

An assessment of impacts of extractive industries on landscape: a case study of gypsum mining in Kajiado, Kenya

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Abstract

Kenya is endowed with a wealth of natural resources comprising minerals, forests, wildlife and other forms of biodiversity. In the recent past, the Country has witnessed increased attention in the extraction of minerals such as titanium, gypsum and gold just to mention a few. Spurred by a progressive Constitution and an aggressive long term development blueprint, the extractive industry is expected to expand. Mining activities are potentially important contributors to landscape changes and loss of biodiversity. Kajiado County residents have in the past violently protested against land degradation and it is therefore necessary to understand the nature and magnitude of landscape changes in the study area. Discussions in the literature on impacts of gypsum mining on landscape are site specific and lack in details. This study sought to establish the impacts of gypsum mining activities on landscape in Kajiado. The study adopted the Mixed Method Research design. Questionnaires were used alongside interview schedules to collect qualitative data from a sample of 95 respondents and key informants selected through Simple Random Sampling (SRS), Stratified Random Sampling (SRS) and Purposive Sampling. Quantitative data was obtained through Satellite imagery analysis to investigate landscape changes in the study area over the past 32 years. Data was analyzed in descriptive and inferential statistics. Imagery analysis revealed significant land degradation and loss of biodiversity. Questionnaire study however indicated minor importance ($\chi^2 = 95$, $P \leq 0.001$) to the overall contribution of gypsum mining to the county landscape. The study recommends systematic land rehabilitation and re-vegetation.

Key Words: Extractive Industries, Environmental Impacts, Landscape.

Introduction

Kenya is endowed with a wealth of natural resources including minerals, forests, wildlife, water, dry lands, hydropower and wetlands among others. Mineral resources found in Kenya include titanium that is available in commercially viable quantities in Kwale County at Mrima Hill. Substantial deposits of gold are believed to exist in Western Kenya at Macalder mines in Migori County and Ikolomani in Kakamega County, while huge deposits of coal have been established at the Mua Basin in Kitui County. Commercially viable mineral oil deposits are suspected to exist in Turkana and Baringo Counties (RoK, 2016).

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Other minerals found in Kenya include Soda Ash and Trona mined in Lake Magadi, in Kajiado County and Halite (salt) believed to exist in massive amounts at the same region, Ngomen and Fundi Isa in Malindi County. Gemstones extraction potential exists at Mrima hill and some parts of Taita Taveta County, while Diatomite harvesting is possible at Kariandusi, Elmentaita, Naivasha and Lake Magadi in the Rift Valley. Kenya is also endowed with steam (geothermal energy) in the Rift Valley at Kapedo and Suguta Valley in Baringo County, Solai in Nakuru County, the Mua basin of Kitui and Homa Hills of Homa Bay County (Republic of Kenya, 1969). Gypsum availability has been confirmed in Wajir County, Mandera County at Rahmu and Konza in Machakos County. Iron free, excellent quality gypsum in commercial quantities is available at Isinya in Kajiado County (RoK, 2016).

Kenya has in the recent past witnessed increased investment in the mining sector, with new Multi-national mining companies coming on board. This led to intensification and expansion of mining activities across the counties culminating in the discovery of oil deposits in Turkana County in 2012 and, the first shipment for export of twenty five tons of Titanium mined in Kwale County in February 2014. This trend is expected to continue because the Constitution of Kenya 2010 (Articles 69 and 72) and the Kenya Vision 2030 encourage the sustainable exploitation of natural resources for National development (RoK, 2007; RoK, 2010).

The exploitation of mineral resources is however, prone to environmental and socio economic impacts whose net effect could accelerate or slow down economic growth. Even though mining is regarded as a vital economic activity, it tends to have significant negative impacts on the environment. The observed interest in gypsum mining in Kajiado County and the consequent increase in spatial scale, created potential for negative environmental impacts. Gypsum extraction was dominated by open cast mining and manual quarrying methods, which involved the removing of top soil up to the bedrock, effectively making the mining areas bare and devoid of vegetation. Open cast mining involved the drilling of holes, blasting, transportation and initial processing using heavy machines that could impact on landscape (Brahma, 2008).

In the past decade, Kajiado County witnessed violent protests against gypsum mining companies on account of environmental destruction and low compensation rates for the local land owners. If nothing was done to identify the nature and scale of landscape impacts for better planning of gypsum extraction, the simmering protests would be expected to escalate. There was no consensus on the nature and significance of gypsum mining impacts on landscape because available literature on gypsum mining was site specific and lacked in details. For instance, some of the impacts discussed in Environmental Impact Assessment (EIA) reports submitted to NEMA by mining companies in support of mining license applications tended to be merely predictive estimations of broad environmental impacts and do not therefore document matters of landscape changes detail.

A thorough research into the specific impacts of gypsum mining on landscape was a necessity and the study sought to address this gap. The overall objective of the study was to identify and assess the impacts of gypsum mining on the landscape at the mining sites in Kajiado County, so that the scale of landscape changes and its effects on the general environment might be considered.

Bebbington (2010) defines extractive industries as economic activities that remove a natural resource from the environment, submit it to marginal or no processing, and then sell it on. In his definition, he includes industries such as mining, oil, and gas and timber extraction. More recent studies allude to the element of processing and utilization by consumers and thus characterize extractive industries as activities that lead to the extraction of raw materials from the earth (Sigam and Garcia, 2012). The extractive industry sector is very diverse (Klop, 2009). The categorization may refer to the scale of operations, nature of activity, material extracted or degree of capitalization. Mineral extraction is achieved through four main mechanisms namely; open cast mining, which involves the harvesting of mineral materials from the surface mines, open pits, quarries or other diggings open to the sky; underground mining, where mines are accessed through shafts and tunnels; recovery of minerals through boreholes and under water mining (Klop, 2009). Open cast mining is the most preferred form of extraction in situations where the ore size, location and grade make it cost effective to remove the overburden. For the purposes of this study, extractive industries included activities that seek and exploit resources that are naturally stocked in the earth's crust, particularly non-renewable resources such as crude oil and gas, solid minerals, salt, sand and aggregates. It incorporates mining, quarrying, oil and gas extraction (Palacios-Berrios, 2006).

Impacts of Mining on Landscape

Extractive industries have boomed in the recent past spurred by a cyclical rise in commodity prices that gave prominence to mines hitherto deemed marginal. The growth raises concerns that the extractive industry could engender negative environmental impacts including pollution and land degradation. Open cast mining principally is believed to cause serious impacts on landscape as it suppresses or prevents vegetation regeneration, thereby affecting ecosystems' equilibrium through the destruction of habitats, death of species of animals and interruption in genetic flow (Erdiaw-Kwasie *et al*, 2014).

Literature is full of examples of other negative effects of mining on landscape. These include changes to the topography and landforms, vegetation cover, disturbance of the dominant biodiversity forms and the resultant response by the local communities in terms of local resource needs and livelihoods (USDI , 2011 a). Writings on gypsum mining indicate that some gypsum deposits constitute unique habitats that are home to a number of endemics and indeed some of the most sensitive habitats in relation to climate change and mining (Palacio *et al* 2012). Monitoring landscape changes occasioned by mining activities is therefore, important because the changes might alter the ability of the landscape to function efficiently as habitat and in provision of environmental services such as water, food and livelihood opportunities. Further, understanding the direction and extent of the changes in time helps in drafting suitable policy responses and mitigation measures to curb degradation (Wang *et al*, 2009).

Global forces such as the international mineral market dynamics play a major role in determining landscape changes as they amplify or attenuate local factors (Lambin *et al*, 2001). Scholars are in agreement that as people respond to economic opportunities created by global forces and mediated by institutional factors, they drive landscape changes. The resultant disruptions in the landscape patterns compromise its functional integrity through undermining the ecological processes that are necessary for the existence and maintenance of ecosystem health (Li and Mander, 2009; Gathuru, 2011). In other words, as Kenya strives to satisfy international demand

for minerals, the overburden removal, drilling and development of support infrastructure for mining activities disturbs the abundance, species diversity, geographical distribution and productivity of fauna and flora in the mined areas. The inevitable deforestation causes the elimination of some plants and an exodus of the animal species that depended on the plants for food and cover (EPA, 1999; Aigbedion and Iyayi, 2011).

Debate on the scope of anthropogenic conditions that catalyze landscape changes is not settled. While Lambin *et al* (2001), suggest that institutional factors play a catalyst role in landscape changes, he ignores the role of public perception and expectations of communities living near mining sites that are often alive to the potential threats to conservation due to spatial distribution and extent of mining (Gardiff and Adriamanalina, 2007; Martinez *et al*, 2007; Castellanza *et al*, 2010). As mining sites increase in size, they tend to eat into agricultural land thereby threatening production and livelihood systems since opencast mining affects all landscape components and functions (Sklenicka, 2004). Mining therefore, potentially causes serious land degradation. In an examination of the impacts of natural contaminants and mining activities on surface water and agricultural soils, Rahimsouri *et al* (2011) observed that mining and natural sources contributed significantly to soil pollution that in turn reduced agricultural productivity because of the toxicity of the chemical compounds which adversely affected biological functions. The impact of mining on the quality of soils around the mines cannot therefore, be ignored as the cumulative effects of pollution loads on the soil and water resources alter the land use in the host communities (Cockell, *et al*, 2010; Chauhan, 2010; Ezeaku, 2012). In a study aimed at evaluating the influence of open cast mining of solid minerals on soil, land use and livelihood systems, it was established that soils around the mine sites were coarse textured and acidic with a PH of 4.8. Mine soils were found to be strongly acidic with a PH of 3.5 which affected the indigenous vegetation. Research has also established that mining activities cause loss of vegetation cover (Schuler *et al* (2011). Erdiaw-Kwasie *et al* (2014) warn that when communities' loose valuable lands such as farmlands and forests, their livelihood opportunities and consequently their living standards get impacted.

However, there is no agreement in literature regarding the effect of opencast mining on fauna and flora. It has been argued by various scholars that mining activities negatively impact on fauna and flora and consequently disturb the forest eco-system around mining sites (Lameed and Ayodele, 2010). This deprives the local community the ecological diversity upon which the distribution of bio-productive resources and the nature of economic activities undertaken depend (Mugabe, 1994). The notion that mining causes negative impacts to fauna and flora has however been criticized by other scholars. In a study of bird species abundance and richness in mined and non-mined sites in the Jos plateau in Nigeria, Dami and Okafor (2009) concluded that the number of bird species in mined sites was greater than in non-mined areas as the former supported wetland birds. From literature, it is unmistakable therefore that by putting pressure on the ecological base, mining results in land degradation and deforestation. Deforestation leads to further loss of soil and a decline in microbial diversity while the resultant decline of vegetation cover leads to serious loss of plant and animal species. Gyang and Ashano (2010) argue that mining, particularly open cast mining takes place on the earth's crust which is home to organisms whose life patterns get disturbed when mining is undertaken. This position is confirmed in a study toward a World monograph of *Nepenthes Ramos*, where it was established that the species had not been recorded since 1919, despite much exploration in the recent years

specifically for the nepenthes (Cheek and Jebb, 2013; Gyang and Ashano, 2010). It was probably extinct as a result of open cast mining.

Data Collection Methods

Data for the study was acquired from both primary and secondary sources as recommended by Ahmad *et al* (2014), who in a study of the impacts of mining activities on various environmental attributes, obtained study data using both primary and secondary sources. In this study, primary data was obtained through interviews, questionnaire study satellite imagery analysis. Aerial photographs and remote sensing imagery were examined to reveal land use changes in the study area for the past 32 years (Antwi, 2009).

Satellite imagery is a valuable tool for determining temporally changes like forest clearing as well as gradual long term changes like precipitation decline. Setiawan and Yoshino (2012) believe that simultaneous analysis on land surface attributes by remote sensing is the best way to examine environmental changes, as long as the change detection methods allow identifying a change within long term data sets and seasonal variations. The basic premise in using remote sensing data for change detection is that changes in land cover result in radiance values, large enough in respect to radiance changes caused by other factors. Analysis of land cover and land use changes using satellite imagery is therefore efficient in natural resource assessment and monitoring (Musa and Jiya, 2011).

Study Location

The study area was located in Kajiado County, Kajiado East Sub County. It covered Enkirigirri, Olturoto, Ipolosat and Nkama locations. Enkirigirri, Olturoto and Ipolosat locations are approximately 20 Km from the County Headquarters while Nkama location is nearly 50 Km from the Headquarters (see Fig. 1).

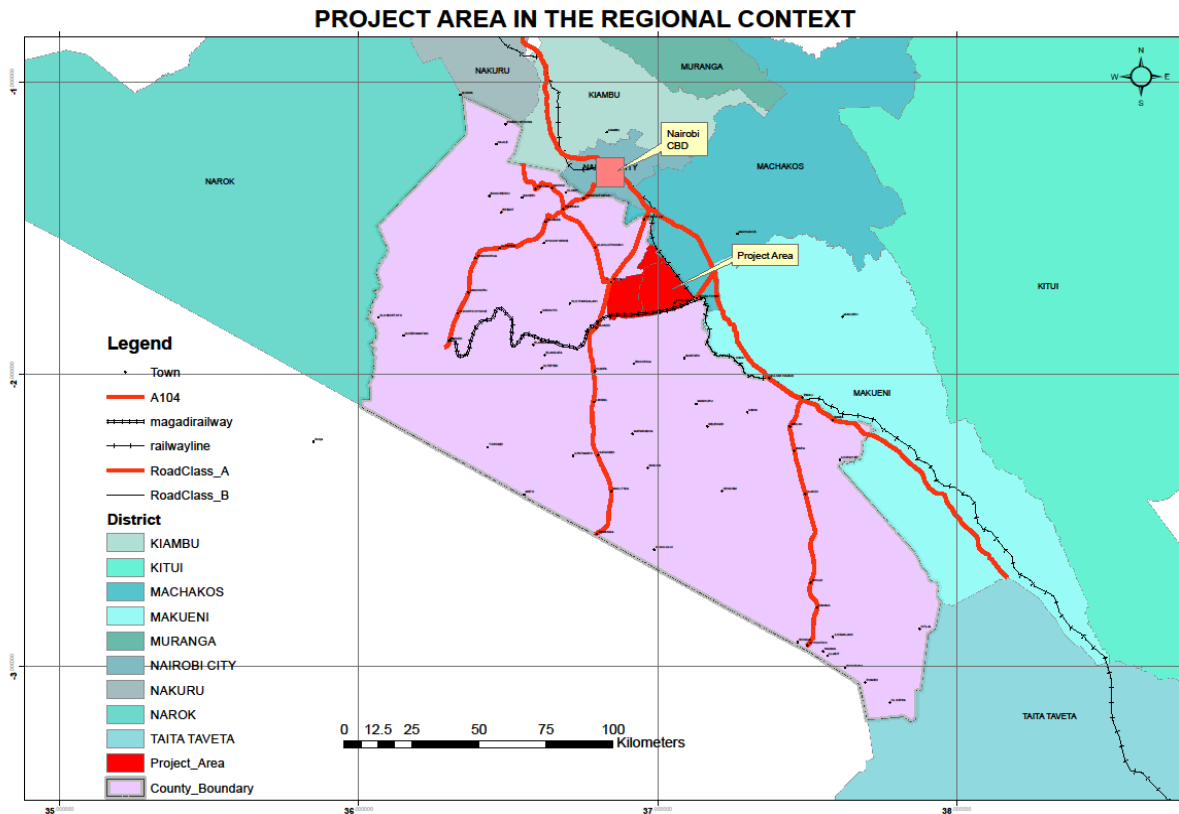


FIGURE 1: STUDY AREA IN REGIONAL CONTEXT

Findings and Discussion

In the course of questionnaire study, we prepared a Likert scale and computed a total score for each respondent. These together with other items were rated on a 5 - point Likert scale ranging from: 1 = very positive (VP) to 5 = very negative (VN). As shown in Table 1, respondents indicated the contribution of gypsum mining to the overall county landscape as being of minor importance ($\chi^2 = 95, P \leq 0.001$), but ranked the impact of gypsum mining on land cover through destruction of vegetation and habitats as a very important issue of concern ($\chi^2 = 230, P \leq 0.001$). The contribution of gypsum mining to the general aesthetics of the study area was also indicated as important ($\chi^2 = 241, P \leq 0.001$), and therefore had the strongest association to the significance of gypsum mining, while the accumulation of dust on pasture had the least association ($\chi^2 = 50, P \leq 0.001$).

TABLE 1: ALLEGED IMPACTS OF GYPSUM MINING ON LANDSCAPE

Impact areas	NI Freq (%)	MI Freq (%)	FI Freq (%)	I Freq (%)	VI Freq (%)	χ^2	P- value
Overall land cover/Use	30(31.6)	60(63.2)	3(3.2)	2(2.1)	-	95.02	.001
Loss of vegetation and Habitats	3 (3.2)	4(4.2)	2(2.1)	8(8.4)	78(82)	230.1	.000
Aesthetic appearance	3(3.2)	2 (2.1)	3(3.2)	7(7.4)	79(83)	241.7	.000
Dust accumulation on pasture	43(45.3)	9(9.5)	17(17.9)	3(3.2)	22(23)	50.22	.000
Contributions to environmental management	44(46.3)	27(28.4)	16(16.8)	44.2)	4(4.2)	60.42	.000

Source: Research data, 2015

In order to examine the physical extent of the impacts of mining activities on landscape over time, we used the change detection approach suggested by Forkuo and Frimpong (2012). Change detection can be equated to the determination of when land cover at a given location has been converted from one type to another and is therefore an important tool for evaluating trends in the interaction between people and the environment (Foggin, 1977; Boriah *et al.*, 2008; Prakasam, 2010; Afify, 2011). The change detection process involves comparing aerial photographs or satellite imagery of the subject area, taken at different times. It seeks to identify the pattern of landscape changes, the process involved and the human response to landscape changes. This provides the most accurate means of measuring the extent and pattern of changes in landscape conditions overtime (Forkuo and Frimpong, 2012). According to Kilonzo (2014), landscape changes are often a result of anthropogenic pressure and climatic variability. Anthropogenic factors include deforestation, land degradation and human related green house gas emissions. For accurate change detection, care should be taken to ensure consistence of remote sensed data. This is possible if data is captured using the same sensor or instrument, same resolution and same spatial extent at anniversary or near anniversary dates.

In this study, multi-temporal sets of remote sensing data covering the study area were procured from the Regional Centre for Mapping and Resource Development (RCMRD) in Nairobi. The data set included remote Sensing images for the years 1984, 1995 and 2014, high resolution photographs and the digital image processing software (ERDAS). The images had a path of 8168 and row of 061. Images were examined for change detection using the ERDAS IMAGINE, ENVI and ArcGIS software. To prepare the images for analysis in this study, the different bands were layer stacked using Erdas imagine software. Since the images covered an area larger than the study area, it was necessary to delimit the image by clipping out the area of interest through extracting the shapefiles of the study area Locations (Nkama, Enkirigirri, Ipolosat and Olturoto).

In order to align the images to the Kenya Grid Coordinates, the shapefiles data re-projected to the Universal Transverse Mercator- World Global System 1984, zone 37 North (UTM WGS). Using the Erdas software, the clipped shapefiles were used to subset the three images and obtain the area of interest.

Supervised Image Classification

Digital image classification is the process whereby a human operator instructs the computer to perform an interpretation according to certain conditions, defined by the human operator (Kerle *et al*, 2004; Afify, 2011; Rawat and Kumar, 2015). Image classification is suitable for landscape studies because it enables the investigator to generate various land cover data sets based on supervised or unsupervised classification of the multi spectral satellite data. The classification based on different spectral characteristics of different materials on the earth's surface has been used in different projects by the Food and Agriculture (FAO) to produce data sets such as the Pan-African land cover data set for the African region, while in Europe it has been used to generate a firsthand inventory of land cover (Kerle *et al*, 2004). Chen *et al* (2003) inform that for accurate image classification, the investigator must ensure that the training samples are representative of all possible changes in the study area. Image classification as a technique of change detection has the advantage of atmospheric and environmental impact reduction, possibility of attaining complete matrices of change and ability to minimize the effect of using multi-sensor images. The disadvantages include the requirement for complete and accurate training data and the final accuracy being dependent upon the classification accuracy of the individual images (Hussain *et al*, 2013). In the current study, the image was classified, taking into account five land uses of interest, namely mining/quarry pits, mine ponds, bare ground, woody plants and shrubs/grasses. The classification was done using the supervised classification algorithm. During the supervised classification, high resolution images and familiarity with the site were used to identify pixels that represented patterns and objects of interest. Training samples were selected to enable the computer identify pixels with similar spectral characteristics after which classification of the images was carried out using the maximum likelihood algorithm. The Maximum likelihood decision rule was adopted for classification because it is the most commonly used algorithm (Kerle *et al*, 2004; Nori *et al* 2008; Fichera, 2012).

Accuracy Assessment for Classified Images

Since image classification is based on samples of the classes, actual quality should be checked and quantified after classification. In the current study, this was done by sampling of a number of elements and comparing the classification result and the true world class elements. The true world class elements were obtained from field observations and high resolution photographs. The accuracy assessment reports for the three images were generated as shown in Table 2. The accuracy assessment results are reliable and concur with Setiawan and Yoshino (2012) who used similar methodology and validated the change detection using actual land use change. They obtained an overall accuracy of 76.10%.

TABLE 2: ACCURACY ASSESSMENT FOR CLASSIFIED IMAGES

Year	Classified Image	Overall accuracy (%)	Kappa (%)
1984	Landsat L4-5TM	85.7	76.6
1995	Landsat L4-5TM	94.9	92.5
2014	Landsat L8-TM	99.0	99.0

Source: Research data, 2016

It was established that, as a consequence of gypsum mining, the area occupied by both mine ponds and quarry pits had increased from 398 acres in 1984 to 1344 acres in 2014. Consequently, the area under bare ground increased by 1788 Acres over the same period as shown in Fig. 4. The increase in bare ground acreage is attributable to the primary beneficiation process that included the spreading out of gypsum ore for sun drying before crushing. It was also noted that the area under bush and grasses decreased by 19,853 acres (16%). This could be attributed to land clearance to set up mine infrastructure such as roads, staff housing, mine drying fields and tailings deposits (Fig. 2 and 3) and possibly by climatic changes as suggested by Kilonzo (2014). Over the same period, the area woody plants declined by 12,882 acres (65%). The study also observed loss of vegetation attributable to deforestation by the immigrant population as a result of mine expansion and other anthropogenic factors (See Fig. 3, 5 and 6).

TABLE 3: LANDSCAPE CHANGE DETECTION

Land Cover	Area 1984 (Acres)	Area 1995 (Acres)	Area 2014 (Acres)	Change 1984 1995	Change - 1984 - 2014
Mine Ponds	74	230	449	156	375
Bare Ground	35976	42314	67764	6338	31789
Mine/quarry Pit	324	203	895	-121	572
Woody Plants	19540	4822	6658	-14718	-12882
Shrubs/grasses	125608	133951	105755	8344	-19853
Total	181521	181521	181521	-	-

Source: Research Data 2016

The change detected is shown in Table 4 and Fig 4.2. Figure 2 indicates that as the area under mining increased, the acreage under woody plants, shrubs and grasses decreased. Taking 1984 as the base year, it is evident that by 1995, the area under mining as indicated by the combined acreage of mine ponds and quarry pits declined by 100 acres while, the acreage under shrubs and grasses increased by 8344 acres. By 2014 however, while the area under mining had increased by more than 300%, the area under shrubs and pasture declined by 16%. This demonstrated an inverse relationship between mining and pasture availability in the study area.

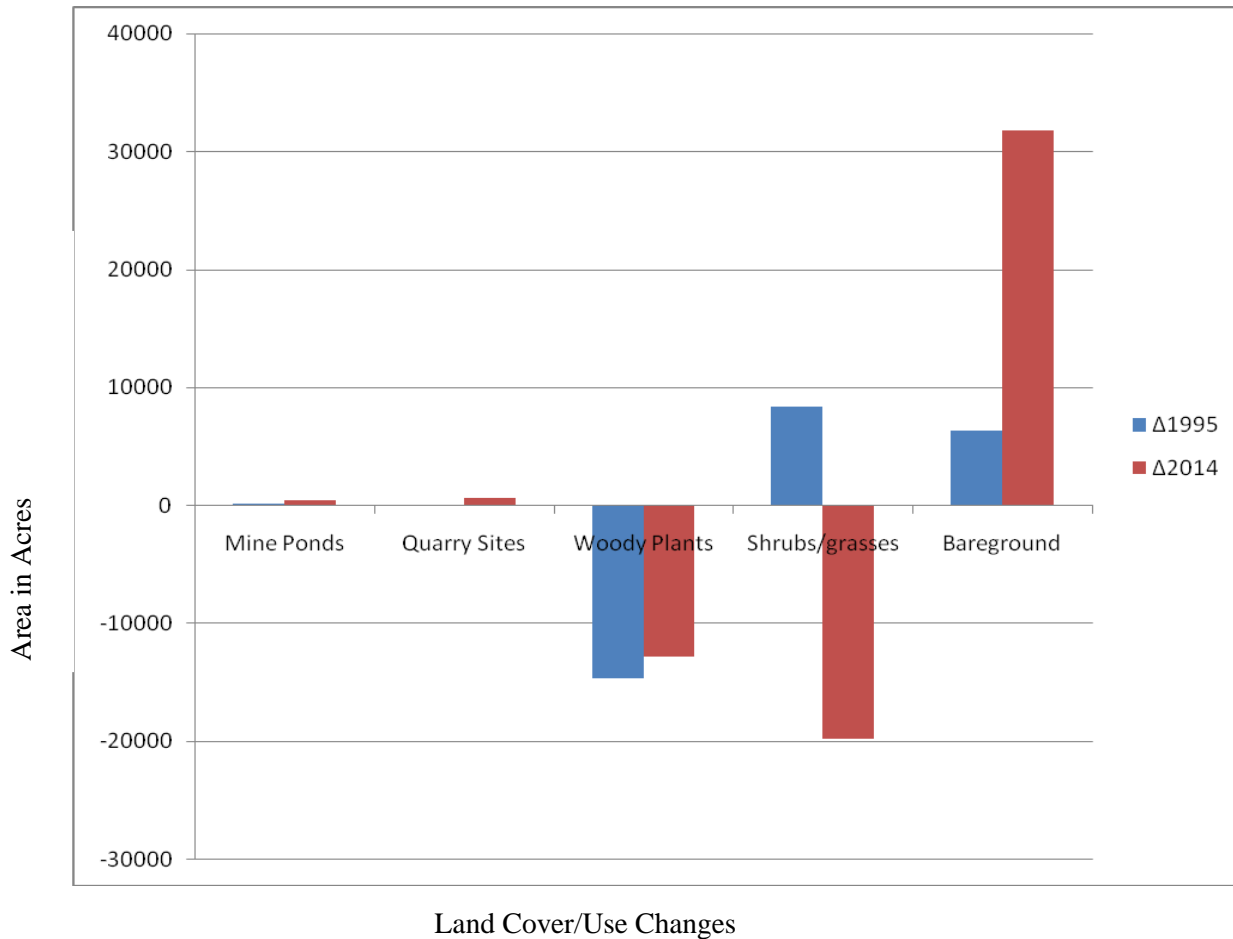


Figure 2: Land Cover Changes 1984 - 2014

Previous research by the Department of Remote Sensing and Resource Surveys (DRSRS, 1987) established that the dominant vegetation types in the study area were open grassland, bushed grassland and wooded grassland. This study established that the main mine site at Kibini is located in an area dominated by wooded grass land while the Enkirigirri and Olturoto areas are under open grassland. The Ipolosat site is under bushed grassland. The study confirmed loss of woody plants and herbaceous plants as a consequence of open cast gypsum mining. Woody plants such as *Pennisetum mezianum*, *Cynodon dactylon*, *Digitaria melanjiana*, *Digitaria scalanun*, *Aristida adoensi*, *Becium ovatum*, *choris roxburgiana*, *Acaia* species and *Balanitis* species are affected at Enkirigirri (DRSRS, 1987). In the Bushed grasslands of Ipolosat, the intensification of *Acacia Mellifera*, *Acacia Nubica*, *Balanitis Aegyptica* and *Acacia Tortilis* is compromised while herbaceous plants such as *Digitaria melanjiana*, *Pennisetum stramenium* and *Eragrostis papposa* are negatively impacted. At the Kibini mine, the affected plant species include *Acacia tortilis*, *Lippia Javanica*, *Grewia tenax*, *Acacia mellifera* and *Commiphora Africana*. Non-woody plants affected include *Chloris roxburghiana*, *Justicia exigua*, *Penicum maximum*, *Themeda triandra* and *Eragrostis papposa* (DRSRS, 1987). The destruction of pasture is likely to affect livestock development while woodland and shrubs reduction compromises wildlife habitat and increases possibilities of human-wildlife conflicts. Since the study area falls

within a wildlife dispersal area, the loss of pasture also limits the free movement of wildlife such as Wildebeest, common Zebra, Impala, Gazelles, Ostrich and Warthogs that are common in the study area owing to proximity to the Nairobi National Park - Amboseli National Park migration corridor.



FIGURE 3: ABANDONED MINE PIT IN THE STUDY AREA

The findings are consistent with Musa and Jiya (2011) who used remote sensing data in an assessment of the mining impacts on vegetation cover at the Jos plateau of Nigeria and noticed a continuous reduction in vegetation cover in the study area, due to intensive mining activities and subsequent soil erosion. In the Musa and Jiya (2011) study, it was concluded that mining had led to loss of vegetation cover and denied both micro and macro organisms their natural habitats. The loss of vegetation due to mining led to soil erosion and loss of pasture for livestock. The findings are also in agreement with Prakasam (2010) who employed satellite imagery to study land cover changes in a biodiversity rich area in India (Kodaikanal taluk) over a 40 year period. Prakasam (2010) established a reduction of area under forestry by 36% and a near commensurate increase in area under agriculture and urban development and concluded that forestry land was taken up by human activities in the form of agriculture and urban development which led to deterioration of ecosystems and loss of biodiversity. The land cover and conversion have also been previously confirmed by Kitetu (2014), who in an ecological assessment of potential impacts of riverbed sand harvesting to riparian ecosystems in Kenya, concluded that mining caused damage to habitats of animals and bottom fauna especially insects and mollusks populations. Mining moreover negatively affected some plants found in semi- arid ecosystems including bacteria, fungi and algae. These resulted in loss of genetic materials and biodiversity (Musa and Jiya, 2011; Kitetu, 2014).

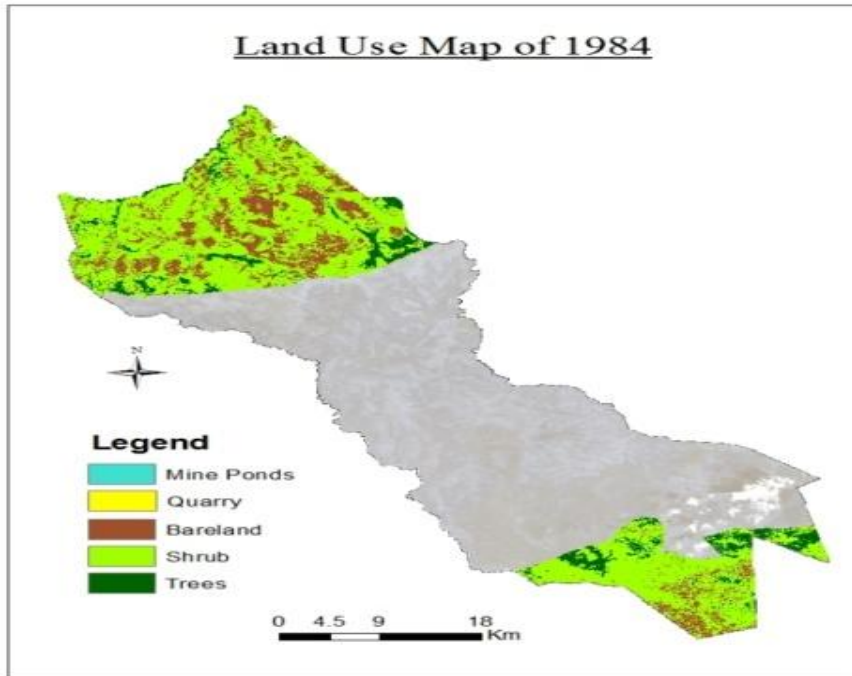


FIGURE 4: LAND COVER 1984

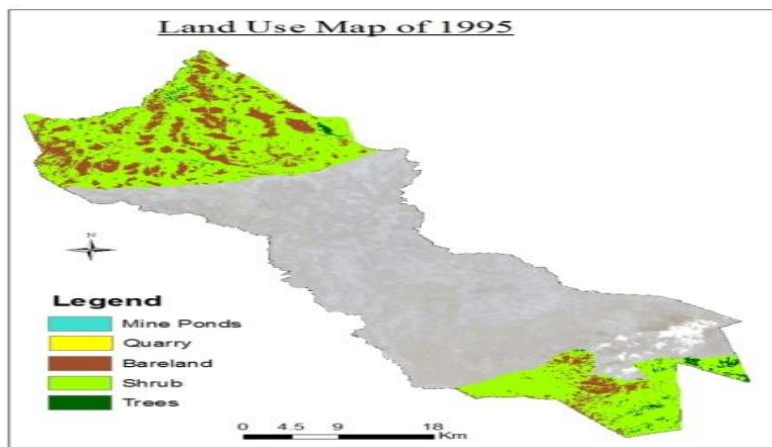


Figure 5 Land Cover 1995

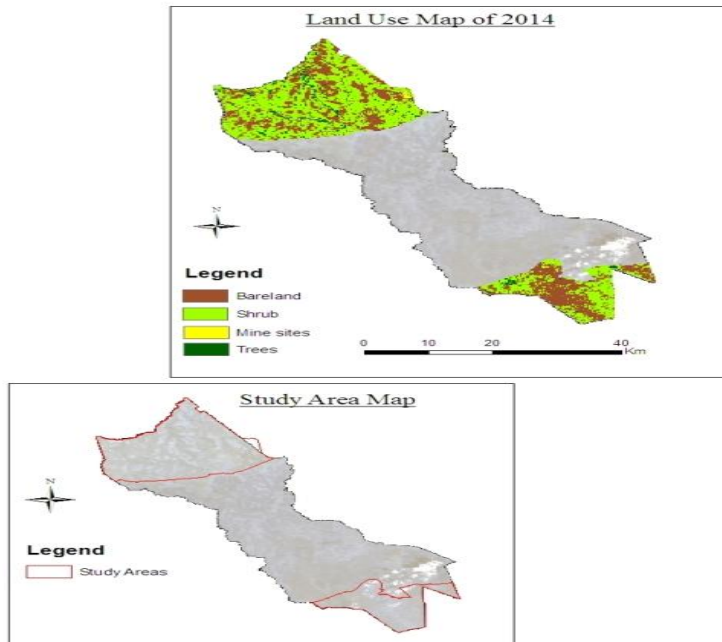


FIGURE 6: LAND COVER 2014

5.0 Conclusion and Recommendations

This study sought to investigate the impact of gypsum mining on landscape in Kajiado County. From the questionnaire study, it was revealed that the most significant impact of gypsum mining on landscape was in terms of the destroyed vegetation cover and habitats ($\chi^2 = 230$, $P \leq 0.001$). The county residents were however, least worried about the general contribution of mining to the county landscape. It can therefore be concluded that landscape was not an important aspect to the residents of Kajiado County. It is probable that environmental importance had been sidelined for commercial benefits accruing from mining related activities. This could be explained by the low awareness levels of local environmental destruction.

It was evident that environmental protection regulations had not been implemented to discourage land derelictions. While it is not possible to completely protect the study area from the negative effects of gypsum mining, it is important to encourage land rehabilitation and re-vegetation after a period of gypsum mining. The study recommends the setting up of a floating fund to facilitate the rehabilitation of dynamically changed mining sites.

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