Impact of cultivation on soil and species composition of the Monavale Vlei, Harare.

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A thesis submitted in partial fulfillment of the requirements for the degree of Masters in Tropical Resource Ecology.

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July 2006

ABSTRACT

The study assessed the impact of cultivation on soil properties, species richness (grass and herbaceous) and species composition on the Monavale vlei. The results revealed that cultivation had an impact on nitrogen levels, organic carbon, moisture content, silt content and clay content of the soil ($P<0.05$). Bulk density, sand levels, pH, phosphorous and species richness did not differ significantly between the sites ($P>0.05$). Cultivation however had an impact on the community structure and species composition of the cultivated and uncultivated sites. Cultivated sites were dominated by weedy species. Biodiversity measures on the vlei indicated that avian species were the most diverse followed by plants and lastly insects.

ACKNOWLEDGEMENTS

My gratitude goes to Prof Magadza who was my supervisor for his guidance and helpful comments. I wish to thank Prof Moyo for his ideas in shaping up this project. I also thank Dr Kativu for his assistance in identifying plant species and for his useful comments.

I am indepted to Mrs Wakeling for allowing me to conduct my research on the Monavale vlei. I am also grateful to Mr Muropa of Monavale for the assistance he offered during my sampling. Special thanks go to Mrs Fortune Shonhiwa of WWF and Mr A. Chigona for offering the revelant material for the literature review. I also thank T. Samukange, S. Mudyazhezha and T. Mutyavaviri for the time we spent together in the field. Not forgetting my other course mates for their encouragement.

Finally I would like to thank my husband Cosmas for all the support, financial assistance, encouragement and time he spent accompanying me to the field.

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1.0 Introduction

1.1 Background

Wetlands are important resources with multi-functional purposes. Wetlands vary, and are differently defined across the globe. The most commonly used definition is that of the RAMSAR Convention (1971) which defines wetlands as "areas of marsh, fern, peatland 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."

Wetland ecosystems in Zimbabwe include dambos (mapani), flood plains, artificial impoundments and pans. They are estimated to cover an area of 1.28million hectares of the country, with 20% of them in communal areas (Mharapara *et al.,* 1997). Globally, wetlands account for 6% of the land surface (Turner, 1991). These ecosystems share a common feature of retaining excess water, long enough to influence land use, soil characteristics and life forms that flourish within them.

In developing countries, wetlands are a critical natural resource. They perform a range of environmental functions, and provide numerous socio-economic benefits to local communities (Dixon and Wood, 2003). Wetlands are important for the recharge of rivers. In Zimbabwe, where water is relatively scarce, for example, they serve as reservoirs for dry season water supply (du Toit, 1994). In addition they serve to purify and improve river water quality (Bowden, 1987; Breen *et al.,* 1997). They also provide important habitats for many bird and animal species (Bowden, 1987).

Despite these important functions, research and policy markers have ignored wetlands because they have often wrongly regarded them as wastelands that can be sacrificed for the sake of increasing social welfare (Seyam *et al.,* 2001) or as natural resources with no need for management (Mharapara *et al.,* 1997). This has consequently led to their loss. In addition, many people do not have a full understanding of the benefits that are offered by wetlands. Instead of protecting them or engaging in their sustainable use, wetland use has resulted in loss of these habitats. Inefficient management and inconsistence of government policies regarding development and conservation has also led to loss of wetlands (Seyam *et al.,* 2001). Although there are various laws, which prohibit utilization of wetlands, many people are not aware of them.

Whilst wetlands can provide water, food and increased incomes through productivity as compared to uplands, their utilization should not be done at the expense of the hydrology or environmental condition (Mharapara *et al.,* 1997). Excessive pressure on wetlands results in degradation and eventual loss (Mharapara *et al.,* 1997). Different land uses, which include cultivation, grazing and housing development, can negatively affect these ecosystems.

1.2 Justification

The degradation of wetland resources in Zimbabwe both in urban and rural areas is approaching unacceptable levels (Mkwanda, 1995). Degradation is due to several activities, which include cultivation, grazing, and other human activities. Cultivation of wetlands in the country dates back to the Iron Age (Katerere, 1994), and is still a common practice, especially in the communal areas. Infact, wetland cultivation (in particular dambo) is a tradition of the rural people of Zimbabwe (Matiza , 1992). Of late, however, cultivation of wetlands has also become a common practice in urban areas. This can be attributed to population increase and increased urbanisation. Due to their small size, however, dambos are generally vulnerable to cultivation (Breen *et al.,* 1997). Thus the practice becomes a threat to wetland existence. Wetland ecosystems in urban areas are also reclaimed for settlements, industrial activities and rubbish dumping.

Though the cultivation of wetlands can make a key contribution to food and livelihood security in the short term, there are concerns over sustainability of this utilization (Dixon and Wood, 2003). Field observations in Zimbabwe have shown that cultivation, animal grazing and water abstraction (Chigona, 2005) are contributing to the deterioration of wetlands. These observations, however, often lack scientific evidence except for the studies by Chigona (2005).

It is, therefore, important for research to concentrate on the management of wetlands through maintenance of those areas that have not been disturbed. It is also important to assess whether restoration of the disturbed areas is possible. This restoration can be implemented by first understanding the impact of a disturbance on the different wetland characteristics through scientific studies. These studies should try and assess the impacts of human activities such as cultivation on soil physical and chemical properties, water table fluctuations and plant, bird, insect and animal species richness, as these are the key variables affected by these activities.

The present study aims at investigating the impact of cultivation on wetland soils and plant communities.

1.3 Aim

The primary objective of the study is to assess the impact of cultivation on wetlands as a basis of restoration and management of degraded urban wetlands.

1.4 Objectives

a) To evaluate the herbaceous species composition and richness of Monavale Vlei;

b) To investigate the impact of cultivation on herbaceous species richness and composition;

c) To investigate the impact of cultivation on organic carbon and soil properties;

d) To record avian species that utilize the wetland; and

e) To record insect species found on the wetland.

1.5 Research questions

a) What is the richness and composition of grass and herb species on Monavale vlei?

b) What is the effect of cultivation on grass and herb species richness and composition, and soil properties

c) What is the diversity of insect and bird fauna of the wetland?

1.6 Hypotheses

a) There is no difference in plant species richness and composition on cultivated and uncultivated areas on the vlei.

b) There is no difference in structure, organic carbon, bulk density, pH, conductivity, moisture holding capacity, phosphorous and nitrogen of soils in the cultivated and uncultivated areas of the vlei.

1.7 Study Area

Monavale vlei

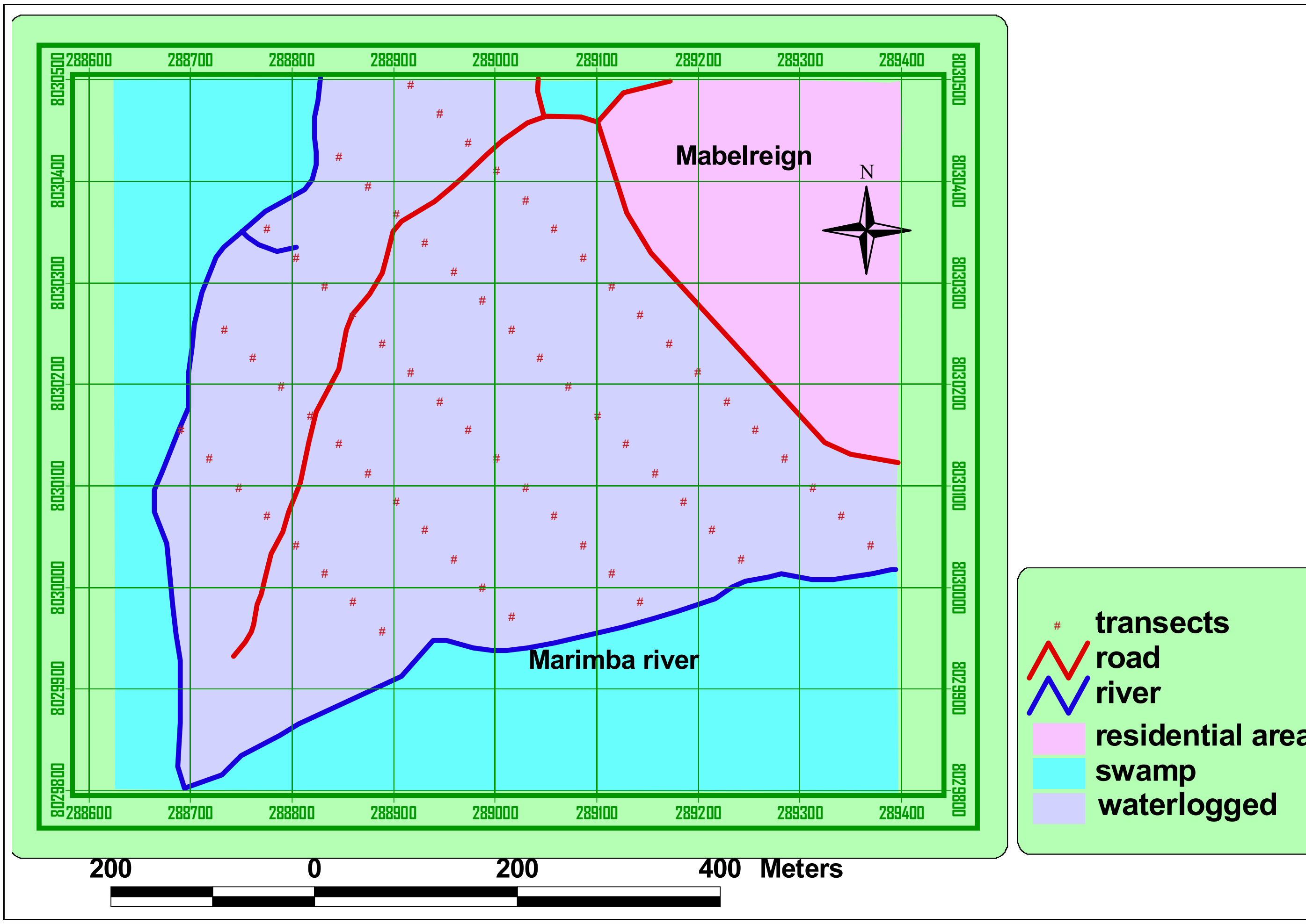


Figure 1.7. The Monavale vlei area.

The waterlogged areas constituted the sampling sites. Coordinates are in metres based on the Universal Transverse Mercator (UTM) zone 36 south. Refer to overleaf for the Google Earth map.

Monavale vlei is located in Monavale residential area of Harare. It lies between 288600 and 289300 E and 8030500 and 8029900 N and covers an area of approximately 40ha. Soils of Monavale vlei generally belong to the Fersiallitic group. According to Nyamapfene (1991) these soils are grouped as 5E.2.

Like most vleis found in the country Monavale has been under cultivation for some years. However for the 2005-2006 agricultural season, cultivation had been banned and so the recently cultivated areas were cultivated in the rain season of 2004-2005. The area is now under protection.

2.0 LITERATURE REVIEW

2.1Wetlands as centres of biodiversity

Biodiversity refers to the natural variety and variability among living organisms, the ecological complex in which they occur naturally, and the ways in which they interact with each other and the physical environment (Redfor and Ritcher, 1999). Wetland ecosystems are rich centres of biodiversity. They sustain large populations of interacting organisms (Maltby, 1986; Hails, 1996). These organisms include invertebrates, rodents, avian species, insects, plant species, reptiles and vertebrate species.

The ability of wetlands to sustain such large populations of living organisms depends on ecological features and processes characteristic of these ecosystems. Water level fluctuations and vegetation distribution patterns make a range of continuously changing wetland habitats which are available at different times of the year to the aquatic, terrestrial and arboreal animals (Hails, 1996). In addition, many wetlands have abundant food resources in form of living plants and their decomposition products. Thus they can sustain a diverse collection of organisms that are dependent on one another. Besides providing food, breeding sites and shelter for resident species, wetlands also provide habitats by serving as resting and feeding stations along migratory flyways for different avian species (Dugan, 1990; Hails, 1996). These species benefit from the diversity of organisms and favourable conditions found in wetland areas. The entry into wetlands by these visiting species tends to change the diversity of animals that may be seen in wetlands from time to time.

The seasonal fluctuations that occur in wetlands are important as they influence grazing and feeding behaviour of terrestrial animals. The seasonal drawdown in water levels permits the movement of these animals that include livestock into wetland areas where they can feed on the abundant plant resources. Thus wetland areas become more important during dry seasons and drought years.

2.2 Wetland threats, loss and consequences on biodiversity

Wetlands are fragile ecosystems, susceptible to different environmental changes. Their continued existence depends on the maintenance of a delicate balance between water, soils and vegetation (Turner, 1986). This balance is critical since a change in any of the features can result in changes in the wetland ecosystem. This will affect the different life forms found on the wetland. Wetland ecosystems are usually threatened either by an increased rate of erosion or lowering of the water table (Turner, 1986; Ingram, 1991; Owen, 1994). Lowering of the water table leads to gradual drying out while an increased rate of erosion may lead to either gradual downstream removal of the deposits or rapid destruction by gullying (Mharapara, 1995).

Erosion and lowering of the water table are usually a result of either human activities or natural disturbances. Infact studies indicate that both natural as well as human factors are important in changing the wetland characteristics (Turner, 1986; Ingram, 1991). In Zimbabwe for example the causes of desiccation and channel incision in wetlands is not clear, as it is difficult to judge whether climatic changes or human activities have a greater impact (Whitlow, 1985; Rattray *et al.,* 1953). Therefore it is important to consider these two together when studying wetland degradation.

The loss of a wetland site can imply a loss of fundamental resources provided by these ecosystems. It can result in the reduction and loss of some habitats (FitzGibbon, 1999), thus disturbing those animals, which live on them. This can also disrupt the movement of other organisms into the wetland. For those species, which are confined to one wetland, it implies that if that particular wetland is destroyed then the species is lost (Maltby, 1986). Therefore for those wetland areas that contain rare or endangered species such kind of a loss can lead to extinction of the species. Wetland loss hence can result in biodiversity loss.

2.3 Wetlands and their agricultural importance

Wetland farming is an integral part of the agricultural system (Bell *et al.,* 1987), though in some areas, it is important in complementing dryland farming, (Scoones, 1991). The cultivation of these ecosystems therefore increases the food security especially in rural area communities where people depend mainly on agriculture for their survival. In some rural areas of Zimbabwe the early maize from wetlands is important in alleviating the 'hunger period' in the early midy rainy season that is January to March. Wetland agriculture also opens up opportunities for cash cropping of vegetables and other products in the non-agricultural season. In Zimbabwe and Zambia the dry season gardening wetlands is an important earning activity, especially for women (Bell *et al.,* 1987; Priestley and Green**,** 1954). Another key to the successful exploitation of these ecosystems is the flexibility of the cropping system (Ingram, 1991), thereby allowing the cultivation of a variety of crops at different times of the year.

The utilization of wetlands is due to their characteristics as compared to the adjacent uplands. Wetness and fertility have been recognized as the dominant characteristics influencing the utilization of wetlands (Mharapara, 1995; Matiza, 1992). In addition the fact that they remain wet far into the dry season makes them valuable for agricultural activities (Ingram, 1991, Mharapara, 1995). Therefore the hydrological properties of wetlands, in particular the availability of water during the dry season are important factors in determining the agricultural potential of a wetland (Mkwanda, 1995).

Besides retaining moisture in the dry season, wetland soils are more fertile than the surrounding top soils (Thompson, 1969; Mharapara, 1995). The accumulation of soil fines and their constituent nutrients in wetland soils is generally believed to increase their physical and chemical fertility when compared to adjacent slopes (Ingram, 1991). The high content of organic matter in wetlands further enhances their fertility (Rattray *et al.,* 1953; Turner, 1985). Wetland soils therefore often represent fertile patches, with a high potential for agriculture.

The production of crops in wetlands is sometimes however restricted by some physical conditions, which exist in the wetland. The heavy textures of soils and water logging (Ingram, 1991), can affect the growth of some crops. Weed infestation, flooding, acidity and pest and disease attacks are other crop production constraints in wetlands. Frosty conditions also tend to cause damage in some wetland crops (Law, 1978; Whitlow, 1980).

2.4 Legislation and the use of wetlands in Zimbabwe

Cultivation of wetlands in Zimbabwe has been a long standing tradition such that there were no laws prohibiting the utilization of these ecosystems. Laws were only passed after the arrival of white farmers who were draining wetlands so as to get maximum yields from these ecosystems. This led to the passing of the Natural Resources Act (1952) and the Water Act (1927).These Acts were meant to protect wetlands from the degradation caused by cultivation. Thus, these ecosystems were designated as grazing areas not suitable for agriculture (Mharapara, 1995).

Currently the Environmental Management Act (EMA) restricts development on wetland areas. The Act states, "no person should reclaim or drain any wetland, disturb by any means or introduce an exotic plant species into wetlands unless authorized" (Government of Zimbabwe, 2003). Despite the existence of the different legislation wetland utilization continue to increase both in rural and urban areas. As a result there has been a progressive loss of wetland ecosystems in Zimbabwe during the past decades (Owen, 1994) through drying.

2. 5 Wetland cultivation and its effects

Disturbances of the soil because of cultivation practices alter the different wetland characteristics. The infiltration capacity, soil moisture retention, rate of runoff and erosion, pH of the soil and the availability of nutrients can be affected. The effects however, tend to vary with the type of cultivation (Kowal, 1969; Whitlow, 1983; Staples, 1939) and the type of soils. In addition, wetland soils are easily broken down when subjected to crop monoculture and deep ploughing with heavy machinery (Bell *et al.*, 1987).

2.5.1 Soil organic matter

Chemical properties of wetlands as well are altered by cultivation. Cultivation usually aerates the wetland causing a change from a seasonally anoxic to a largely oxic soil regime (Roberts, 1988). Upon oxidation some chemical changes occur. These affect soil reaction and consequently the availability of nutrients as well as other soil properties.

Cultivation of wetland soils generally causes a decline in organic matter (Roberts, 1988; Brady, 1974; Knops and Tilman, 2000; Bell *et al.*, 1987). Wet soils accumulate organic matter because decomposition is slowed and organic matter is preserved by anoxic conditions. During cultivation drainage improves aeration and causes the organic matter to decline gradually (Troeh *et al.,* 1991). According to Thompson and Troeh, 1978 oxidation losses cause organic soils to shrink at rates of 2 to 5cm per year when they are drained and cropped.

Besides those losses attributed to oxidation, it is important to note that following cultivation much of the plant material is removed such that little finds its way back to the soil. On the other hand in uncultivated areas all the organic matter produced by the vegetation is returned to the soil hence organic matter levels remain high. The decomposition of organic material reduces productivity and also the amount of water that could be retained in the soils (Whitlow, 1980).

2.5.2 Soil pH

Soil pH is a measure of how acidic or alkaline the soil is. It is important because it influences the solubility of nutrients within the soil (Killham, 1994). Some agricultural practices have been shown to alter pH values of the soil significantly. The addition of ammonium-based N fertilizers lowers pH and makes the soil more acid (Moody, 2006). The decomposition of wetland vegetation sometimes lowers the soil pH due to the accumulation of acids (Thompson and Troeh, 1978).

2.5.3 Phosphorous

The availability of phosphorous is dependent on the soil pH and the presence of mycorrhizal fungi (Killham, 1994). At either high or low pH the availability of phosphorous is reduced because of the formation of insoluble complexes. Cultivation can destroy the mycorrhizal fungi resulting in a reduction of the available phosphorous. On the other hand cultivation can aerate and warm the soil resulting in the decomposition of organic matter and hence the release of organic phosphorous (Moody, 2006). In most cases however, phosphorous tends to decline due to cultivation. Thompson and Troeh, 1978 reported that during the first few years of cultivation many soils have adequate amounts of phosphorous but these later become depleted hence the need of phosphorous fertilizer.

2.5.4 Nitrogen

Plant production depends on readily available mineralizable nitrogen. The availability of nitrogen is influenced by natural and anthropogenic changes (Bowden, 1987).

Agricultural activities lead to a decline of total nitrogen in the soil (Chan *et al.*, 1992; Dalal and Mayer, 1986a; Thompson, 1950). In a study carried out by Dalal and Mayer, (1986b) total nitrogen declined over the 20-25 years of cultivation period studied. Saikh *et al*., (1998) also reported significant losses of nitrogen in the first 5-15 years of cultivation. These losses could be accounted for by crop N removal, leaching below the root zone (Dalal and Mayer, 1986b), increased decomposition of organic matter and erosion (Knops and Tillman, 2000; Thompson and Troeh, 1978).

2.5.5 Bulk density

Variation in bulk density of the soil depends on the soil texture, organic matter content and management practices (Thompson and Troeh, 1978; Brady, 1974). Cultivation usually increases bulk density of the soil. This can occur following loss of organic matter from the soil. Organic matter is important since it increases aggregate stability to a soil. Thus it is important in reducing the bulk density. Compaction due to heavy machinery also tends to increase bulk density of the soil.

2.5.6 Hydrological properties

Wetland cultivation can alter the hydrological properties of wetlands. Most wetland soils are usually waterlogged such that their cultivation requires drainage so as to allow aeration and proper root development. This poses a danger of lowering the water table. Turner 1986 reported a rapid fall in the water table early in the dry season following wetland drainage. Since the retention of moisture is one of the most important characteristics of these ecosystems, this can lead to their degradation. The effect however varies with soil types such that on sandy soils it is more pronounced because of the slow movement of water in them (Ingram, 1991).

Some crops can lead to loss of water from the wetland ecosystem. Rattray *et al,* 1953 in Zimbabwe observed that winter crops increased evapotranspiration losses in wetlands. He observed that ploughing exposes the damp soil surface to high evaporation rates of the dry season. Begg (1986) on the other hand suggests that maize evapotranspires at a lower rate than normal wetland plants. Its cultivation therefore might be considered as a means of conserving ground water.

2.5.7 Wetland vegetation

Wetland vegetation provides food, habitats to the different wildlife species that use the wetland. Cultivation however, often results in the removal of the vegetation with a consequent reduction in plant cover. Seed banks are also degraded through prolonged drainage and artificially shortened hydro periods (Galatowitsch and van de Valk, 1994). Wetland erosion can also have an impact on the plant propagules in the wetland (Gleason *et al.,* 2002). The eroded soils can cover viable seed banks with a consequent reduction in species richness.

Wetland vegetation protects these ecosystems from the direct effects of rainfall (Bell *et al.,* 1987). Its clearance during cultivation reduces infiltration. This can result in more surface runoff hence increasing the risk of erosion in wetland ecosystems. Reduced infiltration also induces a greater degree of aridity (Whitlow, 1983) in wetlands. The removal of vegetation also tends to expose the wetland soil to erosion. Erosion leads to the deposition of sediments, which may make the wetland become shallower thereby reducing its storage capacity (Ingram, 1991).

2.6 Effects of burning

The burning of wetland vegetation is usually done to clear land for cultivation or to promote the regeneration of new grass. Intense fires however, have some deleterious effects on the different wetland properties. Intense burning can lead to a greater loss of organic matter. This may reduce the water holding capacity and moisture content of the soil as well as fertility (Ingram, 1991; Johnson, 1992). According to Whitlow, 1985 burning leads to a gradual decline in soil nutrients through erosion, leaching and loss of nitrogen by volatilization. In some instances, it can reduce the plant cover thereby exposing the soil to the desiccating effects of the sun and wind. The resultant effect is an increase in the evaporative losses from the soil surface. Fires can also kill part of the seed bank in the soil. This may reduce the diversity of plant species on the wetland.

2.7 Effects of cultivation on avian population

Wetlands provide habitats for different avian species. These species use wetlands for breeding, resting, rearing their young, as a source for drinking water, feeding, shelter and social interaction. The availability of water is a very important wetland feature in influencing the presence of a species. The presence or absence of vegetation, are additional features which are also important. An alteration in any of these will cause subtle, but distinct differences in bird use (http://waterusgs.gov).

Cultivation can reduce the availability of water and or can cause the openness of vegetation. In North America widespread draining and altering of wetlands has affected bird populations (http://waterusgs.gov). The reduction in waterfowl populations, which has occurred since 1930, has been attributed to the loss or degradation of wetlands (Bellrose and Trudeau, 1988). The degradation of wetlands results in habitat fragmentation and sometimes loss (Fletcher, 2003), hence can impact on avian populations. Reproduction and survival rates can be reduced.

The invasion of wetlands by some non-native plant species can cause profound changes in wetland structure. This could make the wetland become unsuitable for some bird species. In the mid-western United States many wetlands that have been invaded by Purple Loostrife (*Lythrum salicaria*) have been found to have lower avian diversity than other wetland types (Fletcher, 2003).

Besides human activities, climate change can also have an effect on the wetland structure if precipitation declines. This can result in altered water levels and habitat structure within wetlands, hence can affect the avian communities. Drought conditions can also cause habitat loss through transformation of small, shallower wetlands into grassland or open habitat. This in turn can affect bird populations.

3.0 Materials and Methods

3.1 Species composition on the vlei.

Five transects lines 400m long and 2m wide were laid parallel to each other on the vlei. These transects were laid from the northern direction towards the south (that is towards Marimba Stream) of the vlei. Positions of transect lines were permanently marked by a GPS (Global Positioning System). Their positions on the vlei are shown in the table below.

Table 3.1. Position of transects on the vlei.

Transect	Coordinates
1	$17^0$48’24.5”S,$31^0$00’38”E
2	$17^0$48’25.6”S,$31^0$00’35.6”E
3	$17^0$48’25. 7”S, $31^0$00’32”E
4	$17^0$48’26”S,$31^0$00’29. 4”E
5	$17^0$48’26”S, $31^0$00’25. 8”E

These transects were 80m apart. Twenty quadrats of 100cm×100cm were laid systematically along each transect line. The quadrats were 20m apart. A total of 100 quadrats were therefore sampled on the whole vlei. In each quadrat the different plant species were identified. After identification individual plant species were counted.

3.2 Comparison of cultivated and uncultivated areas.

The wetland was stratified into two areas, uncultivated and cultivated. From the uncultivated area, ten quadrats were chosen. The quadrats were chosen using a random number table. Two quadrats were picked along each transect as shown below.

Table 3.2. Quadrats picked in the uncultivated areas.

Transect	Quadrats
1	2, 8
2	3, 13
3	11, 17
4	7, 19
5	9, 16

For the cultivated areas, ten patches were randomly picked from the wetland and a 100cm×100cm quadrat was laid in each site. Soil sample collection and species richness were noted in each of the quadrats. Plant species were identified according to Gibbs-Russell *et al.,* (1991) with the help of Dr Kativu. Unidentified samples were taken to the National Herbarium. There they were identified with help of Mr Chapano.

3.3 Soil sample collection and analysis

Soil samples were collected from the 20 quadrats (that is 10 from the uncultivated and 10 from the cultivated areas). They were collected using a soil augur from a 50mm depth. The samples were collected from each quadrat at three randomly chosen points and were bulked into one sample. The sample would be packed into a khaki envelope to avoid drying up. These samples were analysed for soil texture, pH, conductivity, moisture content, total nitrogen, extractable phosphorous and bulk-density as according to Page *et al.,* 1982. Organic carbon was determined using the Walkley-Black method (Walkley and

Black, 1934). Analysis was done at the Analytical Services Laboratory in the Department of Soil Science and Agricultural Engineering at the University of Zimbabwe.

3.4 Insect sampling

Sampling of insects was carried out along the five transects, using the sweep-net method. The insects were preserved in alcohol. Identification was carried out according to Weaving (1977).

3.5 Bird sampling

A point count was used for sampling avian species on the wetland. Point-count stations were laid out in both the cultivated and uncultivated areas. Bird species visiting the Vlei were observed in the morning and afternoon over a five-day period. Identification of birds was carried out in the field according to Maclean (1993).

3.6 Data analysis

Soil variables of pH, conductivity, organic carbon, bulk density, nitrogen, phosphorous, moisture, clay, silt and sand were subjected to one way ANOVA to compare between cultivated and uncultivated sites, using MINITAB Version 12. The grass and herb, bird and insect species richness data were used to estimate the number of species that are found on the vlei. PCA was used to define species assemblages. Hierarchical cluster analysis was used to explore similarities among quadrats from the cultivated and uncultivated sites. PCA and HCA were performed using STATISTICA Version 6.

The species-environment relation was explored using CCA. This technique is a direct gradient analysis, which seeks relationships between vegetation and explanatory variables. The analysis was performed using CANOCO Version 4 for Windows package (ter Braak and Smilauer, 1997).

Shannon-Wiener index (H) was used to compare diversity between cultivated and uncultivated sites. The formula used to calculate the index is given below.

$$H = -\Sigma p_i \ln p_i$$

Where

H: Shannon-Wiener index

p_i: proportion of the *i*th species to the total count.

4.0 Results

The study on Monavale vlei revealed that cultivation could change the physical and chemical properties of soils. Results of One-Way ANOVA (Table 4.1) indicate that of 10 environmental variables assessed clay, silt, moisture, organic carbon and nitrogen were significantly different in the two treatments, ($P \leq 0.05$). Sand levels, pH, phosphorous and bulk density did not show significant differences between the two treatments ($P > 0.05$). Plant communities on the vlei were altered by cultivation as well.

Table 4.1. Summary of One-Way ANOVA for variables between sites

Variable	F-value	P-value
pH	0.15	0.706
Nitrogen ppm	5.88	0.026
Phosphorous ppm	1.35	0.261
% Organic carbon	30.25	0.00
Bulk Density (g/cm^3)	2.58	0.126
% Moist	26.41	0.00
% Clay	11.27	0.004
% Silt	9.5	0.006
% Sand	1.14	0.299
Species richness	1.28	0.273

4.1 Impact of cultivation on soil properties.

There was no significant difference in pH levels in the cultivated and uncultivated sites of the vlei (ANOVA F-0.15, p-0.706) (Fig 4.1.).

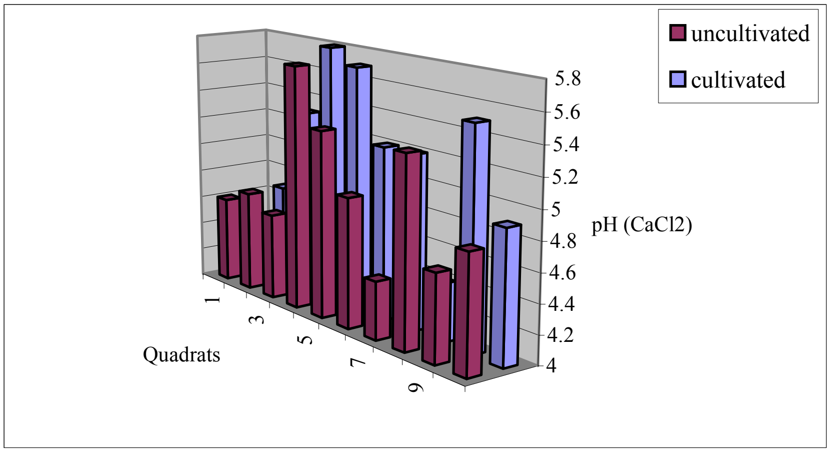


Figure 4.1. pH ($CaCl_2$) in the cultivated and uncultivated sites of the vlei.

Nitrogen levels were generally high in the uncultivated sites of the vlei and when subjected to ANOVA the observed differences were significant F-5.88, p-0.026 (Fig 4.2).

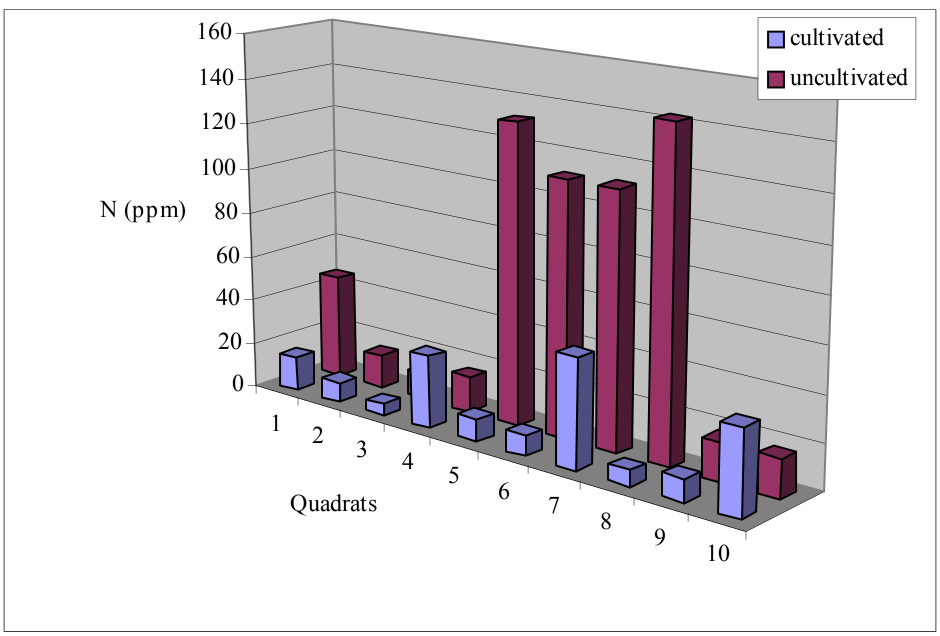


Figure 4.2. Nitrogen levels in the cultivated and uncultivated sites of the vlei.

Four quadrats in the cultivated sites and 3 in the uncultivated sites contained detectable amounts of phosphorous (Fig 4.3). Levels were high in the cultivated sites but the difference was insignificant (ANOVA F-1.35, p-0.261).

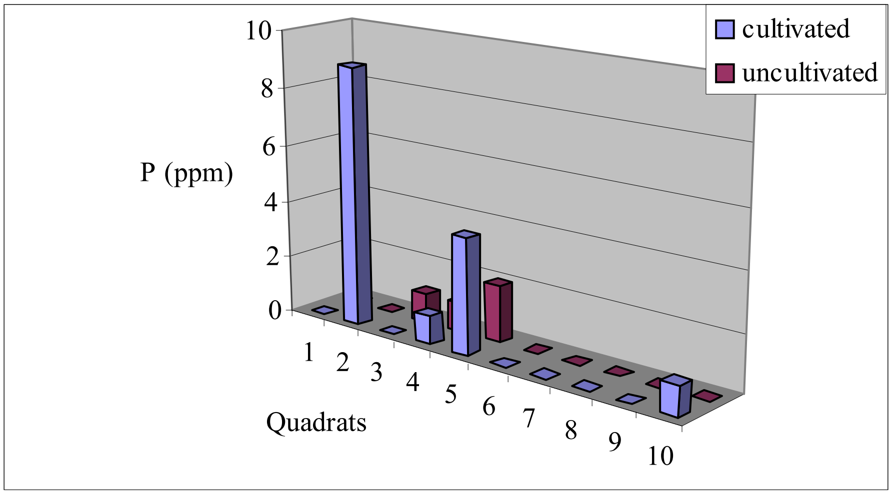


Figure 4.3. Phosphorous levels in the cultivated and uncultivated sites of the vlei.

Organic carbon was higher in uncultivated sites as compared to the cultivated sites (Fig 4.4.). The difference was significant (ANOVA F-30.25, p-0.00).

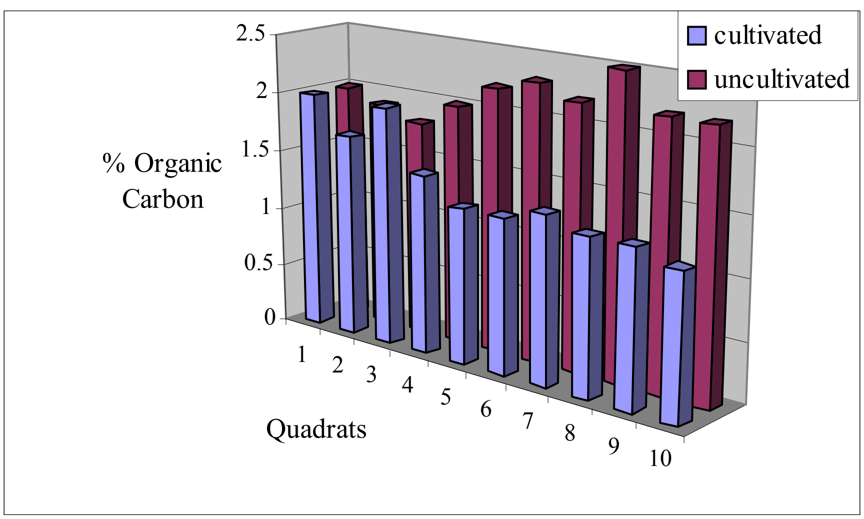


Figure 4.4. Percent organic carbon of the soil in cultivated and uncultivated sites of the vlei.

There was no significant difference in the bulk density of the two sites on the vlei (Fig 4.5.) and (ANOVA F-2.58, p-0.126).

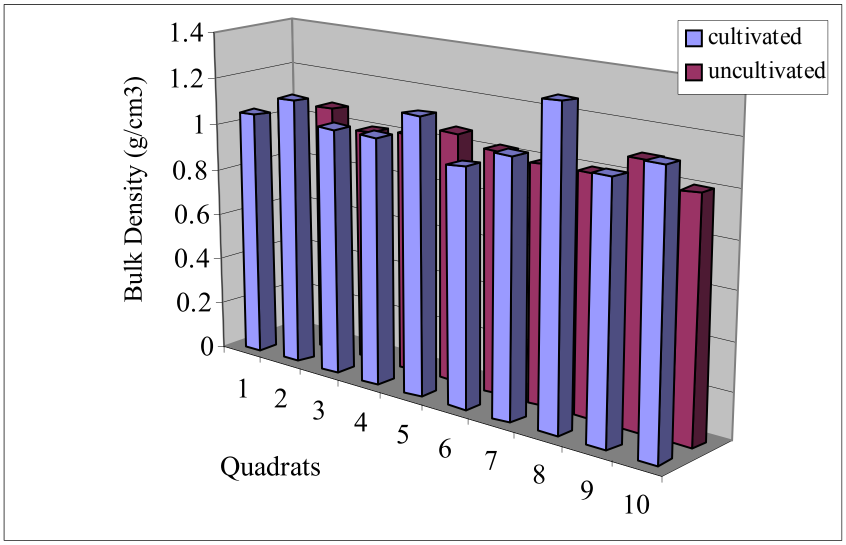


Figure 4.5. Bulk density of the soil in the cultivated and uncultivated sites of the vlei.

Moisture levels of the soil were higher in the uncultivated sites as compared to the cultivated sites of the vlei (Fig 4.6.). The difference was significant (ANOVA F-26.41, p-0.00).

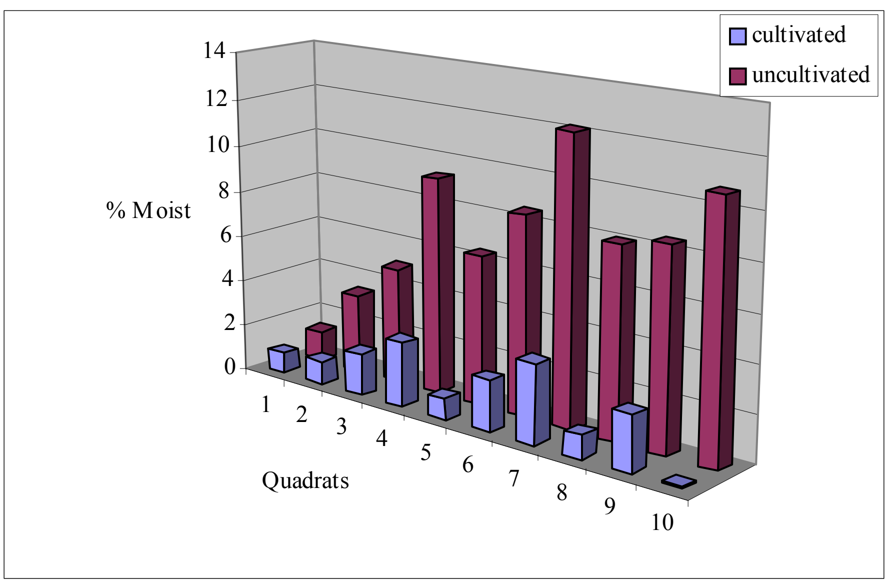


Figure 4.6. Moisture content of the soil in the cultivated and uncultivated sites.

The observed clay content in the uncultivated sites was higher as compared to the cultivated sites (Fig 4.7.). This observed difference was significant (ANOVA F-11.27, p-0.004).

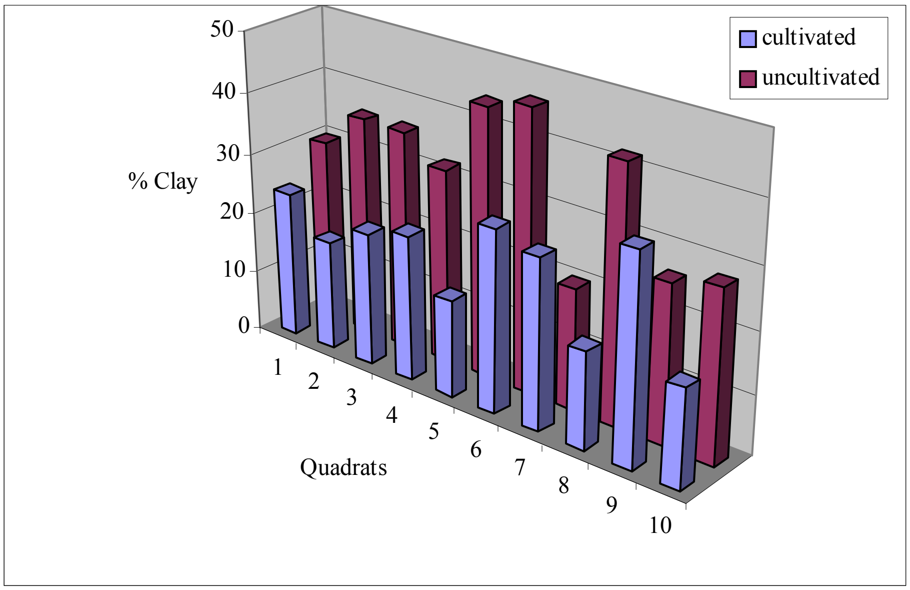


Figure 4.7. Percentage clay in the cultivated and uncultivated sites of the vlei.

Silt content was higher in the cultivated sites as compared to uncultivated sites (Fig 4.8.). The difference was significant (ANOVA F-9.58, p-0.006).

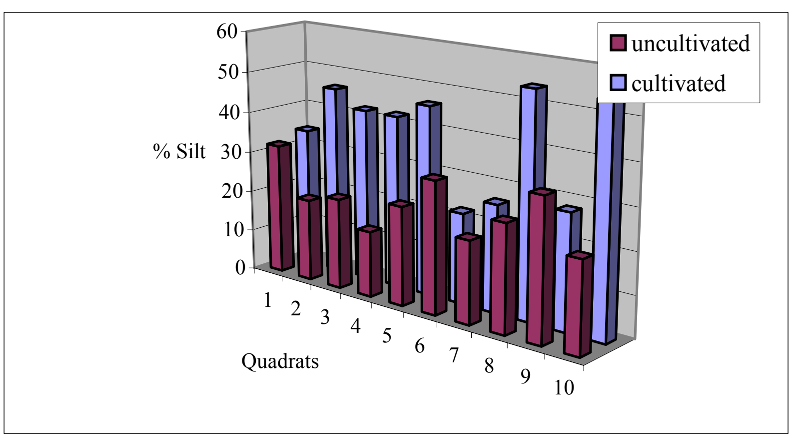


Figure 4.8. Percentage silt content in the cultivated and uncultivated sites of the vlei.

In quadrats 6, 7 and 10, sand content levels were high in the cultivated sites and in quadrats 4 and 9 levels were high in the uncultivated sites (Fig 4.9.). The observed differences however were not significant (ANOVA F-1.14, p-0.299).

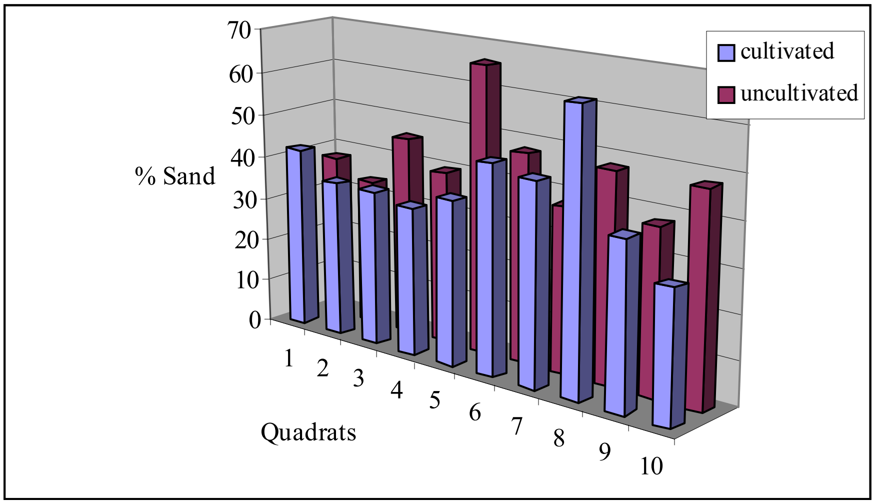


Figure 4.9. Percentage sand levels in the cultivated and uncultivated sites of the vlei.

4.2 Indirect gradient analysis

Principal Component Analysis of 10 environmental variables show factor 1 accounting for 28.93% of the variance (Fig 4.10.). The principal component largely represents a gradient from clay to silt content. Clay content is associated with moisture content and electrical conductivity on one end of the gradient while silt content, bulk density and phosphorous are associated with the other end of the gradient. This principal component therefore represents the cultivation gradient.

The second principal component accounts for 19.70% of the variance. It represents a gradient from electrical conductivity to organic carbon. Organic carbon is associated with nitrogen content, sand content and moisture content on one end of the gradient while electrical conductivity is associated with clay content on the other end of the gradient. From these observations this principal component therefore represents the uncultivated gradient.

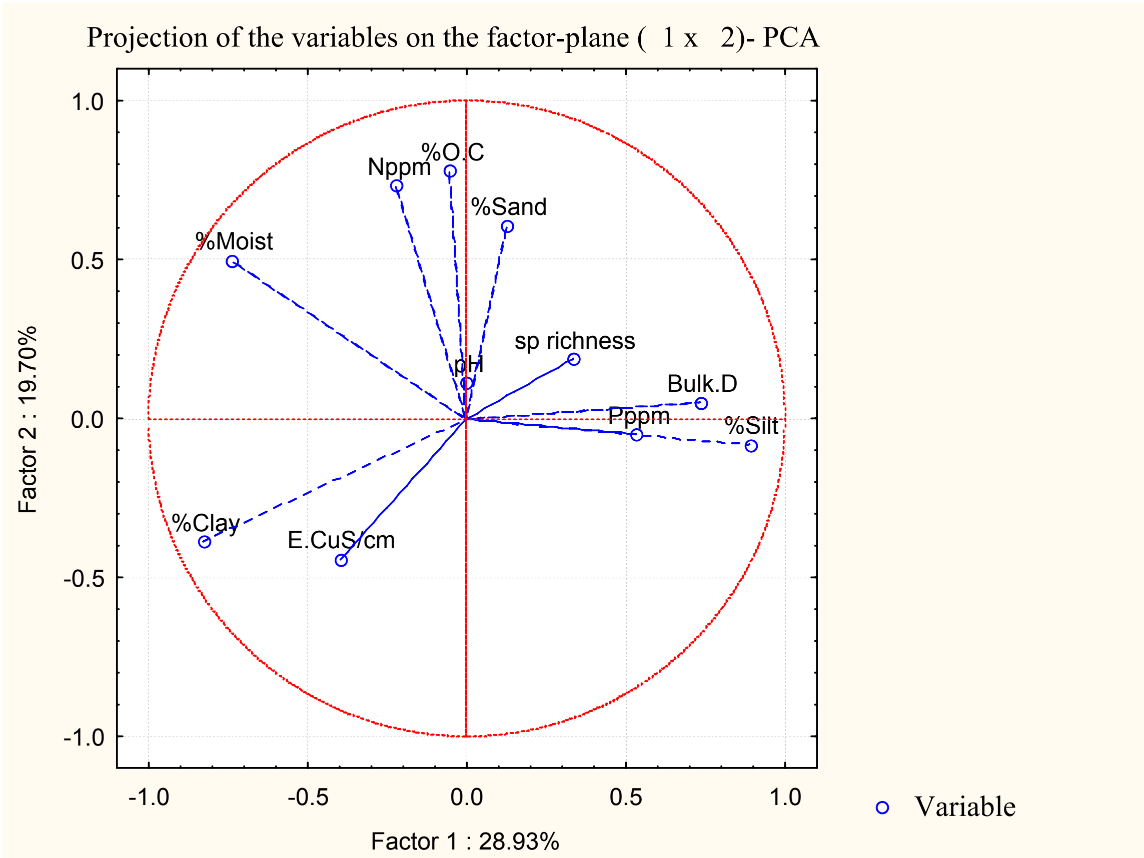


Figure 4.10. Projection of environmental variables on Axes 1 and 2.

4.3 Species richness and composition in the cultivated and uncultivated sites of the vlei.

There was no significant difference in the species richness between the cultivated and uncultivated sites of the vlei as shown on (Fig 4.11), (ANOVA F-1.28, p-0.273-Table 4.1.).

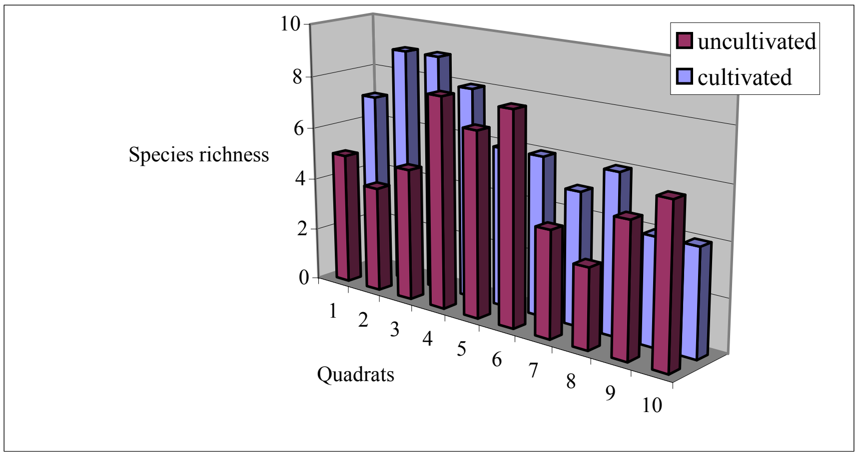


Figure 4.11. Species richness of the cultivated and uncultivated sites of the vlei.

Table 4.2. Biodiversity measures of the cultivated and uncultivated sites.

Measure	cultivated	uncultivated
Species richness (O)	29	25
(E)	52±0.05	66±0.05
Shannon-Wiener (H)	2.79	2.6
Evenness (E)	0.83	0.81

From the measures of diversity computed, the observed species richness was higher in the cultivated sites (29) as compared to 25 of the uncultivated sites. Species richness was however, higher in uncultivated sites (66±0.05). Shannon Wiener index of biodiversity and Evennness did not differ much between the two sites.

4.3.1 Community Structure of the Cultivated and Uncultivated sites

Results from Fig 4.12 and 4.13 revealed some marked differences in plant communities of the two treatments. *Leucas martinicensis* was the most abundant species in cultivated sites followed by *Bidens pilosa.* These two, which were the most dominating species, are both weeds. In the uncultivated sites *Scleria bambariensis* was the dominant species followed by *Heteropogon contortus, Eragrotis sp* and *Dicanthium annulatum*.

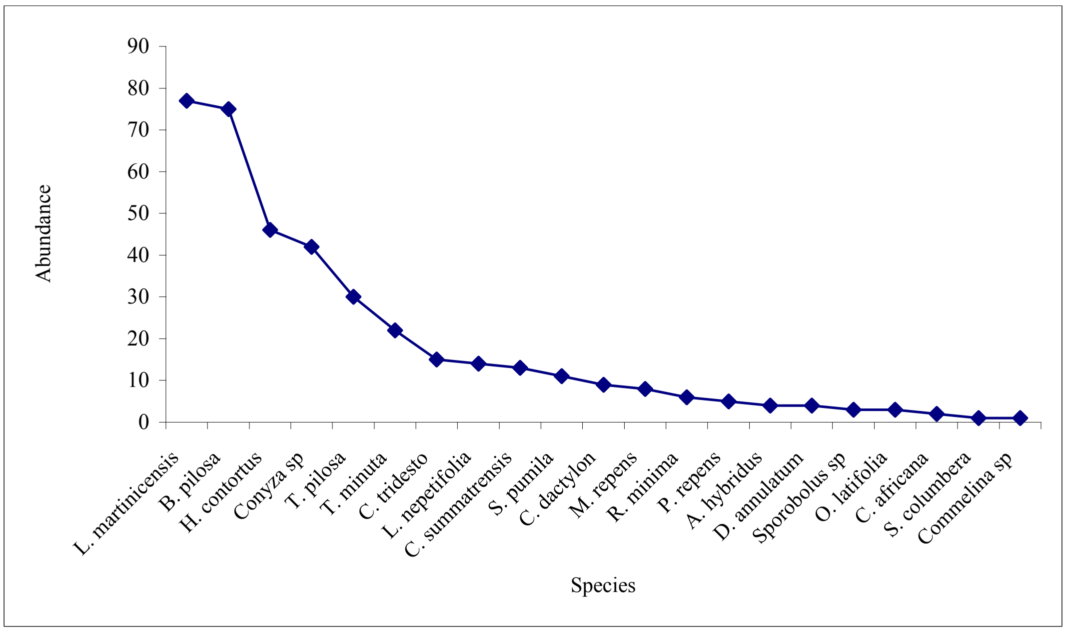


Figure 4.12. Importance curve of species in cultivated sites.

L. martinicensis was the most abundant species followed by *B. pilosa* in the cultivated sites.

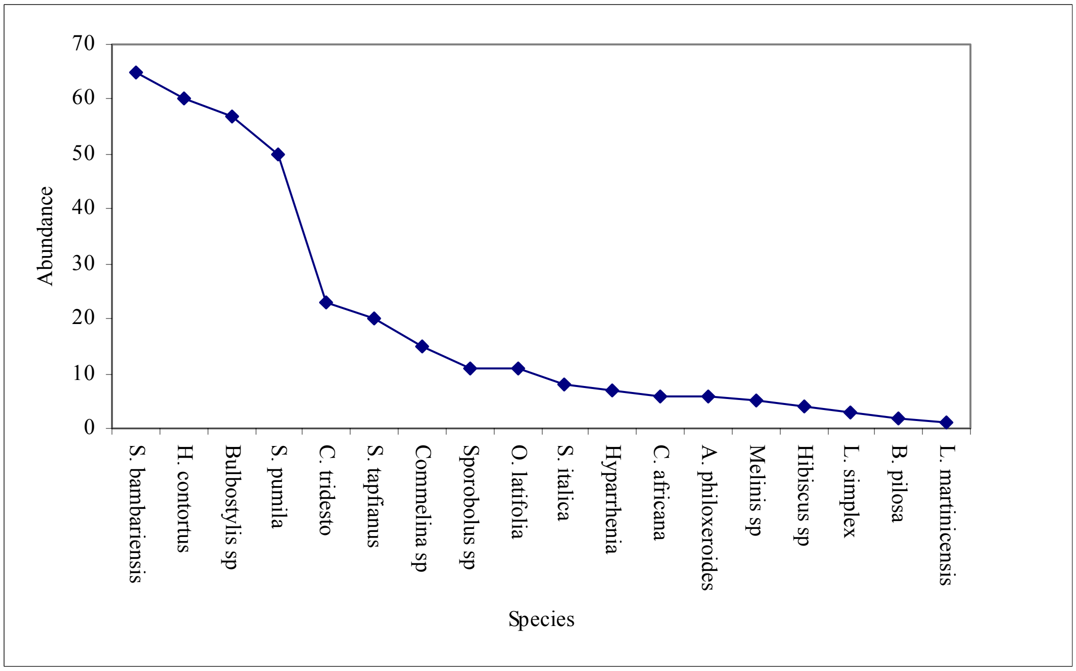


Figure 4.13. Importance curve of species in uncultivated sites.

S. bambariensis was the most abundant species in the uncultivated sites. It was followed by *H. contortus, Bulbostylis sp* and *Setaria pumila*.

4.3.2 Relationship of species between sites and among quadrats

The hierarchical cluster analysis shows the linkage of quadrats to form different groups (Fig 4.14). Groups B and C were linked by a shorter distance because they were more similar to each other. Both groups were found in the uncultivated sites. Group B was characterized by the occurrence of *Cochorus tridesto* and *Senna italica* while group C was characterized by the occurrence of *C. tridesto* and *B. pilosa*. *C. tridesto* is common in both groups hence they have a shorter linkage distance. Groups A, D and E contained quadrats from cultivated sites except quadrat 19. Group D was characterized by the occurrence of *H. contortus* and *D. annulatum*. The classification of quadrat 19 in this group was due to the presence of *H. contortus.* Quadrats 3 and 4 were classified together due to the presence of *R. minima, C.dactylon, B.pilosa* and *Sorghum bicolor*. Quadrats 1 and 2 occurred together in group E due to the presence of *L.martinicensis, Tephrosia sp,* *C dactylon* and *T. pilosa*. The abundance of all the species was almost similar in both quadrats hence were linked by a short distance.

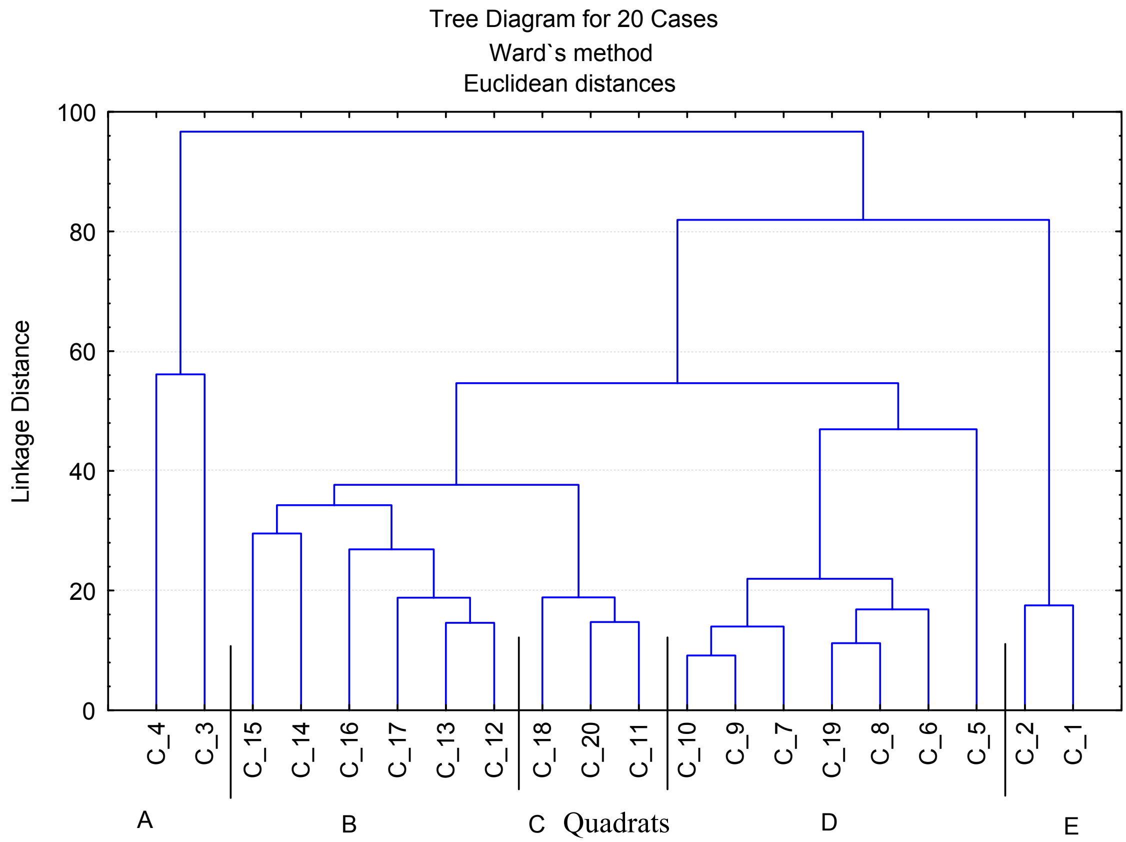


Figure 4.14. Cluster analysis based on species richness.

Hierarchical classification of the quadrats based on species composition produced 5 distinct clusters. Cluster A consists of quadrats, 3 and 4 and cluster E consists of quadrats 1 and 2. The four quadrats were located in the cultivated sites of the vlei but were clustered differently. This grouping could have been due to age of cultivation and moisture content of the soil. Quadrats 1 and 2 were recently cultivated and were found on the drier parts of the vlei. Cluster B consists of quadrats 15, 14, 16, 17, 13 and 12. These quadrats were found in the uncultivated sites of the vlei. The third cluster (C) consists of quadrats 18, 20 and 11, which were also located in uncultivated sites. Cluster D consists of quadrats 10, 9, 7, 19, 8, 6 and 5. All these quadrats were in the cultivated sites of the vlei except 19.

4.3.3 PCA species assemblages

The use of PCA to define species assemblages between the cultivated and uncultivated sites indicates the existence of two major groups within the data set. The first group is composed of species such as *R. minima, C. dactylon, A. hybridus, Tephrosia sp, and L. martinicensis.* These species are found on the positive end of Axis 1. A look at the PCA plot (Fig 4.10) of environmental variables reveals that these species were found in quadrats with high levels of silt content, high levels of phosphorous and increased bulk density of the soil. These variables and the species were found in quadrats located in cultivated sites. This is confirmed by the PCA plot of quadrats (cases) (Fig 4.15). It reveals the positive association of quadrats 1, 2, 3 and 4 with Axis 1. These quadrats were from the cultivated sites of the vlei.

The second group consists of species such as *H. contortus, S. bambariensis* and *D. annulatum.* These species had a positive association with Axis 2. On the PCA plot (Fig 4.10) of environmental variables these species occurred in quadrats that had high levels of moisture content, high levels of Nitrogen and high levels of organic carbon. A look at the PCA plot of cases (Fig 4.15) reveals that quadrats 15, 14 and 16 were also positively associated with Axis 2. It therefore implies that the species were characteristic of uncultivated sites as confirmed by the environmental variables and the quadrats.

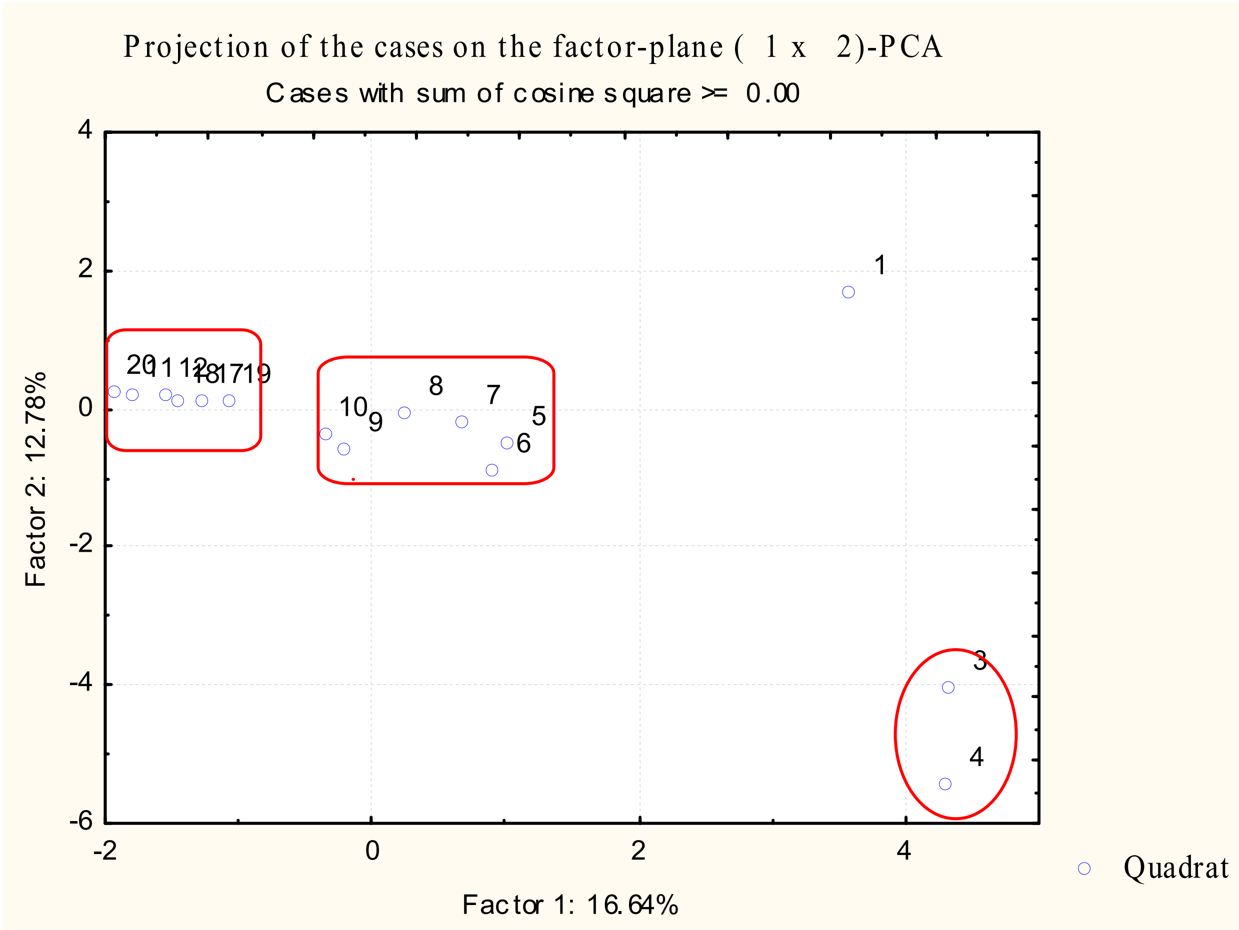


Figure 4.15. PCA scatter plot of the quadrats

Principal Component Analysis (PCA) results on species show factor 1 accounting for 16.64% of the variance and factor 2 accounting for 12.78% of the variance. The plot reveals the existence of three distinct groups of quadrats, with 1 and 2 (not shown) as outliers. Quadrats 3 and 4 occur together because of the presence of species such as *Rhynchosia minima, Bidens pilosa* and *S. bicolor* in both quadrats. Quadrats 5, 6, 7, 8, 9 and 10 form the second group. These are grouped together because of the presence of species such as *Conyza sp* and *Cochorus tridesto*.

The third group consists of quadrats 11, 12, 17, 18, 19 and 20. These are characterized by the presence of species such as *Setaria pumila, Dicanthium annulatum, Becium fimbriatum* and *Panicum repens*.

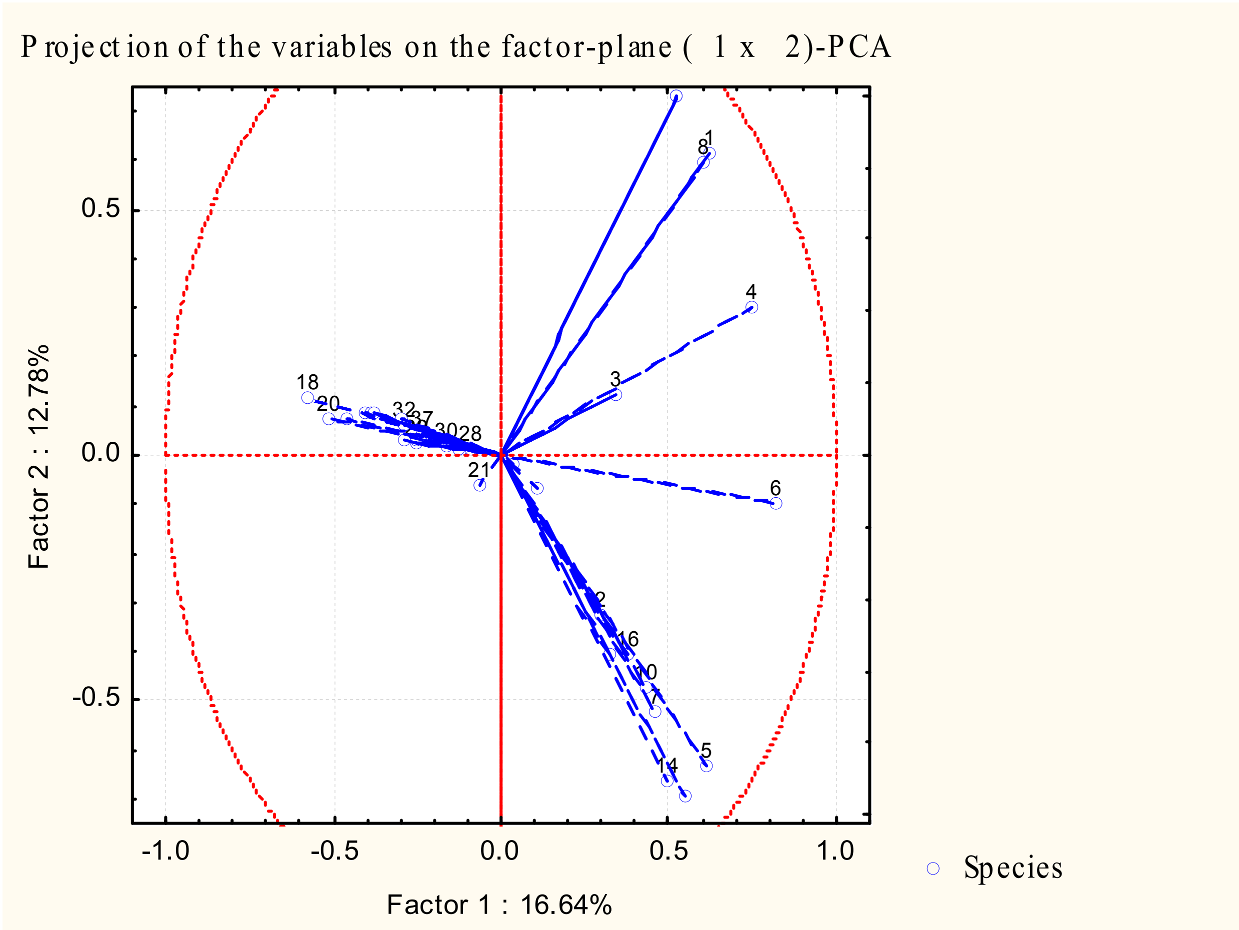


Figure 4.16. Projection of species on Axis 1 and 2. of the principal component analysis ordination. (Species and Codes are shown in Appendix 5).

The plot indicates that *R. minima (5)*, and *Tephrosia sp (4)*, were some of the species associated with the positive end of Axis 1. These species are typical of those found in disturbed soils. On the negative end there is occurrence of species such as *H. contortus (14), D. annulatum(18)* among others which are species that occur naturally in wetland soils. Axis 2 is positively associated with species such as *H. contortus(14),D.annulatum (18).* It is negatively associated with *R. minima (5)*, *S.bicolor(20)* and *C. dactylon(6).*

4.4 Species-environment relationship

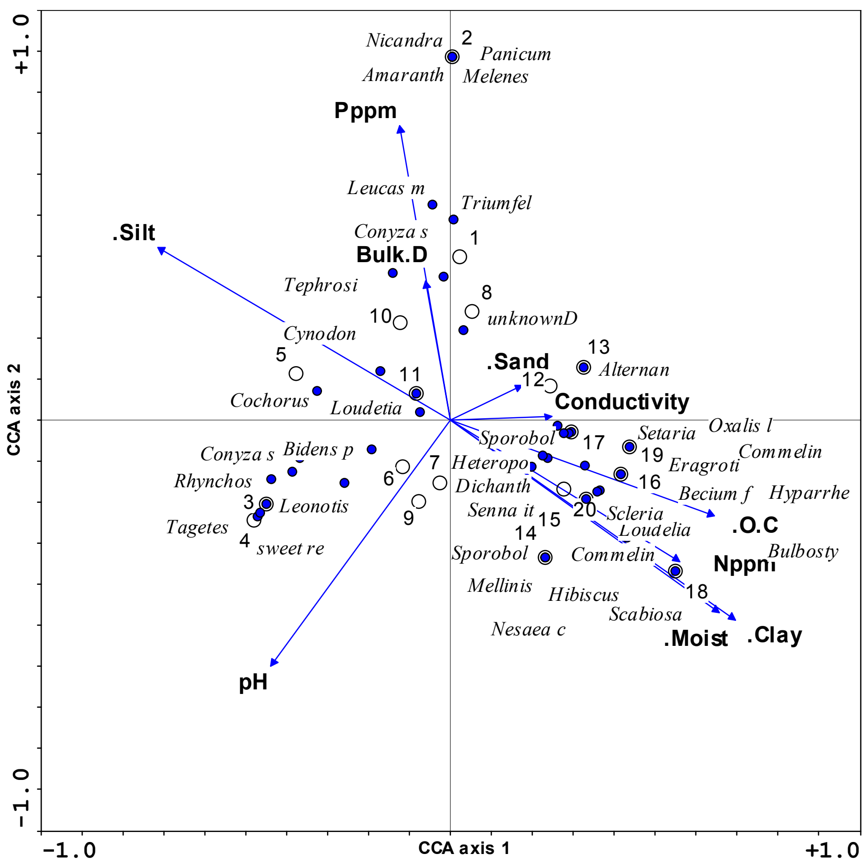


Figure 4.17. CCA ordination for species and environmental variables.

The results of the CCA technique indicate that Axis 1 accounts for 18.9% of the observed variation, whereas Axes 2, 3 and 4 account for 16.35%, 12.6% and 11.1% respectively (Table 4.3). The analysis shows the grouping of species with corresponding environmental variables. Quadrats 14, 15, 16, 17, 18, 19 and 20 were found in uncultivated sites. High moisture content, clay levels, nitrogen and organic carbon were important factors influencing species composition in this group of quadrats. Quadrats 3, 4, 6, 7 and 9 were found in cultivated sites. Soil pH was the main environmental variable influencing species composition in these quadrats.

In quadrats 12 and 13 (from the uncultivated sites), sand levels and conductivity were influencing species compositions. Quadrats 1, 5, 8, 10 and 11 contained those species whose composition was influenced by silt levels, bulk density and phosphorous levels (Fig 4.17).

Table 4.3. Summary of the Canonical Correspondence Analysis (CCA).

Axes	1	2	3	4
Eigen values	0.7940	0.6810	0.5280	0.4660
Species-environment correlations	0.9530	0.9480	0.9690	0.9560
Cumulative percentage variance of species-environment relations	18.9	35.2	47.8	58.9
pH	-0.4190	-0.5683	0.2272	0.0571
P ppm	0.1172	0.6794	0.1290	-0.1163
N ppm	0.5330	-0.3271	-0.4673	-0.0258
% Organic Carbon	0.6139	-0.2209	-0.2841	-0.5750
Conductivity	0.2350	0.0097	0.4196	0.3517
% Clay	0.6251	-0.4432	-0.0840	-0.1071
% Silt	-0.6808	0.4001	-0.1004	-0.0061
% Sand	0.1674	0.0793	0.2949	0.2756
% Moist	0.6625	-0.4621	0.0788	-0.1064
Bulk Density	-0.0581	0.3215	-0.1846	0.2918

The analysis revealed that organic carbon, clay, nitrogen, and moisture content were positively correlated with Axis 1 (r=0.61, r=0.63, r=0.53 and r=0.66 respectively). On the other hand pH and silt content were negatively correlated with Axis 1 (r=-0.42 and r=-0.68 respectively. Phosphorous, silt and bulk density were positively correlated with Axis 2 (r=0.67, r=0.40 and r=0.32 respectively).

4.5 Biodiversity assessment of the Monavale vlei.

The number of plant species on the vlei was increasing up to transect 4 (quadrat 64) where no new species were encountered (Fig 4.18). Using the fitted distribution the number of grass and herbaceous species predicted for the Monavale Vlei is 60 ± 0.05.

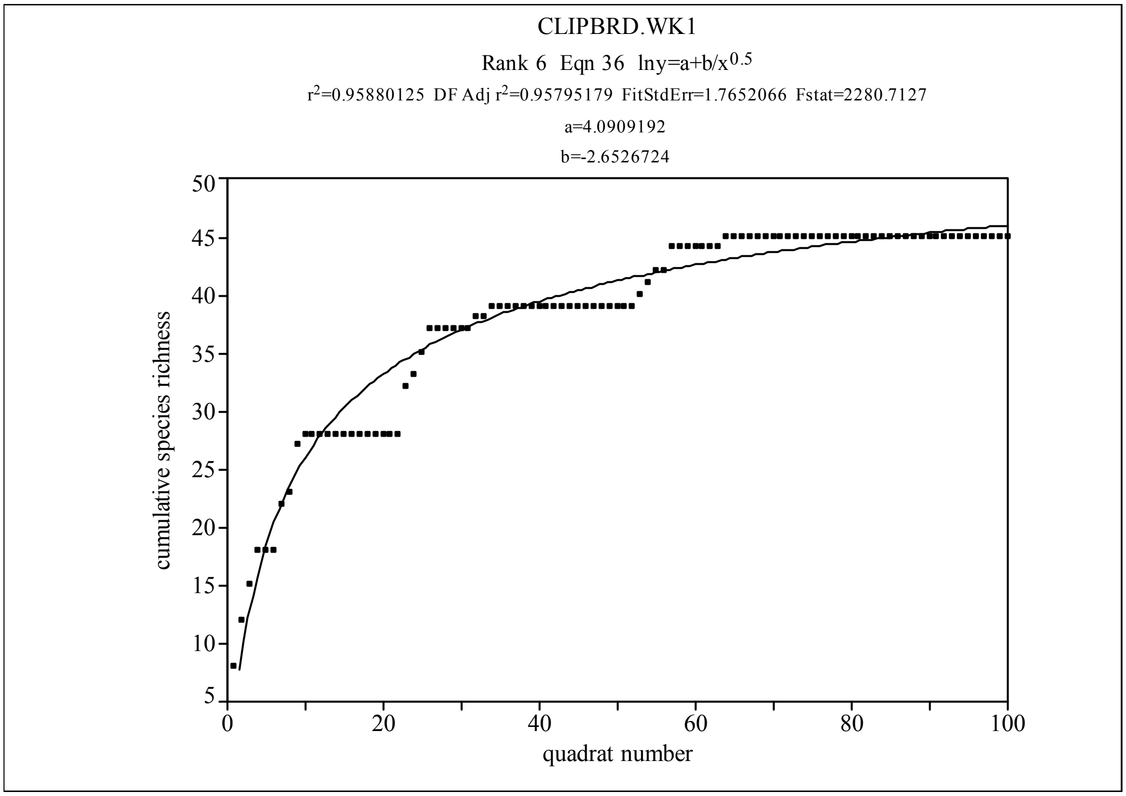


Figure 4.18. Cumulative plant species richness of the vlei.

The number of bird species was increasing up to day five where no new species were encountered (Fig 4.19). Using the fitted equation the number of bird species on the vlei is 45 ± 0.04.

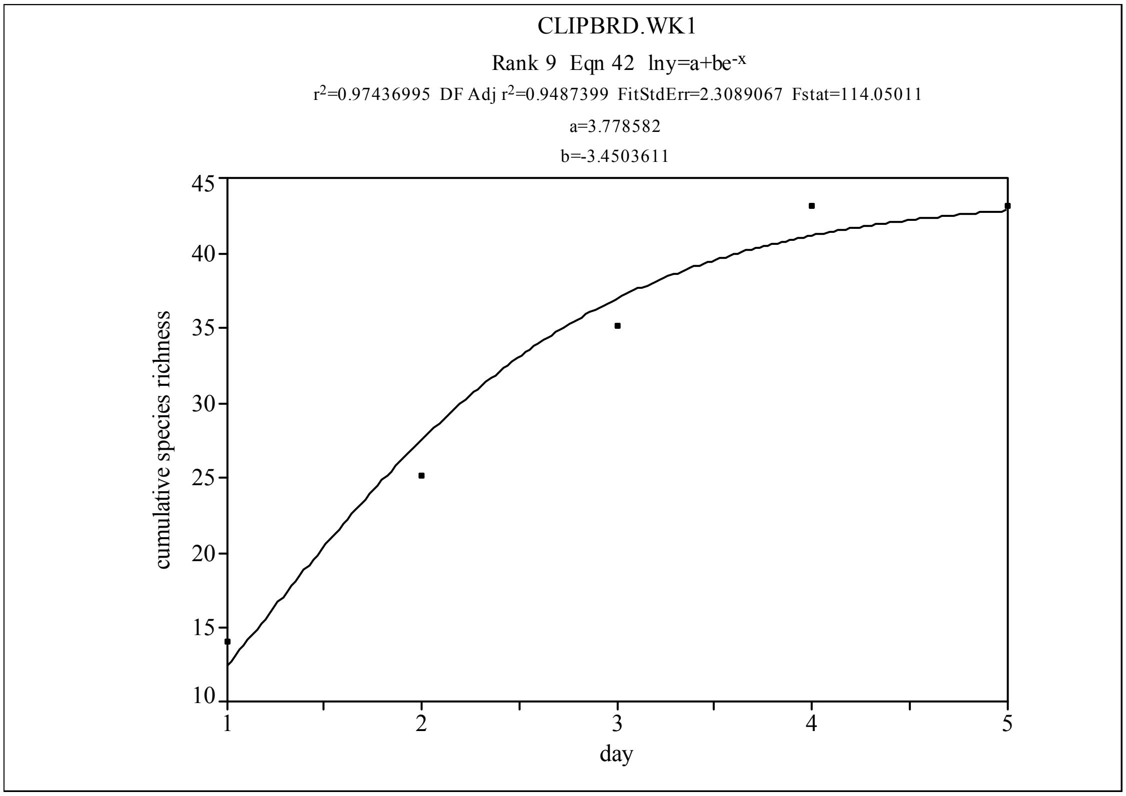


Figure 4.19. Cumulative bird species richness of the vlei.

The number of insect species increased from transects 1 to 5, where only one new species was encountered (Fig 4.20). The number of these species was used to predict the number of insect species, which are present on the vlei, and it was found to be 27 ± 0.01.

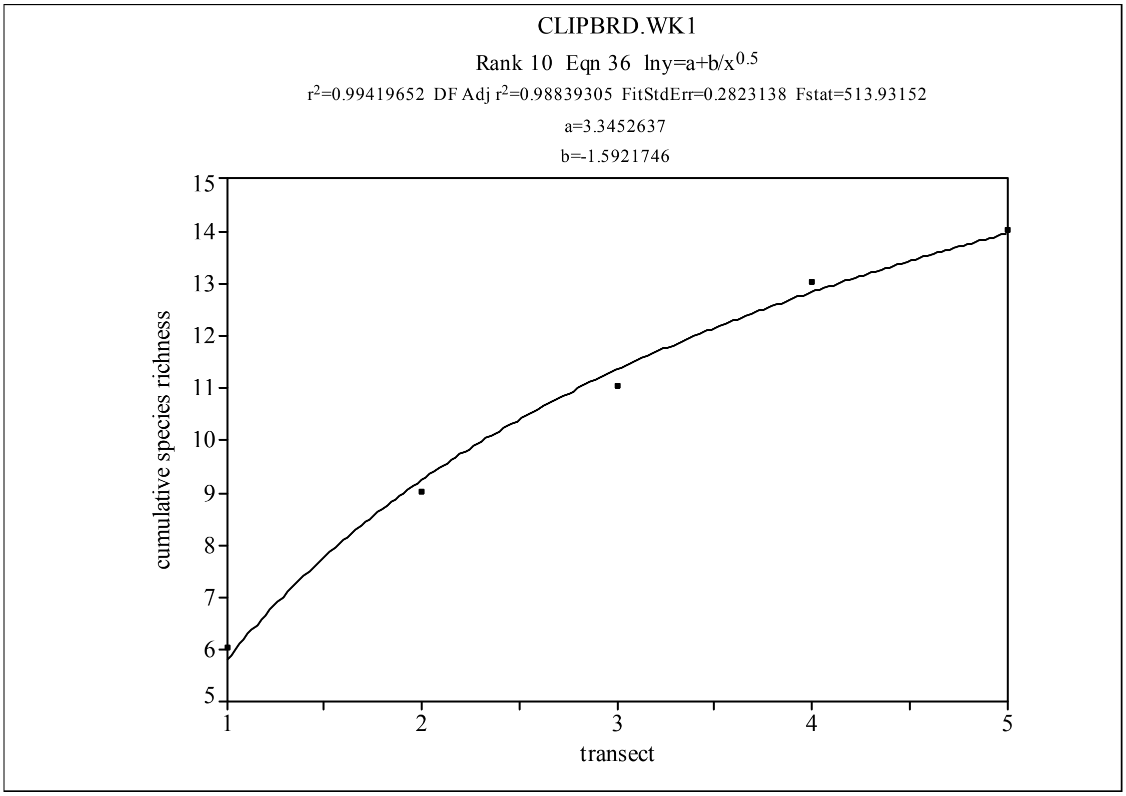


Figure 4.20. Cumulative insect species richness of the vlei.

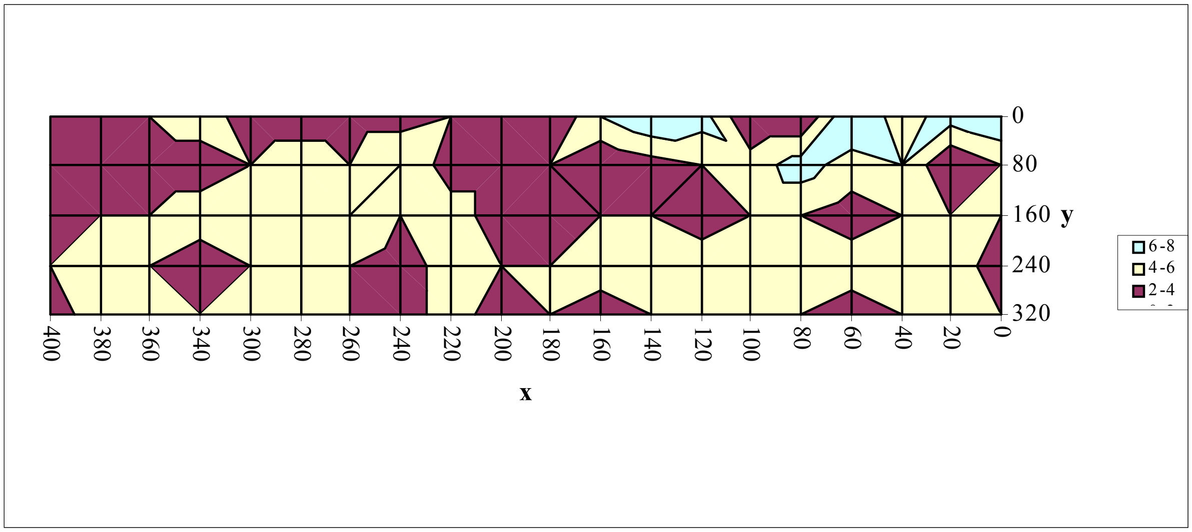
Table 4.4 Biodiversity measures of the vlei.

Measure	Grasses and herbs	Birds	Insects
Species richness (S)	60	45	27
Shannon-Wiener (H)	2.83	3.39	2.54
Evenness (E)	0.69	0.89	0.77

The predicted number of grass and herb species, birds and insect species were used to calculate the different biodiversity measures. Species richness of grasses and herbs was the highest, followed by birds and lastly insects. In terms of diversity the avian species were the most diverse followed by grasses and herbs and lastly insects.

4.6 Surface maps of Monavale vlei

The surface maps (Fig 4.21 and 4.22) of Monavale vlei indicate that there is random distribution of plants in terms of richness and diversity on the vlei. A look at the physical map indicates that there are different variables that influence these two measures. Moisture content and level of disturbance are the important factors on the vlei. Areas with high moisture content usually have low species richness, thus have low diversity. On the other hand low moisture content and intermediate levels of disturbances result in high species richness hence high species diversity.

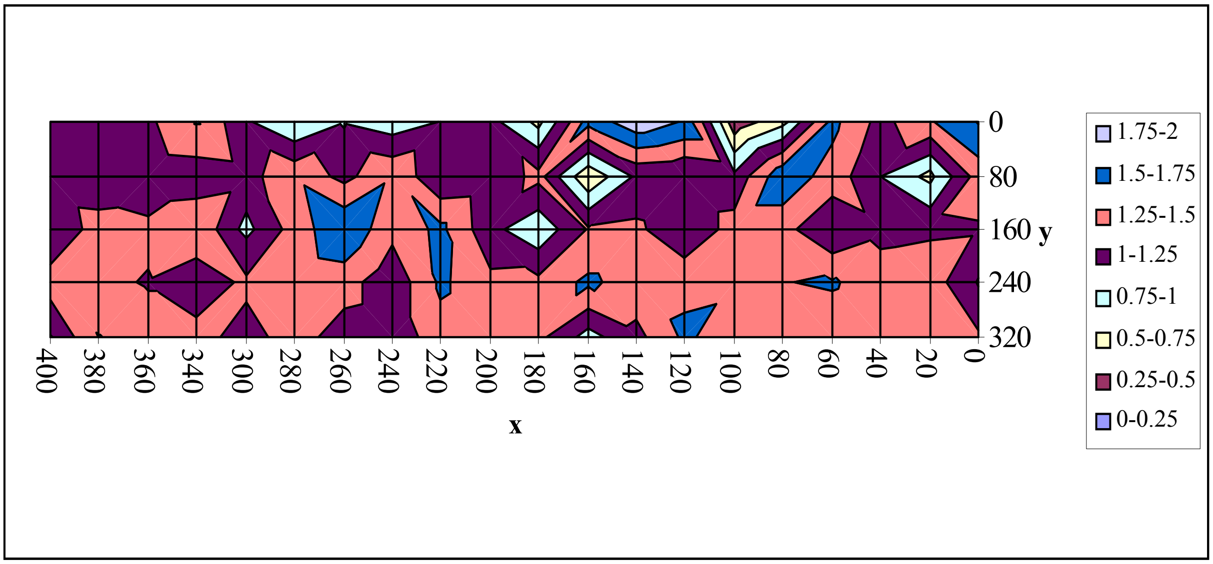


x- Distance from first quadrat

y- Distance from first transect

Figure 4.21. Surface map based on species richness.

The chart reveals that areas of high species richness on the vlei were found along transects 1 and 2, in the first 9 quadrats. On the vlei these areas had high levels of disturbance as compared to adjacent areas. Apart from these areas species richness of 4-6 was relatively dominant.



x- Distance from first quadrat
y- Distance from first transect

Figure 4.22. Surface map based on species diversity (Shannon-Wiener).

From the chart it can be seen that highest diversity on the vlei was found along transect 1 in quadrat 8. This was followed by a diversity of 1.5-1.75. These were found in few areas of the vlei however. The most dominant diversities were 1.25-1.5 and 1-1.25. The lowest diversity was along transect 3 in quadrat 16.

5.0 Discussion and Conclusions

5.1 Impact of cultivation on soil properties

There was no significant difference in pH ($CaCl_2$) levels between the cultivated and uncultivated sites. In wetland areas pH levels are generally expected to be <5 due to incomplete decomposition of organic matter (Grant, 1995). Low oxygen levels in the soil cause incomplete decomposition, which leads to the accumulation of acids such that pH tends to be more acid. In this case however values were around 5 indicating that there were other factors, which were influencing it besides the decomposition of organic matter.

In the cultivated sites pH levels were around 5 indicating similar results to uncultivated sites. The results could be attributed to the use of farmyard manure to improve yields (Muropa pers comm). Farmyard manure is known to contain calcium, which could reduce the acidity of the soil (Youdeowei *et al.,* 1986). The removal of vegetation in preparation of cultivation usually exposes the soils such that aeration and temperatures in the soil is increased. These two cause rapid decomposition of organic matter and this prevents the accumulation of acids and pH shift towards alkaline conditions. The results could also be attributed to lack of organic matter. The removal of crop stacks or residue after harvesting means that accumulation of organic matter in the cultivated sites is reduced. This can cause alkaline conditions to prevail in the soils.

Cultivated sites had lower levels of nitrogen as compared to uncultivated sites. This is consistent with the observations of (Chigona, 2005; Thompson, 1950; Dalal and Mayer, 1986). Nitrogen is usually lost through crop removal from the cultivated sites, which is what used to take place on the Monavale vlei (Muropa pers comm). After harvesting most farmers would remove the crop remains. Besides being lost through crop removal, nitrogen could also get lost due to increased drainage.

Mineralisation could also have resulted in the loss of nitrogen from the cultivated sites of the vlei (Brady, 1974). The process is enhanced in well-drained aerated soils. In most of the cultivated sites soils were cracked on the surface indicating that aeration was high, which then could promote mineralisation. Erosion could also account for losses, however evidence of this process on the vlei was low. Thus losses could not be attributed to this factor.

In the uncultivated sites nitrogen levels were however high. This could have been as a result of the accumulating organic matter from dying off wetland plants. The presence of these decaying plant remains increases the amount of organic matter in the soil with a consequent increase in nitrogen levels of the soil (Knops and Tillman, 2000).

The results indicate that there were no significant differences in phosphorous concentration between the cultivated and uncultivated sites. This is because some quadrats from both sites had no detectable amounts (Fig 4.3). In those few quadrats where it was present levels were higher in the cultivated sites as compared to the uncultivated sites. These results conform to those of Chigona, 2005 and Mochoge and Beese, 1988. The high levels in cultivated sites could be attributed to the use of phosphate containing fertilizers (Muropa pers comm) for soil fertility improvement.

On the other hand the unavailability of phosphate could be attributed to the pH levels and low levels of organic matter decomposition. At a pH of less than 5, there is fixation of phosphorous by hydrous oxides of Fe, Al and Mg (Brady, 1974), which can result in the low availability of this nutrient. The existence of phosphorus in the inorganic form can also reduce the availability of this nutrient in the soil (Saikh *et al.,* 1998). Beside these factors the sensitivity of the method used could also account for the low levels of phosphorous found in the soil samples.

High organic carbon levels in the uncultivated sites could be attributed to the reduced decomposition rate as a consequence of less soil residue contact, lower aeration and lower soil temperature in the uncultivated sites (Hussain, 1997). Increased organic matter inputs to the soil from dying-off plants could also account for the increased organic carbon levels in the uncultivated sites.

On the other hand most of the cultivated sites had cracked exposed surfaces. This can increase soil temperatures as well as aeration such that organic matter decomposition rate becomes high resulting in low organic carbon levels in these sites. The drying up of the wetland may cause rapid depletion of organic matter, which in turn results in low organic carbon levels. The low levels of organic carbon could also be attributed to decreased organic matter inputs to the soil due to crop stalk harvesting, a practice which was quite evident on the vlei.

Bulk density of the soil in the cultivated and uncultivated sites did not show significant differences. According to Thompson and Troeh 1978, clay soils and clay loams have low bulk density, which ranges from 1.00 to 1.60g/cm^3. Since soils on the Monavale vlei are rich in clay (Nyamapfene, 1991) and the results from both sites fell within 1.00–1.60g/cm^3 range it therefore implies that cultivation did not have deleterious effects to the soil structure. Infact according to Brady, 1974 it is intensive cultivation with heavy machinery which tends to increase the bulk density of the soil. On the vlei however people used hoes for ploughing (Muropa pers comm.). This reduces the risk of increasing bulk density of the soil.

Moisture levels in the cultivated sites were significantly lower than in the uncultivated sites. During cultivation the removal of the vegetation cover results in the loss of moisture holding capacity of the soils (FitzGibbon, 1999). Cultivated sites on the vlei had less vegetation cover. Soils in these sites were exposed to sunny and windy conditions. These two can therefore increase chances of evaporative losses.

On the other hand the higher moisture content in the uncultivated sites could be attributed to the presence of high vegetation cover and high organic matter of the soil. According to Turner, 1991 the amount of organic matter content influences the ability of soils to retain water. Soils with high clay content tend to have high water holding capacity. Thus the high levels of moisture content in uncultivated sites could also be attributed to this factor since clay content was higher in these sites.

Clay content of the soil was significantly different between the two sites. Cultivated sites had lower levels of clay content as compared to the uncultivated. This suggests that cultivation was promoting disintegration of the vlei soil leading to precipitation of clay particles into lower horizons. On the other hand levels in the uncultivated sites could be attributed to the absence of disturbances and the high clay content that is characteristic of some vlei soils.

Silt content of the soil was higher in the cultivated sites of the vlei than as compared to the uncultivated sites. These observations conform to those of Chigona, 2005. It therefore implies that cultivation had an impact on the soil structure. The precipitation of clay particles into the lower horizons can lead to the accumulation of the fine silt particles hence producing the observed results.
The observed results indicate that sand levels between the cultivated and uncultivated sites were not significantly different.

5.2 Indirect gradient analysis

PCA analysis of the environmental variables indicated the existence of two major gradients within the data. Clay content was associated with moisture content, conductivity and nitrogen content on one end of the gradient, while silt content, bulk density and phosphorous levels were associated with the other end. This gradient was labelled as the cultivation gradient. The evidence indicates that if cultivation is prolonged bulk density, silt content and phosphorous will increase. On the other hand clay content and moisture levels together with other associated variables will decrease due to cultivation. These results are consistent with those of Chigona, 2005.

The second gradient was labeled as uncultivated. This had positive association with organic carbon, nitrogen levels and moisture content. These variables are normally high in uncultivated areas hence the gradient was labeled as uncultivated. The two factors managed to extract about 48.63% of the total variation. Though this variation is less than 50%, these two managed to bring out the major gradients that exist within the data.

The analysis therefore managed to indicate that indeed cultivation had an impact on the different soil properties.

5.3 Impact of cultivation on species richness and composition and community structure.

Cultivation is usually associated with increased species richness because it encourages the proliferation of weeds (Youdeowei *et al,* 1986) and also opens up new niches (Davies *et al.,* 2000). The results however indicate that there was no difference in species richness, diversity and evenness between the cultivated and uncultivated sites of the vlei. This can be attributed to a reduced seedbed. The seedbed can be reduced by the shortened hydroperiods, which are increased during cultivation (Galatowitsch and van de Valk, 1994). Besides shortened hydroperiods, the use fires in land preparation can also reduce the seedbed.

There was a difference in terms of community structure between the two sites (Figs 4.12 and 4.13). Cultivated sites were dominated by weedy species (*L. martinicensis* and *B. pilosa*) while the uncultivated sites were dominated species such as *S. bambariensis* and *H contortus*. This indicates that though cultivation had no impact on species richness and diversity; it can have an impact on the community structure. This can cause changes in terms of habitat use by some animal species. Biodiversity on the vlei therefore will be affected.

The cluster analysis of the data indicates that there was separation of quadrats into two five groups based on species composition. Quadrats from uncultivated sites formed two groups B and C (Fig 4.14) indicating that they were more similar to each other in terms of species composition. Those found in the cultivated sites formed three groups A, D and E. The analysis therefore generally indicates that quadrats found in uncultivated sites were more similar to each other. Likewise those found in cultivated sites were also more similar to each other. Therefore cultivation influences species composition.

5.4 Species assemblages

PCA plot (Fig 4.16) indicates the existence of two major groups within the data set. The first group consists of species such as *C. dactylon, A. hybridus, Tephrosia sp, R. minima* and *L. martinicensis*. These species were found in quadrats with high levels of silt content, high phosphorous levels and increased bulk density (PCA plot-Fig 4.10). These species were therefore found in cultivated sites. This can even be confirmed by the PCA plot of cases (Fig 4.15) which indicates the occurrence of quadrats from cultivated sites on the positive end of the cultivation gradient.

The second group consists of species such as *H. contortus*, *S. bambariensis* and *D. annulatum.* These species occurred in quadrats, that had high moisture content, high nitrogen levels and high levels of organic carbon (Fig 4.10). These species were found in uncultivated areas as confirmed by the occurrence of those quadrats in which they were found (PCA plot- Fig 4.15). Therefore the species were characteristic of uncultivated sites.

The analysis therefore indicates that cultivation had an impact on species composition. Species from the two sites were grouped separately into weedy species and those that are normally found on undisturbed vleis.

5.5 Species-environment relationships

Moisture levels, clay content, nitrogen and organic carbon are the important variables that were influencing species composition in uncultivated areas. (Fig 4.17). pH, bulk density and phosphorous were the important variables that influenced species composition in the cultivated sites. Therefore it clearly indicates that these are the environmental variables that are important in these sites. The Monte-Carlo permutations indicate that pH and moisture were the variables that were influencing species composition significantly ($P<0.05$).

The surface maps indicate variation in species richness and diversity on the vlei due to moisture content and level of disturbance. Low moisture content was associated with high species diversity but is a threat to wetland ecology.

Conclusion

Cultivation affects wetland ecology. Moisture content, clay content, organic carbon and nitrogen levels of the soil were significantly different between the two sites. These differences are an indication that cultivation can have adverse effects on wetland ecology. However, besides cultivation climate change can also have adverse effects on wetland ecology. When for example, the water holding capacity of the soil is low the vlei's sensitivity to climate change becomes high. Thus cultivation together with climate change will eventually lead to the drying up of the vlei. Therefore it is important to note that it is not only the anthropogenic stresses or factors that affect wetland ecology but natural factors as well. Cultivation also had an impact on the community structure of the vlei. There was dominance of weeds in cultivated areas though species diversity was high in these areas. This can result in habitat loss for some species that utilizes the wetland. The net result will be a decrease in diversity of the ecosystem.

Cultivation of wetlands however should not be done at the expense of the integrity of these ecosystems and therefore should be stopped. Cessation of cultivation can lead to the recovery of these ecosystems provided it is done on time. Researchers should therefore try and ensure that the responsible authorities as well as those people who utilize wetlands are informed about the impacts of unsustainable wetland use.

Recommendations.

The study concentrated on the impact of cultivation on soil properties and plant species but these are not the only characteristics that are altered. Future studies should try and assess impacts on biodiversity. It is also important to conduct studies on the succession of plant communities on those wetlands where cultivation has been stopped. Such studies are important because they give an indication on the recovery of a wetland. Besides concentrating on human factors, long term studies that assess the effects of natural factors are also of importance since these two can together affect wetland ecology.

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APPENDICES

APPENDIX 1.

Grass and herbaceous species on the Monavale vlei

Species	Type
Alternanthera philoxeroides	herb
Becium fimbriatum	grass
Bidens pilosa	herb
Bothrochloa inscupta	grass
bryophytes	
Bulbostylis sp	grass
Cochorus tridesto	herb
Commelina africana	grass
Commelina sp	grass
Conyza summatrensis	herb
Cynodon dactylon	grass
Dichanthium annulatum	grass
Eragrotis sp	grass
Heteropogon contortus	grass
Hibiscus sp	grass
Hyparrhenia sp	grass
Indigofera sp	herb
Indigofera sp	herb
Loudetia simplex	grass
Loudetia sp	grass
Mellinis nerviglume	grass
Mellinis sp	grass
Mimulus gracilis	grass
Nesaea cordata	herb
Oxalis latifolia	grass
Phylanthus nummulariifilius	herb
Scabiosa columbera	grass
Scleria bambariensis	sedge
Senna italica	herb
Setaria pumila	grass
Sida alba	herb
Sporobolus sp	grass
Sporobolus tapfianus	grass
Tagetes minuta	herb
Tephrosia sp	herb
Typha latifolia	sedge

APPENDIX 2

Grass and herb species in the cultivated and uncultivated sites

Species	cultivated	uncultivated	Plant type
Alternanthera philoxeroides	1	0	herb
Amaranthus hybridus	1	0	herb
Becium fimbriatum	1	0	grass
Bidens pilosa	1	1	herb
Bulbostylis sp	1	0	herb
Cochorus tridesto	1	1	herb
Commelina africana	1	0	grass
Commelina sp	1	0	grass
Conyza sp	1	0	herb
Conyza summatrensis	1	1	herb
Cynodon dactylon	1	0	grass
Dichanthium annulatum	1	1	grass
Eragrotis sp	1	0	grass
Heteropogon contortus	1	1	grass
Hibiscus sp	1	0	herb
Hyparrhenia sp	1	0	grass
Leonotis nepetifolia	1	0	herb
Leucas martinicensis	1	0	herb
Loudetia simplex	1	0	grass
Loudetia sp	1	0	grass
Mellinis repens	1	0	grass
Mellinis sp	1	0	grass
Nesaea cordata	1	0	herb
Nicandra physaloides	1	0	herb
Oxalis latifolia	0	1	grass
Panicum repens	1	0	grass
Rhynchosia minima	1	0	herb
Scabiosa columbera	1	0	herb
Scleria bambariensis	1	1	sedge
Senna italica	1	0	grass
Setaria pumila	1	1	grass
Sporobolus sp	1	1	grass
Sporobolus tapfianus	1	0	grass
Sorghum bicolor	1	0	grass
Tagetes minuta	1	0	grass
Tephrosia sp	1	0	herb
Triumfelta pilosa	1	0	herb

APPENDIX 3

Summary of variables assessed on Monavale vlei

Quadrat	pH	Mgl^{-1}	Pppm	Nppm	%O.C	E.CuS/cm	%Clay	%Silt	%Sand	%Moist	Bulk D g/cm3	sp richness
1	3.9	0.125	0	15	2	205	24	34	42	0.9	1.05	
2	4.7	0.019	9	9	1.7	190	18	46	36	1	1.14	
3	5.3	0.005	0	5	2	112	22	42	36	1.8	1.05	
4	5.8	0.0015	1	132	2.1	213	24	42	34	2.8	1.05	
5	5.7	0.0019	4	10	2.1	199	16	46	38	0.9	1.17	
6	5.2	0.0063	0	9	1.3	175	30	22	48	2.2	1	
7	5.2	0.0063	0	48	1.3	155	28	26	46	3.4	1.08	
8	4.4	0.0398	0	7	1.3	95	16	54	64	1	1.32	
9	5.5	0.0031	0	10	1.3	243	34	28	38	2.4	1.07	
10	4.9	0.0125	1	37	1.3	281	16	54	30	0.1	1.15	
11	4.6	0.0251	0	46	1.3	134	30	32	38	1.3	1.06	
12	4.7	0.0199	0	15	1.3	291	36	20	34	3.4	1.07	
13	4.6	0.0251	1	12	1.3	249	32	22	46	5	1	
14	5.7	0.0019	1	16	1.3	264	44	16	40	9.3	1.02	
15	5.3	0.005	2	132	2.2	104	10	24	66	6.4	1.06	
16	4.9	0.0125	0	112	2.2	319	20	32	48	8.5	1.02	
17	4.4	0.0398	0	112	2.2	199	42	20	38	12.2	1	
18	5.3	0.005	0	143	2.2	160	26	26	48	8.1	1.2	
19	4.6	0.0251	0	17	2.2	145	28	34	38	8.5	1.09	
20	4.8	0.0158	0	17	2.2	195	30	22	48	10.8	1	

APPENDIX 4

ONE-WAY ANALYSIS OF THE ENVIRONMENTAL VARIABLES

Analysis of Variance for %O.C

```
Source    DF      SS       MS       F      P
status     1   1.9845   1.9845   30.25   0.000
Error     18   1.1810   0.0656
Total     19   3.1655
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level      N     Mean    StDev               ----+---------+---------+---------+
0         10   1.5000   0.2981               (--*-----)
1         10   2.1300   0.2058               (-----*-----)
                                             --+---------+---------+---------+
Pooled StDev =   0.2561           1.50      1.80      2.10      2.40
```

Analysis of Variance for pH based on H^+

```
Source    DF      SS       MS       F      P
status     1  0.000116  0.000116    0.15   0.706
Error     18  0.014223  0.000790
Total     19  0.014339
                          Individual 95% CIs For Mean
                          Based on Pooled StDev
Level      N     Mean    StDev     --+---------+---------+---------+----
0         10  0.02191  0.03796     (--------------*---------------)
1         10  0.01710  0.01180     (--------------*---------------)
                                   --+---------+---------+---------+----
Pooled StDev =  0.02811          0.000     0.012     0.024     0.036
```

Analysis of Variance for P ppm

```
Source    DF      SS       MS       F      P
status     1     6.05     6.05    1.35   0.261
Error     18    80.90     4.49
Total     19    86.95
                          Individual 95% CIs For Mean
                          Based on Pooled StDev
Level      N     Mean    StDev               -------+---------+---------+-------
0         10    1.500    2.915               (--------*-----------)
1         10    0.400    0.699               (--------*-----------)
                                             -----+---------+---------+-------
Pooled StDev =    2.120               0.0       1.2       2.4
```

Analysis of Variance for N ppm

```
Source    DF      SS       MS       F      P
status     1     9680     9680    5.88   0.026
```

```
Error     18   29637     1647
Total     19   39317
                              Individual 95% CIs For Mean
                              Based on Pooled StDev
Level      N     Mean    StDev          -+---------+---------+---------+---
0         10    18.20    15.08          (----*--------)
1         10    62.20    55.37          (-------*--------)
                                        ---------+---------+---------+---
Pooled StDev =   40.58            0        30        60        90
```

Analysis of Variance for % Clay

```
Source    DF      SS       MS       F       P
status     1    627.2    627.2   11.27   0.004
Error     18   1001.6     55.6
Total     19   1628.8
                              Individual 95% CIs For Mean
                              Based on Pooled StDev
Level      N     Mean    StDev          ---------+---------+---------+-----
0         10   22.800    6.408          (-----*-------)
1         10   34.000    8.380          (-------*-------)
                                        -------+---------+---------+-----
Pooled StDev =   7.460        18.0      24.0      30.0      36.0
```

Analysis of Variance for % Sand

```
Source    DF      SS       MS       F       P
status     1     72.2     72.2    1.14   0.299
Error     18   1138.0     63.2
Total     19   1210.2
                              Individual 95% CIs For Mean
                              Based on Pooled StDev
Level      N     Mean    StDev          ---+---------+---------+---------+--
0         10   43.600    9.559          (----------*------------)
1         10   39.800    5.922          (---------*-------------)
                                        -+---------+---------+---------+--
Pooled StDev =   7.951          36.0      40.0      44.0      48.0
```

Analysis of Variance for % Silt

```
Source    DF      SS       MS       F       P
status     1    696.2    696.2    9.58   0.006
Error     18   1307.6     72.6
Total     19   2003.8
                              Individual 95% CIs For Mean
                              Based on Pooled StDev
Level      N     Mean    StDev          +---------+---------+---------+---
0         10   37.000   10.467          (-----*-------)
```

```
1         10   25.200    5.978                    (-----*-------)
                                                  ---------+---------+---------+---
Pooled StDev =   8.523          21.0      28.0      35.0      42.0
```

Analysis of Variance for % Moist

```
Source    DF       SS       MS       F       P
status     1   162.45   162.45   26.41   0.000
Error     18   110.71     6.15
Total     19   273.16
                               Individual 95% CIs For Mean
                               Based on Pooled StDev
Level      N     Mean    StDev                    --------+---------+---------+------
0         10    1.650    1.035                    (---*-----)
1         10    7.350    3.351                    (---*------)
                                                  -------+---------+---------+------
Pooled StDev =   2.480                 2.5       5.0       7.5
```

Analysis of Variance for Bulk Density (g/cm3)

```
Source    DF       SS       MS       F       P
status     1   0.01568   0.01568    2.58   0.126
Error     18   0.10952   0.00608
Total     19   0.12520
                               Individual 95% CIs For Mean
                               Based on Pooled StDev
Level      N     Mean    StDev                    --------+---------+---------+------
0         10   1.1080   0.0916                    (--------*---------)
1         10   1.0520   0.0614                    (-------*----------)
                                                  ------+---------+---------+------
Pooled StDev =   0.0780                1.050     1.100     1.150
```

Analysis of Variance for Species richness

```
Source    DF       SS       MS       F       P
status     1     4.05     4.05    1.28   0.273
Error     18    56.90     3.16
Total     19    60.95
                               Individual 95% CIs For Mean
                               Based on Pooled StDev
Level      N     Mean    StDev                    -----+---------+---------+---------
0         10    6.400    1.838                    (---------*-----------)
1         10    5.500    1.716                    (--------*-----------)
                                                  ---+---------+---------+---------
Pooled StDev =   1.778               5.0       6.0       7.0
```

Analysis of Variance for E.C uS/c

```
Source    DF       SS       MS       F       P
status     1     1843     1843    0.44   0.515
```

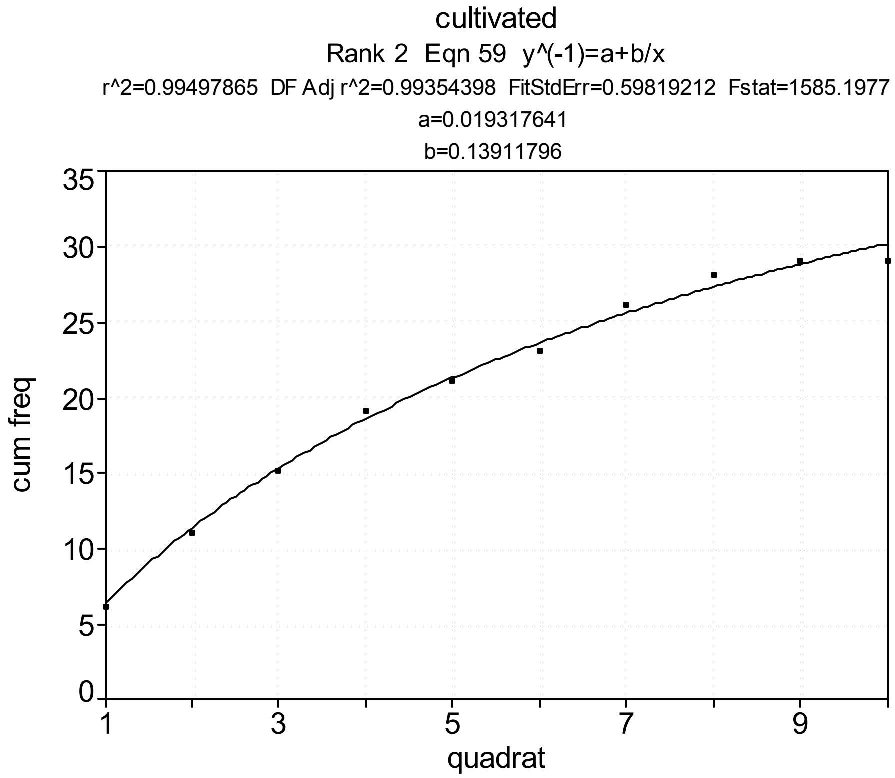
```
Error     18    75184    4177
Total     19    77027
                         Individual 95% CIs For Mean
                         Based on Pooled StDev
Level    N    Mean    StDev          -+---------+---------+---------+---
0       10   186.80   56.16          (-----------*--------------)
1       10   206.00   72.11          (-------------*-------------)
                                     ---------+---------+---------+---
Pooled StDev =   64.63          150       180       210       240
```

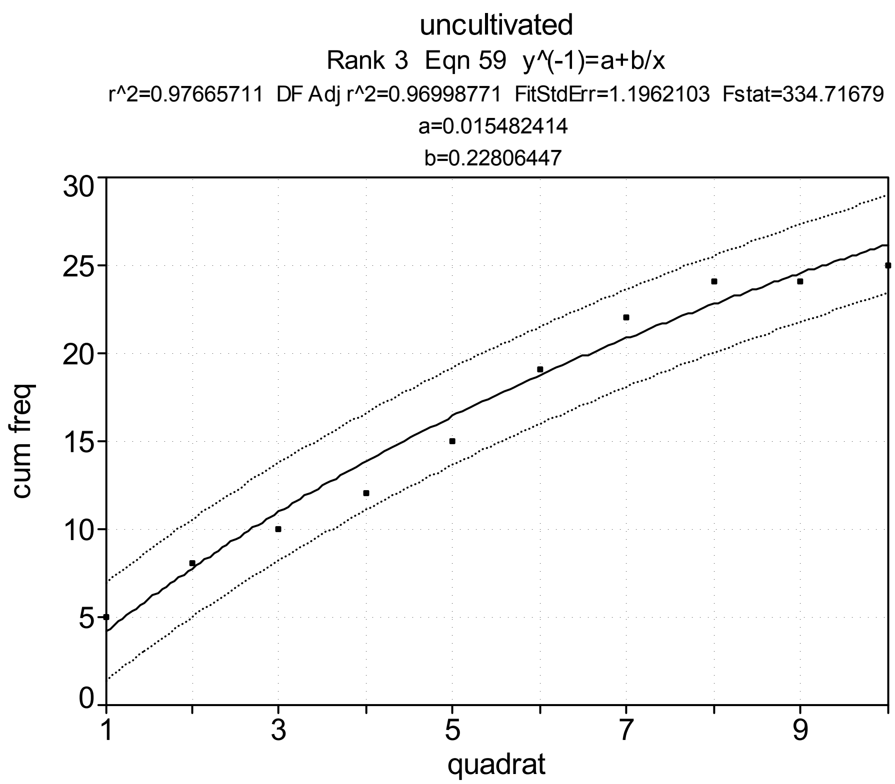
APPENDIX 5

Species and codes

Code	Species
1	*Leucas martinicensis*
2	*Leonotis nepetifolia*
3	*Conyza summstrensis*
4	*Tephrosia sp.*
5	*Rhynchosia minima*
6	*Cynodon dactylon*
7	*Conyza sp*
8	*Triumfelta pilosa*
9	*Amaranthus hybridus*
10	*Tagetes minuta*
11	*Melinis repens*
12	*Panicum repens*
13	*Nicandra physaloides*
14	*Heteropogon contortus*
15	*Scleria bambariensis*
16	*Cochorus tridesto*
17	*Setaria pumila*
18	*Dicanthium annulatum*
19	*Bidens pilosa*
20	*Sorghum bicolor*
21	*Sporobolus sp*
22	*Oxalis latifolia*
23	*Commelina africana*
24	*Scabiosa columbera*
25	*Commelina sp*
26	*Alternanthera philoxeroides*
27	*Hibiscus sp*
28	*Melinis sp*
29	*Nesaea cordata*
30	*Sporobolus tapfianus*
31	*Becium fimbriatum*
32	*Bulbostylis sp*
33	*Eragrotis sp*
34	*Senna italica*
35	*Loudetia sp*
36	*Loudetia simplex*
37	*Hyparrhenia sp*

APPENDIX 6
Cumulative frequency curves for predicting species richness in cultivated and uncultivated sites





APPENDIX 7

Bird species which were found on the Monavale vlei.

Scientific name	Common name
Acrocephalus arundinaceus	Great reed warbler
Amaurornis flavirostis	Black crake
Anomalospiza imberbis	Cuckoo finch
Ardea melanocephala	Blackheaded heron
Asio capensis	Marsh owl
Bradypterus baboecala	African sedge warbler
Bubulcus ibis	Cattle egret
Chloropeta natalensis	Yellow warbler
Chrysooccyx caprius	Diederik cuckoo
Cisticola juncidis	Fantailed cisticola
Cisticola natalensis	Croaking cisticola
Clamator levaillantii	Striped cuckoo
Colius striatus	Speckled mousebird
Corvus albus	Pied crow
Cypsiurus parvus	Palm swift
Dicrurus adsimilis	Forktailed drongo
Estrilda erythronotos	Common waxbill
Euplectes capensis	Yellowrumped widow
Gallinula angulata	Lesser moorhen
Gallinula chloropus	Common moorhen
Hirundo griseopyga	Grey rumped swallow
Laniarius aethiopicus	Tropical boubou
Lanius collaris	Fiscal shrike
Lophaetus occipitalis	Long crested eagle
Lybius torquatus	Black-collared barbet
Macronyx croceus	Yellowthroated longcla
Merops apiaster	European bee eater
Muscicapa striata	Spotted flycatcher
Oriolus larvatus	Blackheaded oriole
Phoeniculus purpureus	Redbilled woodhopoe
Ploceus cucullatus	Spottedbacked weaver
Ploceus velatus	Masked weaver
Porphyrula alleni	Lesser gallinule
Scopus umbretta	Hamerkop
Serinus mozambicus	Yelloweyed canary
Serinus sulphuratus	Bully canary
Spermestes cucullatus	Bronze mannikin
Streptopelia capicola	Cape turtle dove
Streptopelia semitorquata	Red eyed dove
Streptopelia senegalensis	Laughing dove
Turloides jardineii	Arrowmarked babbler
Uraeginthus angolensis	Blue waxbill
Vidua macroura	Pintailed whydah

APPENDIX 8

Insect species on the Monavale vlei.

Acrida acuminata
Anacridium moestum
Cheilomenes sp
Clonia wahlbergi
Danaus chrysippus
Eumenes sp
Henotesia sp
Hypolimnas missipus
Nezara viridula
Ornithacris sp
Palpopleura jucunda
Phymateus viridipes
Ropalidia cincta
Steganocerus mutipunctatus

APPENDIX 9

Field Data Sheet 1

Transect No.:_________________________ Transect length:______________________
Location:____________________________ Date:______________________________

Transect	Quad	Sp1	Sp2	Sp3	…	pH	Nitrogen	%O.C	Insect species
1	1					7	45	2	
1									
2									

APPENDIX 10

Field Data Sheet 2 – cultivated areas

Number of patch:____________________
Location:___________________________ Date:_____________________________

Quadrat No	**Plant Species**		**Soil variables**			
	Name	Number	pH	%O.C	cond	nitrogen