Determination of vegetation species composition and soil characteristics of different selected ephemeral water bodies of the Cuvelai Etosha Basin.

Submitted in partial fulfillment of Bachelor of Science (Honors) in Environmental Biology major, Geography minor

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November 2014

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ABSTRACT

Vegetation refers to groups of plants growing together forming species populations at local scales, and this group of species populations grow together to form plant communities. Water is an essential need for all living organisms on Earth. The Cuvelai Etosha Basin support about 40% of the Namibian population. Agricultural activities such as crop cultivation and livestock farming are the most human activities that take place in the area. These activities rely on the soil for high yield and therefore knowing the soil characteristics and a type of vegetation that the soil can support is very important. The objectives of the study were to determine the vegetation composition, herbaceous cover and soil characteristics of selected ephemeral water bodies of the Cuvelai Etosha Basin. For vegetation, three areas were sampled (Oshigambo, Oshakati and Okashana). A total of 27 transects were laid (9 transects per each area Oshigambo, Oshakati and Okashana) parallel to the water flow of the ephemeral water bodies. Per each transect; the 3 most dominant species were recorded and the average herbaceous cover was recorded. The soil samples were taken at random from each transect. The cluster analysis was used to determine whether there were similarities in species composition of woody vegetation between the sites. The soil characteristics (pH, Electrical Conductivity and moisture content) were analysed in the Geology Department laboratory. The study findings showed an overall variation in both species composition and herbaceous cover among the different ephemeral water bodies in the Cuvelai Etosha Basin. Species composition and herbaceous cover in each of the three areas was influenced by soil characteristics, vegetation type and extent of grazing.

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ACKNOWLEDGEMENTS

Firstly, I want to thank the Almighty God for giving me the energy and strength to complete this research project. Secondly, I would love to thank my supervisor Mrs Mujoro-Kaukuetu for correcting and directing me in the whole project, Dr Heike Wanke and Josephine Hamukoto for helping me out with data collection, soil sampling equipment and soil analysis in the laboratory. I would also love to give my sincere gratitude to the Southern Africa Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) for the financial support. Great thanks to the National herbarium of Namibia staff members (David, Leevi, Josephine and Hendrina) for helping me out with plant identification. Finally, I want to thank my mom plus all my friends (especially Paulina, Rosalia and M’tangeni) and family for their help and support through this study.

DECLARATIONS

I Wilhelmina KL Nuule hereby declare that this study is my own work. I grant the University of Namibia the right to reproduce this thesis in whole or as part by electronic or any other means that the University of Namibia think is best fit for any institution or individuals requiring them for any research purposes. I Wilhelmina declare that this work is my very own and it has not been submitted for any honors degree in any institution. Other works done by other people or from various sources have been referenced.

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CHAPTER 1: INTRODUCTION

1.1 Background

Vegetation refers to groups of plants growing together forming species populations at local scales, and this group of species populations grow together to form plant communities (Kangombe, 2010). Vegetation is the most physical representation of an ecosystem in most terrestrial habitats of the world and it is responsible for primary production in these ecosystems. Plants are the primary producers in nature; they capture sunlight energy and convert this basic form of energy (sunlight) into chemical energy in the form of sugars and other more complex compounds (Strohbach, 2001). Animals are dependent on plants for their source of energy. Vegetation serves as wildlife habitat where other organisms live, grow, reproduce and die. Vegetation is therefore the energy source for the large numbers of animal species on the planet. Vegetation protects the land by covering it and can therefore prevent soil erosion and it can strongly affect soil characteristics including soil water volume, chemistry and texture.

Water is an essential need for all living organisms on Earth. Therefore, in any areas, both the vegetation structure and diversity or the vegetation natural patterns are determined mainly by water availability. Apart from water availability, other factors that play an important role in vegetation growth are soil properties such as soil moisture content, pH, water holding capacity and Electrical conductivity (Cleland, 2012). There exist thus a mutual relationship between vegetation and soils. This association is between the soil and vegetation, but not individual soil properties and vegetation or selected attributes of vegetation (Hinoroka, Fosberg, & Neiman, 2007). Some areas are associated with high vegetation diversity and some with low vegetation diversity. Apart from the effects of climate on the overall biodiversity of an area, vegetation diversity in an area is influenced by soil characteristics and water (Forseth, 2012). Vegetation and soil mutually influence each other and neither is the result of the other.

Soil pH is defined as the measure of acidity or alkalinity of the soil. Salinity, toxicity and extremes in soil pH result in poor plant growth. If the soil is acidic, this influences the availability of nutrients to the plants (Hinoroka et al., 2007). Plants require nutrients to grow, and, if there are no proper nutrients in proper concentration plant function is affected. Calcium, potassium, magnesium and sodium are alkaline elements, which are lost with increasing acidity whereas phosphorous is more available in acidic soil conditions (Bryla, Shireman, & Machado, 2010). Acidity can also induce deficiencies of micronutrients such as Molybdenum, Copper and Boron (Bryla et al., 2010). For most plants species, there is an optimum growth in soil with pH level of 5 to 7 (Cleland 2012). This is because during this range, that is when most nutrients are readily available to the plants. According to Bryla et al. (2010), Electrical conductivity is a measure of the amount of soluble salt ions in the soil (salinity of the soil). Bryla et al. (2010) further stated that high concentration of salt in the water reduces its water potential making it less available to the plant, the salt therefore causes water stress in the plant.

High vegetation diversity is usually found in areas with good water holding capacity soils, proper concentration of essential nutrients that are readily available to plants, optimum temperature with maximum light intensity for plants' photosynthesis, optimum pH and good precipitation (Cleland, 2012). If an area has one of these in short supply, it becomes a limiting factor and lowers the chances of plant growth and thus low plant diversity (Forseth, 2012), since it is only plants that are able to tolerate such environmental conditions grow in that particular area. Many studies have been done on vegetation and soils; however, they do not clearly show the link and relationship between soil characteristics and the type of vegetation in the studied regions.

1.2 Problem statement

The Cuvelai Etosha Basin houses about 40% of the Namibian population and it support agricultural activities which are seasonally fed by rain and flood water (Zandler, 2011). The challenges of high population growth have created pressure on vegetation and soil. In general, vegetation in an area depends on soil characteristics and mostly on the amount of water available in the soil. Currently, there is no adequate documented information on soil and vegetation association and it is only a few studies that have been made on the association of vegetation-soils in the Cuvelai Etosha Basin. A lot of studies that have been made in the Cuvelai Etosha Basin have focused more on soil characteristics and ground water quality. This reflects that studies and research on soil characteristics and vegetation need to be done in that particular area. Vegetation and soil characteristics studies are not only important for ecological studies but they can also be applied in environmental sciences. Most people in the study area depend on livestock and crop production as their source of food and income. Therefore, a study on vegetation species composition and soil properties can help by providing knowledge to the communities in the study area to know better about type of vegetation that their soil can support.

1.3 Significance of the study

This project looks at determining the soil characteristics and vegetation composition in the Cuvelai Etosha basin in Northern Namibia. It is essential to improve farmers' knowledge and understanding on sustainable farming and land use, especially in a country like Namibia, whose economy strongly relies on agricultural production. For planning purpose, more than just a vegetation map is needed. Baseline information on species composition can reveal problems with poisonous plants and/or encroacher species early and reveal the presence of unproductive soils.

A general need for long-term monitoring is also being realised. Therefore, studying soil characteristics and vegetation in Cuvelai Etosha Basin cannot only provide information and improve our understanding on the functioning of vegetation and soils in the community, but it can also provide a scientific basis for effective environmental planning, management and sustainable land-use in the area (Kangombe, 2010). The study of an association between vegetation and soils can contribute much needed information on local land use by providing knowledge to the farmers on the soil characteristics and the types of crops the soil can support so that they can plant right crops and manage the number of livestock that can be supported by the land without degrading it. Species composition also tells the farmers the number and types of palatable species for their livestock in an area helping them to manage and choose the right numbers and types of livestock species to farm. This study will provide much needed information about vegetation composition and the associated soil characteristics in the Cuvelai Etosha basin.

1.4 Objectives

1. To determine the vegetation species composition at selected ephemeral water bodies in the Cuvelai Etosha Basin.
2. To determine herbaceous cover at selected ephemeral water bodies of the Cuvelai Etosha Basin.
3. To determine soil characteristics (soil moisture content, pH and Electrical conductivity) at selected ephemeral water bodies in the Cuvelai Etosha Basin.

1.5 Research Questions

1. What is the species composition of the selected ephemeral water bodies of the Cuvelai Etosha Basin?
2. What is the herbaceous cover of the selected ephemeral water bodies of the Cuvelai Etosha Basin?
3. What are the soil characteristics of the selected ephemeral water bodies (soil moisture content, pH, Electrical conductivity) of the Cuvelai Etosha Basin?

CHAPTER 2: LITERATURE REVIEW

2.1 Vegetation

Namibia has a broad variety of plant species from desert and semi-desert vegetation to evergreen subtropical plants species (Southern Domain, 2010). Mainly due to the differences in climatic patterns, Namibia can be divided into three distinct vegetation zones: Savannah which covers 64% of Namibia land area, Dry woodlands and Forests which covers 20%, while desert and semi-desert cover 16% of Namibia's land area (Guide to the floras of Namibia, 2013). All together, these vegetation zones can support more than 4000 seed bearing vascular plants, over 120 different species of trees (ranging from the umbrella shaped camel-thorn, *Acacia erioloba* to the valuable Ana tree, *Faidherbia albida*, with its creamy yellow flowers and nutritious pods), over 200 species of endemic plant species (including *Welwitschia mirabilis, Aloe asperifolia* and *Aloe namibensis*) and 100 varieties of lichens (Guide to the floras of Namibia, 2013). Namibia receives very low precipitation and most of the time, the land looks very dry. The central part of the country is dominated by thorn-bush savannah with extensive grassland and Acacia bush (Southern Domain, 2010). The north-east of the country receives high rainfall and the thorn-bush savannah slowly turns into Mopane savannah and there is high number of trees. In the relatively high humid Zambezi region, the dominant vegetation form is woodland savannah, mostly with single Baobab trees, Wild figs and Makalani palm trees (Southern Domain, 2010).

Due to arid conditions in the Southern part of the country, there is less vegetation (Southern Domain, 2010). A few grasses grow there, trees are also scarce and mostly succulent plants (water storing plants) can be seen frequently in this region (Nature wheels, 2014). The most frequently seen is the Quiver tree (*Aloe dichotoma*) which is endemic to Namaqualand-Namibia (Guide to the floras of Namibia, 2013). The silvery-yellowish grasses grows in bunches and cover the reddish-brown soil sparsely (Southern Domain, 2010). During the rainy season (December to March), the shrubs and grasslands turn green and carpets of wild flowers can be seen covering the Desert (Southern Domain, 2010).

Northern Namibia is made up of a variety of vegetation (Yuichiro, 2005). During the dry, cold winter months and hot early summer months only little vegetation grows and most surface water evaporates. All of this change due to the arrival of rain which stimulates the germination and growth of natural vegetation and allows people to start cultivating crops. The region is allocated to the Tree and Shrub savannah biome. North-east contain woodlands, east and west contain mainly sparse shrubs and saline grasslands mostly in the central region (Mayr, 2012). The area along Iishana (shallow pans) Cuvelai is covered mostly by grassland as well (Mayr, 2012). The most dominant species in the Northern-central region *is Colophospermum mopane* (Yuichiro, 2005*)*, mainly found in the form of shrubs (Mayr, 2012). Fewer trees are found because of deforestation and used as firewood and construction purposes (Yuichiro, 2005).

Other species found at high elevation in the region are fruit trees such as, *Sclerocarya birrea*, *Berchemia discolor* and *Hyphaene petersiana* (Mayr, 2012). The shrub life form in the area is dominated by species such as, *Pichuel loeschea leubnitzia*, *Acacia arenaria* and *Acacia hebeclada*. The grasses found in the region are *Odyssea paucinervis*, *Sporobolus lenellus* and *Willkommia sarmentosa* (Mayr, 2012). The wet and saline margins of Iishana are surrounded by perennial grasses and sedges such as *Cyperus sedges, Diplachne species, Brachiaria deflexa* and *Eragrostis viscosa* (Mayr, 2012). The annual grass *Sporobolus salsus* grows on the pan itself, after good rains or flooding and blue-green algae cover the surface of the pan during the rainy season. The sedge *Cyperus marginatus* is also common on the pan margins, as are several perennial grasses. Halophytic vegetation lines the edge of the pan which mainly consists of *Sporobolus spicatus, S. ioclados, S. tenellus, Odyssea paucinervis,* and the small shrubs, *Suaeda articulata* and *Salsola tuberculata* (Mendelsohn et al., 2000). *Atriplex vestita* and *Sporobolus tenellus* are also present as are the occasional patches of annuals such as *Chloris virgata*, *Diplachne fusca*, *Dactyloctenium aegyptium,* and *Eragrostis porosa*

The grass cover varies between 15-40% (Mayr, 2012). Grass in the region is influenced by alteration of soil moisture balance by shallow impermeable layer and human activities (Zandler, 2011). This results in false-grasslands/human-induced grasslands which are usually maintained by fire and high density of livestock (Mayr, 2012). The natural vegetation patterns in this area are mostly determined by salinity and water availability of the soil. Along the alluvial marshes, adapted vegetation can be found; mainly perennial grasses while on the areas with high elevation are associated with a mosaic of shrub and grassland with isolated palm trees (Zandler, 2011).

2.2 Soils

Northern Namibia is characterized by its arid environment and the soils in the area reflect their aridity (Zandler, 2011). The soils have characteristics such as; shallow soil as a result of low soil formation rate, low fertility due to lack of organic matter in the soil and high salinity which reflect continuous flooding and high evaporation rate. The areas around Iishana are mainly made up of clay sodic sand that has high concentration of salt (Mayr, 2012). In high elevated areas, the soil is sodic sand and it is the most fertile soil in the region (Zandler, 2011). This soil sometimes contain an impermeable layer at the depths of 5-10cm, where calcrete (cemented calcium carbonate accumulate). When rain falls, the salt from calcrete dissolves and are transported upward toward the soil surface, leading to high salinity in the large part of the area (Zandler, 2011).

Large proportion of the area is also made up of Cambic Arenosol, a typical Quartzous Kalahari sands which are coarse texture, high water permeability and low nutrient concentration (Mayr, 2012). Other soil types are, Haplic Cacisol which contains a calcrete layer and Eutric Cambisol which has high saturation of Base, hence it has high fertility. The Etosha Pan is a salt pan, lying on a basement of impermeable limestone that has been eroded away by wind to form a depression into which floodwater flows and then evaporates, leaving salt deposits (Mayr, 2012). Clay pans in the area are much smaller depressions in sandy areas that are permeable to water, and the soils are rich in nutrients (Mayr, 2012). The sands and loam soils of the central and northern part of the Cuvelai are much lower in salinity and provide quiet good soils for crop cultivation (Zandler, 2011).

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CHAPTER 3: METHODOLOGY

3.1 Description of the study area

The Namibian part of the Cuvelai-Etosha basin (CEB) is situated in the north-central part of Namibia and it covers an area between the Okavango and Kunene Rivers and ends up in the Etosha pan. It lies within the Omusati, Ohangwena, Oshikoto and Oshana region. Cuvelai Etosha basin is the Namibian part of the Cuvelai river catchment with perennial tributaries occurring only in Angola. In Namibia, the tributaries are ephemeral and only flow during the rainy season (Hamukoto, 2013). CEB is about 97600km² and it stretches from E 14°10’ to 18° latitude and S 17°20’ to 20° longitude. The basin is made up of shallow pans known as Iishana, which form a shallow ephemeral river system draining up south in the Etosha pan. The CEB basin is sub divided into four sub-basins by the Ministry of Agriculture, Water and Forestry (MAWF): Tsumeb, Cuvelai-Iishana, Niipele-Odila and Olushandja sub-basin. The Etosha pan is the center point for drainage with an elevation that ranges from 1,071 m to 1,086 m and has an area of 6,133 Km² (McGinley, 2007).

3.2 Climate

The climate of the Cuvelai Etosha basin is characterized as semi-arid and has high annual temperatures which lead to high evaporation and low annual rainfalls. The mean annual rainfall in the area ranges from 400 mm/a in the west up to 600 mm/a in the east. About 90% of the rain falls between October and March with its maximum in February (Hamukoto, 2013). January and December are the hottest months with an average temperature of approximately 26˚C. The average minimum and maximum temperature for summer is 18˚C and 35°C. During winter (in June and July) the temperature decreases to as low as 7°C, even if temperatures close to zero may also recorded, (Hipondoka, 2005). Day temperatures in winter may rise up to 17 ˚C. Hipondoka (2005) distinguished three climatic periods based on precipitation and temperature stratification: A wet and hot season starts in January and last until April. A dry and cold season follows from May to August, before the dry and hot season commences in September and lasts until December.

3.3 Land use

The Cuvelai Etosha basin is the most densely populated area in Namibia, where most inhabitants live in rural communities and depend on subsistence agriculture. Land use in the study area is generally influenced by soil and vegetation patterns. Human settlement has strongly influenced the vegetation pattern in the region. Zandler (2011) reported that, since the 19^{th} century, large forested areas have been transformed into arable lands and grazing areas. Wood is used as fuel (by 91% of the ovawambo households), for building (84% of Ovawambo homesteads are mostly made up of wood) and fencing (Kangombe, 2010). About a third of the land belongs to the communal farmers. The agricultural activities are mostly dominated by livestock farming such as goats, cattle, donkeys, horses and poultry and crop farming such as Mahangu, Sorghum and Maize. Most of these agricultural activities are rain-fed and only a very few farmers practice small-scale irrigation by using groundwater. The land surrounding a particular given homestead is fenced off reserved for private grazing, leaving limited land in the surrounding for open access grazing.

3.4 Fauna

Seasonal changes have marked effects on all life in the Cuvelai Etosha-Basin. When heavy rains fall, which is normally in the second half of summer (January to March), most of the pans get filled with water and the Oshanas begin flowing from north to south bringing rich harvests of fish with them (Zandler, 2012). Large terrestrial animals include wild animals that are found in the Etosha national park such as Elephants, Springboks, Rhinos, Kudus, Impalas, Lions and Cheetahs just to mention a few. Small wild animals include Ground squirrels, Mice, Rats, Birds, Poccupines. Domesticated animals include cattle, goats, donkeys and Horses. These animals are all supported and housed by the Cuvelai Etosha basin.

3.5 Geology

The Cuvelai-Etosha Basin is part of the intra-continental Ovawambo Basin which is an extensive sedimentary basin which is part of much larger Kalahari Basin covering parts of Angola, Namibia, Zambia, Botswana and South Africa (Miller, 1997). The intra-continental Ovawambo basin was formed during the post-cretaceous tectonic development of southern Africa (Hamukoto, 2013). The geology in the whole CEB is mainly covered by three main events; Damara sequence, Karoo sequence and Kalahari sequence with Precambrian rocks being the basement. The Damara sequence is deposited on top of the late Precambrian basement rocks is during Lower Permian to Jurassic overlaid by the Karoo sequence sediments and volcanics which is up to 360 m thick (Miller, Pickford, & Senut, 2010). This is then covered by about 600 m thick, semi-consolidated to unconsolidated sediments of the Kalahari Sequence.

3.6 Materials and methods

3.6.1 Vegetation

The data was collected from the following 3 areas (Oshigambo Ephemeral River in Oshikoto region, The Oshanas in Oshakati, Oshana region and Okashana area, Oshikoto region.) In each of the 3 areas (Oshigambo, Oshakati and Okashana), 3 sampling sites were selected at random and in each of these sample sites, 3 transects were laid at a distance of 40 m apart, parallel to the flow of the water in these water bodies.

The line intercept method was used. A line of 50 m was laid along the sampling site (parallel to the water flow) and each woody plant that touches the line was identified and recorded in the field data sheet. The plants' life form/structure (shrub or tree) was also noted using height classes. Trees were recorded in the following categories of height classes and based on these were described in various growth forms as follow: High tree > 20 m, Tall tree 10-20 m Small tree 5-10 m and Low tree 2-5 m. Shrubs were recorded in the following categories: Tall shrub 1-2 m, Small shrub 0.5-1 m and Low shrub < 50 cm.

A 1 m x 1 m quadrant was used to estimate the herbaceous cover in the categories of 0-25%, 26-50%, 51-75% and 76-100%, using visual estimation as per Braun-Blanquet method. The ground cover was taken at every 10 m on the line intercept. That is at, 10 m, 20 m, 30 m and 40 m of the 50 m line transect. In each quadrant, three most dominant species were recorded together with their abundance (number of individuals of each species). Species which could not be identified in the field (names unknown) had their samples collected for later identifications. Grass and Herbaceous plants were identified with the help of the National Herbarium of Namibia staff members and the use of identification books such as Grasses of Namibia book written by Muller (2007), whereas the woody species were identified using several plant identification books such as Le Roux and Muller's Field Guide to the Trees and Shrubs of Namibia.

Figure 1. Sampling of vegetation and herbaceous cover

3.6.2 Soils

Samples of soils were taken from the three sampling areas. 1. Oshigambo ephermeral river in Oshikoto region. 2. Oshanas in Oshakati area, Oshana region. 3. Okashana area, Oshikoto region.

In each of the 3 areas (Oshigambo, Oshakati and Okashana), three sites were selected at random and per each site, three transects were demarcated parallel to the water flow at a 40 m distance apart. In each transect, a soil sample was taken on the surface using a hand auger. This makes a total of 9 soil samples collected per each area (Oshigambo, Oshakati and Okashana). The soil moisture content, electrical conductivity, soil pH and the water holding capacity were measured in the UNAM Geology Department laboratory. The soil moisture content was measured as follow: the samples were weighed on the scale balance; the mass of each sample was recorded (wet mass/g). The samples were then put in the oven and dried at 105˚C for 24 hours. After 24 hours, the samples were allowed to cool down for 10 minutes and then they were weighed again. The mass of all the samples after they were dried in the oven was recorded (dry mass/ g). The moisture content was then determined as wet mass (g)-dry mass (g).

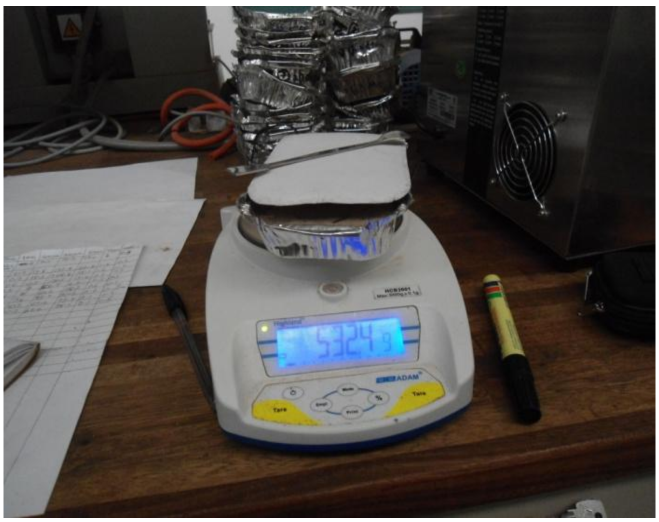

Figure 2. Weighing soil samples.

Figure 3. Drying soil sample in the oven.

The soil pH was measured as follow: 20 g of soil was weighed on the scale balance and put in 250 ml bottles. 50 ml of De-ionised water was added to the bottle with 20 g of soil. The bottles were shaken vigorously to mix the soil and the de-ionised water well. The solutions were allowed to stand for 2 hours. The pH was then measured using a pH meter. The Electrical Conductivity was measured in this solution as well, using the Electrical Conductivity meter. The measurements were then recorded.

3.7 Data manipulation and analysis

A cluster analysis was used to determine whether there were similarities in species composition between the sites. This was done through the following steps. The sites with no observations were excluded from the analysis. Data matrix (5x16) was generated and the data was transformed using log(x+1) because it contained zeros. The similarity matrix was computed using Bray Curtis similarity measure and a Dedrogram was generated using group average clustering algorithm

CHAPTER 4: RESULTS

At Oshigambo, the pH level ranged slightly from acidic 6.1 to 8.8 which is alkaline. Site 4 had the highest pH (8.8) than all the other sites and site 9 had the lowest pH level (6.1). The soil temperatures ranged between 14.1 ˚C to 14.6 ˚C. The Electrical conductivity ranged between 47.4 µs/cm to 8.5 µs/cm (table 1).

Table 1. Soil characteristics recorded in each site in Oshigambo area

Site	pH in de-ionised water	Temperature ˚C	EC µs/cm
1	6.8	14.3	12.4
2	6.7	14.4	18.6
3	6.9	14.4	8.5
4	8.8	14.2	47.4
5	7.9	14.1	24.0
6	6.9	14.1	11.2
7	6.6	14.5	5.8
8	6.9	14.4	10.0
9	6.1	14.6	9.6

Table 2 shows that the pH of the soil varied from neutral to alkaline. Site 4, 5 and 6 had the lowest pH levels (7.7) while site 9 had the highest pH level of 9.6 which is alkaline. The soil temperatures ranged between 15.4 ˚C to 15.7 ˚C. The Electrical conductivity ranged between 571.0 µs/cm to 2.9 µs/cm. Site 9 had the highest EC followed by site 7 while site 2 and 3 had the lowest EC.

Table 2. Soil characteristics recorded per each site in Oshakati area

Site	pH in de-ionised water	Temperature ˚C	EC µs/cm
1	7.9	15.7	4.3
2	7.8	15.6	2.9
3	7.8	15.6	2.9
4	7.7	15.4	4.2
5	7.7	15.5	3.0
6	7.7	15.4	3.5
7	8.0	15.5	160.5
8	8.2	15.5	63.2
9	9.6	15.6	571.0

As shown in table 3, soils recorded in all sites had an alkalinity pH level. Site 3 had the lowest pH level (9.4) and site 2 had the highest pH level (10.7). The temperatures varied from 17.3 ˚C to 18.0˚C. The highest EC recorded was 651.0µs/cm and it was recorded in site 3 while the lowest EC recorded was 3.4µs/cm and it was recorded in site 1.

Table 3. Soil characteristics recorded per site in Okashana area

Transect	pH in de-ionised water	Temperature ˚C	EC µs/cm
1	10.5	17.4	3.4
2	10.7	17.3	12.3
3	9.4	17.6	651.0
4	10.3	17.7	17.6
5	10.5	17.6	20.2
6	10.5	17.5	22.5
7	10.2	17.8	4.9
8	10.0	18.0	6.3
9	10.4	18.1	22.5

The *Eragrostis* species, *Odyssea Paucinervis*, and *Aristidia* species were recorded in more than 3 transects for each area. Species like *Cleome kalahariensis (Schinz) Gilg & Benedict Cyperus, compressus L, Corchorus trilocularis L, Indigofera flavicans Baker var.flavicans, Pogonarthria squarrosa* and *Zornia glochidiata Dc.* were only recorded once in any area were they occurred (table 4).

Table 4. Three most dominant species in each area per transect. Two or only one species in the cell indicates that the transect only contained two or one species.

	3 most dominant species recorded per area.		
Transect	*Oshigambo*	*Oshakati*	*Okashana*
1	*Odyssea paucinervis (Nees) stapf.* *Eragrostis trichophora coss. & durieu* *Aristidia meridionalis Henrard*	*Odyssea paucinervis (Nees) stapf.* *Willkommia sarmentosa* *Aristida adscensionis*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*
2	*Odyssea paucinervis (Nees) stapf.* *Dicoma tementosa cass.* *Indigofera flavicans Baker var.flavicans*	*Odyssea paucinervis (Nees) stapf.* *Eragrostis porosa*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*
3	*Eragrostis trichophora coss. & durieu* *Dicoma tementosa cass.* *Pogonarthria squarrosa*	*Odyssea paucinervis (Nees) stapf.* *Eragrostis porosa* *Panicum coloratum var. coloratum*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*
4	*Eragrostis trichophora coss. & durieu* *Schimtdia kalahariensis. stent* *Zornia glochidiata Dc.*	*Eragrostis porosa* *Aristida adscensionis* *Dichanthium annulatum var.papillosum*	*Odyssea paucinervis (Nees) stapf.*
5	*Aristidia meridionalis Henrard* *Dicoma tementosa cass.* *Eragrostis trichophora coss. & durieu*	*Odyssea paucinervis (Nees) stapf.* *Willkommia sarmentosa* *Eragrostis porosa*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*

6	*Eragrostis viscosa (Retz.) Trin.* *Eragrostis trichophora coss. & durieu* *Acanthospermuim hispidum*	*Odyssea paucinervis (Nees) stapf.* *Willkommia sarmentosa* *Eragrostis porosa*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*
7	*Eragrostis lehmanniana Nees var. cahunantha (Pilg.) de Winter* *Cleome kalahariensis (Schinz) Gilg and Benedict* *Cyperus Compressus L.*	*Eragrostis porosa* *Odyssea paucinervis (Nees) stapf.* *Panicum coloratum var. coloratum*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*
8	*Schimtdia kalahariensis. stent* *Eragrostis trichophora coss. & durieu* *Corchorus trilocularis L.*	*Eragrostis porosa* *Aristida adscensionis* *Eragrostis trichophora coss. & durieu*	*Odyssea paucinervis (Nees) stapf.*
9	*Odyssea paucinervis (Nees) stapf.* *Acanthospermuim hispidum* *Schimtdia kalahariensis. stent*	*Dichanthium annulatum var.papillosum* *Eragrostis porosa* *Panicum coloratum var. coloratum*	*Odyssea paucinervis (Nees) stapf.* *Panicum lapines*

Site 4, 7 and 9 had about 30% similar species composition while site 7 and 9 had about 45% similar species composition. The other sites (1, 3, 6, and 8) did not have any similarity with any site and the other species that are not shown on the figure contained no woody species (figure 4).

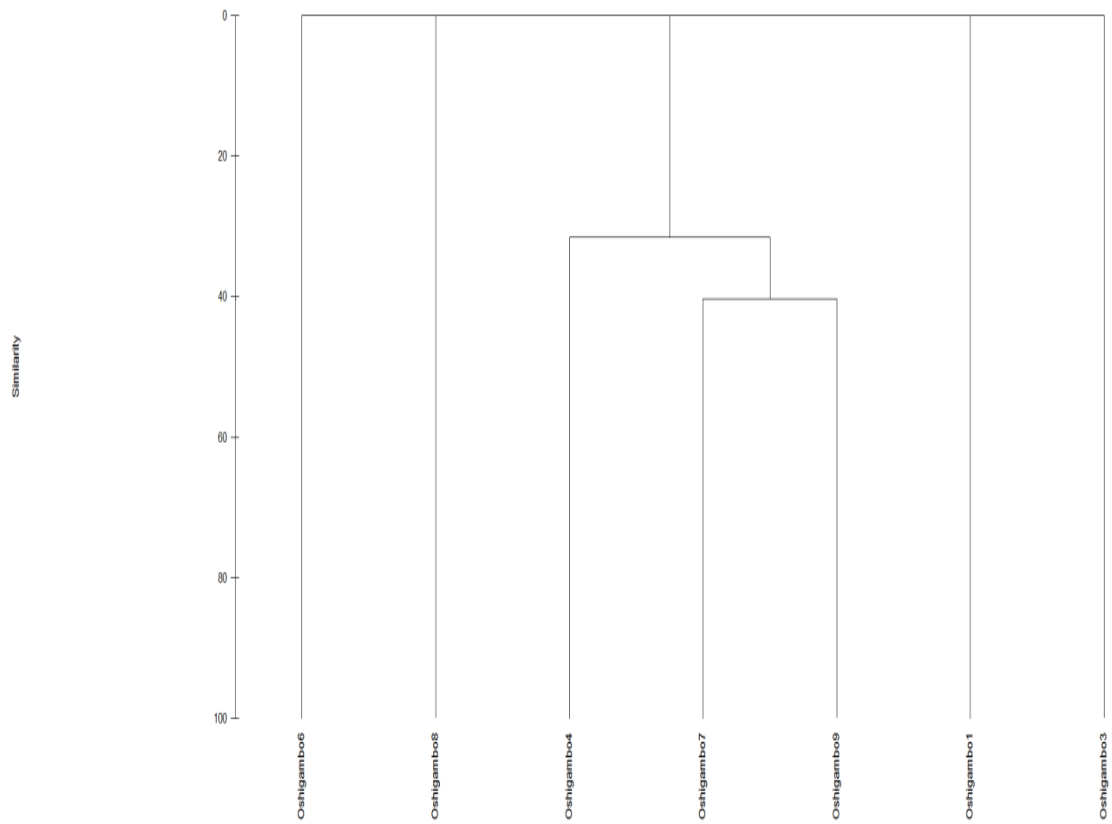

Figure 4. Cluster analysis showing similarities in species composition (%) of woody plants between different sites.

In Oshigambo, site 2 had the highest amount of moisture content (28.2 g), followed by site 8. The lowest moisture content was recorded in site 7 and 9 respectively (figure 5).

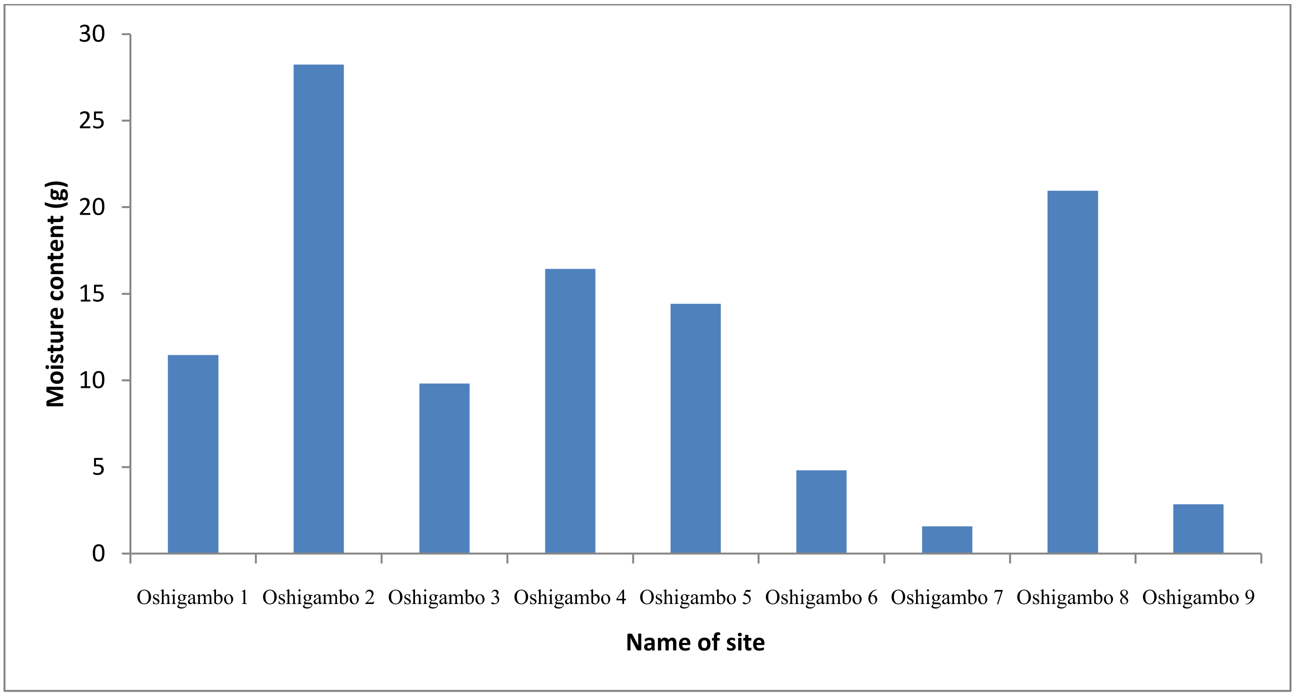

Figure 5. The amount of moisture content (g) recorded per each site in Oshigambo area.

In Oshakati, the highest moisture content was recorded in site 7 and 8 and the lowest moisture content was recorded in site 9 and 2 (figure 6).

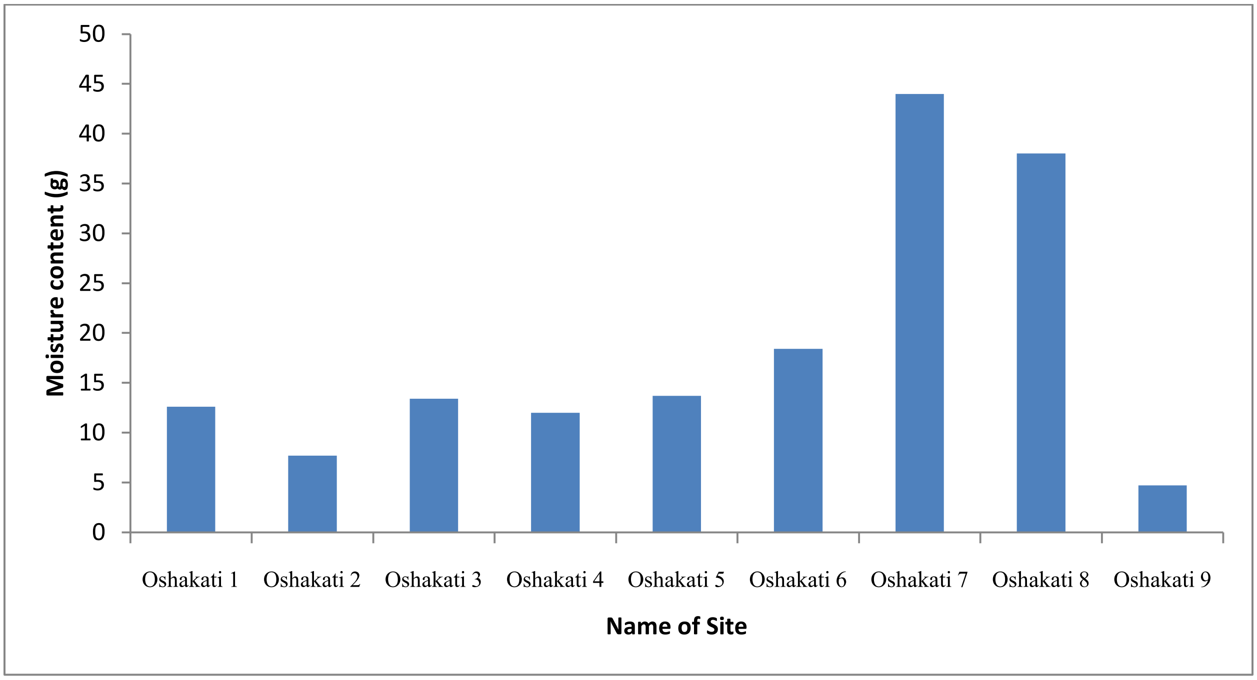

Figure 6. The amount of moisture content recorded in each site in Oshakati area.

In Okashana, site 8 had the highest moisture content (69.3g), followed by site 5 (66.2 g) and the two sites with the lowest moisture content were site 3 and 1 with 4.4g and 7.1g respectively (figure 7).

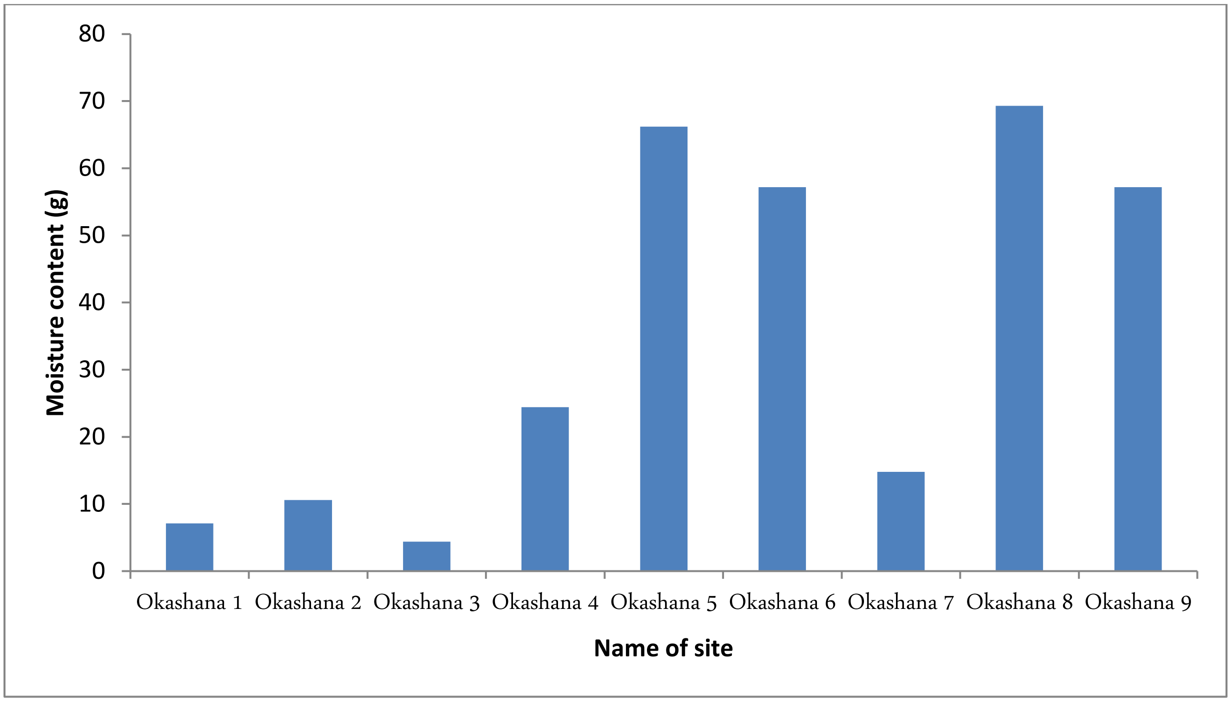

Figure 7. The amount of moisture content recorded per each site in Okashana area.

In Oshigambo, site 6 had the highest ground cover, followed by site 3. The lowest average grass was recorded in site 8 and 7 respectively (figure 8).

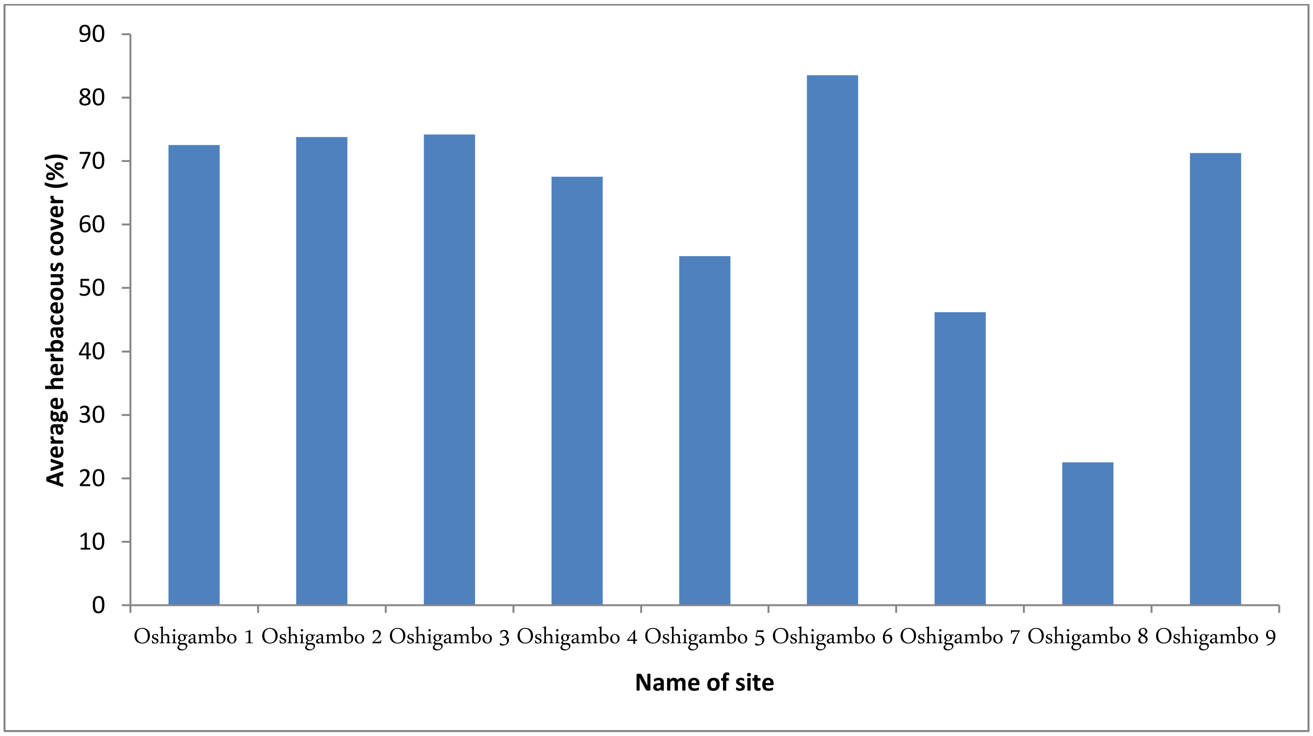

Figure 8. Average herbaceous cover (%) recorded in each site in Oshigambo area.

In Oshakati, the average grass cover in all sites was between 30% and 65%. Site 9 had the highest average grass cover followed by site 7 (57.5%) while the lowest average grass cover was recorded in site 8 (figure 9).

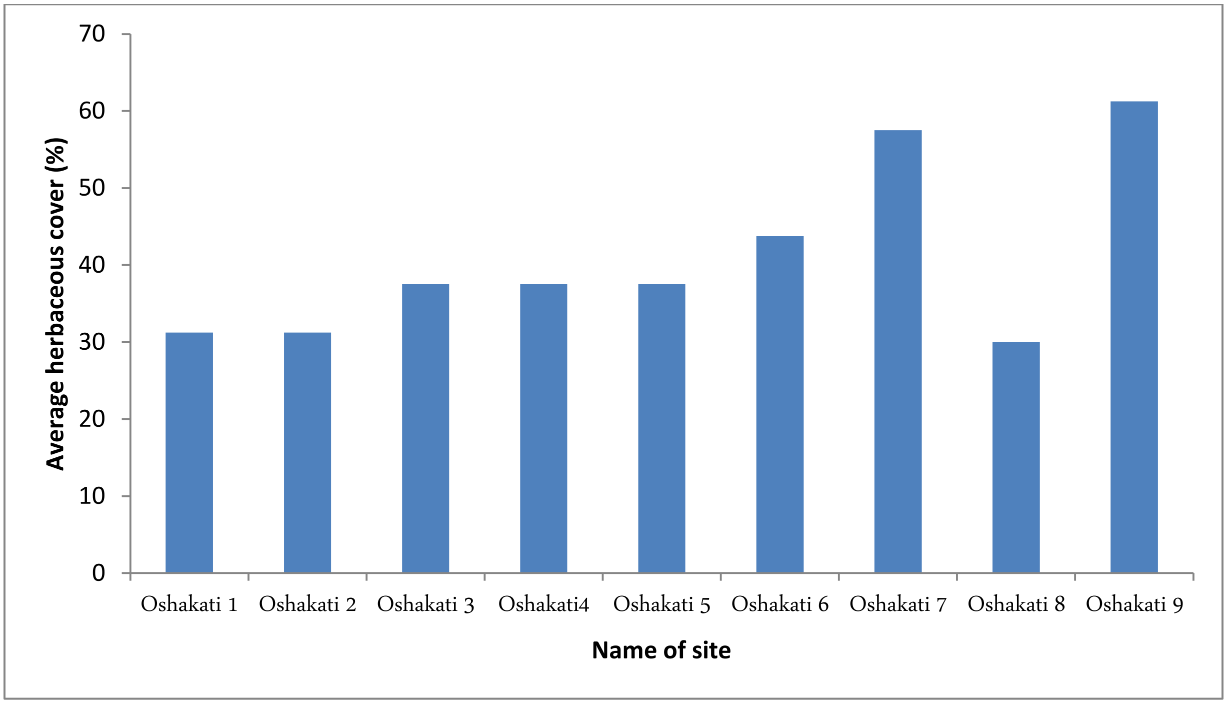

Figure 9. Average herbaceous cover (%) recorded in each site in Oshakati area.

In Okashana, site 8 and 7 had the highest average cover (80 and 79.5 %) respectively while the lowest average grass cover was recorded in site 6 and 5 (33 and 36%) respectively, (figure 10).

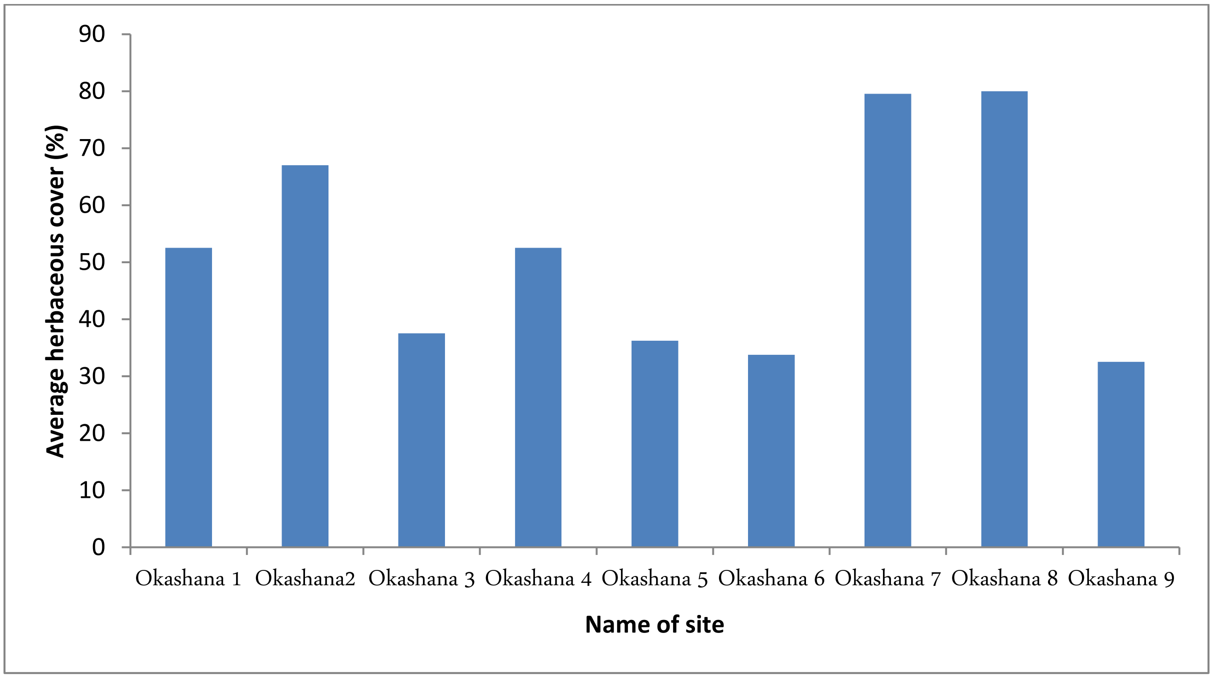

Figure 10. Average grass cover (%) recorded in each site in Okashana area.

CHAPTER 5: DISCUSSION

5.1 Vegetation characteristics

5.1.1 Species composition

According to the cluster analysis, sites 4, 7 and 9 share about 30% similar species composition of woody vegetation. Site 7 and 9 share about 45% similar species composition. The species recorded in these three sites were *Acacia karoo, Acacia erioloba, Acacia hebeclada, Terminalia prunioides, Albizia antlemantica, Diospyros mespiliformis, Ficus sycomorus, Euclea divinorum, Combretum imberbe* and *Combretum hereroense.* Most of these species growth forms that were recorded were short shrub, tall shrub, small tree, short tree or high tree. Every species grows according to the environmental conditions it is exposed to and each species is adapted and tolerate a particular environmental conditions. Most of the species found in these sites can grow in very dry conditions and they are drought resistant; they have long taproots that enable them to absorb water and nutrients from deep down underground. The species are also matured plants (growth forms ranging from short shrub to high tree). On small scale, difference and similarity in species composition is influenced by the soil properties (Rankin, Semple, Murphy, & Koen, 2007). Sites 7 and 9 have similar levels of pH and they have low moist content. This may then explain why the two sites have 45% similar vegetation species composition because the types of species that grow in these sites are able to adapt and tolerate low moisture content (occurring in both sites) and their roots are able to spread and collect water from deep down underground. Therefore, this indicates that, the species that grows in these two sites require and tolerate the same soil properties and environmental conditions.

The other sites did not have any similarity in species composition of woody vegetation. This could be due to that, each one of them has different soil characteristics from the others and each species in these sites require and can only tolerate a particular range of environmental conditions which is only offered by the area where it was found. Therefore, the species could not be found in any other site apart from that site. Vegetation species availability can also play a major role because some propagules of a particular species are not available in all areas due to inability to disperse/ dispersal barriers (Rankin, et al., 2007). This limits some species from growing in areas even where the soils, climate and other environmental conditions are able to support them.

For the non-woody vegetation, some species such as *Eragrostis* species, *Aristidia* species and *Odyssea paucinervis* were recorded in many sites. This can be due to that, these species (*Eragrostis*, *Odyssea paucinervis* and *Aristidia*) are generalists and can grow in any soil type (at any pH and electrical conductivity level) with poor water availability and can tolerate a wide range of environmental conditions. Other species were only recorded once and this can be due to that, they specialists and only grow on a particular soil type with particular soil properties because specialist species can only tolerate a narrow range of environmental conditions (Townsend, Begon, & Harper, 2003) or these are rare species that are not just found everywhere but only found in certain places where they can tolerate the environmental conditions. It could also be that, some species such as *Corchorus trilocularis L*, *Zornia glochidiata Dc* and *Cyperus compressus* are annuals and by the time of data collection (May-July), these species have already reached the end of their growing seasons and only a few were remaining/found, thus only one individual recorded. *Pogonarthria squarrosa* species indicate poor nutrients soils and are found in disturbed areas (Muller, 2007), therefore in other areas where it was not found these did not contain poor soils or the areas were not disturbed. *Odyssea Paucinervis* species grows in saline areas and are tolerant of salt (Nadoo, Somary, & Achar, 2008) therefore this could be that, the areas where these species were found had high salt concentration that other species cannot tolerate.

5.1.2 Herbaceous cover

Site 6 and 3 has the highest average herbaceous cover in Oshigambo, in Oshakati; the sites with high average herbaceous cover were in site 9 and 7 while in Okashana it was site 8 and 7 which had the highest average grass cover. Herbaceous cover is influenced by soil properties (pH, Electrical conductivity, moisture content, nutrients). Herbaceous plants can tolerate different soil properties, some herbaceous plants can occur in abundance at different concentration of soil properties. In Oshigambo, Figure 1 shows that site 6 and 9 have the lowest moisture content but still has high average herbaceous cover with the soil pH of 6.9 and 6.1 respectively. In Oshakati area, the sites with high average herbaceous cover all had the pH level of alkaline. Most of the sites with high herbaceous cover also had low moisture content. This could be due to that, the types of species that grows in these sites grows well and are able to tolerate low moisture content as long as the pH, electrical conductivity and nutrients are in good concentrations (Champson & Atkison, 2000). Species recorded in these sites (shown in table 4) are *Eragrosti*s species, *Odyssea Paucinervis, Schimtdia kalahariensis, Acanthospermum hispidum, Dichanthium annulatum var.papillosum, Panicum species* and *Aristida adscensionis.* Most of these species are indicators of land degradation and are usually found in disturbed areas (Muller, 2007). This means that, the sites where these species were found are disturbed and therefore these species were able to grow well in abundance without competition from other species that are unable to grow on disturbed land.

In each area (Oshigambo, Oshakati and Okashana), the sites with high herbaceous cover seem to have the same pH level (Table 1 to 3) with a high variation in moisture content same applies to the sites with low herbaceous cover. This then indicate that in these areas, the herbaceous cover depends or is mostly influenced by soil pH and than by moisture content because some sites had high moisture content but the herbaceous cover is low and others had low moisture content with high herbaceous cover. High herbaceous cover in these sites could be due to that, species in each of these areas (Oshigambo, Oshakati and Okashana) prefer or require a particular soil pH which is slightly acidic in Oshigambo and alkaline in Oshakati (around 8 pH level) and not more than 10.2 pH level in Okashana. Therefore the sites that did not have the required soil pH had low herbaceous cover. Electrical conductivity does not seem to have an effect on herbaceous cover since no clear pattern to show any influence was observed. Another reason can also be that the sites that had high average herbaceous cover were not really or heavily disturbed (grazed by animals) as the other sites that have low herbaceous cover reduced by livestock grazing on them. For example, species such as *Aristida adscensionis, Acanthospermum hispidum* are unpalatable (Muller, 2007) by animals and therefore are able to occur in abundance because they were not reduced by grazing.

The growth forms of species also influence the total surface that can be covered. Some herbaceous plants such as *Odyssea Paucinervis* grow spreading to the ground surface (horizontal) and this causes a large surface area to be covered hence high herbaceous cover, whereas other species grow upright (vertically). This may explain that species that were found in sites with high herbaceous cover grows in a horizontal way covering a large surface area on the ground.

5.2 Soil characteristics

5.2.1 Moisture content

Moisture content in Oshigambo was high in site 2 and 8 (figure 1), in Oshakati high moisture content was recorded in site 7 and 8 while in Okashana high moisture content was recorded in site 8 and 5. This could be due to that, the soils in these sites were wetter and had good water holding capacity than the other sites. Wetness depends largely on the porosity of a soil (Lawrence & Hornberger, 2007). Site 2 and 8 of Oshigambo area were inside the river bed, hence high moisture content. Site 7 and 8 of Oshakati had more dark clay soils than the other sites, clayey soils which have a high porosity generally, have larger water content than do sandy soils (Lambe & Whitman, 2006). This may explain why these sites have high moisture content, because the soil types are clayey and have high porosity and thus hold high amount of moisture than other soil types. In site 8 and 5 of Okashana, high moisture content could be explained by clay soils in the area and that there was still water on the surface. The amount of water that can be stored in soil is reduced by actual evapotranspiration (Zandler, 2011). Therefore, sites with low moisture content could be caused by high evapotranspiration and availability of sandy soils which have poor water holding capacity.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study showed an overall variation in species composition and herbaceous cover among the three different ephemeral water bodies in the Cuvelai Etosha Basin, as seen from the cluster analysis that only revealed few similarities.

Oshigambo area has pH level ranging from slightly acidic to alkaline. The most dominant woody species recorded were *Acacia karoo, Combretum hereroense* and *Diospyros mespiliformis*. Most dominant herbaceous species recorded were *Odyssea paucinervis, Eragrostis trichophora* and *Schimtdia kalahariensis.* The highest average herbaceous cover recorded in Oshigambo was 74.5%. This could be explained by the pH level that ranges from slightly acidic to alkaline and low moisture content which was between 1.5 (g) and 21 (g) since most of these species are able to grow well in that particular pH level and tolerate low moisture content which they are adapted to. In Oshakati area, the most 3 dominant herbaceous species were *Odyssea paucinervis, Eragrostis porosa* and *Aristida adscensionis.* No woody species were recorded. The highest average herbaceous cover recorded was 65%. The vegetation species in this area are more adapted to pH levels between neutral and alkaline, electrical conductivity of 2.9 µs/cm to 571.0 µs/cm and moisture content between 4.7 (g) to 44 (g). In Okashana, only two herbaceous species were recorded which were *Odyssea paucinervis* and *Panicum lapines*. No woody species were recorded. This area has the highest moisture content recorded of 69.3g. The highest average herbaceous cover recorded was 61.3%. This is due to the pH level which is alkaline and high salt concentration which these species are adapted to. Sites that were heavily grazed by livestock had low herbaceous cover than the other sites that were lightly grazed.

6.2 Recommendations

Extensive studies need to be done especially on the rooting depth of different vegetation. This will be able to show whether certain plants have an influence on soil properties for example how the rooting depths influence the soil water availability, how certain plant roots can influence the soil pH, soil structure, and nutrient contents. Further analysis on the association between vegetation and soil characteristics has to be carried out in order to determine whether there is a clear association between certain soil characteristics and specific vegetation species composition.

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