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Research paper

Assessing composition and diversity of woody vegetation in mined arid and semi arid lands of Kerio valley, Kenya

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Abstract

The woody vegetation in semi-arid area is important in providing ecosystem services and goods. However, it faces threats manifested in land-use changes such as mining. This study aimed at assessing the composition and diversity of woody vegetation as well as inherent soil physico-chemical parameters in a previously mined area and comparing it with a semi-pristine adjacent area. Six transects containing five plots each were established within two blocks separated by a river. In each plot, data was collected on woody tree growth characteristics and soil parameters. Thirteen woody species were recorded in the rehabilitated mined and twenty two in semi-pristine sites with *Ficus sycomorus* L Moraceae being the dominant species at the two sites. Woody vegetation diversity was higher in semi-pristine site than in the rehabilitated mined site. However, this was not significant (t-test, =D.F=1 P=0.767). Mean soil nutrients ($F_{2,\,7}$. = P=0.821), pH ($F_{2,\,7}$. =109.88, P=xxx), was higher in rehabilitated mined sites while mean soil temperature ($F_{2,\,7}$. =9.08, P=0.011) was higher in mined areas. Rehabilitating mined sites can bring back species diversity, composition, however what is not clear is whether ecosystem functions are restored.

Keywords: *Composition; Diversity; Mined; Rehabilitated; Woody Vegetation.*

1. Introduction

Semi-arid environments 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, they accounts for 46.1% of the total area while in Kenya it covers 80% of the total area (UNEP, 2006).

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).

The Kerio valley is rich in minerals especially flourites used to manufacture ornamentals. 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.

Assessing distribution and composition of woody vegetation is important in informing plans on their harvesting and conservation (Newton, 2008) as well as providing information on their ecological status and resilience to disturbances caused by human or natural pressures (Omambia *et al.*, 2009). Mining activities have been noted as key driver in microbiological changes in soil properties (Ghose *et al.*, 2004). Comparing soil characteristics in rehabilitated and undisturbed mining sites is key in identifying appropriate soil and woody vegetation conservation measures. This study aimed at assessing the composition and diversity of woody vegetation as well as inherent soil physico-chemical parameters in a previously mined area and comparing it with a semi-pristine adjacent area. The findings are useful to natural resources managers as well as development partners in informing appropriate rehabilitation and management approaches in woody vegetation.

2. Materials and methods

2.1. Study area

This study was carried out in Kerio Valley (0° 19' 0" North, 35° 38' 0") located in Rift Valley, Kenya. The Kerio valley borders Elgeyo escarpment to the West and Tugen hills to the East. It is classified as semi-arid area in ecological zone V. The average annual temperature at the valley is 24ºC and it receives a mean annual rainfall of below 1000mm. 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.

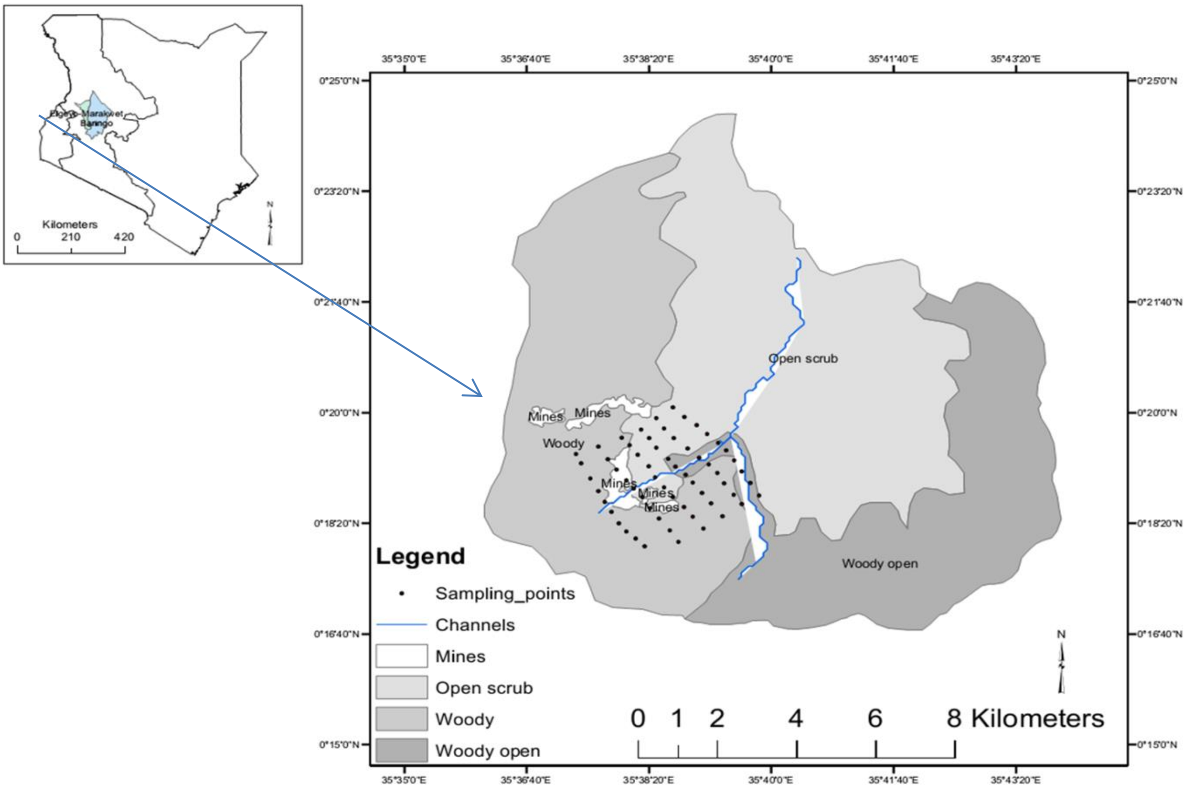


Fig. 1: Map of the Study Area.

2.2. Research 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 1). 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.

2.2.1. Assessment of 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.

2.2.2. Species richness and diversity

Simpsons diversity index (excel) was used to compute diversity index of species between the two sites as follows;

$D=1-(\Sigma n (n-1)/N (N-1))$

Where;
D= Diversity index
n> the total number of trees of a particular species
N=the total number of trees of all species
To calculate species richness, Menhnick's index was used
$D=s/\sqrt{N}$
Where; s-number of different species
N- Total no. of individual species

2.2.3. 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)

2.3. 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 were used.

3. Results

3.1. 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 and a high of 50 in the undisturbed site.

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 species richness (SR) 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).

3.2. 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 2).

3.3. Status 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 (12.1±3.0) whereas the undisturbed site 8.6±2.8 recorded a lower mean.

3.4. 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 4).

3.5. 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 5a). Soil pH in recently mined site was significantly higher than in the other two sites (Figure 5b). Amounts of soil nitrogen were significantly high in rehabilitated mined site than the other two sites (Figure 5c). Soil organic carbon was significantly higher in rehabilitated mined site than in the other two sites (Figure 5d). Soil phosphorous in rehabilitated mined site was significantly higher than in the other two sites (Figure 5e). Soil potassium was significantly higher in the recently mined site than in the other two sites (Figure 5f). Soil calcium was significantly higher in rehabilitated mined site than in the other two sites (Figure 5g).

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 5). Soil manganese was significantly higher in rehabilitated mined site than in the other two sites (Figure 5). 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 5k). 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 5).

Table 4: Abundance and Composition of Woody Vegetation in Rehabilitated Mined Site and Undisturbed Site

Species Rehabilitated mined site	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
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	

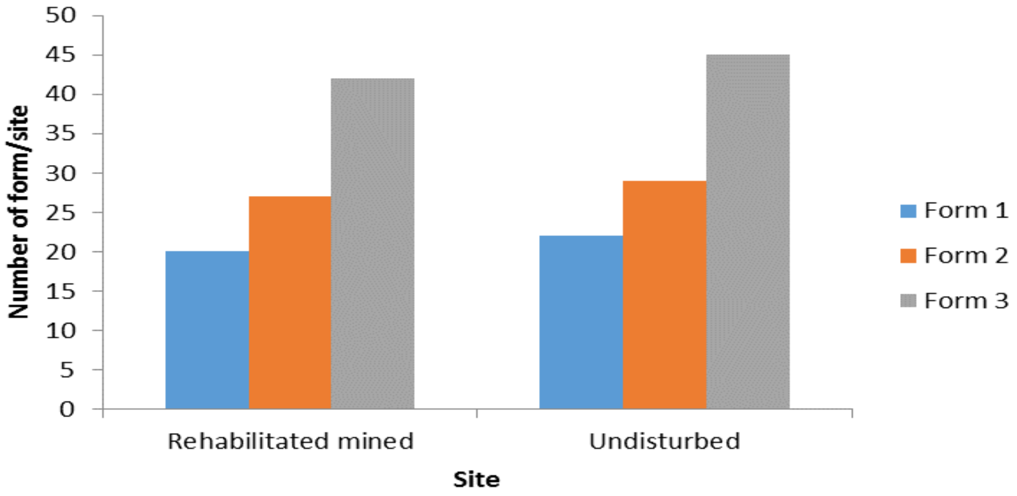


Fig. 2: Distribution of Tree Form in Both Rehabilitated Mined and Undisturbed Site.

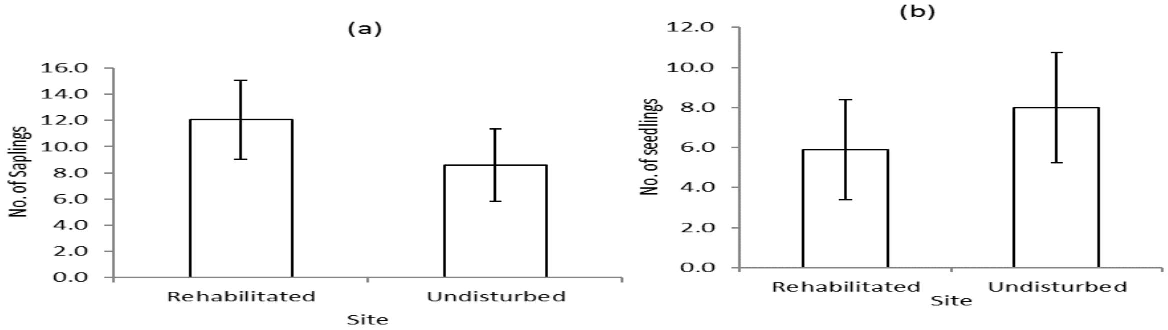


Fig. 3: The Mean Distribution of Seedlings in Both the Rehabilitated Mined and the Undisturbed Sites.

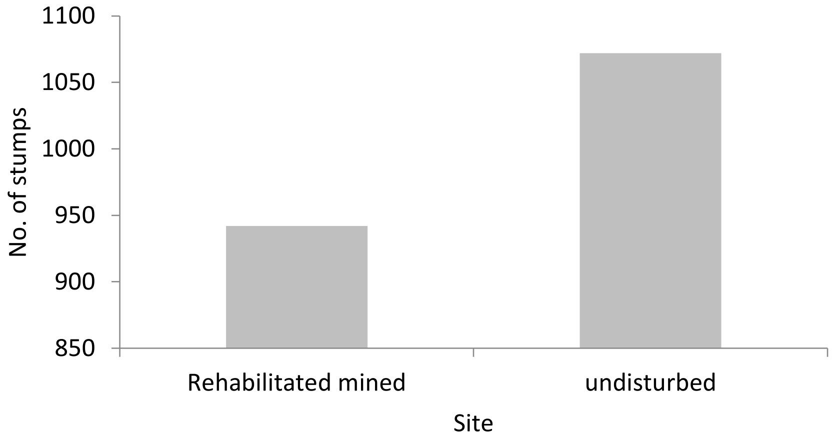
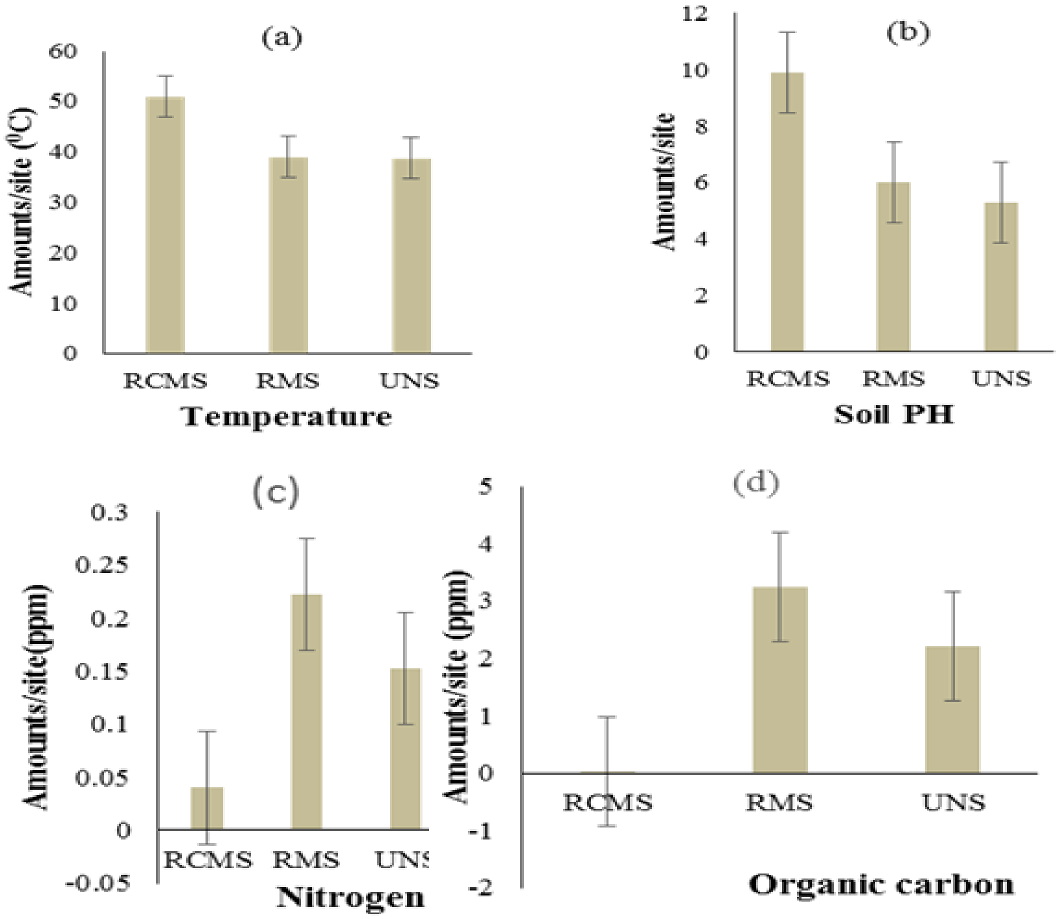
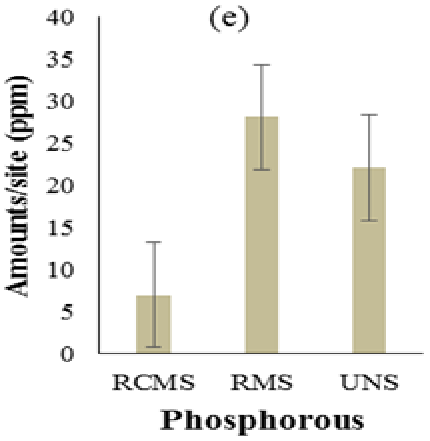


Fig. 4: Number of Stumps in both Rehabilitated and Undisturbed Sites.

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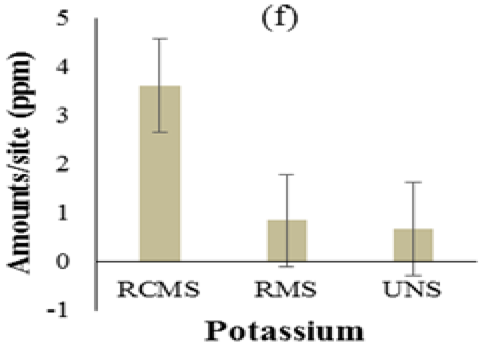
35
30
25
20
15
10
5
0
RCMS
RMS
UNS
Phosphorous


(f)
Amounts/site (ppm)
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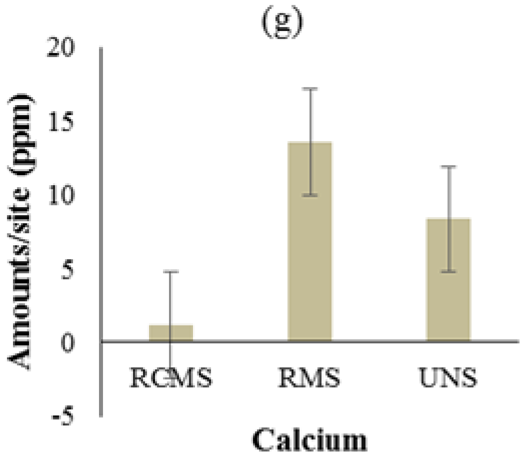
4
3
2
1
0
-1
RCMS
RMS
UNS
Potassium


(g)
Amounts/site (ppm)
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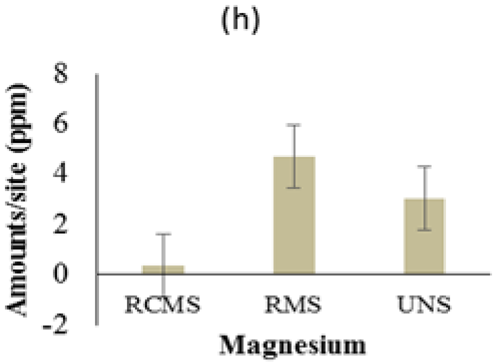
15
10
5
0
-5
RCMS
RMS
UNS
Calcium


(h)
Amounts/site (ppm)
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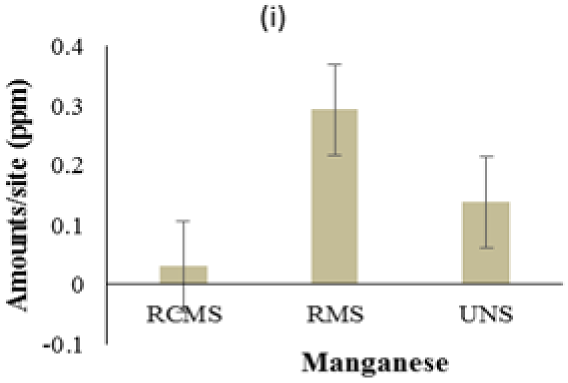
6
4
2
0
-2
RCMS
RMS
UNS
Magnesium


(i)
Amounts/site (ppm)
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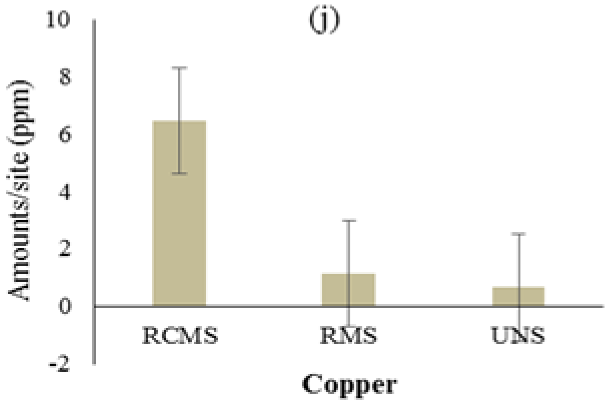
0.3
0.2
0.1
0
-0.1
RCMS
RMS
UNS
Manganese


(j)
Amounts/site (ppm)
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8
6
4
2
0
-2
RCMS
RMS
UNS
Copper

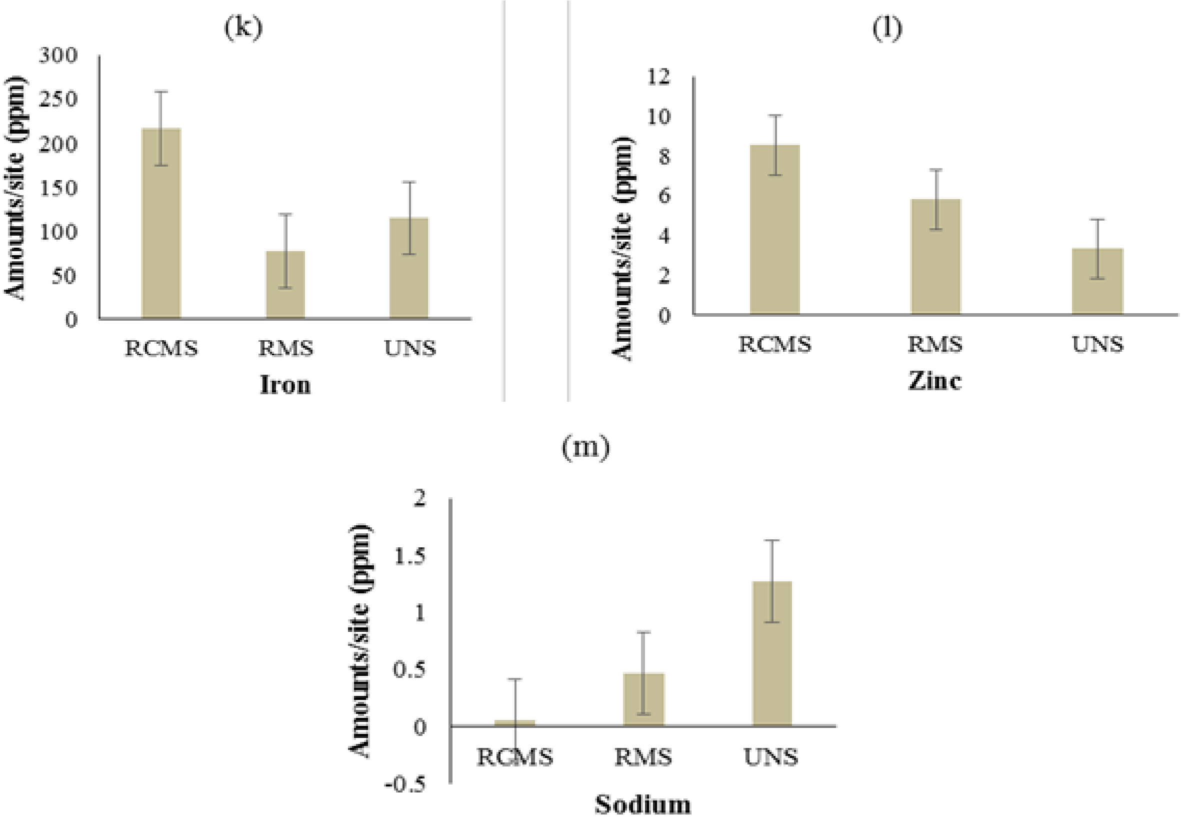

Fig. 5: Mean (±S.E) Soil Characteristics Per 0.4m2/Ha Between the Three Sites of the Study: (A)Temp 0C (B)Soil Ph (C) Total Nitrogen (D)Organic Carbon(E) Phosphorous (F)Potassium (G)Calcium (H)Magnesium (I)Manganese (J)Copper (K)Iron (L)Zinc (M)Sodium. RCMS=Recently Mined RMS=Rehabilitated Mined UNS=Undisturbed Site

4. Discussion

4.1. Characterizing woody vegetation

Acacia tortilis was found to be the dominant 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 (1985) 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).

4.2. 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).

4.3. 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.

4.4. 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., 2000). 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 (Kapkyiai et al., 1998).

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 1968). 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. Conclusion and recommendations

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.

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