DIVERSITY AND LOCAL USES OF WOODY VEGETATION IN MINED ARID AND SEMI ARID LANDS OF KIMWARER, KERIO VALLEY, KENYA

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DECLARATION AND RECOMMENDATION

I hereby declare that this thesis is my original work and has not been presented for the award of degree in this university or any other university and that all the sources used herein have been acknowledged.

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ABSTRACT

The woody vegetation in arid and semi-arid area is of immense importance performing a myriad of ecosystem services and providing a wide array of goods. However, the woody vegetation is threatened by both natural and anthropogenic activities at global, national and local levels. In Kerio Valley, the threat is manifested in the form of overexploitation for fuel wood and land-use change due to mining activities. This study aimed to assess the effects of mining activities on the composition, diversity and local utilization of woody vegetation in Kerio valley, located in Baringo County. The composition of woody vegetation, its abundance and diversity was compared between rehabilitated mined sites and sites that had not experienced human disturbance. The study was conducted between the months of October 2014 and May 2015 and six transects were established within two blocks separated by Kerio river. Each transect contained five plots measuring 20m by 20m. In each of the plots, data was collected on woody tree growth characteristics, seedling regeneration, tree form quality and soil phyto-sociological parameters. Indigenous knowledge on usage of the woody vegetation was captured using a questionnaire. Thirteen woody vegetation species were encountered in the rehabilitated mined sites with *Ficus sycomorus* being the dominant (22.1%) and *Teclea nobilis* the least dominant species (1.0%). Twenty two species were encountered in undisturbed sites with *Ficus sycomorus* as the dominant (15.5%) and *Euclea divinorum* being the least dominant (0.7%). Woody vegetation diversity was higher in undisturbed site than in the rehabilitated mined site. However, this variability in species diversity was not significant (T-test, =D.F=1 P=0.767). Among the phyto-sociological parameters measured, there was significant difference in the mean soil temperature ($F_{2,\ 7}$. =9.08, P=0.011), pH ($F_{2,\ 7}$. =109.88, P<0.01), and soil nutrients ($F_{2,\ 7}$. = P<0.05) between the three sites (rehabilitated mined, undisturbed and recently mined). Majority of the respondent identified *Combretum molle* as the most common woody vegetation while *Balanites aegyptiaca* was noted as the woody vegetation commonly used but highly threatened by mining activities. Rehabilitating mined sites can bring back species diversity, however what is not clear is whether ecosystem functions are restored. Indigenous uses of woody trees necessitate the need for reforestation of mined sites.

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LIST OF ABBREVIATIONS

DBH	: Diameter at Breast Height
ASAL	: Arid and Semi-arid areas
KEFRI	: Kenya Forest Research Institute
JICA	: Japan International Cooperation Agency
UNCCDC	: United Nations Convention to Combat Desertification.
DLDD	: Desertification Land Degradation and Drought Dry lands.
GOK	: Government of Kenya
UNEP	: United Nations Environmental Program
KFC	: Kenya Flourspar Company
KFS	: Kenya Forest Service

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Arid and semi-arid environments (ASALs) are areas that receive annual rainfall of between 300-500mm and they account for 18.8% of the total land area of the world and are diverse in their soils, fauna, flora, land forms, human activities and water balance (UNEP, 2006). Much of the water it receives from precipitation is lost through evapotranspiration and the vegetation cover is sparse and woody species is low (Thom, 1983). In Africa, ASALs accounts for 46.1% of the total area while in Kenya it covers 80% of the total area (UNEP, 2006). The ASALs in Kenya are concentrated in 19 of the 47 Counties (GOK, 2009). The deciduous woodland occurs throughout the Kenya ASALs and is dominated by *Acacia tortilis* with other notable species being *Hyphaene ventricosa, Salvadora persica, Acacia nubica* on the Northwest and northern Kenya and *Commiphora* and *Acacias* in the southern parts. (Kigomo, 2001). These areas provide support to about 30 % of the total population in Kenya with the main economic activities being pastrolism and agro-pastrolism (Nangulu, 2001). However, degradation in ASAL areas is a common phenomenon driven by pressures associated with increasing human populations which has resulted in decline in vegetation cover and quality over time (Mengich. *et al*., 2013).

The woody vegetation in ASALs is of immense importance performing a myriad of ecosystem services and providing a wide array of goods. They are useful particularly in terms of herbages for livestock, energy provision and also as herbal sources (Maitima, 2009). For example Assessing their distribution and composition is important for management as this can provide information necessary for plans on harvesting, conservation, identification of presence of endangered or rare species and sites with high or low species richness (Newton, 2009). In addition the number of trees and shrubs that can tolerate drought stress has declined due to factors such as frequent fire outbreaks, climate change, clearing of land for human settlement and mining activities can be identified (Omambia *et al*., 2009). Soil microorganisms in ASAL areas are paramount in the biogeochemical cycling of both organic and inorganic nutrients in the soil and maintenance of soil quality (Jeffries *et al.*, 2003).

However mining causes chemical, physical and microbiological changes in soil properties (Ghose *et al.,* 2004). Therefore comparing soil characteristics in rehabilitated and undisturbed mining sites was necessary for soil and woody vegetation conservation. Soil fertility and good land productivity is as a result of soil nutrients and in most ASAL areas the soils are deficient of nitrogen and phosphorous (Hancock *et al.*, 2006).

Understanding the local uses of trees is important to appreciate their usage and assist in policy making a measure of conservation (Johansson and Svensson, 2002). Plants are exploited as life supporting commodities and sources of food in developing countries and thus providing high level of nutrition to mankind aside from animal feed, construction materials as poles, fitos and for fencing (Aberoumand and Deokule, 2010). According to (Akubuiro *et al.*, 2007), trees are an indispensable constituent of human diet that serve in supplying the body with certain hormone precursors, minerals and vitamins in addition to energy and proteins. This is what most of the trees have and thus showing their importance in the society and even in the wild. According to (Sundriyal, 2001) the edible plants with high diversity are distributed widely in mountain forests; they serve as medicine for domestic and commercial purposes and valuable sources of food. However, trees provide numerous benefits that can improve environmental quality and human health (Kalacska *et al.,* 2005). These benefits include improvements in air and water quality, building energy conservation, cooler air temperatures, reductions in ultraviolet radiation, and many other environmental and social benefits (Kangalawe *et al.*, 2008).

1.2 Statement of the Problem.

Arid and semi-arid areas in Kenya are associated with low development indicators and with high incidence of poverty. It is estimated that more than 60% of its population live below poverty line (UNEP, 2006). The residents of Kerio Valley are faced with high incidence of poverty caused by conflicts over resources, harsh climatic conditions such as low and unreliable rainfalls, frequent droughts and fragile ecosystem resulting in low and declining land productivity. People in these areas live in tough and inhospitable environments and face several constraints and uncertainties in meeting their day to day livelihood needs, however this area is rich in minerals (flourites) used to manufacture ornamentals. This led to establishment of Kenya Flourspar Company (KFC) in 1971 after the discovery of the mineral in 1967. As a result large areas of the valley have been exposed through activities of mining, leading to loss of vegetation. Extensive areas have been cleared of vegetation to create areas where mining activities are carried out. This has had devastating effects on landscapes leading to unavailability of vegetation for livestock, bio-fuel sources and sources of herbal medicine. Mining has led to changes in soil composition leading to difficulties in vegetation re-establishment. However, there has been no prior documentation on effects of mining activities on woody vegetation diversity, composition and local uses thus the need for this study.

1.3 Objectives of the Study

1.3.1. Broad objective

To provide baseline information on ecosystem health status in reference to woody vegetation and its local utilization which can be used by the natural resources managers at County, National levels as well as development partners to inform rehabilitation and management of ASALs woody vegetation in Baringo and Keiyo- Marakwet counties.

1.3.2. Specific objectives

i. To determine the composition of woody vegetation in Kerio Valley
ii. To compare woody vegetation diversity in rehabilitated mined sites and undisturbed sites
iii. To compare soil characteristics in rehabilitated mined sites and undisturbed sites
iv. To assess the levels of uses and utilization preferences of woody vegetation in Kerio valley

1.4 Null hypothesis

i. **Ho:** There is no difference in species diversity and richness between rehabilitated mined sites and undisturbed sites
ii. **Ho:** There is no difference in soil characteristics between rehabilitated mined sites and undisturbed sites

1.5 Research questions

i. What is the abundance and composition of trees species in Kerio Valley?
ii. What is the extent of local uses of woody vegetation in Kerio Valley?

1.6 Justification of the Study

A management strategy of tree resource in ASALs of Kerio valley is necessary in providing information on forest ecology, conservation, management and providing an insight in trees dynamic processes enabling species regenerational characteristics and identification of presence of rare or threatened species. However Kerio Valley is a clear representation of ASAL areas where mining is evident and as a form of disturbance to woody vegetation. This therefore influenced the choice of the study area. A study relating growth parameters such as composition, height, DBH, soil characteristics and local uses had not been conducted and implemented in ASALs of Kerio valley for woody vegetation. Due to mining activities in the area, soil erosion and decline in land productivity is on the rise, leading to loss of woody vegetation. Such similar scenarios have often prompted institutions such as Kenya Forest Research Institutes to conduct several studies in areas such as Kitui, Baringo and Coastal regions to solve both environmental and livelihood problems. The findings of this study are therefore imperative for sustainable management and development of a conservation plan (Millennium Development Goals) by the stakeholders due to the reported decline in tree conservation and interventions in ASAL areas especially of Kerio valley of Baringo and Elgeyo-Marakwet counties. The results are useful in ASALs of Kerio valley, the country and beyond where the same problems are being experienced. This is in accordance with the Kenya's vision 2030, to eradicate poverty under the economic pillar which is the major cause of reduced forest cover by fostering sustainable use of natural resources. In addition to increasing the forest cover from the current 5.9% as per the statistics released in 2012 by Kenya Forest Service (KFS).

1.7 Scope of the Study

The study was conducted in Soy and Chemoibon locations of soy division in Elgeyo-marakwet County, North rift Kenya. Composition and diversity of woody vegetation which is characterized by a high exploitation for charcoal and other uses was assessed. People living in the study area and areas adjacent were interviewed. Soil characteristics studies were limited to the plots falling under the undisturbed areas and those under rehabilitated mining sites.

1.8 Definition of terms

Diversity; is the biodiversity of an ecosystem that includes a variety of species, communities, genes and the ecosystems.

Species richness; refers to the number of species in a particular area.

Species diversity; refers to a combination of richness and relative abundance.

Regeneration; is the ability to replace lost or damaged body parts and in plants it is through sprouts from cut trees.

Local uses: is utilization of the three species of trees by the indigenous community (Elgeiyo and Tugen) either for medicinal, food or other uses.

Seedlings; are any plants under the height of 1.3m and a DBH of less than 10cm.

Saplings; are trees with a DBH of less than 10cm but with a height of more than 1.3m.

Abundance; is an ecological concept referring to the relative representation of a species in a particular ecosystem.

Indigenous knowledge: is the local understanding by a certain community with the same culture on existence of the three species of F. indica, U. scheffleri, and T. indica on their uses within a certain period of time i.e. ancient, current times.

Woody vegetation: are plants that produce wood as their structural tissues (stems).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Introduction on ASAL areas

Arid and semi-arid environments (ASALs) are areas that receive annual rainfall of between 300-500mm. They account for 18.8% of the total land area of the world and are diverse in their soils, fauna, flora, land forms, human activities and water balance (UNEP, 2006). Much of the water it receives from precipitation is lost through evapotranspiration and the vegetation cover is sparse and woody species is low (Thom, 1983). In Africa, ASALs accounts for 46.1% of the total area while in Kenya it covers 80% of the total area (UNEP, 2006). The arid areas in Kenya are concentrated in 19 of the total 47 counties in Kenya. The ASAL areas in Kenya provide support to 30 % of the total population with the main economic activity being pastrolism and agro-pastrolism (Nangulu. *et. al.*, 2001). Land degradation in ASAL's is driven by pressures associated with increasing human populations and subsequent rising demand for various tree products and services. This has resulted into a decline in vegetation over time (Mengich. *et. al.*, 2013). In addition, Maitima. *et. al.*, (2009) alludes that expansion of urban centers and mining activities has risen from 7% in 1960 to 36% in 2008 and is responsible for land use change and degradation leading to expansion of ASAL areas in Kenya. In a study conducted in semi arid areas of south east Kajiado County Kenya, (Campell, 2003) reported the expansion of agriculture into critical grazing areas as a result of increase in human population. While working in Kitengela in Kajiado County, (Kristanjson, 2002) found considerable social and ecological changes to have occurred in the area for the past 40 years.

2.2 Survey of soil and woody vegetation in ASAL areas

Biamah, (1988) notes that ASAL areas are typically resilient and capable of recognition even though this can be delayed by natural forces (1-year and multi-years droughts) or by interference of human activities like grazing, mining, time of grazing and settlements. The removal of vegetation cover from an ecosystem results in a compounding effects of degradation with the soil being the worst hit component. With absence of vegetation, the soil is deprived of organic matter which is the key to soil fertility and productivity especially in ASALS (FAO. 2004), and is highly exposed to agents of soil erosion. Once vegetation cover is restored, it improves the soil structure, soil water balance, chemical soil fertility and restores soil biodiversity and ecosystem services through reduced soil erosion (Mekuria *et al.*, 2007).

Protecting soil from erosion agents the tree canopy-herbaceous layer interaction improves soil fertility through addition of nitrogen and organic matter, the vegetation supplies plant litter which decomposes to supply the soils organic carbon pools (Kellman, 1979). Shrubs play an important role in maintaining a pool of soil nutrients in desert ecosystems by creating Islands of fertility beneath their canopies through accumulation of organic matter. In ASAL areas any dead material above the soil surface is referred to as litter, mulch or plant residues which increases soil moisture through its effect on infiltration, evaporation and runoff and tends to stabilize soil moisture and temperature thus improving condition for germination (Ekaya, 2001). Organic matter has many beneficial effects on soils physical, chemical and microbiological properties like increasing water holding capacity and caption exchange capacity lowering the bulk density of the soil and increasing the microbial activity among others (Dumanski, 2000).

In arid and semi- arid areas nitrogen concentration is the most limiting resource after water as a result the growth of native species is favored. Plants absorb more nitrogen during high growth periods hence the ability of a plant species to trap nitrogen depends on its growth pattern. An experiment was carried out in a grassland area where two species of grass were planted, two of invasive and two of indigenous that occur in intermountain West. Medusahead and Cheatgrass are the most common invasive grass, the native perennial species pseudoroegnerialspicata and sandberg's bluegrass are the major herbaceous plants in the region and are largely used for restoration (Duncan *et al.,* 2009). The seeds for this study were collected in a local population and the soil was collected in the northern great basins of riley Oregon where it was dried and mixed to provide a uniform texture. The different plant species were planted and uniform spacing was provided. During harvest the seedlings were separated and dried at 65ºc for 48h and the total biomass was determined and roots were washed in a mesh screen. Growth analysis was carried out where the relative magnitude and strength of competition changes among species in response to nitrogen availability over time of harvest. The objective of this experiment was to identify the impact of a neighbor plant on target plant growth in terms of resource competition(Duncan *et al.,* 2009).

The number of trees and shrubs that can tolerate drought stress has declined due to factors such as frequent fire outbreaks, climate change, clearing of land for human settlement and mining activities can be identified (Omambia *et al.,* 2009). According to Kigomo, (2003). These factors have resulted into restrained to severe land degradation leading to loss of trees due to poverty, depletion of vegetation cover and physical, biological and chemical composition of soil properties. Use of exotic tree species to try and rehabilitate these ASAL areas have resulted in a shift in vegetation dynamics leading to colonization of an area which results in loss of indigenous trees suitable for such areas (Mengich, 2013).

Vegetation cover in arid and semi-arid areas provides an important cover for the easily eroded soil, shelter for livestock, people and wildlife. Changes in climate have been felt in these areas especially to those communities who mainly rely on animal products and wild plants products. Most indigenous food plants and wild fruits have been threatened with extinction in these regions due to decline in rainfall amounts. For example in Eastern province of Kitui, a rehabilitation project was undertaken by KEFRI/ JICA social forest project with *Melia vol- kensii* a local species. This species has shown potential progress hence it needs to be expanded to cover the whole area (Kaminski *et al.,* 2002).

Counting seedlings, saplings and mature trees, and taking measurements of the stem diameter, DBH, complexity index, importance value, relative density, and species richness and diversity will enable the explanation of ecosystem processes that affect existence and growth of these trees. Forest disturbance is one of the three main dynamics in understanding forest communities. (Veblen, 1989) recognize the role of natural disturbances in his research on forest temperate. He further recognizes major implications in forest conservation and management that have been as a result of ecological paradigm shift. In characterizing regimes of forest disturbances Picket and White 1983 defines disturbance as a relatively discrete event disrupting community, ecosystem or structure of the population and changes the resource availability or the physical environment. Some of these include browsing, grazing, farming, charcoal burning, harvesting for construction purposes and mining.

2.3 Effects of disturbance on woody vegetation.

Several surveys in south Europe on ethno botanical over a few decades have focused on the use of botanical medicinal practices and in the whole of Mediterranean a few studies focused on edible wildfruits have been conducted (Guarrera and Manzi, 2005). According to Kipkiror and Towett (2003), this is the same scenario to the ASALS of Kerio valley where very little has been documented about the use of these trees. The evaluation on the use of these trees by the community is necessary to investigate the regeneration process, their growth viability, structure and composition that could influence the acceptance and appreciation of these trees (Giulia, 2009).

Khyade *et al.,* (2009) states that botanical foods have been used traditionally as commonly ingested and multi-contextually as medicinal food. One of the objectives of this study tries to address the indigenous knowledge of these species of trees and thus develop a cultural significance of the trees. An evaluation of this kind can be theoretically done by the people of that culture (Saina *et al.,* 2001). The hurdle of address in such an evaluation have been addressed by previous works Lee, (2004) and Franklin, (1998). Berlin (1998) in particular used a scale of four values in order to classify the vegetable resources of the Tzeltal-Tzotzil society: "cultivated," "protected," "wild but useful," "culturally in significant," while Lee (2004) later classified Kung San plants in six classes: "primary," "major," "minor," "supplementary," "rare," and "problematic." These scales represented a first simple attempt to measure the cultural significance of plants. These scales, however, did not consider any special variables involved in the complex issue of the evaluation of cultural meanings of biological resources (Pieroni, 2001).
Surveys conducted by forest department at Sarawak community (Lee, 2004) shows that a large number people largely depend on plants as since the communities are located away from the urban areas. The demand for medicinal plants was met through enrichment of natural population, wild collection and cultivation in house gardens, among these communities are Australia, Malaysia and Sarawak.

In Turkana County above 103 plant species are used as food, vegetable, medicine and fruits, some are used for blood preservation and local brew an example of these is *H. compressa* (FAO, 2004).Several decades ago, trees have vitally been supplementing people’s diet. Its dependence has declined gradually following the introduction of exotic fruits into the market though some indigenous communities still use them to supplement their diet. They preserve them to be consumed during the dry seasons and even for sell in the rural markets(Khyade *et al.,* 2009). They are not only used as food but also they are edible and have nutritional values providing minerals such as sodium, magnesium, calcium, iron, potassium and phosphorous among others. Wild fruits are immune to many diseases and are utilized as medicine providing fibers preventing constipation. Thus important attention must be given to this source of food. Some botanical exploration and publications have emphasized on the diversity and food value of edible plants (Sundriyal, 2001).

2.4 Survey on factors affecting ASAL vegetation

Soil erosion has led to nutrient depletion especially in many sub- Saharan countries, an estimate nutrient balance for 38 countries has been identified where an annual fertility depletion rates was estimated at 15kg K ha-1, 3kg P and 22kg N. Soil erosion resulted to an annual loss of P and N (potassium and nitrogen) in Zimbabwe. About 950 million hectors of salt-affected lands occur in semi- arid and arid regions where irrigated, lands are threatened by salinity in the root zones. It is also found that most affected areas are mining areas where toxic minerals like Al, Mn, and other heavy metals like lead and mercury are highly concentrated, these raises the soil acidity. This effect brings about weather and climatic changes causing extinction of important plant species and lowering land productivity (Eswaran *et al.,* 2001).

According to Franklin, (1995) landscapes is characterized depending on factors that affect plant growth, such as moisture and soil fertility, and those properties that affect mortality like the intensity of human or natural disturbances and frequency. Those disturbances that cause unexpected mortality can increase or decrease species diversity and population survival (Antuono and Lovato, 2003). Stress generated by abiotic factors always occurs in unfavorable climatic conditions or due to low availability of resources caused by soil infertility, geological conditions, and soil toxicity. Biotically generated stress occur in favorable environments where a variety of species can grow well but the most dominant species eliminates the entire population of less competitive population by limiting important resources like light (Huston and DeAngelis 1994).

Sax *et al.,* (2002) notes that the continuous increase of environmental destruction of these ASALs makes it hard for these communities to attain their daily standard of living. To curb these issues a sustainable forest management is needed to increase the ability to adapt and recover from climate factors. Afforestation and land reclamation can be used to safeguard the biophysical changes such as temperature increase, floods and droughts, tree planting in degenerated areas, homes, social places and market places will increase productivity and provides a cooler environment especially in hot areas. In addition trees both wild and domestic offers nutritional, environmental and economic benefit (Camargo *et al.,* 2002; Sax *et al.,* 2002). All these provide sufficient evidence to take this study and check the structure, composition, uses and growth viability of these trees so as to help come up with recommendations on the conservation and bringing them back to their original state as it used to.

2.5 Local uses of woody vegetation

The connection between useful woody vegetation and the daily products derived from them are dissolving in the modern society, this is much remains clearer in most indigenous communities, where woody vegetation use is often necessary for multiple functions of daily life. These include the daily use of woody vegetation as food for human and fodder for livestock, the use of woody parts as stem and branches for construction or tool making as well as in religious practices and traditional medicine. Indigenous use of woody vegetation is considerably linked to its floristic appreciation and knowledge (Kristensen et al., 2003). The indigenous use of woody vegetation globally represents an instrumental reservoir of knowledge of a large potential of undiscovered use for example products used in the modern society such as industrial cosmetic products and drugs (Bero et al., 2009). Due to the decreasing interest of younger generations in indigenous lifestyle and changes in human population, knowledge on indigenous woody vegetation utilization is in danger of being lost (Nadembega et al., 2011). This scenario is even amplified by the influence of climate change and land use changes resulting in loss of woody vegetation. Therefore a comprehensive and clear documentation of indigenous knowledge and use of woody vegetation is necessary to preserve the knowledge and thus sustainable use of woody vegetation and an understanding of woody vegetation use in a larger spatial and woody vegetation systematic context might help to focus future research exertion and advance conservation plans.

Though several studies have been conducted, Land degradation and desertification issues are now pillars of international and environmental agendas. Not only because they affect the livelihoods of billions of people and have direct consequences on the entire societies but also due to devastating effects on ecosystem stability, functions and services and loss of biodiversity. Problems are exacerbated when land degradation, mostly human induced process is combined with naturally occurring droughts. It is for this reasons that recent terminology adopted by UNCCD involved; Desertification, Land degradation and Drought (DLDD). However UNCCDC major focus is still placed on dry lands and particularly in Africa. It is in line with these findings that establishing a management strategy of tree resource in ASALs of Kerio valley is necessary in providing information on forest ecology, conservation, and management and providing an insight in trees dynamic processes enabling species regenerational characteristics and identification of presence of rare or threatened species.

Although several studies have been conducted, a study relating growth parameters such as effects of soil composition, height, DBH, diameter with local uses has not been conducted and implemented in ASAL of Kerio valley for woody vegetation. As a consequence the woody vegetation has been declining over the last three decades. Due to mining activities in the area, soil erosion and decline in land productivity has been rising, leading to loss of woody vegetation. Such similar scenarios have often prompted institutions such as Kenya Forest Research Institutes to conduct several studies in areas such as Kitui, Baringo and Coastal regions to solve both environmental and livelihood problems. This study is therefore imperative for sustainable management and development of a conservation plan by the stakeholders due to the reported decline in tree conservation and interventions in ASAL areas especially of Kerio valley of Baringo and Elgeyo-Marakwet counties.

2.6 Conceptual framework

Disturbance in forest has caused a paradigm shift in ecology (Veblen 1989). However, disturbances which comprise mining are a major erosion of the ecosystem. This leads to decline in species diversity and richness and on the other end affecting soil characteristics through lowering its nutrient content.

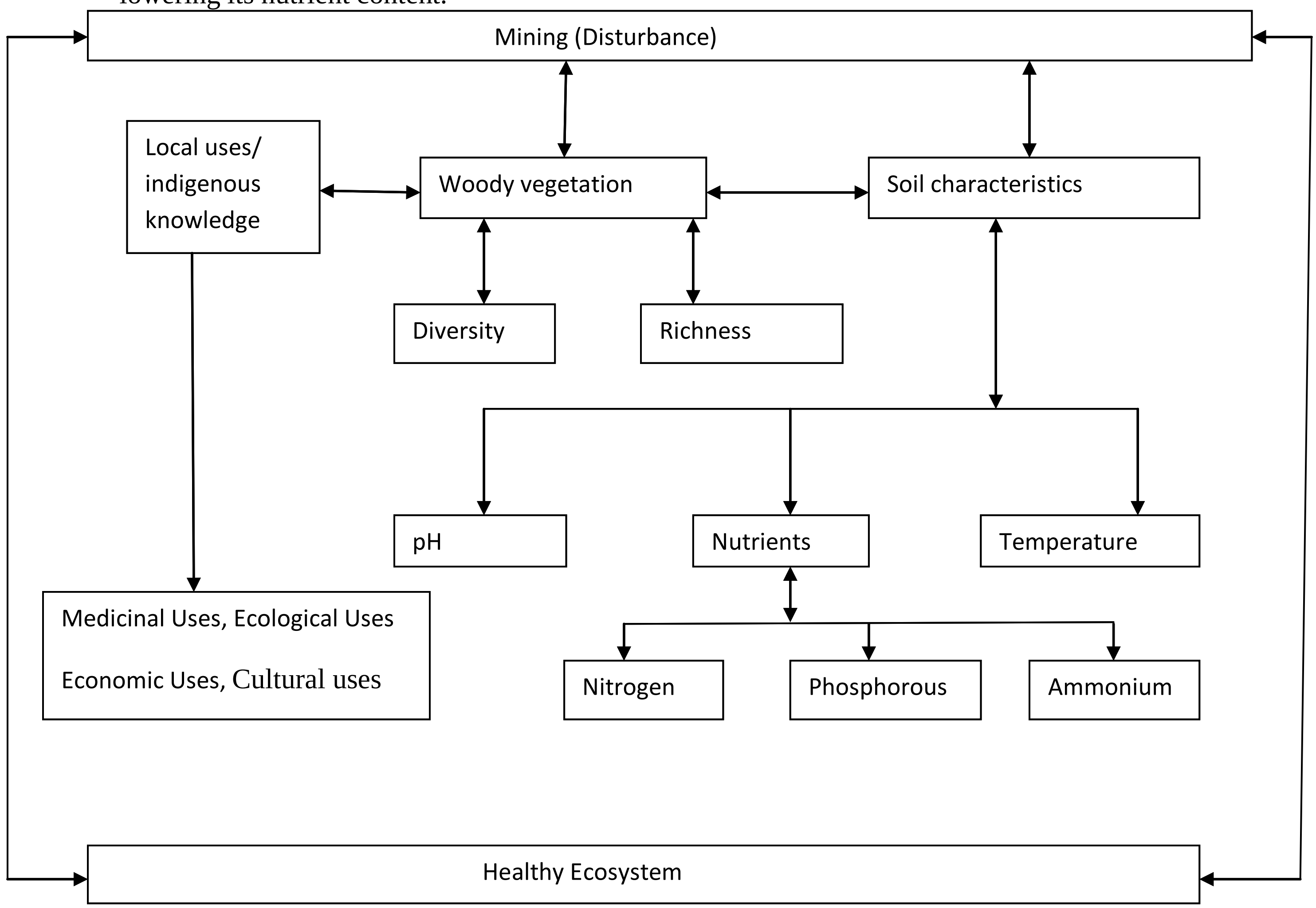


Fig.1: Conceptual Framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of study area

This study was carried out in Kimwarer, Kerio valley (0° 19' 0" North, 35° 38' 0") located in Elgeyo-Marakwet County, in Central Rift Valley, Kenya. The Kerio valley borders Elgeyo escarpment to the West and Tugen hills to the East. Kimwarer is classified as semi-arid area in ecological zone V (Thom 1983) . The average annual temperature at the valley is 24ºC and it receives a mean annual rainfall of below 1000mm (SARDEP. 2002). The study area is primarily alluvial plain with varying soils ranging from black-dark cotton soil, and four fluorite rich soils to fine textured soils covered with acacia woodland and scattered shrubs and woody vegetation comprising of *Acacia tortilis* and *Acacia seyal.*

Kerio Valley is inhabited by two indigenous communities of the Elgeyo origin and the Tugen and the total population is 20,624 (GOK 2010). Their major economic activity is livestock keeping, where the livestock kept are mainly beef breeds of cows and browsers (Goats) which are better suited to the high prevalence of woody vegetation and low levels of grass cover. Small scale subsistence farming (practiced at pockets of green areas within the Valley) and bee keeping is also practiced (SARDEP. 2002).

The area is semi-arid and rich in fluorites, and mining activities by Kenya Fluorspar Company has resulted in large areas being cleared of vegetation. However there is no clear plan on rehabilitation and in the mined areas vegetation is left to grow naturally. This however has resulted into thick vegetation cover by *lantana camara* dominating the area. The company is planting acacia species and other indigenous species (*Olea spp*, *Prunus africana,Euclea divinorum* and *Rhus natalensis* which die as a result of the prevailing conditions (low water, high temperatures and poor soils).

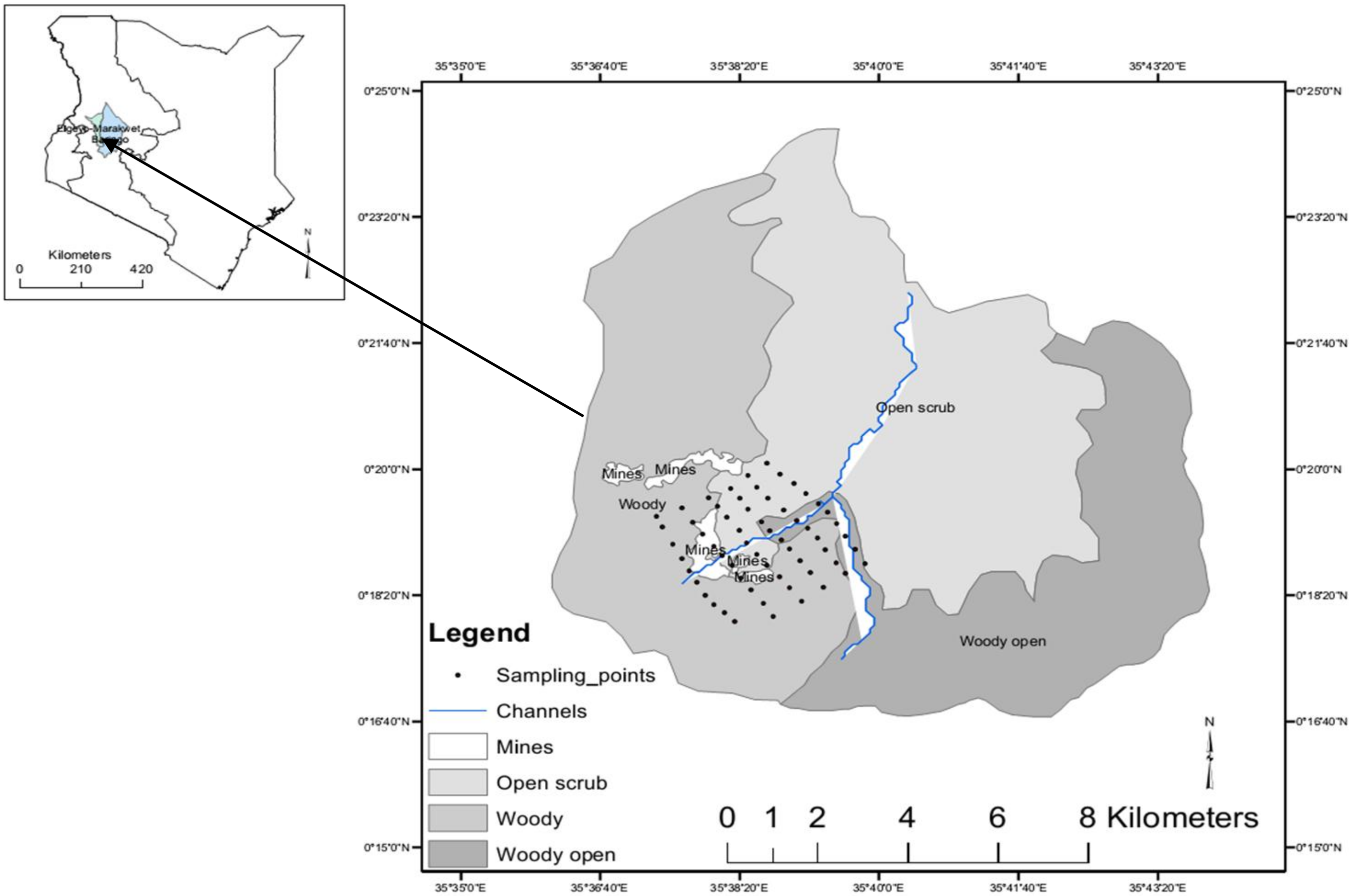


Figure 2. Map of the study area

3.2 Research and Sampling Design

To determine abundance and composition of woody vegetation and to compare the disturbed and undisturbed sites within the study area, random block design was used with six transects (three each) established between two blocks separated by River Kerio (Figure 2). At each side of the river, transects were established perpendicularly to the river shore. In each transect 5 plots measuring 20m by 20m. The distance between plots in each transect was 50 meters. A number of these plots felt between areas where mining activities were conducted previously and provided an opportunity to compare growth characteristics with those in the undisturbed area.

To assess indigenous knowledge and uses of these trees in the study area, a survey design was employed. A stratified random sampling technique was employed to generate the sample. The strata were the administrative locations. Samples from each location were drawn using systematic random sampling. The Head of the household was chosen as the respondent on the assumption that he/she has the historical knowledge on local usage of woody vegetation. 68 respondents were interviewed from a population of 5,624 as per the 2009 population census. This is according to (Kothari 2004);

$n=Z^2.p.q.N/e^2 (N-1) +Z^2.p.q$

Where;

e is 0.02 as acceptable precision

Z is 2.005 since the confidence level is 95%

P is 0.02. as the desired sample proportion.

3.3 Data collection

3.3.1 Abundance and composition

Within the 20m by 20m plots established, data on the following parameters were collected; total counts per species, tree height, Diameter at Breast Height (DBH), Basal area, total woody vegetation counts, tree form and regeneration. Subplots measuring 5m by 5m and 1m by 1m was established within the plots for counting of sapling (<10cm DBH, >1.3m Height) and seedlings (<10cm DBH, <1.3m Height) for regenerations. The table below summarizes the approach and tools that were used to collect data on the parameters above.

Table1 Approaches used in collecting plot and tree parameters of interest

ATTRIBUTES	Tools	Approach	Data sheet
Tree height	Suunto, graduated pole	Suunto hypsometer was used to measure the heights of tall trees and a graduated pole was used to measure relatively short trees.	APPENDIX 2.
Diameter at Breast Height	Forest caliper	DBH was measured at 1.3m above the ground surface	Appendix 2
Basal area	Derived parameters	Basal area was computed using the following formula: $BA = (\Pi DBH^2)/4 \quad cm^2$ where, π=3.14	
Relative frequency Relative density Relative dominance	Derived parameters	= (frequency of species ÷ total frequency of the stand) 100 = (density of individual species ÷ total density of all species) 100 = (dominance of a species ÷ dominance of all species) 100	
Complexity index	Derived parameters	Was derived from combining all the measured stand structural characteristics (stem density (number of stems/0.1ha x 10^{-3} in a 0.1 ha plot), D_{130} calculated into basal area (m^2/0.1ha), height (m) and number of tree species). Holdridge et al. (1971)	
Regeneration	Observations		Appendix2
Form	Stem characteristics	FORMS X, Y and Z; To Denote straight stems good for construction without them being modified, Denotes stems that would require slight modifications for them to be used for construction and Represent stems that are not suitable for construction respectively	Appendix 2

3.3.2 Species richness and diversity

Table 2. Showing the diversity characteristics to be obtained

Characteristics	Tool
Species diversity	Simpsons Diversity index (excel) $D=1-(\sum n(n-1)/N(N-1))$ n> the total number of trees of a particular species N=the total number of trees of all species
Species richness	Menhnick's index $D=s/\sqrt{N}$ Where; s-number of different species N- total no. of individual species

3.3.3 Soil characteristics

Surface scrapes (to 1cm depth) were taken for nutrient analysis. Surface temperature (thermometer probe inserted to 1 cm below sediment surface) was measured at midday on a clear sunny day. Sediments for nutrient analysis were collected in the field and preserved in an ice box before being taken to the laboratory. Lab nutrient extraction was done using potassium chloride flushed with nitrogen gas (2 min) and shaken for 2 h, to ensure maximum extraction. The samples were then centrifuged at a speed of 2000 rotations per minute for 10 min. The extract was decanted and diluted with distilled water and used for the determination of nutrients. Soil nutrients was determined according to (Parsons 1984).

3.3.4. Local uses of woody vegetation

The local uses of woody vegetation were assessed using a questionnaire (appendix 1). locals were asked to describe (i) the dominant woody plant species, (ii) their trend as stable, increasing, or decreasing, and (iii) their local usages e.g. suitability (palatability) to grazing animals as very palatable or not palatable. Other authors (Roba and Oba 2009) indicated that local communities commonly use terms such as increasing, not changing, or decreasing during assessment of species trends. Locals were also asked whether woody vegetation composition had changed historically and what were the causal factors linked to the observed changes.

3.4 Data analysis

Summary of data analysis is provided in Table 3. Analysis was carried out using Minitab and Excel. Data was then cleaned and tested for normality and homogeneity of variance and transformed where these assumptions were not met. Descriptive and inferential statistics was used.

Table 3.Data analysis approaches

STUDY OBJECTIVE	VARIABLES	STATISTICAL TEST
To determine the abundance and composition of woody vegetation in Kerio Valley	Tree variables measurements: stem diameters, heights, dominant species/ type	Descriptive statistics (means+ standard error) presented in tables and graphs
To compare woody vegetation diversity in rehabilitated mined sites and undisturbed sites	Species richness Species diversity	2 sample t-test Descriptive statistics
To compare soil characteristics rehabilitated mined sites and undisturbed sites	Redox pH Nutrients (Ammonium, Phosphates and nitrates)	2 sample t-test Descriptive statistics
To assess the indigenous knowledge and local uses of woody vegetation	medicinal uses, ecological uses, economic uses, cultural uses	Descriptive statistics Cross tabulations

CHAPTER FOUR

4.0 RESULTS

4.1 Characterizing woody vegetation

4.1.1. Species description at the two sites

Analysis of characteristics of woody vegetation is summarized in table 4 below. There were thirteen woody vegetation species encountered in the rehabilitated mined sites with *Ficus sycomorus* being the dominant species (22.1%) followed by *Tamarindus indica* (21.8%). *Teclea nobilis* was the least observed species (1.0%). At the undisturbed sites, twenty two different species were encountered with *Ficus sycomorus* being dominant (15.5%) followed by *Cordia africana* (12.1%) and *Euclea divinorum* being the least observed (0.7%).

Trees in the rehabilitated mined site had the lowest mean height (8.2±0.4m) with individual tree heights ranging from 5.0m for *Euclea divinorum* to 11.8m for *Ficus sycomorus.* The highest mean height recorded at the undisturbed site was 8.8±0.7m with individual tree heights ranging from 2.0m (*U. scheffleri)* to 17.0m (*S. siamea)* (Tables 4 and 5). Rehabilitated mined site had the highest basal area of (644.0cm^2/plot) with *F. sycomorus* species having the highest mean basal area ((1854.1±29.3cm^2/plot) followed by *T. indica* species (1823.7±28.93cm^2/plot) and *T. nobilis* species with the lowest basal area (85.7±19.9 cm^2/plot). In the undisturbed site the basal area was 472.2 cm^2/plot, with *F. sycomorus* recording the highest basal area (1610.9±28.4 cm^2/plot) followed by *Cordia africana* (1260.2±23.6 cm^2/plot). *Euclea divinorum* (80.1±16.7 cm^2/plot) had the lowest basal area at this site.

Based on Importance Values (IV), *A. tortilis* was dominant species in both sites with an IV of 67.2 and 31.5 in rehabilitated mined and undisturbed site respectively. *T. nobilis* had the lowest IV in rehabilitated mined site with an importance value of 5.5 while *P. vilidiflorum, U. scheffleri, V. madagascariensis* species individually with an importance value of 3.0 being the least dominant in the undisturbed site. Complexity index was at a low of 22 in rehabilitated site.

Table 4: Abundance and composition of woody vegetation in rehabilitated mined site and undisturbed site

Species	No. of species	Mean DBH±SE	Mean Tree Ht±SE	Basal area (m^2/plot) ± SE	Species Diversity	Species Richness	Relative Frequency (%)	Relative density %)	Relative dominance %)	I.V	C.I
Rehabilitated mined site											
A. elatior	2	33.2±2.3	7.7±0.6	865.3±12.5		9.2	2.2	2.2	10.3	14.8	22
A. seyal	11	26.9±3.8	9.2±0.8	569.2±7.3		3.9	12.4	12.4	6.8	31.5	
A. tortilis	27	26.5±0.8	9.6±1.0	550.5±8.1		2.5	30.3	30.3	6.6	67.2	
A.schimperi	6	13.5±2.9	5.8±1.3	142.4±18.8		5.3	6.7	6.7	1.7	15.2	
B.aegyptica	11	32.0±2.1	9.4±0.9	805.2±10.7		3.9	12.4	12.4	9.6	34.3	
C.farinose	3	11.4±3.2	5.8±1.3	102.0±19.6		7.5	3.4	3.4	1.2	8.0	
E.divinorum	4	11.9±3.1	5.0±1.5	110.2±19.4		6.5	4.5	4.5	1.3	10.3	
Fi.sycomorus	2	48.6±4.0	11.8±1.6	1854.1±29.3		9.2	2.2	2.2	22.1	26.6	
S.siamea	6	27.9±1.3	11±1.4	612.5±4.7		5.3	6.7	6.7	7.3	20.8	
T.indica	3	48.2±4.0	8.7±0.6	1823.7±28.9		7.5	3.4	3.4	21.8	28.5	
T. nobilis	2	10.5±3.3	6.5±1.1	85.7±19.9		9.2	2.2	2.2	1.0	5.5	
Te. Brownie	8	30.3±1.8	9.0±0.8	722.5±7.4		4.6	9.0	9.0	8.6	26.6	
U. scheffleri	4	12.8±3.0	7.3±0.8	128.6±19.1	**0.86**	6.5	4.5	4.5	1.5	10.5	
Undisturbed site											
Acacia elatior	3	14.8±2.3	6.0±1.4	172.7±14.6		12.1	3.1	3.1	1.7	7.9	50
Acacia seyal	8	27.5±2.0	8.8±0.1	593.12±9.2		7.4	8.3	8.3	5.7	22.4	
Acacia tortilis	13	24.2±2.5	6.8±1.2	459.7±3.0		5.8	13.5	13.5	4.4	31.5	
A.schimperi	9	13.6±2.5	6.7±1.2	145.2±15.2		7.0	9.4	9.4	1.4	20.1	
B. aegyptica	9	33.4±2.8	9.8±0.8	876.88±16.9		7.0	9.4	9.4	8.4	27.2	
Cedar	1	31.4±2.6	8.3±0.6	774.0±14.6		21.0	1.0	1.0	7.5	9.5	
C. Africana	3	40.1±3.6	12.4±1.6	1260.2±23.6		12.1	3.1	3.1	12.1	18.4	
D.viscosa	1	13.1±2.5	6.7±1.2	134.7±15.4		21.0	1.0	1.0	1.3	3.4	
E. divinorum	2	10.1±2.9	5.5±1.5	80.1±16.7		14.8	2.1	2.1	0.8	4.9	
F. sycomorus	3	45.3±4.1	10.4±1.1	1610.9±28.4		12.1	3.1	3.1	15.5	21.8	
L. glauca	2	16.5±2.0	14.8±2.0	213.7±13.5		14.8	2.1	2.1	2.1	6.2	

M. lutea	5	15.0±2.2	16.5±2.3	177.6±14.4		9.4	5.2	5.2	1.7	12.1
P. vilidiflorum	1	11.2±2.8	16.0±2.3	98.5±16.3		21.0	1.0	1.0	0.9	3.0
O. europaea	5	12.9±2.5	5.8±1.5	131.1±15.5		9.4	5.2	5.2	1.3	11.7
S. siamea	5	23.4±1.0	17.0±2.4	429.1±5.5		9.4	5.2	5.2	4.1	14.5
T.indica	4	35.4±3.1	11.1±1.3	985.1±19.0		10.5	4.2	4.2	9.5	17.8
T.brownie	6	33.2±2.8	8.3±0.6	867.0±16.7		8.6	6.3	6.3	8.3	20.8
T. nobilis	7	12.3±2.6	4.9±1.7	118.1±15.8		7.9	7.3	7.3	1.1	15.7
T. brownie	5	32.1±2.7	7.8±0.8	808.9±15.4		9.4	5.2	5.2	7.8	18.2
T. camphoratus	2	18.1±1.7	4.5±1.8	257.2±12.3		14.8	2.1	2.1	2.5	6.6
U. scheffleri	1	11.0±2.8	2.0±2.2	95.0±16.3		21.0	1.0	1.0	0.9	3.0
V.madagascariensis	1	11.3±2.8	4.3±1.8	100.2±16.2	**0.93**	21.0	1.0	1.0	1.0	3.0

There was no significant difference in woody vegetation diversity between the two sites (T-test= d.f=1 p=0.767). Woody vegetation diversity was higher in undisturbed site than in the rehabilitated mined site (Table 4). In the undisturbed site *cedar*, *Dodonea viscosa*, *Pittosporum vilidiflorum*, *Uvaria scheffleri* and *vanguera madagascariensis* recorded the highest level of richness of 21.0 each whereas *Acacia tortilis* had the lowest recording of species richness of 5.8 (Table 4). In the rehabilitated mined site *Acacia elatior, Ficus sycomorus* and *Teclea nobilis* recorded the highest species richness of 9.2 each while *Acacia tortilis* had the lowest species richness of 2.5 (Table 4).

4.1.2. Description of form tree woody stem

Woody stem is used as an indicator of natural and anthropogenic pressures prevalent in a stand where straight woody stems are indicative of prevalent growth and development conditions (Hall, 1994). A qualitative approach of classifying woody stems is based on categories referred to as stem form, where a straight form is classified as form 1 and the least straight woody stem classified as form 3 (Hall, 1994). At the study area, the undisturbed sites had the highest number of all the quality class Form 1, 2 and 3 (22, 29 and 45 poles/0.4ha or 22.9%, 30.2% and 46.9%) respectively whereas the rehabilitated sites had slightly lower distribution of the form 1, 2 and 3 (20, 27 and 42 poles/0.4ha or 22.5%, 30.3% and 47.2%) respectively. However Form 1 contributed the least proportion of stems in both undisturbed and rehabilitated mined sites at 22.9% and22.5% respectively, while form 3 had the highest proportion (46.9% and 47.2%) respectively (Figure 3).

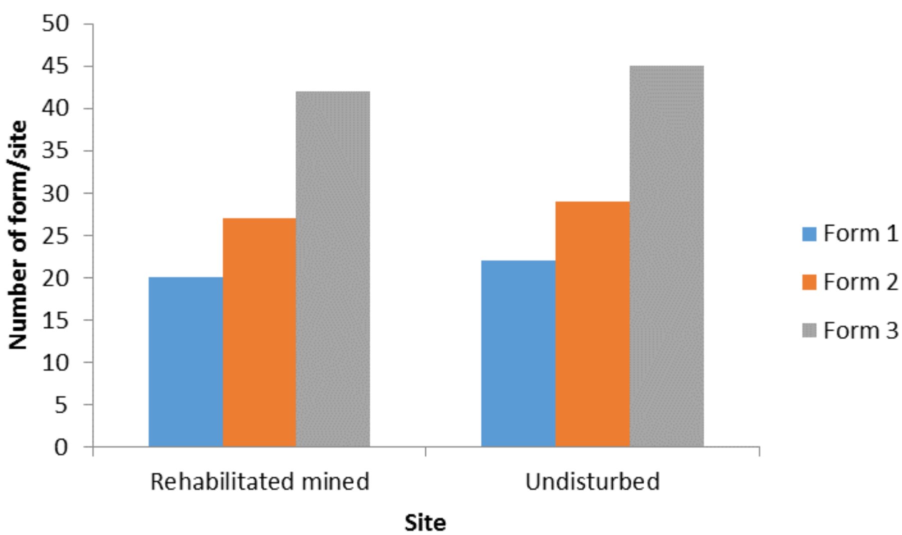


Figure 3: Distribution of tree form in both rehabilitated mined and undisturbed site

4.1.3 Status of regeneration of saplings and seedlings

The mean number of seedlings in the undisturbed site (8±2.8) was higher as compared to the mean of seedlings in the rehabilitated mined site (5.9± 2.5), while the mean distribution of saplings was higher in rehabilitated mined area (fig.4a) whereas the undisturbed site 8.6±2.8 recorded a lower mean.

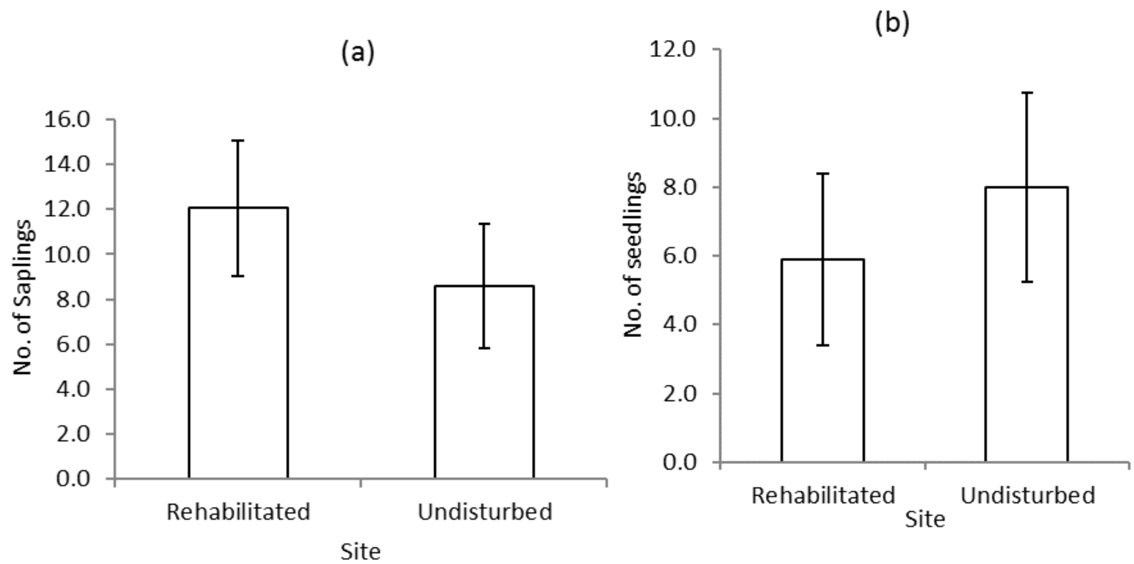


Figure 4: The mean distribution of (a) saplings and (b) seedlings in both the rehabilitated mined and the undisturbed sites

4.1.5 Number of cut stumps at the two sites

Cut stumps are an indicator of the anthropogenic pressures prevalent at a site. The highest number of cut stumps were recorded in the undisturbed site (1072 stumps or 53.2%) and rehabilitated site (942 stumps or 46.8%) the lowest (Figure 5).

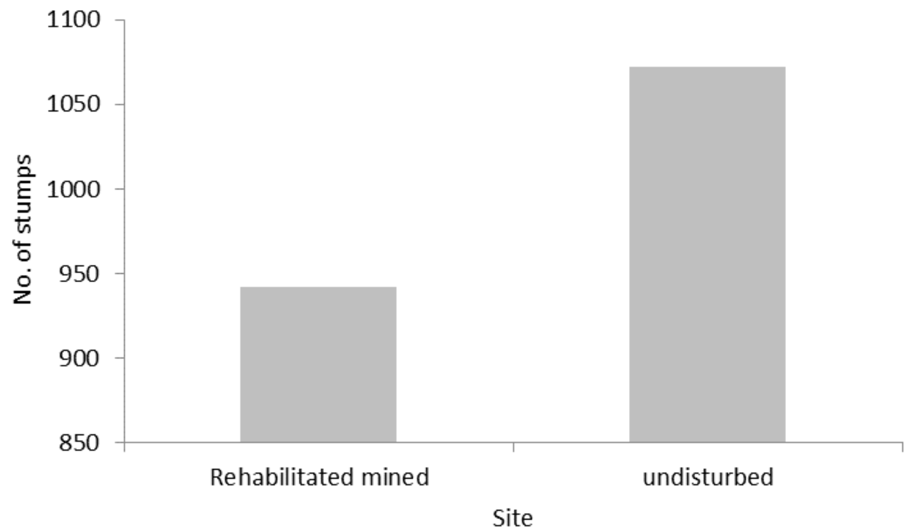
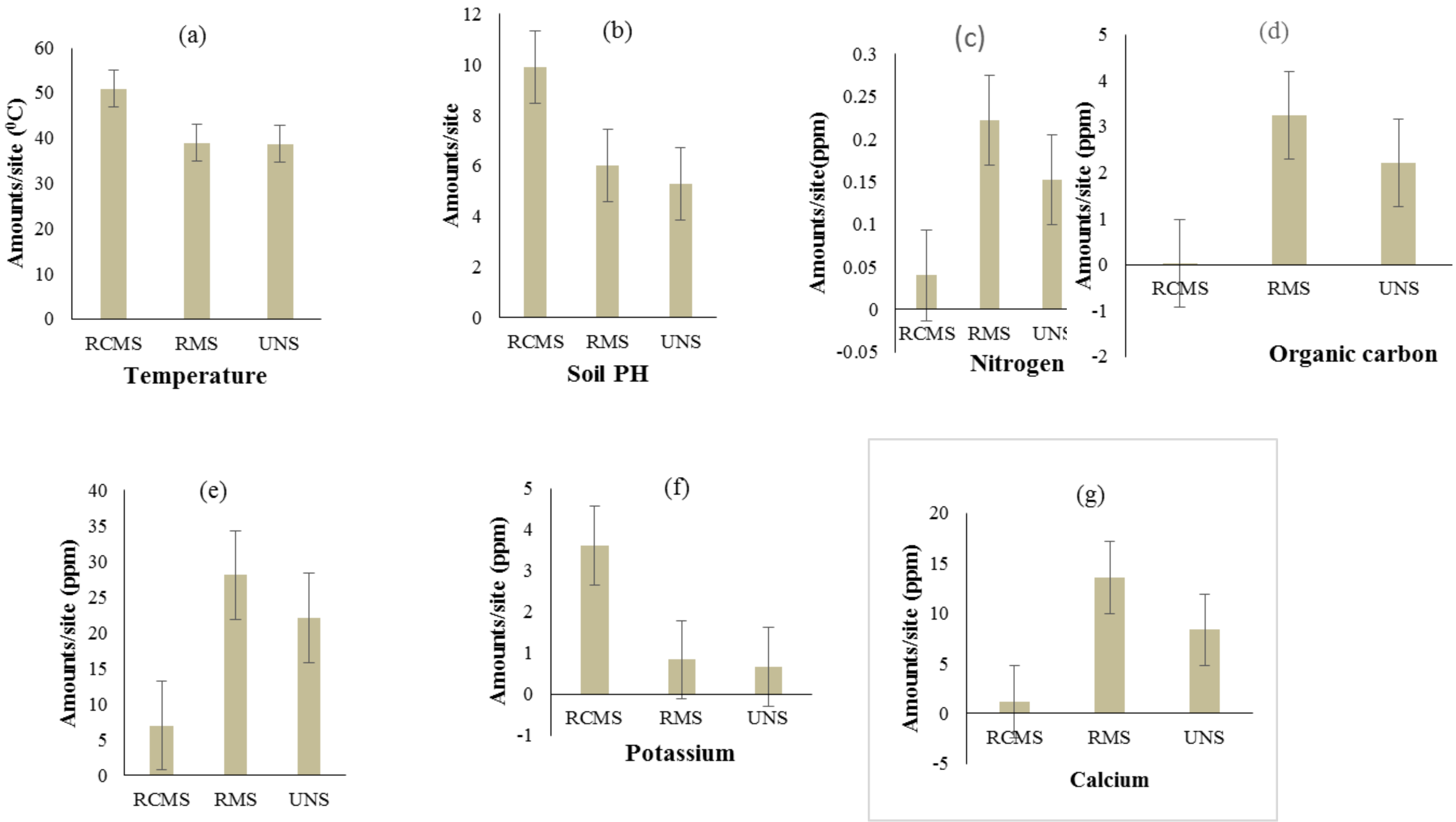


Figure 5: Number of stumps in both rehabilitated and undisturbed sites

4.2 Soil characteristics at the two sites

There was significant difference in the mean soil temperature, pH, nitrogen, organic carbon, phosphorous, potassium and calcium between the three sites ($F_{2,\ 7.}$ =9.08, P=0.011, $F_{2,\ 7.}$ =109.88, P<0.01, $F_{2,\ 7.}$ =22.47, P=0.001, $F_{2,\ 7.}$ =29.93, P<0.01, $F_{2,\ 7.}$ =295.2, P=0.005, $F_{2,\ 7.}$ =53.97, P<0.001 and $F_{2,\ 7.}$ =50.7, P<0.001) respectively. Soil temperature in the recently mined sites was significantly higher than the other two sites (Figure 6a). Soil pH in recently mined site was significantly higher than in the other two sites (Figure 6b). Amounts of soil nitrogen were significantly high in rehabilitated mined site than the other two sites (Figure 6c). Soil organic carbon was significantly higher in rehabilitated mined site than in the other two sites (Figure 6d). Soil phosphorous in rehabilitated mined site was significantly higher than in the other two sites (Figure 6e). Soil potassium was significantly higher in the recently mined site than in the other two sites (Figure 6f). Soil calcium was significantly higher in rehabilitated mined site than in the other two sites (Figure 6g).

There was significant difference in soil magnesium, manganese, copper, iron, zinc and sodium between the three sites ($F_{2,\ 7.}$ =50.58, P<0.001, $F_{2,\ 7.}$ =27.36, P<0.001, $F_{2,\ 7.}$ =141.17, P<0.001, $F_{2,\ 7.}$ =7.91, P=0.016, $F_{2,\ 7.}$ =5.15, P=0.042 and $F_{2,\ 7.}$ =7.86, P=0.016) respectively. However Soil magnesium was significantly higher in rehabilitated mined site than in the other two sites (Figure 6). Soil manganese was significantly higher in rehabilitated mined site than in the other two sites (Figure 6). Soil copper was significantly higher in recently mined site than in the other two sites. Soil iron in recently mined site was significantly higher than in the other two sites (Figure 6k). Soil zinc was significantly high in recently mined site than in the other two sites. Soil sodium was significantly high in undisturbed site than in the other two sites (Figure 6).


(a)
Amounts/site (⁰C)
60
50
40
30
20
10
0
RCMS
RMS
UNS
Temperature
(b)
Amounts/site
12
10
8
6
4
2
0
RCMS
RMS
UNS
Soil PH
(c)
Amounts/site(ppm)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
RCMS
RMS
Nitrogen
(d)
Amounts/site (ppm)
5
4
3
2
1
0
-1
-2
RCMS
RMS
UNS
Organic carbon
(e)
Amounts/site (ppm)
40
35
30
25
20
15
10
5
0
RCMS
RMS
UNS
Phosphorous
(f)
Amounts/site (ppm)
5
4
3
2
1
0
-1
RCMS
RMS
UNS
Potassium
(g)
Amounts/site (ppm)
20
15
10
5
0
-5
RCMS
RMS
UNS
Calcium

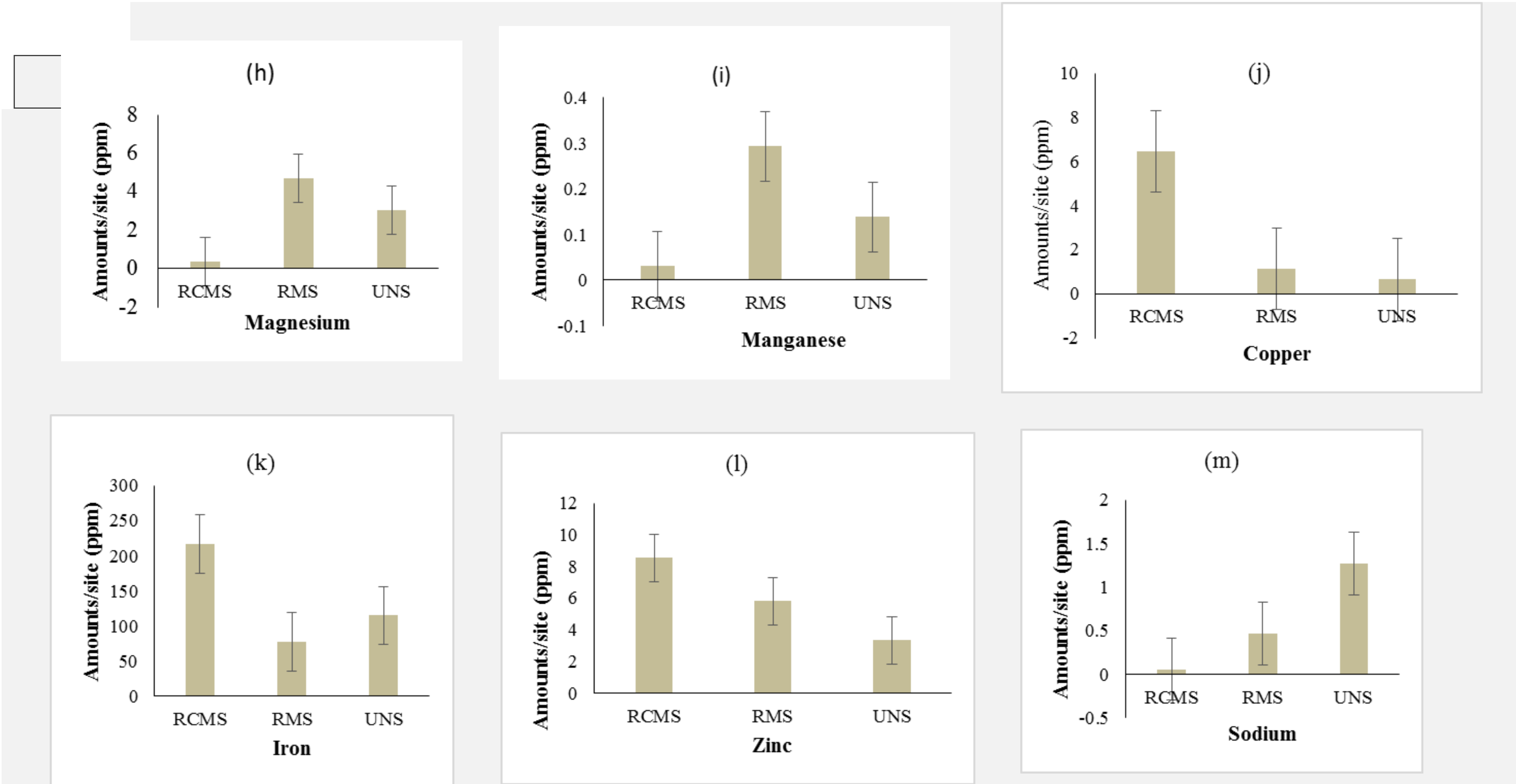


Figure 6: Mean (±s.e) soil characteristics per 0.4m2/ha between the three sites of the study: (a)Temp ^{0}C (b)Soil pH (c) Total nitrogen (d)Organic carbon(e) phosphorous (f)Potassium (g)Calcium (h)Magnesium (i)Manganese (j)Copper (k)Iron (l)Zinc (m)Sodium. RCMS=recently mined RMS=Rehabilitated mined UNS=Undisturbed site

4.3 Levels of local knowledge on uses of woody vegetation

4.3.1. Respondents levels of knowledge on woody vegetation

Combretum molle was the species commonly identified woody vegetation followed by *Acacia hockii* while *Acacia tortilis* was the least known woody plant species in terms of indigenous knowledge (Table 5). Majority of the respondents also listed these species as indigenous to the area.

Table 5: Species identified by respondents as common in the study area

Species identified	Respondents (%)
B. aegyptica	9
Vanguera m	8
E. divinorum	9
G. bicolor	9
T. nobilis	7
O. Africana	6
A. schimperi	6
D. viscosa	8
A. hockii	10
A. tortilis	4
T. brownie	9
C. molle	16

Many of the respondents (49%) reported that woody vegetation species were widespread in the study area with 20% of the respondents indicating that the species identified in Table six were common locally. 19% of the respondents reported these species as threatened and 12% considered them as endangered (Figure 6).

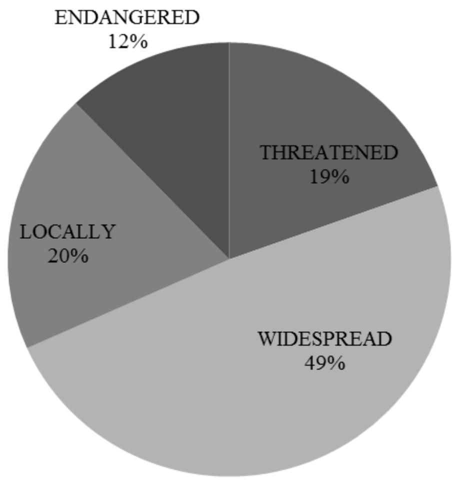


Figure 7: Respondents perceptions on distribution and levels of threats to woody vegetation in the study area

The products from the woody vegetation was identified as mostly used as source of firewood (19%), followed by use for charcoal (17%), building poles (17%), medicinal uses (16%), timber (12%), fencing (9%) and as fodder source (7%) while other uses such as fruits and food had the least priority use (3%) (Figure 8).

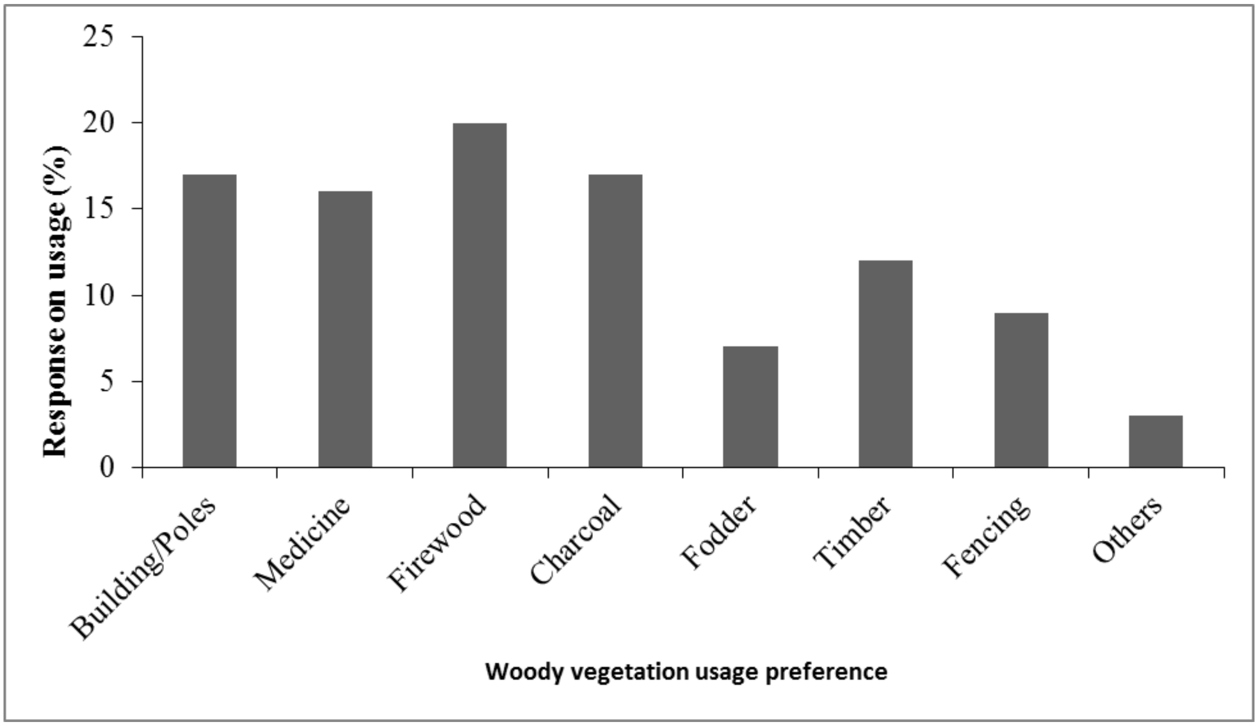


Figure 8: Uses of woody vegetation

4.3.2. Respondents perception on uses and utilization preference of various species found in the study area

Acacia tortilis, Uvaria divinorum were the preferred species as a source of fuel respectively. For building and construction, *Terminalia brownie, Croton dichogamus, Olea africana, Acacia elatior*, *Acacia hockii* and *Dodonea viscosa* were the preferred species. The species which were preferred for medicinal use included *Croton dichogamus, Balanites aegyptica* and *Melia azedarach* (Figure 9).

Croton dichogamus, Balanites aeygptica and *Uvaria scheffleri* were the preferred woody vegetation species for food while *Balanites aegyptica, Terminalia brownii* and *Croton dichogamus* respectively were preferred species for resins and gums. For honey production, *Terminalia browni, Aconthera schimperi* and *Acacia tortilis* were prefered woody species (Figure 9).

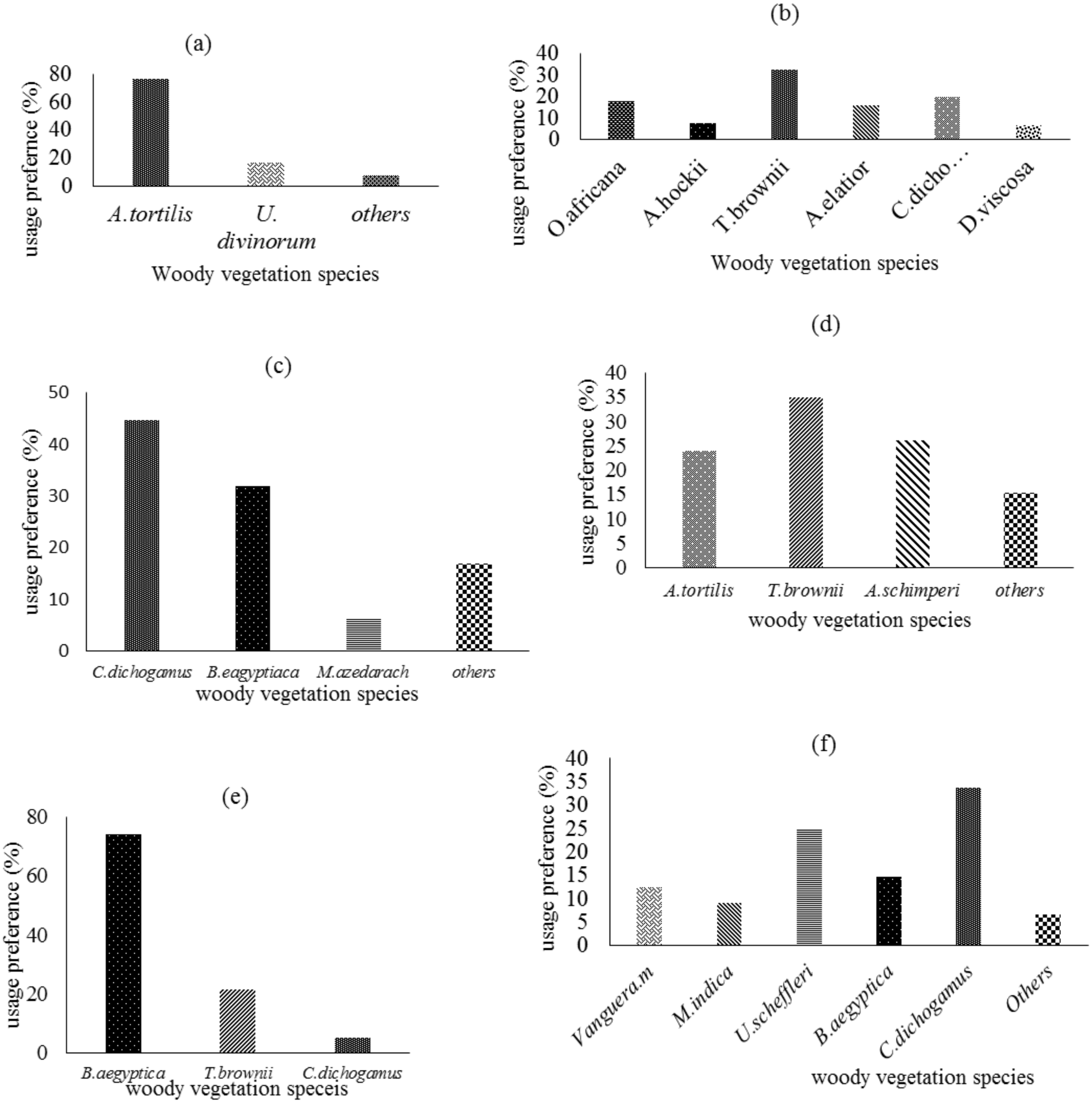


Figure 9: Woody vegetation usage preference where (a) are species preferred for fuel (b) Species preferred as building material (c) medicine (d) food (e) resins/gums (f) honey.

The 47 % of the respondents indicated *Balanites aegyptica* as the species highly valued due to its medicinal and food-source properties Other species which were noted as receiving protection included *Teclea nobilis, Olea africana* and *Syzygium guineensee* (Figure 10).

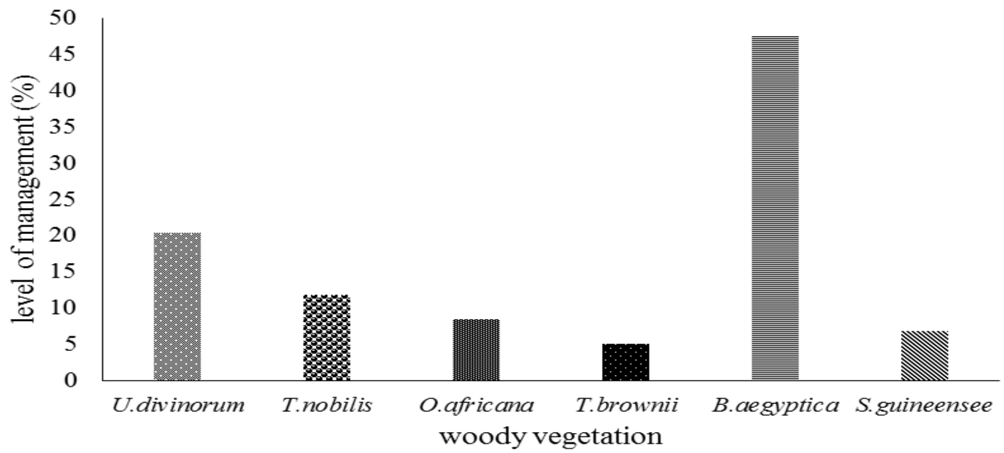


Figure 10: Most valued woody vegetation species

The study indicated that majority of the people in the study area were aware of the presence of laws in protection of woody vegetation (Figure 11). A number were aware of the existence of laws knew of the Forest Act 2005 and existence of environmental policy but did not know of any specific policy, others knew of policies safeguarding the endangered species and other conservation policy (Figure 11).

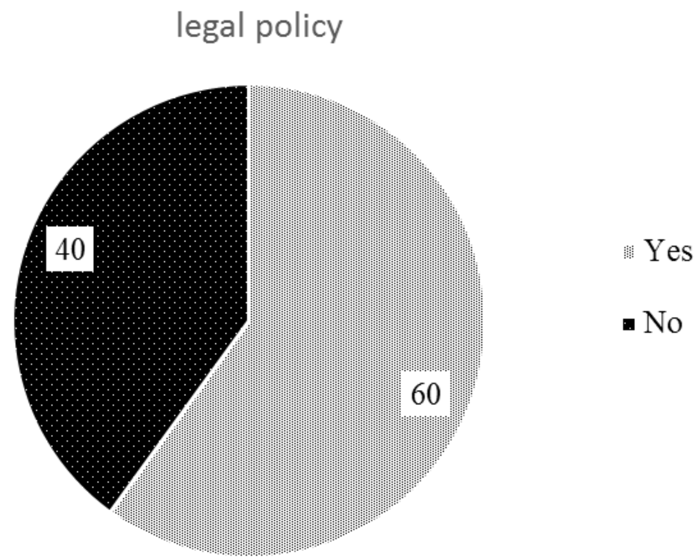


Figure 11: Level of awareness on existence of laws for protection of woody vegetation amongst the respondents

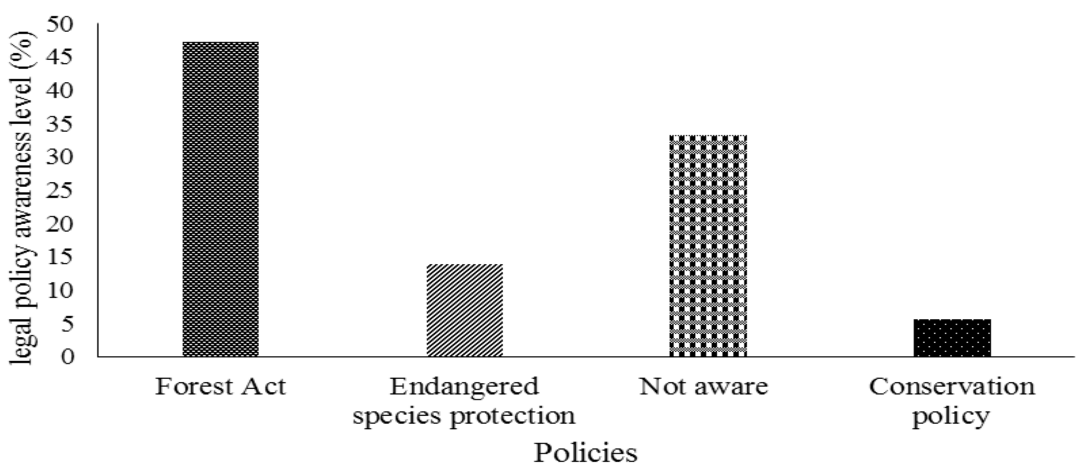


Figure 12: Local knowledge on various types of conservation legislation

Figure 13 shows the factors affecting the availability of woody vegetation products; apart from policy other factors that affects the supply of woody vegetation products included mining activities, marketing, topography, seasonality while some indicated that there was no factor that affected the supply of woody vegetation products.

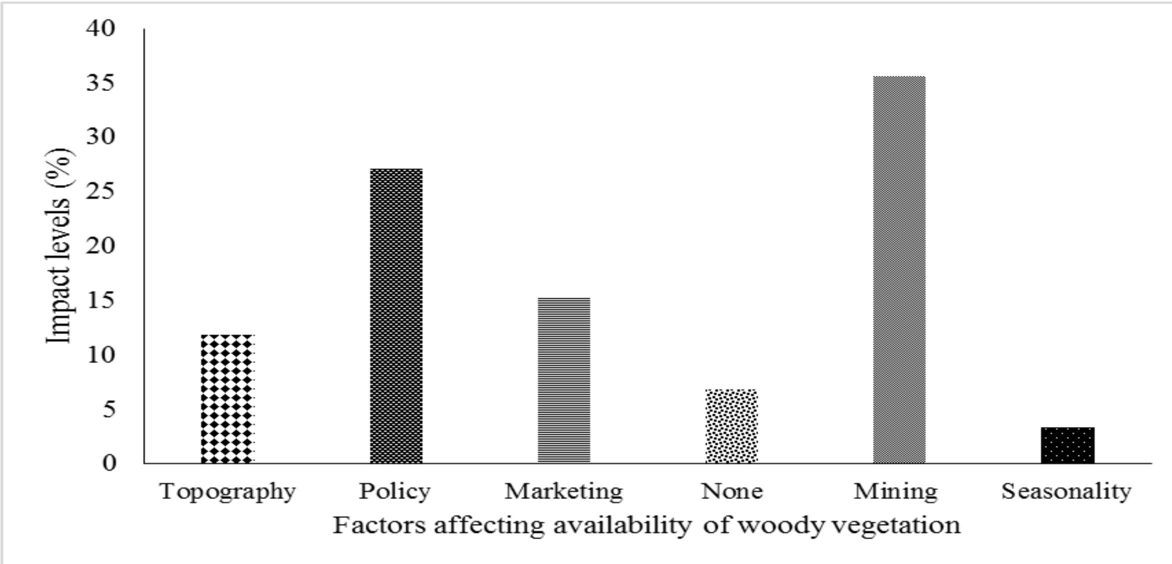


Figure 1: Factors affecting the availability of woody vegetation products

CHAPTER FIVE

5.0 DISCUSSION

5.1 Characterizing woody vegetation

Acacia tortilis was found to be the abundant species in both rehabilitated mined and the undisturbed site respectively. This is attributed to its tolerance to prolonged drought and poor soils. *Balanites aegyptica* also had a high frequency due to its importance to the indigenous community in Kerio Valley-leaves are used as fodder, stem for construction, fruits for human consumption and as animal feed during droughts with its bark and roots used for medicinal purposes. Kellman (1979) links soil properties, predation by understory animals and disturbance history to vegetation characteristics.

Exotic tree species in rehabilitation has resulted in a shift in vegetation dynamics leading to colonization of an area which results in loss of indigenous trees (Mengich, 2013). This is evident in the rehabilitated mined site in our study area which seems to be undergoing succession as evidenced by existence of *Lantana camara* non-woody shrub. White (1983) defines disturbance as a relatively discrete event disrupting community ecosystem or structure of the population and changes the resource availability or the physical environment. Seedlings had a low frequency in the rehabilitated mined site due to canopy cover as a result of *Lantana camara*, this inhibits the growth of the juveniles whereas saplings had a high frequency, which might have resulted in earlier growth before the dominance by the invasive species while in the undisturbed site the number of seedlings had a high frequency due to favorable canopy to allow seedlings growth. The saplings however recorded a low frequency as compared to rehabilitated mined site due to these sites being accessible to human disturbance. The saplings are cut to be used as fittos for construction.

Stand structure (basal area, DBH and tree height) is a reliable indicator of forest development Ludwig (2001). Undisturbed site had the lowest basal area with total number of stumps being the highest due to its accessibility, whereas rehabilitated mined site recorded the highest basal area and with less number of cut stumps. The rehabilitated mined area is under the protection of the Kenya Flourspar Company thus the low number of stumps. The site is also characterized by rich nutrient soils as a result of high organic matter from decomposition of the leaves of *Lantana camara* and soil deposits from the farms uphill as compared to undisturbed sites that have compacted soils. Other factors may be attributed to habitat alteration and inadequate legislation (UNEP, 2009).

5.2 Form quality characteristics

According to Mengich, (2013), environmental conditions, species composition and anthropogenic pressure are factors that the quality of poles is dependent on. Both sites (rehabilitated and undisturbed) had the least densities of Form 1 poles due to human impacts while Form 3 had the highest density. This explains the existence of selective extraction of quality poles compromising the long term quality of the woody vegetation. The absence of high quality (Form 1) of *Terminalia brownii* in both sites is as a result of its preference for posts for construction due to its durability and charcoal burning.

Kokwaro (1985) points out that the preferred size classes for construction poles range between 8cm to 13cm. This explains why Form 3 had a high density as compared to Form 2 and 1. High stand density for low diameter classes (≤7cm) in a forest leads to a high C.I values (Kipkiror *et al.,* 2003). This explains the high C.I values of 50 and 22 in undisturbed and rehabilitated mined sites respectively. However this scenario was more evident in the undisturbed site which is easily accessible by human thus compromising on diameters. Forest size classes assume the inverted J-curve common for natural forests that portray attributes of uneven ages (Leak, 1965). This again may be attributed to the economic value and wood quality of pole size classes which is low, thus multiple harvesting of wood should be harmonized and stem density per class be reduced to avoid these indiscretions (Towett, 2003).

5.3 Comparison of wood vegetation diversity between rehabilitated and undisturbed sites

Woody vegetation diversity was significantly high in undisturbed site as compared to rehabilitated site. This can be attributed to a number of factors ranging from land use or disturbance, soil characteristics and vegetation characteristics i.e. abiotic and biotic factors. Biotically generated stress occur in favorable environments where a variety of species can grow well but the most dominant species eliminates the entire population of less competitive population by limiting important resources like light (Huston and DeAngelis, 1994). Rehabilitated mined site had a diversity index of 0.86 as compared to 0.93 in undisturbed site. Domination of rehabilitated site by *Lantana camara* generates biotic stress. This situation has hindered woody vegetation from growing due to poor light penetration an essential element for regeneration.

The continuous increase of environmental destructions (mining and deforestation) makes it hard for woody vegetation diversity to attain its standard of existence (Sax et al. (2002). Anthropogenic activities such as mining and woody vegetation harvesting for domestic uses result in a paradigm shift in woody vegetation diversity in Kerio valley. However Riha *et al.* (1986) states that beneath a woody vegetation cover, heterogeneity of soil results in both spatial and temporal effects of vegetation. Mining changes the soil nutrient characteristics; this however is attributed to less diverse woody vegetation in rehabilitated mined site. Though undisturbed site was highly diverse than rehabilitated mined there was no significant difference. This can be attributed to soil fertility in the undisturbed site and its accessibility by human beings who exploit the woody vegetation for domestic use. The rehabilitated area is under the protection of Kenya Flourspar Company and thus minimal number of stumps as compared to undisturbed site.

5.4 Soil characteristics

Mining has significant effects on soil chemical properties. In this study, soils from rehabilitated mined site contained significantly higher organic matter compared to the other two sites. Rehabilitated mined site is dominated by *Lantana camara* providing soil fertility through leaf foliage in contrast with undisturbed site which had no vegetation beneath the woody vegetation and recently mined site had no vegetation. This result compares favorably with studies done by Emadi et al., 2008; FAO, 2004). Various studies have examined the effects of land use on physio-chemical properties of soil (Emadi *et al.*, 2008). With absence of vegetation, the soil is deprived of organic matter which is the key to soil fertility and productivity especially in ASALS (FAO. 2004), and is highly exposed to agents of soil erosion. Organic carbon is a sensitive quality indicator suggesting that within a narrow range of soil, it may serve as a suitable indicator of soil quality among other soil properties (Murage *et al*., 2001). Once vegetation cover is restored, it improves the soil structure, soil water balance, chemical soil fertility and restores soil biodiversity and ecosystem services through reduced soil erosion (Mekuria *et al.*, 2007). Soil organic matter may offer an insight into soil fertility changes and the sustainability of past management history (Kapkiyai *et al.,* 1999).

Land use plays an important role in soil nutrient accumulation and losses (Fu *et al.,* 2000). In addition to protecting soil from erosion agents, the tree canopy-herbaceous layer interaction improves soil fertility through addition of nitrogen and organic matter, the vegetation supplies plant litter which decomposes to supply the soils organic carbon pools (Kellman, 1979). Recently mined site had significantly high soil pH, zinc, copper, iron and potassium while manganese, sodium, magnesium, calcium, phosphorus and nitrogen were significantly low. This result can be explained by effects of mining on soil. The top fertile soils are buried deep while the inner infertile soils are exposed to the surface. Vegetation is removed destabilizing soil nutrient and even decomposers. Moreover, woody vegetation depletion of base cations effects on soil pH and nutrients can be attributed to a high amount of some nutrients in sites (Challinor 2007).

Phosphorous however is an essential nutrient for woody vegetation growth hence its uptake by plants and subsequent removal through mining is attributed to acidifying effect on soil. This explains why soils from rehabilitated mining were the most acidic.

5.5 Levels of local knowledge on uses and utilization preferences of woody vegetation

Local people often possess detailed indigenous knowledge on woody vegetation and ecological value of individual species (Seely and Moser, 2004). The survey showed that *Combretum molle* was the most known woody vegetation species among the respondents. This can be attributed to its importance in providing durable poles for construction, quality charcoal and the seeds have medicinal value used in curing throat ailments. Respondents were also more knowledgeable on *Acacia hockii* which can be attributed to its dominance and its vital role in fencing of cowsheds. The thorns keep off predators and cattle from entering or moving out of the cow sheds respectively. This has however been practiced by pastoralists in Northern Kenya where large amounts of thorny woody vegetation branches are used to construct kraals (livestock enclosures) to protect cattle against predation by wild animals keeping them together at night (Lusigi, 1986). On indigenous knowledge in distribution of woody vegetation, respondents reported that woody vegetation was widespread across the study area, Kerio valley varies in its ecological zonation as its altitude ranges between 1500m to 1800m above the see level. Large part of Kerio valley falls under ecological zone V (Kipkiror and Towett, 2003) explaining why woody vegetation is widespread.

It was evident that woody vegetation usage preference varied from one use to another. Fuel was the leading use of woody vegetation with a high proportion of the respondents utilizing woody vegetation as firewood. Nangulu *et al.*, 2001 attributes this phenomenon to increase in human population and poverty resulting into land degradation. However, the indigenous way of living and lack of alternative ways of living is a major factor that makes woody vegetation to be utilized mostly as firewood. *Acacia tortilis* was the most preferred woody vegetation for fuel *Acacia tortilis* makes quality charcoal and its firewood does not produce smoke. During wet season they can be easily lit. *Acacia tortilis* has been used elsewhere as a source of fuel. For example according Hall (1994), in Sudan an evaluation on uses of vegetation was done and it was evident that *Acacia tortilis* has been exploited not only for fuel but even for construction.

The local community preferred *Terminalia brownie* for building and construction. Thirty two percent of the respondents had their preference in *T. brownie* woody vegetation for making poles used in building residential homes and making fencing poles while thirty five percent preferred it for food. Children collect its fruits for consumption and are believed to cure throat infections. The trunk or stem is resistant to woody parasites and resistant to different seasons. *Terminalia brownie* has been used in Sudan for the fencing among other reasons such as medicinal purposes in curing epilepsy (Zakaria *et al.*, 2007). *Croton dichogamus* acts as yeast in fermentation of tradition honey liquor. Forty five percent of the respondents preferred it for medicinal uses used in curing lung and stomach aches while thirty four percent preferred it for use in honey production. The nectar provided by *Croton dichogamus* is believed to produce the best honey and soon after foliage the indigenous people consider it time to harvest honey (Towet *et al.*, 2003).

Balanites aegyptiaca was the most actively valued woody vegetation, this is due to its several functions; the fruits are edible and are fodder to livestock, the leaves are animal fodder and can be cooked as vegetables during the dry seasons, the bark and the roots are used as herbs and the stem produces resins and gums with medicinal value and is used in building and construction.

Previous studies (Katewa *et al.,* (2004; Koch *et al.,* 2005 and Gad *et al.,* 2006) have reported that the brown greasy outer rind of the *Balanites aegyptiaca* fruit is used in treating skin diseases and the root bark as an anti-malarial agent. In the African subcontinent Balanites herb is used as a complementary theraphy for different diseases (Chaudhry and Khoo, 2004). Balanites seed extract is used as an anticancer (Koko *et al*., 2000).

It was evident that majority of those interviewed were aware of the Forest Act 2005 while the rest were not specific on any law though they knew that the law is there. The Forests Act Cap 385 is applicable to gazetted forest areas (Forest Reserves) only, and so did not directly apply to forests in trust and private lands. The provisions of Forests Policy (Sessional Paper No.1 of 2007) and the Forests Act No. 7 of 2005 through The Forests policy and the Forests Act 2005 provide for community participation in the management of state forests. The goal of the Policy is to enhance the contribution of the forestry sector in the provision of economic, social and environmental goods and services. This safeguards overexploitation of woody vegetation and other endangered species in the study area where mining has not been executed. However mining was considered to be a major factor that limits the availability of forest products. Both processed (charcoal and honey) and unprocessed (firewood) forest products are lost due to poor mining activities. The vegetation cover is buried deep into the ground in order to extract fluorspar. It was also evident that where it had not been mined and other adjacent areas were under the strict restrictions of the Kenya Flourspar Company. This has however rated mining as a major factor contributing to a low availability of woody vegetation products in the Kerio valley visa a vi other factors such as topography and forest policy implementation.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The findings of this study indicate that mining has an effect on woody vegetation. Woody vegetation composition in Kerio valley varied differently between the rehabilitated mined site and the undisturbed site. This variation is controlled by environmental setting, land use changes, accessibility of woody vegetation and local knowledge on uses of woody vegetation. However, woody vegetation diversity was not significantly different between the two sites. This is due to accessibility of the undisturbed mined site, the vegetation cover, site elevation and soil nutrient characteristics.

Form quality characteristics between the two sites (rehabilitated and undisturbed) does not differ. Both had the least densities of Form 1 poles due to human impacts while Form 3 had the highest density. Existence of selective extraction of quality poles compromises the long term quality of woody vegetation. However, colonization of the rehabilitated mined area by *Lantana camara* has had devastating effects on regeneration of woody vegetation hindering light essential for woody vegetation seedlings and saplings growth. Restoration of vegetation improves soil structure, soil water balance, chemical soil fertility and restores soil biodiversity and ecosystem services through reduced soil erosion. Heterogeneity of soil results in both spatial and temporal effects of vegetation. Land use plays an important role in soil nutrient accumulation and losses (Fu *et al.*, 2000).

Protecting soil from erosion agents, the tree canopy-herbaceous layer interaction improves soil fertility through addition of nitrogen and organic matter, the vegetation supplies plant litter which decomposes to supply the soils organic carbon pools (Kellman, 1979). *Lantana camara* has assisted in enrichment of soil nutrients and prevention of soil erosion. Soil characteristics differed significantly between the two sites. This is as a result of land topography, where rehabilitated mined site seems to be flat whereas most parts of the undisturbed sites is slant and raised. The underground vegetation cover is bare in undisturbed site thus prone to erosion while rehabilitated mined site is covered by *Lantana camara* curbing soil erosion.

The local knowledge on uses of woody vegetation entirely depended on the different usage of woody vegetation by different groups. *Combretum molle* is the most known woody vegetation as a result of its use. *Balanites aegyptiaca* is the most actively managed woody vegetation due to its usefulness especially its medicinal value and provision of food for human and livestock during the dry season. However, usage of woody vegetation for different purposes such as fuel, building, medicine, food, resins and honey production differs from one group to another. Nevertheless, mining is a major factor in the study area which is contributing to a low supply of woody vegetation products apart from policy implementation and restrictions put in place by Kenya Flourspar Company in woody vegetation conservation.

6.2 Recommendations of the study

To protect and conserve the diversity, the ecosystem services provided by woody vegetation and indigenous knowledge on local usage of woody vegetation in Kerio Valley, there is need to manage and conduct human activities in a way that it enhances the resilience of woody vegetation and its indigenous knowledge on local uses. This study recommends:

- There is need to assist locals develop alternative means of livelihoods in Kerio valley. This will lessen the overdependence on the products from woody vegetation. Stakeholders should come up with rehabilitation plans that must account for loss of woody vegetation as a result of mining activities and colonization of rehabilitated mined area by *Lantana camara.* This can be achieved through improvement of policy implementation and awareness creation on the need to protect the environment through sustainable exploitation of woody vegetation and natural resources.
- Restoration of woody vegetation should be expanded and or encouraged beyond company premises. This can be achieved through development of proper drainage systems to curb soil erosion which reduces soil nutrient content in bare undisturbed sites which tend to be more elevated than the rehabilitated mined sites and restricting exploitation of woody vegetation for human use through fencing. However, systems should be put in place through conducting thorough soil vulnerability assessments in order to come up with proper management strategies to reduce soil nutrient loss.

- Encourage enhanced protection and expansion of woody vegetation due to benefits and values the local community derive. Development of management processes that would create awareness on the need to document indigenous knowledge on uses of woody vegetation in Kerio Valley and assist in implementation of policies involved in safeguarding woody vegetation is necessary. The relevant authorities in conjunction with the locals should conduct conservation education in order to create awareness on the need to conserve woody vegetation.

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7.1 Appendices

7.1.1 Woody Vegetation Data sheet

Forest type………………Date…………………..

Plot size……………….No. of stumps……….

Plot no…………………….. Temp…………………………

Tree No.	**species**	**DBH (cm)**	**HT (m)**	**Form**	**Species**	**<10cm dbh, >1.3m Ht**	**<10cm dbh, <1.3m Ht**

Remarks…………………………………………………………………………………………
…………………………………………………………………………………………………

7.1.2 Indigenous knowledge/local uses survey of woody vegetation in Kerio Valley.

1. What are some of the woody vegetation that are in this area, where they introduced or they are indigenous. Categorize them in terms of their distribution in the table below (local names allowed).

s/n	**Species name (local/common)**	**Status (indigenous/introduced)**
1		
2		
3		
4		
5		

2. If introduced who introduced them (Men/women/children/ not known)
3. What are the uses/services of woody vegetation?

s/n	Use/service
1.	
2.	
3.	
4.	

4. Which woody vegetation is preferred for the following uses and who uses or controls them?

s/n	Usage	Woody vegetation	Who uses/controls
1.	Fuel		
2.	Building/construction		
3.	Medicine		
4.	Food		
5.	Resins/gums		
6.	Honey		

5. Which woody vegetation is actively managed?

   a)

   b)

6. Are you aware that there is a policy which safeguards woody vegetation?

7. What are some of these policies?

   a)

   b)

8. What are some of the factors which affect availability of woody vegetation products?

   a)

   b)

Thank you and God bless you