a high base status. The occurrence of sour and sweet grasses is the difference between the eastern and western Free State, as the eastern parts are at high altitudes and therefore have sour grass species (Mucina & Rutherford 2006).

2.3.2 Structure of the Grassland biome

Grasslands are dominated by a single layer of grasses, although the amount of cover depends upon the rainfall and the degree of grazing (Low & Rebelo 1996; Mucina & Rutherford 2006). Although the Grassland biome is dominated by grasses with either a C_3 (those plants that fix CO_2 into 3-phosphoglyceric acid), C_4 (plants that fix CO_2 into four-carbon acids – most of the monocot species – grasses) metabolism (Salisbury & Ross 1992), trees also occur but they are mostly restricted to a few localised habitats which have a high moisture input (hills, deep ravines and gullies, steep slopes and incised valleys) (Low & Rebelo 1996; Mucina & Rutherford 2006). The areas where trees occur in the grassland biome are called 'shrubland units' and these units are mostly found on alluvial soils or on hills and ridges (Mucina & Rutherford 2006).

Approximately 30% of the Grassland biome is permanently transformed because of cultivation, plantation forestry, urbanisation and mining. Seven percent of the remaining area is severely degraded by erosion, cultivation and other factors (Mucina & Rutherford 2006). This biome is the mainstay of dairy, beef and wool production in South Africa and also most of South Africa's maize is produced in the grassland biome (Low & Rebelo 1996). Other crops that are produced on a smaller scale are sorghum, wheat and sunflowers. Large parts of the remaining vegetation are secondary lands or degraded due to the encroachment of woody species. Most natural vegetation in the biome is threatened because of the area being of economic value for agriculture (Mucina & Rutherford 2006).

The overall species number in grassland often is determined by a small number of grass species and a large number of forbs that occur scattered among the grasses, so forbs contribute often more to species richness than grass species. There are 34 grass taxa endemic to the Grassland biome of South Africa and Lesotho, however the other endemics other than grasses might be around 179. The herbs and especially the orchids have high endemism – 161 of the orchid taxa found in the Grassland Biome is endemic (Mucina & Rutherford 2006). Furthermore the biome has 640 species that are on the Red Data List of endangered species. Of these species, a number of 136 are threatened with extinction and six are already extinct (Mucina & Rutherford 2006).

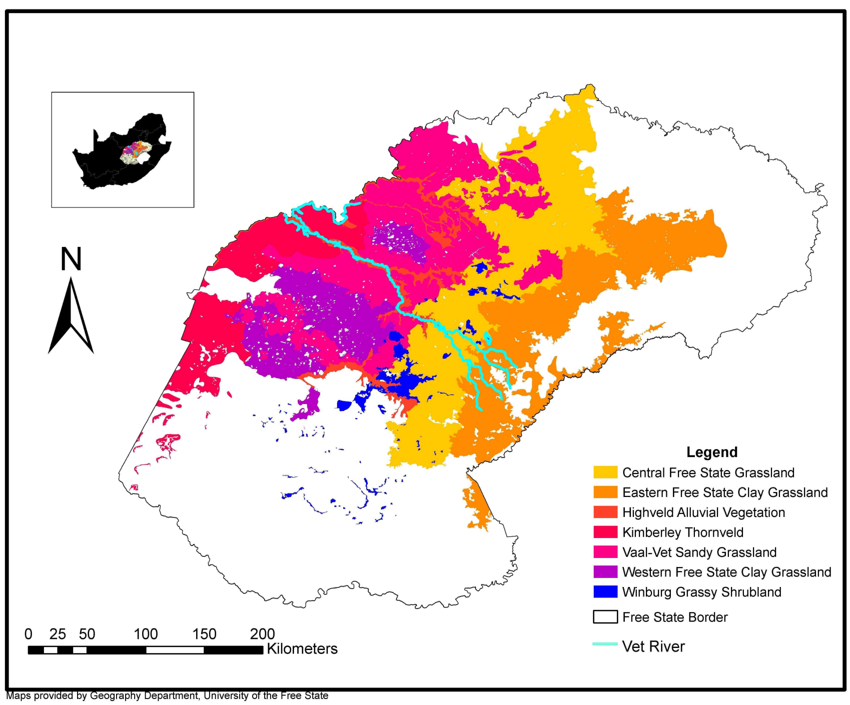


Figure 2.10: Map of the different vegetation types present in the vicinity of the study area.

2.3.3 Vegetation Units

Mucina & Rutherford (2006) divided the Grassland biome into various bioregions and subdivided these bioregions into smaller vegetation units. The area of study includes the following zonal (refer to vegetation typical of climatic zones (Mucina &

Rutherford 2006)) vegetation units as they were defined by Mucina & Rutherford (2006) (Figure 2.10): Central Free State Grassland (Gh 6), Winburg Grassy Shrubland (Gh 7), Western Free State Clay Grassland (Gh 9), Vaal-Vet Sandy Grassland (Gh 10) and the Eastern Free State Clay Grassland (Gm 3). Azonal vegetation is vegetation influenced by the substrate (soil types or bedrock) and/or hydrogeological conditions (Mucina & Rutherford 2006). Vegetation around the river is azonal and Mucina & Rutherford (2006) classified the study area`s riparian vegetation as Highveld Alluvial Vegetation (AZa 5).

2.3.3.1 Central Free State Grassland (Gh 6)

Within the boundaries of the study area (banks of the Vet River), this vegetation type is only present in the vicinity of Winburg. The landscape is mostly undulating plains with short grassland which are dominated by *Themeda triandra,* under natural conditions, while *Eragrostis curvula* and *E. chloromelas* dominate degraded areas. Some areas that are extremely degraded by overgrazing are invaded by dwarf karoo shrubs as well as the small tree *Acacia karroo* (Mucina & Rutherford 2006).

The area is vulnerable with only a small portion conserved. Approximately a quarter of the area has been inundated by large dams in the area: the Allemanskraal Dam and the Erfenis Dam. Although the infestation of aliens in this vegetation unit is not severe, there are some aliens occurring in the degraded southern parts of this vegetation unit (Mucina & Rutherford 2006).

2.3.3.2 Winburg Grassy Shrubland (Gh 7)

This vegetation unit is present in the vicinity of Winburg but is restricted to the slopes of hills and ridges. The vegetation structure of this vegetation unit ranges from open grassland to shrubland. The vegetation in this unit becomes taller than the surrounding grasslands because slow-growing shrubs and trees which are protected against veld fires in late winter to early spring (Mucina & Rutherford 2006).

This vegetation unit is found on ridges, plateaus and slopes of hills as well as escarpments which mark the erosion terraces which are formed by extensive dolerite sills. This vegetation type is protected against fire (Mucina & Rutherford 2006).

This vegetation unit is not threatened, but of the target 28% of protected land only 2% are protected. A further 10% have been transformed due to cultivation and urban sprawl. The vegetation that is found in this unit is remarkably variable and varies in both species composition and structure (Mucina & Rutherford 2006).

2.3.3.3 Western Free State Clay Grassland (Gh9)

The vegetation of this unit occurs in the western district of Bloemfontein, Boshof, Hertzogville, Wesselsbron and Brandfort. This vegetation unit is restricted to flat bottom lands which support dry grassland which are poor in species composition with a high occurrence of mainly salt pans. In disturbed areas dwarf karoo shrubs will surround the playas (Mucina & Rutherford 2006).

This vegetation unit is least threatened. However 20% of this unit is already transformed for the cultivation of maize and wheat. An alien species that appear on occasion in this unit is the tree *Prosopis velutina* (Mucina & Rutherford 2006).

2.3.3.4 Vaal-Vet Sandy Grassland (Gh 10)

This vegetation unit is present in the Bothaville and Brandfort areas north of Bloemfontein. The landscape is mostly dominated by plains, but a number of undulating plains and isolated hills also occur. The vegetation is mostly composed of tussock grasses with a karroid component. Heavy grazing and erratic rainfall in the area leads to an increase in *Elionurus muticus, Cymbopogon pospischilii* and *Aristida congesta* in a previously *Themeda triandra* dominated area (Mucina & Rutherford 2006).

The geology in this vegetation unit is dominated by the Karoo (which dominate the entire study area) and older Ventersdorp Supergroups. Aeolian and colluvial sand overlay the sandstone, mudstone and shale of the Karoo Supergroup. The soil forms present are mostly Avalon, Westleigh and Clovelly (Mucina & Rutherford 2006).

This vegetation unit is endangered. Only about 0.3% of the area is conserved and more than 63% is under cultivation. The rest of the area is subjected to severe grazing pressure by sheep and cattle (Mucina & Rutherford 2006).

2.3.3.5 Eastern Free State Clay Grassland (Gm 3)

The vegetation of this vegetation unit is situated in the vicinity of Excelsior in the eastern parts of the study area and towards the headwaters of the Vet River. The landscape is flat to gently rolling with grassland dominated by *Eragrostis* species, *Themeda triandra, Cymbopogon pospischilii, Setaria sphacelata, Elionurus muticus* and *Aristida congesta*. The patchy appearance that occurs in this vegetation unit is due to the overgrazing and selective grazing of herbivores within the unit (Mucina & Rutherford 2006).

Although some areas within this type are effectively conserved in the form of the Willem Pretorius Nature Reserve, the overall conservation status of this vegetation unit is endangered. Approximately half of the area has been used for cultivation or has been inundated by the Allemanskraaldam (Mucina & Rutherford 2006).

2.3.3.6 Highveld Alluvial Vegetation (AZa 5)

Within the study area, this vegetation occurs along the Vet River, and is mostly confined to floodplains, which is the focus of the present study (Mucina & Rutherford 2006).

The landscape has a flat topography which supports riparian thickets which are dominated by trees such as *Acacia karroo* and *Salix mucronata* and shrubs such as *Diospyros lycioides, Searsia pyroides* and *Ziziphus mucronata.* The undergrowth is dominated by various grasses and numerous alien weeds which are subjected to frequent impacts such as annual floods, fires and grazing (Mucina & Rutherford 2006).

This vegetation unit is less threatened as 10% of the targeted 31% of the area is conserved. Approximately a quarter of the original extent is transformed for cultivation and the building of dams and weirs. Although this area is the least threatened the occurrence of alien species along the rivers is high because of the high nutrient status as well as the ample water supply in the soils. Overgrazing is becoming a problem in certain areas of this vegetation unit (Mucina & Rutherford 2006).

2.3.4 The Savanna biome

The Savanna biome occupies parts of the Northern Cape, North-West Province, Gauteng, Limpopo, Mpumalanga, Swaziland, KwaZulu-Natal and the Eastern Cape as well as the extreme western parts of the Free State Province. Savannas are mostly tropical and occupy great areas of the southern continents and parts of the northern continents. The Savanna biome clearly occurs in areas with a summer-rainfall regime, however worldwide the savanna is dominated by strongly seasonal rainfall with a distinct dry season which usually occur in winter. In South Africa and Swaziland the Savanna biome mostly occur below altitudes of 1 500m. Temperatures in the Savanna biome are higher than the temperatures in the Grassland biome which occur at higher altitudes. The occurrence of hail and lightning are relatively low when compared to the Grassland biome (Mucina & Rutherford 2006).

The Kimberley Thornveld (SVk 4) dominates the area between Hoopstad and the Bloemhof Dam.

2.3.4.1 Kimberley Thornveld (SVk 4)

This vegetation unit occurs in the vicinity of Hoopstad and Bloemhof with altitudes which range between 1 050 and 1 400 m. The tree and shrub layers of this vegetation unit are dominant and mostly dominated by different species of *Acacia*. The grass layer is open with much uncovered soil. The soils are mostly dominated by deep sandy to loamy soils of the Hutton soil form (Mucina & Rutherford 2006).

This vegetation unit is least threatened and is conserved in the Sandveld Nature Reserve near Bloemhof Dam. Erosion in this area is very low and the area is mostly used for cattle farming and game ranching (Mucina & Rutherford 2006).

2.4 INFLUENCE OF FIRE AND GRAZING

2.4.1 Fire

Fire is an important environmental factor and plays an important ecological role in plant communities (Tainton 1999; Mucina & Rutherford 2006). Furthermore fire is important in maintaining the grass cover by preventing successional development beyond the grassland stage (to thicket) (Tainton 1999). The absence of fire may lead to the ecosystem being dominated by trees (as seen on the koppies and rocky ledges, where fire cannot reach), so fire is vital for the maintenance of vegetation structure (Mucina & Rutherford 2006). Fire can also be seen as a generalist herbivore as it destroys all the biomass (Bond 1997). In areas with a rainfall higher than 650 mm per year where fire is excluded, the vegetation will be dominated by trees and shrubs. The frequency, seasonality and intensity of the fires are important determinants of the vegetation development after fire. The intensities of fire are dependent on the fuel moisture, air temperature as well as the wind speed. Lightning is in most cases the natural source of ignition (Mucina & Rutherford 2006). Therefore fires are more frequent in moist areas than in dry areas and can occur annually (Rutherford & Westfall 1994; Bond 1997). The occurrence of fire in moist areas is due to the presence of sufficient fuel to be burned. Furthermore the shape, size and arrangement of the plant parts also play a role in the flammability of the vegetation. Narrow leaves and thin branches are more flammable than other vegetation shapes (Bond 1997).

The burning of biomass is an important process in the ecosystem of southern Africa as it has significant implications for regional and global atmospheric chemistry and biogeochemical cycles. Furthermore fire is an important source of trace gasses and aerosols which enhance the seasonal tropospheric ozone due to biomass burning. The production of the grass layer is not necessarily affected, but annual burning and the effect of fire on soil moisture availability keeps individual grass plants small. The effect that fire has on vegetation is dependent on the characteristics of the fire (Mucina & Rutherford 2006). However fire was used by early humans to stimulate a flush of new growth to improve grazing and to aid hunting (Tainton 1999).

2.4.2 Grazing

Grazing has an influence on canopy cover and structure (Rutherford & Westfall 1994), as well as on species composition (Mucina & Rutherford 2006). Therefore it can be said that there is a close relation between the vegetation and the animal life that depend on it, for food (Tainton 1999). Grasses are adapted to resprout after defoliation although excessive occurrence of defoliation can deplete their reserves. Seed production of grasses can also be negatively affected by overgrazing. The effects and pressures of grazing vary from farm to farm and in some cases the fence-line effect is created. In some areas pastures are stocked to 3-4 times their capacity (Mucina & Rutherford 2006). The composition and cover of the present plant species can be altered by the presence of high concentrations of herbivores, there are however a difference between the wild herbivores that range the grassland then and domestic livestock that are present today. The wild herbivores moved seasonally along the rainfall gradients, while the present day domestic livestock are kept in the area with the additional supplement of fodder during dry periods which maintain the grazing pressure (Mucina & Rutherford 2006). A balance is established between the vegetation and the animal population for co-existence to occur for the stability of association (Tainton 1999).

REFERENCES: CHAPTER 2

AGIS. 2010. http://www.agis.agric.za/agisweb/viewer.htm?pn=2015.

AGIS .2010a. http://www.agis.agric.za/agisweb/?MIval=landtypes&rb=Landtypes_ introduction.

BARDGETT, R. 2005. *The biology of soil: A community and ecosystem approach*. Oxford University Press. New York, USA.

BOND, W.J. 1997. Fire. *In* COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. Vegetation of Southern Africa. Cambridge University Press. United Kingdom.

CONNEXIONS. 2010. cnx.org/content.m22272/latest/graphics1.png.

COURTNEY, F.M. & TRUDGILL, S.T. 1984. *The soil: An introduction to soil study.* Second Edition. Hodder and Stoughton LTD. London.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM. 2009. www.environment.gov.za

D-MAPS. 2010. http://d-maps.com/pays.php?num-pay=7&lang=en

DU PREEZ, P.J. 1991. A syntaxonomical and synecological study of the vegetation of the south-eastern Orange Free State and related areas with special reference to Korannaberg. Unpublished PhD dissertation. University of the Free State, Bloemfontein.

ELS, W.C. 1952. Waterverbruik en Grondbenutting in die Vet- en Sandriviergebied. Unpublished M. Artium dissertation at the Faculty of Arts, University of the Orange Free State, Bloemfontein.

EYRE, S.R. 1968. *Vegetation and Soils. A World Picture*. 2nd edn. Edward Arnold Publishers Ltd. Great Britian.

HENSLEY, M., LE ROUX, P.A.L., DU PREEZ, C.C., VAN HUYSSTEEN, C.W., KOTZE, E. & VAN RENSBURG, L.D. 2006. Soils: The Free State's Agricultural Base. *South African Geographical Journal* 88(1): 11-21.

LOW, A.B. & REBELO, A.G. (eds). 1996. *Vegetation of South Africa, Lesotho and Swaziland*. 2 nd edn. Department of Environmental Affairs and Tourism. Pretoria.

McCARTHY, M. & RUBIDGE, B. 2005. *The Story of Earth and Life: A southern African Perspective on a 4.6-billion-year journey.* Struik Publishers. South Africa.

MONEY, D.C. 1972. *Climate, Soils and Vegetation.* 2nd edn. University Tutorial Press LTD. Foxton, near Cambridge.

MÜLLER, D.B. 1986. Plantekologie van die Willem Pretorius-Wildtuin. Unpublished PhD dissertation. University of the Free State, Bloemfontein.

MÜLLER, M.E. 2002. The phytosociology of the central Free State. Unpublished MSc thesis. University of the Free State, Bloemfontein.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South Africa National Biodiversity Institute, Pretoria, South Africa.

PLUMMER, C.C. & McGEARY, D. 1979. *Physical geology*. Wm.C. Brown Company Publishers. United States of America.

RUTHERFORD, M.C. & WESTFALL, R.H. 1994. Biomes of southern Africa: an objective categorization. *Memoirs of the botanical survey of South* Africa No. 63. National Botanical Institute, Pretoria, South Africa.

SALISBURY, F.B. & ROSS, C.W. 1992. *Plant Physiology 4th* edn. Wadsworth Publishing Company. Belmont, California.

SAWS. 2002. Climate of South Africa: Climate statistics to 1990.WB 42. SAWS, Pretoria, South Africa.

SCHULZE, B.R. 1965. *Climate of South Africa*. Part 8. General Survey. Weather Bureau and Department of Transport. South Africa.

SCHULZE, R.E. 1997. Climate. *In* COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. Vegetation of Southern Africa. Cambridge University Press. United Kingdom.

TAINTON, N.M. 1999. *Veld Management in South Africa.* University of Natal Press, Pietermaritzburg, South Africa.

TRUSWELL, J.F. 1970. *An introduction to the historical geology of South Africa*. Purnell & Sons (Pty)Ltd, Cape Town, South Africa.

TRUSWELL, J.F. 1977. *The Geological Evoltion of South Africa.* Purnell & Sons (Pty)Ltd, South Africa.

VAN ZYL, D. 2003. *South African Weather and Atmospheric Phenomena*. Briza Publications, Pretoria, South Africa.

VILJOEN, A.J. 1979. Die Plantekologie van die Sandveld-Natuurreservaat, Hoopstad. Unpublished MSc thesis. University of the Free State, Bloemfontein.

WEATHER BUREAU. 1960. *Climate of South Africa.* Part 6. Surface Winds. Weather Bureau and Department of Transport. Pretoria, South Africa.

WINEGARDNER, D.L. 1996. *An introduction to soils for environmental professionals.* Lewis Publishers. United States of America.

CHAPTER 3

WETLANDS AND RIPARIAN AREAS

3.1 INTRODUCTION

This chapter will define and classify wetlands in general and then will focus on the wetlands occurring along the Vet River. Wetlands have various definitions, but the overall accepted definition is that of the RAMSAR convention. The classification of wetlands differs from country to country as each has different wetlands and different terms to describe wetlands. In this study the classification system of SANBI (2009) was used to classify the wetlands along the Vet River.

Wetlands perform certain functions which are natural to these unique systems. These processes are important for the formation of wetlands and include the hydrology (inputs, outputs and throughputs) as well as sedimentation. The functions that wetlands perform are necessary in the environment and can be advantageous to humans. Wetland functions include the prevention of floods by the retention of water, the removal of chemical compounds from the water, providing habitat for animals and plants in a favourable environment and the decomposition of excess organic matter. Furthermore, wetlands are valuable ecological laboratories because of their habitat and species diversity (Davies & Day 1998).

The vegetation present in any wetland environment play an important role in the ecosystem as these plants provide oxygen in the wetland environment and are a major source of energy as they are the primary producers in the wetland. Furthermore the plants also have an influence on the hydrology of the wetland as well as the sediment regime thereof. The vegetation present in the wetland environment can differ from emergent, submerged, floating-leaved plants and floating plants. The plants that live in wetland environments are subjected to certain stress factors which include the frequent occurrence of anaerobic conditions, limited light if the plants are rooted at the bottom and limited nutrients (Cronk & Fennessy 2001; Ewart-Smith *et al.* 2006).

Wetlands are endangered environments as humans utilise these areas because they have fertile soils which are useful in agriculture and therefore most early humans have lived close to or near wetlands. Humans have exploited these ecosystems for extended periods. The result is that these ecosystems became threatened because of human actions which include the alteration of the hydrological cycles. The intrusion of exotic species in wetlands also threatens native species that are present in the wetland. The change in the present global climate also affects these ecosystems. Therefore, wetlands need to be conserved and restored (Mitsch & Gosselink 1993; Keddy 2000; Cronk & Fennessy 2001).

Riparian areas are the narrow strips of vegetation that occur along channels or rivers. Most of the processes and functions that occur in wetlands also occur in the riparian areas. However the occurrence of floods plays a more important role in riparian areas than in wetlands. The occurrence of floods also has an influence on the vegetation and sometimes may even strip the banks of their vegetation and leave bear patches of land which are vulnerable to erosion because of the valuable top soil being lost (Davies & Day 1998).

The riparian areas and wetlands that occur along the Vet River are linked with each other through floodplains which are periodically inundated during the summer.

3.2 DEFINITION AND CLASSIFICATION OF WETLANDS

3.2.1 Definition

Davies & Day (1998) stated that it is easier to recognise a wetland than to define it as a bit of land that hold water and are neither a river nor a lake and can be seen as wet land. However Van der Valk (2006) stated that the term wetland is a relatively new term which is being used collectively for all the local terms like: marsh, swamp, fen, slough, bog, glade, hammock, vlei, jheel, etc.

Ellery *et al.* (2008) describe wetlands as the interface between aquatic and terrestrial environments, as well as between groundwater and surface-water systems. Wetlands occur naturally in various places in the landscape because of the presence of surface water or the periodical presence of water or groundwater that forms waterlogged soils (Tiner 1999). A wetland can be seen as an area where water accumulates for long enough to create anaerobic conditions in the rooting zone of the herbaceous plants (Mitsch & Gosselink 1993; Ellery *et al.* 2008).

More than 50 definitions of wetlands are used worldwide (Dugan 1993). The defining of the term 'wetland' has led to a large number of debates, however in 1971 the RAMSAR convention defined wetlands and this definition is in use worldwide (Ewart-Smith *et al.* 2006).

The RAMSAR definition that is being used by scientists worldwide, including South Africa, is: "wetlands are areas of marsh, fen (peat-accumulating wetland that receives some drainage from surrounding mineral soil and usually supports marshlike vegetation), peatland (generic term of any wetland that accumulates partially decayed plant matter) or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Dugan 1993; Mitsch & Gosselink 1993; Cowan 1995; Ewart-Smith *et al.* 2006; DWAF 2008; SANBI 2009). Although South Africa is a signatory of the RAMSAR Convention, the definition that is used in our country has a slight adaptation. The depth for marine ecosystems is extended from 6 m to 10 m because this defines the shallow photic zone in marine ecosystems (Ewart-Smith *et al.* 2006).

More important than the question which wetland definition is being used, is the consistency with which the definition is applied, especially when scientific and legal issues meet, as often happens when decisions regarding resource management are made. For the purpose of applying the definition successfully a generation of well-trained wetland scientists and managers are needed. These people must also have a fundamental understanding of the processes that are important and unique to wetlands (Mitsch & Gosselink 1993). In South Africa the legal definition of a wetland is found in The National Water Act of South Africa (Act no.36 of 1998) as presented by Ewart-Smith *et al.* (2006): "land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances support or would support vegetation typically adapted to life in saturated soil" (Ewart-Smith *et al.* 2006; Kotze *et al.* 2007; SANBI 2009). This definition is narrower than the RAMSAR definition as it excludes open water up to a depth of 6 meters in both marine of freshwater environments. Regulations regarding these open water systems as well as rivers are stated separately in the National Water Act (Ewart-Smith *et al.* 2006).

Generally, there are three main components that are used to define a certain area as a wetland (Ewart-Smith *et al*. 2006; Van der Valk 2006; Reddy & DeLaune 2008);

- Hydrology (presence of water at or near the surface for a period of time)
- Hydrophytic vegetation (wetland plants adapted to saturated soil conditions, usually called macrophytes);
- Hydric soils (saturated soil conditions exhibiting temporary or permanent anaerobiosis).

There is some evidence that wetlands have unique characteristics that are neither aquatic nor terrestrial. These characteristics mostly follow from the fact that they have waterlogged soils which results in, anoxic conditions and special adaptations in plants and animals for survival in this environment (Mitsch & Gosselink 1993).

Tiner (1999) identified more specific questions that should be taken into consideration when identifying or delineating a wetland:

- How long and how frequent must the area be wet?
- Is the area wet in the growing or in the non-growing season?
- How deep is the groundwater table throughout the year?

When defining the boundaries, water cannot be used as a criterion, because water varies on a seasonal and annual base. One must rather use wetland plants (hydrophytes) as well as wetland soils (hydromorphic) for the correct identification of the boundaries (DWAF 2008).

Tiner (1999) defines wetlands as the universe of wet habitats which include marshes, swamps, bogs, fens and similar areas. The wetland environment is permanently or periodically inundated or has soils with prolonged saturation which is sufficient for the establishment of hydrophytes (aquatic plants living on or in the water (Lawrence 2000)) and the development of hydric soils. A distinction needs to be made between the wetlands and riparian areas (Mitsch & Gosselink 1993). Mitsch & Gosselink (1993) see riparian areas as the interface between aquatic and terrestrial ecosystems, however Lawrence (2000) define riparian zones as frequenting, growing on, or living on the banks of streams or rivers. These areas are usually narrow and linear. The vegetation that occurs in riparian areas is shaped by disturbances. These disturbances include wind, fire, flooding (floods can either occur as rare occasions of exceptional floods or as the spill of water over the banks every year during the wet season (Davies & Day 1998)), debri flows and sedimentation processes (Holmes *et al*. 2005).

Wetlands can further be classified using vegetation, hydrology, water chemistry, origin of water, soil types, landscape position and landform, wetland origin, wetland size and ecosystem form or energy sources (Tiner 1999). Hydrology and landform in South Africa are two of the most fundamental features to determine the existence of wetlands, although climate, soils, vegetation and origin also play a role. Internationally there is at present a general agreement that wetland classification based on geomorphic and hydrological aspects are far more robust consistent than classification systems based on other criteria (Ewart-Smith *et al.* 2006).

3.2.2 Classification

In South Africa little is known about the distribution, physical and biotic characteristics as well as the way of functioning of wetlands (Ewart-Smith *et al.* 2006).

Brinson (1993) suggests that classification of wetlands has two main purposes, firstly to simplify the concept of wetlands and secondly to describe the uniqueness of each wetland more accurately by categorizing wetlands based on their properties that are shared with other wetlands. However, there are various classifications by various authors which include: Tooth & McCarthy (2007); Van der Valk (2006), Brinson (1993), Mitch & Gosselink (1993) as well as classifications for different continents and countries as presented in the above mentioned literature.

In South Africa a hierarchical structured classification system to identify wetlands, has been developed by Ewart-Smith *et al.* (2006). The classification of Ewart-Smith *et al.* (2006) was taken as base for the refinement that has been done on the classification of wetlands in SANBI (2009), which is presented here. The main focus in SANBI (2009) as well as in the current study is on inland systems which are defined as ecosystems that have no existing connection to the ocean but which are inundated or saturated with water, either permanently or periodically.

The classification systems that have been proposed by SANBI (2009) are as follows: The system is divided into 6 levels which consist of primary, secondary and tertiary discriminators. The primary discriminators are classified as level 1 to 3.

Level one is the system level and is distinct on the characters of the connectivity to the open ocean. There are three ecosystems present namely: marine, estuarine and inland.

Level two are the sub-systems and here drainage is the important discriminator. This system is not applicable to marine systems. In estuarine systems the tidal exchange is important, but in inland systems it is important to know whether the sub-systems are linked through surface water or not. This classification has lead to disputes and therefore needs further investigation (Ewart-Smith *et al.* 2006). However, in the new classification as it appears in SANBI (2009) this level consists of Ecoregions which are delineated on the basis of physical/abiotic factors. There are a total of 31 Ecoregions.

Level three are the functional units and have landform and tidal regime as discriminators. The different discriminators vary between different systems. From landform shape and settings to the hydro-period because of the frequency and degree of inundation, this plays an important role in defining wetlands (Ewart-Smith *et* al. 2006). However, in SANBI (2009) the third level of discriminators is based on the landscape settings which include the topographical position.

Level four are the structural units and form part of the secondary discriminators where the dominant cover types are used as distinguishing factor. The dominant cover types are the substratum, surface/subsurface vegetation or emergent vegetation. The characteristics of the cover have an effect on the characteristics of the habitat, which determine the composition of the wetland biota and the biological functions the wetland can perform (Ewart-Smith *et al*. 2006). This level in SANBI (2009) is decided on the basis of hydrology and geomorphology.

Level five are the habitat units and form part of the tertiary discriminators where the dominant vegetation characteristics are important. Wetland units which are defined as herbaceous vegetation can be further divided into sedges, grass, reeds ect. The habitat units would be useful at a finer level of the hierarchy, because these units would form the basis of understanding the biotic integrity of wetlands (Ewart-Smith *et al*. 2006). However in SANBI (2009) this level are now decided on the basis of the hydrological regime.

Level six now include wetland characteristics which are being used as descriptors. These include the geology of the area, whether the wetland is natural or artificial, the vegetation cover, the substratum, salinity and acidity/alkalinity.

Although there are different classification systems for the classification of wetlands as mentioned in the literature the classification of SANBI (2009) were used for the purpose of this study as it is the most recent classification.

Inland Systems

Inland wetlands mostly rely on rainfall for water supply which can either be as runoff or as contribution to groundwater recharge which enters the wetlands. The largest diversity of wetland ecosystems occur in the inland systems and for the purpose of this study the focus will be on this system (Ewart-Smith *et al.* 2006).

The second level of classification includes the regional settings of the system which include the ecoregions as seen in Figure 3.1. This figure shows the area where the study took place namely the Vet River in the Free State Province, South Africa, as a part of the Highveld ecoregion:

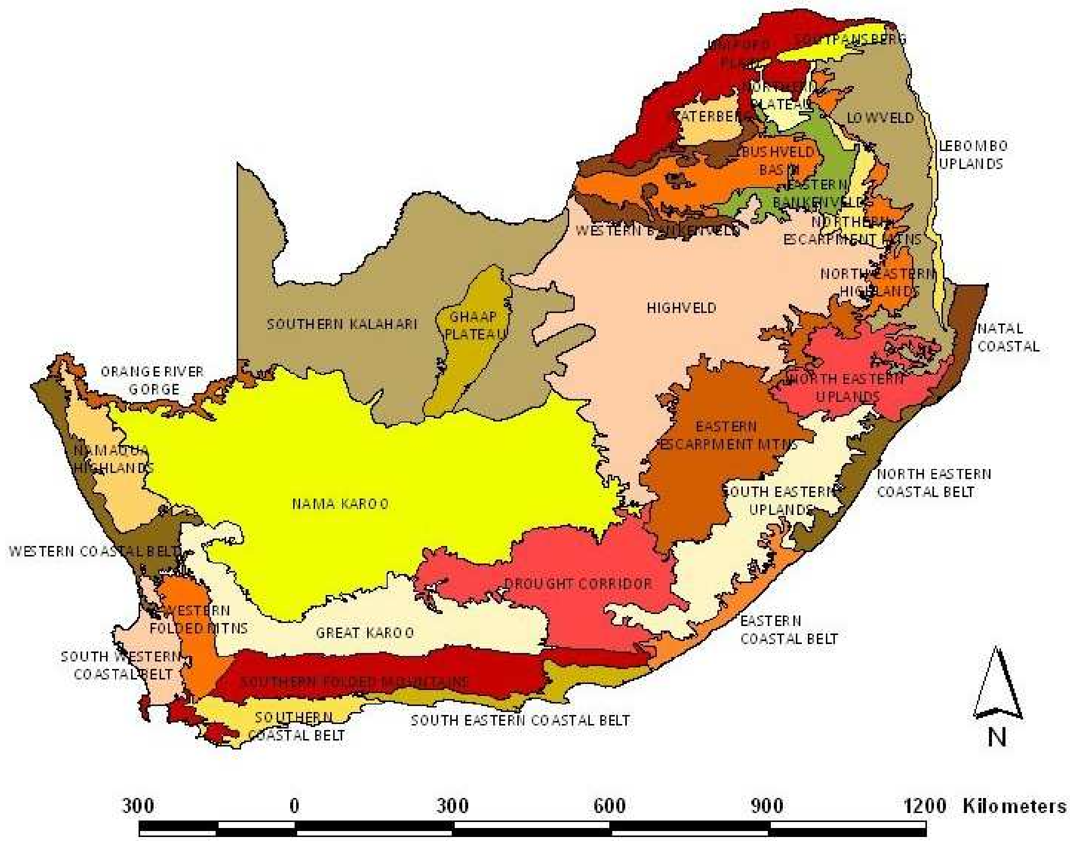


Figure 3.1: Map of DWAF Level 2-Ecoregions (SANBI 2009).

The third level of classification is the landscape units which include the topographical position:

- *Slope*: this is an area that is not part of a valley floor but located on the side of a mountain, hill or valley. The gradient of this area should be ≥ 0.001 or 1:1000.
- *Valley floor*: this area is a gently sloping, lowest surface of a valley. The gradient of the area is between 0.001 and 0.1, although a valley floor may have a gradient smaller than 0.001.
- *Plain*: an area of low relief with relatively level, gentle undulating or uniformly sloping land. This landscape unit include coastal plains, interior plains and plateaus. For this classification system plains are the flat areas not located between two side-slopes.
- *Bench (hilltop/saddle/shelf)*: areas with level or nearly level high ground. For this classification bench areas are considered as the high-lying areas, although the bench areas are less extensive than plains. The gradient of these area are less than 0.001.

The fourth level of classification use hydrology and geomorphology as the discriminators. There are 8 primary hydrogeomorphic units. These units include the following:

- *Channel (river, including the banks):* The area contains flowing water continuously or periodically or forms the connection between two water bodies. The main source of water are concentrated surface flow from upstream areas and tributary channels, diffuse surface flow as well as interflow and last but not least groundwater flow. Channels in general refer to rivers and streams.
- *Floodplain wetland:* This is gently sloping wetlands which are adjacent to rivers. These areas are subjected to periodic inundation due to overtopping of the channel bank. The input of water and sediment in these wetlands are usually due to overtopping of the major channel.

The Hydrogeomorphic (HGM) Units can be further divided into sub-categories on the basis of longitudinal geomorphological zonation or localised landforms: This classification is as follow (SANBI 2009):

- *Channels (including the banks):* This category is divided on the basis of primary longitudinal zones. These include the Mountain Headwater Stream, Mountain Stream, Transitional River, Upper Foothill River, Lower Foothill River and Lowland River. The other channels are divided on their rejuvenated longitudinal profile. These include the Rejuvenated Bedrock Fall, Rejuvenated Foothill River and the Upland Floodplain River.
- *Floodplain wetlands:* Which can be divided into floodplain depressions and floodplain flats.

The fifth classification level is determined on the basis of hydrological regime and the depth of inundation. It is however necessary to distinguish between the hydrological regime for channels and HGM Units. Channels has flow regime as the major discriminator while inundation and saturation periodicity is the major discriminators for HGM Units. Therefore the classification in terms of the primary flow regime for channels is as follow (SANBI 2009):

- *Non-perennial:* Water is not held or flowing continuously throughout the year
  - *Seasonal:* Water is present for extended periods during the wet season but absent during the rest of the year.
  - *Intermittent:* Containing water for a relatively short period of time, sometimes even less than a season. Therefore the situation is not predictable as is the case with perennial and seasonal flows.
- *Seasonally inundated:* Soils with surface water present for extended periods during the wet season but drying up annually

The fifth level of classification is further refined into various periods in which the top 0.5m of the soil is saturated. The classification is as follow (SANBI 2009):

- *Seasonally saturated:* All the spaces between the soil particles are filled with water for an extended period of time which are usually the wet season.

Following the classification of SANBI (2009) the wetlands present in the study area can be classified as floodplain wetlands which occur on gentle slopes which are barely detected and covered with large quantities of alluvial sediment on the surface.

The surface next to the river is the floodplain which are flooded when the river overtops its banks. The frequency of flooding depends on the local circumstances. Some of the floodplains may flood more than once a year while others only floods every few years. Further the deposition of bedload sediment may occur continuously, while the deposition of suspended sediment only occurs during large floods. Meandering rivers usually give rise to oxbow lakes and levees which provide elevated ground (Ellery *et al.* 2008).

3.3 PROCESSES AND FUNCTIONS OF WETLANDS

An ecotone is defined as a zone where two ecosystems (community of different species interdependent on each other, together with non-living environment, which is relatively self-containing in terms of energy flow) overlap, and which supports species from both ecosystems as well as species found only in this zone (Lawrence 2000).

The wetlands of the world are a transition between uplands and deepwater aquatic systems and can therefore be seen as ecotones or ecotonal habitats because they occur between land and water (Mitch & Gosselink 1993). The fact that wetlands are the connection between the uplands and aquatic systems leads to the assumption that these areas are among some of the most productive ecosystems on earth. Therefore wetlands can function as organic exporters or inorganic nutrient sinks (Mitch & Gosselink 1993). According to Keddy (2000) wetlands are also important transformers of nutrients and metals. Wetlands might also act as sinks for phosphorus which erode from the surrounding terrestrial ecosystems.

Tiner (1999) stated that although certain wetland plant communities or portions of wetlands are excellent examples of ecotones one cannot assume that wetlands are ecotones, as the ecotone concept is sometimes misapplied when looking at all wetlands. Ecotones are usually regarded as a tension zone with an emphasis on the struggle between two adjacent communities which are connected by physical conditions. Further, it is clear that an ecotone is seen as a belt between two communities, which may vary in width dependent on the ecosystem type eg. the edge of a forest and a grassy field or the streambank beside a meadow. The width must be more than a few centimetres so that it can be of ecological significance. However the physical conditions of the ecotone differ from the adjacent communities as the communities have an influence on the ecotone. Some species of animals and plants only occur in the ecotone and may be absent from the two adjacent communities. It is important to keep in mind that the ecotone is the result of a combination of the adjacent communities. However a change in either of these communities may also affect the ecotone (Tiner 1999).

3.3.1 Processes

Physical processes in river are determined by the following factors (Robert 2003):

- The volume and time distribution of water supplied from upstream;
- The volume, time distribution and character of sediment delivered to the channel;
- The nature of the material through which the river flows and
- The topographic gradient down which the river flows.

3.3.1.1 Hydrology

A surplus of water at or close to the surface of the earth is usually an indication of wetlands. The unique features of wetlands are due to the periodic saturation of the soils by water (Ellery *et al.* 2008). These systems are dynamic in the sense that the environmental conditions change daily, seasonally and interannully (Van der Valk 2006). Water is important to transport nutrients and sediment into and out of the wetland and bring about unique physiochemical conditions in wetlands. Wetlands are physically shaped by the interaction of the inflow and outflow of sediment, energy and nutrients over a period of time (Ellery *et al.* 2008).

The term wetland implies land that has water in the vicinity and therefore the hydrology of wetlands is very important as these are seen as systems that are transitional between the terrestrial habitat and the open water of an aquatic environment. The wetland transitional area are seen as the edge of many terrestrial and aquatic plants and animals, therefore a slight change in the hydrology of the area may result in significant changes in the biotic environment. The slightest change in the hydrology may lead to a massive change in species composition and richness of the ecosystem and its productivity (Mitsch & Gosselink 1993).

Hydrology in general, is the study of the movement and storage of water (Van der Valk 2006). Viessman & Lewis (2003) also stated that hydrology is the science of water and includes the occurrence, distribution, movement and properties of water on earth.

Water is a primary factor that organizes the landscape in a wetland area through processes such as transport, erosion, leaching, solution and evapotranspiration. The hydrological regime is a key variable that determine the composition, distribution and diversity of wetland plants. The hydrological regime that affect the plant communities in a wetland include water depth, water chemistry and flow rates of water. The hydrological conditions in a wetland have an effect on the species composition, successional trends, primary productivity and the accumulation of organic matter. The hydrology has an important influence on the composition of the plant community and the primary production by influencing the availability of nutrients, soil characteristics and the deposition of sediment (Cronk & Fennessy 2001).

The wetland`s hydrology influence the vegetation`s composition which determine the value of the wetland and its organisms. The hydrological budget and the geology determine the quantity and chemistry of the water in the wetland (Cronk & Fennessy 2001). Hydrology provides a basis for understanding the ecology of wetland plants, their association with flooded and saturated conditions. The establishment of plants are influenced by a number of hydrological processes namely: inflow rates, water depth, internal flow rates and patterns, the timing and duration of flooding and groundwater exchange (Cronk & Fennessy 2001).

Keddy (2000) mentioned that wetlands also provide the function of flood retention and therefore store water in the substrate. This function is not only provided by peatlands and depressions but also by floodplain wetlands. The floodplain wetlands allow water to spread over a large surface of the landscape and therefore reduce the velocity and the depth of the water being discharge. The discharge of rivers may vary as some rivers are seasonal and are characteristic of temperate zones, where floods are occurring in early spring. The seasonal variation is not the only variation as the water levels may also vary among years. The frequency of water level fluctuation controls the characteristics of the wetlands. Most of the time the water sources of wetlands are precipitation, ground water and surface flow (Keddy 2000).

3.3.1.1.1 Hydrological character of wetlands

The source and nature of water as well as its movement through and out of the wetland are important when distinguishing different inland wetland types (Ewart-Smith *et al.* 2006). The balance of a wetland`s water inflows and outflows over time is the hydrological budget which in turn is an important part of the hydroperiod of a wetland. The hydrological budget is important because it reveals the importance of each hydrologic process for a given wetland (Cronk & Fennessy 2001). The following descriptors are important and specifically applied to inland wetlands and should be applied on Level 3 in the hierarchy of identifying wetlands as proposed in Ewart-Smith *et al.* (2006).

a) Inputs:

Groundwater: wetland predominantly fed by groundwater sources (Ewart-Smith *et al.* 2006). Groundwater is a major source of water for a lot of wetlands. Groundwater is an important factor that influences riparian wetlands (Ellery *et al.* 2008).

Interflow: wetland predominantly fed by near-horizontal flow of water through the subsurface soil profile.

Precipitation: wetland fed by direct rainfall.

Channelled flow: wetland predominantly fed by surface runoff that is channelled.

Diffuse surface flow: wetland predominantly fed by dispersed surface runoff.

Cronk and Fennessy (2001) stated that inflows are generally driven by the climate and therefore include precipitation, surface runoff and groundwater inflows.

b) Throughputs:

Interflow: water moves through the wetland by near-horizontal flow of water through the subsurface soil profile.

Channelled flow: water moves through the wetland by surface runoff that is channelled.

Diffuse surface flow: water moves through the wetland by dispersed surface flow.

c) Outputs:

Groundwater: water flow directly into the groundwater once it leaves the wetland.

Interflow: water exits the wetland as soil water as near-horizontal flow of water through the subsurface soil profile.

Evapotranspiration: water exits the wetland through evaporation.

Channelled flow: water exits the wetland as surface flow via a defined channel.

Diffuse surface flow: water exits the wetland as diffuse surface runoff.

Although Ewart-Smith *et al.* (2006) mentioned the importance of evapotranspiration as part of the outputs, Cronk & Fennessy (2001) stated that the transpiration is an important parameter to determine the interaction between the wetland`s hydrological regime and its vegetation. Transpiration is the only component of the water budget that is entirely dependent on the plants in the wetland. The evapotranspiration is a combination of transpiration and evaporation, which are affected by the solar radiation, wind speed and turbulence, available soil moisture as well as the relative humidity. Therefore on ecosystem level the water outputs due to evapotranspiration are controlled by vegetation and the water supply (Cronk & Fennessy 2001).

3.3.1.1.2 Hydroperiod of Inland Systems

In Ellery *et al.* (2008) it is clear that the hydroperiod of a wetland is the signature describing the seasonal pattern of water level fluctuations. In seasonal wetlands the flood duration and flood frequency is usually the important characteristics of the wetland. Hydroperiod is an important factor that affects the functioning, management and rehabilitation of wetlands and can be influenced by the activities of humans in the catchment (Ellery *et al.* 2008). Therefore the severity of floods can be increased by the activities of humans like the clearing of forests, building of dykes and the draining of wetlands (Keddy 2000).

The hydroperiod is limited to the frequency and level of inundation, with waterlogging or saturation not considered as criterions, because the detection of the saturation degree is difficult without detailed and multi-temporal data. Where there is detailed information on the hydroperiod a classification is possible as presented by Ewart-Smith *et al*. (2006) in the classification of wetlands.

3.3.1.1.3 The influence of dams on the hydrology

According to Keddy (2000) the distribution of species are influenced by the development of land, forestry practices and dams. In some cases the species might be eliminated entirely. The building of dams around the world has a significant influence on the natural fluctuation of the water levels and therefore disrupts the natural environment. The building of dams might have the following effects on the environment (Keddy 2000):

- *Water levels stabilized*
  The saturation or permanent inundation of substrates that were previously periodically exposed.
- *Shifted-flood timing*
  The building of dams causes a lag in the release of flood water, which can cause delayed flooding and that will affect the vegetation that would normally develop after floods.
- *Increased flooding*
  Levees can be seen as linear dams which can increase the flood peaks by contributing to the flow of water onto floodplains.
- *Decreased flooding*
  The decrease in flooding is the major consequence of many projects which include the use of water for the generation of hydroelectricity and irrigation.

Further the damming of water reduces the flooding which in turn leads to the shrinking of wetlands and herbaceous wetlands are being invaded by woody species (Keddy 2000).

3.3.1.2 Sedimentation

Most of the time, sediment is associated with the silt and mud that turn water grey or brown, but rivers transport several types of sediment (Ellery *et al.* 2008). According to Kotze *et al.* (2007) the presence of sediment reduces the water quality and provides attachment for other pollutants which might include phosphate and certain toxins.

The banks of rivers represent a significant source of sedimentation and erosion varies significantly along river channels. The occurrence of erosion is usually due to the detachment of aggregates of grains from the parent material. The occurrence of mass failure is due to the drying and wetting of banks, which will lead to cracks which increase the susceptibility to erosion. Mass failure is more dominant in the downstream areas than in the river reaches because of the increase of bank height downstream (Robert 2003).

3.3.1.2.1 Chemical sedimentation

The chemical sedimentation is influenced by biotic processes. The evaporation of surface water leads to an enrichment of solutes, while root uptake by plants exclude solutes. This leads to the saturation of silica which precipitates in the sediment of the floodplain soils (Tooth & McCarthy 2007). Tooth & McCarthy (2007) compared the rivers in the Free State and other provinces in South Africa to the Klip River near Memel and according to the findings from those rivers chemical sedimentation does not occur in the area of study. However in the southern parts of Africa chemical sedimentation is important because of the general arid climate on the continent (Ellery *et al.* 2008). The chemicals present in the wetlands are introduced via the dissolved load in streams and the overall sediment load. The deposition of this sediment occurs because of the evaporation and transpiration of water into the atmosphere. Plants however are selective in their uptake and may exclude some of the solutes, these solutes then become saturated and precipitate out of solution which will then accumulate in the soil. Ellery *et al.* (2008) called this type of sedimentation dissolved sediment which consist of elements like nitrogen and phosphorous which normally occur in low concentrations and therefore limit plant growth. But if the concentrations of these elements increase then there will be an increase in the primary production of the system. Elements that are less considered when looking at dissolved sediment are elements that do not limit plant growth. These elements include potassium, sodium, chlorine and silica. These elements either have no effect on the growth rate or may be detrimental to such growth. Therefore these elements are being called detrimental solutions (Ellery *et al.* 2008).

3.3.1.2.2 Clastic sedimentation

The sediment show a fining-upward succession, where the wetter areas have sediment that are higher in organic content because of the slow clastic input, greater plant growth and the reduction in decomposition (Tooth & McCarthy 2007). Tooth & McCarthy (2007) as previously mentioned compared the rivers with the Klip River and therefore clastic sedimentation occurs in their area of study. According to Ellery *et al.* (2008) clastic sediment are composed of particles of clay, silt, sand, cobbles and boulders. However a distinction is needed between the suspended sediment which are silt and clay and bedload sediment which are anything from sand to boulders. In South Africa the deposition of clastic sediment occur in areas where the stream has a reduced ability to carry its sediment load. This usually occurs in the head of a wetland where the inflowing stream reduces its gradient, or along the length of the wetland where contributing rivers enter the wetland and supply additional sediment. In most of the wetlands there is a net accumulation of clastic sediment if there is available space to accommodate the sediment (Ellery *et al.* 2008).

3.3.1.2.3 Organic sedimentation

In humid areas the continuous inundations prevents decomposition and therefore lead to a thick accumulation of organic matter/peat. This organic matter accumulation occurs in anaerobic and acidic conditions at low ground temperatures with low rates of clastic inputs (Tooth & McCarthy 2007; Ellery *et al.* 2008). The continuous wetness of the wetlands prevents fires to some extent although in some areas fires may occur. In contrast with the humid areas in more arid areas the widespread drought means that there is almost no accumulation of organic or peaty deposits and therefore clastic or chemical sedimentation usually dominates.

In the dryer areas fires are also frequent and consume vegetation and therefore reduce the deposition of peat and organic matter. The ashes that remain, deposit nutrients into the environment which will promote the regrowth of grasses, shrubs and trees. The loss of vegetation due to fire increases the potential erodibility of the surface sediment by water and wind (Tooth & McCarthy 2007). Ellery *et al*. (2008) stated that the accumulation of organic matter only occur in low energy environments, therefore environments with standing or slow moving water, and does not include rivers, but are common in wetlands. This organic matter is usually decomposing plant material.

3.3.1.2.4 Erosion

Normally wetlands are regarded as sediment sinks rather than sediment sources, but because of human activities erosion are threatening the health and existence of wetlands. Some of the wetlands are being over utilized which may disturb the natural balance of the wetland and decrease the vegetation cover. With a change in the vegetation and presence of water the soil become exposed to precipitation and wind which increase desiccation and cracking. Whether the sediment supply of a wetland decrease or increase the natural balance is affected and the consequences might be significant. Most of the wetlands in the past were drained for crop production by means of artificial channels. The vulnerability of a wetland to erosion is determined by the relationship between the slope and the wetland size. Erosion is a significant threat to wetlands and is the most important process leading to wetland degradation and loss (Ellery *et al.* 2008).

Erosion can either be splash erosion caused by rain drops, soil wash on valley slopes, bank erosion and the slumping in valley bottoms. The eroding of river banks cause the removal of established plant communities and therefore allow for succession new banks are being deposited by the eroded sediment (Keddy 2000). Vegetation cover also plays an important role in reducing the hazard of erosion by binding the soil with roots as well as protecting the surface with leaves and stems (Kotze *et al.* 2007).

3.3.2 Functions

Many cultures are dependent on and lived along wetlands for centuries because of the benefits for agriculture, although there are also many misunderstandings and fear for wetlands (Mitsch & Gosselink 1993). Although wetlands are generally advantageous to humans, they have also often been a source of suffering because of diseases like malaria (Keddy 2000).

In other parts of the world, wetlands have a large impact on the local economy, because of their high productivity. In China rice is harvested from domestic or artificial wetlands, in Russia and parts of Europe peatlands are mined for peat as a source of energy, and in most mangroves in Indo-Malaysia, East Africa and Central America timber, food and even tannin are harvested by local communities. Reeds from wetlands are commonly used today for thatching (Mitsch & Gosselink 1993). The soils of wetlands are fertile and may be used as areas valuable to agricultural development but in some cases the instability of the soil makes it hazardous for travel or building (Tiner 1999).

The benefits of wetlands in drylands are very evident as these are the only sources of water in otherwise dry areas (Tooth & McCarthy 2007).

The ecological functionings of wetlands are related to the presence, quantity, quality and movement of water (Cronk & Fennessy 2001). Wetlands fulfil important hydrological as well as biogeochemical functions and support a high biodiversity (Tooth & McCarthy 2007). Hydrologic and geomorphic controls are responsible for the maintenance of functional aspects of wetland ecosystems (Brinson 1993). Vegetation often provides important clues of hydrogeomorphic drivers operating in wetlands. Cronk & Fennessy (2001) divide the functions of wetlands into three categories namely: hydrology, biogeochemistry and habitat.

3.3.2.1 Wetlands' influence on hydrology

Although it is said that hydrology is the most important variable to distinguish wetlands from other ecosystems and from each other, a lack in quantitative work can not reveal how and why hydrology influence wetland types (Brinson 1993). The hydrological functions of wetlands include the recharge and discharge of ground water, the storage and conveyance of floodwater as well as shoreline and erosion protection (Cronk & Fennessy 2001).

- Groundwater Supply

  Groundwater can move into a wetland via springs or seeps. Water can also move from the wetland and seep into the groundwater which is known as groundwater recharge. The recharge of groundwater is important for replenishing aquifers for water supply (Cronk & Fennessy 2001).
- Flood Control

  Wetlands can store excess water and release it over time and therefore serve as a buffer that ameliorates the impact of floods. If the vegetation of a riparian wetland is intact then the wetlands can also prevent the damage of flooding rivers (Cronk & Fennessy 2001).
- Erosion and Shoreline Damage Reduction

  Wetlands along rivers, lakes and seafronts protect the shoreline against the impacts and energy of waves and currents (Cronk & Fennessy 2001).

As previously mentioned, hydrology is the study of water movement and storage therefore the inflows of water include the following: Precipitation in the form of rain and snow, surface inflows and groundwater inflows (discharge) (Van der Valk 2006; Tooth & McCarthy 2007). The outputs of wetlands include the following: Evapotranspiration, surface outflows and groundwater outflows (recharge) (Van der Valk 2006; Tooth & McCarthy 2007).

Precipitation is a source of water for almost all wetlands and because precipitation varies with climate a comparison between wetlands in climatic regions is possible (Brinson 1993), although precipitation and ground water only contribute to a small extent (Tooth & McCarthy 2007). Wetlands that occur in dry lands mainly occur where river inflows combine with other natural factors promote a positive water surface balance. In South Africa which is a semi-arid area the average runoff only contribute approximately 9% of the total volume of water in the form of rain, 91% of the water evaporates again (Ellery *et al.* 2008).

In areas with low ratios between precipitation and potential evapotranspiration wetlands are found only in areas where there is a positive surface water balance for at least part of the year. Because of the arid climate southern Africa most of the wetlands present in the subcontinent are associated with areas that receive water inputs from river inflows and where there are circumstances that impede drainage and reduce infiltration. Wetlands in dry areas, as compared to wetlands in general, have more often than not some of the following characteristics (Tooth & McCarthy 2007):

- Longer or more frequent periods of desiccation.
- Channels that decrease in size or even disappear downstream.
- High levels of chemical sedimentation.
- Wetlands mostly linked to streams.
- Frequent fires that reduce the accumulation of organic matter and rather promote aeolian activity.
- Longer timescales of development.

South Africa can be categorized as a dry area where annual potential evaporation greatly exceeds the precipitation (Tooth & McCarthy 2007; Ellery *et al.* 2008). The degree of aridity increases along an east-west gradient with the hyperarid areas occurring on the west of the continent (Ellery *et al.* 2008).

The variety of wetlands that occur in southern Africa is due to the differences in geology, drainage and climate as well as human influences, but to a lesser extent. Considering the evapotranspiration and precipitation in most of the dry areas one would not expect to find large numbers of wetlands and peat-lands. Most wetlands on the subcontinent form an integral part of a drainage network which is comprised of rivers, which have been shaped by the power of moving water. Moving water carries a sediment load dependent on its velocity, and the combination of moving water and sediment will determine the character of the river and associated wetlands (Ellery *et al*. 2008).

3.3.2.2 Biogeochemistry

In biogeochemical terms wetlands can be defined as follows (Reddy & DeLaune 2008): ”Wetlands consist of a biologically active soil or sediment in which the content of water in or the overlying floodwater is great enough to inhibit diffusion into the soil/sediment and stimulate anaerobic biogeochemical processes and support hydrophytic vegetation.”

There are a number of biogeochemical processes that mostly occur in wetlands because of shallow water, high primary productivity, aerobic and anaerobic sediment and accumulation of litter. These conditions often lead to natural cleansing of water in the wetland. Because of reduced water velocity in wetlands incoming suspended solids settle from the water column (Cronk & Fennessy 2001). Keddy (2000) stated that minerals tend to accumulate in wetlands. The suspended solids may include phosphorous which are removed from the water, nitrogen which is transformed by microbial activities in the presence of aerobic and anaerobic conditions. Plants can take up nitrogen and phosphorous from the water, but these chemicals are put back when the plants die. Wetlands also have an influence on the global cycles of sulphur and carbon because the anaerobic forms are produced under wetland conditions (Cronk & Fennessy 2001). During the transforming processes that occur in wetlands denitrification, methanogenesis and the microbial breakdown of organic matter occur which form part of the global nutrient cycles (Reddy & DeLaune 2008). Figure 3.2 represents the different elements which are present in the upland soils which are not inundated and the wetland/riparian soils which are inundated. Some of these elements are being used during the nutrient cycles.

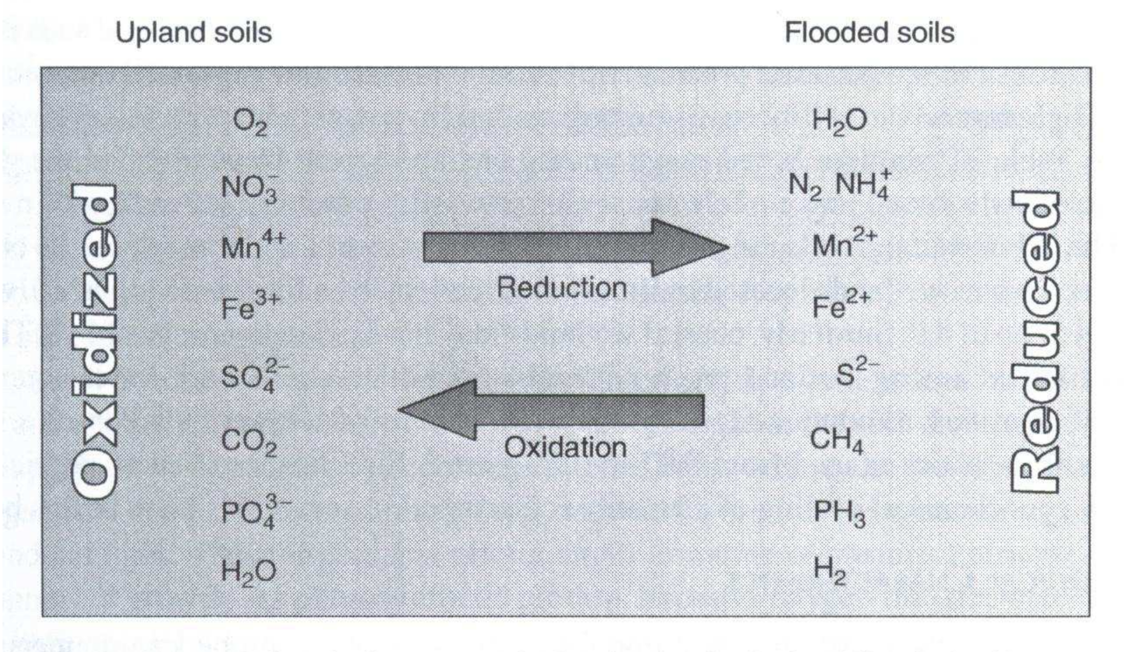


Figure 3.2: Figure of the different elements found under non-flooded and flooded conditions as presented in (Reddy & DeLaune 2008).

One of the most important social values that wetlands, offer is the capacity of a wetland to purify water. Both natural and constructed wetlands worldwide are used for the treatment (uptake by plants, dilution and reduction in redox reactions) of waste water from industrial, agricultural and domestic courses (Cronk & Fennessy 2001).

In humid climates ions are flushed from surface and subsurface sediments, while in dry climates ions accumulate in wetlands to high levels which increase the alkalinity of wetlands. In pans (playas) the case is even worse as the evaporation usually exceed transpiration. This might lead to high salinities which in turn have an osmotic effect on the plants (Tooth & McCarthy 2007).

3.3.2.3 Habitat

Highly productive ecosystems such as wetlands support a large number of fish and wildlife species. Some animals like fish, reptiles and amphibians depend exclusively on wetlands as habitat. Other species only utilize wetlands for short periods of time for example: during breeding times, as a resting ground or as a source of food and water (Cronk & Fennessy 2001). In rivers, bed stability is one of the most significant factors which influence the aquatic habitats in alluvial channels. The presence of aquatic vegetation leads to better bed stability which in turn promotes spatial diversity.

3.3.2.4 Primary production

The presence of dead or living plant material is the result of oxygenic photosynthesis. The oxygenic photosynthesis is the reduction of dead material to the most oxidized forms of carbon and organic matter as well as the release of oxygen for the survival of other organisms (Van der Valk 2006).

3.3.2.5 Litter decomposition

When herbivores that eat macrophytes die, the result is litter (dead organic matter) which serves as an energy source to heterotrophic organisms. The wetlands functions depend on the quantity and quality of the produced organic matter. When decomposition of litter occurs in wetlands the wetland serves as a sink for nutrients (Van der Valk 2006). Van der Valk (2006) stated that the decomposition of litter is the most important process in wetlands and occur in two stages namely: leaching and microbial mineralization.

3.4 WETLAND VEGETATION

Wetland plants occur throughout the world in suitable habitats. However their distribution largely depends on the occurrence of wetland ecosystems. It is estimated that 60% of the aquatic species ranges on more than one continent. Monocots are the most widely dispersed species. These plants are dispersed by wind and water transport, migratory birds and an increasingly movement of humans. There is however concern about the invasive potential of some species like

Eichhornia crassipes (water hyacinth), *Hydrilla verticillata* (hydrilla), and *Lythrum salicaria* (purple loosestrife) (Cronk & Fennessy 2001). In the area of study only *Eichhornia crassipes* is present.

Although plants can be used for wetland classification not all wetlands can be recognized on vegetation only, because of the broad ecological amplitude which make these plants tolerant and adaptable to various environmental conditions (Tiner 1999). Plants may be used as wetlands classifiers where one would rather look at the ecotypes (subspecific form within a true species, resulting from selection within a particular habitat and therefore adapted genetically to that habitat, but which can interbreed with other members of the species (Lawrence 2000)) than at the good Linnaean species (Tiner 1999). The ecotypes are better to use in these areas as these plants are adapted to the conditions that they live in. Hydrophytic vegetation is one of the principal indicators of freshwater wetlands as most of the wetlands are easily recognized by their vegetation. Because vegetation plays an important role in the identification as well as delineation of wetlands it is important to know which plants or groups of plants can be used as wetland indicators (Tiner 1999).

The terminology used to describe wetland plants are usually based on the hydrological regime that the species requires. Wetland plants are usually seen as wetland hydrophytes, which are defined as plants ‘growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content’ (Tiner 1999; Cronk & Fennessy 2001). Aquatic plants however are defined as submerged species or those with floating leaves, while marsh plants are seen as terrestrial plants. Tiner (1999) stated that helophytes (plants in marshes) can live in water or wetlands although these plants usually occur in wetlands with shallow water. Aquatic species require flooding and are not able to tolerate desiccation. Terrestrial species does not require flooding as saturation during the growing season will lead to drowning. Wetland plants are able to tolerate flooding as well as desiccation (Cronk & Fennessy 2001).

3.4.1 Types of Wetland Plants

The plants that occur in wetlands are usually divided into categories according to their growth form (Cronk & Fennessy 2001).

3.4.1.1Emergent Plants

These plants are rooted in the soil with the basal portions growing beneath the water`s surface, but the stems, leaves and reproductive organs are aerial. Most of these plants are herbaceous although some of them are woody. Most of the common emergent species are from families of monocotyledons like Poaceae, Cyperaceae, Juncaceae and Typhaceae. Woody species include trees from the genera *Salix* and *Populus* as well as shrubs from the family Rosaceae (Cronk & Fennessy 2001).

3.4.1.2 Submerged Plants

Submerged plants typically spend their entire life cycle beneath the water surface of coastal, estuarine, and freshwater habitats although these plants are flowering above the surface of the water. These plants are either rooted or free floating in the water column, however the flowers are areal. The families with submerged plants are Callitrichaceae, Ceratophyllaceae, Haloragaceae, Potamogetonaceae, Lentibulariaceae and Hydrocharitaceae (Cronk & Fennessy 2001).

3.4.1.3 Floating-Leaved Plants

The leaves of these plants float on the water while the roots are anchored in the substrate. A combination of petioles and stems or just petioles connects the leaves to the bottom. The floating species shade the water column below and often outcompete the submerged species for light, especially when the turbidity are high and light penetration are reduced. Families of floating-leaved plants are Nymphaeaceae and Nelumbonaceae (Cronk & Fennessy 2001).

3.4.1.4 Floating Plants

The leaves and stems of these plants float on the water`s surface. When roots are present they hang free in the water and are not anchored into a substrate of any kind. The most wide spread family of all the floating plants are the Lemnaceae of which *Lemna gibba* occur in the area of study. *Eichhornia crassipes* (water hyacinth) are one of those invasive species that also occur in the area of study (Cronk & Fennessy 2001).

3.5 PLANTS` ADAPTATIONS AND STRESS IN WETLAND ENVIRONMENTS

The deficiency of oxygen in water may be partial which is then called hypoxia or complete which is then called anoxia. This oxygen deficiency may occur in the water of a wetland or in the soil of a wetland (Keddy 2000). The deficiency of oxygen has an influence on the physiological functioning of plants (Cronk & Fennessy 2001).

Types of water that flood wetlands also play an important role in effecting the environment. Wetlands that are saturated with moving, partly oxygenated waters are more favourable habitats than ones with stagnant water. The flowing environment allows roots to develop and penetrate into the substrate, while in stagnant water the roots form on the soil surface. Flooding and soil saturation causes changes in the soil environment which can affect the plants' growth and survival. Flooded soils have a lower soil temperature than well-drained soils. It was found that the soil temperature difference is an average of 6^0C in the surface layer. The temperature of the soils may further have an effect on the soil chemistry, nutrient release, phytotoxin production, organic matter decomposition and plant growth (Cronk & Fennessy 2001).

3.5.1 Anaerobic sediment

When plants grow in upland conditions with soil moisture the plants experience the same oxygen levels as the atmosphere which is about 21%. The prolonged flooding or waterlogging that occurs in wetlands restricts the movement of oxygen from the atmosphere to the soil (Tiner 1999; Cronk & Fennessy 2001). The pore spaces are then rather filled with water than gas (Cronk & Fennessy 2001). The diffusion of oxygen is 10 000 times slower in saturated soils than in aerated soils (Tiner 1999). The slow rate of oxygen diffusion as well as the respiratory demands of plant roots and the soil micro-organisms that occur in the soil results in little to no oxygen available for either of the named organisms. Reduced organic and inorganic compounds accumulate in the soil. Hours or days after flooding the soil becomes hypoxic (low levels of oxygen) and eventually will become anoxic (depleted of oxygen). Some wetlands are permanently flooded with an anoxic soil profile, or flooded only for part of the time. The drainage of wetland soils lead to the oxidization of the upper soil profile which enables seed germination and even the invasion of upland plants. Because most wetlands are flooded for most of the time, the rooted plants have adapted to live with a lack of oxygen (Cronk & Fennessy 2001).

3.5.1.1 Reduced forms of elements

In flooded soils anaerobic soil organisms thrive because these organisms use other terminal electron acceptors in respirations namely: Nitrate (NO_3^-), manganic ions (Mn^{4+}), ferric ions (Fe^{3+}), sulphate (SO_4^{2-}), carbon dioxide (CO^2) and some organic compounds. Because of the anaerobic microbial respiration and chemical oxidation-reduction reactions these elements are present in reduced forms in the soil. These reduced forms of the elements that are present in the soil create a stressful and even toxic environment for plants (Cronk & Fennessy 2001).

In aerated soils, nitrogen is present as nitrate, but with oxygen depletion nitrate decline drastically and can even reach levels of zero within three days (Cronk & Fennessy 2001).

Manganese is slightly more available to plants in the reduced form (Mn^{2+}) than in the oxidized form (Mn^{4+}), however high levels of the reduced form may interfere with the enzyme structure and nutrient consumption of plants. Some wetland plants have a higher manganese resistance than upland plants (Cronk & Fennessy 2001).

Iron concentrations are higher in wetland plant tissue than in upland plants. The affects of high iron are usually discoloured leaves, diminished photosynthetic activity, and decreased root respiration. Iron also interferes with magnesium during chlorophyll formation (Cronk & Fennessy 2001).

Sulphur is taken up in the form of sulphate (SO_4^{2-}). Sulphur is more abundant in salt/sea water than in freshwater. Sulphur uptake is metabolically controlled. Sulphide inhibits photosynthetic enzymes and reduces the generation of energy (Cronk & Fennessy 2001).

3.5.1.2 Nutrient availability under reduced conditions

The availability of nutrients in wetlands is determined by sediment and watershed characteristics as well as hydrology. Wetlands with a higher through flow of water tent to have higher levels of nutrients (Cronk & Fennessy 2001).

3.5.1.3 The presence of toxins under reduced conditions

A wide range of soluble organic compounds found in the soils of wetlands are toxic to plants. The anaerobic decomposition of cellulose and lignin are some of the toxins. Microbial metabolism contributes to the accumulation of toxins like acetic and butyric acids, while anaerobic metabolism adds ethanol. These toxins together with the phytotoxins produce a hostile environment for the growth of plants. The affects of the toxins can be withstood by the diffusion of oxygen into the adjacent soil through plant roots (Cronk & Fennessy 2001).

3.5.2 Light availability

Submerged plants could struggle to overcome poor light conditions. This is one of the most important regulators of submerged plants and their distribution within a water body. The availability of light to submerged plants is affected by season and latitude, the absorption by oxygen, ozone, carbon dioxide and water vapour. Light is also reflected once reaching the water surface, with the greatest reflection occurring in winter, as well as during the beginning or end of a day. After light rays have entered the water column the rays are scattered. Photosynthetic plants occur in the euphotic zone (Cronk & Fennessy 2001) (well-illuminated, zone of surface water to a depth of 80-100m (Lawrence 2000)).

Submerged plants require between 4-29% of the light measured just below the water surface. Therefore vascular plants are limited to a maximum depth of 12-17 m. This depth is further affected by the water clarity (suspended solids which is the result of tributary inputs, sedimentation and resuspension) (Cronk & Fennessy 2001).

3.5.3 Carbon dioxide availability

The atmospheric gas, carbon dioxide (CO_2), is vital for photosynthesis. The diffusion of CO_2 is 10 000 times slower in water than in air. With the presence of other nutrients and sufficient, light the transport of carbon from the atmosphere to water are essential. In water, carbon dioxide is in equilibrium with carbonic acid, bicarbonate and carbonate. When carbon dioxide is taken up by plants, the pH of the water increase because of less carbonic acid in solution. Where the pH of water is 5 or lower carbon dioxide is the predominant form of inorganic carbon (Cronk & Fennessy 2001).

3.5.4 Adaptations to hypoxia and anoxia

Plants have adapted a number of ways to isolate oxygen or to tolerate the consequences of low oxygen levels. The most common adaptation that plants undergo is the formation of aeranchyma (porous tissue) in the roots and the stems (Cronk & Fennessy 2001).

3.5.4.1 Structural adaptations

- *Aerenchyma*

  According to Keddy (2000) the presence of aerenchyma is a well developed characteristic in most wetland plants. For the purpose of internal gas-transportation most of the rooted wetland plants form large gas-filled spaces called lacunae. Aerenchyma is the large porous tissue that holds the lacunae together. Gas-transport in the plants is then allowed via the aerenchyma tissue which provides no resistance against the movement of gas. The aerenchymatic tissue forms in new and old tissue of roots, rhizomes, stems, petioles, and leaves of both woody and herbaceous wetland plants (Cronk & Fennessy 2001).

Aerenchyma mostly forms in flood-tolerant species and may occur, but to a lesser extent in flood-intolerant species. Although aerenchymatic tissue aerates the tissue of roots and rhizomes, the aeration is often incomplete (Cronk & Fennessy 2001).

3.5.4.2 Stem and root adaptations

Although aerenchyma is present in the stems and roots of plants, many stems and roots undergo other changes in response to flooded conditions (Cronk & Fennessy 2001).

3.5.4.2.1 Stem adaptations

- *Rapid Underwater Shoot Extension*

  The elongation of the shoots brings the plant near or above the surface of the water which cause a better access to light, oxygen and carbon dioxide. The accumulation of ethylene is responsible for the elongation of shoot cells, eg. *Typha capensis* (Cronk & Fennessy 2001).
- Hypertrophy

  Hypertrophy is excessive growth due to increase in the cell size. Ethylene is the stimulus for this rapid growth which is due to accelerated cell expansion caused by cell separation and rupture that occur as aerenchyma forms. Hypertrophy increase the porosity of the stem and therefore enhances aeration (Cronk & Fennessy 2001).
- *Stem Buoyancy*

  The aerenchyma present in submerged plants does not only fulfill the function of channels for diffusion of gasses, but also play a role in the buoyancy of the stems. The stems are kept upright in an optimum position to get maximum oxygen and carbon dioxide at the water`s surface (Cronk & Fennessy 2001).

3.5.4.2.2 Root adaptations

- *Adventitious Roots*

  These roots grow into the surface layers of the soil, or grow above the surface of the soil. Where plants appear in standing water the adventitious roots are in contact with oxygen-containing water (Cronk & Fennessy 2001).

- *Shallow Rooting*

  The oxygen shortage is overcome by surface or sub-surface roots which are above the soil or in the oxygenated portion of the soil profile, eg. *Phragmites australis* (Cronk & Fennessy 2001).

- *Pneumatophores*

  These roots are modified, erect roots which grow upward from the roots of certain plants. The pneumatophores are commonly called "knees". Pneumatophores mostly occur in mangroves. The gas exchange occurs through lenticels in the aboveground portions of the roots (Cronk & Fennessy 2001).

- *Prop Roots and Drop Roots*

  Prop roots develop from the lower part of stems and branches towards the substrate, while drop roots drop from branches and upper parts of the stems into the soil. Both drop roots and prop root are covered with lenticels which allow oxygen to diffuse into the roots and carbon dioxide and other gases to diffuse from the plant (Cronk & Fennessy 2001).

3.5.4.3 Gas transportation

Gas can move easily between the aerial and subterranean portions because of the aerenchyma which enables the gas to move. The movement of gas are driven by passive molecular diffusion. Stomata and lenticels allow oxygen to diffuse freely into the aerial parts of the plant, the gas then diffuses through gas spaces to the buried portions of the plants. The aerial parts of wetland plants usually have a greater oxygen concentration than the belowground parts. The oxygen gradient that is present in wetland plants indicates that diffusion is the major way of gas transportation (Cronk & Fennessy 2001).

3.5.4.4 Avoidance of anoxia in time and space

The active growth or sensitive periods of plants such as seedling establishment will occur during the dry season, if flooding is seasonal. Most of the plant species that occur in wetlands are perennials and overwinter as rootstocks, rhizomes, tubers, turions, bulbs or as other overwintering structures. To overcome anoxic conditions in the sediment some plants like *Typha, Nymphaea, Nuphar* and others avoid oxygen stress by entering a period of dormancy (low metabolic activity). Germination of some seeds only takes place when the water level is low and the substrate exposed (Cronk & Fennessy 2001).

Some plants are able to survive in anoxic conditions for between four and ninety days, these plants are called flood-tolerant species. Flood-intolerant plants cannot survive anoxia for more than three days (Cronk & Fennessy 2001).

3.5.5 Adaptation to limited nutrients

Precipitation, dry atmospheric deposition, weathering of rocks and soil minerals as well as the decomposition of organic matter are all sources of nutrients. Decomposition occurs slowly in wetlands and nutrients are bound in organic matter rather than mineralized. Some wetland plants have adaptations to obtain nutrients which include (Cronk & Fennessy 2001):

3.5.5.1 Mycorrhizal associations

Mycorrhizae are symbiotic fungi associated with plant`s root systems. Mycorrhizae increase the plant`s ability to capture water, phosphorus, nitrogen and potassium (Cronk & Fennessy 2001).

3.5.5.2 Nitrogen fixation

Gaseous nitrogen (N_2) is made available to plants and organisms through the process of nitrogen fixation. Some soil bacteria are capable of fixing nitrogen and live in symbiosis with plants. Root nodules form on the host plant, which is a source of energy for the bacteria and provide additional nutrients to the plant (Cronk & Fennessy 2001).

3.5.5.3 Carnivory

Carnivorous plants have the ability to trap animal prey which range from zooplankton to insects and sometimes even small frogs and birds, which serve as additional nutrients to enhance the plant`s fitness to increase growth, enhance survival and pollen production (Cronk & Fennessy 2001).

3.5.6 Submerged plant adaptations to limited light

Although all plants suffer a lack of light due to shading upland, emergent and floating-leaved plants cope with shading by growing fast, growing towards the light source or growing into an opening. The chloroplasts of submerged freshwater and several marine species are concentrated in the epidermis. Therefore, the surface of submerged leaves is the site of most photosynthesis (Cronk & Fennessy 2001).

3.5.7 Submerged Plant Adaptations to limited Carbon Dioxide

Submerged plants have a number of adaptations to limited or variable CO_2. Some of the adaptations for low light and oxygen levels are also important for low CO_2 levels. Aerenchyma promotes buoyancy which enables the plant to grow close to the surface of the water where there are more light and atmospheric CO_2. The surface-to-volume ratio is increased by ribbon-like leaves, a thin cuticle and the presence of chloroplasts in the epidermis. This also decrease the distance that inorganic carbon must travel to be used. Submerged plants however have some other adaptations to low CO_2 levels (Cronk & Fennessy 2001):

- Some submerged plants are able to assimilate bicarbonate ions as a carbon source for photosynthesis.
- Some submerged plants assimilate CO_2 at night when it is more plentiful, this mechanism is called Aquatic Acid Metabolism (AAM).
- Some species recycle respired CO_2 within their aerenchyma and assimilate it in photosynthesis.
- High soil respiration creates a pool of available CO_2 which submerged plants are able to use.

3.5.8 Adaptations to fluctuating water levels

Many plants are able to grow as submerged and emerged plants, these plants usually occur on the edges of lakes, streams or wetlands, where flooding is regularly alternated. There may be a difference in the shape of leaves between submerged and emergent plants. This is called heterophylly and allows plants to survive under dry as well as submerged conditions (Cronk & Fennessy 2001).

3.6 THREATS TO WETLAND ECOSYSTEMS

Many cultures are dependent on and lived along wetlands for centuries because of the benefits for agriculture, although there are also many misunderstandings and fear for wetlands (Mitsch & Gosselink 1993). Although wetlands are generally advantageous to humans they have also often been a source of suffering because of diseases like malaria (Keddy 2000).

The earliest civilization arose along the edges of rivers and in the fertile soils of floodplains (Keddy 2000). In highly populated and developed areas the impacts could range from severe to total destruction. In the United States of America some of the major cities as well as airports have been built on wetland areas eg. Washington, Boston, New Orleans and J.F Kennedy, to mention a few (Mitch & Gosselink 1993). In South Africa the newly built King Shaka airport near Durban is also situated next to two large wetlands.

Fifty percent of the world's wetlands have been destroyed or degraded due to land-use practices, development pressures, abstraction of water, modification of drainage, chronic degradation due to nonpoint pollution and alien invasion (Cronk & Fennessy 2001; Ewart-Smith *et* al. 2006; Tooth & McCarthy 2007). However the global effects that humans have on wetlands are difficult to measure (Ewart-Smith *et al.* 2006). The reason for the destruction might be that most of the wetlands that occur on the earth's surface are freshwater ecosystems (Keddy 2000). The decline in wetland areas also affects the decline in species diversity which will lead to a large number of rare species (Cronk & Fennessy 2001).

Wetlands are some of the most important ecosystems in the world providing a host of services to society (Kotze *et al.* 2007). One of the primary services of wetlands is to manage water and therefore protect and regulate our water resources. They act as great sponges which retain water during floods and release water during dry periods. In South Africa, which is a water scarce country, this is crucial. The regulation of water during floods reduces the damage of floods and prevents soil erosion. Wetlands also recharge ground water sources and remove pollutants from the water. They act as natural filters which purify water by trapping pollutants which includes sediment, heavy metals, disease-causing bacteria and viruses. (Cowan 1995; Land-use and Wetland/Riparian Habitat Working Group 2000). Other support services that wetlands provide include food, points of interest for environmental education and recreation (Kotze *et al.* 2007).

3.6.1 Hydrological alteration

Human activities such as agriculture or flood control lead to a decrease in wetland area or change the hydrological regime of areas. In this case dams in the area of study have an influence on the hydroperiod and can change the distribution of wetlands. The depletion of ground water also affects the structure of both wetland and riparian communities. With an increase in the distance to groundwater there is a decrease in the amount of abundant herbaceous vegetation. The channelization of rivers has an influence on the riparian zone`s geomorphology and the wetland`s hydroperiod which influence the structure of plant communities which lead to a decrease in species diversity (Cronk & Fennessy 2001).

3.6.2 Exotic species

Exotic or non-indigenous species are a threat to all ecosystem types. The impact that these plants have on the environment can be severe and include the alteration of nutrient cycles, the development of monocultures and extirpation or extinction of native species: This result in the lost of native biodiversity. The fact that the capacity and speed of human travel have increased also increased the rate of biological invasion. Humans introduce species in several ways: purposefully, some escaped into natural areas after import, while others entered areas accidentally.

When the ecosystem become more degraded the invasive species increase (Cronk & Fennessy 2001). The invasion of alien plants will be discussed in detail in Chapter 4.

3.6.3 Impact of global change

Human activities have a negative impact on land use patterns, atmospheric chemistry and climate. The increase in temperature of the global climate may result in the expansion of some wetland areas and the retraction of others, depending on the location and type of wetland. There will be predicted changes in the hydrological cycle and this will drive changes in wetland plant communities. Groundwater play an important role in wetlands as a source of water, but the change in the balance between precipitation and evapotranspiration will have an effect on the groundwater levels. The predicted rise in sea level will cause a net loss of wetland area which will cause a loss of wetland plant diversity (Cronk & Fennessy 2001). The change in climate mainly temperature and precipitation will change the hydrology of wetlands and therefore have an effect on the fauna and flora. Furthermore the changes could cause the release of large amounts of carbon which are currently stored in wetlands (Van der Valk 2006).

3.6.4 Conservation and restoration of wetlands

Wetlands not only provide ecosystem services, they also help to conserve biodiversity. In South Africa alone an estimate of more than 50% of the wetlands has already been destroyed. The main reason is drainage of the wetlands for crops and pastures, poorly managed burning and grazing which resulted in headcut and donga erosion, the planting of alien trees in wetlands, mining, pollution and urban development (Land-use and Wetland/Riparian Habitat Working Group 2000).

The continued destruction of wetlands will result in the degradation of water quality, less reliable water supplies, increased severe flooding, lower agricultural productivity and more threatened and endangered plant and animal species. (Land-use and Wetland/Riparian Habitat Working Group 2000; Cronk & Fennessy 2001).

In the past wetlands were destroyed and degraded because of development pressures, but recently the focus shifted towards the intense conservation of wetlands. The establishment of the RAMSAR Convention in 1971 promoted the sustainable use of wetlands (Tooth & McCarthy 2007).

The World Conservation Strategy (Cowan 1995) identified wetlands as the third most important life support systems on the planet. Most of the wetlands are habitats that transcend international boundaries and cooperation among states are necessary for the effective conservation of wetlands. The Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat) was adopted in February 1971. When a country adopts the Ramsar Convention this country must at least have one wetland to be included in the List of Wetlands of International Importance when signing the Convention. The broad objectives of the Convention include the following (Cowan 1995):

- Prevent the loss of wetlands;
- Promote wise use of all wetlands;
- Promote special protection of listed wetlands;
- Promote the training of personnel;
- Promote the implementation of parties` obligations under the Convention.

This framework for the conservation of wetlands leads to identification more of than 1 600 wetlands that is seen as internationally important on their ecological, botanical, zoological, limnological or hydrological values (Tooth & McCarthy 2007).

Wetlands can be seen in two ways namely: as living machines that provide services for humans or as natural communities off living organisms and therefore we strive to maintain the patterns and processes within each wetland. However wetlands can have various functions which might include the control of hydrology, yielding wildlife, producing methane, fixing nitrogen and supply of human recreation (Keddy 2000).

Before a wetland can be treated, it is important to be able to predict the response of the ecosystem to change weather human induced or natural. It is also difficult to conserve and manage wetlands by deciding which changes are acceptable and which not (Keddy 2000). To effectively rehabilitate a wetland it is important to treat the cause of degradation rather than the symptoms of degradation (Ellery *et al.* 2008).

When protecting wetlands it is important to protect bigger areas and therefore protect more species. Furthermore, it is important that each protected wetland have a buffer zone where land use practices are being regulated to prevent the adding of extra nutrients, pollution and exotic species. But the largest affect on wetlands are the damming of water and the deposition of nutrients into the natural water systems (Keddy 2000).

The restoration of riparian areas and wetlands are important to restore hydrological flows in rivers which then have benefits for humans. The major invader in the riparian areas is mostly trees which use more water than the indigenous vegetation and therefore reduce the water yields in catchment areas (Holmes *et al.* 2008). Humans alter and influence the natural systems by manipulating natural characteristics of a system and therefore accelerate the change of natural processes. This influence might force the system to changes beyond its natural changes and therefore lose its value to society. It is thus important to understand the natural drivers of change and the characteristics of a system to manage the system (Ellery *et al.* 2008).

Why should we restore and protect wetlands? What is the benefit to humans when restoring and protecting wetlands? The answer lies in the fact that wetlands provide more advantages to humans than disadvantages. The advantages include the following (Kotze *et al.* 2007):

- Flood attenuation – the spreading out and slowing down of water;
- Streamflow regulation – wetlands are water users rather than generators;
- Sediment trapping – affecting the storage capacity of dams;

- Removal of phosphate, nitrate and toxins – enhancing the water quality;
- Erosion control – reducing downstream flooding intensity;
- Carbon storage – organic matter decomposition is slowed down under waterlogged conditions;
- Maintenance of biodiversity – provision of habitat and maintenance of natural processes;
- Water supply for direct human use – extraction of water directly from the wetland for domestic as well as agricultural and other purposes;
- Provide harvestable nature resources – provide food, game, flowers, craft and construction material and more;
- Provide cultivated food – food security for subsistence farmers;
- Cultural significance – for different cultures in South Africa;
- Tourism, recreation and natural scenic value – because of the abundant wildlife;
- Education and research – elements of both aquatic and terrestrial as well as a strategic location in the environment.

3.7 RIPARIAN AREAS

As already mentioned riparian areas are the strips of vegetated areas along the banks of streams or rivers (Lawrence 2000). Rivers plays various roles in the environment which may vary from cleansers and renewers, destroyers and creators, sculptors of landscapes, life-givers and life-takers (Davies & Day 1998). Rivers also provide corridors through the landscape, interaction with the catchment, aesthetic enjoyment and recreational opportunities, important navigational routes for people, water, food and serve as sinks for human wastes (Petts & Carlow 1996). Rivers can be seen as self-regulating systems which support a variety of important communities which are influenced by urban development, pollution, erosion and agricultural practices which lead to the degradation of the river system (Davies & Day 1998). They are dynamic systems and are influenced by processes and features of upper reaches which influence the entire river from origin to sea therefore it can be said that rivers are longitudinal functional units. In rivers there are continuous gradients of physical and chemical conditions which are modified as the stream flow. The biota in rivers have to adapt to ever changing environments of chemical and biological variables (Davies & Day 1998).

3.7.1 Processes and functions in riparian areas

The processes and functions of riparian areas are similar to those of wetlands. The functionality of rivers is dependent on the nature of the catchment and the activities of humans and natural processes in the catchment. The removal of wetlands that regulate the flow of water to the river will result in flash floods and less water will be stored which may lead to the dry up of the river in the summer months. The removal of topsoil during these flash floods as well as the removal of plants from river banks may lead to the banks collapsing which contribute to erosion. Therefore the health of a river can tell the health of the catchment (Davies & Day 1998).

3.7.2 Vegetation of riparian areas

Riparian corridors have high numbers of plant species and may support a significant portion of the flora present in the area (Keddy 2000). Davies & Day (1998) stated that the rivers are isolated geographical entities and are therefore the focus point in the environment where biological diversity occur and can therefore be seen as genetic resources.

The vegetation that occur in the riparian areas influence the amount and nature of the organic matter input into the streams and rivers, which is an important source of food and therefore play an important role in the food webs. Furthermore, the riparian vegetation has the ability to influence the chemistry of the water in the river by either intercepting chemical ions or by retaining nutrients from the catchment before they reach the river. The vegetation also has an influence on the nett water yield from the catchment and therefore influences the river's discharge levels. Lastly, the vegetation also play a role in the physical channel morphology as the bank stabilization by roots and the formation of partial or complete woody debri dams are important in shaping the rivers (Giller & Malmqvist 1998).

Although the diversity of flowering plants, in the aquatic environment, are quite low, the riparian zones have abundant species of plants that are dependent on the seasonal water of the rivers which inundate the riparian zone. One also has to take into account that riparian zones are nutrient rich due to the high water levels of the system. The river is then influenced by the plants as dense stands of vegetation reduce the velocity of the water current which in turn leads to an increase in sedimentation (Giller & Malmqvist 1998).

3.7.3 Adaptations and stress in the riparian areas for plants

Most of stress adaptations that are present in wetlands are also present in riparian areas. Giller & Malmqvist (1998) stated that a lotic habitat like rivers poses distinctive adaptive challenges to animals and plants. As these organisms have to adapt to unique physical, chemical and biological environments. The three most common stress factors include oxygen, temperature and light of which oxygen and light were discussed in the wetland component.

The organisms that occur in rivers are poikilothermic (ectothermic) which means that their temperature varies with their surrounding environment. The physiological processes of the organisms are based on biochemical reactions which are dependent on the temperature of the water. Therefore the temperature of water is important for the organisms which life cycles depend on it. Solar radiation and conduction from the air is the main sources of heat. However, heat is lost through radiation at the surface. There are also a difference in the temperature of the surface and the bottom. The shading by riparian vegetation also contributes to the decline of water temperature in rivers and streams (Giller & Malmqvist 1998).

Floods are also an important stress factor in the riparian environment as floods can lead to a disturbance or can wash biota away. This introduces unpredictability in the community and favours the evolution of recolinization abilities (Petts & Carlow 1996).

3.7.4 Link between riparian areas and wetlands: floodplains

Rivers are seldom confined to their channels and may sometimes overflow their banks during the wet season or occasional floods. These parts of the landscape that are being inundated by the rivers are called floodplains (Davies & Day 1998). Floodplains are important as these areas form part of the surface flow during floods as well as baseflow during discharge. Furthermore, the physical and chemical characteristics of the floodplains determine the channel material during flows. Lastly, floodplains are formed because of past sediment deposits and therefore preserve an extended record of changes (human influences, formative factors which include climatic change ect.) that occurred in the river (Petts & Carlow 1996).

Rivers in southern Africa overtop their banks and soon after the water will disappear into the soil, but areas may also be inundated for a period of time and are then called wetlands. Although the true floodplain ecosystems are common throughout the world, it is rare in southern Africa. The floodplains can be seen as lentic ecosystems which are dependent on the rivers for their water. Floodplains mostly occur in areas where the surrounding environment is relatively flat. The deposition of sediment in the floodplains leads to an environment with lots of deposited material which are rich in nutrients and therefore ideal for the planting of crops as well as the growth of natural floodplain vegetation (Davies & Day 1998). However Carlow & Petts (1992) stated that wetlands can also be important accumulation zones for pollutants which are derived from agricultural treatments, urban effluent and industrial and mining activities.

The floodplains are seasonally recharged and therefore point out the wetting and drying cycles of the areas which are vital for the ecotonal nature of the floodplains. Furthermore floodplains are dynamic systems which play an important role in the balance of seasonal changes which include the amount of water, nutrients and sediment which enter the system. The flood pulses in drylands are less predictable and therefore influence the response of the biota (Davies & Day 1998).

The biomass and productivity of floodplains are affected by the length of time that the floodplain remains inundated which further influence the processes of decomposition and nutrient cycles. Most of the time floodplains are affected by the dams upstream, which prevent small floods to inundate the floodplains. Furthermore floodplains are characterised by diverse biotopes and the fast production of biomass by both plants and animals. In floodplains terrestrial plants are dying due to inundation during floods which contribute biomass to the floodplain. After the wet season the water of the river subside and the terrestrial plants starts growing rapidly again because of the rich alluvium deposited in the area (Davies & Day 1998).

It can be said that floodplains are complex ecological ecosystems that depend on the interaction between the river which provide the water for inundation and the land on which the floodplains lie. These ecosystems are very productive and are easily disrupted by humans which will change the balance between aquatic and terrestrial influences (Davies & Day 1998).

REFERENCES: CHAPTER 3

BRINSON, M. 1993. A *Hydrogeomorphic Classification for Wetlands*. Wetland Research Program Technical Report WPR-DE-4. US Army Corps of Engineers. Waterways Experiment Station. USA.

CARLOW, P. & PETTS, G.E. 1992. *The rivers handbook. Volume 1.* Blackwell Scientific Publications, London.

COWAN, G.I. (ed). 1995. *Wetlands of South Africa*. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

CRONK, J.K. & FENNESSY, M.S. 2001. *Wetland Plants: Biology and Ecology*. Lewis Publishers. United States of America.

DAVIES, B. & DAY, J. 1998. *Vanishing Waters*. University of Cape Town Press. Cape Town, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2008. A practical field procedure for identification and delineation of wetlands and riparian areas. Department of Water Affairs and Forestry. Pretoria, South Africa.

DUGAN, P. 1993. *A Mitchell Beazley World Conservation Atlas. Wetlands in Danger.* Reed Consumer Books Limited. United Kingdom.

ELLERY, W.N., GRENFELL, M., GRENFELL, S., KOTZE, D.C, McCARTHY, T.S., TOOTH, S., GRUNDLING, P-L., BECKEDAHL, H., LE MAITRE, D. & RAMSAY, L. 2008. *WET-Origins: Controls on the distribution and dynamics of wetlands in South Africa*. WRC Report No TT 334/08, Water Research Commission, Pretoria

EWART-SMITH, J.L., OLLIS, D.J., DAY, J.A. & MALAN, H.L. 2006. National wetland inventory: development of a wetland classification system for South Africa. The Water Research Commission and South African National Biodiversity Institute. ISBN: 1-77005-429-4.

GILLER, P.S. & MALMQVIST, B. 1998. *The biology of streams and rivers*. Oxford University Press, New York.

HOLMES, P.M., RICHARDSON, D.M., ESLER, K.J., WITKOWSKI, E.T.F. & FOURIE, S. 2005. A decision-making framework for restoring riparian zones degraded by invasive alien plants in South Africa. *South African Journal of Science* 101: 53-564.

HOLMES, P.M., ESLER, K.J., RICHARDSON, D.M. & WITKOWSKI, E.T.F. 2008. Guidelines for improved management of riparian zones invaded by alien plants in South Africa. *South African Journal of Botany* 74: 538 – 552.

KEDDY, P.A. 2000. *Wetland Ecology: Principles and Conservation*. Cambridge University Press. United Kingdom.

KOTZE, D.C., MARNEWECK, G.C., BATCHELOR, A.L., LINDLEY, D.S. & COLLINS, N.B. 2007. *WET-EcoServices:* A technique for rapidly assessing ecosstem services supplied by wetlands. WRC Report No. TT339/08, Water Research Commission, Pretoria.

LAND-USE AND WETLAND/RIPARIAN HABITAT WORKING GROUP. 2000. *Wetland/Riparian habitats: A practical field procedure for identification and delineation*. Version 2.0

LAWRENCE, E. 2000. *Henderson's Dictionary of Biological Terms*. 12th edn. Pearson Education Limited. Malaysia.

MITSCH, W.J. & GOSSELINK, J.G. 1993. *Wetlands*. 2nd edn. Van Nostrand Reinhold. New York.

PETTS, G. & CARLOW, P. 1996. *River biota: Diversity and dynamics.* Blackwell Science Ltd, Oxford, London.

REDDY, K.R. & DELAUNE, R.D. 2008. *Biogeochemistry of Wetlands*. CRC Press. United States of America.

ROBERT, A. 2003. *River processes: An introduction to fluvial dynamics.* Oxford University Press Inc., New York.

SANBI. 2009. Further Development of Proposed National Wetland Classification System for South Africa, *Primary Project Report* Prepared by the Freshwater Consulting Group (FCG) for the South African Biodiversity Institute (SANBI).

TINER, R.W. 1999. *Wetland Indicators: a guide to wetland identification, delineation, classification, and mapping.* CRC Press LLC, United States of America.

TOOTH, S. & McCARTHY, T.S. 2007. Wetlands in drylands: geomorphological and sedimentological characteristics, with emphasis on examples from southern Africa. *Progress in Physical Geography* 31(1): 3-41.

VAN DER VALK, A.G. 2006. *The biology of freshwater wetlands.* Oxford University Press Inc., New York.

VIESSMAN, W.Jr. & LEWIS, G.L. 2003. *Introduction to hydrology*. 5th ed. Pearson Education Ltd., London.

CHAPTER 4

ALIEN PLANT INVASION

4.1 INTRODUCTION

Alien plants are defined as plant species thought to have been introduced by humans but now more or less naturalized and are able to grow unassisted in nature (Lawrence 2000). Other terms also used to describe these plants are: **exotic, non-indigenous, adventives, immigrant** and **non-native** (Cronk & Fennessy 2001). The alien plant species currently found in South Africa were either introduced intentionally, regarded as useful plants (ARC 2008) or unintentionally and later became naturalized (Henderson 2001).

Lawrence (2000) defines **indigenous** as belonging to the locality; not imported; native. These plants evolved and originated in a specific region. Indigenous plants are plants that have occurred in that region for thousands of years and a large number of natural enemies have co-evolved with them to keep the population in check (ARC 2008).

Although South Africa has a long history of environmental problems, one of the major problems worldwide is the invasion of alien plants (Holmes *et al.* 2005). It is well known that invasive alien plants have an impact on the structure and the function of the indigenous vegetation and ecosystem processes (Beater *et al.* 2008). Cullis *et al.* (2007) stated that because of alien invasive vegetation, an amount of 523×10^6 m^3 of water is lost every year. If the conditions worsen and the riparian zones alone become fully invaded the estimated water lost in a year would increase to $1\,314 \times 10^6$ m^3/a for South Africa only.

The loss of water is not the only problem caused by aliens, there is also concern about the invasion of the nation`s grazing lands, which reduces their carrying capacity and subsequently their value for stock farmers (Macdonald 2004). The production of livestock generates an estimated R1.25 billion annually in South Africa.

The increased invasion of rangelands by trees, shrubs, succulents and unpalatable grasses will have a negative effect on the economy (Van Wilgen *et al.* 2008). The efforts of clearing alien vegetation may result in an even bigger disturbance especially when the alien species occurs in very dense stands. Riparian areas are the area's most affected by alien invasion, they are regularly impacted by floods, but floods are not the only disturbing factor. The areas may be highly utilized by large herbivores and humans especially in African savannas (Beater *et al.* 2008). The invasion of alien species in riparian zones is not only a problem present in South Africa, but has degrading effects worldwide (Holmes *et al*. 2008). Floods can remove vegetation and increase the soil moisture, nutrients and light for various periods of time which then gives an advantage to the invading alien plants as they get a foothold in the habitat because the competitors are absent. These invasive plants have a vigorous growth rate and outcompete the indigenous species. High nutrient levels exist in these areas, because of flooding, and because of runoff containing additional fertilizers from agriculture fields and forest. Alien species can (re)colonize an area quickly after a disturbance event and are therefore dominant in the early successional stages, because of early seedling establishment. Some of the trees that invade areas reduce the ground cover vegetation (which provides surface stability). As a result soil erosion may occur in these areas which are then further invaded by alien vegetation (Beater *et al.* 2008). The negative influence of exotic plants in an environment is of cardinal importance for the well being of any river (Myburgh & Bredenkamp 2004).

The abundance of invasive species produces a significant change in terms of community composition or ecosystem processes. When wetlands are affected by invasive alien plants it has a direct effect on humans by obstructing water flow, reducing recreational value of the waters, blocking hydroelectric and other installations (Cronk & Fennessy 2001).

The invasion of alien plants is not such an obvious problem to the general public, so there is a need for education about alien invasion (Macdonald 2004). In the study area, one of the farmers along the Vet River is having problems with the alien tree

Prosopis velutina. The people that previously lived on the farm introduced this plant. It has spread all over the farm and the current farmer is having serious problems to eradicate it. Furthermore, farmers know the common names of alien invasive species but do not know how they look, therefore they don't know that these plants are threats and that they need to be eradicated. This is not only the case with farmers, the general public is also not able to identify these aliens and can therefore keep them in their gardens which will allow for further dispersal.

4.2 CHARACTERISTICS AND SURVIVAL STRATEGIES OF ALIEN PLANTS

The successful establishment of invasive species after introduction depends on the species` adaptation to the new habitat (Cronk & Fennessy 2001), availability of nutrients (Foxcroft *et al*. 2008) as well as the availability of moisture, growth and vigour of the plants (Le Maitre *et al.* 2000). The likelihood of a species to spread throughout the region depends on whether the seeds or propagules are dispersed easily by dispersal agents such as domestic or wild animals, waterfowl or humans. Alien invasive species are successful in the new environments because of (Cronk & Fennessy 2001):

- The ability to spread through both sexual reproduction and vegetative regeneration;
- Aquatic environments are very similar across the world and therefore many of the submerged and floating-leaved plant species are cosmopolitan (widely distributed throughout the world);
- A wide ecological tolerance occurs in wetland plants, worldwide;
- The invasive exotic species are usually not susceptible to pests or herbivores in the new habitat. The diseases and consumers that evolved with the exotic at their location do not accompany the plant to its new habitat;
- The native plants poses little to no competition to the invasive exotic plants in the new habitats;
- Some of the invasive plants are resistant to flooding, fire and drought.

Most of the already dispersed alien species have spread through natural dispersal mechanisms, but recently humans and their land use practices are the cause of an ever increasing rate of alien dispersal and spread. Humans introduce new species to wetlands in a number of ways (Cronk & Fennessy 2001):

- The species can be introduced unintentionally. This type of transport started centuries ago, but each new development in transportation creates new opportunities for the transportation of exotic plants;
- Some invasive wetland exotics escape from agriculture and horticulture;
- People transport several submerged and floating-leaved plants through the world because the foliage are attractive and use in aquaria. Most of the aquarium plants have been introduced deliberately in natural waters to create wild populations which are harvested and sold at a later date;
- People sometimes introduce an exotic species intentionally in the hope that it will solve a certain problem (Cronk & Fennessy 2001).

The success of exotic species depends on the conditions of the community that are being invaded rather than on the aggressive traits of the exotic species. Most often it is disturbed areas that are susceptible to invasion (Cronk & Fennessy 2001; Foxcroft *et al*. 2008). Disturbances can lead to opportunistic exploitation by invasive species, when there were only a small number present before the disturbance. Although most of the disturbances are caused by nature itself, humans can also cause disturbances (Cronk & Fennessy 2001; D'Antonio & Meyerson 2002; Foxcroft *et al*. 2008).

Disturbances caused by nature itself include changes due to climate, topography, geology or disturbances like fire, floods, hurricanes and anthropogenic land-surface alterations (Foxcroft *et al.* 2008) and even the outbreak of insect's species (D'Antonio & Meyerson 2002). The above mentioned disturbances can lead to a change in the environmental conditions which will promote the germination of seeds of many species and unfortunately these species also include exotics. Environmental changes include the following (D'Antonio & Meyerson 2002):

- Physical disturbance of the soil surface causes exposure to light and a greater fluctuation in temperature which can increase the mineralization of nitrogen;

- Increased resource levels favour fast-growing species which may be favourable for the increased dominance of alien species;
- Most of the alien species that thrive on enriched nutrient levels have the ability to exclude native species for many years to come;
- The germination of weed seeds is increased by the high pools of nitrate available in soils after disturbances;
- Alien species have a large seed bank from where germination can take place. These seed banks are even larger in new homes than in their native ranges.

The disturbances caused by humans include altering wetland hydrology, developing wetlands or land adjacent to wetlands by releasing nutrient and pollutants in the air and water. Cronk & Fennessy (2001) noted some of the disturbances caused by humans:

- Land changes open formerly vegetated land and the colonisers that respond the fastest will take over the vacant space;
- The damming of rivers leads to invasive problems by eliminating the variations in the river`s hydrology to which native species are adapted;
- The spread of alien invasives is encouraged by the fragmentation of natural habitats by agriculture and urban development;
- The inflow of fresh water into salt marshes changes the community structure;
- The change in climate and the increasing levels of CO_2 may bring shifts in the species composition of many communities (Cronk & Fennessy 2001).

Rivers play an important role in the dispersal of aliens as these are the only continuous systems in the landscape and these systems provide migration corridors for indigenous as well as invasive species (Foxcroft *et al.* 2008).

4.3 ALIEN PLANTS` NEGATIVE EFFECTS ON WETLAND ECOSYSTEMS

Alien species pose threats to the indigenous vegetation and have an effect on the ecological function and natural systems of the invaded area (Henderson 2001). In the past the invasion of alien species led to concern about the impact on conservation areas, areas with natural vegetation and the productivity of agriculture, however little information was available about the impact that woody vegetation had on water resources. Le Maitre *et al.* (2000) aimed to report about the impact on the water resources. The area invaded by alien species in South Africa is equivalent to the size of Kwazulu Natal and covers approximately 10.1 million hectares (Lesotho included) and it is still expanding fast (Le Maitre *et al.* 2000; Henderson 2001). The degree of invasion may also differ from province to province. The Free State Province, where this study was conducted, has an area of approximately 12 993 575 hectares of which 166 129 hectares have been invaded by alien invasive plants. Le Maitre *et al.* (2000) also listed the top 10 invading species in South Africa on the basis of dense stands of alien vegetation, one of the species that occur in the area of study namely *Prosopis velutina* is listed as one of the top 10 invaders. Although the surface area, occupied by riparian areas, is limited most of the top 10 invading species are found in these areas.

Worldwide the concern about the invasion of alien plants is an increased concern. There is also a concern about the impacts on biodiversity and natural systems. Scientists in South Africa also recognised what impact alien invaders might have on the indigenous vegetation as well as on the ecological services of ecosystems (Le Maitre *et al.* 2000).

The invasive species present on river banks are mostly woody plants. Riparian areas are often protected from fire and therefore these species can attain greater ages and grow larger (Le Maitre *et al.* 2000). Smith (1990) stated that plant roots that have access to freely available water use more water than plants growing outside the zone where moisture is present (this is true for the indigenous vegetation). These plants also have a significant impact on the water use and if these invaders are allowed time and space they will invade an even larger area of South Africa than they have already done (Le Maitre *et al.* 2000).

In some situations it is difficult if not impossible to remove alien species and managers need to make the best of a bad situation. Therefore the managers might try to enhance the seed bank and population size of native species that can tolerate the competition from the alien species (D'Antonio & Meyerson 2002).

Although not all alien plants are invaders, a large portion of them are used in agriculture and for fibre and timber (ARC 2008). Humans use alien plants and re-distribute the species to support agriculture, forestry, mariculture, horticulture and recreation as well as accidental introductions (Van Wilgen *et al.* 2008). However many of the naturalized species are causing problems and are currently displacing the indigenous vegetation, which leads to a wide range of associated problems (ARC 2008).

- The greater size and density of alien plants (*Salix babylonica* and *Populus* spp.) along river courses and catchment areas usually reduces the volume of water that reach dams and rivers, and can even cause the rivers to stop flowing (ARC 2008);
- Dense stands of alien shrubs and trees such as *Sesbania punicea* choke water courses. When floods occur these trees are ripped out easily and can damage or dislodge indigenous vegetation and create bare soil, which is subject to erosion;
- Most of the alien plants in South Africa are large trees, overshadowing indigenous vegetation which will decline as a result. Alien vegetation is the most important cause of extinction of plants worldwide (ARC 2008);
- The presence of alien plants from the legume family (Fabaceae) changes the composition of the soil by fixing of nitrogen which creates more nutrient-rich conditions in the soil. This has a negative impact on the natural vegetation;
- A change in the composition of the vegetation also leads to a change in the animals present in the area, or reduce the associated animal life;
- Several alien species such as *Cestrum laevigatum* and *Sesbania punicea* are toxic to humans and livestock (Van Wyk *et al.* 2002). Others such as *Eucalyptus* species, secrete chemicals into the soil which prevents the germination of other plants in that area;
- Many alien species are unpalatable to livestock and dominate pastures, because the edible species are selectively grazed;

- Many of the alien invaders are a fire hazard;
- Certain alien species produce berries that the indigenous bird fauna prefer over indigenous fruits and therefore the birds disperse the invaders and not the indigenous plants.

4.3.1 Threats to wetland biodiversity

The biodiversity plays an important role in the delivery of ecosystem services. The biodiversity of an ecosystem can be a service in its own right, like the basis of nature-based tourism. Although there are debates on what is important for the continuous delivery by an ecosystem, the general agreement is that the overall biodiversity is important to ensure the resilience of ecosystem functions and services. The presence of aliens in the ecosystem has a significant impact on the biodiversity (Van Wilgen *et al.* 2008).

The invasion of alien plants disrupts the vegetation dynamics by altering the colonization ability of the indigenous vegetation and thereby affects the establishment of indigenous species (Vosse *et al.* 2008)

4.3.2 Threats to wetland community structure

There is a general loss in natural plant species diversity as the communities change from indigenous vegetation to a monospecific stand of invasive species. Many of the alien emergent species are outcompeting the native vegetation by rapidly filling in unvegetated areas and therefore crowding out the native species. Seed banks in the wetland also gradually become dominated by seeds of the alien species. With the changes in vegetation composition, the wetland animal community is also impacted (Cronk & Fennessy 2001).

4.3.3 Threats to wetland ecosystem function

The presence of invasive species can result in an accumulation of detritus and this in turn decreases the dissolved oxygen content of the water because of the demand for oxygen during decomposition. Very often, alien plants have an impact on the hydrology of the wetland because of their high transpiration rates (Cronk & Fennessy 2001).

4.3.4 Threats to wetland riparian systems

Riparian zones are highly susceptible to invasion by alien plants because these areas are complex disturbance-mediated systems. The frequent disturbances by nature and humans disturb the nutrient levels, hydrology, and water aided dispersal of propagules and the role of stream banks as a reservoir for propagules of both the indigenous and alien species (Holmes *et al.* 2005; Vosse *et al.* 2008). The early attempts to combat alien invasion in the riparian areas only focused on the removal of localized aliens, and little was done considering restoration of the whole catchment area (Holmes *et al.* 2005). With this in mind Van Wilgen *et al.* (2008) stated that invaders in the riparian strips potentially have additional access to water from the river itself, to groundwater in the area as well as lateral discharge of groundwater.

Holmes *et al.* (2005) mentioned that the full extent of the invasion by alien plants along the rivers of the country have not been documented to date. The river zones in all the biomes are however the most densely invaded as many of the alien species spread along the watercourses (Holmes *et al.* 2005). Marais & Wannenburgh (2008) stated that the total area that invaders could possibly invade are estimated at 857 200 ha. 572 600 ha thereof are perennial, 253 900 ha are non-perennial and the other 30 800 ha are on unclassified rivers. Marais & Wannenburgh (2008) state that the vegetation of perennial rivers never comes under water stress as water is always available but in contrast with this the vegetation of non-perennial rivers can be compared to upland vegetation, with periodic droughts.

In the summer rainfall area where the study was concluded, riparian areas are extensively invaded and 50% of all the invasive woody species are recorded along the corridors of rivers. A higher frequency of disturbances creates more opportunities for aliens to invade. The invasion of large trees and shrubs has a negative effect on riparian vegetation all through the country (Holmes *et al.* 2005). In the area of study, namely the Vet River in the Free State Province, the following woody alien species were noted: *Populus* x *canescens, Salix babylonica* and *Sesbania punicea.*

Riparian areas worldwide are the focus of human habitation and development which result in direct and indirect degradation of the ecological integrity. Some of the direct effects of degradation include clearing of vegetation for agriculture, grazing and trampling by livestock, pollution from the surrounding catchment and planting of alien species. The dynamic hydrology and opportunities for recruitment after flooding make riparian ecosystems prone to invasion. The dispersal of alien propagules in water and the continuous access to water are advantages to aliens (Holmes *et al.* 2005). Invading plants have a relative large impact on the water resources in South Africa (Le Maitre *et al.* 2000). Cullis *et al.* (2007) stated that alien invasive plants have the ability to reduce the availability of water through reduction in the mean annual runoff and therefore also reduce the water yield. Because South Africa is a semi-arid country the reducing of run-off have a negative impact on the country`s scarce water resources (Holmes *et al.* 2005).

The aliens that invade the riparian areas in South Africa are mostly large trees with higher water consumption than the native vegetation (Holmes *et al.* 2005). Görgens & Wilgen (2004) stated that research demonstrated that trees like pines, eucalypts and wattles reduce the total annual and low-season streamflow as well as increase evapotranspiration when compared to indigenous vegetation that are being replaced. If alien species are given time and sufficient area the density and extent of invasion will increase and a larger portion of the available water will be lost in the catchment areas (Le Maitre *et al.* 2000).

Although invading plants have a large impact in the water resources, the alien species also cause other problems in the riparian areas. These problems include the following (Holmes *et al.* 2005).

- Suppression and replacement of indigenous species (Holmes *et al.* 2005);

- Increase in transpiration and a reduction in flows which lead to a greater biomass of aliens when compared to the indigenous vegetation (Holmes *et al.* 2005);
- Increase in soil erosion in areas densely invaded by alien trees which lead to a loss in indigenous ground cover. The degree of erosion is determined by the balance between the erosive force of flow and the erodibility of the substrata (Holmes *et al.* 2005);
- Changes in the natural fire regime which may either be a decrease in the frequency of fires due to invasion or an increase in the intensity of fires due to the accumulation of fuel for the fires (Holmes *et al.* 2005);
- Changes in the hydrology which may indirectly affect the geomorphology of a river. Sediment load after fires in dense alien stands may change the geomorphology of the downstream areas (Holmes *et al.* 2005);
- Dense stands of alien species increase the flow resistance, dampen turbulence and aid sediment deposition (Holmes *et al.* 2005).

The influence that the alien plants have on the water resources of South Africa, as well as the occurrence of aliens in the riparian areas and the immediate catchment make these areas the main targets of clearing by the Working for Water initiative (Holmes *et al.* 2005).

4.4 CONTROL OF INVASIVE ALIEN PLANTS AND REHABILITATION OF DISTURBED AREAS

4.4.1 Mechanical control

This treatment involves the removing or physical damaging of the plants such as uprooting, mowing or ring-barking (ARC 2008). Mechanical disturbance of the sediment and harvesting of the plants is also used. After the alien plants have been harvested they must be taken to shore for disposal, this method does not completely remove the species, but reduce the biomass and clear the area. The harvesting of plants is usually only effective in small areas (Cronk & Fennessy 2001). Follow up actions are very important as seedlings may resprout (ARC 2008). The removal of alien species by hand and therefore mechanical control are some of the most commonly used methods of control (D'Antonio & Meyerson 2002).

4.4.2 Chemical control

Registered herbicides are applied to the invasive plants or the soil surrounding them, with the aim to kill these plants (ARC 2008). Chemical herbicides are used worldwide to control invasive plants, an example of this is the control of *Eichhornia crassipes* with the chemical 2,4-D in America (Cronk & Fennessy 2001).

There are some problems with the application of herbicides in an aquatic environment as these herbicides are instantly diluted when applied to under water plants or sediment. The herbicides must quickly be absorbed and applied at sufficient rates to harm only the targeted plants without affecting other organisms or humans (Cronk & Fennessy 2001).

4.4.3 Biological control

This method of controlling involves the use of host specific natural enemies to reduce the population size to an acceptable level through the reduction of growth (Cronk & Fennessy 2001; ARC 2008). This control method does not entirely eliminate the alien species, but rather maintain the population at a tolerable level (Cronk & Fennessy 2001) or reduce the ability of the alien species to spread further into extended areas (Holmes *et al*. 2005). Marais & Wannenburgh (2008) stated that biocontrol agents in most cases simply reduce the rate of spred rather than reducing the total extent of the invasion. D'Antonio & Meyerson (2002) stated that the use of biological control agents is mostly used primarily in rangeland or agricultural settings. This method has not been used greatly in habitat restoration. However, the technique used in a certain area depends on the biology of the species as well as socioeconomic, political and cultural factors.

Since 1913 a total of 48 weed species were controlled by 95 species of biocontrol agents in South Africa. None of these biocontrol agents have switched to other hosts. 25% of these introductions resulted in the complete control of the target weed specie, 32% substantially suppressed the target weed, while on the other 25% no judgement have been passed. This is clear why South Africa is seen as the leaders in the field of biological control research (Macdonald 2004).

4.4.4 Restoration prospective for invaded areas

The restoration of areas after the invasion by alien plants is a unique challenge, because certain species can still have an effect on the system after the removal of the alien plants. This influence will have an effect on the desired restoration of the area. D'Antonio & Meyerson (2002) stated that several researchers found that alien species are able to control certain aspects of the ecosystems biogeochemistry. The alien species are not only able to alter the nitrogen availability in the soil but also alter the soil salinity. The effects that the aliens have on the environment can be seen long after the aliens have been removed and therefore make it difficult for native species to recolonize an area.

In South Africa certain invasive species increase the rate of soil erosion. These species include some of the *Acacia`s* like: *A. longifolia, A. mearnsii, A. saligna* and *Pinus pinaster* and in the area of study, *Sesbania punicea*. Most of these species occur in the fynbos where they are not adapted to tolerate floods and when these species are ripped out during floods they take large areas of the native vegetation along, which expose mineral soil and therefore increase the rates of erosion (D'Antonio & Meyerson 2002).

D'Antonio & Meyerson (2002) stated that a site that has been degraded due to alien invasion and soil erosion pose a particular challenge. After the invasion the topography of the site may no longer resemble the conditions that existed before the invasion and erosion. The removal of the invasive species may even cause further erosion, especially if long periods of time elapse before the native plants establish themselves.

Although alien plants mostly degrade the environment and lead to the extinction and replacement of native species, these plants can also play an important role in the restoration of the environment (D'Antonio & Meyerson 2002).

- The presence and dominance of invasive alien species may be part of the conditions which lead to the assessment that restoration in a certain area is needed. In some areas restoration may be as easy as removing the invasive alien species;
- The alien species may be the first to colonise an area after a disturbance which are associated with the removal of species;
- Aliens may be the first species to colonise an area after a planned disturbance even if these aliens were not present prior to the disturbance. This might alter the successional process that would otherwise lead to the establishment of native species in the area;
- Alien species may leave behind seed banks or chemical or physical alterations in the habitat which makes the area unfavourable for the native species. And therefore makes long-term restoration of the site difficult;
- Managers may use alien species to restore certain functions in the area if the native species are not available (D'Antonio & Meyerson 2002).

4.4.5 The South African initiatives to control and eradicate alien species

According to Henderson (2007) roadside surveys of invasive alien plants started in 1979 in the Central parts of Gauteng and the rest of Mpumalanga, Limpopo en Northwest in 1982 and 1983. In 1986, Henderson surveyed the rest of South Africa starting with KwaZulu-Natal, Free State, northern Cape, eastern Cape, western and central Cape and lastly the southern and south-western Cape. During January 1994 the Southern African Plant Invaders Atlas (SAPIA) launched a mapping project to collect information on the distribution, abundance and habitat type of invasive and naturalized alien plants in southern Africa. From this project 161 alien invaders were identified species which have been included in a field guide by Henderson to help with the identification of the species (Henderson 2007).

In the surveys done by Henderson and colleagues during the period 1979 to 2000 in South Africa, Swaziland and Lesotho they found a total number of 548 naturalized and casual alien plant species that are catalogued in the SAPIA database for these three countries. An updated list were presented (Henderson 2007) that contain 601 species which are estimated to be only half the total number of naturalized and casual alien plants species present in southern Africa. Henderson further stated that there are 97 outstanding invasive species in South Africa, Swaziland and Lesotho (Henderson 2007).

Henderson (2007) stated that 32 of the prominent invading species are present in the Grassland biome. Along the Vet River in the Free State *Populus x canescens, Salix babylonica* and *Sesbania punicea* were found. These three are of the 55 most prominent alien invasive species that are commonly found in riparian habitats. Figure 4.1 indicates that in the area of study there are no data available or the area is invaded with a 1 – 5 % alien plant cover (DEAT 2010).

Most of the alien species present in the Grassland biome are species that have their origin in the northern temperate regions and the tropics. The most conspicuous invading species are woody trees and shrubs from the families Rosaceae, Fabaceae and Salicaceae (Henderson 2007).

Not all the biomes present, are invaded to the same extent and one can look at the environmental conditions as well as the history of planting; species were deliberately introduced and cultivated. Some of the invading species were planted widely in the country, but are only adapted to specific natural habitats (Henderson 2007).

Sixty-eight percent of the total amount of invaders is perennial trees or shrubs, with only two grasses listed as prominent invaders and only fourteen non-perennial species are invaders. The areas invaded by *Populus* x *canescens* and *Salix babylonica* are underestimated, as these are two species that are recorded most often as invaders in riparian and wetland habitats (Henderson 2007).

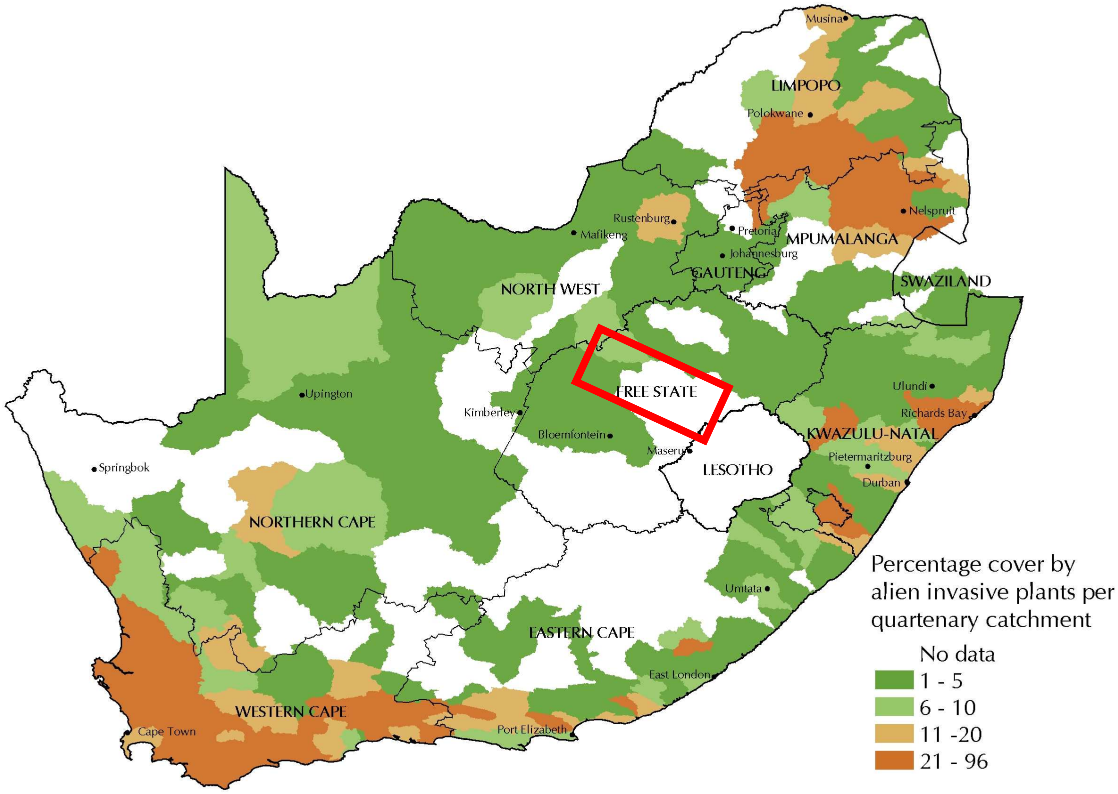


Figure 4.1: Map of the percentage of alien plant cover in South Africa, Lesotho and Swaziland. The red block indicates the study area (Department of Environmental Affairs and Tourism 2010).

The riparian ecosystems of the Fynbos, Grassland and Savanna biomes have a relatively high ecological resilience to the invasion of alien plants. Therefore the clearing of aliens may be enough for the recovery of the indigenous vegetation`s structure and diversity, as long as the area covered by invasive plants is less than 75% (Holmes *et al*. 2008). After removal of the alien vegetation it is better to restore the vegetation cover of that area by planting indigenous species that are resilient to flood events, while their establishment prevents the return of alien plants (Holmes *et al.* 2008).

Many invasive plants occur at low densities but, if left uncontrolled these low densities may develop into dense closed stands over time. The present situation can also worsen when new invasive species become established. The rapid growth in the introduction rate of new alien species and the fact that most of the introductions only happened recently, most of the alien invaders may be in the 'lag period'. Therefore the global changes in climate and the biogeochemical cycles may further worsen the situation which may bring about favourable conditions for invasive species (Van Wilgen *et al.* 2008).

4.4.5.1 Working for water

The establishment of the Working for Water (WfW) initiative was due to the calculations that alien invasive plants use significant amounts of water (Görgens & Wilgen 2004). Görgens & Wilgen (2004) stated that the aim of Working for Water is to protect the water recourses by clearing areas of alien plants. People from the area, were the clearing of aliens took place, and are usually employed. This contributes to the upliftment of poor rural communities as well as to conserve water (Görgens & Wilgen 2004).

Working for Water (WfW) is an initiative that deals with the clearing of invasive plants, operating since 1995, by the end of 2003 almost 1.2 million ha of invasive alien species were cleared (Görgens & Wilgen 2004), this is 12% of the estimated 10.5 million ha of infestations in the country, however this figure is misleading as it covers a range of densities (Macdonald 2004). However recent analysis indicates that only 7% of the closed stand invasions have been cleared since then (Holmes *et al*. 2008). Although not all riparian areas are invaded to the same extent, if these invaded areas are compressed to closed stands, the stands would be equivalent to 33% closed stand invasion across the total perennial and non-perennial riparian areas. Results from Working for Water studies indicate that the invasive plants are a threat to the biodiversity and reduce the productivity of land as well as reduce the water yield (Holmes *et al*. 2008). Working for Water was initiated in order to restore the environments in which the invasive plants occur, therefore the invasive plants are being removed from the vegetation. However, there may be some areas, where invasive vegetation has occurred for such a long period of time that the environment is not capable of restoring itself because it has been altered. These environments require extra efforts for restoration like vegetation manipulation, modification of the physical environment or a bit of both to enhance the recovery. Although restoration of the sites is the goal of Working for Water, it must be kept in mind that only sites with light invasion or sites that have been invaded recently have the potential for natural recruitment. It is unattainable in a short to medium period to restore sites with a long history of invasion without enormous expenses (Holmes *et al*. 2008). Most of the goals set in the rehabilitation process of the riparian areas are to remove the alien vegetation and leave the area to be dominated by indigenous species from the surrounding area. After the restoration of the riparian ecosystem the ecological state as well as the productivity of the river where restoration took place will be improved (Holmes *et al.* 2008).

Previous studies in the Sabie River in Mpumalanga with high and low invasion intensities indicated that Working for Water are successful when it comes to the removal of large individuals, but there is a lack in controlling regeneration and new invasions of alien species. In the same river the problems were addressed and frequent follow-up rounds were carried out with success. From the study in Kruger National Park it also became clear that attention is required during years with above average rainfall. Caution are needed when planning alien plant control in the riparian zones of the Savanna and Grassland biomes, because alien plants in these biomes respond rapidly to disturbances like floods in high rainfall years. Therefore clearing schedules need to be updated to prevent the re-occurrence of these unwanted species (Holmes *et al*. 2008). Holmes *et al.* (2008) stated that the establishment of indigenous vegetation is a fundamental requirement for recovery from the invasion of alien plants in the long term.

To conclude: the removal of alien species in most cases improves the ecosystem and facilitates the restoration of indigenous riparian vegetation which supports the Working for Water programme (Holmes *et al*. 2008).

Macdonald (2004) stated that the interaction of alien invasive plants and the catchment hydrology can be summarized as follows:

- The removal of alien plants has a positive influence on the available water;
- The removal of dense stands of alien species has the greatest effect;

- The removal of alien plants from riparian areas has a larger effect than removing these species from upland areas;
- The effect of removal is greater when native vegetation is much lower than the infestation that replaces it;
- Dense stands of infestation of alien invasive plants in the catchment of impoundments can have a serious effect on the security of the water supply for such an impoundment.

The ecology of ecosystems is also negatively affected by the invasion of alien species. One example of this is the extremely negative effect that dense stands of alien plants in riparian areas have on certain endemic dragonfly species in South Africa. Because of this, some of the dragonfly species are now rated as highly threatened (Macdonald 2004). In Marais & Wannenburgh (2008) it is clear that of the 31 endemic Southern African dragonflies 12 are globally Red Listed while 11 of these species are threatened by alien invasion in riparian areas.

Macdonald (2004) stated that the outcome of post-clearing regeneration depend on the interactions. The interactions however varies according to the vegetation and soil types, alien plant species, age and density of infestations, the number of fire cycles that an infestation experience, clearing treatments and pre- and post-clearing fire regimes which all act together.

The cost of active rehabilitation after clearing are so high and the results uncertain, and the clearing may even lead to a greater loss of biodiversity that it is better to prevent invasion in the first place rather than to clear alien species after invasion (Macdonald 2004). In Macdonald (2004) it is predicted that the change in the global climate may have severe effects on the ecosystems of South Africa.

REFERENCES: CHAPTER 4

AGRICULTURAL RESCEARSH COMISSION (ARC). 2008. www.arc.agric .za

BEATER, M.M.T., GARNER, R.D. & WITKOWSKI, E.T.F. 2008. Impact of clearing invasive alien plants from 1995 to 2005 on vegetation structure, invasion intensity and ground cover in a temperate to subtropical riparian ecosystem. *South African Journal of Botany.* 74: (2008): 495 – 507.

CRONK, J.K. & FENNESSY, M.S. 2001. *Wetland Plants: Biology and Ecology*. Lewis Publishers. United States of America.

CULLIS, J.D.S., GÖRGENS, A.H.M. & MARAIS, C. 2007. A strategic study of the impact of invasive alien plants in the hihg rainfall catchments and riparian zones of South Africa on total surface water yield. *Water SA*. 33 (1): 35-42.

D'ANTONIO, C. & MEYERSON, L.A. 2002. Exotic Plant Species as Problems and Solutions in Ecological Restoration: A Synthesis. *Restoration Ecology* 10 (4): 703-713.

DEPARTMENT OF ENVIROMNENTAL AFFAIRS AND TOURISM, Republic of South Africa. 2010. http://soer.deat.gov.za/Themes.aspx?m=271.

FOXCROFT, L.C., PARSONS, M., McLOUGHLIN, C.A. & RICHARDSON, D.M. 2008. Patterns of alien plant distribution in a river landscape following an extreme flood. *South African Journal of Botany* 74: 463-475.

GÖRGENS, A.H.M. & VAN WILGEN, B.W. 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges. *South African Journal of Science* 100: 27-33.

HENDERSON, L. 2001. *Alien weeds and invasive plants. A complete guide to declared weeds and invaders in South Africa.* Plant Protection Research Institute and Agricultural Reserch Council. Paarl Printers. Cape Town.

HENDERSON, L. 2007. Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA). *Bothalia* 37 (2): 215-248.

HOLMES, P.M., RICHARDSON, D.M., ESLER, K.J., WITKOWSKI, E.T.F. & FOURIE, S. 2005. A decision-making framewerok for restoring riparian zones degraded by invasive alien plants in South Africa. *South African Journal of Science* 101: 53-564.

HOLMES, P.M., ESLER, K.J., RICHARDSON, D.M. & WITKOWSKI, E.T.F. 2008. Guidelines for improved management of riparian zones invaded by alien plants in South Africa. *South African Journal of Botany* 74: 538 – 552.

LAWRENCE, E. 2000. *Henderson's Dictionary of Biological Terms*. 12th edition. Pearson Education Limited. Malaysia.

LE MAITRE, D.C., VERSFELD, D.B. & CHAPMAN, R.A. 2000. The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. *Water SA* 26 (3): 397-408.

MACDONALD, I.A.W. 2004. Recent research on alien plant invasions and their management in South Africa: a review on the inaugural research symposium of the Working for Water programme. *South African Journal of Science* 100: 21-26.

MARAIS, C. & WANNENBURGH, A.M. 2008. Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa – Costs and water benefits. *South African Journal of Botany* 74: 526-537.

MYBURGH, W.J. & BREDENKAMP, G.J. 2004. Macro channel riparian vegetation of the Olifants River System in the Savanna Biome, Mpumalanga. *Koedoe* 47 (2): 37-60.

SMITH, R.E. 1990. Comparison of the plant water relations of *Cunonia capensis* and *Pittosporum undulatum* in a riparian woodland in the south-western Cape. *South African Journal of Botany* 56(3): 409-412.

VAN WILGEN, B.W., REYERS, B., LE MAITRE, D.C., RICHARDSON, D.M. & SCHONEGEVEL, L. 2008. A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. *Journal of Environmental Management* 89: 336-349.

VAN WYK, B-E., VAN HEERDEN, F. & VAN OUDTSHOORN, F. 2002. *Poisonous Plants of South Africa.* Briza Publications, Pretoria, South Africa.

VOSSE, S., ESLER, K.J., RICHARDSON, D.M. & HOLMES, P.M. 2008. Can riparian seed banks initiate restoration after alien plant invasion? Evidence from the Western Cape, South Africa. *South African Journal of Botany* 74: 432 – 444.

CHAPTER 5

MATERIALS AND METHODS

5.1 INTRODUCTION

Vegetation is build up of individual plants which can be classified according to a hierarchical system of identification and nomenclature using a certain criteria of growth form and physiognomy. When individuals of a certain species are put together it will form a certain species population which will occur in a specific area. When different groups of species populations are growing together in an area it is known as a plant community (Kent & Coker 1992). Westhoff & Van der Maarel (1978) and Van der Maarel (2005) define a plant community or phytocoenose as a piece of vegetation in a uniform environment with a relatively uniform floristic composition and structure that is distinct from the surrounding vegetation.

Kent and Coker (1992) stated that the vegetation is important in ecology for three reasons:

- Vegetation usually is the most obvious physical representation of an ecosystem;
- Vegetation is the result of primary production where solar energy is transformed through the process of photosynthesis. The vegetation is important in the food web as it is usually the primary food source;
- Vegetation forms the habitat in which organisms of other types than plants live, grow, reproduce and die.

Vegetation ecology (phytosociology) is not only concerned with the identification of plant communities, but is also concerned about how the plants are related to each other and to environmental factors (Mueller-Dombois & Ellenberg 1974; Lawrence 2000; Van der Maarel 2005). Early vegetation scientists have studied pieces of vegetation which they have seen as samples of a plant community. These samples that they considered should however be uniform and different from the surrounding vegetation. Vegetation can be seen as a system of largely spontaneously growing plants (Van der Maarel 2005).

Early work in vegetation science was concerned with the description of unusual landscapes and their vegetation. The tradition of this science is more than two centuries old. The first person who looked at systematic descriptions of recurring vegetation patterns was Von Humboldt in 1806. He used, the today well known, 'associations' to describe plants growing in communities. The first clearly defined systematic description of numerous plant communities was done by Schouw in 1832. In the twentieth century scientist like Raunkiaer, Clements, Du Rietz, Braun and Braun-Blanquet developed various methods to analyse and classify vegetation. Their aim was also to increase the accuracy and to find a standard basis for quantitative evaluation (Mueller-Dombois & Ellenberg 1974).

The systematic classification of plant communities in Europe was developed by Braun-Blanquet by the combination of initiations of his predecessors. This development leads to a system of "Phytosociology" which was accepted throughout the world and had a significant influence on the development of European vegetation science (Mueller-Dombois & Ellenberg 1974). Except for the development in European vegetation science, Braun-Blanquet made a major contribution by selecting, simplifying and modifying a system that could be used for analysis of vegetation. This system is relatively simple but not superficial which led to the rapid exception by many investigators and proved to be useful in areas where a large number of species occur (Mueller-Dombois & Ellenberg 1974).

5.2 THE BRAUN-BLANQUET-METHOD

The Braun-Blanquet technique was developed with the purpose of assessing and constructing an extensive classification of the plant communities in Europe. However when using Braun-Blanquet there are several fundamental concepts and assumptions that have to be kept in mind (Kent & Coker 1992):

A sample plot is equivalent to a quadrat in vegetation description. The location of these plots should be carefully selected as the area should be representative of a particular vegetation type. The vegetation to be sampled should be uniform and homogeneous. Furthermore, the plot size should be large enough to be a representative sample of the uniform vegetation (Kent & Coker 1992). The plot sizes used during the study were $100m^2$ for tree and shrub communities and $16m^2$ in the grass dominated areas (Dingaan *et al.* 2001; Malan *et al.* 2001; De Klerk *et al*. 2003; Cleaver *et al.* 2005; Siebert & Siebert 2005; Grobler *et al.* 2006; Zietsman & Bredenkamp 2006; Bezuidenhout 2009; Brand *et al.* 2009).

Associations are the basic units of classification and are on the same level as plant communities. A plant community is the grouping of various relevès that have a number of species in common. The final associations are formed by the sorting and rearrangement of both relevès and species. The associations formed by the groupings of relevès can sometimes be subdivided into sub-associations and the sub-associations can be divided into variants. When using this hierarchy in vegetation units the vegetation in a certain region can be described and their relation to each other can also be displayed (Kent & Coker 1992).

According to Werger (1974), the Braun-Blanquet-method is one of the most significant tools in studying the environment, because it addresses three essential requirements which are needed when studying vegetation ecology. The Braun-Blanquet-method:

- is efficient and reliable;
- fulfils the necessity of classification at an appropriate level, and
- is the most efficient and versatile amongst comparable approaches.

Quite a number of studies in the Grassland biome were done by using this specific method (Bezuidenhout *et al.* 1994; Bredenkamp & Bezuidenhout 1995; Brand *et al.* 2009). It has also been used in other biomes (Bredenkamp & Bezuidenhout 1995; Dingaan *et al.* 2001; Malan *et al.* 2001; De Klerk *et al*. 2003; Götze *et al*. 2003;

Cleaver *et al.* 2005; Siebert & Siebert 2005; Grobler *et al.* 2006; Zietsman & Bredenkamp 2006; Bezuidenhout 2009).

Wikum & Shanholzer (1978) stated that the Braun-Blanquet-method only requires one third to one fifth of the time in the field than required for other density studies. Furthermore the cover-abundance ratings are better than density values to show graphically relationships between the species and the environment. This method can also be used to compare the plant cover values of disturbed and undisturbed areas by looking at the estimated reduction in the plant cover. The use of the cover-abundance scale does not reduce the information gained, but rather add distributional and structural considerations which are important when assessing the faunal habitat (Wikum & Shanholzer 1978). It can be concluded that the system undoubtedly works and in Europe a detailed and accurate classification of most of the vegetation units occurring, had been achieved (Kent & Coker 1992).

Although Braun-Blanquet is a method widely used all over the world (Wikum & Shanholzer 1978), there is also some criticism of the method. The criticism includes the following (Kent & Coker 1992):

- The selection of typical of representative relevès is said to be highly biased and non-homogeneous and transitional or ecotone areas are not recorded in the samples taken;
- The concept of ‘abstract’ communities can be confusing for students and inexperienced researchers;
- The tabular rearrangement, has been criticised because each worker applies his/her own methodology although the principles how to do it are agreed upon;
- The discarding of relevès, if the relevè do not fit any of the associations – but the explanation is that the specific relevè could have been chosen badly;
- The method uses strange and sometimes unnecessary terminology at all stages;
- The method is not well described in the literature and has many variations with an air of mystique about it which is difficult to dispel – this makes the topic difficult for students and young ecologists;

- The steps used in the scale are not proportional and the combination of abundance and cover in one scale is in principle illogical (Werger 1974).

5.3 CLASSIFICATION OF THE VEGETATION OF THE STUDY AREA

5.3.1 Data collection

In the phytosociological study of the Vet River, the Zurich-Montpellier method, or Braun Blanquet method has been used to assess, classify and describe the natural vegetation.

In the study area, 240 sample plots or relevès were placed within the different homogenous vegetation types along the Vet River. The aim was to sample and study the different vegetation types that occur within the riparian areas and the associated wetlands. Within each sample plot the habitat information and species present, were recorded. A cover-abundance value was assigned to each species, using the Braun-Blanquet cover-abundance scale as presented in Table 5.1. Cover-abundance is a combined parameter of cover in case the cover exceeds a certain level (Van der Maarel 2005). Cover is defined as the area of ground within an area which is occupied by above-ground parts of each species when viewed from above (Kent and Coker 1992). Because of the visual estimation, a certain degree of error may occur, but because the cover-abundance is expressed in different classes, error is restricted to the minimum. The explained method was used because the method is rapid, compatible to existing phytosociological data sets in South Africa and the problems of subjectivity may have been over-emphasised (Kent & Coker 1992).

Fieldwork was conducted during March/April 2008 and again in January 2009. The fieldwork was completed during March 2009. During the field analysis the following environmental data were collected: Aspect, slope, exposure to the sun, topography, water saturation, terrain units and channel depth for the water`s surface. The exact position of each sample plot was taken by using a Global Positioning System (GPS).

5.3.2 Data analysis

The environmental and floristic data were processed using a floristic database programme TURBOVEG (Hennekens 1996). Each relevé's data were imported into this programme, to be used by other classification programmes.

Table 5.1: Braun Blanquet cover-abundance scale as presented by Van der Maarel (2005).

Braun Blanquet value	**Abundance category**	**Cover: interpreted interval**
R	1-3 individuals	c≤5%
+	Few individuals	c≤5%
1	Abundant	c≤5%
2m	Very abundant	c≤5%
2a	Irrelevant	5<c≤12.5%
2b	"	12.5<c≤25%
3	"	25<c≤50%
4	"	50<c≤75%
5	"	c>75%

The data processed in TURBOVEG were then exported into the JUICE (Tichy & Holt 2006) programme, which is a multifunctional editor with the ability of advanced classification and parametrization of phytosociological tables from where TWINSPAN the classification programme can be applied independently (Tichy 2002).

TWINSPAN (two way indicator species analysis) is the most widely used method of numerical classification of vegetation data at present. TWINSPAN (Hill 1979) a numerical classification programme was applied to the data in order to obtain a first approximation. This method is based on the progressive refinement of a single axis ordination from the reciprocal average or correspondence analysis. TWINSPAN performs a joint classification of the quadrants and the species simultaneously (Kent & Coker 1992). Although this is a complex method, the most attractive feature is the fact that the end product is a two-way table. The two-way result is an indication of the species present and relevè number, where the relevès are sorted column-wise and the species row-wise (Kent & Coker 1992). TWINSPAN is regarded as a successful approach for the classification of phytosociological analysis (Brown *et al.* 2005).

The initial TWINSPAN classification is then refined, by means of Braun-Blanquet procedures in the visual editor JUICE (Tichy & Holt 2006).

The arrangement of the relevés and species in this physiognomic table leads to a classification system of syntaxa (Westhoff & Van der Maarel 1978). The syntaxa can be defined by diagnostic species (character-species, differential species, and constant companions). Westhoff & Van der Maarel (1978) define character-species as species that are relatively restricted to the stands (or samples) of a given phytocoenon, and therefore characterize it and indicate its environmental affiliation. However, for a species to serve as a character-species that species should have a narrow distribution, even if it is not simply restricted to the association (Westhoff & Van der Maarel 1978).

The floristic classification leads to the formation of certain communities, sub-communities and even variants. The classification of species into communities can be affected by the species present, but the growth-forms, life-forms or strata can show relative independence of one another. This can lead to different combinations within particular communities (Whittaker 1978).

Ordination is the relationship of the plant and animal communities with their environment (Ter Braak & Smilauer 2002). Ordination methods developed from the individualistic viewpoint of Gleason, where he stated that although plant communities exist in the sense of a group of species at one point in space, they cannot be identified as combinations of associated species repeating over space. Gleason also stated that plant species respond individually to variation in environmental factors and that the environmental factors vary both in space and time (Kent & Coker 1992).

Determining the degrees of similarity that individual samples has to each other as well as the order in which the individuals are correlated with the underlying environmental controls is the essential of ordination methods. Methods of ordination and gradient analysis are descriptive and enable researchers to form ideas about the plant community structure and the possible relationship between the vegetation and the environment. Furthermore in plant ecology the application of gradient analysis and ordination can help with the following (Kent & Coker 1992):

- Summarising the data of plant communities and provide an indication of the true nature of variation within the vegetation in the area of study;
- To examine and compare the distribution of individual species within different communities;
- Environmental gradients can be defined by summarizing the variation within sets of vegetation samples which can be correlated with environmental controls.

Canonical correspondence analysis (CCA) differs from the other indirect approach in that the CCA incorporates the correlation and regression between floristic data and environmental factors in the ordination itself. Therefore CCA uses data matrices of species and samples as well as environmental factors and samples. This is the reason why CCA can be seen as the best defined method of direct ordination. The end product represents the variability of environmental data and the variability of species data. The ordination diagrams are thus not only a result of the patterns of variation in floristic composition, but also demonstrate the relationships between the species and each of the environmental variables (Kent & Coker 1992).

The ordination of the vegetation and environmental data was done using CANOCO 4.5 (Ter Braak & Smilauer 2002). CANOCO can provide insights into biological communities and the impact that natural and human-induced disturbances has on the biological assemblages (Ter Braak & Smilauer 2002).

Plant taxon names used in this study confirm to those as listed by Germishuizen & Meyer (2003). The only exception is the genus *Rhus* which was changed to *Searsia* (Moffett 2007).

REFERENCES: CHAPTER 5

BEZUIDENHOUT, H. 2009. The classification, mapping and description of the vegetation of the Rooipoort Nature Reserve, Northern Cape, South Africa. *Koedoe* 51(1): Art. #695, 11 pages.

BEZUIDENHOUT, H., BREDENKAMP, G.J. & THERON, G.K. 1994. Phytosociological classes of the western Transvaal grassland, South Africa. *Koedoe*. 37(1): 1-18. Pretoria.

BRAND, R.F., DU PREEZ, P.J. & BROWN, L.R. 2009. A classification and description of the shrubland vegetation on Platberg, Eastern Free State, South Africa. *Koedoe* 51(1): Art. #696, 11 pages.

BREDENKAMP, G.J. & BEZUIDENHOUT, H. 1995. A proposed procedure for the analysis of large phytosociological data sets in the classification of South African grasslands. *Koedoe* 38(1): 33-39.

BROWN, L.R., MARAIS, H., HENZI, S.P. & BARRETT, L. 2005. Vegetation classification as the basis for baboon management in the Bourke`s Luck Section of the Blyde Canyon Nature Reserve, Mpumalanga. *Koedoe* 48: (2): 71-92.

CLEAVER, G., BROWN, L.R. & BREDENKAMP, G.J. 2005. The Phytosociology of the Vermaaks, Marnewicks and Buffelsklip valleys of the Kammanassie Nature Reserve, Western Cape. *Koedoe* 48(1): 1-16.

DE KLERK, J., BROWN, L.R. & BEZUIDENHOUT, H. 2003. Plant communities of the Ebenhaezer section of the Mountain Zebra National Park. *Koedoe* 46(2): 9-20.

DINGAAN, M.N.V., DU PREEZ, P.J. & VENTER, H.J.T. 2001. Riparian and wetland vegetation of natural open spaces in Bloemfontein, Free State. *South African Journal of Botany* 67: 294-302.

GERMISHUIZEN, G & MEYER, N.L. (eds). 2003. Plants of southern Africa: an annotated checklist. *Strelitzia 14*. National Botanical Institute, Pretoria.

GÖTZE, A.R., CILLIERS, S.S., BEZUIDENHOUT, H. & KELLNER, K. 2003. Analysis of the riparian vegetation (Ia land type) of the proposed Vhembe-Dongola National Park, Limpopo Province, South Africa. *Koedoe* 46(2): 45-64.

GROBLER, C.H., BREDENKAMP, G.J. & BROWN, L.R. 2006. Primary grassland communities of urban open spaces in Gauteng, South Africa. *South African Journal of Botany* 72: 367-377.

HENNEKENS, S.M. 1996. TURBOVEG: A software package for input, processing and presentation of phytosociological data. User`s guide, version July 1996, IBN-DLO. Lancaster: Wageningen and Lancaster University.

HILL, M.O. 1979. TWINSPAN. A FORTRAN program for arranging multivariate data in an ordered two-way table classification of individuals and attributes. New York: Cornell University.

KENT, M. & COKER, P. 1992. *Vegetation description and analysis. A Practical Approach.* John Wiley & Sons Ltd. New York.

LAWRENCE, E. 2000. *Henderson's Dictionary of Biological Terms*. 12th edition. Pearson Education Limited. Malaysia.

MALAN, P.W., VENTER, H.J.T. & DU PREEZ, P.J. 2001. Vegetation ecology of the southern Free State; Vegetation of the drainage channels. *South African Journal of Botany* 67: 58-64.

MOFFETT, R.O. 2007. Name changes on the Old World *Rhus* and recognition of *Searsia* (Anacardiaceae). *Bothalia* 37 (2) 165-175.

MUELLER-DOMBOIS, D & ELLENBERG, H. 1974. *Aims and methods of vegetation ecology.* Wiley, New York.

SIEBERT, F. & SIEBERT, S.J. 2005. Dolomitic vegetation of the Sterkfontein Caves World Heritage Site and its importance in the conservation of Rocky Highveld Grassland. *Koedoe* 48(1): 17-31.

TER BRAAK, C.J.F. & SMILAUER, P. 2002. CANOCO Reference manual and CanoDraw for Windows User`s guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY, USA.

TICHY, L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13: 451 – 453.

TICHY, L. & HOLT, J. 2006. JUICE: A program for management, analysis and classification of ecological data. Vegetation Science Group, Masaryk University Brno, Czech Republic.

VAN DER MAAREL, E. 2005. *Vegetation Ecology*. Blackwell Publishing, United Kingdom.

WERGER, M.J.A. 1974. On Concepts and Techniques applied in the Zurich-Montpellier method of vegetation survey. *Bothalia* 11(3): 309-323.

WESTHOFF, V. & VAN DER MAAREL, E. 1978. The Braun-Blanquet Approach. *In:* WHITTAKER, R.H. (ed.). *Classification of Plant Communities.* Pp289-399. Junk, The Hague, Netherlands.

WHITTAKER, R.H. 1978. *Approaches to Classifying Vegetation. In:* WHITTAKER, R.H. (ed.). *Classification of Plant Communities.* Pp289-399. Junk, The Hague, Netherlands.

WIKUM, D.A. & SHANHOLTZER, G.F. 1978. Application of the Braun-Blanquet Cover-Abundance Scale for Vegetation Analysis in Land Development Studies. *Environmental Management*. 2 (4): 323 – 329.

ZIETSMAN, M.M. & BREDENKAMP, G.J. 2006. Dune vegetation and coastal thicket plant communities in threatened limestone fynbos of Andrew`s Field and Tsaba-Tsaba Nature Reserve, Struisbaai, Western Cape. *Koedoe* 49(1): 33-47.

CHAPTER 6

RESULTS AND DISCUSSION

6.1 CLASSIFICATION

The communities identified, after classification of the Vet River's riparian and aquatic vegetation data, can be divided into those that occur in the mountainous areas (headwaters), the communities which occur along the river and the wetland communities associated with the river course.

Table 6.1 represents the phytosociological classification of the vegetation along the Vet River in the Free State Province, South Africa. The vegetation of the study area can be divided into 14 communities (a well-defined assemblage of plants, clearly distinguishable from other such assemblages (Lawrence 2000)), 21 sub-communities and 11 variants.

The identification is as follow:

1. *Selaginella dregei - Tulbaghia acutiloba* Seepage Community
2. *Morella serrata – Scolopia mundii* Riparian Tree Community
3. *Phragmites australis – Equisetum ramosissimum* Reed Community
    - 3.1 *Phragmites australis – Cyperus longus* Reed Sub-Community
    - 3.2 *Phragmites australis – Verbena bonariensis* Reed Sub-Community
4. *Salix mucronata – Xanthium strumarium* Riparian Tree Community
    - 4.1 *Salix mucronata – Phragmites australis* Riparian Tree Sub-Community
    - 4.2 *Salix mucronata – Cyperus longus* Riparian Tree Sub-Community
    - 4.3 *Salix mucronata – Hemarthria altissima* Riparian Tree Sub-Community
5. *Hemarthria altissima – Equisetum ramosissimum* Grassy Community
    - 5.1 *Hemarthria altissima – Verbena bonariensis* Grassy Sub-Community
    - 5.2 *Hemarthria altissima – Paspalum dilatatum* Grassy Sub-Community
6. *Salix babylonica – Oenothera rosea* Riparian Tree Community
    - 6.1 *Hemarthria altissima – Oenothera rosea* Grassy Sub-Community
    - 6.2 *Bromus catharticus – Plantago lanceolata* Grassy Sub-Community

7. *Acacia karroo – Asparagus africanus* Shrub Community

- 7.1 *Themeda triandra – Crotalaria distans* Grassy Sub-Community
    - 7.1.1 *Imperata cylindrica* Variant
    - 7.1.2 *Andropogon appendiculatus* Variant
- 7.2 *Cestrum laevigatum – Acacia karroo* Shrub Sub-Community
- 7.3 *Searsia pyroides – Acacia karroo* Shrub Sub-Community
    - 7.3.1 *Artemisea afra* Variant
    - 7.3.2 *Diospyros lycioides* Variant
- 7.4 *Diospyros lycioides – Acacia karroo* Shrub Sub-Community
- 7.5 *Medicago polymorpha – Acacia karroo* Shrub Sub-Community
- 7.6 *Eragrostis plana – Acacia karroo* Shrub Sub-Community
- 7.7 *Ziziphus mucronata – Asparagus africanus* Shrub Sub-Community
    - 7.7.1 *Lycium hirsutum* Variant
    - 7.7.2 *Bromus catharticus* Variant

8. *Eragrostis trichophora – Verbena bonariensis* Grassy Community

9. *Eragrostis lehmanniana – Verbena bonariensis* Grassy Community

10. *Cyperus longus – Equisetum ramosissimum* Macrophyte Community

11. *Cynodon dactylon – Berkheya pinnatifida* Pan Community

- 11.1 *Cynodon dactylon – Felicia muricata* Pan Sub-Community
- 11.2 *Cynodon dactylon – Chloris virgata* Pan Sub-Community

12. *Leptochloa fusca* **–** *Ammocharis coranica* Pan Community

- 12.1 *Verbena brasiliensis – Persicaria lapathifolia* Forb Sub-Community
    - 12.1.1 *Pseudognaphalium luteo-album* Variant
    - 12.1.2 *Brachiaria eruciformis* Variant
    - 12.1.3 *Berkheya pinnatifida* Variant
- 12.2 *Echinochloa holubii – Ammocharis coranica* Grassy Sub-Community
    - 12.2.1 *Chloris virgata* Variant
    - 12.2.2 *Conyza bonariensis* Variant
    - 12.2.3 *Selago saxatilis* Variant

13. *Eichhornia crassipes* Macrophyte Community

14. *Azolla filiculoides* Macrophyte Community

6.2 DESCRIPTION OF PLANT COMMUNITIES

1. *Selaginella dregei - Tulbaghia acutiloba* Seepage Community

Habitat

Geology: Clarens Formation sandstone.

Soils: Sandy soils on bedrock.

Soil depth: Very shallow. Depth varies between 20mm – 100mm.

Hydrology: Water-logged to moist soils. Water seeps slowly through the sand.

Exposure: Full sun.

Disturbance: Relatively undisturbed

Species

Average number of species per relevè: 15

Number of diagnostic species: 13

Diagnostic species:

Grasses: *Cymbopogon dieterleniae, Digitaria ternata, Eragrostis gummiflua, Eragrostis micrantha, Hyparrhenia hirta, Panicum stapfianum,* (species group A)

Fern: *Selaginella dregei* (species group A)

Sedges: *Cyperus capensis, Cyperus rupestris*, *Kyllinga* sp., *Scirpus* sp., (species group A)

Succulent: *Crassula dependens* (species group A)

Forb: *Lobelia flaccida* (species group A)

Discussion: This community (Figure 6.1) is a typical seepage community situated on sandstone outcrops. It is characterized by about six hydrophilous grasses, four sedges, one poikolohydric fern, a higrophillous forb and a succulent. The two generalists that also occur in this community are *Oxalis depressa* and *Tulbaghia acutiloba* (species group C).

Figure 6.1: *Selaginella dregei - Tulbaghia acutiloba* Seepage Community

2. *Morella serrata – Scolopia mundii* Riparian Tree Community

Habitat

Geology: Clarens Formation sandstone.

Features: Sheltered ravines and valleys, stream with rocks and boulders.

Soils: Sandy sediments.

Soil depth: Relatively deep.

Hydrology: Moist soils.

Exposure: Full sun to semi shade.

Disturbance: Relatively undisturbed, except during strong floods.

Species

Average number of species per relevè: 31

Number of diagnostic species: 25

Diagnostic species:

Grasses: *Eragrostis plana* (species group R), *Leersia hexandra* (species group B), *Phragmites australis* (species group D), *Sporobolus africanus* (species group B).

Shrubs: *Clutia pulchella, Diospyros whyteana, Euclea crispa* subsp. *crispa, Grewia occidentalis, Gymnosporia buxifolia, Halleria lucida, Heteromorpha arborescens, Leucosidea sericea, Maytenus* *acuminata, Morella serrata, Myrsine africana, Searsia dentata,* (species group B).

Trees: *Maytenus undata, Olea europaea* subsp. *africana, Ilex mitis, Scolopia mundii,* (species group B).

Aquatic forbs: *Berula erecta* (species group B).

Fern: *Adiantum capillus-veneris, Asplenium aethiopicum, Asplenium cordatum, Cheilanthes hirta,* (species group B).

Forb: *Conyza bonariensis* (species group AK), *Helichrysum aureonitens* (species group B), *Senecio glutinosus* (species group X).

Sedges: *Schoenoxiphium rufum* (species group B).

Discussion: This is a typical tree community (Figure 6.2) that is restricted to sheltered ravines and valleys. It is characterized by twelve shrubs and four trees which forms the dominant woody component. Species that occur underneath the dominant tree/shrub layer are an aquatic forb, four ferns, four grasses, one sedge and two forbs. The generalists that occur in this community are *Tulbaghia acutiloba*, *Oxalis depressa* which are geophytes (species group C). The reed *Phragmites australis* (species group D) and the grass *Eragrostis plana* (species group R) are also important species in this community.

Figure 6.2: *Morella serrata – Scolopia mundii* Riparian Tree Community

3. *Phragmites australis – Equisetum ramosissimum* Reed Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey sedimentary soils.

Soil depth: Varies from 0.30m to deeper than 1m.

Hydrology: Moist to waterlogged. Water is sometimes seeping through the soil.

Exposure: Full sun.

Disturbance: Relatively undisturbed, except after floods and fires.

Species

Average number of species per relevè: 4

Number of diagnostic species: 2

Diagnostic species:

The grass *Phragmites australis* (species group D) and the fern *Equisetum ramosissimum* (species group W).

Discussion: This community (Figure 6.3) is a typical wet bank riparian community which is characterised by three grasses, two ferns, three trees, six forbs, one sedge and an aquatic forb. *Phragmites australis* (species group D) usually forms monospecific stands however in this community the aquatic fern *Marsilea macrocarpa* (species group AC) and a number of other species occur between the *P. australis* shoots.

Figure 6.3: *Phragmites australis – Equisetum ramosissimum* Reed Community

3.1 *Phragmites australis – Cyperus longus* Reed Sub-Community

Habitat

Geology: Beaufort and Ecca Groups

Soils: Sandy to clayey sedimentary soils.

Soil depth: Varies from 0.30m to deeper than 1m.

Hydrology: Moist to saturated. Water is sometimes flowing slowly through these reed beds.

Exposure: Full sun.

Disturbance: Relatively undisturbed except during floods.

Species

Average number of species per relevè: 3

Number of diagnostic species: 3

Diagnostic species:

The grass *Phragmites australis* (species group D), the fern *Equisetum ramosissimum* (species group W) as well as the sedge *Cyperus longus* (species group X).

Discussion: The presence of *Cyperus longus* (species group X) distinguishes this sub-community form the other sub-community as this species is more dominant in this sub-community. The tree *Salix babylonica* (species group H) is also present in this sub-community and absent from the next sub-community. This sub-community mostly occur in areas were water is present at the surface or where water saturated situations dominate throughout the year. The exotic tree *Salix babylonica* (species group H) almost always occurs near the water.

3.2 *Phragmites australis* – *Verbena bonariensis* Reed Sub-Community

Habitat

Geology: Beaufort and Ecca

Soils: Sandy to clayey sedimentary soils.

Soil depth: Varies from 0.30m to deeper than 1m.

Hydrology: Moist soils.

Exposure: Full sun.

Disturbance: Relatively undisturbed except during floods.

Species

Average number of species per relevè: 5

Number of diagnostic species: 4

Diagnostic species:

The grass *Phragmites australis* (species group D), the forbs *Verbena bonariensis, Tagetes minuta* (species group V) as well as *Conyza bonariensis* (species group AK).

Discussion: This sub-community occurs on the riverbank where groundwater levels are relatively low during dry seasons. It is also much more likely to find this sub-community near the headwaters of the river. Here the river tributaries are not always flowing except after heavy rains. Therefore it can be said that this sub-community usually prefers relatively drier conditions than sub-community 3.1. Both *Verbena bonariensis* (species group V) and *Tagetes minuta* (species group V) are alien weeds. The presence of *Verbena bonariensis, Tagetes minuta* and *Conyza bonariensis* (species group AK) define this sub-community as these species are absent from 3.1.

4. *Salix mucronata* – *Xanthium strumarium* Riparian Tree Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy to silty soils, usually among boulders or on bedrock.

Soil depth: Deep sedimentary soils, boulders are present in the stream beds.

Hydrology: Moist to water-logged soils.

Exposure: Full sun.

Disturbance: Relatively disturbed due to constant base flow and frequent floods.

Species

Average number of species per relevè: 5

Number of diagnostic species: 2

Diagnostic species:

The tree *Salix mucronata* (species group E), and the forb *Xanthium strumarium* (species group W).

Discussion: This community is a typical wet bank community (Figure 6.4). The tree, *Salix mucronata* is always present and occurs close to the edge of the water. It is more dependent on water-logged conditions than the exotic *Salix babylonica* (species group H). *Salix mucronata* (species group E) is indigenous. The vegetation in this community is typically of a pioneer nature because of the frequent erosion or deposition of sediment during floods. The vegetation in this community is composed of seven grasses, two trees/shrubs, five forbs, one sedge, one suffrutex and one shrub.

Figure 6.4: *Salix mucronata* – *Xanthium strumarium* Riparian Tree Community

4.1 *Salix mucronata* – *Phragmites australis* Riparian Tree Sub-Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy to silty soils.

Soil depth: Deeper than 1m.

Hydrology: Constantly moist to water-logged.

Exposure: Full sun.

Disturbance: Relatively disturbed due to frequent floods.

Species

Average number of species per relevè: 4

Number of diagnostic species: 2

Diagnostic species:

The grass *Phragmites australis* (species group D) and the tree *Salix mucronata* (species group E).

Discussion: This sub-community is defined by the presence of the reed *Phragmites australis* (species group D), which is absent from all other sub-communities. This woody grass mostly occurs in deep, moist or water-saturated sediment. Furthermore this sub-community is composed of a tree/shrub layer and a grass/forb layer.

4.2 *Salix mucronata* – *Cyperus longus* Riparian Tree Sub-Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy to silty sedimentary soils.

Soil depth: Shallower than 1m.

Hydrology: Moist to water-logged.

Exposure: Full sun.

Disturbance: Relatively disturbed due to frequent floods.

Species

Average number of species per relevè: 3

Number of diagnostic species: 3

Diagnostic species:

The tree *Salix mucronata* (species group E), the forb *Xanthium strumarium* (species group W) and the sedge *Cyperus longus* (species group X).

Discussion: The distinguishing factor in this sub-community is the presence and dominance of the sedge *Cyperus longus* (species group X). The alien *Xanthium strumarium* (species group W) is also present to some extent in this community although the species is not that prominent. This sub-community is also characterised by the absence of the reed *Phragmites australis* (species group D) and the grasses *Hemarthria altissima* (species group F) which represents the dominant species that define sub-communities 4.1 and 4.3 respectively. This sub-community mostly occur in disturbed areas. The prominent forbs are mostly aliens and pioneer species. This sub-community also has a very low species number which indicates that only a few species can survive these extremely fluctuating environmental conditions.

4.3 *Salix mucronata* – *Hemarthria altissima* Riparian Tree Sub-Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy to silty soils.

Soil depth: Relatively deep.

Hydrology: Moist to seasonally water-logged.

Exposure: Full sun.

Disturbance: Relatively disturbed due to sediment deposition during floods.

Species

Average number of species per relevè: 7

Number of diagnostic species: 3

Diagnostic species:

The grass *Hemarthria altissima* (species group F), the tree *Salix mucronata* (species group E) and the sedge *Cyperus longus* (species group X).

Discussion: The occurrence of the grass *Hemarthria altissima* (species group F) distinguishes this sub-community (Figure 6.5). This grass is characteristic in this sub-community as it is absent from the other sub-communities. Although *Diospyros lycioides* (species group O) are not dominating this sub-community it also only occurs in this sub-community. The vegetation of this sub-community is also trampled by the livestock and game that are kept in the camps along the river.

Figure 6.5: *Salix mucronata – Hemarthria altissima* Riparian Tree Sub-Community

5. *Hemarthria altissima – Equisetum ramosissimum* Grassy Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy soils.

Soil depth: Deep sedimentary soils.

Hydrology: The habitat is relatively dry during the winter months. During summers it becomes temporary flooded.

Exposure: Full sun.

Disturbance: Relatively disturbed due to erosion or sediment deposition during floods.

Species

Average number of species per relevè: 7

Number of diagnostic species: 3

Diagnostic species:

The grass *Hemarthria altissima* (species group F), the fern *Equisetum ramosissimum* (species group W) and the sedge *Cyperus longus* (species group X).

Discussion: This is a typical dry bank, non-woody community that occur on the banks of the Vet River (Figure 6.6). The community is mostly dominated by the grass *Hemarthria altissima* (species group F) which occur throughout the community. The primitive fern *Equisetum ramosissimum* (species group W) also occurs in this community, but it is not restricted to this community. This community consists of eight grasses, one suffrutex, nine forbs, two shrubs, one geophyte, one tree/shrub, one fern and one sedge. The woody species that occur in this community are *Acacia karroo* (species group R) seedlings and a few individuals of *Populus* x *canescence* (species group K) and *Sesbania punicia* (species group U).

Figure 6.6: *Hemarthria altissima – Equisetum ramosissimum* Grassy Community

5.1 *Hemarthria altissima – Verbena bonariensis* Grassy Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Sandy soils.

Soil depth: Deep sedimentary soils.

Hydrology: Constantly moist to seasonally wet.

Exposure: Full sun.

Disturbance: Relatively disturbed due to sedimentation during floods.

Species

Average number of species per relevè: 9

Number of diagnostic species: 4

Diagnostic species:

The grass *Hemarthria altissima* (species group F) and the following forbs: *Verbena bonariensis, Tagetes minuta* (species group V), and *Conyza bonariensis* (species group AK).

Discussion: This sub-community is characterised by the occurrence of *Verbena bonariensis* (species group V) and *Tagetes minuta* (species group V) as well as *Conyza bonariensis* (species group AK) which are absent from the other sub-community. In this sub-community shrubs and trees are present although these are either small or young plants. The possible reason is that this community occurs in areas where the river is strongly perennial with a stable riparian aquifer which supplies these trees and shrubs of enough moisture.

5.2 *Hemarthria altissima – Paspalum dilatatum* Grassy Sub-Community

Habitat

Geology: Beaufort and Ecca Groups

Soils: Sandy soils.

Soil depth: Deep sedimentary soils

Hydrology: Relatively dry.

Exposure: Full sun.

Disturbance: Relatively disturbed due to sedimentation during floods.

Species

Average number of species per relevè: 5

Number of diagnostic species: 3

Diagnostic species:

The grasses *Hemarthria altissima* (species group F), *Setaria pumila,* and *Paspalum dilatatum* (species group U).

Discussion: This sub-community is distinguished from the other because of the presence of the grass *Paspalum dilatatum* (species group U). There are no trees or shrubs present in this sub-community and therefore it can be said that this vegetation unit is a grass-forb sub-community. This sub-community occurs in areas where water-saturated conditions occasionally occur.

6. *Salix babylonica* – *Oenothera rosea* Riparian Tree Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Mostly dry but moist to wet during summer.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 10

Number of diagnostic species: 2

Diagnostic species:

The forb *Oenothera rosea* (species group H), and the tree *Salix babylonica* (species group H).

Discussion: This is a typical dry bank community (Figure 6.7). *Salix babylonica* (species group H) dominate the tree layer. These trees provide shade and shelter for the other members of the community during the day. This community is composed of eight grasses, thirteen forbs, one tree, two shrubs, one geophytes, one climber, one fern and one sedge.

Figure 6.7: *Salix babylonica* – *Oenothera rosea* Riparian Tree Community.

6.1 *Hemarthria altissima* – *Oenothera rosea* Grassy Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Sedimentary soils with a sandy texture.

Soil depth: Deep sedimentary soils of alluvial origin.

Hydrology: Moist to dry.

Exposure: Trees in full sun. Ground layer species in semi-shade.

Disturbance: Relatively undisturbed

Species

Average number of species per relevè: 9

Number of diagnostic species: 2

Diagnostic species:

The grass *Hemarthria altissima* (species group F) and the forb *Oenothera rosea* (species group H).

Discussion: This dry bank sub-community is characterised by the presence of the grass *Hemarthria altissima* (species group F). The absence of the fern *Equisetum ramosissimum* (species group W) and the sedge *Cyperus longus* (species group X) from this sub-community. *Salix babylonica* (species group H) is the only woody species that occur in this sub-community the rest of the vegetation is composed of grasses and forbs. Therefore the percentage groundcover of this sub-community is high, although bare patches occur due to grazing and trampling by livestock.

6.2 *Bromus catharticus* – *Plantago lanceolata* Grassy Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca Groups

<u>Soils:</u> Alluvial deposits

<u>Soil depth:</u> Deep sandy soils

<u>Hydrology:</u> Moist to dry

<u>Exposure:</u> Semi-shade under the protection of nearby trees.

<u>Disturbance:</u> Relatively disturbed

Species

<u>Average number of species per relevè:</u> 10

<u>Number of diagnostic species:</u> 3

<u>Diagnostic species:</u>

The grass *Bromus catharticus* (species group G), the forb *Plantago lanceolata* (species group G) and the fern *Equisetum ramosissimum* (species group W).

Discussion: This dry bank sub-community is dominated by the presence of the two diagnostic species *Bromus catharticus* (species group G), *Plantago lanceolata* (species group G) and the fern *Equisetum ramosissimum* (species group W) which also distinguishes this sub-community form the others. This sub-community contains more woody species than vegetation unit 6.2, although there are also grasses and forbs present. The percentage ground cover of this vegetation is not that high as there are a lot of bare patches present. The trampling by livestock is the main cause for this disturbance.

7. *Acacia karroo – Asparagus africanus* Shrub Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Deep clayey soils.

Soil depth: Deep sedimentary soils. These clay soils form cracks during the dry seasons.

Hydrology: Water table is relatively low.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 11

Number of diagnostic species: 4

Diagnostic species:

A tree *Acacia karroo* (species group R), a climber *Asparagus africanus* (species group R) and two forbs namely *Tagetes minuta* and *Verbena bonariensis* (species group V),

Discussion: This community (Figure 6.8) occur on the edge of the riparian fringe where severe erosion might sometimes occur. *Acacia karroo* (species group R), which dominates this community, has wide ecological amplitude and occurs in almost any soil type, however fertile and clayey soils are preferred (Coates Palgrave 2005; Dingaan 2008; Smit 2008). This community is mostly dominated by trees and shrubs (*Searsia pyroides* (species group N), *Acacia karroo* (species group R), *Diospyros lycioides* (species group O), *Ziziphus mucronata* (species group Q), *Cestrum laevigatum* (species group

L), *Lycium cinereum* (species group M), *Lycium hirsutum* (species group N) and *Asparagus africanus* (species group R)). This community occurs mainly on dry clayey soils on the upper banks of the river. The vegetation is composed of twenty two grasses, seventeen forbs, three trees, one suffrutex, eight shrubs, two climbers, one geophyte, three trees/shrubs, one fern, one sedge and one dwarf shrub.

Figure 6.8: *Acacia karroo – Asparagus africanus* Shrub Community

7.1 *Themeda triandra – Crotalaria distans* Grassy Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca

<u>Soils:</u> Dry clay soils.

<u>Soil depth:</u> Deep sedimentary soils.

<u>Hydrology:</u> Seasonal dry to wet.

<u>Exposure:</u> Shaded by the tree/shrub layer.

<u>Disturbance:</u> Relatively disturbed – trampling by livestock.

Species

<u>Average number of species per relevè:</u> 14

Number of diagnostic species: 1

Diagnostic species:

Aristida congesta (species group T).

Discussion: This dry bank community is mostly composed of plants other than trees and shrubs and mostly occur in open patches between the dominant tree layer. The strong presence of the pioneer grass *Aristida congesta* (species group T) distinguishes this sub-community from the other sub-communities. The presence of *Aristida congesta* (species group T) is an indication of overgrazing as this grass colonizes bare patches (Van Oudtshoorn 2004).

7.1.1 *Imperata cylindrica* Variant

Habitat

Geology: Beaufort and Ecca Groups

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonally dry or wet.

Exposure: Partly shaded by the trees/shrubs.

Disturbance: Trampled by cattle and game.

Species

Average number of species per relevè: 13

Number of diagnostic species: 1

Diagnostic species:

Imperata cylindrica (species group I).

Discussion: The strong presence of the grass *Imperata cylindrica* (species group I) distinguish this variant from all the others as this grass only occur in this variant where it has a high dominance. Van Oudtshoorn (2004) stated that *Imperata cylindrica* (species group I) mostly occur in poorly drained soils like clay deposits along rivers. Furthermore

I. cylindrica plays an important role in stabilization and prevention of erosion as it may form very dense stands.

7.1.2 *Andropogon appendiculatus* Variant

Habitat

<u>Geology:</u> Beaufort and Ecca Groups.

<u>Soils:</u> Clayey soils.

<u>Soil depth:</u> Deep sedimentary soils.

<u>Hydrology:</u> Seasonally moist to wet soils.

<u>Exposure:</u> Full sun or shaded by trees and shrubs.

<u>Disturbance:</u> Trampled by cattle and game.

Species

<u>Average number of species per relevè:</u> 14

<u>Number of diagnostic species:</u> 1

<u>Diagnostic species:</u>

Andropogon appendiculatus (species group J)

Discussion: This variant (Figure 6.9) is characterised by the strong presence of *Andropogon appendiculatus* (species group J) and to a lesser extent *Searsia lancea* (species group J) which only occur in this variant. *Andropogon appendiculatus* (species group J) prefers seepage areas while *Searsia lancea* (species group J) is a typical streambank species that occurs higher up away from the channel. Like *Imperata cylindrica* and *Andropogon appendiculatus* usually forms dense stands in seepage areas or areas where water is retained for some time.

Figure 6.9: *Andropogon appendiculatus* Variant

7.2 *Cestrum laevigatum – Acacia karroo* Shrub Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonal dry to wet.

Exposure: Full sun.

Disturbance: Relatively disturbed.

Species

Average number of species per relevè: 11

Number of diagnostic species: 1

Diagnostic species:

Cestrum laevigatum (species group L)

Discussion: The exotic *Cestrum laevigatum* (species group L) only occurs in this sub-community. This is an alien invader and according to the farmers (Els, *pers comm.* 2008)[2] along the Vet River they are losing

[2] Mr Fanie Els, Driekop, Exelcior

grazing because of the presence of this species. *Cestrum laevigatum* contains a strong neuro toxin which kills cattle and game (Van Wyk *et al.* 2002). This plant has the ability to form dense stands on the river banks and encroaches onto the indigenous vegetation. It is spread by frugivorous birds, which perch on the branches of the larger trees from where they release their seed-containing faeces.

7.3 *Searsia pyroides – Acacia karroo* Shrub Sub-Community

Habitat

Geology: Beaufort and Ecca Groups

Soils: Sandy to loamy soils.

Soil depth: Deep sedimentary soils.

Hydrology: Moist to dry soils.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 11

Number of diagnostic species: 4

Diagnostic species:

The shrubs *Searsia pyroides* subsp. *pyroides* and *Lycium hirsutum,* the climber *Riocreuxia torulosa* and the forb *Achyranthes aspera* (species group N).

Discussion: This sub-community is dominated by two shrubs, a climber and a forb. Although some of the species that occur in this sub-community also occur in others. The dominant vegetation layer is the shrub layer which is dominated by the above-mentioned two shrubs. They usually form dense stands.

7.3.1 *Artemisea afra* Variant

Habitat

Geology: Beaufort and Ecca Groups

Soils: Sandy soils

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to moist.

Exposure: Shaded by the tree/shrub layer.

Disturbance: Relatively disturbed

Species

Average number of species per relevè: 15

Number of diagnostic species: 3

Diagnostic species:

The shrubs *Artemisia afra* and *Lycium cinereum* as well as the forb *Cineraria aspera* (species group M).

Discussion: The high vegetation cover of this variant is due to the dominance of the diagnostic species. The three diagnostic species are either absent or occur in lower cover values in all the other vegetation units that occur on Table 6.1. Scattered individuals of *Acacia karroo* (species group R) is also present in this variant.

7.3.2 *Diospyros lycioides* Variant

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Sandy soils.

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Relatively undisturbed

Species

Average number of species per relevè: 6

Number of diagnostic species: 1

Diagnostic species:

Diospyros lycioides (species group O).

Discussion: Although the shrubs *Searsia pyroides* subsp. *pyroides* (species group N) and *Lycium hirsutum* (species group N) dominate this variant, it is the presence of *Diospyros lycioides* (species group O) that distinguishes this variant from variant 7.3.1. Furthermore *Artemesia afra, Lycium cinerium*, *Cineraria aspera* (species group M) and *Acacia karroo* (species group R) are absent from this variant. This variant only consists of the following species: *Searsia pyroides* subsp. *pyroides* (species group N), *Lycium hirsutum* (species group N), *Riocreuxia torulosa* (species group N), *Achyranthes aspera* (species group N), *Asparagus africanus* (species group R) and the diagnostic species *Diospyros lycioides* (species group O).

7.4 *Diospyros lycioides – Acacia karroo* Shrub Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Sandy soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 8

Number of diagnostic species: 3

Diagnostic species:

Diospyros lycioides (species group O), *Acacia karroo* and *Asparagus africanus* (species group R).

Discussion: This sub-community is mostly a dominated by trees and shrubs. The presence of *Diospyros lycioides* (species group O) distinguishes this sub-community from the others. The plants are growing close together and form densely entangled masses.

7.5 *Medicago polymorpha – Acacia karroo* Shrub Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Sandy soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonal dry to wet.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 12

Number of diagnostic species: 5

Diagnostic species:

Medicago polymorpha, Chenopodium schraderianum, Gomphocarpus fruticosus, Indigofera filipes and *Oxalis corniculata* (species group P).

Discussion: This sub-community is distinguished from the other sub-communities due to the presence of the diagnostic species. The diagnostic species occur with a high dominance in this sub-community and are absent in the other sub-communities or occur in lower values.

7.6 *Eragrostis plana – Acacia karroo* Shrub Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca Groups

<u>Soils:</u> Sandy soils

<u>Soil depth:</u> Deep sedimentary soils

<u>Hydrology:</u> Seasonally dry to wet.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Relatively disturbed. In most cases it is due to trampling by cattle and game.

Species

<u>Average number of species per relevè:</u> 9

<u>Number of diagnostic species:</u> 2

<u>Diagnostic species:</u>

Eragrostis plana and *Acacia karroo* (species group R).

Discussion: This sub-community is dominated by trees *Acacia karroo* (species group R) and the grass *Eragrostis plana* (species group R). Together with this two forb species are also prominent in this sub-community due to high cover-abundance values. These forbs are *Tagetes minuta* (species group V) and *Verbena bonariensis* (species group V). It can therefore be said that this sub-community is composed of two layers, namely a tree layer and a grass/forb layer.

7.7 *Ziziphus mucronata – Asparagus africanus* Shrub Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca Groups.

<u>Soils:</u> Alluvial soils.

<u>Soil depth:</u> Deep sedimentary soils

<u>Hydrology:</u> Water table relatively low.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Relatively undisturbed

Species

Average number of species per relevè: 11

Number of diagnostic species: 2

Diagnostic species:

Ziziphus mucronata (species group Q) and *Asparagus africanus* (species group R).

Discussion: The presence of the tree *Ziziphus mucronata* (species group Q) in this sub-community is distinguishing this sub-community from the others. This tree is very dominant in this sub-community and does not have similar high cover-abundance values in any other community. *Asparagus africanus* (species group R) is also dominant in this sub-community, but to a lesser extent.

7.7.1 *Lycium hirsutum* Variant

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Alluvial soils.

Soil depth: Deep alluvial deposits.

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 9

Number of diagnostic species: 1

Diagnostic species:

Lycium hirsutum (species group N)

Discussion: The presence of the shrub *Lycium hirsutum* (species group N) in this variant distinguishes this variant from the others. The total absence of the grass *Eragrostis plana* (species group R) is also visible in this variant.

7.7.2 *Bromus catharticus* Variant

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Alluvial soils.

Soil depth: Deep alluvial deposits

Hydrology: Seasonal dry to wet.

Exposure: Full sun.

Disturbance: Relatively undisturbed.

Species

Average number of species per relevè: 12

Number of diagnostic species: 1

Diagnostic species:

Bromus catharticus (species group G)

Discussion: This variant is distinguished from the previous variant because of the occurrence of the grass *Bromus catharticus* (species group G) and the shrub *Diospyros lycioides* (species group O).

8. *Eragrostis trichophora – Verbena bonariensis* Grassy Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Alluvial soils.

Soil depth: Deep sedimentary soils

Hydrology: Seasonally moist. Seeping of water may occur.

Exposure: Full sun.

Disturbance: None to relatively disturbed.

Species

Average number of species per relevè: 7

Number of diagnostic species: 1

Diagnostic species:

The grass *Eragrostis trichophora* (species group S).

Discussion: This is a typical dry bank community (Figure 6.10). The vegetation of this community is mostly composed of nine forbs, four grasses, one suffrutex, one fern, one climber, two tree/shrubs and two shrubs. The shrubs and trees that occur in this community are mostly saplings although this community is dominated by grasses and forbs. The grass *Setaria pumila* (species group U) usually occurs on bare patches and helps to prevent soil erosion (Van Oudtshoorn 2004).

Figure 6.10: *Eragrostis trichophora – Verbena bonariensis* Grassy Community

9. *Eragrostis lehmanniana – Verbena bonariensis* Grassy Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Alluvial soils.

Soil depth: Deep sedimentary soils.

Hydrology: Dry, but seasonally moist.

Exposure: Full sun.

Disturbance: None.

Species

Average number of species per relevè: 8

Number of diagnostic species: 3

Diagnostic species:

Aristida congesta, Digitaria eriantha and *Eragrostis lehmanniana* (species group T).

Discussion: The diagnostic species namely *Eragrostis lehmanniana, Aristida congesta* and *Digitaria eriantha* (species group T) (Figure 6.11) distinguishes this community from the other communities and sub-communities. From the phytosociological table (Table 6.1) it is clear that *Digitaria eriantha* (species group T) and *Eragrostis lehmanniana* (species group T) does not co-occur with *Eragrostis trichophora* (species group S). This community is also a grass-forb dominated community as the trees and shrubs that occur here, are young plants. The vegetation is composed of seven grasses, three forbs, one climber, one tree and two shrub species.

Figure 6.11: *Eragrostis lehmanniana – Verbena bonariensis* Grassy Community

10. *Cyperus longus – Equisetum ramosissimum* Macrophyte Community

Habitat

Geology: Beaufort and Ecca Group.

Soils: Sandy to clayey soils.

Soil depth: 0.3 – 0.5m

Hydrology: Water-logged.

Exposure: Full sun.

Disturbance: Relatively disturbed due to sediment deposition or erosion during floods.

Species

Average number of species per relevè: 4

Number of diagnostic species: 2

Diagnostic species:

The sedge *Cyperus longus* (species group X) and the fern *Equisetum ramosissimum* (species group W).

Discussion: This is a typical macrophyte community (Figure 6.12). The presence of *Cyperus longus* (species group X) in this community is an indication of the fact that this community occur in water-saturated areas along the river. The community is composed of the following plants: eight forbs, two ferns, six grasses, one sedge, one tree and one aquatic forb.

Figure 6.12: *Cyperus longus – Equisetum ramosissimum* Macrophyte Community

11. *Cynodon dactylon – Berkheya pinnatifida* Pan Community

Habitat

Geology: Beaufort and Ecca Groups

Soils: Dry clayey soils

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet

Exposure: Full sun.

Disturbance: Grazed by game and cattle.

Species

Average number of species per relevè: 7

Number of diagnostic species: 3

Diagnostic species:

The grass *Cynodon dactylon* (species group AA) the forb *Berkheya pinnatifida* (species group AA) and the suffrutex *Selago saxatilis* (species group AA).

Discussion: This is a typical floodplain community (Figure 6.13) that occurs along the Vet River. The grass *Cynodon dactylon* (species group AA) occurs in moist, fertile clayey to sandy soils (Van Oudtshoorn 2004). This community is composed of ten forbs, four grasses, one suffrutex, one dwarf shrub, one shrub, one climber and one tree/shrub.

Figure 6.13: *Cynodon dactylon – Berkheya pinnatifida* Pan Community

Although this community is being severely grazed and trampled by livestock and game, two layers can be distinguished in this community. One layer is dominated by trees (*Acacia karroo*) and the other layer by grasses and forbs.

11.1 *Cynodon dactylon – Felicia muricata* Pan Sub-Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonally dry to wet. The pan floor can be seasonally inundated.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Grazed by game and cattle.

Species

<u>Average number of species per relevè:</u> 8

<u>Number of diagnostic species:</u> 2

<u>Diagnostic species:</u>

The dwarf shrub *Felicia muricata* (species group Y) and the forb *Lepidium bonariensis* (species group Y).

Discussion: This pan sub-community is distinguished from the others due to the presence of the two diagnostic species and the strong presence of the tree *Acacia karroo* (species group R) which are absent or barely occurring in the other sub-communities. In this sub-community the *Acacias* are usually large individuals.

11.2 *Cynodon dactylon* – *Chloris virgata* Grassy Pan Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca

<u>Soils:</u> Clayey soils.

<u>Soil depth:</u> Deep sedimentary soils

<u>Hydrology:</u> Seasonal dry to wet.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Grazed by game and cattle.

Species

<u>Average number of species per relevè:</u> 5

<u>Number of diagnostic species:</u> 1

<u>Diagnostic species:</u>

The grass *Chloris virgata* (species group Z)

Discussion: The species that distinguishes this sub-community from the other is the grass *Chloris virgata* (species group Z), because of its dominance. This grass usually occurs in disturbed places and is a valuable pioneer on bare soil to re-colonize areas (Van Oudtshoorn 2004). The species that are diagnostic in sub-community 11.1 is totally absent in this sub-community.

12. *Leptochloa fusca – Ammocharis coranica* Pan Community

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonal dry to wet. Water-logged conditions can prevail for long periods during summer months. After high summer rainfall, inundation can occur deep into the dry season as well.

Exposure: Full sun.

Disturbance: Grazing livestock.

Species

Average number of species per relevè: 7

Number of diagnostic species: 2

Diagnostic species:

The grass *Leptochloa* [*Diplachne*] *fusca* (species group AJ) and the geophyte *Ammocharis coranica* (species group AJ).

Discussion: This is a typical pan community (Figure 6.14). The grass *Leptochloa fusca* (species group AJ) dominates because it occupies a unique niche in seasonally inundated pans and other water sources (Van Oudtshoorn 2004). Trees are completely absent from this community. The vegetation in this community is composed of sixteen forbs, two geophytes, six grasses, one fern, one suffrutex and one tree/shrub.

Figure 6.14: *Leptochloa fusca – Ammocharis coranica* Pan Community

12.1 *Verbena brasiliensis – Persicaria lapathifolia* Forb Sub-Community

Habitat

Geology: Beaufort and Ecca Groups

Soils: Clayey soils

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 7

Number of diagnostic species: 2

Diagnostic species:

Two forbs *Persicaria lapathifolia* (species group AE) and *Verbena brasiliensis* (species group AE).

Discussion: Both diagnostic species that occur in this sub-community are alien invasive species. From the phytosociological table (Table 6.2) it is clear that *Verbena brasiliensis* (species group AE) only occurs in the depressions along the Vet River.

12.1.1 *Pseudognaphalium luteo-album* Variant

Habitat

Geology: Beaufort and Ecca Groups

Soils: Clayey soils.

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet. Water tends to stand for long periods after rains.

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 9

Number of diagnostic species: 8

Diagnostic species:

The forbs *Amaranthus hybridus, Cotula hispida, Marsilea macrocarpa, Physalis angulata, Pseudognaphalium luteo-album, Senecio burchellii, Xanthium spinosa* (species group AC) and the geophyte *Ammocharis coranica* (species group AJ).

Discussion: The diagnostic species together with the species from species group AB and AD are more common in this variant of the sub-community and the community than in the others.

12.1.2 *Echinochloa holubii* Variant

Habitat

Geology: Beaufort and Ecca Groups

Soils: Clayey soils.

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 6

Number of diagnostic species: 1

Diagnostic species:

The grass *Echinochloa holubii* (species group AI).

Discussion: In this variant *Conyza bonariensis* (species group AK) and *Tagetes minuta* (species group V) also play an important role in terms of the dominance. However *Alternanthera nodiflora* (species group AG) occur in all the other variants, but is absent from this one.

12.1.3 *Berkheya pinnatifida* Variant

Habitat

Geology: Beaufort and Ecca

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 7

Number of diagnostic species: 1

Diagnostic species:

The forb *Berkheya pinnatifida* (species group AA).

Discussion: This pan variant is dominated by the forb which is also the diagnostic species. In this variant *Conyza bonariensis* (species group AK) show an absolute absence but do occur within the other variants.

12.2 *Echinochloa holubii – Ammocharis coranica* Grassy Sub-Community

Habitat

<u>Geology:</u> Beaufort and Ecca Groups

<u>Soils:</u> Clayey soils.

<u>Soil depth:</u> Deep sedimentary soils.

<u>Hydrology:</u> Seasonally dry to wet.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Grazed by livestock and game.

Species

<u>Average number of species per relevè:</u> 7

<u>Number of diagnostic species:</u> 2

<u>Diagnostic species:</u>

The grass *Echinochloa holubii* (species group AI) and the geophytes *Ammocharis coranica* (species group AJ).

Discussion: This is a pan sub-community which is defined by the presence of the grass *Echinochloa holubii* (species group AI) and the geophytes *Ammocharis coranica* (species group AJ). This grass usually occurs in wet areas such as vleis and pans which are at least water saturated during the rainy season (Van Oudtshoorn 2004).

12.2.1 *Chloris virgata* Variant

Habitat

<u>Geology:</u> Beaufort and Ecca Groups.

<u>Soils:</u> Clayey soils.

<u>Soil depth:</u> Deep sedimentary soils.

<u>Hydrology:</u> Seasonally dry to wet.

<u>Exposure:</u> Full sun.

<u>Disturbance:</u> Grazing by livestock and game.

Species

Average number of species per relevè: 9

Number of diagnostic species: 2

Diagnostic species:

The grasses *Chloris virgata* (species group Z) and *Eragrostis plana* (species group R).

Discussion: This variant is defined by the presence of the diagnostic species as this is the only variant in which these species are present within this sub-community.

12.2.2 *Conyza bonariensis* Variant

Habitat

Geology: Beaufort and Ecca Groups

Soils: Clayey soils.

Soil depth: Deep sedimentary soils

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 5

Number of diagnostic species: 1

Diagnostic species:

The forb *Conyza bonariensis* (species group AK).

Discussion: Although *Conyza bonariensis* (species group AK) occur in variant 12.2.3 the presence in this variant are more dominant because of higher cover-abundance values. It is then also *Conyza bonariensis* (species group AK) that distinguish this variant from the others.

12.2.3 *Selago saxatilis* Variant

Habitat

Geology: Beaufort and Ecca Groups.

Soils: Clayey soils.

Soil depth: Deep sedimentary soils.

Hydrology: Seasonally dry to wet.

Exposure: Full sun.

Disturbance: Grazing by livestock and game.

Species

Average number of species per relevè: 6

Number of diagnostic species: 1

Diagnostic species:

The suffrutex *Selago saxatilis* (species group AA).

Discussion: The presence of the suffrutex *Selago saxatilis* (species group AA) in this variant defines this variant, however there are also a forb namely *Verbena brasiliensis* (species group AE) and another suffrutex namely *Selago densiflora* (species group K) that are unique to this variant.

13. *Eichhornia crassipes* Macrophyte Community

Habitat

Geology: Not applicable.

Soils: Not applicable because this is a floating hydrophyte.

Soil depth: Not applicable.

Hydrology: Slow flowing streams and pools in the river.

Exposure: Full sun.

Disturbance: Prefers eutrophicated water.

Species

Average number of species per relevè: 1

Number of diagnostic species: 1

Diagnostic species:

Eichhornia crassipes (species group AL).

Discussion: This is a typical floating macrophyte community (Figure 6.15) that occurs in deep standing or slow flowing water. This community is dominated by an alien invasive species. The plant has been introduced from South America and can be seen as one of the world`s most noxious waterweeds (Bromilow 2001). This community is free-floating because of the deep water, however the plants have the ability to anchor themselves to the bottom if the water is shallow enough. In this study, this community only occurs in the Vet River near the Bloemhof Dam, downstream of Hoopstad.

Figure 6.15: *Eichhornia crassipes* Macrophyte Community

14. *Azolla filiculoides* Macrophyte Community

Habitat

Geology: Not applicable

Soils: Not applicable.

Soil depth: Not applicable

Hydrology: Occurs as a free floating plant in pools.

Exposure: Full sun.

Disturbance: Not applicable.

Species

Average number of species per relevè: 1

Number of diagnostic species: 1

Diagnostic species:

Azolla filiculoides (species group AM)

Discussion: This is also a free-floating macrophyte community and occurs in several areas in the Vet River where water is either slow flowing or stagnant. These plants have the ability to clog waterways and provide sheltered areas for mosquitoes and bilharzia – hosting snails. This water fern prevents the normal use of water by humans, birds and animals. This species was introduced from South America as an aquarium plant (Bromilow 2001).

6.3 ORDINATION

Ordination is a method to investigate the relations between plants and their environment (Ter Braak & Smilauer 2002). Different environmental factors were used during the ordination of the vegetation along the Vet River. These environmental factors include the degree of saturation, channel depth and terrain units.

The Monte Carlo permutation test was performed to see if there is a statistical significance for the relationship between the species and the environmental variables collected in the field. The Monte Carlo permutation test is a test of statistical significance obtained by repeatedly shuffling the samples (Ter Braak & Smilauer 2002). The test was performed and the results are represented in Table 6.2. From this table it is clear that the P-value for the test performed is <0.05 for the first and all canonical axes, and therefore the environmental variables that were measured are statistically significant at explaining the species variation.

Table 6.2: Table of the results of the Monte Carlo permutation test performed in CANOCO (Ter Braak & Smilauer 2002).

Test of significance of first canonical axis: eigenvalue = 0.739
F-ratio = 6.514
P-value = 0.0020
Test of significance of all canonical axes: Trace = 2.440
F-ratio = 3.384
P-value = 0.0020

The eigenvalues in Tables 6.3 and 6.4 represent the relative contribution of each axis and explain the total variation in the species data. The magnitude of the eigenvalue is a direct indication of the importance of the component at explaining the measured species variation (Kent & Coker 1992). Also, to determine whether the most important environmental variables were measured, the results of the CCA were compared to the results of a CA. CA extracts the largest gradients in the species date without regard (constraint) to secondary ecological variables, while CCA (constrained ordination) extracts the largest gradient in the species data explainable by measured environmental variables. Therefore, when CA and CCA produce similar results, then we assume that the measured environmental variables explain most of the variation in the species data (Lepš & Šmilauer 2007).

Table 6.3: Table of the results for the CCA analysis done in CANOCO (Ter Braak & Smilauer 2002).

Axes	1	2	3	4	Total inertia
Eigenvalues:	0.733	0.486	0.314	0.265	16.269
Species-environment correlations:	0.95	0.891	0.858	0.82	
Cumulative percentage variance					
of species data:	4.5	7.5	9.4	11	
of species-environment relation:	33.6	55.9	70.3	82.4	
Sum of all eigenvalues					16.269
Sum of all canonical eigenvalues					2.18

Table 6.4: Table of the results for the CA analysis done in CANOCO (Ter Braak & Smilauer 2002).

Axes	1	2	3	4	Total inertia
Eigenvalues:	0.83	0.637	0.615	0.519	16.269
Cumulative percentage variance					
of species data:	5.1	9	12.8	16	
Sum of all eigenvalues					16.269

A review of Table 6.3 and 6.4 shows that the eigenvalues of the first axis of the CCA is comparable to that of the CA, while the eigenvalues of the second axis is notably less, and the eigenvalues of the third and fourth axes are significantly less. The same applies for the cumulative percentage variance of the species data. It is therefore concluded that although the most important variables, responsible for the species variation, were measured, other variables that also have an important influence were not. Interpretation of the first two canonical axes reveals the relation between the species and the most important measured environmental variables.

The most striking figure of Table 6.3 is the high amount of unexplained variation as suggested by the difference between the sum of all eigenvalues (16.269) and the sum of all canonical eigenvalues (2.18). Although CCA usually does not display an arch because it is constrained by environmental variables which do not have an arch like structure, the tendancy of CCA, being founded on CA, to form an arch is still there. Significant is that the arch by itself has an inertia or variance. In most cases this inertia is expressed as part of the unexplained inertia, which could result in the total variance explained being low. The amount of unexplained variation might also be the result of a low number of species per relevé and a strongly aggregated distribution of species within plots (Pyšek & Lepš, 1991).

When looking at environmental variables like vegetation type or soil type one looks at nominal data. Therefore the environmental variable tested is either present (indicated by 1) or absent (indicated by 0). This is also the case in this study. Ter Braak & Smilauer (2002) stated that when working with nominal data, correspondence analysis can be used to investigate the interrelations. Like in the study where there are more than two environmental variables, the analysis is called multiple correspondence analyses and the data can be analysed by canonical correspondence analysis (CCA).

CCA was used for ordination and interpretation of the data in the study. Furthermore, from Table 6.3 it is clear that the sum of all canonical eigenvalues is very low, implying that all canonical axes collectively explains 13,39% of the variance.

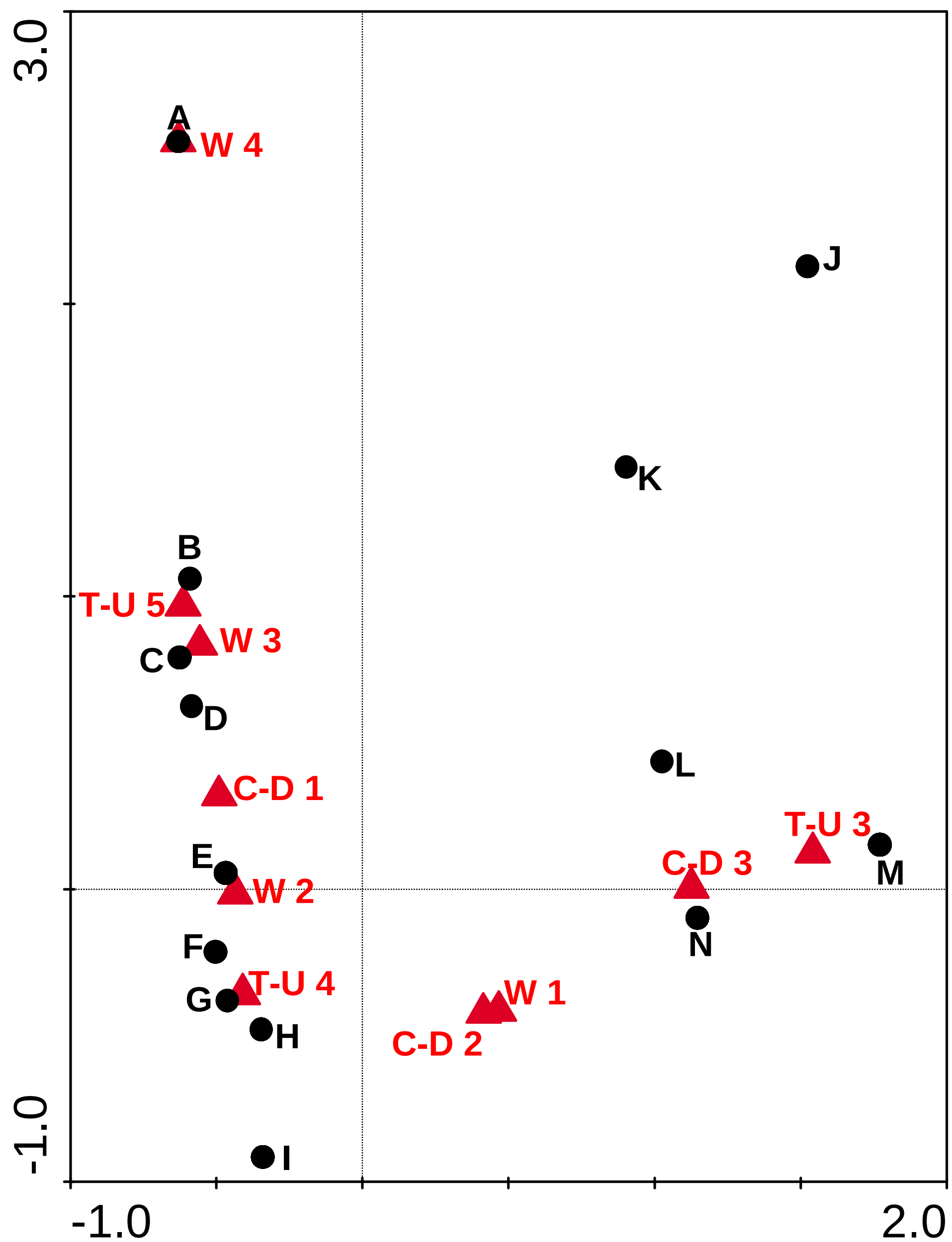


Figure 6.16: Graph of the different sample plots taken along the Vet River and how they are influenced by the different environmental factors. **Terrain Units:** T-U 3 – Plain**,** T-U4 – Bank and T-U 5 – Channel. **Water presence:** W 1 – Dry, W 2 – Moist, W 3 – Saturated and W 4 – Surface water. **Channel depth form water's surface:** C-D 1 – 1-2m, C-D 2 – 2-4m andC-D 3 – 4-6m

The following table represents the different ordination groups and the related relevès as found in the phytosociological table (Table 6.2). The table is inserted as the ordination groups are not restricted to the classification of communities, sub-communities and variants. This might be an indication of the wide ecological tolerance that occur in some species.

Table 6.5: Table of the different ordination groups and their related relevès.

ORDINATION GROUP	**RELEVèS (Table 6.1)**
A	76, 78. 80, 85, 116, 220, 223, 226, 41, 13, 38, 238, 239, 240
B	120, 124, 122
C	33, 113, 110, 108, 27, 25, 5, 15, 184, 196, 9, 202, 34, 55, 129, 132, 58, 83, 136, 8, 176, 180, 199, 16
D	221, 224, 227
E	6, 2, 50, 20, 19, 17, 77, 79, 114, 118, 133, 177, 185, 229, 231, 35, 53, 56, 65, 68, 106, 111, 117, 126, 130, 181, 203, 230, 232, 233
F	47, 45, 1
G	11, 22, 86, 137
H	72, 61, 39, 21, 109, 182, 81, 62, 46, 60, 178, 186
I	3, 4, 7, 14, 204, 179, 135, 138, 128, 131, 121, 125, 119, 123, 57, 115, 51, 54, 18, 29, 183, 187, 198, 201, 32
J	235, 236, 237, 234
K	170
L	174, 175
M	87, 88, 100, 101, 89, 102, 90, 188, 91, 92, 93, 94, 95, 191, 193, 194, 205, 96, 97, 98, 206, 207, 208, 99, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219
N	139, 140, 141, 151, 152, 157, 158, 159, 160, 161, 167, 166, 165, 164, 163, 168

According to Figure 6.16 group A is strongly associated with the presence of surface water. The relevès that occur in A (Table 6.5) are also found in the channel of the river which represents the terrain units, although the association is not that strong. The vegetation present in these relevès is usually found right alongside the river and includes species like *Phragmites australis, Paspalum dilatatum* and *Salix babylonica*. The latter is a hygrophilous tree. Except for these species that anchor themselves in the water there are also floating communities that occur in this association. These floating communities include the alien species *Azolla filiculoides* and *Eichhornia crassipes*.

Group B (Figure 6.16) is strongly associated with the terrain unit which represents the channel, but are also associated with saturated soils and occur not more than two meters away from the channels edge. Species that play an important role in these relevès (Table 6.5) include *Salix mucronata, Phragmites australis* and *Hemarthria altissima*. Both *Phragmites australis* and *Hemarthria altissima* are members of the Poaceae that occur in areas where water are present.

The relevès present in group C (Figure 6.16) are strongly associated with saturated conditions. These relevès (Table 6.5) were sampled on or near the channel and also occur not more than two meters away from the surface of the water. Species that occur in these relevès include *Cyperus longus, Hemarthria altissima* and *Xanthium strumarium.* The sedge *Cyperus longus* and the grass *Hemarthria altissima* are known for their presence in areas where moisture is present. The forb *Xanthium strumarium* is an alien invader and has a high ecological tolerance and occurs anywhere in moist but disturbed conditions.

Group D (Figure 6.16) is most strongly associated with the deeper channels and with wet banks not more than two meters away from the channels edge. These relevès (Table 6.5) are also associated with water saturated conditions and occur in the channel of the river. However the latter two associateions are not as strong as the first one. The species that are most frequently present in these relevès are: *Phragmites australis, Verbena bonariensis* and *Equisetum ramisissimum*. Although the reed *Phragmites australis* usually occurs in the river itself in this case it also occurs in areas with moist to water-saturated soils. *Verbena bonariensis* is an alien invasive plant and also has a wide ecological tolerance.

The relevès present in group E (Figure 6.16) are strongly associated with moist conditions, also occur not more than two meters up in the channel form the surface of the water, although the association is not that strong. There is also an association with the occurrence in the bank of the river, but the association is also not that strong. Species that are associated with these conditions are: *Tagetes minuta, Eragrostis plana* and *Setaria pumila*. These relevès (Table 6.5) mostly forms part of the grass/forb dominated communities, sub-communities and variants. However the community that occur in the cracks and crevices Korannaberg is also associated with these conditions. This community are mostly composed of trees and shrubs as seen on Table 6.2 species group B.

Group F (Figure 6.16) is strongly associated with moist conditions and these vegetation units occur on the bank of the river although the association with the bank and the distance up in the channel from the water`s surface of less than two meters is not that strong. Species that occur in these relevès (Table 6.5) include *Oenothera rosea, Salix babylonica* and *Setaria pumila.*

The relevès (Table 6.5) present in group G (Figure 6.16) is strongly associated with the bank of the river and occur in moist conditions up in the channel of the river and therefore between two and four meters away from the surface of the water in the river. These relevès are mostly dominated by forbs like *Tagetes minuta, Senecio glutinosus* and *Conyza bonariensis*.

Group H (Figure 16.6) is associated with the bank of the river and also occurs between two and four meters up the riverbank away from the water. There is also an association with drier conditions. The species that occur on the bank of the river and are having the ability to survive in the drier conditions include: *Eragrostis lehmanniana, Eragrostis plana* and *Andropogon appendiculatus.*

The relevès (Table 6.5) present in group I (Figure 6.16) are not very strongly associated with any of these environmental variables, although the presence on the bank and in relative dry conditions, between two and four meters away from the channel play a role. The species present in these conditions include: *Verbena bonariensis, Tagetes minuta* and *Asparagus africanus.*

Group J (Figure 6.16) is most strongly associated with the presence of surface water, as this community represents the seepage community. The relevès (Table 6.5) present in this community occur on the sandstone outcrops of Korranaberg. The vegetation is dominated by the presence of grasses and sedges.

In group K (Figure 6.16) there is only one relevè (Table 6.5) with only one species namely *Cyperus longus* dominating it. This relevè is strongly associated with most of the environmental variables.

The relevès (Table 6.5) present in group L (Figure 6.16) are most strongly associated with the channel depth of between four and six meters from the surface of the river`s water and the occurrence on the plain with drier conditions. These relevès include the following species: *Cyperus longus, Conyza bonariensis* and *Xanthium spinosum.*

The relevès (Table 6.5) present in group M (Figure 6.16) are strongly associated with habitats on plains, between four and six meters away from the surface of the water in the river. The conditions in these areas are also dry, however during the rainy season it might be saturated. The species that occur in these relevès include: *Leptochloa fusca, Echinochloa holubii* and *Verbena brasiliensis.*

Group N (Figure 6.16) is strongly associated with deep sediments on the banks. The distance from the channel varies between four and six meters, sometimes these communities also occur on the plains in drier conditions. However the dry conditions do not prevail during the rainy season. The species that occur in these relevès (Table 6.5) are: *Acacia karroo, Persicaria lapathifolia* and *Berkheya pinnatifida.*

The latter two groups namely M and N (Figure 6.16) with their associated relevès represent the pans that occur along the Vet River near Hoopstad and therefore the species composition differs considerably from those of the other communities.

After classification and ordination it is clear that the vegetation along the Vet River in the Free State can be summarized as follows. There are mountain communities that occur in the mountains where the river has its origin. These communities can be divided into those communities that occur in seepage areas (Figure 6.17 A) and those communities that occur in cracks and crevices (Figure 6.17 B).

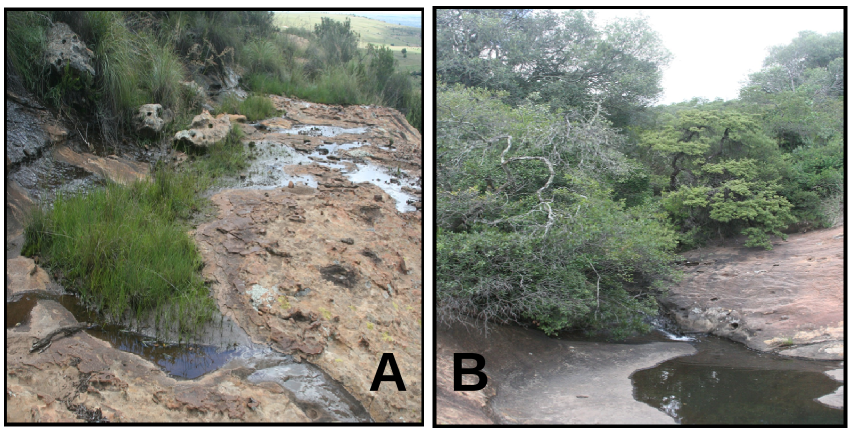


Figure 6.17: The different mountain communities. A – Seepage communities and B – Cracks and Crevices communities

Then there are the riverine communities that occur in the river as well as on the banks of the river. These communities can be divided into surface water communities (Figure 6.18 A), water saturated communities (Figure 6.18 B), moist communities (Figure 6.18 C) and dry communities (Figure 6.18 D).

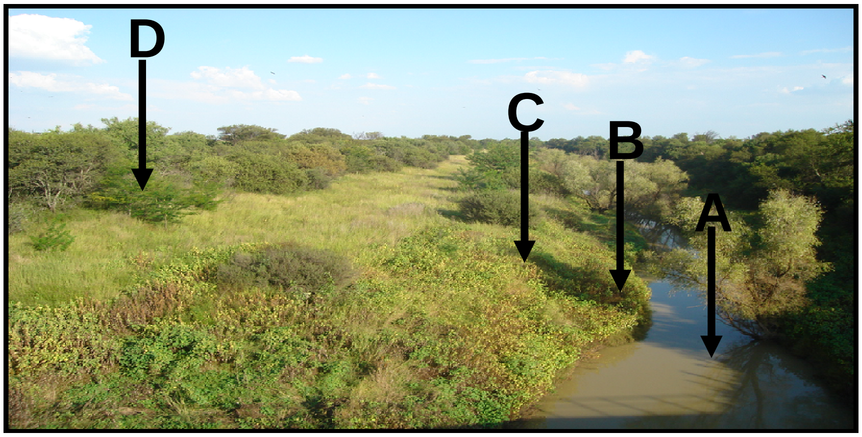


Figure 6.18: The different riverine communities. A – Surface water communities, B – Water saturated communities, C – Moist communities and D – Dry communities.

Lastly there are also communities that occur on the floodplains of the Vet River and are seen as seasonal pans. These pan communities can be divided into communities that are grazed by either cattle or game (Figure 6.19 A) and those communities which are protected from grazing (Figure 6.19 B).

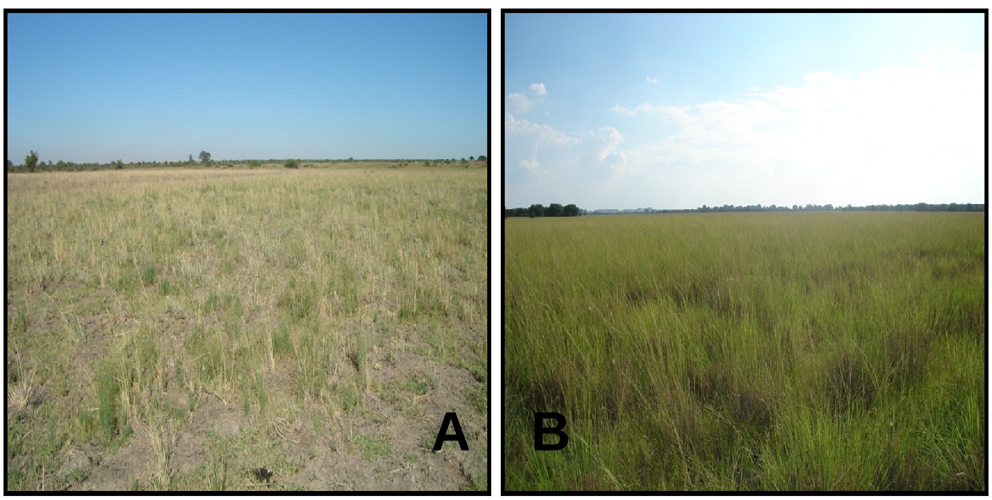


Figure 6.19: The different pan communities: A – pan community grazed by cattle and game and B – pan community not grazed.

6.4 WATER ANALYSIS

Water samples were taken at different sites in the Vet River (Figure 6.20). These samples were analysed by the Institute of Groundwater Studies at the University of

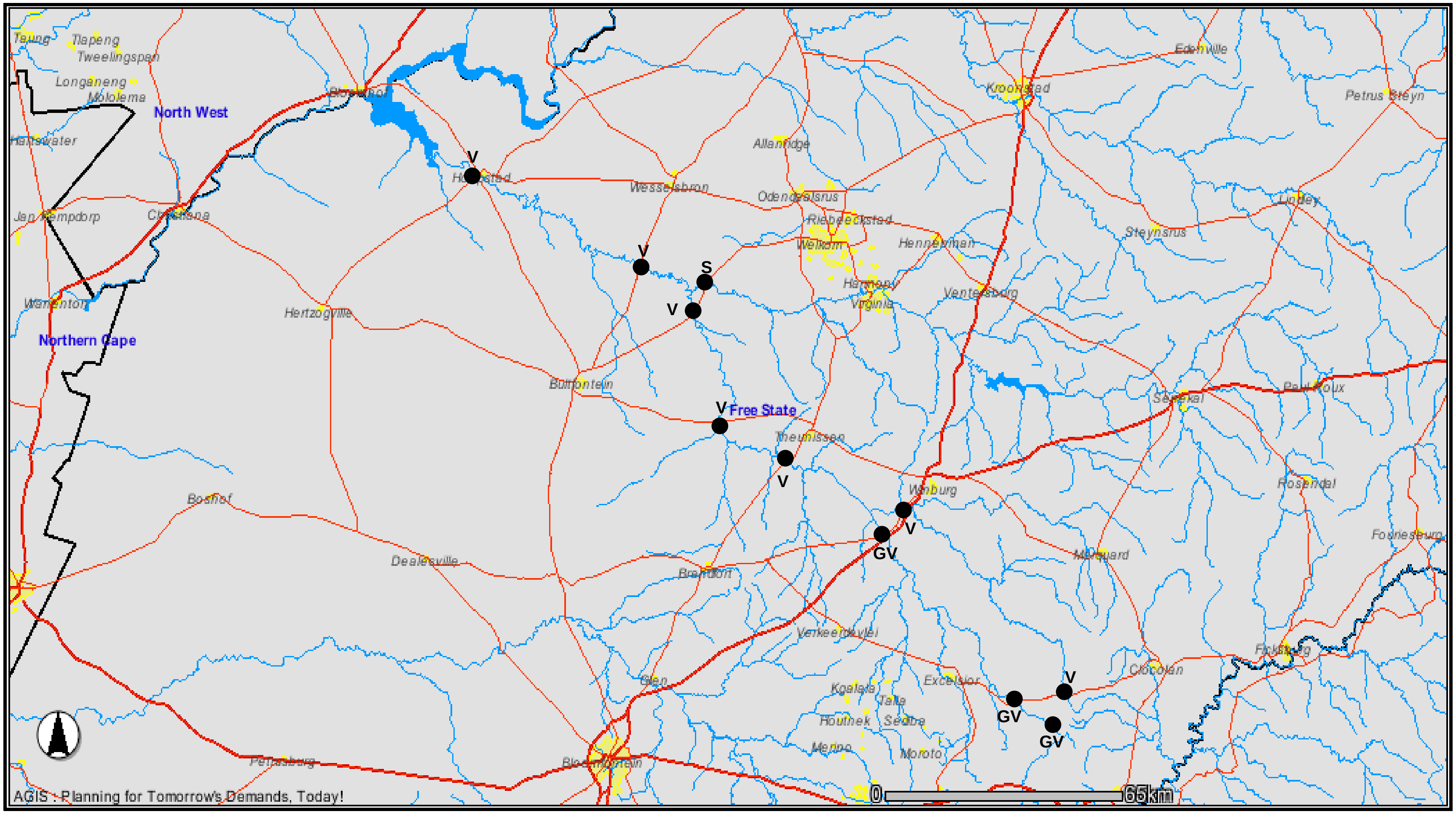


Figure 6.20: Map of the Vet River, Free State Province, South Africa (AGIS 2010). Black dots indicating sample points were water was sampled.

the Free State. In the following graphs (Fig.6.21, 6.22, 6.23, 6.24 and 6.25) GV represents the Groot Vet River, V the Vet River, which includes the Klein Vet River and S which represents the Sand River.

6.4.1 pH

When looking at Figure 6.21 it is clear that the pH of the water in the Groot Vet River is relatively neutral (pH close to 7). The values of the Vet River however vary from neutral to close to neutral (7) to alkaline (8) further downstream. The Sand River has a relative high pH in comparison to that of the Vet River. The red arrow on Figure 6.21 indicates the confluence of the Sand and Vet Rivers. It is clear that the higher pH value of the Sand River has an effect on the pH of the Vet River. However further downstream the pH value again shows a decrease. The higher pH value of the Sand River can be due to the mining activities in the vicinity of Virginia and Welkom. The mines can pump their treated effluent with a higher pH back into the river system.

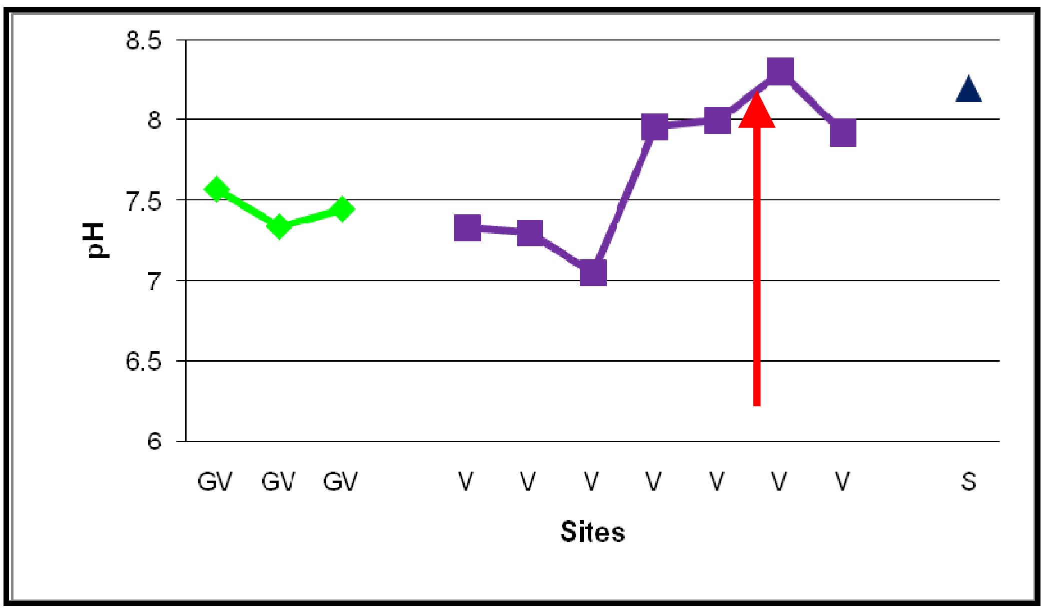


Figure 6.21: Graph showing the pH values of different sites along the Vet and Sand Rivers Free State Province.

The Target Water Quality Range according to DWAF (1996a, b, c and d) varies between a pH value of 6.00 and 9.00 for domestic use. For agricultural uses such as irrigation the pH range should be within 6.5 – 8.4. There is no specific pH range for livestock watering. Therefore the water in the Vet River can be used for domestic, irrigation and livestock purposes. The impact of the pH on the aquatic system will not be significantly negative as the pH ranges between 7 and 8.

6.4.2 Total dissolved solids

The values of the total dissolved solids (TDS) in the Groot Vet River show a decreasing tendency down stream (Figure 6.22). The Groot Vet River shows a decrease as the water flow down stream. The Vet River however shows an increase in TDS from the Koranna Mountains towards the Bloemhof Dam. This increase in TDS is also evident when looking at the Figure 6.22. The TDS value of the Sand River is very high and also have a significant influence on the value of the Vet River where these two rivers joins (indicated by the red arrow).

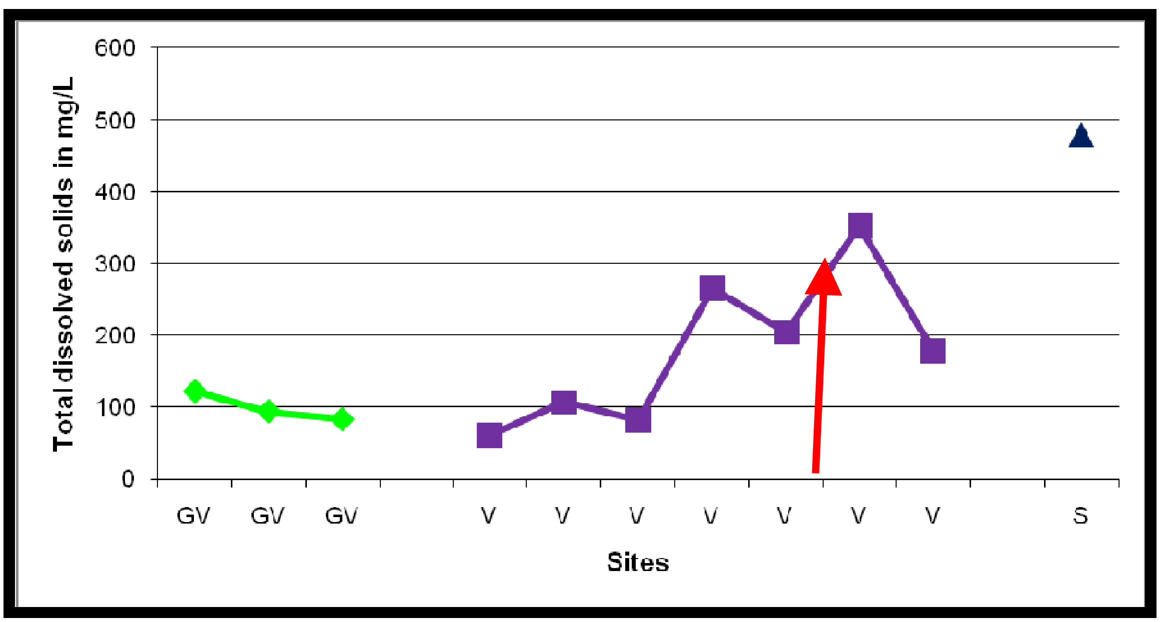


Figure 6.22: Graph of the Total Dissolved Solids (TDS) present at different sites along the Vet and Sand Rivers, Free State Province.

According to DWAF (1996a) the Target Water Quality Range (TWQR) for TDS ranges from 0 to 450 mg/L for domestic use. If the TDS values fall within this range then there will be no significant influence on the health of people. Therefore the water in the Groot Vet and Vet River can still be used for domestic purposes, but the one value taken of the Sand River is higher than the TWQR for water used for domestic purposes. DWAF (1996b) states that water used for irrigation should not have a TDS value of higher than 40 mg/L. If the values are higher, then the yield of the crop under irrigation could be affected. For the aquatic environment the TDS values should not changes with more than 15% from the normal amplitudes of the environment (DWAF 1996d).

6.4.3 Dissolved inorganic nitrogen

Both the nitrate and ammonia concentrations in the samples that were tested represent the amount of nitrogen present in the water. Dissolved inorganic nitrogen is the combination of ammonia, ammonium, nitrite and nitrate. Figure 6.23 indicates a decreasing trend in the dissolved inorganic nitrogen (DIN) of the Groot Vet River. A similar trend is notable for the Vet River. The DIN present in the Sand River is also relatively low.

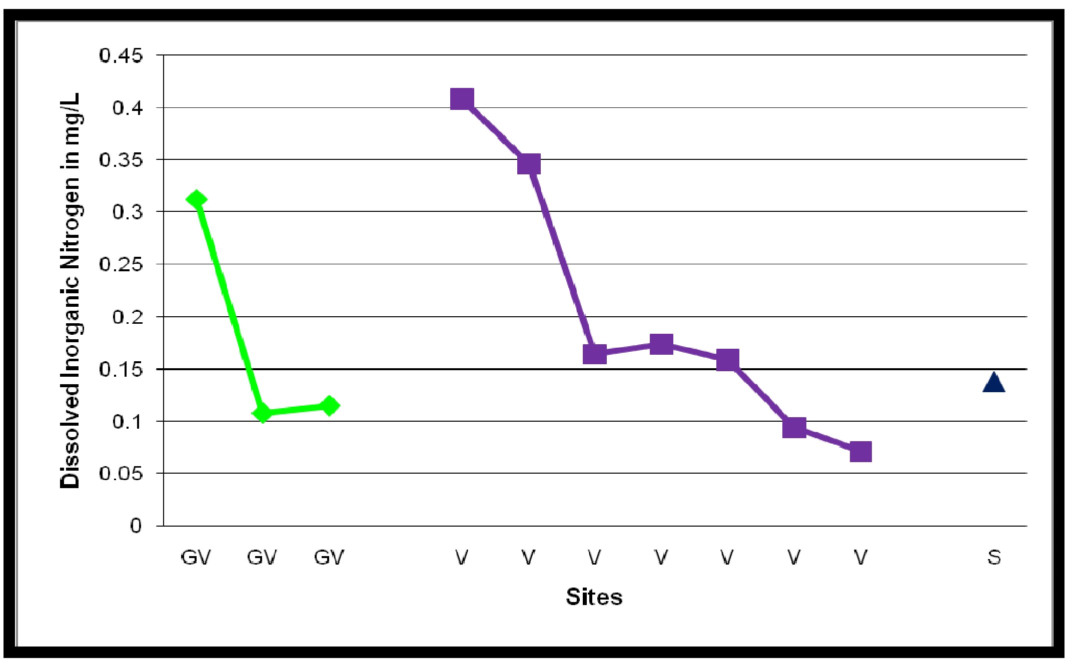


Figure 6.23: Graph of the Dissolved Inorganic Nitrogen present at different sites along the Vet and Sand Rivers, Free State Province.

For domestic use, the TWQR for nitrate should be between 0 and 6 mg/L. If the concentration of the nitrate is that low then there will not be any effects on the health of consumers (DWAF 1996a). For irrigation purposes the nitrogen concentration should be less than 5 mg/L which will then not even affect the sensitive crops (DWAF 1996b). Water used for livestock watering should contain an ammonia concentration of less than 7 mg/L (DWAF 1996c). However, the TWQR for the aquatic ecosystem sould be less than 0.5 mg/L which also indicates that the ecosystem is oligotrophic (DWAF 1996d). This is the case for the Vet River. An oligotrophic system is a system that contains low concentrations of nutrients.

6.4.4 Coli-forms

The *Echerichia coli* concentrations in the Groot Vet River vary considerably (Figure 6.24). It ranges from just more than 200 coli-form units (cfu)/100ml to almost 1600 cfu/100ml. The *E. coli* count in the Vet River also varies from less than 200cfu/100ml to as high a count as 1400cfu/100ml. The Groot Vet River shows a trend line which indicate a downstream decrease in the *E. coli* counts, however the Vet River show a slight increase towards the Bloemhof Dam. The Sand River has no significant influence as the count in the river is lower than 200cfu/100ml. A possible explanation for these varying results is that point sources along the river could cause these spikes in the results. Such a point source could be were a cow dung has been released in the water just upstream from where the sample was taken.

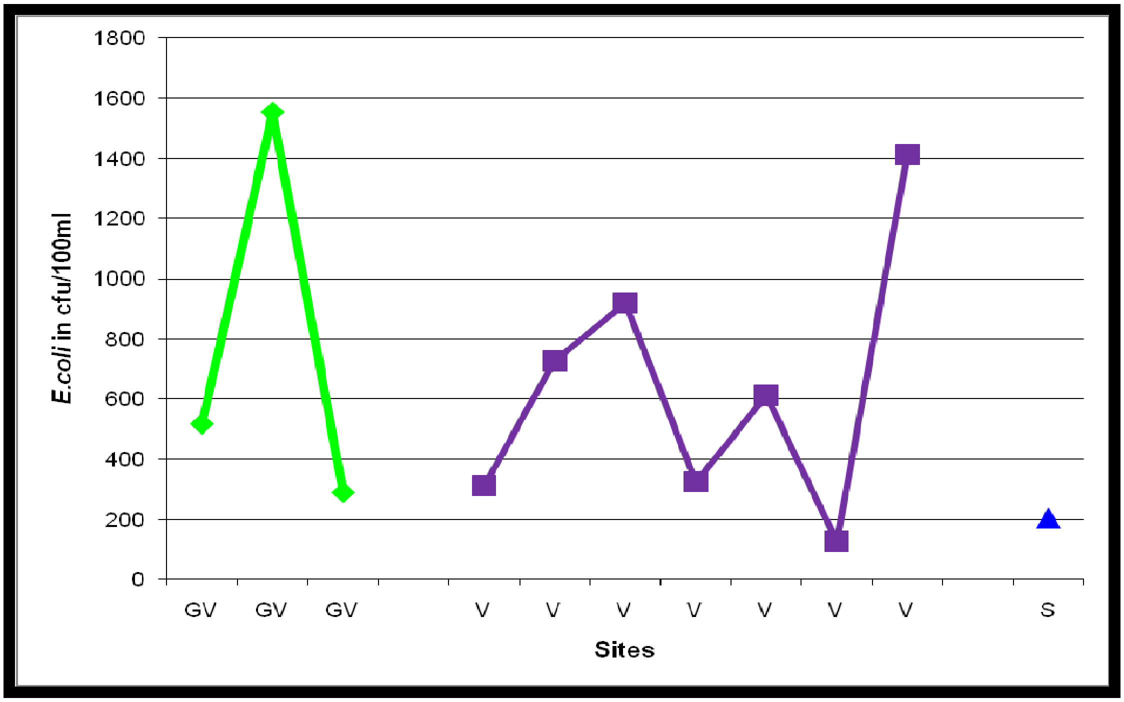


Figure 6.24: Graph of the *Echerichia coli* present at different sites along the Vet and Sand Rivers, Free State Province.

DWAF (1996a) stated that an *E. coli* count of between 0-10 might cause health risks if the exposure is continual. Any value above 10 cfu/100ml poses a serious health risk and can cause water borne diseases. For irrigational purpose DWAT (1996b) stated that the count should be less than 1cfu/100ml. In those cases where the count of *E. coli* is between 1 and 1 000 cfu/100ml, contaminations of fruit and crop might occur. The *E. coli* can be transferred via raw food to humans and to livestock through their food and feed. In conclusion, water of the Vet River should therefore first be treated before it can be used for domestic and irrigational purposes.

6.4.5 Macro elements

From Figure 6.25 it is clear that, in the Groot Vet River, all the macro elements have concentrations lower than 20 mg/L. In the case of the Vet River the concentrations of the ions are gradually increasing mainly due to the influence of the Sand River. Downstream from the Sand/Vet River confluence, the ion concentrations show a significant increase.

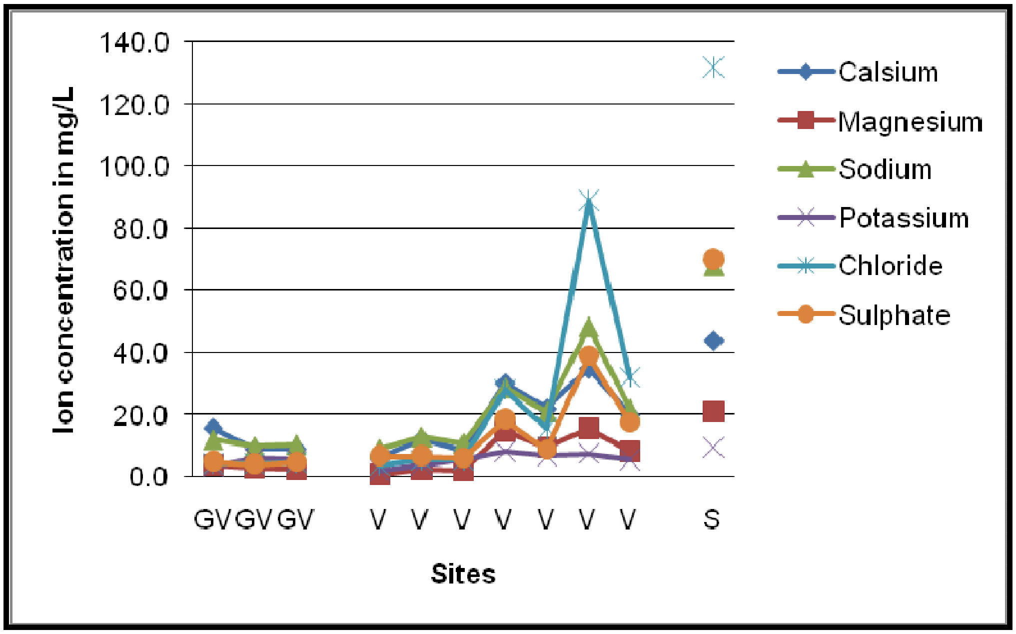


Figure 6.25: Graph of the different ion concentrations at different sites along the Vet and Sand Rivers, Free State Province.

According to DWAF (1996a) the Target Water Quality Range (TWQR) for Domestic purposes of calsium should be between 0 and 32 mg/L to be safe for consumers. Magnesium's TWQR is between 0 and 30 mg/L. Within this range no health effects or bitter taste will occur. Between the values of 30 and 50 mg/L there will still be no bitter taste. The TWQR for sodium is between 0 and 100 mg/L within this range no health effects will occur. For potassium the TWQR is between 0 and 50 mg/L, all the tested sites fall within this range and therefore will have no effect on the health of consumers. The TWQR for chloride falls between 0 and 100mg/L with no health effects within this range, but the chloride concentration of the Sand River is very high, although it will have no effect on the health of consumers. Sodium within a range of 0 and 200mg/L will according to the TWQR also have no effects on the health of consumers.

DWAF (1996b) stated that the TWQR for Agricultural purposes namely irrigation will be as follows: Sodium must have a value of less than 70mg/L. If the concentration of sodium in the water is higher than that then the sodium might accumulate to levels toxic to the crops. The TWQR for chloride is less than 100 mg/L which will also prevent the accumulation of chloride to levels toxic to crops. Levels between 100 and 140 mg/L might be toxic to sensitive crops.

According to DWAF (1996c) the TWQR for water used for the watering of livestock are as follows: Calcium has a TWQR between 0 and 1 000 mg/L and will have no effects on the animals. The TWQR for magnesium ranges between 0 and 500 mg/L. Within this range the magnesium will not have an effect on the animals utilizing the water. The sulphate ranges between 0 and 1 000 mg/L which will also have no effect on the consuming animals.

Water needs to be a safe medium for the aquatic environment so that ecosystems can function to their full potential. However the TWQR for the aquatic environment is less than 2 µg/L, which is much lower than the measured values in the Vet River. Therefore the health of the Vet River can be seen as under threat when considering the chloride concentrations present in the water samples of the different sites.

6.5 SPECIES COMPOSITION

Although the natural flora of South Africa is unique and recognisable in the vegetation of the world, it is also one of the most polluted and threatened. One of the greatest threats to the earth`s biological diversity is the spread of exotics and biological pollution. The invaders present in South Africa have the ability to suppress the indigenous species (Bromilow 2010). Table 6.6 summerises Annexure A. From this table (Table 6.6) it is clear that 23% of the total number of species that occur along the Vet River are aliens. This is a relatively high percentage and the high number of individuals and significant percertage these species cover in the sample plots (Table 6.1) indicate that these species pose a threat to the health and normal functioning of the riparian ecosystem.

Table 6.6: A summary of the major taxa present in the Vet River riparian ecosystem.

	Pteridophyta		**Eudicots**		**Monocotyledons**		**Total**	**% exotics**
	Number	%	Number	%	Number	%		
Famalies	6	9	47	75	10	16	63	0
Genera	7	4	110	70	41	26	158	13%
Species	8	3	144	67	64	30	216	23%

From Table 6.6 it is also clear that most of the species present in the study area are eudicots and comprise 67% of the overall species present. The monocotyledons comprise 30% and the pteridophyta 3%.

REFERENCES: CHAPTER 6

BROMILOW, C. 2001. *Problem Plants of South Africa. A guide to the identification and control of more than 300 invasive plants and other weeds*. Briza Publications, Pretoria, South Africa.

BROMILOW, C. 2010. *Problem Plants and Alien Weeds of South Africa.* Briza Publications, Pretoria, South Africa.

COATES PALGRAVE, M. 2005. *Keith Coates Palgrave Trees of Southern Africa,* 3rd edn. Struik Publishers, Cape Town.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996a. *South African Water Quality Guidelines.* 2nd edn. Volume 1: Domestic Use. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996b. *South African Water Quality Guidelines*. 2nd edn. Volume 4: Agricultural Use: Irrigation. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996c. *South African Water Quality Guidelines*. 2nd edn. Volume 5: Agricultural Use: Livestock Watering. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996d. *South African Water Quality Guidelines.* Volume 7: Aquatic Ecosystems. Pretoria, South Africa.

DINGAAN, M.N.V. 2008. The syntaxonomical classification of the *Acacia karroo* Class in southern Africa. Unpublished Ph.D dissertation. University of the Free State, Bloemfontein.

KENT, M. & COKER, P. 1992. *Vegetation description and analysis. A Practical Approach.* John Wiley & Sons Ltd. New York.

LAWRENCE, E. 2000. *Henderson's Dictionary of Biological Terms*. 12th edition. Pearson Education Limited. Malaysia.

LEPŠ, J., & ŠMILAUER, P. 2007. *Multivariate analysis of ecological data using CANOCO.* Cambridge: Cambridge University Press.

PYŠEK, P., & LEPŠ, J. 1991. Response of a weed community to nitrogen fertilization: a multivariate analysis. *Journal of Vegetation Science*, 2(2): 237-244.

SMIT, N. 2008. *Veldgids tot die Akasias van Suid-Afrika.* Briza Publications, Pretoria, South Africa.

TER BRAAK, C.J.F. & SMILAUER, P. 2002. CANOCO Reference mannual and CanoDraw for Windos User`s guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power)Ithaca, NY, USA).

VAN OUDTSHOORN, F. 2004. *Gids tot Grasse van Suider Afrika.* Briza Publications, Pretoria, South Africa.

VAN WYK, B-E., VAN HEERDEN, F. & VAN OUDTSHOORN, B. 2002. Poisonous Plants of South Africa, Briza Publications, Pretoria, South Africa.

CHAPTER 7

CONCLUSION

The aims of the study as set in Chapter 1 were satisfactory attained. The natural vegetation along the Vet River were successfully assessed, classified and described. The vegetation, along the Vet River, was classified into 14 communities of which two communities occur in the mountains where the Vet River has it origin, 12 communities occur along the river and floodplains.

The communities that occur on Korannaberg are relatively undisturbed in terms of alien invasion as no alien species were noted in the communities. The possible reason for this is the fact that humans do not have a significant influence on the vegetation as it is not readily accessible. Therefore the vegetation on Korannaberg is natural and undisturbed.

The communities that occur along the course of the river are relatively disturbed with the occurrence of a large number of alien invasive species. These invaders occur in almost all the growth forms which include grasses, forbs, trees, shrubs, geophytes and the worst alien invaders namely the aquatic forbs which include *Eichhornia crassipes* and *Azolla filiculoides.* This invasion is partly caused by humans and their impacts on the river. Causes include eutrophication of the river, over grazing by livestock which causes the formation of bare patches for the invaders to colonize or to stimulate erosion, etc. Nature itself also plays a role in the disturbances that occur along the river. These disturbances include floods which are the major causes of disturbance in this system.

The vegetation of the riverine areas can be divided into four categories which occur in the following major habitats: Stagnant and slow flowing water, water-saturated soils, moist soils and dry areas. The vegetation that occurs in the presence of surface water is dominated by alien invasive species. The vegetation that occurs in the water saturated areas also has invaders in their presence, although the invaders are not dominating the vegetation. In these areas trees such as *Salix babylonica* and *Populus* x *canesence* are important, however the forb *Xanthium strumarium* is also often found here. Along the river there are also toxic species such as *Sesbania punicea* and *Cestrum laevigatum* that are posing a threat to humans and animals.

The last two communities that occur on the floodplains of the river are the pans. The pans can be divided into two different communities which include pans grazed by livestock and game and pans that are not being grazed. The grazed pans are dominated by the pioneer grass *Cynodon dactylon*. There are also a fair amount of alien invaders present in this community due to the disturbance by livestock and game. The ungrazed pans also have an amount of disturbance indicated by the presence of weeds, but this community is dominated by pan grass, *Leptochloa fusca.*

With the above mentioned in mind one can say that the vegetation along the Vet River is not in a relatively good state. However the presence of alien species and their future effects on the natural vegetation is a cause for concern. Awareness of farmers needs to be improved to help with alien weed control. The advantages of alien plant control should be emphasised.

The Vet River is a perennial river, with frequent floods. It is an important corridor for numerous species. Naiman *et al.* (1993) stated that the natural riparian corridors are the most diverse, dynamic and complex biophysical habitats on earth. These areas serve as the interface between the terrestrial and aquatic systems, which include sharp environmental gradients, ecological processes and communities. The vegetation in this environment is influenced by the elevated water tables or flooding and the ability of soil to hold water. The disturbances that occur in these corridors include floods and debri flows which create a shifting mosaic of landforms over large areas. The variations that occur in the plant species composition along the stream or river have an influence on the in-stream biota and processes. Furthermore, the riparian vegetation has an influence on the light, temperature, nourishment provided to the terrestrial as well as aquatic biota. The vegetation also plays an important role in maintaining the biodiversity and providing of habitat and ecological services to animals that live in the corridor (Naiman *et al.* 1993). The animals that use the Vet River corridor include fish, birds, Vervet monkeys and other mammals.

In fluvial systems which forms part of drainage networks embedded in the landscape the riparian corridor is seen as the heart of the drainage basin since it may be the ecosystem-level component most sensitive to environmental change (Naiman *et al.* 1993). Therefore the water in the Vet River has been analysed and the results are presented in Chapter 6. These results indicate that the water quality of the Vet River is still suitable for agriculture, industrial and domestic use, however the high chloride concentration might pose a threat to the health of the organisms and the ecosystem as a whole.

REFERENCES: CHAPTER 7

NAIMAN, R.J., DÉCAMPS, H. & POLLOCK, M. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications.* 3(2): 209-212.

ABSTRACT

The aim of this study was to assess, classify and describe the natural vegetation along the Vet River. The study was restricted to the vegetation of the islands, banks as well as the floodplains.

The Vet River is situated in the Free State Province, South Africa. The study area covers approximately 8 928 hectares including the surface area of the Erfenis Dam, which is situated downstream of the confluence of the Groot Vet and Klein Vet Rivers. There are several towns in the catchment of the Vet River which include: Exelcior, Winburg, Theunissen and Hoopstad. The area around the river also has a provincial nature reserves namely: Willem Pretorius Game Reserve along the Sand River, a tributary of the Vet River, the Erfenis Dam Nature Reserve near Theunissen and the Sandveld Nature Reserve downstream of Hoopstad.

The area is mostly situated in the Highveld climatic region with cold and dry conditions due to the high elevation and the inland continental aspects of the area. Furthermore the area is characterised by warm summers with strong summer rainfall patterns and mild winters with drought. The rainfall received is mostly in the form of regular showers and thunderstorms during the months of October to March. The geology of the area is dominated by the Karoo Supergroup which was deposited during the period of 310 to 182 million years ago. Only the Ecca, Beaufort and Stormberg Groups occur in the study area.

In the area, two biomes are present. These biomes are the Grassland biome (which occur between sea level to 2 850m above sea level) which mainly represent the high central plateau of South Africa and the Savanna biome (occur at altitudes below 1 500m above sea level) which mostly occur in areas with a strongly seasonal rainfall and a distinct dry season which usually occur in winter. The Vet River cuts through seven vegetation types.

Various kinds of wetlands occur along the Vet River. All of them falls within the RAMSAR definition of a wetland namely: "wetlands are areas of marsh, fen (peat-

accumulating wetland that receives some drainage from surrounding mineral soil and usually supports marshlike vegetation), peatland (generic term of any wetland that accumulates partially decayed plant matter) or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". The presence of wetlands in the study area lead to the search for a proper definition for these unique systems as they also perform certain functions and can be seen as valuable ecological laboratories because of their habitat and species diversity. Riparian areas is seen as the interface between aquatic and terrestrial ecosystems, however these areas can also be defined as frequenting, growing on, or living on the banks of streams or rivers. These areas are usually narrow and linear and can be regarded as corridors for migrating species.

During the study 240 sample plots were placed within various homogenous vegetation types along the Vet River. The Braun Blanquet cover-abundance scale was applied in this study. The vegetation analysis led to the classification and identification of 14 plant communities, 21 sub-communities and 11 variants which were discussed phytosociologically: The communities can be divided into those communities that occur in the mountains, those communities that occur in the riverine areas on plains and the communities that occur in the floodplains or pans along the Vet River.

KEY TERMS:

Braun-Blanquet method, CANOCO, JUICE, ordination, phytososiology, riparian areas, TWINSPAN, vegetation analysis, vegetation classification, Vet River.

OPSOMMING

Die doel van die studie was om die natuurlike plantegroei langs die Vetrivier te klassifiseer en te beskryf. Die studie was beperk tot die plantegroei van eilande, oewers en die vloedvlaktes van die rivier.

Die Vetrivier is geleë in die Vrystaat Provinsie, Suid-Afrika. Die studie area beslaan ongeveer 8 928 hektaar wat die oppervlak van die Erfenis Dam insluit. Die ErfenisDam is geleë net onder die sameloop van die Groot en Klein Vetriviere. In die opvangs gebied van die Rivier is daar verskeie dorpe wat onder andere Exelcior, Winburg, Theunissen en Hoopstad insluit. In die omgewing van die Rivier is daar ook verskeie provinsiale natuur reservate naamlik: Willem Pretorius natuurreservaat langs die Sandrivier, `n sytak van die Vetrivier, die Erfenis Dam natuurreservaat naby Theunissen en die Sandveld natuurreservaat, wes van Hoopstad.

Die studie area is geleë in die Hoëveld-klimaatstreek wat `n koue droë klimaat het as gevolg van die hoë hoogte bo seevlak en die binnelandse kontinentale invloede van die area. Die area word ook gekenmerk deur warm somers met sterk somer reënvalpatrone en gematigde winters wat gekenmerk word deur droogtes. Die meeste reën val gewoonlik in die somer maande, gedurende Oktober tot Maart. Die reënvalseisoen word gekenmerk deur donderstorms. Geologies word die gebied onderlê deur die Karoo Supergroep wat tussen 310 en 182 miljoen jaar gelede, gevorm is. Die Ecca, Beaufort en Stormberg-groepe is die enigste wat in die studiegebied voorkom.

In die studie gebied kom twee biome voor: Die biome is die Grasveld bioom wat vanaf seevlak tot ongeveer 2 850m bo seevlakvoorkom en die Savanna bioom wat voorkom in areas met sterk seisoenale reënval en `n kenmerkende droë seisoen wat gewoonlik in die winter voorkom. Die Vetrivier vloei deur sewe verskillede plantegroei eenhede.

Verskillende soorte vleilande kom langs die Vetriveir voor. Almal val binne die breë RAMSAR definisie van vleilande naamlik: ‘vleilande is moeras of veenagtige areas wat natuurlike of kunsmatige, permanente of tydelike water het, wat staties of vloeiend is, vars of brak wat mariene gebiede met `n diepte van nie meer as ses meter tydens laagwater insluit nie'. Oewer areas word as die raakpunt tussen die akwatiese en terrestriele ekosisteme beskou, maar kan ook beskou word as oewer areas waar groei of lewe op die banke van strome en riviere voorkom. Oewergebiede word ook gesien as smal liniêre stroke wat as korridors vir migrerende spesies optree.

Tydens die studie is daar 240 persele uitgeplaas in verskillende homogene plantegroeitipes langs die Vetrivier. Die Braun-Blanquet veelheidsskaal is gebruik tydens die studie. Die plantegroeiklassifikasie het gelei tot die klassifikadie en identifikasie van 14 plant gemeenskappe, 21 sub gemeenskappe en 11 variante wat fitososiologies beskryf is. Die gemeenskappe kan verdeel word in die gemeenskappe wat in die berge voorkom, die gemeenskapppe wat langs die rivier op die vlaktes voorkom en die gemeenskappe wat op die vloedvlaktes of panne langs die Vetrivier voorkom.

<u>KERN WOORDE:</u>

Braun-Blanquetmetode, CANOCO, fitososiologie, JUICE, Oewergebiede, ordinansie, plantegroei-analise, plantegroeiklassifikasie, TWINSPAN, Vetrivier.

REFERENCES

AGIS. 2010. http://www.agis.agric.za/agisweb/viewer.htm?pn=2015.

AGIS .2010a. http://www.agis.agric.za/agisweb/?MIval=landtypes&rb=Landtypes_ introduction.

AGRICULTURAL RESEARCH COMMISSION (ARC). 2008. www.arc.agric .za 03/06/2008

BARDGETT, R. 2005.*The biology of soil: A community and ecosystem approach*. Oxford University Press. New York, USA.

BEATER, M.M.T., GARNER, R.D. & WITKOWSKI, E.T.F. 2008. *Impact of clearing invasive alien plants from 1995 to 2005 on vegetation structure, invasion intensity and ground cover in a temperate to subtropical riparian ecosystem*. *South African Journal of Botany.* 74: (2008): 495 – 507.

BEZUIDENHOUT, H. 2009. The classification, mapping and description of the vegetation of the Rooipoort Nature Reserve, Northern Cape, South Africa. *Koedoe* 51(1): Art. #695, 11 pages.

BEZUIDENHOUT, H., BREDENKAMP, G.J. & THERON, G.K. 1994. Phytosociological classes of the western Transvaal grassland, South Africa. *Koedoe*. 37(1): 1-18. Pretoria.

BOND, W.J. 1997. Fire. In COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. Vegetation of Southern Africa. Cambridge University Press. United Kingdom.

BRAND, R.F., DU PREEZ, P.J. & BROWN, L.R. 2009. A classification and description of the shrubland vegetation on Platberg, Eastern Free State, South Africa. *Koedoe* 51(1): Art. #696, 11 pages.

BREDENKAMP, G.J. & BEZUIDENHOUT, H. 1995. A proposed procedure for the analysis of large phytosociological data sets in the classification of South African grasslands. *Koedoe* 38(1): 33-39.

BRINSON, M. 1993. A *Hydrogeomorphic Classification for Wetlands*. Wetland Research Program Technical Report WPR-DE-4. US Army Corps of Engineers. Waterways Experiment Station. USA.

BROMILOW, C. 2001. *Problem Plants of South Africa. A guide to the identification and control of more than 300 invasive plants and other weeds*. Briza Publications, Pretoria, South Africa.

BROMILOW, C. 2010. *Problem Plants and Alien Weeds of South Africa.* Briza Publications, Pretoria, South Africa.

BROWN, L.R., MARAIS, H., HENZI, S.P. & BARRETT L. 2005. *Vegetation classification as the basis for baboon management in the Bourke`s Luck Section fo the Blyde Canyon Nature Reserve, Mpumalanga. Koedoe* 48: (2): 71-92.

CARLOW, P. & PETTS, G.E. 1992. *The rivers handbook. Volume 1.* Blackwell Scientific Publications, London.

CLEAVER, G., BROWN, L.R. & BREDENKAMP, G.J. 2005. The Phytosociology of the Vermaaks, Marnewicks and Buffelsklip valleys of the Kammanassie Nature Reserve, Western Cape. *Koedoe* 48(1): 1-16.

COATES PALGRAVE, M. 2005. *Keith Coates Palgrave Trees of Southern Africa,* 3rd edn. Struik Publishers, Cape Town.

CONNEXIONS. 2010. cnx.org/content.m22272/latest/graphics1.png.

COWAN, G.I. (ed) 1995. *Wetlands of South Africa*. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

COURTNEY, F.M. & TRUDGILL, S.T. 1984. *The soil: An introduction to soil study.* Second Edition. Hodder and Stoughton LTD. London.

CRONK, J.K. & FENNESSY, M.S. 2001. *Wetland Plants: Biology and Ecology*. Lewis Publishers. United States of America.

CULLIS, J.D.S., GÖRGENS, A.H.M. & MARAIS, C. 2007. *A strategic study of the impact of invasive alien plants in the hihg rainfall catchments and riparian zones of South Africa on total surface water yield. Water SA*. 33 (1): 35-42.

D'ANTONIO, C. & MEYERSON, L.A. 2002. Exotic Plant Species as Problems and Solutions in Ecological Restoration: A Synthesis. *Restoration Ecology* 10 (4): 703-713.

DAVIES, B. & DAY, J. 1998. *Vanishing Waters*. University of Cape Town Press. Cape Town, South Africa.

DE KLERK, J., BROWN, L.R. & BEZUIDENHOUT, H. 2003. Plant communities of the Ebenhaezer section of the Mountain Zebra National Park. *Koedoe* 46(2): 9-20.

DEPARTMENT OF ENVIROMNENTAL AFFAIRS AND TOURISM, Republic of South Africa. 2010. http://soer.deat.gov.za/Themes.aspx?m=271.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM. 2009. www.environment.gov.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996a. *South African Water Quality Guidelines.* 2nd edn. Volume 1: Domestic Use. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996b. *South African Water Quality Guidelines*. 2nd edn. Volume 4: Agricultural Use: Irrigation. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996c. *South African Water Quality Guidelines*. 2nd edn. Volume 5: Agricultural Use: Livestock Watering. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996d. *South African Water Quality Guidelines.* Volume 7: Aquatic Ecosystems. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 2008. A practical field procedure for identification and delineation of wetlands and riparian areas. Department of Water Affairs and Forestry. Pretoria, South Africa.

DINGAAN, M.N.V. 2008. The syntaxonomical classification of the *Acacia karroo* Class in southern Africa. Unpublished Ph.D dissertation. University of the Free State, Bloemfontein.

DINGAAN, M.N.V., DU PREEZ, P.J. & VENTER, H.J.T. 2001. Riparian and wetland vegetation of natural open spaces in Bloemfontein, Free State. *South African Journal of Botany* 67: 294-302.

D-MAPS. 2010. http://d-maps.com/pays.php?num-pay=7&lang=en.

DUGAN, P. 1993. *A Mitchell Beazley World Conservation Atlas. Wetlands in Danger.* Reed Consumer Books Limited. United Kingdom.

DU PREEZ, P.J. 1991. A syntaxonomical and synecological study of the vegetation of the south-eastern Orange Free State and related areas with special reference to Korannaberg. Unpublished PhD dissertation. University of the Free State, Bloemfontein.

ELLERY, W.N., GRENFELL, M., GRENFELL, S., KOTZE, D.C, McCARTHY, T.S., TOOTH, S., GRUNDLING, P-L., BECKEDAHL, H., LE MAITRE, D. & RAMSAY, L. 2008. *WET-Origins: Controls on the distribution and dynamics of wetlands in South Africa*. WRC Report No TT 334/08, Water Research Commission, Pretoria.

ELS, W.C. 1952. Waterverbruik en Grondbenutting in die Vet- en Sandriviergebied. Unpublished M. Artium dissertation at the Faculty of Arts, University of the Orange Free State, Bloemfontein.

EWART-SMITH, J.L., OLLIS, D.J., DAY, J.A. & MALAN, H.L. 2006. National wetland inventory: development of a wetland classification system for South Africa. The Water Research Commission and South African National Biodiversity Institute. ISBN: 1-77005-429-4.

EYRE, S.R. 1968. *Vegetation and Soils. A World Picture*. 2nd edn. Edward Arnold Publishers Ltd. Great Britian.

FOXCROFT, L.C., PARSONS, M., McLOUGHLIN, C.A. & RICHARDSON, D.M. 2008. Patterns of alien plant distribution in a river landscape following an extreme flood. *South African Journal of Botany* 74: 463-475.

FUGGLE, R.F. & RABIE, M.A. 1992. *Environmental management in South Africa.* Juta & Co, Ltd. Cape Town, South Africa.

GERMISHUIZEN, G & MEYER, N.L. (eds). 2003. Plants of soutern Africa: an annotated checklist. *Strelitzia 14*. National Botanical Institute, Pretoria.

GILLER, P.S. & MALMQVIST, B. 1998. *The biology of streams and rivers*. Oxford University Press, New York.

GÖRGENS, A.H.M. & VAN WILGEN, B.W. 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges. *South African Journal of Science* 100: 27-33.

GÖTZE, A.R., CILLIERS, S.S., BEZUIDENHOUT, H. & KELLNER, K. 2003. Analysis of the riparian vegetation (Ia land type) of the proposed Vhembe-Dongola National Park, Limpopo Province, South Africa. *Koedoe* 46(2): 45-64.

GROBLER, C.H., BREDENKAMP, G.J. & BROWN, L.R. 2006. Primary grassland communities of urban open spaces in Gauteng, South Africa. *South African Journal of Botany* 72: 367-377.

HENDERSON, L. 2001. *Alien weeds and invasive plants. A complete guide to declared weeds and invaders in South Africa.* Plant Protection Research Institute and Agricultural Reserch Council. Paarl Printers. Cape Town.

HENDERSON, L. 2007. Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA). *Bothalia* 37 (2): 215-248.

HENNEKENS, S.M. 1996. TURBOVEG: A software package for input, processing and presentation of phytosociological data. User`s guide, version July 1996, IBN-DLO. Lancaster: Wageningen and Lancaster University.

HENSLEY, M., LE ROUX, P.A.L., DU PREEZ, C.C., VAN HUYSSTEEN, C.W., KOTZE, E. & VAN RENSBURG, L.D. 2006. Soils: The Free State's Agricultural Base. *South African Geographical Journal* 88(1): 11-21.

HILL, M.O. 1979. TWINSPAN. A FORTRAN program for arranging multivariate data in an ordered tow-way table classification of individuals and attributes. New York: Cornell University.

HOLMES, P.M., RICHARDSON, D.M., ESLER, K.J., WITKOWSKI, E.T.F & FOURIE, S. 2005. A decision-making framewerok for restoring riparian zones degraded by invasive alien plants in South Africa. *South African Journal of Science* 101: 53-564.

HOLMES, P.M., ESLER, K.J., RICHARDSON, D.M. & WITKOWSKI, E.T.F. 2008. Guidelines for improved management of riparian zones invaded by alien plants in South Africa. *South African Journal of Botany* 74: 538 – 552.

KEDDY, P.A. 2000. *Wetland Ecology: Principles and Conservation*. Cambridge University Press. United Kingdom.

KEDDY, P.A. 2007. *Plants and Vegetation: origins, processes and consequences.* Cambridge University Press. United Kingdom.

KENT, M. & COKER, P. 1992. *Vegetation description and analysis. A Practical Approach.* John Wiley & Sons Ltd. New York.

KLEIN, R.G. 1977. The ecology of early man in Southern Africa. *Science*. 197: 115-126.

KOTZE, D.C., MARNEWECK, G.C., BATCHELOR, A.L., LINDLEY, D.S. & COLLINS, N.B. 2007. *WET-EcoServices:* A technique for rapidly assessing ecosstem services supplied by wetlands. WRC Report No. TT339/08, Water Research Commission, Pretoria.

LAND-USE AND WETLAND/RIPARIAN HABITAT WORKING GROUP. 2000. *Wetland/Riparian habitats: A practical field procedure for identification and delineation*. Version 2.0

LAWRENCE, E. 2000. *Henderson's Dictionary of Biological Terms*. 12th edition. Pearson Education Limited. Malaysia.

LE MAITRE, D.C., VERSFELD, D.B. & CHAPMAN, R.A. 2000. The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. *Water SA* 26 (3): 397-408.

LEPŠ, J., & ŠMILAUER, P. 2007. *Multivariate analysis of ecological data using CANOCO.* Cambridge: Cambridge University Press.

LOW, A.B. & REBELO, A.G. (eds) 1996. *Vegetation of South Africa, Lesotho and Swaziland*. 2nd edn. Department of Environmental Affairs and Tourism. Pretoria.

MACDONALD, I.A.W. 2004. Recent research on alien plant invasions and their management in South Africa: a review on the inaugural research symposium of the Working for Water programme. *South African Journal of Science* 100: 21-26.

MALAN, P.W., VENTER, H.J.T. & DU PREEZ, P.J. 2001. Vegetation ecology of the southern Free State; Vegetation of the drainage channels. *South African Journal of Botany* 67: 58-64.

MARAIS, C. & WANNENBURGH, A.M. 2008. Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa – Costs and water benefits. *South African Journal of Botany* 74: 526-537.

McCARTHY, M. & RUBIDGE, B. 2005. *The Story of Earth and Life: A southern African Perspective on a 4.6-billion-year journey.* Struik Publishers. South Africa.

MOFFETT, R.O. 2007. Name changes on the Old World *Rhus* and recognition of *Searsia* (Anacardiaceae). *Bothalia* 37 (2) 165-175.

MONEY, D.C. 1972. *Climate, Soils and Vegetation.* 2nd edn. University Tutorial Press LTD. Foxton, near Cambridge.

MITSCH, W.J. & GOSSELINK, J.G. 1993. *Wetlands*. 2nd edn. Van Nostrand Reinhold. New York.

MÜLLER, D.B. 1986. Plantekologie van die Willem Pretorius-Wildtuin. Unpublished PhD dissertation. University of the Free State, Bloemfontein.

MÜLLER, M.E. 2002. The phytosociology of the central Free State. Unpublished MSc thesis. University of the Free State, Bloemfontein.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South Africa National Biodiversity Institute, Pretoria, South Africa.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and methods of vegetation ecology.* Wiley, New York.

MYBURGH, W.J. & BREDENKAMP, G.J. 2004. Macro channel riparian vegetation of the Olifants River System in the Savanna Biome, Mpumalanga. *Koedoe* 47 (2): 37-60.

NAIMAN, R.J., DÉCAMPS, H. & POLLOCK, M. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications.* 3(2): 209-212.

PETTS, G. & CARLOW, P. 1996. *River biota: Diversity and dynamics.* Blackwell Science Ltd, Oxford, London.

PLUMMER, C.C & McGEARY, D. 1979. *Physical geology*. Wm.C. Brown Company Publishers. United States of America.

PYŠEK, P., & LEPŠ, J. 1991. Response of a weed community to nitrogen fertilization: a multivariate analysis. *Journal of Vegetation Science*, 2(2): 237-244.

REDDY, K.R. & DELAUNE, R.D. 2008. *Biogeochemistry of Wetlands*. CRC Press. United States of America.

RIVER HEALTH PROGRAMME. 2003. State-of-Rivers Report. Free Sate Region River Systems. Department of Water Affairs and Forestry. Pretoria, South Africa.

ROBERT, A. 2003. *River processes: An introduction to fluvial dynamics.* Oxford University Press Inc., New York.

RUTHERFORD, M.C. & WESTFALL, R.H. 1994. Biomes of southern Africa: an objective categorization*. Memoirs of the botanical survey of South* Africa No. 63. National Botanical Institute, Pretoria, South Africa.

SALISBURY, F.B. & ROSS, C.W. 1992. *Plant Physiology 4th* edn. Wadsworth Publishing Company. Belmont, California.

SANBI. 2009. Further Development of Proposed National Wetland Classification System for South Africa, *Primary Project Report* Prepared by the Freshwater Consulting Group (FCG) for the South African Biodiversity Institute (SANBI).

SAWS. 2002. Climate of South Africa: Climate statistics to 1990.WB 42. SAWS, Pretoria, South Africa.

SCHULZE, B.R. 1965. *Climate of South Africa*. Part 8. General Survey. Weather Bureau and Department of Transport. South Africa.

SCHULZE, R.E. 1997. Climate. In COWLING,R.M., RICHARDSON,D.M. & PIERCE, S.M. Vegetation of Southern Africa. Cambridge University Press. United Kingdom.

SIEBERT, F. & SIEBERT, S.J. 2005. Dolomitic vegetation of the Sterkfontein Caves World Heritage Site and its importance in the conservation of Rocky Highveld Grassland. *Koedoe* 48(1): 17-31.

SMIT, N. 2008. *Veldgids tot die Akasias van Suid-Afrika.* Briza Publications, Pretoria, South Africa.

SMITH, R.E. 1990. Comparison of the plant water relations of *Cunonia capensis* and *Pittosporum undulatum* in a riparian woodland in the south-western Cape. *South African Journal of Botany* 56(3): 409-412.

TAINTON, N.M. 1999. *Veld Management in South Africa.* University of Natal Press, Pietermaritzburg, South Africa.

TER BRAAK, C.J.F. & SMILAUER, P. 2002. CANOCO Reference mannual and CanoDraw for Windos User`s guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power (Ithaca, NY, USA).

TICHY, L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13: 451 – 453.

TICHY, L. & HOLT, J. 2006. JUICE: A program for management, analysis and classification of ecological data. Vegetation Science Group, Masaryk University Brno, Czech Republic.

TINER, R.W. 1999. *Wetland Indicators: a guide to wetland identification, delineation, classification, and mapping.* CRC Press LLC, United States of America.

TOOTH, S. & McCARTHY, T.S. 2007. Wetlands in drylands: geomorphological and sedimentological characteristics, with emphasis on examples from southern Africa. *Progress in Physical Geography* 31(1): 3-41.

TRUSWELL, J.F. 1970. *An introduction to the historical geology of South Africa*. Purnell & Sons (Pty)Ltd, Cape Town, South Africa.

TRUSWELL, J.F. 1977. *The Geological Evoltion of South Africa.* Purnell & Sons (Pty)Ltd, South Africa.

VAN DER MAAREL, E. 2005. *Vegetation Ecology*. Blackwell Publishing, United Kingdom.

VAN DER VALK, A.G. 2006. *The biology of freshwater wetlands.* Oxford University Press Inc., New York.

VAN OUDTSHOORN, F. 2004. *Gids tot Grasse van Suider Afrika.* Briza Publications, Pretoria, South Africa.

VAN RENSBURG, C. 1997. *Free State the Winning Province.* Chris van Rensburg Publications (PTY) Limited. Johannesburg, South Africa.

VAN WILGEN, B.W., REYERS, B., LE MAITRE, D.C., RICHARDSON, D.M. & SCHONEGEVEL, L. 2008. A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. *Journal of Environmental Management* 89: 336-349.

VAN WYK, B-E, VAN HEERDEN, F. & VAN OUDTSHOORN, B. 2002. *Poisonous Plants of South Africa.* Briza Publications, Pretoria, South Africa.

VAN ZYL, D. 2003. *South African Weather and Atmospheric Phenomena*. Briza Publications, Pretoria, South Africa.

VIESSMAN, W.JR. & LEWIS, G.L. 2003. *Introduction to hydrology*. 5th edn. Pearson Education Ltd., London.

VILJOEN, A.J. 1979. Die Plantekologie van die Sandveld-Natuurreservaat, Hoopstad. Unpublished MSc thesis. University of the Free State, Bloemfontein.

VOSSE, S., ESLER, K.J., RICHARDSON, D.M. & HOLMES, P.M. 2008. Can riparian seed banks initiate restoration after alien plant invasion? Evidence from the Western Cape, South Africa. *South African Journal of Botany* 74: 432 – 444.

WEATHER BUREAU. 1960. *Climate of South Africa.* Part 6. Surface Winds. Weather Bureau and Department of Transport. Pretoria, South Africa.

WERGER, M.J.A. 1974. On Concepts and Techniques applied in the Zurich-Montpellier method of vegetation survey. *Bothalia* 11(3): 309-323.

WESTHOF, V. & VAN DER MAAREL, E. 1978. The Braun-Blanquet Approach. *In:* WHITTAKER, R.H. (ed.). *Classification of Plant Communities.* Pp289-399. Junk, The Hague, Netherlands.

WHITTAKER, R.H. 1978. *Approaches to Classifying Vegetation. In:* WHITTAKER, R.H. (ed.). *Classification of Plant Communities.* Pp289-399. Junk, The Hague, Netherlands.

WIKUM, D.A. & SHANHOLTZER, G.F. 1978. Application of the Braun-Blanquet Cover-Abundance Scale for Vegetation Analysis in Land Development Studies. *Environmental Management*. 2 (4): 323 – 329.

WINEGARDNER, D.L. 1996. *An introduction to soils for environmental professionals.* Lewis Publishers. United States of America.

ZIETSMAN, M.M. & BREDENKAMP, G.J. 2006. Dune vegetation and coastal thicket plant communities in threatened limestone fynbos of Andrew`s Field and Tsaba-Tsaba Nature Reserve, Struisbaai, Western Cape. *Koedoe* 49(1): 33-47.

ANNEXURE A

Species list

Pteridophyta

Aspleniaceae

Asplenium L.

A. aethiopicum (Brum.f.) Bech.

A. cordatum (Thunb.)Sw.

Azollaceae

Azolla Lam.

*A. *filiculoides* Lam.

Equisetaceae

Equisetum L.

E. ramosissum Desf.

Marsileaceae

Marsilea L.

M. macrocarpa C.Presl

Pteridaceae

Adiantum L.

A. capillus-veneris L.

Cheilanthes Sw.

C. hirta Sw.

Selaginellaceae

Selaginella P. Beauv.

S. dregei (C.Presl) Hieron.

Eudicots

Acanthaceae

Justicia L.

J. protracta (Nees) T.Anderson

Amaranthaceae

**Achyranthes* L.

*A. *aspera* L.

**Alternanthera* Forssk.

*A. *nodiflora* R.Br.

*A. *pungens* Kunth

Amaranthus L.

*A.*caudatus* L.

*A.*hybridus* L.

A. thunbergii Moq.

Anacardiaceae

Searsia F.A. Barkley

S. dentata (Thunb.) F.A.Barkley

S. lancea (L.f.) F.A.Barkley

S. pyroides (Burch.) Moffett

Apiaceae

Berula W.D.J. Koch

B. erecta (Huds.)

*Ciclospermum Lag.
*C.*leptophyllum* (Pers.) Sprague

Heteromorpha Cham & Schltdl.
H. arborescens (Spreng.) Cham. & Schltdl.

Apocynaceae
Brachystelma R.Br.
B. circinatum E.Mey.

Gomphocarpus R.Br.
G. fruticosus (L.) Aiton f.

Riocreuxia Decne.
R. torulosa Decne.

Aquifoliaceae
Ilex L.
I. mitis (L.) Radlk. var. *mitis*

Asteraceae
Arctotis L.
A. venusta Norl.

Artemisia L.
A. afra Jacq. ex Willd.

Aster L.
*A *squamatus* (Spremg.) Hieron.

Berkheya Ehrh.
B. pinnatifida (Thunb.) Thell.
B. radula (Harv.) De Wild

Bidens *L.*

B. *pilosa *L.*

Chrysocoma L.

C. ciliata L.

Cineraria L.

C. aspera Thunb.

C. lyratiformis Cron

**Cirsium* Mill. emend. Scop.

*C. *vulgare* (Savi) Ten.

Conyza Less.

*C. *bonariensis* (L.) Cronquist

C. podocephala DC.

Cotula L.

C. hispida (DC.) Harv.

Felicia Cass.

F. muricata (Thunb.) Nees

Helichrysum Mill.

H. aureonitens Sch.Bip.

Lactuca L.

L. inermis Forssk.

Nidorella Cass.

N. resedifolia DC.

Nolletia Cass.

N. ciliaris (DC.)Steetz

Osteospermum L.

O. muricatum E.Mey. ex DC.

Pentzia Thunb.

Pentzia sp.

P. globosa Less.

Pseudognaphalium Kirp.

P. luteo-album (L.) Hilliard & B.L.Burtt

**Schkuhria* Roth

*S. *pinnata* (Lam.) Cabrera

Senecio L.

Senecio sp.

S. burchellii DC.

S. glutinosus Thunb.

Sonchus L.

*S. *asper* (L.) Hill

*S. *oleraceus* L.

**Tagetes* L.

T. minuta* L.

**Xanthium* L.

*X. *spinosum* L.

X. **strumarium* L.

**Zinnia* L.

*Z. *peruviana* (L.) L.

Boraginaceae

Heliotropium L.

H. lineare (A.DC.) Gürke

Brassicaceae

Lepidium L.

*L. *bonariense* L.

L. transvaalense Marais

Sisymbrium L.

S. capense Thunb.

Buddlejaceae

Buddleja L.

B. salviifolia (L.) Lam.

Gomphostigma Turcz

G. virgatum (L.f.) Baill.

Cactaceae

**Opuntia* Mill.

*O. *ficus-indica* (L.) Mill.

Caryophyllaceae

Herniaria L.

H. erckertii Herm.

Pollichia Aiton

P. campestris Aiton

Celasteraceae

Gymnosporia (Wight. & Arn.) Hook.f.

G. buxifolia (L.) Szyszyl.

Maytenus Molina

M. acuminata (L.f.) Loes.

M. undata (Thunb.) Blakelock

Celtidaceae

Celtis L.

C. africana Burm.f.

Chenopodiaceae

Atriplex L.

A. semibaccata R.Br.

Chenopodium L.

*C. *album* L.

*C. *ambrosioides* L.

*C. *murale* L.

*C. *schraderianum* Roem. & Schult.

Convolvulaceae

Cuscuta L.

*C. *campestris* Yunck.

Crassulaceae

Crassula L.

C. dependens Bolus

C. lanceolata (Eckl. & Zeyh.) Endl. ex Walp.

Ebenacea

Diospyros L.

D. lycioides Desf.

D. whyteana (Hiern) F.White

Euclea Murray

E. crispa (Thunb.) Gürke subsp. *crispa*

Euphorbiaceae

Clutia L.

C. pulchella L.

Euphorbia L.

E. inaequilatera Sond. var *inaequilatera*

Fabaceae

Acacia Mill.

A. karroo Hayne

Argyrolobium Eckl. & Zeyh.

A. pauciflorum Eckl. & Zeyh.

Crotalaria L.

C. distans Benth.

Indigofera L.

I. filipes Benth. ex Harv.

I. hilaris Eckl. & Zeyh

**Medicago* L.

*M. *laciniata* (L.) Mill.

*M. *polymorpha* L.

Prosopis L.

*P. *velutina* Wooton

Sesbania Scop.

*S. *punicea* (Cav.) Benth.

Tephrosia Pers.

T. capensis (Jacq.) Pers.

Flacourtiaceae

Scolopia Schreb.

S. mundii (Eckl. & Zeyh.) Warb.

Geraniaceae

Monsonia L.

M. angustifolia E.Mey. ex A.Rich.

Lamiaceae

Leonotis (Pers.) R.Br.

L. ocymifolia (Burm.f.) Iwarsson

Salvia L.

S. repens Burch. ex Benth.

Stachys L.

S. hyssopoides Burch. ex Benth.

Lobeliaceae

Lobelia L.

L. flaccida (C.Presl) A.DC.

L. thermalis Thunb.

Malvaceae

Hibiscus L.

H. trionum L.

**Sphaeralcea* A.St.-Hill.

*S. *bonariensis* (Cav.) Griseb.

Mesembryanthemaceae

Delosperma N.E.Br. emend. Lavis

D. cooperi (Hook.f.) L. Bolus

Ruschia Schwantes

R. hamata (L. Bolus) Schwantes

Molluginaceae

Limeum L.

L. sulcatum (Klotzsch) Hutch.

Mollugo L.

M. cerviana (L.) Ser. ex DC.

Myricaceae

Morella Lour.'

M. serrata (Lam.) Killick

Myrsine L.

M. africana L.

Oleaceae

Olea L.

O. europaea L. Subsp. *africana* (Mill.) P.S.Green

Onagraceae

**Oenothera* L.

*O. *rosea* L'Hér. ex Aiton

Oxalidaceae

Oxalis L.

*O. *corniculata* L.

O. depressa Eckl. & Zeyh.

Papaveraceae

Papaver L.

P. aculeatum Thunb.

Plantaginaceae

Plantago L.

P. lanceolata L.

Polygonaceae

Emex Campd.

E. australis Steinh.

Persicaria (L.) Mill.

P. hystricula (J.Schust.) Soják

*P. *lapathifolia* (L.) Gray

Polygonum L.

*P. *aviculare* L.

Rumex L.

R. lanceolatus Thunb.

Portulacaceae

Portulaca L.

*P. *oleracea* L.

P. quadrifida L.

Ranunculaceae

Clematis L.

C. brachiata Thunb.

Rhamnaceae

Ziziphus Mill.

Z. mucronata Willd.

Rosaceae

Leucosidea Eckl, & Zeyh.

L. sericea Eckl. & Zeyh.

**Rosa* L.

*R. *rubiginosa* L.

Rubiaceae

Galium L.

G. capense Thunb.

Nenax Gaertn.

N. microphylla (Sond.) Salter

Salicaceae

**Populus* L.

P. x **canescens* (Aiton) Sm.

Salix L.

*S. *babylonica* L.

S. mucronata Thunb.

Scrophulariaceae

Halleria L.

H. lucida L.

Jamesbrittenia Kuntze

J. aurantiaca (Burch.) Hilliard

J. fruticosa (Benth.) Hilliard

Selago L.

S. densiflora Rolfe

S. saxatilis E.Mey.

Sutera Roth

Sutera sp.

Solanaceae

**Cestrum* L.

*C. *laevigatum* Schltdl.

**Datura* L.

*D. *stramonium* L.

Lycium L.

L. arenicola Miers

L. cinereum Thunb.

L. hirsutum Dunal

**Physalis* L.

*P. *angulata* L.

Solanum L.

S. lichtensteinii Willd.

*S. *nigrum* L.

Sterculiaceae

Hermannia L.

H. coccocarpa (Eckl. & Zeyh.) Kuntze

Tamaricaceae

Tamarix L.

*T. *ramosissima* Ledeb.

Tiliaceae

Grewia L.

G. occidentalis L.

Verbenaceae

**Phyla* Lour.

*P. *nodiflora* (L.) Greene

**Verbena* L.

*V. *bonariensis* L.

*V. *brasiliensis* Vell.

Zygophyllaceae

Tribulus L.

T. terrestris L.

Monocotyledons

Alliaceae

Tulbaghia L.

T. acutiloba Harv.

T. leucantha Baker

Amaryllidaceae

Ammocharis Herb.

A. coranica (Ker Gawl.) Herb

Asparagaceae

Asparagus L.

A. aethiopicus L.

A. africanus Lam.

A. cooperi Baker

Cyperaceae

Cyperus L.

C. capensis (Steud.) Endl.

*C. *eragrostis* Lam.

C. longus L.

C. marginatus Thunb.

C. rupestris Kunth

Ficinia Schrad.

F. nodosa (Rottb.) Goetgh., Muasya & D.A. Simpson

Kyllinga Rottb.

Kyllinga sp.

Pseudoschoenus (C.B.Clarke) Oteng-Yeb.
P. inanis (Thunb.) Oteng-Teb.

Schoenoplectus (Rchb.) Palla
S. muricinux (C.B. Clarke) J.Raynal
*S. *tabernaemontani* (C.C.Gmel.) Palla

Schoenoxiphium Nees
S. rufum Nees

Scirpus L.
Scirpus sp.

Iridaceae
Moraea Mill.
M. pallida (Baker) Goldblatt

Juncaceae
Juncus L.
J. exsertus Buchenau
J. rigidus Desf.

Lemnaceae
Lemna L.
L. gibba L.

Poaceae
Andropogon L.
A. appendiculatus Nees

Aristida L.
A. congesta Roem. & Schult.

Brachiaria (Trin.) Griseb.
B. eruciformis (Sm.) Griseb.

Bromus L.
*B. *catharticus* Vahl

Chloris Sw.
C. virgata Sw.

Cymbopogon Spreng.
C. dieterleniae Stapf ex E. Phillips
C. excavatus (Hochst.)Stapf ex Burtt Davy

Cynodon Rich.
C. dactylon (L.) Pers.

Digitaria Haller
D. eriantha Steud.
D. ternata (A.Rich.) Stapf

Echinochloa P.Beauv.
E. holubii (Stapf) Stapf

Ehrharta Thunb.
E. erecta Lam.

Eragrostis Wolf
E. bicolor Nees
E. chloromelas Steud.
E. curvula (Schrad.) Nees
E. gummiflua Nees
E. lehmanniana Nees
E. micratha Hack.

E. obtusa Munro ex Ficalho & Hiern

E. plana Nees

E. trichophora Coss. & Durieu

Helictotrichon Besser

H. turgidulum (Stapf) Schweick.

Hemarthria R.Br.

H. altissima (Poir.) Stapf & C.E.Hubb.

Hyparrhenia E.Fourn.

H. hirta (L.) Stapf

H. tamba (Steud.) Stapf

Imperata Cirillo

I. cylindrica (L.) Raeusch.

Leptochloa P.Beauv.

L. fusca (L.) Kunth

Leersia Sw.

L. hexandra Sw.

Miscanthus Andersson

M. capensis (Nees) Andersson

Panicum L.

P. coloratum L.

P. stapfianum Fourc.

Paspalum L.

*P. *dilatatum* Poir.

P. distichum L.

Phragmites Adans
P. australis (Cav.) Steud.

Pogonarthria Stapf
P. squarrosa (Roem. & Schult.) Pilg.

Setaria P.Beauv.
S. pumila (Poir.) Roem. & Schult.

Sporobolus R.Br.
S. africanus (Poir.) Robyns & Tournay
S. fimbriatus (Trin.) Nees

Themeda Forssk.
T. triandra Forssk.

Urochloa P.Beauv.
U. panicoides P.Beauv.

Pontederiaceae
Eichhornia Kunth
*E. *crassipes* (Mart.) Solms

Typhaceae
Typha L.
T. capensis (Rohrb.) N.E.Br.

Table 6.1: Phytosociological classification of the riparian and wetland communities along the Vet River, Free State Province, South Africa

Community		1	2	3		4			5		6		7										8	9	10	11		12						13	14
Sub-Community				3.1	3.2	4.1	4.2	4.3	5.1	5.2	6.1	6.2	7.1		7.2	7.3		7.4	7.5	7.6	7.7					11.1	11.2	12.1			12.2				
Variant													7.1.1	7.1.2		7.3.1	7.3.2				7.7.1	7.7.2						12.1.1	12.1.2	12.1.3	12.2.1	12.2.2	12.2.3		
Relevé numbers		2 2 2 2	2 2 2 2 2	2	2 2 2 1	1 1	1 1	1 1 1	1 1	1 1 1 1 1						1 1 1	1 2	1 1 1 1 1 1 1	1 1 1	2 1 1 1 1 1	1 1 2	1 1 1	1	1 1 1 1 1	1 1 1 1	1 1 1 1 1 1 1	1 1 1 1 1 1	1 1 1	1 2 2 2	1 1 1 1 1	2 2 2	2 2 2	2 2 2 2 2 2	2 2 2	2 2 2
		3 3 3 3	2 3 3 3 3	1 8 7 7 1 0 4 8 1	3 2 2 2 2	9 3 2	3 3	2 2 2 2	2 3 1 3 1 1	7 8 9 1 8	4 5	5 6 4 5 1 5	7 7 6	8 2 7 2 3 2 8 4	1 1	8 8 7	9 0	3 3 1 2 3 2 3 3	8 7 8	0 1 1 2 6 0 1 3	5 0 0 0	2 2 1	5 5 5 6 6 1	9 7 8 8 8	7 8 7 7 3	5 4 4 5 5 3 5	1 6 5 6 5 9 9	0 9 9 9 9 9 0 8 9 8 9 9 8 0 9 9	6 1 1 1	6 6 6 6 6	0 0 0	0 0 1	1 1 1 1 1 1	2 2 2	3 3 4
		4 5 6 7	9 1 2 3 0	3 3 6 8 6 2 1 1 0 5	6 3 7 4 1 6	9 8 2	6 2	0 4 9 7	5 4 0 5 3 7	6 4 6 6 0	7 0	5 1 5 8 9 6	2 7 8 3	1 9 9 0 9 1 6 6	1 4 4 7	3 7 9	8 1	8 1 5 8 2 3 5 0	5 7 1	3 5 7 4 2 0 6 1 7	1 9 8 4	1 5 9	4 7 3 2 5 8	4 8 6 2 8	9 4 5 5 2 0 3 8	5 0 1 9 1 9 7	8 0 8 1 2 1 3	0 2 3 9 8 1 1 7 5 9 4 6 8 2 0 7	7 7 8 9	3 6 8 4 5	5 6 7	8 9 0	1 2 3 4 5 6	0 3 6	8 9 0
Number of species per relevé		1 1 1 1	3 3 3 3 3						1 1		1	1 1	1 1 1	1 2 1 1 1 1	1 1	1 1 1		1	1 1 1	1 1	1	1 1 1	1					1 1 1 1 1 1							
		5 5 5 5	1 1 1 1 1	2 4 2 2 4 4 5 1 4 6	7 3 5 5 5 4	6 2 3	4 3	7 5 6 9	7 1 7 1 7 8	6 6 6 3 6	7 0	9 0 9 8 6 8	8 4 8 1	3 8 4 4 1 3 7 8	9 6 9 1	5 5 5	6 6	8 9 7 9 0 7 8 7	2 2 2	8 9 0 8 3 5 9 7 8	8 0 9 7	1 2 3	6 8 5 8 5 0	8 8 8 8 8	2 3 5 1 9 1 5 6	9 9 9 9 7 7 9	6 6 7 6 5 3 3	7 9 8 8 9 2 9 8 1 0 8 9 1 8 0 2	7 6 6 6	6 8 6 7 7	9 9 9	5 5 5	6 6 6 6 6 6	1 1 1	1 1 1
Species	**Growth form**																																		
Species Group A																																			
Selaginella dregei	Fern	+ + + +																																	
Hyparrhenia hirta	Grass	+ + + +											1	4 2 2																					
Eragrostis gummiflua	Grass	+ + + +											+	1 1																					
Crassula dependens	Succulent	+ + + +																																	
Panicum stapfianum	Grass	+ + + +																																	
Eragrostis micrantha	Grass	+ + + +																																	
Cyperus rupestris	Sedge	+ + + +																																	
Digitaria ternata	Grass	+ + + +																																	
Cymbopogon dieterleniae	Grass	+ + + +																																	
Kyllinga sp.	Sedge	+ + + +																																	
Lobelia flaccida	Forb	r r r r																																	
Scirpus sp.	Sedge	r r r r																																	
Cyperus capensis	Sedge	r r r r																																	
Species Group B																																			
Morella serrata	Shrub		3 3 3 3 3																																
Scolopia mundii	Tree		3 3 3 3 3																																
Euclea crispa subsp. crispa	Shrub		3 3 3 3 3																																
Olea europaea subsp. africana	Tree		3 3 3 3 3																																
Searsia dentata	Shrub		2 2 2 2 2																																
Heteromorpha arborescens	Shrub		1 1 1 1 1																																
Diospyros whyteana	Shrub		1 1 1 1 1																																
Maytenus undata	Tree		1 1 1 1 1																																
Leucosidea sericea	Shrub		1 1 1 1 1																																
Clutia pulchella	Shrub		1 1 1 1 1																																
Berula erecta	Aquatic forb		+ + + + 3	1 2																					2										
Myrsine africana	Shrub		+ + + + +																																
Halleria lucida	Shrub		+ + + + +																																
Gymnosporia buxifolia	Shrub		+ + + + +																			r													
Ilex mitis	Tree		+ + + + +																																
Asplenium cordatum	Fern		+ + + + +																																
Leersia hexandra	Grass		+ + + + +																																
Cheilanthes hirta	Fern		+ + + + +																																
Adiantum capillus-veneris	Fern		+ + + + +																																
Sporobolus africanus	Grass		+ + + + +																																
Schoenoxiphium rufum	Sedge		+ + + + +																																
Helichrysum aureonitens	Forb		+ + + + +																																
Maytenus acuminata	Shrub		+ + + + +																																
Grewia occidentalis	Shrub		+ + + + +																																
Asplenium aethiopicum	Fern		+ + + + +																																
Species Group C																																			
Tulbaghia acutiloba	Geophyte	+ + + +	+ + + + +																																
Oxalis depressa	Geophyte	r r r r	r r r r r																																
Species Group D																																			
Phragmites australis	Grass		+ + + + +	4 4 2 5 4 2 2 4 4 2	5 5 4 4 4	4 5 4			1 1					+							4														
Species Group E																																			
Salix mucronata	Tree/Shrub					4 4 5	3 4	4 2 4 1																											
Species Group F																																			
Hemarthria altissima	Grass							3 3 3 +	4 4 1 3 2 3	4 4 2 1 4	2 1																								
Species Group G																																			
**Bromus catharticus*	Grass											3 4 3 3						1 4		2 1		3 3													
Plantago lanceolata	Forb											2 1 3 3								1															
Species Group H																																			
**Oenothera rosea*	Forb				r						2 3	r 2 1 2											4 4 3		+										
**Salix babylonica*	Tree			2 1							2	4 3 5								4															
Species Group I																																			
Imperata cylindrica	Grass												2 2 1 r	+																					
Species Group J																																			
Andropogon appendiculatus	Grass													3 + 3 1 2 4 4 r																					
Searsia lancea	Tree													2 r r 1	3			2																	
Species Group K																																			
Themeda triandra	Grass												1 r	1 1 3	r r							1													
Selago densiflora	Suffrutex							r	r r				+ r	+ r 2 +				r															r r r		
Crotalaria distans	Forb							+	r				1 r	1 r 1 1											r										
Pogonarthria squarrosa	Grass												1 1 +	+ 1																					
Hyparrhenia tamba	Grass												r	4 2	1																				
**Populus X canescens*	Tree			2					2					5 1																					
Species Group L																																			
**Cestrum laevigatum*	Shrub														3 4 2 2																				
Species Group M																																			
Artemisia afra	Shrub								1 r					1	r	2 2 2					2		3												
Lycium cinereum	Shrub													2		2 2 2								1			+								
Cineraria aspera	Forb															2 2 2		+			3									+					
Species Group N																																			
Searsia pyroides subsp. pyroides	Shrub											r	5	2 2 3 1		4 4 4	4 4	4			4	4													
Lycium hirsutum	Shrub															3 3 3	4 4	1 1			4 4 3 4		3												
Riocreuxia torulosa	Climber															2 2 2	2 2				2														
Achyranthes aspera	Forb															2 2 2	2 2																		
Species Group O																																			
Diospyros lycioides	Shrub							1	r			r		2 r			4 4	2 3 4 3 r 3 3 2				4 3													
Species Group P																																			
**Medicago polymorpha*	Forb																		2 2 2																
**Chenopodium schraderianum*	Forb									1	1	+							+ + +				1												
Gomphocarpus fruticosus	Shrub													+					+ + +					+											
Indigofera filipes	Shrub												+ r	+					+ + +																
**Oxalis corniculata*	Geophyte								+			1	1	+	r				+ + +										+	1 1					
Species Group Q																																			
Ziziphus mucronata	Tree/Shrub													1							3 2 3 4	3 2 1	3												
Species Group R																																			
Acacia karroo	Tree/Shrub			+ +									1	1 2 2	4 2 4 3	3 3 3		2 3 5 4 5 4 2	1 1 1	+ 2 1 1 3 2 2 2	3	5 5 4	1 1	1	r	4 4 4	+ 2	2		+	+ + +				
Eragrostis plana	Grass		+ + + + +								2	3 2	3 2 1	3 1 2 2 2	2 4 1			1 + +	4 4 4	1 1 3 2 4 2		+ 2			r		+				2 2 2				
Asparagus africanus	Climber											+	2	2 3 2 1 3	3 4 3 4	5 5 5	4 4	4 3 2 2 3 2		+ 2 1 2 2	2 3 2 4	1 3 2	2	1		3 1									
Eragrostis curvula	Grass								2					2 2				1			2	3													
Species Group S																																			
Eragrostis trichophora	Grass												1										4 5 1 1 4 2												
Species Group T																																			
Eragrostis lehmanniana	Grass				r													2						2 4 4 4 3											
Aristida congesta	Grass												r 1	2 r 1 1 3	r									+ 2 2 2 3											
Digitaria eriantha	Grass												1 r	1 2						1	2			1 1 1 2											
Species Group U																																			
Setaria pumila	Grass					3			2	3 3 3	1 2	4 3 4 3 2		1 r 1 1	r	2 2 2		2 3 4		4 1 3 2			2 2 2 3 2	3 2 2 2	2										
Sporobolus fimbriatus	Grass			r				+ 2	2 2 4			3	2 2 + r	2 1 3 2	r	1 1 1		1		2 2 4 1		+ 1			3										
**Paspalum dilatatum*	Grass					2			2 2	2 2 2 2		1	4 r	1	1 + +					3					+										
Panicum coloratum	Grass							1	2									1 2 4		r	1	4	+	2 2 2											
**Medicago laciniata*	Forb							2	r	2	4		r	1	r										r		1								
**Sesbania punicea*	Tree/Shrub					1			4					3						1															
Species Group V																																			
**Verbena bonariensis*	Forb				4 1 2 2 2			1	3 1 2 1 2 3		4 4	2 3 4 3 4	2	1 2 4 2 4	1 + +	1 1 1		1 1 1 1 2	2 2 2	r r 2 1 4 3 4	2 3	+ 1 2	3 1 2 5 5 1	4 2 2 2	r										
**Tagetes minuta*	Forb				1 1 1 1 +				1 2 4 2 2 r		1 4	1 1 2 2 1	2 r r	2 1 2 2 +	r 1 1 +	2 2 2		3 4 3 3 1 4 3	1 1 1	+ r 1 2 2 3 2	2 4 3	4 4 4	1 3 1	1 1 1 1		1 1			+ + +						
Species Group W																																			
Equisetum ramosissimum	Fern			2 4 1 3	1 1 1				1 3 1 2	3 3 3		3 2 2 3 3	+ 3	2 1 1 1				+	2 2 2	3 + 1 1	3		r		2 1 4 3 4										
**Xanthium strumarium*	Forb			4 +	2 5	3 2	4 1	2 1 2	+	4 4 4	2 2	4 4 2 4	2 2		1			3 3	2 2 2	3 1 4 + r 1	1	1	2 2		4 r										
Species Group X																																			
Cyperus longus	Sedge			3 3 2 3 4 1 5	r		2 2	2 3 3 1	1 4 1 r 4	2 2 3 r 2		5 3 4	1		2 3					2 1					4 5 3 5 4 3 1 3										
Senecio glutinosus	Forb		r r r r r	+	r						1	1	+ r	r 1 1 +	+ + + r					1 1			1 +												
Species Group Y																																			
Felicia muricata	Dwarf shrub																					+				1 1 1 + + r +									
**Lepidium bonariense*	Forb																			1						+ 1 1 + r 2									
Species Group Z																																			
Chloris virgata	Grass											+			+										1		r 1 1 1 2 3 3				1 1 1				
Species Group AA																																			
Cynodon dactylon	Grass			3				2 2				3 4	1	2 3	+					3 1 4	3	1	4	3 2	3	3 4 3 2 4 4 2	1 3 2 1 2 4 1								
Berkheya pinnatifida	Forb									+		+														1 1 2 1 + 1	1 + + 1 +			+ + 1 1					
Selago saxatilis	Suffrutex																						r			2 r r 1 + 1	2 + +		1	1 +			r r r 1 1 1		
Species Group AB																																			
Urochloa panicoides	Grass																					2		1		1 3 2 1 2	1 1 2 1 2	2 2 1 2 1 1 2 2 r 1 2		1 2					
**Schkuhria pinnata*	Forb											1		2												1 1 +		+ 3 1 2 1 2 r + + 3 1 + + 1 3 1							
Species Group AC																																			
Pseudognaphalium luteo-album	Forb																											1 1 2 + 1 2 + 1 + 1 + 1 + + 3 +							
**Amaranthus hybridus*	Forb																											+ 1 + 1 1 1 + 1 + 1 + + + +							
Marsilea macrocarpa	Fern			3																					3			r + r 1 r +							
**Physalis angulata*	Forb											r																r + + r							
Cotula hispida	Forb																											r 1 1 2 + 1							
Senecio burchellii	Forb																											1 1 + +							
**Xanthium spinosum*	Forb																								2			+ 1 +							
Species Group AD																																			
**Chenopodium album*	Forb												1	1	2	2 2 2		3 4		2 1	1 +	1 1	+ +			+ + + 1 1 +	r	+ 1 2 + 1 1 1 1 +	+	+					
Species Group AE																																			
**Verbena brasiliensis*	Forb																									2		1 1 + 1 2 2 1 + + 2 + + 2 +	2 2 2 2	1 2 2 + 2			r r r		
**Persicaria lapathifolia*	Forb																	r		r	2		1		4	+	1	1 1 1 1 2 + + +	1 1 1 1	r 1 1 2 1					
Species Group AF																																			
**Polygonum aviculare*	Forb									4		r																		1 1	r + r				
Species Group AG																																			
**Alternanthera nodiflora*	Forb																										+	+ + 1 + + + + 1 + +		1 + 2 2 2	1 1 1				
Species Group AH																																			
Brachiaria eruciformis	Grass																														3 3 3	3 3 3			
Species Group AI																																			
Echinochloa holubii	Grass																												2 2 2		2 2 2	2 2 2	3 3 3 2 2 2		
Species Group AJ																																			
Leptochloa fusca	Grass																											1 1 r 1 + 1 2 + 2 + 1 1 3 1 +	4 5 5 5	+ 4 4 1	4 4 4	4 4 4	5 5 5 4 4 4		
Ammocharis coranica	Geophyte																											r r r r r r r + r r r			+ + +	2 2 2	1 1 1 1 1 1		
Species Group AK																																			
**Conyza bonariensis*	Forb		+ + + + +		2 1 1 1		2	+ r	1 1 1			+	1	1 2 1 1 1		1 1 1		2 1 1 2 2 2	1 1 1	2 1 r 1 3 2	2 2	1 +	1	1 1 1 1	2 1	1 1 1 1	r	r	1 2 2 2			2 2 2	r r r 1 1 1		
Species Group AL																																			
**Eichhornia crassipes*	Forb																																	5 5 5	
Species Group AM																																			
**Azolla filiculoides*	Forb																																		4 4 4

Species with an occurence of less than 4 have been omitted
*** indicates alien invasive species**