THE IMPACT OF WATER POINTS ON SPATIAL DISTRIBUTION OF VEGETATION, RANGE CONDITION AND SOIL PROPERTIES IN MBIRIKANI GROUP RANCH, KAJIADO DISTRICT, KENYA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATES STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULLFILMEMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

IN

DRYLAND BIODIVERSITY

June 2006

Addis Ababa University

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDUES

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A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Degree of Master's in Dryland Biodiversity

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DEDICATION

This study is dedicated to my beloved mother **Mrs. Mary Odoyo** for her affectionate love and persistent prayers that I become successful in pursuit of my academic ambitions

ACKNOWLEDGEMENT

First, I would like to express my sincere and special gratitude to my supervisors Prof. Zerihun Woldu of Biology Department Addis Ababa University and Dr. Jeff Odera of Regional Programme for Sustainable Development (RPSUD), for their constructive criticisms and constant guidance from the onset of proposal development to thesis write-up. I would like to thank the University of Nairobi (Department of Soil science) laboratory technician, Mr. Wangaruro for the assistance he granted me regarding soil analysis.

Much thanks are also extended to the National Museums of Kenya Herbarium staff for their cooperation concerning specimen storage and identification.

Special thanks also go to SIDA- SARREC through RPSUD for their financial support throughout the scholarship period. I am also indented to express my sincere thanks to all my classmates from Kenya, Tanzania and Ethiopia, and most remarkably Frank Alexander Mawi and Susan for the moral support they granted me throughout my stay at the university.

Last but not least, I express lots of thanks to Mbirikani group ranch officials, the area chief, the pastoralists, as well as the entire community members, for the cooperation and hospitality they showed me throughout my stay in the study site. Lastly I send my thanks to my parents, brothers and sisters for their financial an moral support they have always provided to me and not to forget in the long list is Dr Hellida Oyieke of National Museums of Kenya for her strong will of facilitating and strengthening my academic ambitions.

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ABSTRACT

The impact of water points on range condition, woody species density, soil properties dynamics, frequency distribution and palatability levels of shrubs and grasses was investigated around two water points. Density and frequency distribution data was collected from four transects radiating from the water points and sample plots marked at various consistent distance intervals of 0-50m, 200-250m, 400-450m and 600-650m.Whereby, 50m was used as a baseline measurement for all the transects. 20m by 20 m and 1m by 1m plots for density and frequency respectively were used. Range condition and soil properties' data were obtained from 0.5m by 0.5 m respectively. One way analysis of variance (ANOVA) and linear regression based on Minitab version 12.22 computer software was employed to assess the relationship between the environmental variables and the distance from the water points. For the woody species, the number of individual stems per plot increased in number with respect to distance from the water point both within and between transects, however this was tested not significant for all the transect directions. Greater density of mature individuals than saplings was recorded with respect to distance from both water points. Two methods independently followed to assess the status of range condition, revealed similar results. The method by (Naylor and Herlocker, 1987) involved a range condition scoring criteria ranging from 0-3, optimal, minimal status respectively and squarely based on estimations. Method by (Baars *etal*., 1996) involved actual sampling and scoring criteria ranging from 0-10 optimal, minimal status respectively. The area close to the water points (0-50) m, had poor range condition. The other three concentric zones all reflected fair condition. All the five soil nutrients (K, P, Ca, Om and N), showed a decreasing trend in values as the distance increases from the water points. Nevertheless, only Phosphorous and Organic matter showed significant variations. Fourteen shrubs and grass species selected by experienced pastoralists were used to explore the distance, frequency distribution and palatability preference relationships. Highly desirable (highly palatable and intermediate) grasses had high abundance away from the water points. Shrubs closer to the water points were found to be less palatable. Generally, it was apparent that the water points have a contribution to rangeland degradation and that the condition is likely to worsen if the trend remains unchecked.

INTRODUCTION

1.1 Background and Justification

Water points establishment in the rangelands are very vital for the subsistence of the people (Pastoralists) and their livestock. Nevertheless, these water points attract large herds of livestock and affect negatively the vegetation and soils close to the points. Grazing and browsing animals understandably influence the integrity of range vegetation. Although these animals certainly exerted some influence, rangeland vegetation co-evolved with foraging wildlife into a dynamic equilibrium between consumers and producers (Stoddart *et al*., 1975). With introduction of domestic livestock, a new force has been exerted on rangeland vegetation and the equilibrium of the past has changed.

Livestock have altered the composition of rangeland vegetation; plants with high forage values have decreased, giving way for the ones that are less desirable. Livestock have also altered the physiognomic aspects of vegetation. However, it is also worth noting that other factors such as fire, cultivation, and mining have also had some significant influence on vegetation changes in the rangelands (Coppock, 1994).

Range managers appraise the composition of rangeland vegetation to determine range condition and trend, this appraisal is based on how much the current vegetation deviates from its potential at the range site. The climax vegetation is of high forage value and preferred by livestock. Overgrazing shows proportional relationship with infiltration intensity (Heady and Child, 1994), that is, infiltration was lowest with heavy grazing and highest with less grazing.

In arid and semi arid lands, provision and improvement of water supply is the most urgent need perceived by rural communities especially by pastoralists (IFAD, 2000). Hoping to improve the living condition of pastoralists, interventions have been put in place involving the construction of earth dams in Kajiado district. Coppock (1994), discussed that the development effort since 1970s focused on the expansion of the wet season grazing areas for cattle through construction of many ponds. In general, water development is highly appreciated by the pastoralists. Contrary to the development projects, one of the outcomes of these development interventions is high livestock population (Coppock, 1994). Instead of increasing off-take of livestock and improving the livelihood of the pastoralists, the water developments contributed to the overgrazing (Coppock, 1994).

In Kajiado district, large herds of livestock subsist and overgrazing especially, around the watering points is a common phenomenon. This has led to land degradation, changes in plant communities, soil moisture and nutrients dynamics. Heavy grazing can change the composition of plant communities (Lands berg *et al*, 2002). Lange (1969), discussed that, interaction between animals and water points led to the development of distinct concentric ecological units around the water point. These units are at immediate vicinities of livestock watering points and form sacrifice zones.

Grazing gradients have been defined as patterns that reflect the concentricity of stocking pressure around water points (Andrew and Lange, 1986). The requirement of livestock to drink regularly makes watering points foci of livestock activity in the rangelands. Thus, they give spatial expression of grazing behavior and associated impacts. Artificial water structures capable of holding water for long have been developed to support livestock across the rangelands all over the world. It is broadly known that construction of artificial watering ponds support livestock in the rangelands of the world (Lands berg and Gillieson, 1996).

Proliferation of artificial water points occur because animals need to drink water regularly and long lasting water sources are scarce. The physiological dependence of livestock on water, results in livestock activity being concentrated near long lasting water points and this dissipates rapidly with increasing distance from the point (Lange 1969; Andrew and Lange 1986; Ludwing *et al.,* 2000). Therefore, watering places play an important role in structuring spatially, livestock behaviour and their impact on rangeland ecosystems. The spatial structuring of the grazing behavior and impacts, have profound importance for managing and monitoring biodiversity. Many aspects of biodiversity are sensitive to livestock grazing and require water remote areas to persist (Hunt, 1995; Landsberg *et al*., 1999). It has also been recorded that some plant species may require complete proliferation from livestock grazing and hence may only persist in undeveloped remnant areas (Landsberg *etal*., 2002).

Heavily grazed areas often create desirable habitats for invasive, exotic, less palatable species to establish and flourish (Landsberg *et al.*, 1999). It has also been documented that areas remote from watering sources can provide benchmark areas indicative of maximum biological integrity, to provide context for interpreting changes in grazed landscapes (Anger Meier and Karr, 1994)

1.2 Objectives

1.2.1 General Objective

To determine the impact of water points on the range condition, spatial distribution of vegetation and soil properties in the pastoral lands of Mbirikani group ranch, Kajiado district, Kenya.

1.2.2. Specific Objectives

1. To determine the impact of distance from the water point on density of woody species.
2. To determine the impact of distance from the water point on range condition.
3. To determine the impact of distance from the water point on soil properties.
4. To determine the impact of distance from the water point on frequency. distribution of palatable and unpalatable shrubs and grass species around the water point.

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2. LITERATURE REVIEW

2.1 Spatial distribution of woody species

The existence of natural rangeland vegetation was controversial. More recently, natural rangeland vegetation is designated to exist between deciduous tropical forest and sub tropical desert vegetation. The rangeland vegetation can be natural based on edaphic and climatic factors or it can be anthropogenic in origin (Blench and Sommer, 1999). The rangelands of East African countries are almost exclusively found in dryland areas, where there is general moisture deficit (Coopock, 1994; Herlocker, 1999). Therefore understanding the natural vegetation and ecological systems in response to the changing climate and anthropogenic influence is crucial for countries whose people's livelihood is squarely dependent on the rangeland natural resource base.

Grazing is one of the major factors influencing range vegetation types and distribution. According to (Blech and Sommer, 1999), some rangelands have co-evolved with grazing species and include: the Savannas of East Africa (Antelopes and Zebras), and the prairies of North America (Deer and Bison). Many studies that have been conducted to explore the relationship between grazing and dynamics of rangeland vegetation have not always come to a consensus. Disagreements have always existed between scientists.

Even though, there are a number of studies showing the negative impact of grazing, there are also researchers who have documented positive contribution of grazing on species diversity in the rangelands (Lamprey, 1979; Zerihun Woldu, 1985; Oba *et al*., 2001). However, it is clear that grazing and browsing animals have some influence on vegetation composition, biomass production and biodiversity distribution. According to (Oba *et al*., 2001), based on his grazing model, Grazing can either increase or decrease species richness depending on the intensity of the grazing. Overgrazing encourages the growth of unpalatable grasses and woody species and causes environmental degradation. Cumulative overgrazing reduces plant vigour and carrying capacity of rangelands, and the ultimate depletion of ground cover enhances gully erosion and the proliferation of unpalatable thorny and poisonous vegetation. In grazed sites of the Ethiopian highlands, (Zerihun Woldu 1985), found that important species like *Andropogon abyssinicus* and *Hyparrhenia* sp. were either reduced or eliminated and got replaced by less palatable species. Moderate grazing by removal of excess grazers and browsers stabilizes the rangeland ecosystems and therefore recommended (West, 1993).

Heavy grazing is a common phenomenon experienced in watering points especially in distances closer to the water point. Gamedo Dalle (2004), reported that cover of woody species is abundant in distances away from the watering points as opposed to the areas in immediate vicinity and the same applies to the proportion of bare ground. Gradients of utilization pressure are experienced around the water points with the greatest impact realized near the water points (Brits *et al*., 2002)

Differences in grazing gradients around water points are reflected in the differences in vegetation types and distribution around the point (Gamedo Dalle, 2004). Higher grazing pressure of livestock is associated with a decline in perennial and increase of annual cover, reduced litter cover, increased soil erosion, changes in the concentrations of soil nutrients, degradation of soil surface structure, reduced soil water infiltration rates and changes in near ground and soil microclimate (Yates *et al*., 2000)

2.2 Range condition

Range condition is the current productivity of a rangeland relative to what it is naturally capable of producing. Range condition is a vital tool used by the range managers to determine whether the existing management activities in operation are adequate and proper or some modifications are needed to avoid rangeland degradation but optimize its productivity. Different authors have documented different range condition classification based on different features. For instance, Dyksterhuis (1949) stressed on species composition criteria and Humphrey (1979), preferred forage productivity. However many authors encourage a combination of vegetation and soil attributes. Herlocker (1999), has developed range condition classification squarely based on vegetation communities resulting from the influence of different grazing regimes and assumes that grazing by livestock is the dominant land use.

Smith (1978), however, expressed a contrary idea that range condition classification should not necessarily assume grazing as the dominant land use. Therefore, range condition is simply the point at which criteria of interest of an individual or an organization is satisfied. That is, a rangeland classified to be in good condition for cattle production may be in poor condition for supporting camels and goats.

2.2.1 Range condition assessment and classification

There are a number of methods based on different criteria that have been used by different countries and scientists. Naylor and Herlocker (1987) suggested a classification of range condition in Northern Kenya based on the interpretation as ***good, fair, poor***, and ***very poor***. Baars *et al.*, (1996), on the other hand had his classification interpreted as ***excellent, good, fair, poor*** *and* ***very poor***. Heady (1975), suggested range condition evaluation interpreted as ***excellent, good, fair*** and ***poor.***

Regardless of the approach used, range condition is called low when: desirable species are replaced by poor species, there is reduced ground cover, erosion accelerates, reduced litter cover or a combination of all the factors and vise versa (Yates *etal.*, 2000)

2.3 Soil nutrients dynamics and range condition

Yates *et al*., (2000), reported that concentrations of Soil Nitrogen and available Phosphorous were significantly higher in heavily grazed woodlands and that the available potassium, Organic carbon and exchangeable Calcium and potassium, as well as soil pH were lower due to reduced inputs of organic materials for decomposition and nutrients cycling. (Gamedo Dalle (2004), reported, high concentrations of potassium Organic matter, Calcium, Cation Exchange Capacities and magnesium in rangelands away from watering point and that nitrogen and available phosphorous were high in areas in the immediate vicinity to the water point.

2.4. Heavy grazing and distribution of desirable and non-desirable species

Overgrazing of livestock has been considered as a major degrading factor because it changes the vegetation structure and composition, whereby the less desirable or non-palatable vegetation emerge and flourish (Landsberg 1999). Livestock have altered the composition of rangeland vegetation; plants with high forage values have decreased, giving way for the ones that are less desirable. The key problem on these is that rangeland grazing is sufficiently selective against palatable species and there can be a shift to dominance by unpalatable species. Grazing has different effects depending on plant phenology (Wtlktr *et al*., 1986). In particular, early plant growth is dominated by unpalatable species in some years and by palatable species in other years, depending when the first effective rains fall in relation to the intemally- programmed seasonality of the species. Palatable species can be favored by destocking during years when the timing of rainfall coincides with the maximum growth phase of these species.

De- stocking during a year when rainfall timing favors unpalatable species will not achieve the aim of increasing the proportion of palatable species. In summary, the range succession model is unsatisfactory in this instance not so much because of the importance of sudden transitions and extreme events, but more because it is difficult to arrange the possible states of the vegetation in a single linear continuum. Some plants are decreasers under grazing, while others are increasers. We now know that this pattern applies to most types of plants and animals. Furthermore, some decreasers are so sensitive that they occur only where there is negligible grazing pressure. Areas with very light grazing pressure are usually a very long way from water points. This is because domestic stock, native and feral grazing animals all need to drink frequently during hot summers that occur in rangelands. This reliance on water limits how far they can walk to graze between drinks. The number of water points in pastoral areas is increasing because it is good management to spread grazing pressure evenly.

However, one result is that there is now little land left that is only lightly grazed. This may lead to the severe decline of those species that are very sensitive to grazing. The increasers are most numerous near water points, whereas the decreaser species are most numerous in lightly grazed areas further from water. In some habitats there are decreasers that are particularly sensitive to grazing and they are found only at water-remote sites (Wtlktr *et al.,* 1986).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location of Kajiado District

Kajiado district is located at the southern end of the Rift valley Province. The republic of Tanzania borders it to the Southwest, Taita Taveta District to the Southeast, Machakos District to the East, Nairobi and Kiambu to the North and Narok District to the West. The district is situated between 36^0 5’ and 37^0 55’ and 1^0 10’and 3^0 10’ (Kajiado District Development Plan, 1988).

3.1.1.2 Location of Mbirikani Group ranch

This was Mbirikani area found in Southeast part of the district between 37^0 30’and 37^0 50’and 2^0 10’ and 2^0 40’. The area is situated between Mount Kilimanjaro to the south and the Mombasa- Nairobi Road to the North. 3,500 pastoralists living here depend on 5,000 cattle and 28,000 small stocks. (De Leeuw *et al;* 1991) This area has the largest livestock group ranch in Kenya called Mbirikani group ranch and covers an area of 1,350 km^2.

However, it supports people and livestock in Kenya more than any other ranch, more livestock is needed per person to meet the subsistence demand because the area is more arid and its people have very conservative view on livestock management. There are a number of man made water points throughout the area, as well as shallow wells in the Kiboko River in Mureshi. During the rainy season man made ponds, collect water that is shared by both the livestock and people. The location of water sources greatly influence where people live.

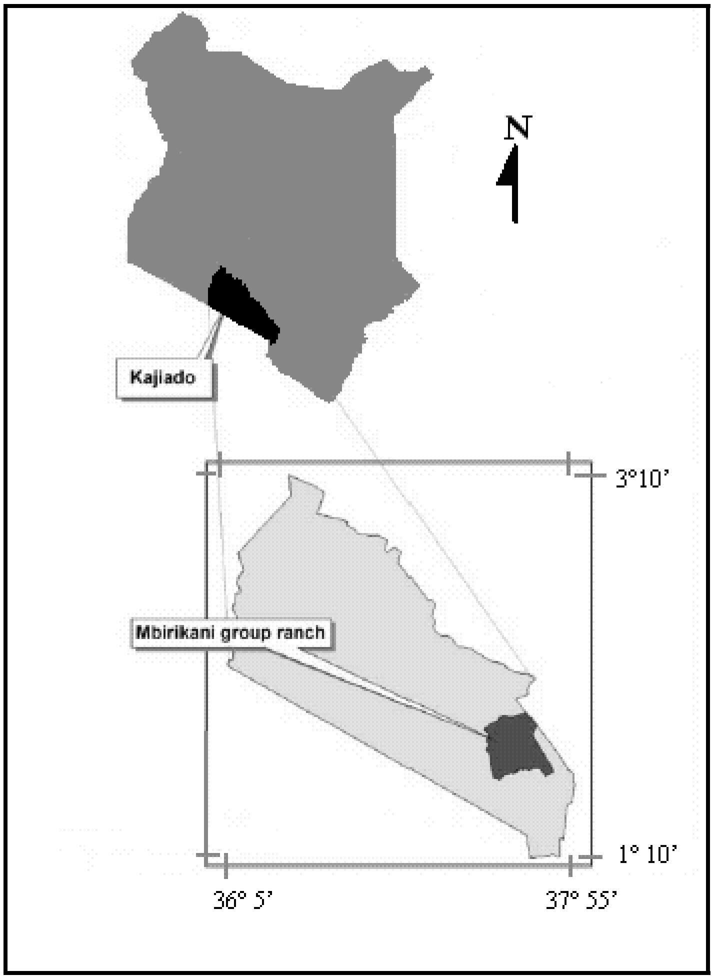

Figure 1: Map of the study area

3.1.2 Land and Soils

Four distinct geologic strata are found in Kajiado district. The Rift Valley floor is mainly characterized by soils of Quaternary volcanic origin that has weathered to yield dark reddish-brown, silty clay, and sandy clay particles. Igneous-basement rocks occupy a greater portion of Central Part of the district. Exposure of these rocks reveals landforms made up of quartzite, crystalline limestone, schist, and gneisses. Alluvial soils are found in isolated patches along River Valleys and Plains. Pleistocene sediments are also found in island drainage lakes, such as Lake Magadi, L. Natron and L. Amboseli (Kajiado District Development Plan, 1988).

3.1.3 Climate

Rainfall regime is bimodal with long rains from April to June and short rains from November to December. There is a long dry season from July to October and short dry season from January to March. However, the spatial distribution and reliability of the rainfall is highly variable. The area receives a mean annual rainfall of 650 mm. The temperatures are normally very high throughout the year especially in the Rift Valley floor (Kajiado District Atlas 1990).

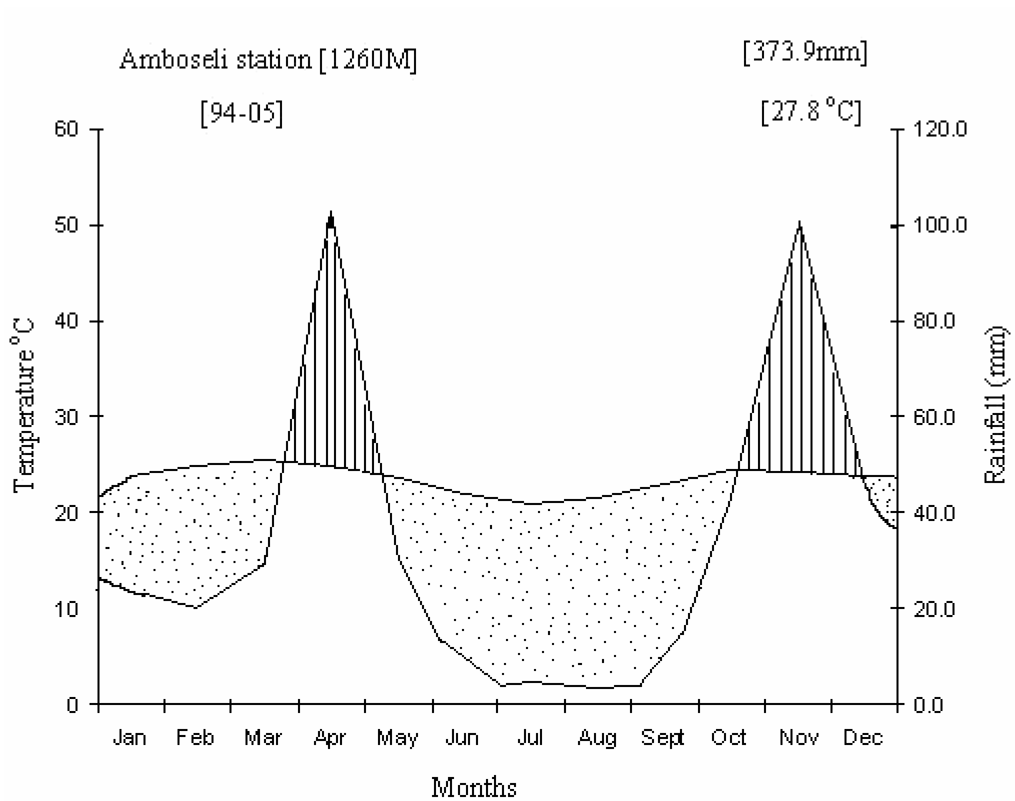

Figure 2: Climatic diagram of the study area

Source: Meteorological Department of Kenya, Dagoreti (1994-2005).

3.1.4 Vegetation

Vegetation cover is predominantly natural and comprises wooded-bush-shrub-open grassland that supports high density and diversity of livestock. The area is characteristically dominated by *Acacia mellifera*, *Acacia xanthophloea* and *Acacia tortilis* (Pratt and Gwynne 1977).

3.2. Study Design and Data Collection

3.1.2 Study design

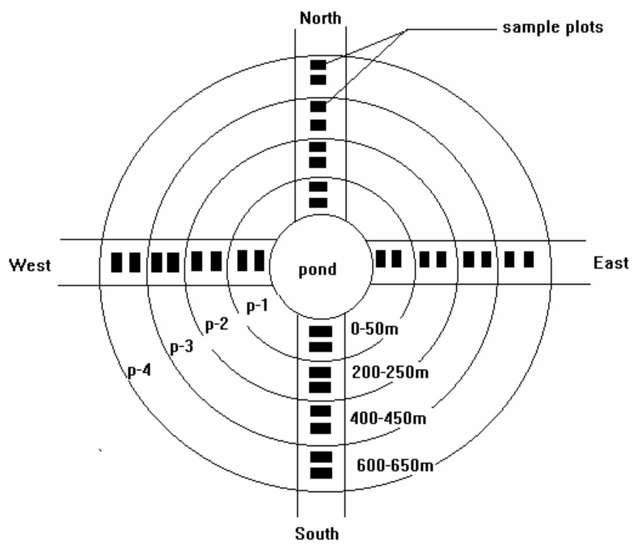

Figure 3: General study design of sampling a round the water point

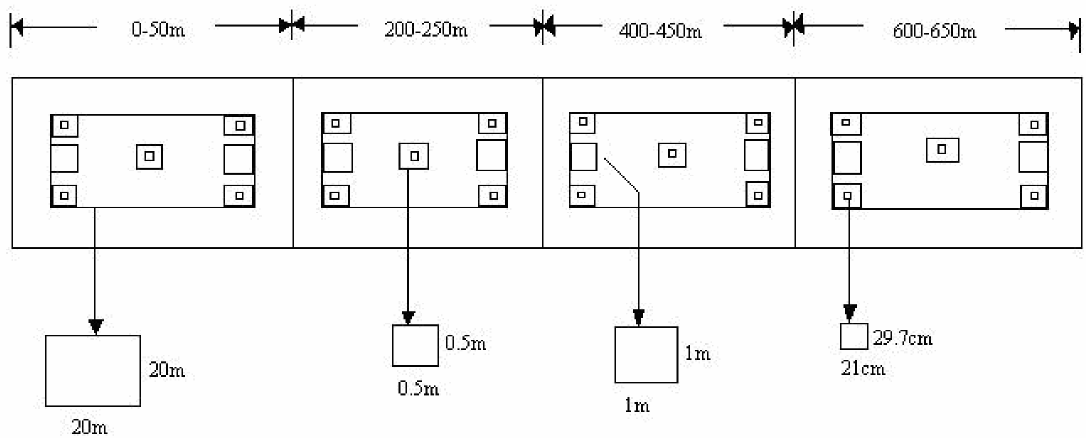

Figure 4: Specific study design of sampling along the transects

3.2.1 Woody species density data

Woody species density data was collected from 4 transects radiating, from the water point to west, east, north and south (Figure 3). A total of 16 plots, measuring 20m by 20m, were sampled. Each transect had 4 of such plots linearly located at distances of 0-50m**,** 200-250m**,** 400-450m**,** 600-650m respectively. Total number of individuals of each species encountered within the plot was counted, both saplings and mature ones separately recorded. Density of saplings and mature ones were considered to be the number of individual stems per plot. The same procedure was repeated for water point two.

3.2.1.1. Identification of specimens

This was done at the herbarium of National Museums of Kenya. The nomenclature followed the published flora of Kenya. The voucher specimen were deposited at the same herbarium.

3.3. Range condition assessment data

For the range condition data, two methodologies were independently and separately followed to validate each other so as to give strong grounds of inference. The first methodology was done following (Baars *et al***.,** 1996*).* Five assessment parameters were used and included; *grass botanical composition, grass basal cover, litter cover, grass age distribution* and *grass seedlings number*. A total of **80** sub-plots of 0.5m by 0.5 m were sampled for the first four parameters, whereas number of grass seedlings were determined from **21cm by 29.7 cm** (A 4 size paper), located at the centre of the sub-plots. The 0.5m by 0.5m sub plots were located within the main plot, 20m by 20m, along all the four transects. Each of the 20 m by 20 m contained 5 sub plots (Refer to figure 4). The score for each parameter was conducted following (Baars *et al***.,** 1996*).* Refer Table 1. The scores of the five parameters were summed up and overall ratings interpreted as***: Very poor*** (≤ 10), ***Poor*** (11-20), fair (21-30), ***good*** (31-40) and ***excellen***t (41- 50). The score r5ange varies from 0 -10 minimal to optimal respectively. This interpretation is based on a standardised range of values directly tied to the standardised scoring criteria table (Table 1) already developed by Baars *etal*., 1996.

Table 1 : Criteria for scoring the different factors determining range condition (Baars *et al.*, 1996).

Score	Grass composition	Grass basal cover	Litter cover	Grass seedlings number	Grass age distribution
10	91-100 % decreasers	>12 %, no bare areas	>40 %		
9	81-90 % decreasers				
8	71-80 % decreasers	>9 %, evenly distributed	11- 40 % evenly distributed		
7	61-70 % decreasers	>9 %, occasional bare spots			
6	51-60 % decreasers	>6 %, evenly distributed	11- 40 %, unevenly distributed		
5	41-50 % decreases	>6 %, bare spots		>4 seedlings on A4 paper	young, medium, old
4	10-40 % decreasers, ≥30 % increasers	>3 %, mainly perennials	3-10 %, mainly grasses	4 seedlings on A4 paper	two size categories present
3	10-40 % decreasers, <30 % increasers	>3 %, mainly annuals		3 seedlings on A4 paper	Only old
2	<10 % decreasers, ≥50 % increasers	1- 3 %	3-10 %, weeds/tree leaves	2 seedlings on A4 paper	Only medium
1	<10 % decreasers, <50 % increasers	<1 %	<3 %	2 seedlings on A4 paper	Only young
0		0 %	0 %	no seedlings	

The second methodology was conducted following (Naylor and Her Locker, 1987). This methodology was rapid and gave a quick overview of the range condition since it mainly involved estimations of sub parameters values. Sixteen 20mx20m main plots were used to sample the estimations along the 4 transects at different distances from the water point. Three components and their respective sub components in parentheses considered for the estimations were: ***Soil component,*** (*Trails*, *surface crust*, *litter*, *erosion*), ***Herb layer component***, (*Growth form*, *Crown vigour*, *herb composition*) and ***Shrub component***, (*hedgeability*, *Shrub vigour*, *shrub composition*).

The components and the sub component ratings were given equal weight. In Each main plot, sub components were rated on a scale of **0 to 3,** based on its position to optimal or minimal condition respectively. Components ratings were obtained by averaging the values of their respective sub components. Averaging the components' values gave the final range condition score of the plot in question.

The overall ratings in this case were interpreted as, ***good*** (0.00-0.55), ***fair*** (0.56-1.55), ***poor*** (1.56-2.55) and finally ***very poor*** (2.56-3.00). For guidelines and scoring criteria, see Appendix 1. The two methodologies were duplicated for the second water point.

3.4. Soil Properties Dynamics Data

Five soil properties considered included; Potassium, Calcium, Phosphorus, Nitrogen and Organic matter. The properties' data were collected from two transects at different linear distances from the water point. The data was obtained from fourty, 0.5m by 0.5m sub plots located within 20 m by 20 m main plots. Each main plot contained 5 of the sub plots at various linear distances. The soil samples were collected at two different depths, 0-15 and 15-30. The five samples of each depth were mixed to obtain a single sample for laboratory analysis. Two soil samples at different depths were obtained from 8 main plots and taken for laboratory analysis (a total of 16 samples from each water point)

3.4.1. Laboratory Soil Analysis Method

Soil analysis was carried out at University of Nairobi, in the laboratory of soil science department

3.4.1.1. Nitrogen

The percentage nitrogen in the samples was analyzed following The Kjeldahl method. This mainly involves the principle of oxidizing organic matter with concentrated sulphuric acid to liberate nitrogen in form of ammonium ions in the soil.

Calculation:

$$\% N = \frac{(a - b)}{s} \times N \times 0.014 \times 100 \times mcf$$

Where:

a = ml of Sulphuric acid required for titration of sample

b = ml of sulphuric acid required for titration of blank

s = air – dry sample weight in grams

N = normality of sulphuric acid (0.1 N)

0.014 = meq weight of nitrogen in g

mcf = moisture correction factor

3.4.1.2. Organic matter

This was principally estimated from the total nitrogen content found in a given sample. The % nitrogen was simply multiplied by a factor of 20. This assumes a 5 % N in the organic matter of a C: N ratio of 11:6. This is because organic matter is conventionally assumed to contain 58 % carbon.

Calculation:

% Organic matter = % Total Nitrogen x 20

3.4.1.3. Available Phosphorous

This was done following (Bray, R. H and L. T. Kurtz. 1945). Principally this involves the use of ammonium fluoride in a cid solution to liberate phosphorous in form of *acid soluble* phosphates.

Calculation:

$$P\ (ppm) = (a - b) \times 20 \times mcf = \frac{(a - b) \times 10 \times mcf}{S}$$

Where**:**

a = ppm P in sample extract   b = ppm P in blank

10 = extraction ratio (20/ 2)   S = sample weight in g (2)

20 = ml of extracting solution   mcf = moisture correction factor

3.4.1.4. Available potassium

This was determined following (Morgan, M .F., 1941**).** Primarily this involves extraction by the use of Morgan's solution and measurement of potassium by flame photometer.

Calculation:

$$\text{Avail. K (mg/kg soil)} = \frac{(a - b) \times 50 \times 1000 \times df \times mcf}{s}$$

Where:

a = concentration of K, measured in the sample (mg/ l)

b = concentration of K, measured in the blank (mg/l)

s = air – dry soil sample weight in g (10 g)

mcf = moisture correction factor

df = dilution factor

50 = ml of extractant used/sample

3.4.1.5. Available Calcium

The analysis of calcium was also done following (Morgan, M.F., 1941)

3.5. Frequency and palatability ranking of selected shrubs and grass species

Frequency of palatable and unpalatable species was calculated as the number of quadrats in which the species occurred over the total number of quadrants per each transect, times 100. Fourteen selected shrubs and grasses were used to explore the palatability category levels and frequency relationships. The frequency data was collected from 32; **1 m x 1m** sub plots located within 20m by 20m main plots at the extreme ends of the plots (Refer to the figure 4). Each transect had 8 such sub plots linearly placed along it. The same was repeated for water point 2.

Palatability preference was based on the perception of the pastoralists. 12, key informants were involved. Six persons, for each water point site. The key informants were randomly picked, but age was a guiding factor in the selection exercise. Only the aged were selected, i.e., those that were 70 years and above.

The palatability rank categories of the 14 selected species were arrived at through consensus among the informants. Then, the species were categorized as, *highly palatable*, *intermediate*, *less palatable* and finally *very less palatabl*e.

3.6 Data analysis methods

Involved both descriptive and inferential statistics. Data was summarized in both tables and graphs. One Way Analysis of Variance (ANOVA) based on Minitab computer software verson 12.22 was employed to explore the woody species density variations within and between transects with respect to distance from the water point but the density itself bwas calculated as the number of individual species per plot.

Regression based on Minitab computer software verson12.22 was carried out to explore the linear relationship between soil properties and distance. Range condition score and its assessment parameters were also analysed by regression for any linear relationship with the distance from water points.

RESULTS

4.1. Woody species density dynamics with respect to distance from the water point

The choice of direction of grazing varies among livestock. However, the choice of direction is determined by the direction of wind and topography. Cattle prefer grazing in the same direction with the wind and on flat land surface while sheep are known to prefer grazing against the direction of the wind and on elevated land surfaces.

4.1.1 Woody species density variations within transects

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Table 1**: One-way Analysis of Variance output of water point 1**

Variables	Transects	DF	F	P- value
Saplings	North	3	2.03	0.110
	West	3	1.22	0.303
	South	3	5.55	0.001**
	East	3	1.61	0.188
Mature	North	3	0.97	0.408
	West	3	1.38	0.250
	South	3	1.10	0.349
	East	3	0.93	0.425
Combined	North	3	1.51	0.212
	West	3	2.81	0.040*
	South	3	2.22	0.086
	East	3	1.44	0.233

Key: ****** = very significant; ***** = significant

The individual number of saplings and mature woody species, that is, the number of stems per plot increases with respect to distance from the water point. However, this increment does not hold to be significant for all the transects. Mature woody species density variations were not significant along all the four transects of water point1 with reference to P-values shown in Table 1. For the saplings, North, West and East demonstrated no significant differences (P = 0.110, 0.303, 0.188) respectively.

South transect on the other hand, showed very significant variations with respect to distance from the water point (P = 0.001) and recorded greater number of saplings compared to distances closer to the water point. In overall, for both mature and saplings combined, West expressed a significant increasing trend with respect to distance from the water point (P= 0.040)

4.1.2. Distribution variations per concentric distance from the water point 1

Table 2: Mean density (no.± Standard deviation) of woody species per 400m^2 with respect to concentric distance from water point 1

Distance (meters)	**Mature** (trees and shrubs)	**Saplings** (trees and shrubs)	**Combined**
0-50	38.25 ± 5.91	46.00 ± 10.10	76.25 ± 24.64
200-250	99.00 ± 34.82	43.25 ± 9.07	143.00 ± 37.40
400-450	121.50 ± 55.59	58.00 ± 35.62	183.50 ± 88.64
600-650	142.00 ± 94.14	72.00 ± 25.78	215.75 ± 119.32

Seventy woody species were recorded from the water points. From Table 2, generated by Kruskal Wallis test revealed that there is a very significant standard deviation for the mature woody species compared to the saplings with respect to distance from the water point 1 (P =0.006, 0.0096) respectively. The mean density for both saplings and mature woody species were not significant in variations.

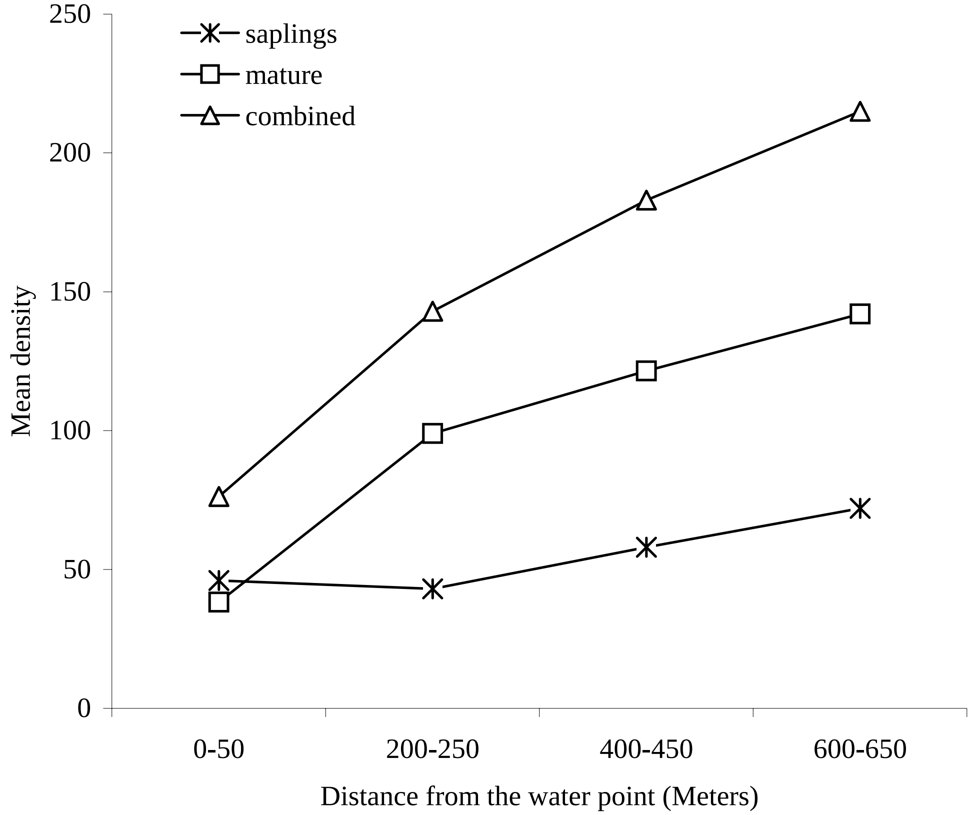

Figure 5: Trend showing mean density distribution of woody species with respect to distance from the water point 1

There is an increasing trend in mean densities for both saplings and mature woody species as the distance increases from the water point. Mature woody species had greater densities than the saplings. Surface crusting and cattle trails recorded greater values at distances closer to the water point compared to the distances away from the water points. High surface crusting and trails are associated with low water infiltration. Therefore, poor infiltration reduces the soil water below the critical threshold to support the regeneration process from the seed bank and vegetative parts. The low numbers of the saplings are likely to be attributed to this.

4.1.3. Distribution variations within transects at different distance from the water point 2.

Table 3 : One-way Analysis of Variance output of water point 2

Variables	Transects	DF	F	P- value
Saplings	North	3	0.78	0.505
	West	3	0.27	0.844
	South	3	0.64	0.587
	East	3	2.51	0.059
Mature	North	3	1.98	0.118
	West	3	1.08	0.359
	South	3	0.72	0.539
	East	3	2.01	0.113
Combined	North	3	2.89	0.036*
	West	3	1.08	0.357
	South	3	1.02	0.385
	East	3	2.95	0.033*

Key**:** ***** = Significant

For the mature, all the four transects showed no significant variations in distribution with respect to distance from the water point. Saplings expressed the same insignificant trend. All the transects recorded p- value greater than 0.05 (Refer to Analysis of variance output in Table 3). Mature and saplings combined, only demonstrated significant variation along north and east transects with p values of (0.036, 0.033) respectively.

4.1.4. Distribution variations per concentric distance from the water point 2

Table 4: Mean density (no.± Standard deviation) of woody species per 400m^2 with respect to distance from water point 2

Distance (meters)	**Mature** (trees and shrubs)	**Saplings** (trees and shrubs)	Combined
0-50	32.50 ± 11.21	31.75 ± 9.98	64.00 ± 16.39
200-250	68.00 ± 32.64	35.50 ± 6.40	103.50 ± 27.67
400-450	148.50 ± 44.52	53.75 ± 12.29	202.25 ± 50.38
600-650	81.00 ± 50.29	56.00 ± 14.02	137.00 ± 61.51

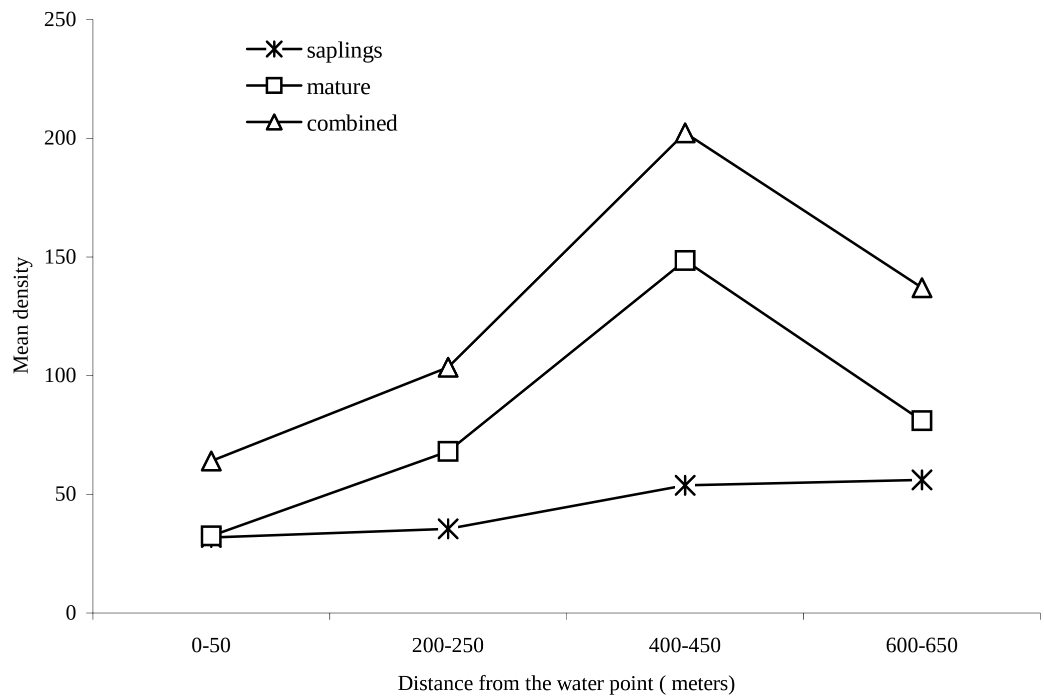

Figure 6: Trend showing mean density distribution of woody species with respect to distance from the water point 2

With reference to figure 6, generally more mature woody species were recorded than the saplings counterparts.) One-way analysis of variance revealed that the variation in mean densities was significant for both with respect to concentric distance from the water point ($P = 0.032$ and 0.042), mature and saplings respectively. The density of woody species increased with increase in distance from the water point up to (400-450) m. thereafter, the density decreased between (450- 650) m. There are human settlements observed at the distance range of (450- 650) m away from the water point. This has possibly contributed to intensified degradation of the area making it even more difficult for the regeneration process.

4.2 Range condition score with respect to distance from water points

4.2.1 Assessment of water point 1

Table 5 : Weighted averages of range condition scores with respect to distance around water point 1: Following (Naylor and Herlocker, 1987)

Parameters	**Sub Parameter**	**Distance** (Meters)			
		0-50	0-250	400-450	600-650
Soil	Erosion	1.25	1.25	1.25	1
	Litter	2.75	1.5	0.5	1
	Trail	1.5	1	1.25	1.25
	Surface crust	1.5	1.25	1	1.25
Herb layer	Growth form	2.25	1	1.5	1
	Crown vigour	1.75	1.75	1.25	1
	Herb composition	2	2	1.25	0.75
Shrub layer	Hedgeability	1.75	1.75	1.75	2.25
	Shrub vigour	2.25	1.75	1.75	1.25
	Shrub composition	2	1.75	1.25	1
Total		22.25	15.25	14.75	11.5
Average		**2.225**	**1.525**	**1.475**	**1.15**
Range condition score (Based on average values)		**Poor**	**Fair**	**Fair**	**Fair**

Table 6: Weighted averages of range condition scores with respect to distance around water point 1: Based on (Baars *et al.*, 1996)

Parameters	**Distance** (Meters)			
	0-50	**200-250**	**400-450**	**600-650**
Grass botanical composition	2.15	4.95	3.7	5.85
Grass basal cover	2.8	5.25	6.45	6.05
Litter cover	3.15	5.75	5.75	5.4
Grass seedlings number	2.8	4.05	3.7	4.5
Grass age distribution	1.5	3.7	4.35	4.25
Total	12.4	23.7	23.95	26.05
Range condition	**Poor**	**Fair**	**Fair**	**Fair**

4.2.2. Assessments of water point 2

Table 7: Weighted averages of range condition scores with respect to distance around water point 2: Following (Naylor and Herlocker, 1987)

Component	**Sub Component**	**Distance** (Meters)			
		0-50	**0-250**	**400-450**	**600-650**
Soil	Erosion	1.25	1.25	1.25	1
	Litter	2.75	1.5	0.5	1
	Trail	1.5	1	1.25	1.25
	Surface crust	1.5	1.25	1	1.25
Herb layer	Growth form	2.25	1	1.5	1
	Crown vigour	1.75	1.75	1.25	1
	Herb composition	2	2	1.25	0.75
Shrub layer	Hedgeability	1.75	1.75	1.75	2.25
	Shrub vigour	2.25	1.75	1.75	1.25
	Shrub composition	2	1.75	1.25	1
Total		19	15	12.75	12.25
Average		**1.9**	**1.5**	**1.275**	**1.225**
Range condition (Based on average values)		**Poor**	**Fair**	**Fair**	**Fair**

Table 8: Weighted averages of range condition Scores with respect to distance a round water point 2: Based on (Baars *et al.*, 1996)

Parameter	**Distance** (Meters)			
	0-50	**200-250**	**400-450**	**600-650**
Grass botanical composition	2.15	3.75	4.1	5.75
Grass basal cover	3.75	5.6	6.25	6.65
Litter cover	3.35	5.1	5.65	5.65
Grass seedlings number	2.4	4.3	3.95	4.1
Grass age distribution	2.1	3.4	3.5	4.5
Total	**13.75**	**22.35**	**23.45**	**26.65**
Range condition	**Poor**	**Fair**	**Fair**	**fair**

The range condition assessment for both water points, conducted following the two independent methodologies revealed similar results for both sites (refer to figures 5,6,7 and 8).

4.3. The relationship between distance from the water point and soil properties Values

4.3.1. Soil properties dynamics of water point 1

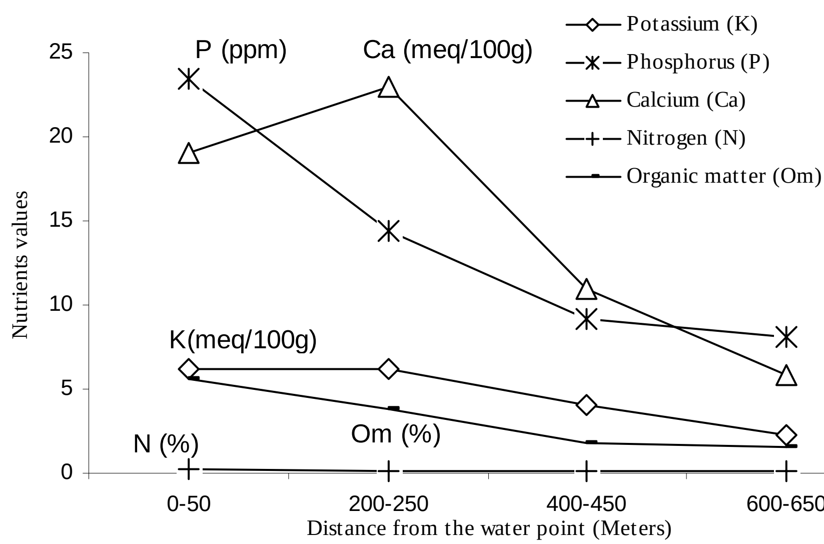

Figure 7: Soil properties distribution trend with respect to distance from water point 1

Table 9: Shows regression analysis summary of the relationship between

distance from the water point and soil properties' values (water point 1)

	K	p	Ca	N	Om
r	-0.8020	-0.9443	-0.8901	-0.8307	-0.9807
F	3.606	26.553	7.629	4.452	50.410
P	0.1980	0.0357*	0.1099	0.1693	0.0193*

Key: *= significant

The five soil nutrients considered, showed a negative correlation with respect to distance from the water point. The concentrations decreased with increase in distance from the water point. However, the decreasing trend was only significant for Phosphorous and Organic matter (Table 9).

4.3.2. Soil properties dynamics of water point 2

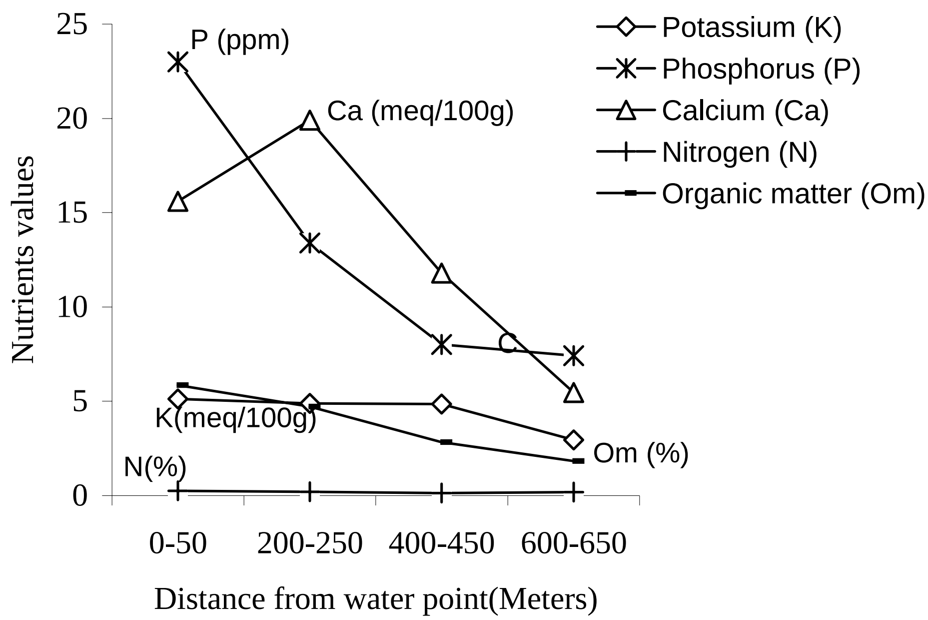

Figure 8: Soil properties distribution trend with respect to distance from water point 2

Table 10: Shows regression analysis summary of the relationship between distances from the water point and soil properties' values (water point 2)

	K	P	Ca	N	Om
r	-0.8581	-0.9093	-0.8485	-0.6664	-0.9924
F	5.587	9.545	5.143	1.598	129.28
P	0.1419	0.0507*	0.1515	0.3336	0.007**

Key: *= significant; **= very significant

Once a gain, the five nutrients correlated negatively with distance from the water point. Organic matter and Phosphorous expressed very significant and slightly significant decrease in concentrations with respect to distance from the water point respectively.

4.4. Distance, Frequency Distribution, and Palatability Preference Relationships

4.4.1. Palatability preference values of selected shrubs and grasses

Table 11: Showing botanical names and palatability preference values of selected grasses and shrub species surrounding the two water points

Botanical Name	Water point 1	Water point2
Pennisetum mezianum	L	L
Panicum maximum	I	L
Cynodon dactylon	H	I
Cenchrus ciliaris	H	H
Sporobolus pellucidus	H	I
Dgitaria milanjiana	I	H
Salvadora persica	I	L
Hibiscus macranthus	L	I
Maerua triphylla	L	L
Cadaba farinosa	VL	VL
Indigofera erecta	VL	VL
Sericocomopsis hildebrandtii	L	H
Barleria acanthoides	L	L
Idigofera spicata	L	L

NOTE: Value = Forage value as perceived by the pastoralists and only cattle preference were considered in the study

H = Highly palatable, I = Intermediate, L = Less palatable, VL = Very less palatable.

From the table 11, three grasses and one shrub were considered highly palatable and includes; *Cynodon dactylon*, *Cenchrus ciliaris*, *Sporobolus pellucidus* and *Barleria acanthoides*. The species that were regarded to be intermediate interms of palatability were *Panicum maximum, Digitaria milanjiana* and *Salvadora persica*. *Pennisetum mezianum*, *Hibiscus macranthus, Maerua triphylla* and *Sericocomopsis hildebrandtii* were listed to be less palatable. The category of very less palatability was shared by three species. These were *Cadaba farinosa, Indigofera spicata* and *Salvadora persica*.

Around water point 2, four species were considered highly palatable. They were, *Cenchrus ciliaris*, *Digitaria milanjiana*, *Sericocomopsis hildebrandti* and *Barleria acanthoides*. Three species were categorized as intermediate; *Cynodon dactylon*, *Sporobolus pellucidus* and *Hibiscus macranthus*. Those species that were regarded as less palatable were, *Pennisetum mezianum*, *Panicum maximum*, *Salvadora persica* and *Maerua triphylla*. Finally, two were recorded to be very less palatable. These were *Cadaba farinosa* and *Indigofera erecta*.

4.4.2. Range condition indicator status of selected shrubs and grasses from both watering points

Table 12: Botanical names of grasses and shrubs and their rage condition indicator categorization

Botanical Name	Growth Form	Increasers/Decreasers Categorizations
Pennisetum mezianum	Grass	Increaser
Panicum maximum	Grass	Increaser
Cynodon dactylon	Grass	Decreaser
Cenchrus ciliaris	Grass	Decreaser
Sporobolus pellucidus	Grass	Decreaser
Dgitaria milanjiana	Grass	Decreaser
Salvadora persica	Shrub	Decreaser
Hibiscus macranthus	Shrub	Decreaser
Maerua triphylla	Shrub	Decreaser
Cadaba farinosa	Shrub	Increaser
Indigofera erecta	Shrub	Increaser
Sericocomopsis hildebrandtii	Shrub	Increaser
Barleria acanthoides	Shrub	Increaser
Idigofera spicata	Shrub	Increaser

*Source: Range Management Handbook of Kenya, Kajiado district, 1992

4.4.3. Relative frequency distribution of the selected shrubs and grasses

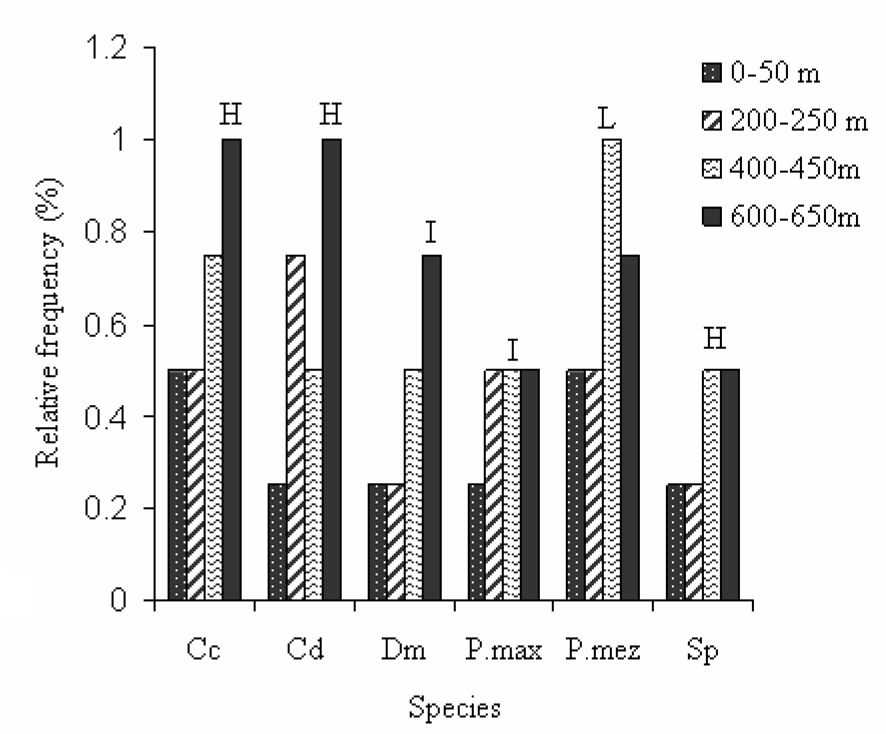

Figure 9: Relative frequency distribution and palatability preference rank of grasses with respect to distance from water point1.

Key: Cc- *Cenchrus ciliaris*; Cd – *Cynodon dactylon*; Dm – *Digitaria melanjiana*;
P.max –*panicum maximum*; P.mez –*Pennisetum mezianum*;
Sp – *Sporobolus pellucidus*

With reference to figure 9, *Cynodon dactylon*, *Cenchrus ciliaris* and *Dijitaria melanjiana* Showed highest frequencies at distance range of 600-650m. They have relatively low frequencies closer to the water point. *Pennisetum mezianum* was found to be more frequent at 400-450m but showed uniform distribution at a distance range of 0 – 250 m. *Panicum mezianum* showed low frequency at the distance range of 0-50, but again was found to uniform distribution between the distance range of 200-650

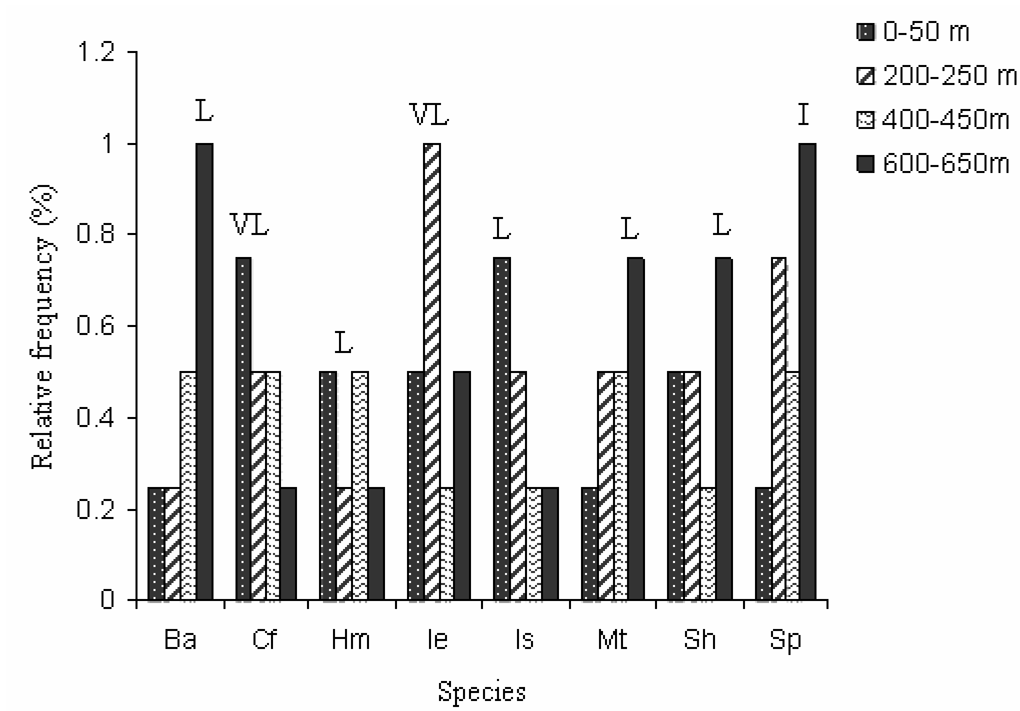

Figure 10: Relative frequency distribution and palatability preference rank of shrubs with respect to distance from water point1.

Key: Ba – *Barleria acanthoides*; Cf – *Cadaba farinose*; Hm – *Hibiscus macranthus*; Ie – *Indigofora erecta*; Is – *Indigofora erecta*; Mt – *Maerua triphyla*; Sh – *Sericocomopsis hildebrandtii*; Sp – *Salvadora persica*

With reference to figure 10, three shrubs were found to have greater frequencies away from the water point at distance range. All showed highest frequency at distance range of 600-650 m. That is *Salvadora persica***,** *Maerua triphylla* and *Barleria acanthoides. Cadaba farinosa*, *Indigofera spicata* and *indigofera erecta* were more abundant at distances closer to the water point than those farther away.

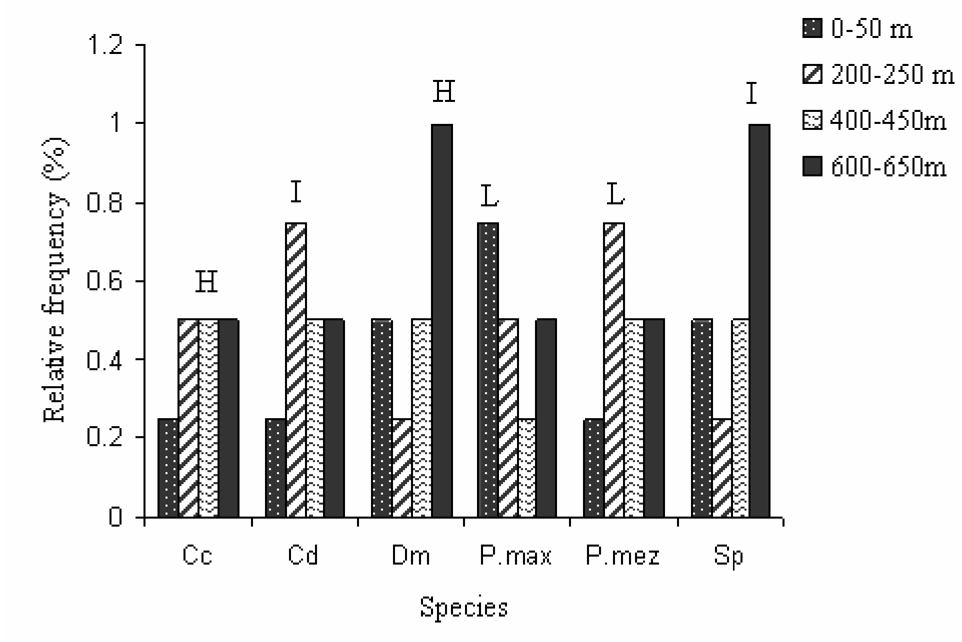

Figure 11: Relative frequency distribution and palatability preference rank of grasses with respect to distance from water point 2

Key: Cc- *Cenchrus ciliaris*; Cd – *Cynodon dactylon*; Dm – *Digitaria melanjiana*;
P.max –*panicum maximum*; P.mez –*Pennisetum mezianum*;
Sp – *Sporobolus pellucidus*

For the second water point, with reference to figure 11, *Sporobulus pellucidus* and *Digitaria milanjiana.* Showed highest frequencies at distance range of 600-650m *Panicum maximum* was found to be more at distances in close proximity to the water point while *Cynodon dactylon* showed highest distribution at distance of 200-250 muniform .

For the shrubs, around water point 2, as shown in the figure 12, four shrubs showed highest frequencies at distance range of 0-50m.That is high frequency close to the water point. no differences in their distribution with respect to change in distance away from the water point and include; *Barleria acanthoides* , *Sericocomopsis hildebrandtii, Maerua triphyla and indigofora erecta.* Out of the four shrubs only *maerwa triphyla* was found to be a decreaser the other three are increasers. Thus high abundance of increasers at distance range of 0-50 m close to the water point

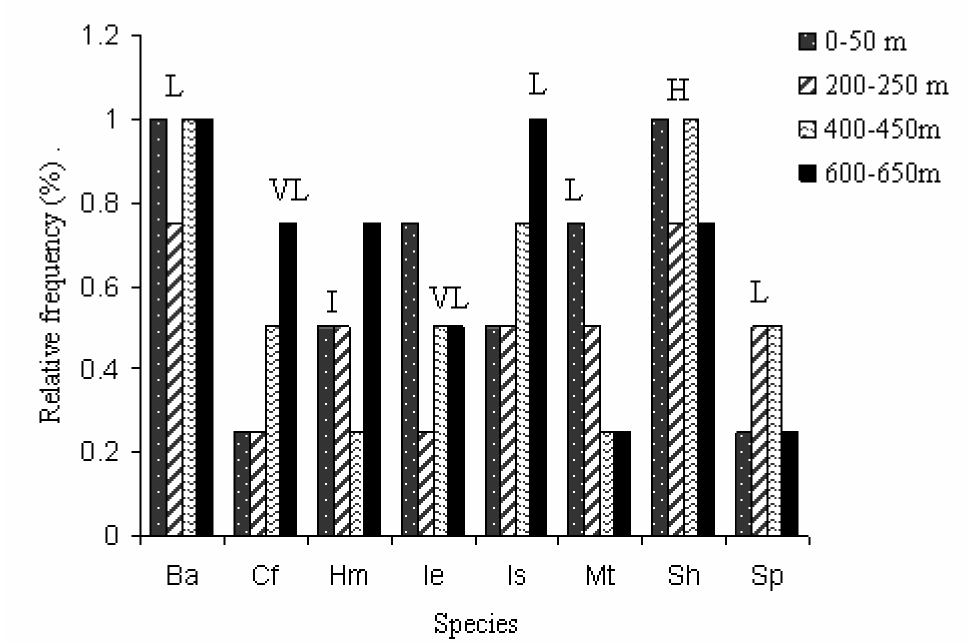

Figure 12: Relative frequency distribution and palatability preference rank of shrubs with respect to distance from water point 2

Key: Ba – *Barleria acanthoides*; Cf – *Cadaba farinose*; Hm – *Hibiscus macranthus*; Ie – *Indigofora erecta*; Is – *Indigofora erecta*; Mt – *Maerua triphyla*; Sh – *Sericocomopsis hildebrandtii*; Sp – *Salvadora persica*

All the environmental variables that were sampled in this study were analysed to reveal if there were linear relationship between them and distance from the two water points. Eighteen variables in total were analysed. Out of the 18 variables, saplings and mature woody species density showed significant relationship with increase in distance from water point 1 (p- value =0.028). For water point 2, five variables showed significant relationship with distance. Saplings, herb composition, crown vigour, shrub composition, grass botanical composition with P values of (0.047; 0.033; 0.037; 0.008

and 0.051) respectively. Herb composition was the only variable found to show common significant relationship with distance from both water points. (P-value = 0.002 and 0.033), water point 1 and 2 respectively (Refer Tables, 13 and14). Range condition score a major component of the study did not show significant relationship with distance from both water points.

Table13: Summary of Analysis of variance (Based on regression) output showing the relationship between environmental variables and distance from the water Point 1.

Environmental variables	**DF**	**SS**	**MS**	**F**	**P**	**R-sq (%)**
Woody species density	1	10254	10254	34.54	0.028*	94.5
Saplings	1	454.09	454.09	14.45	0.063	87.8
mature	1	5318.5	5318.5	15.18	0.060	88.4
Range condition 1	1	0.50955	0.95055	9.74	0.089	83.0
Range condition 2	1	78.1	78.1	4.31	0.174	68.3
Erosion	1	0.4009	0.4009	2.30	2.30	53.5
Liter 1	1	1.6809	1.6809	4.84	0.159	70.8
Trail	1	0.17818	0.17818	1.81	0.311	47.5
Surface crust	1	0.3028	0.3028	0.61	0.517	23.3
Growth form	1	0.5682	0.5682	3.70	0.194	64.9

Crown vigour	1	0.5796	0.5796	3.39	0.207	62.9
Herb composition	1	1.2445	1.2445	456.33	0.002**	99.6
hedgeability	1	0.0384	0.0384	0.28	0.649	12.3
Shrub vigour	1	0.44000	0.44000	14.67	0.062	88.0
Shrub composition	1	0.55687	0.55687	9.68	0.090	82.9
Grass botanical composition	1	4.551	4.551	2.86	0.233	58.9
Grass basal cover	1	5.566	5.566	4.52	0.168	69.3
Litter cover 2	1	1.970	1.970	1.44	0.353	41.9
Grass seedlings number	1	1.062	1.062	4.27	0.175	68.1
Grass age distribution	1	3.6541	3.6541	4.44	0.171	68.8

Key: ** = Very significant; ***** = significant Litter 1 = Based on: (Naylor and Herlocker, 1987); Litter 2 = Based on: (Baars *et al*., 1996)

Table14: Summary of Analysis of variance (Based on regression) output showing the relationship between environmental variables and distance from the water point 2.

Environmental variables	**DF**	**SS**	**MS**	**F**	**P**	**R-sq (%)**
Woody species density	1	4775	4775	1.73	0.319	46.4
Saplings	1	415.13	415.13	19.92	0.047*	90.9
mature	1	2351	2351	1	0.423	33.3
Range condition 1	1	0.24154	0.24154	11.44	0.770	85.1
Range condition 2	1	74.985	74.985	9.31	0.093	82.3
Erosion	1	0.030057	0.030057	3.57	0.199	64.1
Liter 1	1	1.8205	1.8205	3.73	0.193	65.1
Trail	1	0.00818	0.00818	0.14	0.744	6.5
Surface crust	1	0.04455	0.04455	1.11	0.403	35.6
Growth form	1	0.4705	0.4705	1.63	0.330	44.9

Environmental variables	**DF**	**SS**	**MS**	**F**	**P**	**R-sq (%)**
Crown vigour	1	0.39142	0.39142	25.71	0.037*	92.8
Herb composition	1	1.0509	1.0509	28.37	0.033*	93.4
hedgeability	1	0.4809	0.4809	3.57	0.199	64.1
Shrub vigour	1	0.44000	0.44000	14.67	0.062	88.0
Shrub comp.	1	0.61455	0.61455	117.57	0.008**	98.3
Grass botanical composition	1	5.8546	5.8546	18.23	0.051*	90.1
Grass basal cover	1	4.1482	4.1482	10.45	0.084	83.9
Litter cover 2	1	2.5778	2.5778	5.24	0.100	72.4
Grass seedlings number	1	0.9810	0.9810	1.52	0.343	43.2
Grass age distribution	1	2.5826	2.5826	15.90	0.058	88.8

Key: ** = very significant; ***** = Significant

Litter 1 = Based on: (Naylor and Herlocker 1987)

Litter 2 = Based on: (Baars *et al*., 1996)

DISCUSSION

5.1. Woody species density and distance relationships

A total of 70 woody species of 30 families and 55 genera were recorded from the two study sites (Appendix 4). Fabaceae was the most dominant family around the water points followed by malvaceae. More shrubs than trees were found at both watering Points. Generally, the mean density of woody species (mature and saplings) demonstrated an increasing trend with increase in distance from the water point within and between transects for the both water points. This concurs with the findings reported by others (Brits *et al.,* 2002, Gamedo Dalle, 2004). However, the increase did not hold to be significant along all the transects.

In water point one, all the four transects showed no significant variations in density with respect to distance from the water point for the mature woody species. Only South transect showed significant density increase for saplings. This was probably because some sections of the transect was passing through *olopololis* (areas fenced for calves to graze***).*** These fenced areas were observed to be secluded from livestock grazing and movement disturbances. In the second water point, the density of woody species increased with increase in distance from the water point up to (400-450) m. Thereafter, the density decreased between (450-650) m. This can be attributed to sprawling human settlements (Maasai manyattas) observed at this distance range. It is therefore possible to infer that human settlement combined with overgrazing have a compound degrading effect on rangeland.

Apparently, the woody species (mature and saplings) density was entirely low around the water points and this is likely due to extreme and prolonged droughts the area has experiences in the past. Due to drought, the soil water goes below the critical threshold and this hampers the regeneration processes around the water points. The areas around the water points have not been encroached by woody species as a result of grazing disturbance, however it is very apparent that if the livestock utilization trends continue, this will give way for bush encroachment.

From both water points, saplings registered lower density compared to mature woody species. This is an indication of low vegetation regeneration around the water points, despite the fact that, the range condition of the areas can be classified to be generally fair, but again if the trends continue, the range condition is likely to worsen.

5.2 Range condition and distance relationships

From the two independent assessment methods conducted for both water points, it showed that the range condition improves, as distance increased from the water points. All the individual assessment parameters positively correlated with change in distance from the water point, however, the relationship was not significant. From both sites, the area in close proximity to the water point registered poor range condition score compared to other three concentric distant counterparts. The result of the study showed that grass seedlings distribution correlated positively with distance from the water point.

There was higher number of grass seedlings at areas far away from the water point (Refer regression graphs in appendix 3). This finding concurs with (Yates *et al.,* 2000), which reported that in overgrazed areas, soil water could be below critical threshold for seed germination and seedling establishment, therefore low seedlings number. Thus, areas close to the water point can be said to have been overgrazed and soil water infiltration and storage is poor and reduced.

Basal cover also positively correlated with distance from the water point (Refer to appendix 3). More herbaceous cover was found farther away from the water point as compared to those areas close to the water point. O' Connor *et al.,* (2001), reported that basal cover is a determinant for infiltration and surface run-off and reduces with overgrazing close to the water points. This report is in agreement with findings of this study.

Litter cover recorded relatively greater values away from the water point at distance between 400-600m. Interestingly, this concurs with the comparatively high density values of woody species recorded at the same distance range for water point one. Water point two recorded highest density of woody species at concentric distance, 400- 450m from the water point (Refer to Table 4) and at the same distance, litter cover scored the optimal values. Therefore the optimal values can be explained by a lot of defoliation at the distance range (Refer to the regression figures in appendix 3).

Hedgeability (Level of forage utilization by livestock) at water point one was great at distance range of 0-200 and relatively less at 200-600m away (refer to regression figures in the appendix 3).

On the other hand, growth form (Composition of palatable and unpalatable species), negatively correlated with hedgeability. That is, even though there was heavy foraging around the water point, less desirable species were found there. This is likely to mean that the heavy grazing and browsing at close proximity to the water point has contributed to reduced number of highly desirable species around the water point.

5.3 Soil nutrients and distance relationships

From both water points, all the five nutrients considered demonstrated a decrease in values as the distance increases away from the water point. The decrease was only significant for organic matter and phosphorous for both sites. Controlled drinking, whereby different groups of herds are kept waiting next to the water point as others drink water was observed. Therefore, more organic matter at distances closer to the water point can probably be attributed to high accumulation of dung generated by the animals waiting to drink in turns.

The high value of nitrogen closer to the water point even though, not significant with respect to distance change is likely to be so due to urination and defecation by the animals. Yates, *et al., (*2000), reported high concentrations of Nitrogen and phosphorous and low concentrations of Calcium and potassium in heavily grazed woodlands. It is the presence of these animals around the water points that contributes to the high levels of N and P close to the water points. Therefore, high concentrations of these nutrients (N and P) sampled around the water point is a possible indicator that the areas close to the water point are being heavy utilized by livestock. He attributed the low concentration of potassium and calcium to reduced inputs of organic materials for decomposition and nutrients recycling.

Further more, the spatial distribution of Nitrogen and Phosphorous reported in the study concurs with earlier reports (Turner 1998; Angustine, 2003) in that soils near the water points had higher proportions of Nitrogen and phosphorous.

Gamedo Dalle, (2004), also reported greater concentrations of both nitrogen and phosphorous next to the water point and low concentrations of Calcium, potassium and organic matter away from the water point. Thus, regarding the Nitrogen and phosphorous concentrations variations, both of the reports are in agreement with the findings of the study. However, it is in disagreement regarding the variations of Calcium, potassium and organic matter. The disagreement may be due to the system of controlled drinking, herd population, status of the range condition and precipitation regimes found in the pastoral land where the study was conducted.

5.4 Frequency, palatability categories and distance relationships

The selected grasses and shrubs that were used to explore the relationship between frequency distribution, palatability levels and distance were first categorized as increasers and decreasers (Refer table 12).

From the study, it was apparently clear that the decreaser grass species that were once abundant close to the water points were diminishing. *Cenchrus Ciliaris, Digitaria melanjiana* and *Sporobulus pellucidus* were recorded to be of relatively greater abundance away from the water points. This concurs with (Makhabu *et al*., 2002), which reported that *Digitaria melanjiana* is a grass species that prefers undisturbed sites. Thus it can also be inferred that the areas away from the water point are relatively less disturbed. Gamedo Dalle, (2004), reported high abundance of *Digitaria melanjiana* and *Cenchrus Ciliaris* away from the water point and high abundance of *Cynodon dactylon* close to the water point.

Therefore, for the first two species, what he reported agrees with the findings of this study, nevertheless it fails to agree with the distribution of *Cynodon dactylon.* According to this study the abundance of the species (*Cynodon dactylon)* was relatively higher at distances away from the water point probably because it has been reduced by the heavy grazing around the water point. It is perennial and provides forage all year round.

From both water points, the four grasses that were categorized to be highly desirable to cattle (highly palatable and intermediate), that is, the indigenous knowledge of the pastoralists regarding the palatability preference coincided with the sampled information about frequency distribution and some of the already documented literature. All the four grasses are decreasers. Westoby (1980), discussed that some decreasers are so sensitive that they occur only where there is negligible grazing pressure.

Areas with very light grazing pressure are usually found at far areas from water points and that increasers are associated with heavily grazed sites and vise versa for the decreasers. Thus, this is in agreement with the results of this study since most of the grasses identified to be abundant away from the water point are mainly decreasers. However, even though no increaser grass species were recorded, closer to the water point, this does not necessarily mean that the areas close to the water point were not heavily grazed. This is because an alternative hypothesis emphasizes that grazing has different effects depending on plant phenology (Westboy, 1980).

Palatable and unpalatable species exhibit minimum and maximum growth phases and this varies with seasons. At one particular rainy season, unpalatable species may be at its maximum phase and palatable ones at its minimum phase and vise versa. It was leant that, the pastoralists reduce the number of herds per water point to increase the proliferation of palatable species. This would not achieve much if the rainfall coincides with the optimal phase of the unpalatable species. Therefore, there is need for further study of the seasonality proliferation regimes of decreaser and increaser species around the water points in the area.

Pennisetum mezianum, which showed low but uniform distribution regardless of the distance change, was regarded as less palatable by the pastoralists but provides forage through out the year. It is an increaser in the area and was once a major component of the vegetation but has now decreased in abundance with time. This is possibly because it is perennial and is grazed upon across both wet and dry seasons. Landsberg *et al.,* (*2002*), also stated that palatable- drought-hardy- perennial species are likely to decline in abundance with proximity to the water point.

Generally most of the shrubs were considered not to be palatable. This is probably because they are browse and rarely used by cattle, especially in wet season when the grasses are abundant. Generally shrubs, which were considered to be less and very less palatable demonstrated greater frequencies close to the water point. Some of these are increasers in the site and include, *Indigofera erecta, indigofera spicata*. A gain this justifies the concept of increasers being associated with heavily grazed areas thus, suggests that those areas close to the water point have been heavily utilized by cattle.

Barleria acanthoides expressed high frequency distribution regardless of change in distance from the water point and it is an increaser species in the area. This can be attributed to the *increasers' species concept* dynamics, whereby; the increaser species first increase in number with prolonged selective grazing on desirable (decreasers) species and ultimately decrease to give way for invaders (Dyksterhius, 1949). Therefore high abundance of *Barleria acanthoides* in the area suggests that the area has been overgrazed. The desirable (decreasers) species around the water points have been selectively grazed upon and has given way for the proliferation of *Barlaria acanthoides* (increaser)

CONCLUSIONS AND RECOMMENDATION

6.1 CONCLUSION

The number of water points in Mbirikani pastoral area is increasing because it is good management to spread grazing pressure evenly. Water points are vital and indispensable in the rangelands all over the region, for the purpose of pastoralists' survival together with their livestock. Livestock production is the major viable economic activity in the area and should not be substituted but to be improved and where possible complemented by other sources of livelihoods.

Water points in the rangelands of Mbirikani group ranch, Kajiado district, have attracted heavy grazing around them. This has led to land degradation and reduction of the number of desirable grass species in areas close to the water point. Most native plants and animal species in the area have not been affected by grazing but decreaser species do decline in number because of overgrazing around the water points. Some decreasers are found only in areas far away from water points; these areas have very light or no grazing pressure.

The study from both water points revealed that areas around the water points are more degraded than those further away. Areas close to the water point registered poor range condition compared to their distant counterparts. Nevertheless the range condition of the area can be said to be fair but with prominent indications that if the trends remain, it is likely to worsen. The low density of woody species saplings compared to the mature ones is a clear indication that vegetation regeneration is low and poor in both sites and it can be inferred that the water points have a contribution.

The water points and pasture are communally owned, while livestock ownership is private. This scenario is one of the root causes of unsustainable utilization of range resources in the area. The grasses that were once highly desirable by livestock have decreased in frequency around the water point and there are indications that they are likely to disappear in the near future. The area exhibits large herds of livestock that cannot be sustained by the few existing water points. This has exacerbated the degradation processes around the water points. From both water points, the emergence of increaser species could apparently be depicted and this can be attributed to prolonged overgrazing. Therefore, this calls for the need to strike a balance between livestock production and biodiversity conservation.

6.2. RECOMMENDATION

There is a need to strike a balance between range resource utilization and conservation. The following are the recommendations through which the balance can be created between the natural resource base and biodiversity conservation in the area.

1. Property planning for production and conservation purposes. To conserve rangeland species of the area there is need to plan at a broader area i.e. the neighboring ranches should be integrated in any development plan concerning biodiversity conservation for the benefit of livestock production.
2. The disappearance of the decreaser (highly desirable) species was apparent in the area. Therefore, there is a need to develop a network of lightly grazed or ungrazed areas in order to cater for the decreaser species. This can be achieved by:
   - Retaining some paddocks in water –remote areas. Retaining about 10% of the total area for sensitive landscapes and habitats and about 5% of more resilient landscapes.
   - The protected grazing patches should be evenly distributed to alleviate the problem of overgrazing a given area.
   - Fence the protected grazing patches.

3. The establishment of water points should be controlled and evenly distributed so as to evenly distribute grazing pressure. Any given water point should be assigned a given number of livestock it can adequately sustain.
4. There is need to introduce shifting drinking system, whereby once a given water

point has been used for a sustainable period of time, it should be temporarily abandoned to allow for vegetation regeneration around the water point.

5. Many range managers talk of de-stocking as one of the viable solutions to curb the problem of overgrazing (increasers and invaders proliferation around the water point). De- stocking during a year when rainfall timing favors unpalatable species will not achieve the aim of increasing the proportion of palatable species. Therefore there is need to study the proliferation patterns of decreasers, increasers and invaders across the seasons around the water points so as to assist in proper regulation of the number of herds per water point this is to be considered as a gap presented by this study.
6. Conservation education geared towards range resource utilization should be a priority.
7. The water points and human settlements around the water points contribute to a compound degradation effect. Therefore there is need to establish water points away from the settlements and vise versa.

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APPENDICES

Appendix 1

Range Condition Assessment and Rating Guidelines modified for Kenyan situation (Naylor and Herlocker, 1987

*** Rating Criteria for range condition classes**

Condition classes	Rating
Good	0.00 – 0.55
Fair	0.56 –1.55
Poor	1.56 – 2.55
Very poor	2.56 – 3.00

*** Guide to hedgeability and degree of hedging**

Degree	Criteria
Little	Shrubs show little or no browsing and retain their normal shape.
Moderate	Shrubs show truncated branches; near normal branching and retain their normal shape.
Heavy	Shrubs show abnormal growth (Secondary branching, most branches are truncated. It is apparent that browsing is influencing the shape of the shrub.
Very heavy	Little or no branching is apparent. Shrubs resemble a well-trimmed mound or hedge. New growth occurs from large woody stem. Secondary branching may be obvious.

* Component and Sub components Rating Guidelines

Component	Sub component	Criteria	Rating
SOIL	**Erosion**	Soil is level, microtopography is present but slopes. No sign of soil movement.	**0**
		Plants elevated but slopes gentle and angles obtuse or rounded and/ or some other indication of soil loss as in the piling of sand in or on one side of a plant. The presence of micropiles on the sandy surface.	**1**
		Plants considerably elevated on pedestals with abrupt sides and / or evidence as considerable soil movement as shown by the common occurrence of sand piles and blowouts. Sheet erosion is common covering from 10-30 % of the area.	**2**
		Abrupt elevated pedestals with plant roots exposed and/ or evidence of much soil movement. Indicators being; sand dune formation, hummocks, abundant sheet erosion, gullies etc	**3**
	Trails	Few or no trails; may be immediately apparent.	**0**
		Present; several trails may be seen over an area of a bout one hectare	**1**
		Many; may be readily apparent when viewed from one spot; over 10 % of surface area in trails	**2**
		Obliterated by surface erosion so that only bare soil exist. This only applies where it is obvious that livestock have caused the removal of vegetation as for instance, near villages or boreholes or on major roots of livestock.	**3**
	Litter	Herbaceous litter present and fairly equally distributed.	**0**
		Herbaceous litter distributed contagiously (scattered groups) particularly in protected areas.	**1**
		Herbaceous litter occurs only in definite dams or is almost absent. Most litter is woody (twigs and bit of bark)	**2**
		Herbaceous litter absent but some woody litter may occur.	**3**

*** Component and Sub components Rating Guidelines**

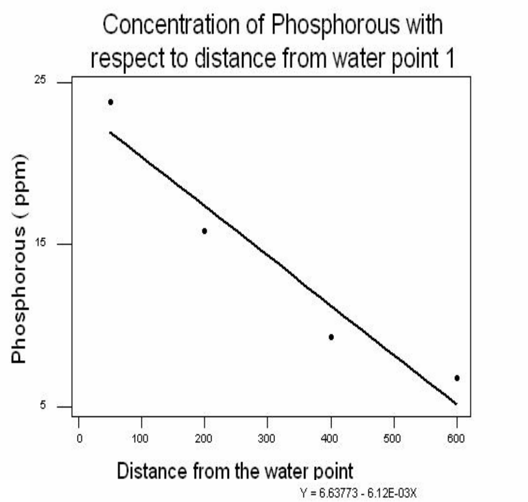
Component	Sub component	Criteria	Rating
SOIL	**Surface crusting**	No surface crust	**0**
		Little or no hard surface crust but small areas with swept appearance.	**1**
		Large areas between plants appear to have been swept and packed.	**2**
		Most bare areas between plants appear swept and packed.	**3**
HERB LAYER	**Growth form**	Palatable bunch grass form obvious and dominant; culms and leaves abundant and tall.	**0**
		Palatable bunch grass form apparent, culms and leaves common but short.	**1**
		Palatable bunch grass form not distinct. Culms and leaves are small and few for the size of the crown Mat forming (Stoloniferous and rhizomatous) grasses may be present.	**2**
		Palatable bunch grass form absent. Mat forming grasses, sedges, forbs, or annual grasses dominate or vegetation is entirely absent.	**3**
	Crown Vigour	Decreaser crowns healthy	**0**
		Decreaser crowns unhealthy/ increaser crowns healthy.	**1**
		Increaser crowns unhealthy/ invader crowns healthy.	**2**
		Invader crowns unhealthy	**3**
	Composition	Decreasers/ increasers share dominance	**0**
		Increasers dominate.	**1**
		Increasers/ decreasers share dominance.	**2**
		Invaders dominate.	3

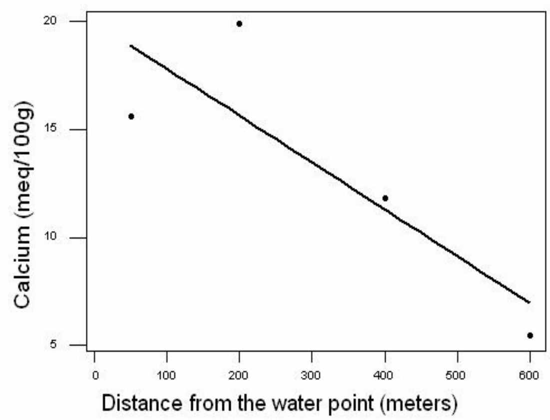
*** Component and Sub components Rating Guidelines**

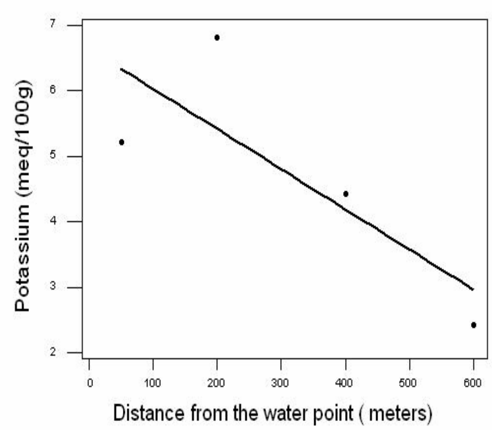
Component	Sub component	Criteria	Rating
SHRUB LAYER	**Composition**	Highly palatable and palatable shrubs share dominance.	**0**
		Palatable shrubs dominate.	**1**
		Palatable and less palatable shrubs dominate.	**2**
		Less palatable and un palatable shrubs dominate	**3**
	Hedging	Most hedgeable shrubs are highly to moderately hedged.	**0**
		Hedgeable shrubs are lightly to moderately hedged	**1**
		Hedgeable shrubs are heavily and very heavily hedged	**2**
		Some usually unhedgeable shrubs are hedged.	**3**
	Shrub vigour	Few or no decadent shrubs	**0**
		Some shrubs are decadent because of hedging.	**1**
		Some shrubs are dead because of hedging	**2**
		Many shrubs are decadent and dead from hedging	**3**

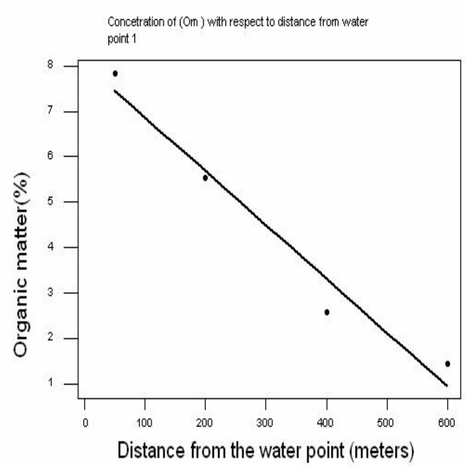
Appendix 2

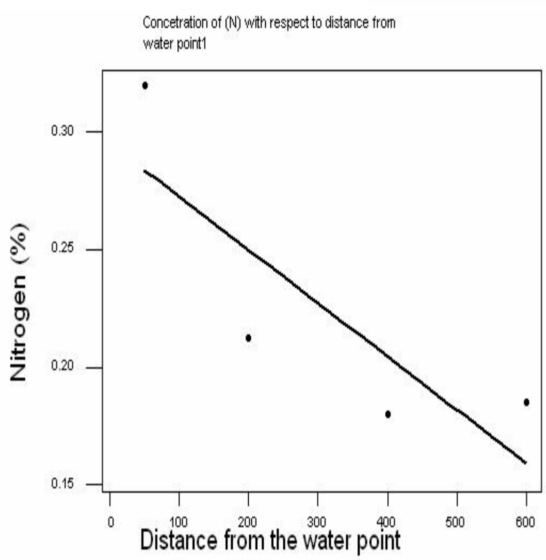
Regression figures of soil nutrients and distance relationships of watering point 1



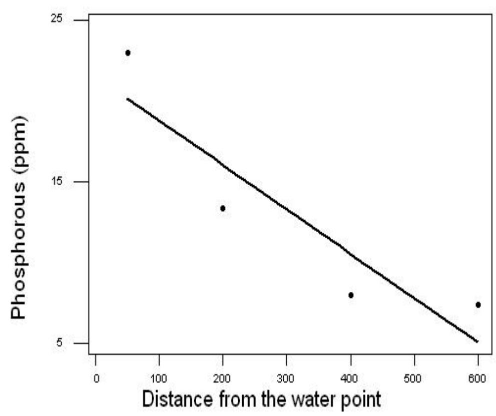


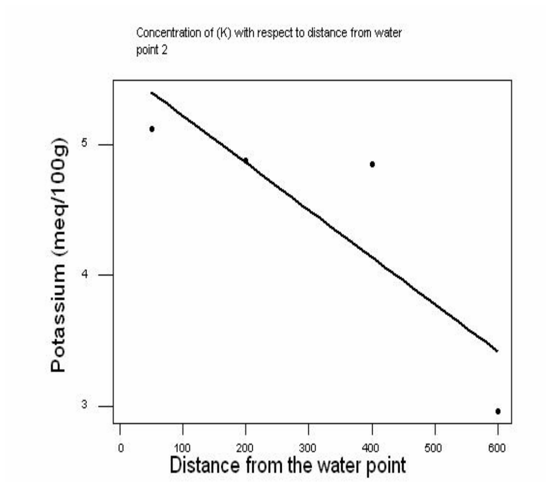


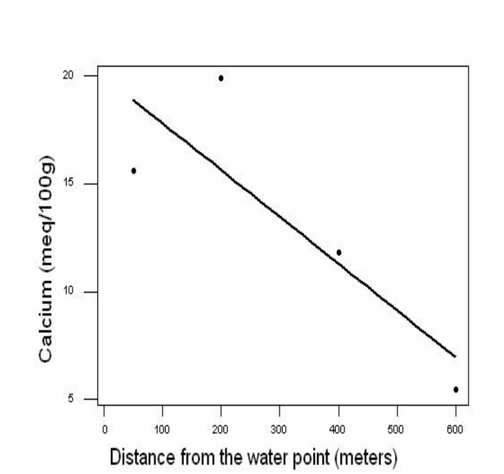


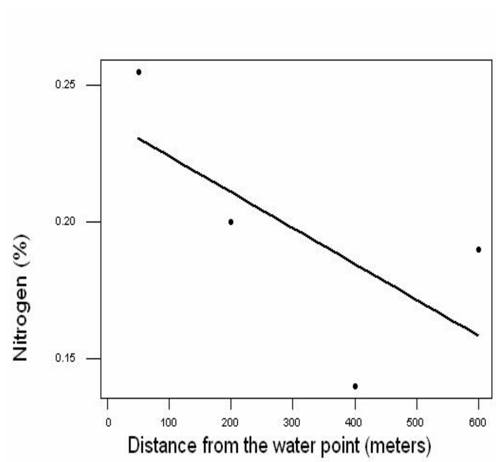


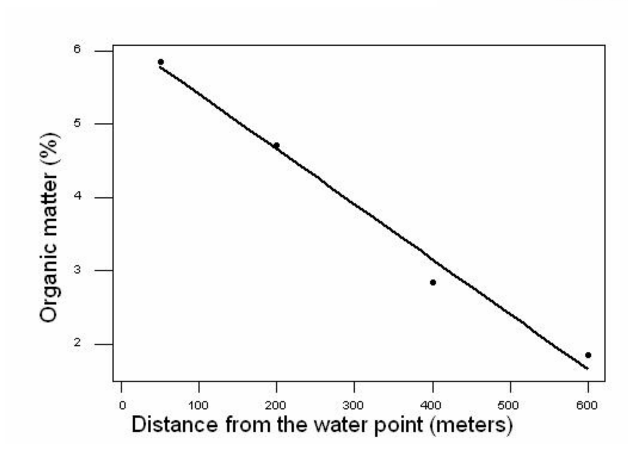
Regression figures of soil nutrients and distance relationships of watering point 2









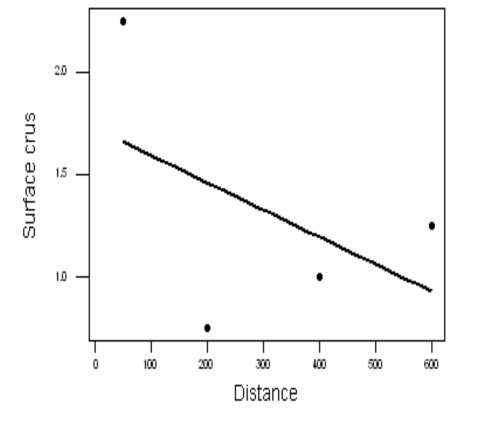


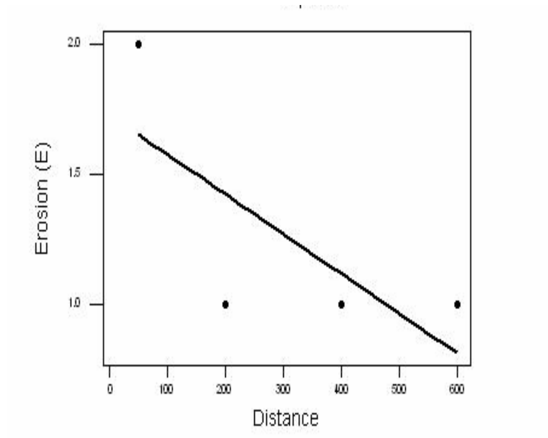
Appendix 3

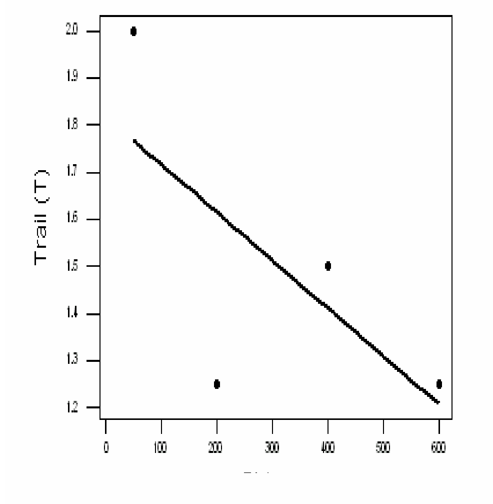
Regression figures of rage condition assessment parameters of watering point 1

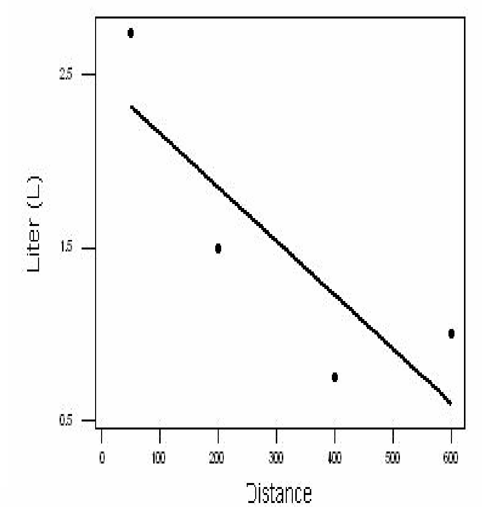
Regression graphs of **water point one** based on (Naylor and Herlocker 1987)

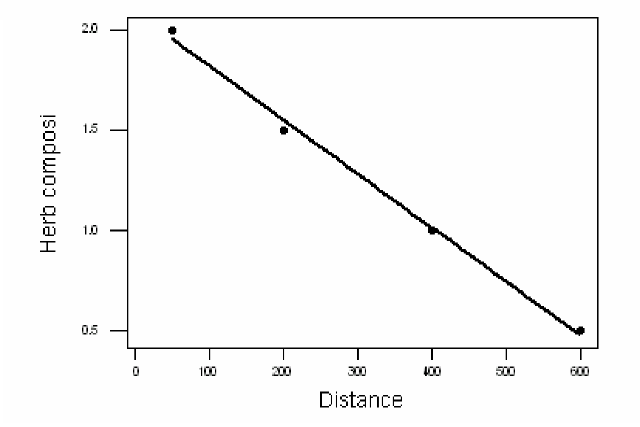
Range Condition Assessment Parameters

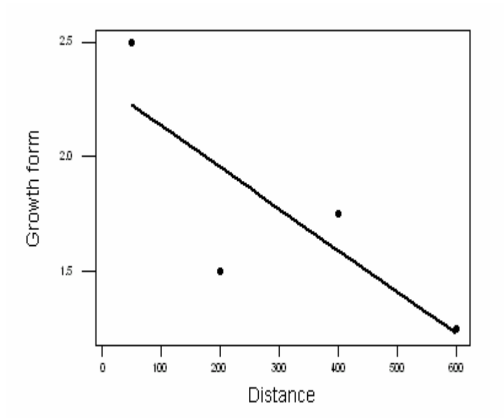


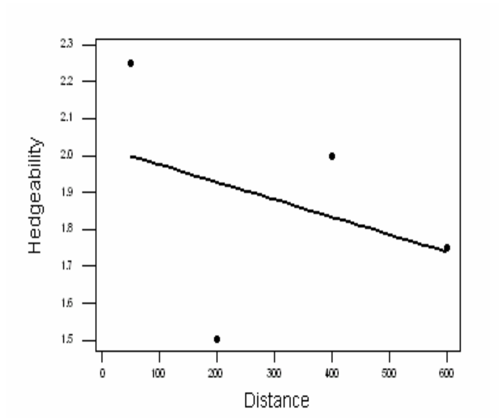


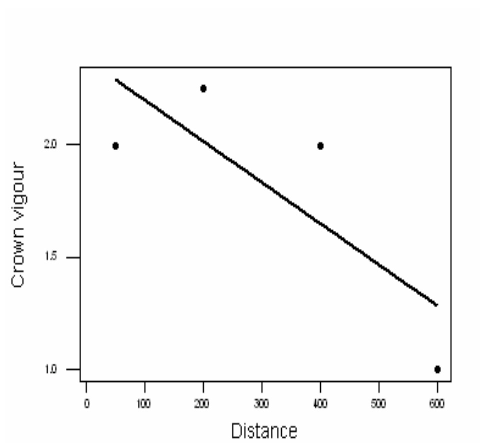


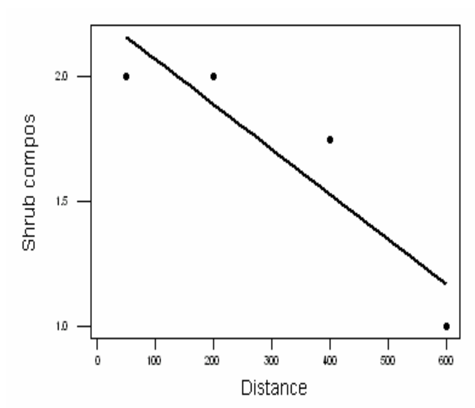


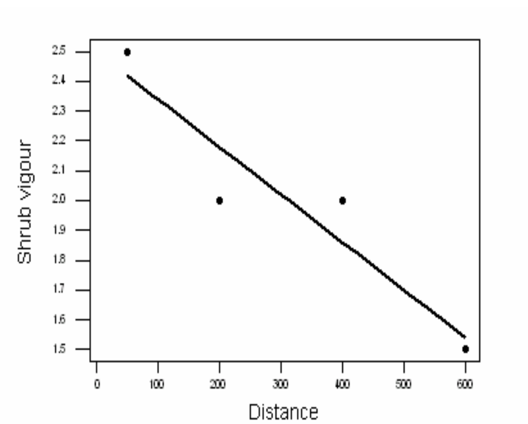



Growth form
Distance

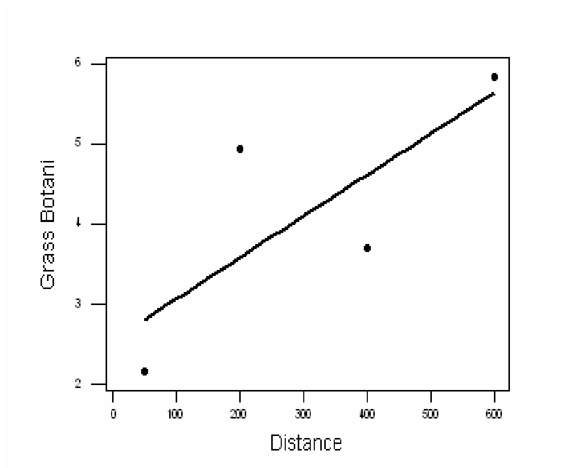

Hedgeability
Distance

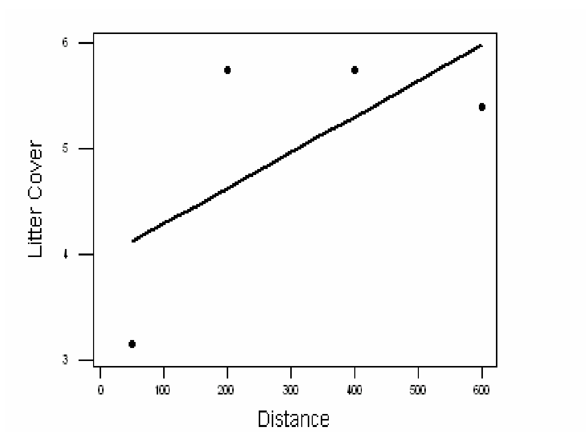

Crown vigour
Distance

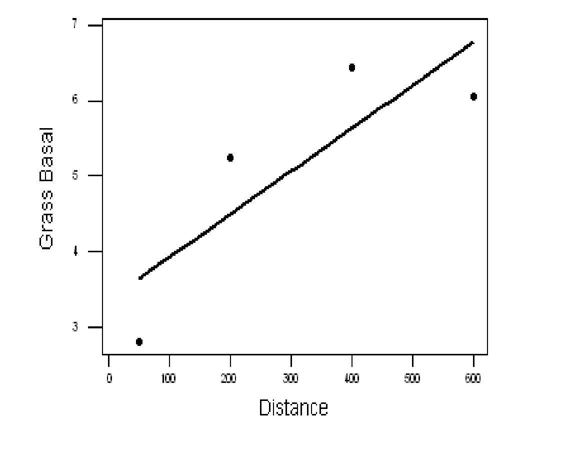

Shrub compos
Distance

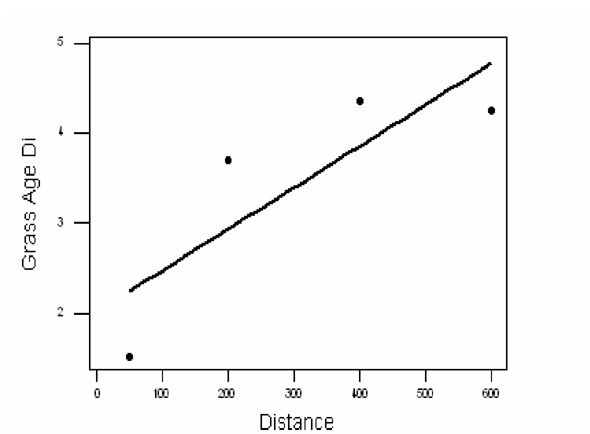

Shrub vigour
Distance

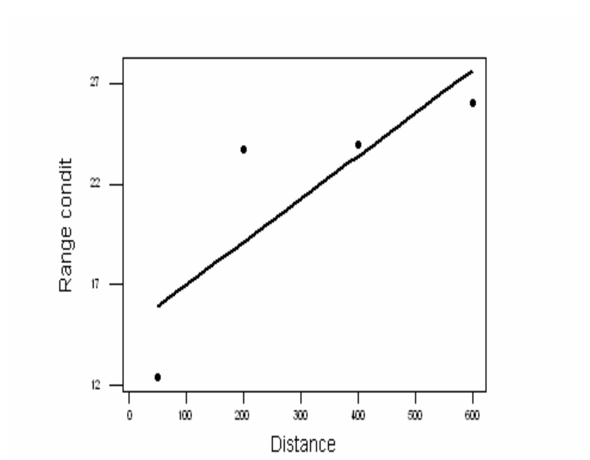
Regression graphs of **water point one** based on (Baars *et al.*, 1996) range condition assessment parameters





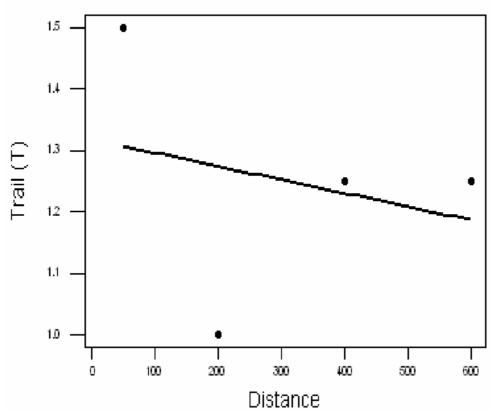


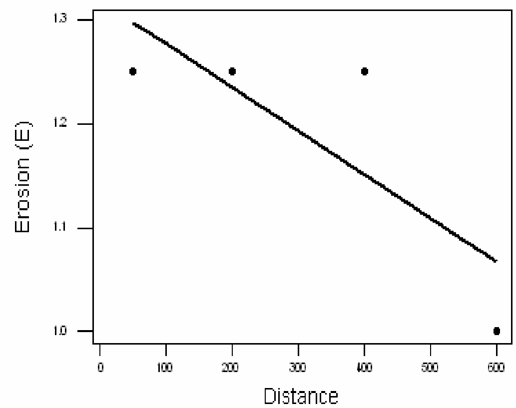


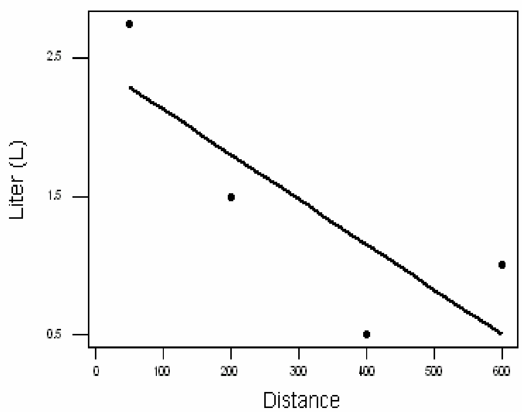


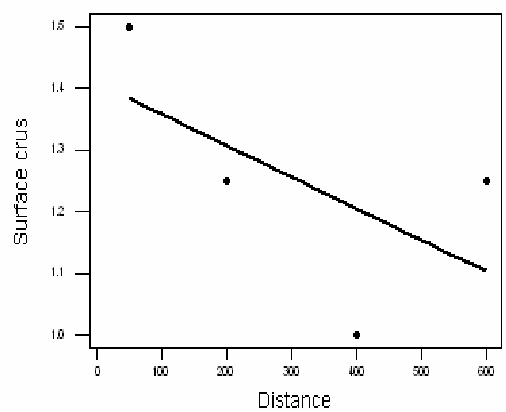
Regression figures of rage condition assessment parameters of watering point 2

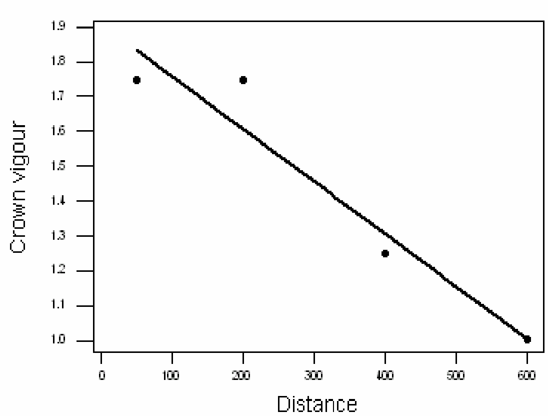
Regression graphs based on (Naylor and Herlocker 1987) Range Condition Assessment Parameters

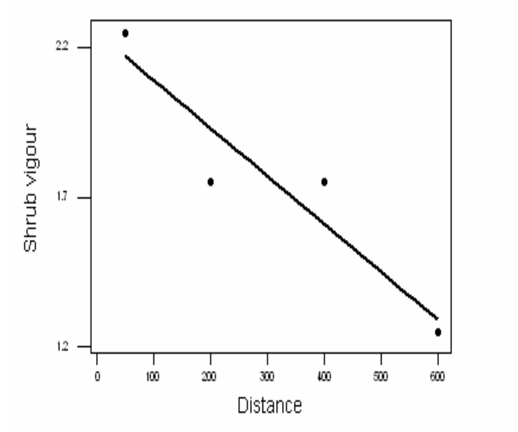


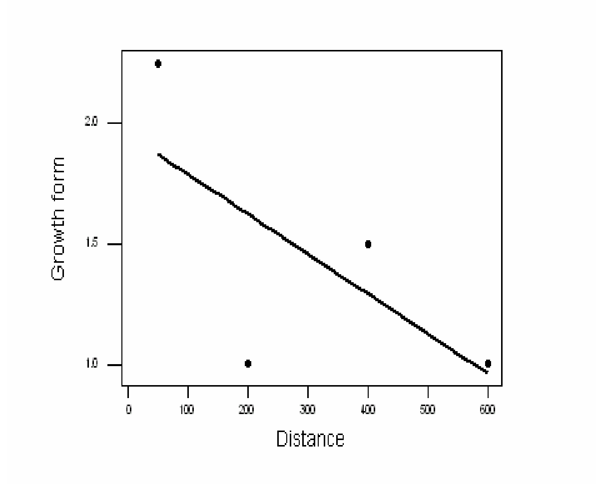


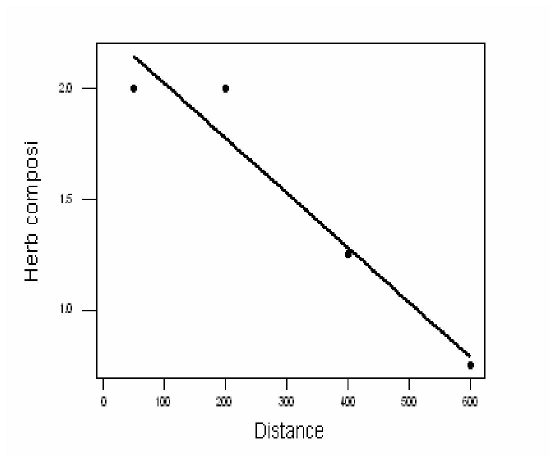


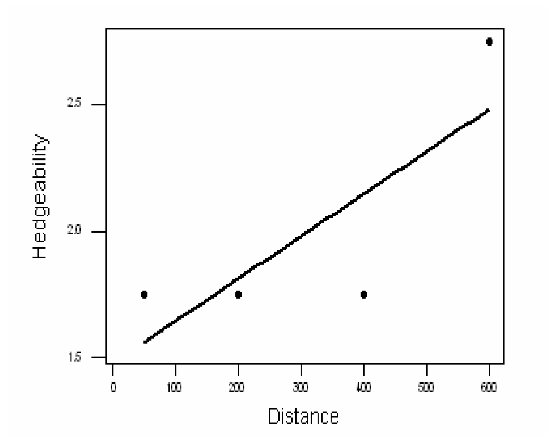




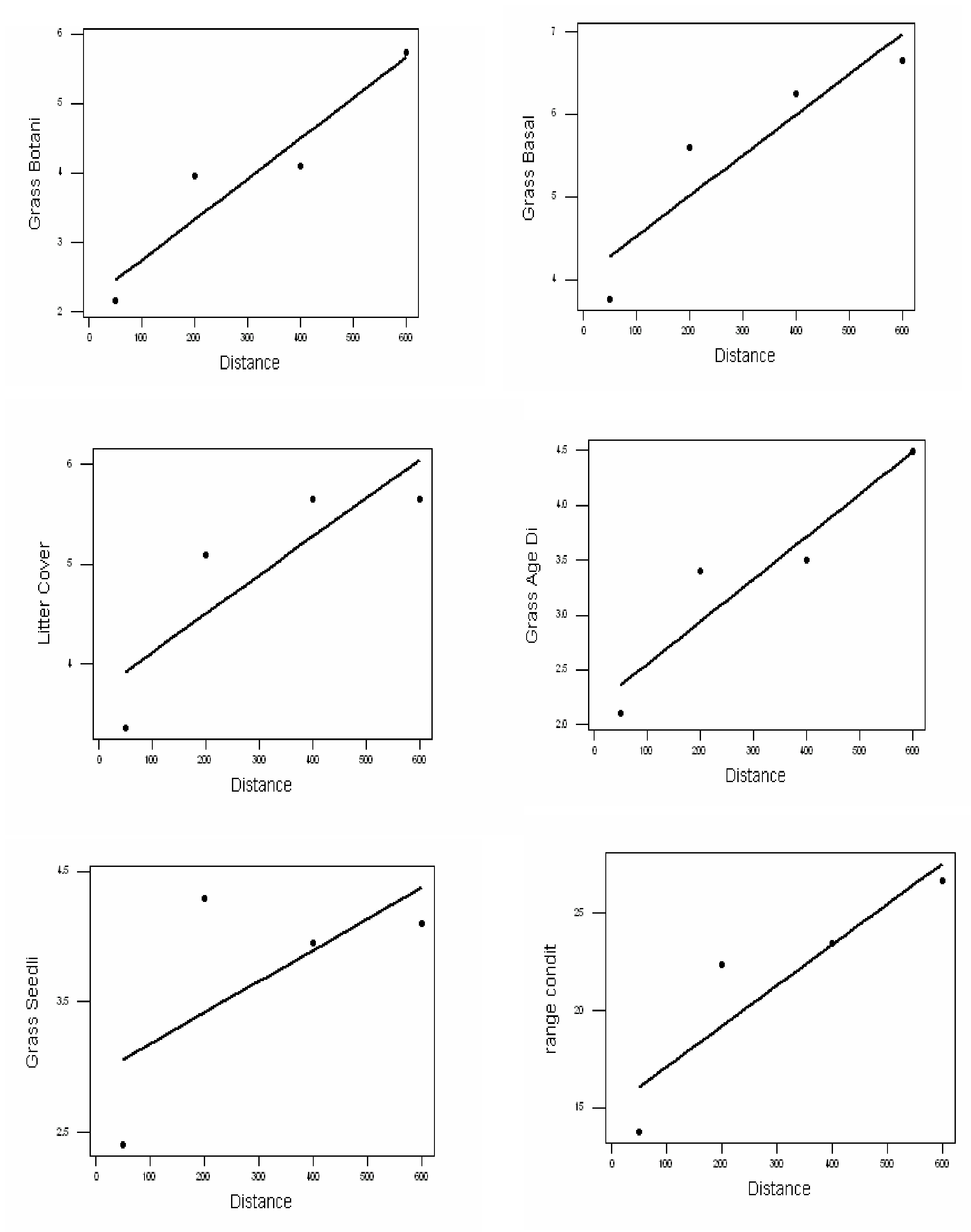

Shrub vigour
2.2
1.7
1.2
0
100
200
300
400
500
600
Distance


Growth form
2.0
1.5
1.0
0
100
200
300
400
500
600
Distance


Herb composi
2.0
1.5
1.0
0
100
200
300
400
500
600
Distance


Hedgeability
2.5
2.0
1.5
0
100
200
300
400
500
600
Distance

Regression graphs of **water point two** based on (Baars *et al.*, 1996) range condition assessment parameters



Appendix 4.

List of woody species and grasses encountered in the two study sites (watering points)

Scientific names	Family
Abutilon mauritianum (Jacq.) Medic	Malvaceae
Abutilon grandiflorum G.Don	Malvaceae
Abutilon graveolens(Hornem.) Wight and Arn.	Malvaceae
Acacia tortilis(Forssk.) Hayne	Fabaceae
Acacia hokii De willd.	Fabaceae
Acacia mellifera (Vatke) Benth	Fabaceae
Acacia nubica Benth.	Fabaceae
Acanthospermum hispidum Dc.	Asteraceae
Achyranthes aspera L.Det. L. Bouls	Amaranthaceae
Adenium obesum (Forsk.) Roem. And Schultes	Apocynaceae
Aloe ukambensis Reynolds	Aloaceae
Alternanthera pungens Kunth	Amaranthaceae
Asparagus africanus Lam	Asparagaceae
Astripomoea hyoscyamoides (Vatke.) Verdc	Convolvulaceae
Astripomea malvacea (Klotzsch.) Meeuse	Convolvulaceae
Balanites aegyptica (L.) Del	Balanitaceae
Barleria acanthoides Vahl	Acanthaceae
Becium filamentosum (Forssk.) Chiov.	Lamiaceae
Blepharis ciliaris L.	Acanthaceae
Boscia coriacea Paz.	Capparidaceae
Cadaba farinosa Forssk.	Capparidaceae
Cissus aphylantha Gilg.	Vitaceae
Cissus quadrangularis L.S.	Vitaceae
Coccinia grandis (L.) Voigt.	Cucurbitaceae
Cleome monophylla L.	Capparaceaceae
Commiphora africana (A. Rich.) Engl.	Burceraceae
Cordia ovalis R. Br.	Boraginaceae
Cyathula cylindrica Moq.	Amaranthaceae
Drimia altissima (l.f.) Bak.	Hyacinthaceae
Euphobia meridionalis Bally and S. Carter (E.Glochidiata aucct.non Pax	Euphorbiaceae
Galinsoga parviflora Cav.plate	Asteraceae
Geniosporum rotundifolium (G.paludosum) Briq.	Lamiaceae
Grewia tembensis Fresen.	Tiliaceae
Grewia villosa Willd.	Tiliaceae
Heliotropium longiflorum (jaub and Spach.) A.DC	Boraginaceae
Heliotropium ovalifolium Forsk.	Boraginaceae
Hibiscus macranthus A.Rich	Malvaceae
Hibiscus flavifolius Ulbr.	Malvaceae
Idigofera errecta A.Rich.	Fabaceae
Indigofera spicata Forsk.	Fabaceae
Ipomea mombassana Vatke.	Convolvulaceae

Ipomea spathulata Hall. f	Convolvulaceae
Leucas urticifolia (vahl.) R.Br.	Lamiaceae
Lippia somalensis Vatke	Verbenaceae
Maerua triphylla A .Rich.Var	Capparidaceae
Melia volkensii Gurke	Meliaceae
Meyna tetraphylla Robyns.	Rubiaceae
Momordica rostrata A. Zimm.	Cucurbitaceae
Opuntia vulgaris L.	Boraginaceae
Pavonia elegans Garcke.	Malvaceae
Pentas parvifolia Hiern	Rubiaceae
Polygala sphenoptera Fres.	Polygalaceae
Portulaca oleracea L.	Portulacaceae
Prosopis juliflora (Sw.) D.C	Fabaceae
Ruellia patula Jacq.	Acanthaceae
Salvadora persica L.	Salvadoraceae
Sansevieria volkensii Gurke.	Dracaenaceae
Scadoxus multiflorus(Martyn.) Raf	Amaryllidaceae
Sericocomopsis hildebrandtii Schinz.	Amaranthaceae
Sida ovata Forssk.	Malvaceae
Solanum coagulans Forsk	Solanaceae
Solanum incanum L.	Solanaceae
Solanum renschii Vatke	Solanaceae
Talinum portulacifolium (Forsk.) schweinf	Portulacaceae
Tephrosia polyphylla (Chiov.) Gillett	Fabaceae
Tribulus terrestris L.	Geraniaceae
Verbena bonariensis L.	Verbenaceae
Vigna membranacea A. Rich.	Fabaceae
Xanthium pungens Wollroth	Asteraceae
Cynodon dactylon (L.) Pers.	Poaceae
Cenchrus ciliaris L.	Poaceae
Digitaria milajiana (Rendle) Stapf.	Poaceae
Panicum maximum Jacq.	Poaceae
Pennisetum mezianum Leeke.	Poaceae
Sporobolus Pellucidus Hochst.	Poaceae

DECLARATION

I, the undersigned, do hereby honestly declare to the Senate of Addis Ababa University, that the content of this thesis is my original work and it has never been submitted in any other academic institution to fulfill a similar purpose.

Martin Shikuku Odoyo	____________________	__________________
Name	**Signature**	**Date**