IMPACTS OF MINING ACTIVITIES ON LAND COVER AND FOREST STOCK IN MBOZI DISTRICT, MBEYA REGION, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA

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ABSTRACT

A study was conducted in three villages of Nanyala ward in Mbozi District to assess the impact of mining activities on land cover and forest stock. Landsat images of 1991, 2000 and 2011 were used to assess the trend of land cover changes. The Forest was stratified into mined and un-mined forest area. A concentric circular shaped sample plot with sampling intensity of 0.19 % was used. 70 sample plots were laid and measurements were taken for estimation of stocking, basal area, volume and tree species diversity. Structured and semi structured questionnaire were administered to randomly selected 90 households in three villages adjacent to the mining area. Spatial data was analyzed by Arc View GIS version 9.3 and ERDAS Imagine version 3.2.and MS Excel was used to analyze N/ha, G and V, while Shannon Wiener Index of Diversity data was analyzed using PAST. ANOVA was used to determine the significant different of forest parameters at $p<0.05$. Quantitative Social economic data were analyzed using SPSS version 16. The results of land cover derived from landsat images from 1991 to 2011 shows the increase of mining area from 0.77 ha to 517.44 ha and bush land from 397.91 ha to 807.61 ha, while forest area decreased from 567.55 ha to 0.77ha. Average number of stems per hectare in un-mined area was 151.31 ±31 (SE) N/ha and in mined area 25.01± 6.276 (SE) N/ha, mean basal area for un-mined forest area was 2.50 ± 0.26 (SE) m^2/ha and in mined forest area was 0.21 m^2/ha. The mean volume for un-mined area was 9.61 ± 0.19m^3/ ha and 0.51 ± 1.18 m^3/ha for mined forest area. Shannon Wiener Index of Diversity shows more species in un-mined forest than mined forest 1.29 ± 0.63 (SE) and 0.36 ± 0.08 (SE) respectively. The finding shows that the drivers of land cover changes are mining activities which accounted for 50 %, charcoal burning 27.8 %, uncontrolled bush fires 11.1 %, fire wood 6.7 % and 4.4 % crop cultivation. Comparatively, limestone processing signifies to have more effects to the environment than granite extraction. The study recommends

conducting environmental auditing and mitigation studies against these damages including regular inspections should be executed to keep these activities of mining under control as stipulated in Environmental Management Act No 20 of 2004.

DECLARATION

I, Hamis, P. Nzunda, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Hamis. P. Nzunda (MSc. Candidate) — Date

The above declaration confirmed by:

Dr. J. J. Kashaigili (Supervisor) — Date

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DEDICATION

This work is dedicated to my mother Frostina Mwasenga and my uncle Yolamu Mgallah and his wife for their love and paved the way for me to recognize the value of education; also to my wife: Rehema Haonga and my children for their tolerance during my long absence from home for the entire study period. May our almighty God bless them forever,

EMEN.

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LIST OF ABBREVIATIONS AND SYMBOLS

AOI	Area of Interest
ANOVA	Analysis of Variance
$CaCO_3$	Calcium Carbonate
DBH	Diameter at breast height
EIA	Environmental Impact Assessment
ERDAS	Earth Resources Data Analysis Systems
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information System
GPS	Geographical Positioning System
G	Basal area
Ha	Hectare
H'	Shannon Wiener index of Diversity
ID	The index of Dominance
LC	Land Cover
LU	Land use
MNRT	Ministry of Natural Resources and Tourism
NEMC	National Environmental Management Council
N/ha	Number of stem per hectare
PAST	Paleontological Statistics Software Package
RGB	Red, Green and Blue color
SE	Standard Error
SPSS	Statistical Package for Social Sciences

Sp	Species
SUA	Sokoine University of Agriculture
TM	Thematic Mapper
URT	United Republic of Tanzania
UTM	Universal Transverse Mercator
V	Volume
WGS	World Geodetic System

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Mining is an extraction of valuable minerals or other geological materials from the earth, usually from an ore which involves the removal of vegetation, soil and rocks (Nayak, 2010). Mineral means any substance, whether in solid, liquid or gaseous form occurring naturally in or on the earth, or in or under the seabed by or subject to a geological process, but does not include petroleum or surface water (URT, 2010). Mining operations which involve mineral extraction from the earth's crust tend to make a notable impact on the environment, landscape and biological communities of the earth (Singh *et al.,* 2010). Mining operations are thus a source of great economic gain on the livelihoods but on other hand contribute into serious threats to the environment, due to the reduction of forest cover, land degradation, air and water pollution and ultimately reduction in biodiversity (Singh *et al.,* 2010).

In India the comparative analysis of land use/land cover derived from 2001 and 2010 data shows that loss of dense forest area are due to the expansion of coal mining activity. Overburden dumps area have increased from 30.4 km^2 in 2001 to 39.44 km^2 in 2010 as a result of expansion of coal mining areas, settlement area has also increased from 39.72 km^2 in 2001 to 44.82 km^2 in 2010. Area of cultivated land has decreased from 104.54 km^2 in 2001 to 92.61 km^2 in 2010 (Javed and Khan, 2012). The drivers for land use/land cover change are mainly coal mining activities and industrial expansion, which have changed this belt into one of the prominent industrial zone (Javed and Khan, 2012). In Ghana during the period of 20 years (1980-2000) small-scale gold miners in Suriname caused cumulative loss of vegetation cover from 1000-2000 km^2 (Peterson and

Heemskerk, 2001). Land use practices and land use change play an important contributory role in human impact on natural forests, the environment and ultimately on the whole biosphere. In eastern Africa severe encroachment and exploitation of mining activities are destroying the forest that occurs in fragmented patches (Mafupa, 2006). The forest in Tanzania are, however, faced with deforestation at a rate of between 130 000 and 5 000 000 hectares per annum, which results from heavy pressure from agricultural expansion, livestock grazing, mining, wildfires, wood fuels and unsustainable utilization of wood resources and other human activities (Mafupa, 2006).

Mbozi District is endowed with rich natural vegetation as well as great reserves of granite, limestone and coal (URT, 2010). Extraction of granite, limestone and coal is currently increasing in Mbozi District causing enormous land degradation associated with damage to the land cover, disturbances of ecosystem and eventually deterioration of the environment. Spontaneous mining of granite coal and limestone without post management of mined sites leaves the ecosystem fragile and more vulnerable to environmental degradation due to the massive alteration of land cover.

The vegetations are first cleared; pits are dug into the ground to win the rocks rich in granite and limestone. Apart from vegetation clearing and removal of top soil, lime production also involves rampant and haphazard cutting of trees from neighboring village forests for burning lime in kilns. Continuous extraction of natural resources leads into direct forest loss due to frequent damage of forest land, removal of top soil layers and subsequently resulted into shortage of fuel woods, grazing area, soil erosion, and air pollution for people living adjacent to mining areas. Dumping of rock wastes in un-mined areas create disturbances to the surrounded plant communities ultimately affecting the ecosystem in the area.

Remote sensing technology has been widely used since the past few decades to monitor land use/land cover changes in time and space. The change detection method can be used to monitor land use/land cover change and to build spatial and temporal patterns of change, in order to derive better understanding of the cause and consequence of the change by using multi-date images (Javed and Khan, 2012). Change detection by remote sensing technologies has become a central component in current strategies for managing natural resources and monitoring environmental change (Dale *et al.,* 1993). Land cover change detection has also been found applicable in land use change analysis and assessment of deforestation. The driving forces of change are multiple variables in time and scale, of which mankind is a key factor (Lambin *et al.,* 2001). The development of various national policies in Tanzania as well as other countries in the World focuses on land cover information and monitoring. Among the national policies that have direct impact on land cover changes includes: the Land Policy of 1995 (URT, 1995), Agricultural and Livestock Policy of 1997 (URT, 1997) Human Settlement and Development Policy of 2000 (URT, 2000), Environmental Management Policy of 1997 (URT, 1997), Mineral Policy of 1997 (URT, 1997) and Forest Policy of 1998 (MNRT, 1998).

1.2 Problem Statement

Land cover changes resulting from mining activities, have serious consequences to vegetation cover and local environment. According to NEMC (2008), the land which is currently used for mining activities in Mbozi District was previously potential for natural forest, agriculture, grazing, fetching fuel woods, ritual and natural herbs for the local livelihoods. However, the current uncontrolled mining activities have resulted into removal of most vegetation cover, through the process of forest clearing pits creation, settlement establishment and road construction. Undoubtedly, mining activities necessitate the removal of vegetation cover where community depends for their livelihood. Generally, the process of surface extraction of granite and limestone minerals accelerate clearing vegetations which result into change of land cover, forest stocking and pre-existing land scape. Despite the fact that, mining activities result into land cover and forest stock changes, yet studies on the impact of mining on land cover and forest structure is scanty. Likewise, the community perceptions on ecological impacts of mining are little understood. Therefore this study was an attempt to fill the existing knowledge gap.

1.3 Justification

Mining activities definitely have brought employment opportunity in the area, but concurrently has lead to extensive environmental degradation. The conflict between mining activities and environmental protection has intensified over recent years, emphasizing the need for improved information on the dynamics of impacts at local and regional scale (Latifovic *et al.*, 2004). Based on the aforesaid information gap, this study was conducted to explore the information on the extent and dynamics of land cover changes, forest stocking and community perception due to mining activities at Marmo forest in Nanyala ward. Therefore, the finding from this study will be used as a base for monitoring land cover and forest structure changes and socio-economic implications due to mining activities for the purpose of implementing the environmental management plans and possible solution.

1.4 Objectives

1.4.1 General objective

The general objective of the study was to assess the impacts of mining on land cover and forest stocking in Mbozi District.

1.4.2 Specific objectives

i. To assess the land cover changes as a result of mining activities using landsat images from the period of 1991, 2000 and 2011
ii. To assess the impact of mining activities on forest structure
iii. To assess the community perception on the impacts of mining activities and other land uses on land cover and forest stock

1.4.3 Research questions

i. To what extent land cover changes have occurred as a result of mining activities and other land uses for the period of 1990, 2000 and 2011?
ii. What are the impacts of mining activities on forest structure?
iii. To what extent is community aware on the impacts of mining activities and other land uses on land cover and forest stock?

1.5 Conceptual Framework for the Study

The conceptual framework (Fig.1) reflects the relationships between mining activities as key drivers of land cover change and forest stock. Mining activities have direct and indirect effects on land cover, through forests clearing, settlement expansion and removal of top soil covers during road construction and rocks excavation. This could ultimately change the terrain. Mining impacts are complex which results into severe forest degradation and other environmental externalities due to changes of land cover and forest structure.

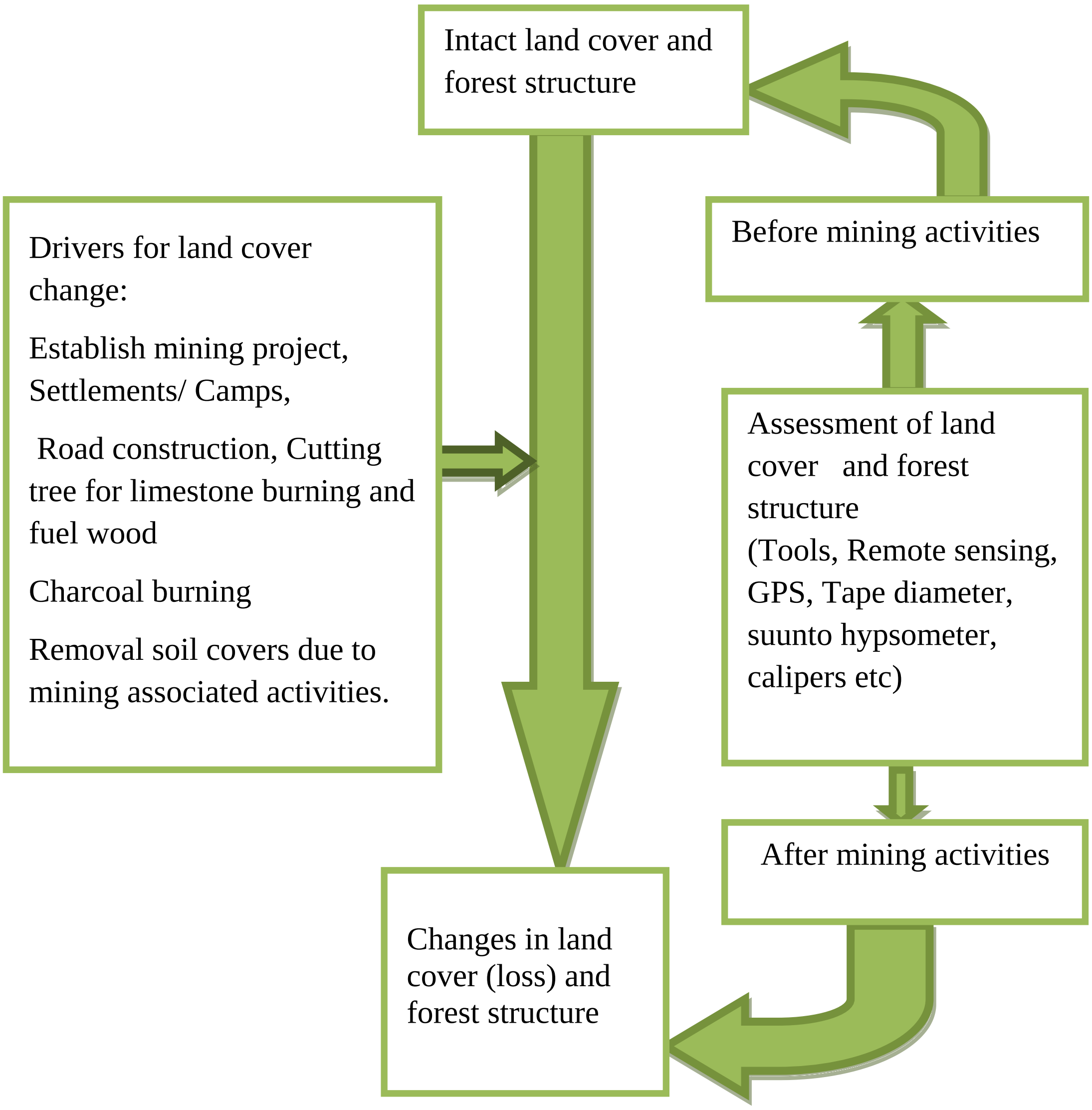

Figure 1: Conceptual framework for the study

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Land Cover and Land Use Change

In most instances, the terms land use (LU) and land cover (LC) tend to be used interchangeably but their actual meanings are quite distinct. Land use refers to the purposes for which humans exploit the land cover. Common land uses include agriculture, grazing, forestry, mineral extraction, and recreation. Several examples illustrate the difference between land cover and use. Cropland designates a land-cover type of soil, water, and cultivated plants. In agriculture, land use refers a system of human inputs and management that sustains the land cover. Forest is a land cover dominated by woody species, which may be exploited for uses as varied as recreation, timber production, or wildlife conservation. Changes in human land use are frequent causes of land-cover conversion and modification (Kusimi, 2007).

On the other hand LC is the natural landscape recoded as surface components including water, vegetation, soil, rocks and urban infrastructure physically present and visible. Land cover can be interpreted and documented by analyzing satellite and aerial imagery. LUs may or may not be manifested as visible land cover features. Example of LUs that are manifested as visible LC include mining activities, stores, offices buildings, apartments (Commercials), factories assembly plants (Industrial and agricultural areas). Land cover must be considered in a geographically explicit feature that other disciplines may use as a geographical reference example for land use, climatic or ecological studies (FAO, 2010).

2.2 Land cover/use change

Land cover can be classified according to numerous criteria, depending on the scientific purposes for which the classification is being developed. Land cover change is defined as the alteration of the physical or biotic nature of a site, for example, the transformation of forest to grassland. Land cover change involves the full spectrum of alteration from minor modification of the existing cover to complete conversion into a new cover type. In some instances, these alterations occur in patterned sequences moving from modification to conversion. Land cover change detection is a function of class's variation over time. Both land use and land cover change is arguably the most important factor among many components of global change that affect human environment (Vitousek, 1994). Land use changes can move in two directions: either, in the negative sense, leading to forest degradation and loss of production potential or in the positive sense, resulting in a higher value or potential (Lipton, 1995).

In India the comparative analysis of land use/land cover derived from 2001 and 2010 data shows that loss off dense forest area are due to the expansion of coal mining activity. Open scrub area has increased from 29.82 km^2 in 2001 to 42.45 km^2 in 2010 due to the plantation activities, overburden dumps area have increased from 30.4 km^2 in 2001 to 39.44 km^2 in 2010 as a result of expansion of coal mining areas, settlement area has also increased from 39.72 km^2 in 2001 to 44.82 km^2 in 2010, whereas area of cultivated land has decreased from 104.54 km^2 in 2001 to 92.61 km^2 in 2010 (Kusimi, 2007). The author further argued that, one of the most severe impacts of mining is that it causes changes in land use pattern. Land is lost due to mining both directly and indirectly (Kusimi, 2007).

2.3 Remote Sensing and Geographical Information System

Remote Sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon in question (Kashaigili, 2006). Remotely sensed data are useful tool and have scientific value for the study of human environment interactions, especially land use and land cover changes (Dale *et al.*, 1993).

2.3.1 Utilization of landsat image

Different types of satellite images now days are available for space technology studies, from different sensors with different spatial resolutions. Although Landsat imagery has low spatial resolutions compared to other images like Quick Birds (60cm), SPOT (2.5m-20m), and IKONOS (1m), it is adopted in most vegetation analysis studies because Landsat images were originally designed for vegetation and Geologic investigations and the landsat images are more cost-effective than Quick Birds, SPOT and IKONOS (Aber, 2007).

2.3.2 Land covers change detection

Detecting change of Earth's surface features provides the foundation for better understanding of relationships and interactions between human activities and natural phenomena. In remote sensing it is useful in land use/land cover change analysis such as monitoring deforestation. Mbilinyi (2000) used panchromatic aerial photographs (1963 and 1978); Landsat TM satellite imagery (1995) incorporated into GIS environment to assess land degradation and its consequences at Ismani Division in Iringa Region. The analysis showed that a large part of Miombo woodland decreased by about 26 000ha in the period of 1970s. Change detection is a very common and powerful application of satellite based remote sensing. Change detection analysis entails findings the type, amount and location of land use changes that are taking place (Yeh *et al.,* 1996).

Remote sensing technology has been widely used since the past few decades to monitor land Use/land cover changes in time and space (Khan and Javed, 2012)**.** The change detection method can be used to monitor land use/land cover change and to build Spatial and temporal patterns of change, in order to derive better understanding of the cause and consequence of the change by using multi-date images (Javed and Khan, 2012)**.** It also solves the problem of inaccessibility to the area of interest due to both physical and social barriers. However, Landsat Thematic Mapper sensors with spatial resolution of 30m are sensitive to forest structure differences of young secondary vegetation. They cannot help in distinguishing older secondary growth or selectively logged forests. Therefore, extensive field or a prior knowledge of the study area is necessary (Clarck *et al.,* 2004).

2.3.3 Geographical Information System

Geographical information system has imaged as a powerful tool for handling spatial and non-spatial geo referenced data for preparation and visualization of input and output and for interaction (Kimaro, 2004). Geographically referenced data describes both the location and characteristics of spatial features such as forest, rivers, watersheds etc. The ability of GIS to handle and process both location and attribute data distinguishes GIS from other information's system and establishes GIS as a technology necessary for a wide variety of applications. Since 1970s, GIS has played an important role in natural hazard assessment and land use planning (Kimaro, 2004).

2.3.4 Image classification

Land cover classification based on statistical feature extraction for pattern recognition is one of the most common techniques of information extraction (Sheoran, 2005). Lillesand *et al.*, (2004) states that there is no single "right" manner in which to approach an image classification problem, the particular approach might depend upon the nature of the data being analyzed, the computational resources available and the intended application of the classified data There are two basic types of classification techniques, unsupervised and supervised.

The supervised classification involves the interpreter who selects the sets of sample data on the image, each representing a category of identified patterns. The choice of the sample data should consider the selecting method, the number of sample data and the statistical distribution of the sample data, the location of the sample pixels should be located by using some form of random sampling scheme (Kishebuka, 1997). The computer then classifies the remaining pixels relating and grouping them in their respective predefined categories (Kashebuka, 1997). Unsupervised classification involves computer selection and grouping of pixels into classes based on their spectral relationship. This kind of pixel separation produces classes with their unique spectral response (Kashebuka, 1997).

2.3.5 Accuracy classification

The process of classification in essence is segmenting the images into unique classes or informational categories based on land covers/uses. The process of determining accuracy for a classified image is one of the most important steps undertaken in post classification. A classified image for land cover/uses without an accuracy assessment is not considered reliable as it does not convey any scientific consistency. To undertake an accuracy assessment it is essential to have ground truth or validation information (Sheoran, 2005).

The most common way to represent the classification accuracy of remote sensed data is in the form of an error matrix (Congalton, 1991). An Error matrix is a square array of numbers set out in rows and columns which express the number of sample units assigned to a particular category related to the actual category. The columns usually represent the reference data while the rows indicate the classified data on the ground (Congalton, 1991). Overall accuracy summarizes the total agreement/disagreement between the maps and actual ground.

2.4 Forest Stock Determination

Forest inventory involves measuring and assessing forest resources to provide information about the quantity and quality of the forests and monitoring their changes and health over time (Luoga, 2000). Stocking generally include: number of stems, basal area and volume of standing trees and shrubs in a given area. This is done by measuring influencing factors of stocking which are diameter at breast height or 1.3 m above the ground (DBH), tree height (Ht) and counting of number of stems per hectare (N) (Malimbwi, 1997). The stand parameters are useful in describing forest conditions. Data analysis involved calculation of number of stems per hectare (N), basal area (G- m^2/ha) and volume (V- m^3/ha) for each plot using Microsoft Excel Programme. The information obtained was used to determine the distribution of stand parameters for each forest stratum namely stocking, basal area and volume by species. Forest species composition can change with time due to variations in moisture levels associated with seasonal rainfall fluctuations, unpredictable disturbance, environmental contrast (Munishi *et al.,* 2010). Understanding species composition is of paramount important as it helps to determine forest condition and trend, which are valuable tools to judge the impact of previous management and guide future decisions (Mbwambo *et al.,* 2008).

2.4.1 Impact of mining activities on forest stock

Forests are the major victims of mining activities, which can be gauged from the depletion of the forests in all the time belts (Ghosh, 1998). The indiscriminate and unscientific mining, absence of post mining treatment and management of mineral areas are making the fragile ecosystems more vulnerable to environmental degradation and leading to large scale land cover changes (Sarma, 2005). The consequences of mining activities leads to the change in the natural topography of the region and causing severe impacts, including destruction of lands, mountains, forests and agricultural lands (Ghosh, 1998).

2.4.2 Shannon-Wiener Index of Diversity (H')

Diversity is defined as the structural and functional variety of plants and animals at generic, species, population, community and ecosystem levels. According to Mafupa (2006) pointed out that the most widely used index of diversity which combines species richness and evenness and also not affected by sample size, is the Shannon-wiener index of diversity. Diversity indices provide more information about community composition than simply species richness. They also take relative abundances of different species into account (Mafupa, 2006). Shannon diversity index (H') was employed to measure both abundances (richness) and evenness of the species present in both strata of the forest. The larger the value of H' the greater is the diversity and vice versa. The index increases with the number of species in the community but in practices, for biological communities it does not excess 5.0 (Mafupa, 2006). Index of dominance (ID) was used to measure the distribution of individuals among the species in a community. The greater the value of ID, the lower is the species diversity in the community and vice versa. The index increases with the number of species in a forest community but in practices, for biological communities H' does not exceed 5.0 (Malimbwi, 1997). Species diversity is a very useful parameter for comparison of forest structure. High species diversity is considered by most ecologists as a desirable property of any ecosystem and this criterion has dominated most methods of ecological and conservation evaluation techniques cited (Rwamugira, 2008).

2.5 Impacts of Mining on the Environment

Although the mining activity occupies a relatively small part of the land surface, it does have significant and often irreversible impacts (Boocock, 2002). Environmental impacts can occur during all phases of mining projects, exploration, disposal of wastes rock and overburden, ore processing and plant operation (processing wastes) management and during construction of infrastructure (Boocock, 2002). Presently, over 60% of the materials mined in the world are extracted by the open cast method, causing devastation of the ecosystems where they are operating (Boocock, 2002). The destruction caused by minerals extraction is generally considered to be inevitable consequences of economic development. Meanwhile, the prices of minerals on the world market reflect only production cost; environmental costs are not factored (Lassey, 2003). Mining is presently doubly destructive both due to its large scale and application of technology, which has increased its productive capacity (Latifovic *et al.*, 2004).

2.6 Mining and Mineral Exploration in Mbozi District

Mbozi District is endowed with valuable minerals and attractive rocks that can fit for many purposes. Marble granite and limestone at Nanyala ward, Salt ponds Ivuna ward, coal at Magamba, red garnet, gold, rhodolite, stone quarrying and travertine are identified in many places of Mbozi. The coal deposit is under exploration of M/S Troll Mining Company LTD and Marbo granite is under exploitation by MARMO E-Granite Company (URT, 2010).

2.7 Relevant Policies to Mining and Land use/ Cover Changes

Like most other projects, mining projects results in a number of environmental impacts that must be addressed during the life of the project. The activities associated with projects construction, execution of quarrying and crushing activities and the closure of the project have various positive and negative environmental impacts. The execution of a quarrying project touches on various sectors, one have to comply with a number of policies and legislation, especially those that relate to land, water, forestry and mining (NEMC, 2008). The policies provide directives on the management of the mining projects in order to ensure minimum impacts on the concerned natural resources and sensitive ecosystem.

2.7.1 The National Environmental Management Policy 1997

The National Environmental Policy sets broad goals committing Tanzania to sustainable development of its natural resources heritage. The policy provides the framework for formulation of plans, programmes and guidelines for the achievement of sustainable development. The key objectives of the policy include preventing and controlling the degradation of life support resources such as land, vegetation, air and water. The environmental policy objective from an environmental perspective is the prevention, reduction, control and elimination of damage, and minimization of the risk thereof from the generation, management, transportation, handling and disposal of hazardous, other wastes and emissions (URT, 1997).

2.7.2 Tanzania Mineral Policy 1997 and Mining Act No. 14 of 2010

The Mineral Policy of Tanzania 1997 recognizes the importance of integrating environmental and social concerns into mineral development programmes as a way of ensuring sustainability of mining. In order to achieve sustainable mining development, the policy underscores the need to balance the protection of flora, fauna and the natural environment with the need for social and economic development (URT, 1997). It also recognizes that severe environmental management and appalling living conditions that exist in mining camps have been a result of lack of coordination, insufficient operation funds and inadequate expertise. The 1997 Mineral Policy of Tanzania provides opportunity for private sector mineral exploration and development while the government only regulates, promotes and facilitates URT (1997). Mineral Policy of Tanzania provides opportunity for private sector to lead mineral development and the government regulates, promotes and facilitates.

The major challenges which the Mining Policy faces, is to ensure environmental protection and management to mining activities. However, the ministry of energy and mineral, issues license for mining without knowing where the mining will really take place and without monitoring the activities. Mining act No 14 of 2010 stipulate that mining companies should prepare the environmental management plan in order to safe guard the environmental conditions at the project site (URT, 2010). Also the mining Act No 14 of 2010 does not stipulate on how the contribution of mining sector from private investors will be managed and monitored by the government, this situation which offer the investors a loophole of not fulfilling their commitment on community's project (NEMC, 2008).

2.7.3 The National Land Policy of 1995

Land is the platform of all human activities. Therefore whatever is done in any sector of the economy has an impats on land. At present lincense, rights, and claims for mining, water rights, hunting rights/leases and timber harvesting license are issued without regard to existing land tenure rights. This creates environmental degradation, land use conflicts and disputes between the distributors of land and other users. The National Land Policy of 1995 advocates to ensure that permits, license, claims and rights for exploitation of natural resources are issued in line with land use policies (URT, 1995). The policy addresses several environmental issues of relevance to the mining project is land use planning, which takes into consideration the land capability to ensures proper management of land resources, promote resource sharing and multiple land use techniques in area of conflicting land use and lastly advocates the involvement of community in resources management.

2.7.4 The National Forest Policy of 1998

The National Forest Policy of 1998 addresses that, various types of investment projects in forest areas may cause adverse environmental impacts. Socio-environmental Impacts Assessment (SEIA) must therefore, be incorporated in the planning and decision making process in order to ensure beforehand that unnecessary damage to the environment is avoided and possible mitigation measures are identified (MNRT, 1998). Key policy areas are forest land management, ecosystem conservation and management. Some of the policy strategy statements that are relevant for mining project include the following, to enable sustainable management of forest on public lands, clear ownership for all forests and trees on these lands should be defined and management responsibility promoted. Biodiversity conservation and management as well as watershed management and soil conservation have to be included in the management plans for all protection forests (URT, 1998). In line with this it is imperative that the mining environmental guidelines in place are reviewed to ensure environmental compliance. Forest Policy statement (23): environmental impacts assessment will be required for the investments which convert forest land to other land use or may cause potential damage to the forest environment (MNRT, 1998).

2.8 Change Detection

Change detection procedures can be grouped under three broad headings characterized by the data transformation procedures and the analysis techniques used to delimit areas of significant changes, image enhancement, multi-date data classification and comparison of two independent land cover classifications. Various algorisms have been developed for change detection analysis the common used are explained below:

2.8.1 Image deferring

In this method, registered images acquired at different times are subtracted to produce a residual image which represents the change between the two dates. Pixels of no radiance change are distributed around the mean, while pixels of radiance change are distributed in the tails of the distribution two subtracted images were created for bands 2 and 4, respectively. Data transformations were confined to these bands because they are considered to be the most useful for discriminating forest canopy and vegetation alterations (Mas, 1999).

2.8.2 Vegetation index differencing

This technique used a data transformation shown to be related to green biomass (Tucker, 1979). The Normalized Difference Vegetation Index (NDVI) is calculated by NDVI= (NIRÐ RED)/ (NIR+RED) where NIR is the near-infrared band response for a given pixel, MSS band 4 and RED is the red response, MSS band 2. The vegetation index was calculated for both dates and then subtracted (Mas, 1999).

2.8.3 Selective principal components analysis

In the Selective Principal Components Analysis (SPCA), only two bands of the multi-date image are used as input instead of all bands. By using only two bands the information that is common to both is mapped to the first component and information that is unique to either one of the two bands (the changes) is mapped to the second component (Mas, 1999). Principal components are usually calculated from a variance-covariance matrix. Selective standardized principal components analysis was performed using bands 2 and 4 (Mas, 1999).

2.8.4 Direct multi-date classification

The direct multi-date classification is based on the single analysis of a combined dataset of the two dates in order to identify areas of changes .Classes where changes are occurring are expected to present statistics significantly from where change did not take place and so could be identified. Unsupervised classification was carried out using the ISODATA method of the ERDAS software which uses spectral distance and iteratively classifies the pixels, redefines the criteria for each class, classifying again, so that the spectral distance patterns in the data gradually emerge (Mas, 1999).

2.8.5 Post-classification analysis

The most obvious method of change detection is a comparative analysis of spectral classifications for times t_1 and t_2 produced independently. In this context it should be noticed that the change map of two images will only be generally as accurate as the product of the accuracies of each individual classification. Accuracy of relevant class changes depends on spectral separability of classes involved. In the present study, Landsat MSS data of both dates were independently classified using the maximum likelihood classifier. A post classification change detection method was used in this study; satellite images data have conceived a large range of methodologies for identifying environmental changes (Mas, 1999).

2.8.6 Combination image enhancement/post-classification analysis

In this method, the change image produced through an enhancement procedure is recoded into a binary mask consisting of areas that have changed between the two dates. The change mask is then overlaid onto the date 2 image and only those pixels that were detected as having changed between the two date 2 imagery. A traditional post-classification comparison can then be applied to yield from-to change information. This method may reduce change detection errors and provides detailed from to change information (Mas, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Geographical location

Mbozi District is located at the south western part of Mbeya Region, between latitudes 8^0 and 9^0 12’ South of the Equator and longitudes $32^0$7’ 30” and 33^0 2' 0” East of the Greenwich. It shares borders with Mbeya District on the eastern part, Ileje District on the south, Republic of Zambia and Rukwa Region on the western part and Chunya District on the north. It occupies a total area of 9 679 km^2 generally classified as arable land 766 649 ha (79%), forest reserves 93 738 ha (9.7%), Settlement and other uses 78 322 ha (8.1%), area covered by water 29 200 ha (8.1%) (URT, 2010). The District has tropical type of climate with clearly distinguished rainy and dry seasons. It lies between 900-2 750 meters above the seal level and receives rainfall between 1 350-1 550 mm per annum; while temperature ranges 20-28 ^{0}C. It is divided into two main zones; the high plateau which is situated to the eastern part of the district covering mainly three divisions namely; Igamba, Vwawa and Iyula which occupies 36% of the district area. The lowland zone is located in the western part of the district covering the major parts of Ndalambo, Msangano and Kamsamba divisions and occupies 64 % of the district area (URT, 2010). Thus the study to assess the impacts of mining activities on land cover and forest stock in Mbozi District was conducted specifically at Nanyala ward including three villages (Nanyala, Songwe and Senjele) adjacent to Marmo mining forest (Fig. 2).

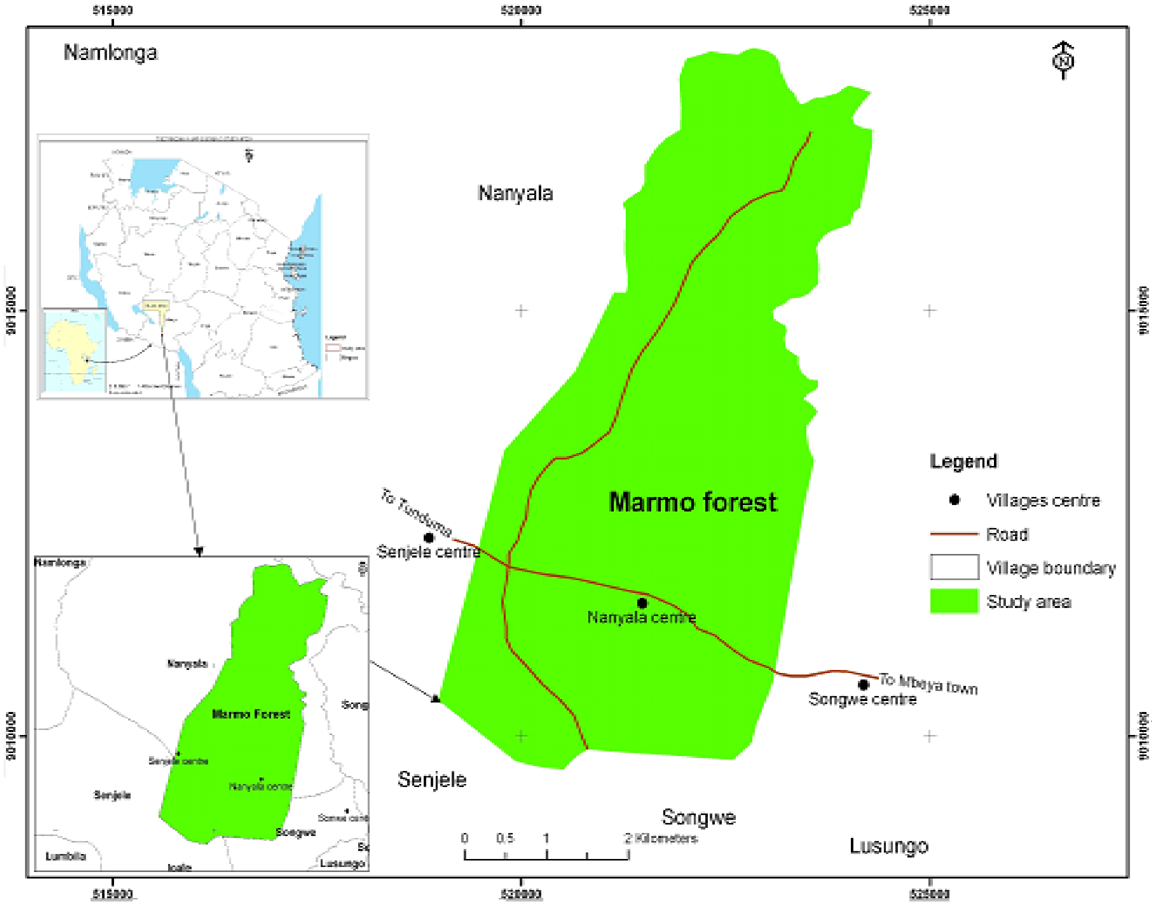

Figure 2: Location of Marmo forest at Nanyala ward in Mbozi District

3.1.2 Population and ethnicity

According to population and housing census of 2002, Mbozi District had a population of 513 600 people of which 243 948 were males and 269 652 females (URT, 2002). Population projection in 2011 of both sexes was about 722 242 people URT (2010). The major ethnic tribes are Nyiha and Nyamwanga followed by Wanda, Nyakyusa, Ndali, Lambya, Malila, and Safwa (URT, 2010).

3.1.3 Description of mining activities

The development of mining activity in Nanyala ward began during the year 1990s. The ward is endowed with two types of mineral resources which are limestone and granite. Marmo E-granito is the dominant company deals with granite extraction at Marmot forest. Companies involved in extraction and production of limestone products are Jambo, , Mama Diame, Nyati, Twiga, Duma, Akimu, Shiboko, Ngole and Simkoko. Also there are few individual local miners engaging with limestone extraction and burning the extracted $CaCO_3$. The local miners after burning limestone they sell to the companies for further processing and packaging. The companies apply mineral right (licenses) from Ministry of Energy and Minerals thereafter. Open cast mining technology is the prominent technology used in extraction of minerals at Marmo forest. Mining activity in the area is associated with logging of trees and clear-cutting vegetation above the ore deposit, this leads to the potential negative environmental impacts such as air pollution, land degradation, water pollution, and depletion of native forest.

3.2 Methodology

3.2.1 Research design

The cross-sectional study design was adopted, whereby the study area was visited once during data collection (Kothari, 2004). Socio-economic and biophysical surveys was used for data collection. Purposive random sampling of villages was used in socio-economic survey and a systematic sampling procedure was used in biophysical survey.

3.2.2 Spatial data collection

Different data sets which were purchased and used for this study includes satellite images in electronic form Landsat TM 1991, Landsat ETM+ 2000 and landsat ETM 2011 (Table 1). Images of the same season free from cloud cover and identifiable features not affected by seasonality were considered in the selection. Data from the same season gives uniform spectral and radiometric characteristics and minimize the seasonal variation, in spectral reflectance of land cover types. The Focused group discussion noted that mining activities started gradually in 1991 but active mining operation progressed from 2007 onwards. So, the year 1991 was considered as a base year before mining activities and 2000 and 2011 being years of active mining activities. Global positioning system was used on ground verification of land covers mapping units of the base map.

Table 1: Landsat images used in the analysis of land-cover change

Land sat	Satellite Sensor	Path/ Row	Date of acquisition	Resolution	(%) Cloud cover	Source
1	Landsat 5 TM	170/66	22nd August1991	28.5m	0	Geo-network Ltd, DSM
2	Landsat 7 ETM+	170/66	01st July 2000	28.5m	0	Geo-network Ltd, DSM
3	Landsat 5 ETM	170/66	3rdJuly 2011	28.5m	0	Geo-network Ltd, DSM

3.2.3 Forest inventory data

Reconnaissance survey was conducted to determine the size of the study area, direction of transects and variation within the forest. The area was stratified into two sites namely; mined and un-mined forest area. Sampling intensity of 0.19 % was used to determine number of plots. The sampling intensity can be low up to 0.01 % (Malimbwi and Mugasha, 2002). Thus a total number of 70 plots (0.071ha) were established 14 and 56 in mining and un-mining respectively. Tree heights were measured using Suunto Hypsometer while DBH was measured using calliper. Distribution of the plots was based on the proportionality of each stratum to total forest area (Malimbwi, 1997). Plots were established systematically where by first plot was set randomly and the rest were systematically located in three transects; 700 m apart; and distance between plots was

608m. Direction of transects were maintained by using GPS. Total number of plots was determined by using the following formula (Malimbwi *et al.*, 1998).

$$N = \frac{TA * S_i}{P_s * 100} \quad \text{………………………...…………………………………………….. (1)}$$

Where;

N = Total number of sample plots;

TA =Total area of the forest;

Si = Sampling intensity and

Ps = Plot size

Concentric circular shaped sample plots were used as they reduce edge effects compared to rectangular plots (Njana, 2008). The plots were subdivided into three sub-plots (concentric plots) of 5 m, 10 m and 15 m. Data collected within each specified circle include;

i Within 5 m radius, all trees with DBH ≥4 cm<10 were recorded

ii Within 10 m radius, all trees with dbh ≥10 cm<20 cm were recorded

iii Within 15 m radius, all trees with dbh ≥20 cm were recorded

Trees in each plot were identified in local, swahili and botanical names and DBH of all trees with DBH ≥4 cm were measured using caliper, while height measurement for three trees with diameter (smallest, Medium and large) in each plot were recorded using Suunto hypsometer (Appendix 1). These were used for height DBH relationship development for un-measured trees. Tree species identification was done with the help of local language (Kinyiha) under assistance of two local people experienced in tree species identification. Botanical naming was done using trees and shrubs checklist. Species that were not easily identified in the field, voucher specimens were collected to the herbarium for identification by a botanist.

3.2.4 Social economic survey

Social economic survey was conducted in the villages surrounding mining sites to get the information regarding the community perceptions on impacts of mining activities on land cover and forest structure. Purposive sampling was done where by three villages namely; Nanyala, Songwe and Senjele out of five villages in Nanyala ward were selected based on their proximity to the mining centre. Thus, 30 households' heads from each village in Songwe, Nanyala and Senjele were randomly selected from village register as a sampling frame obtained from respective village offices. According to Bailey (1994) a sample size of 30 from one observation unit is considered adequate provided that characteristics of the study population were well excluded.

3.2.4.1 Primary data collection

Primary data were collected from households mainly by using structured and semi structured interview based on the specific objectives (Appendix 2). Pre-testing of the questionnaire was done during reconnaissance survey in order to check reliability and validity of the questionnaire. Pre-testing is necessary before beginning any survey. Whereby, in each household, the head of the household were interviewed, but other members were encouraged to attend and supplement information.

3.2.4.2 Participant observation

The researcher tried to be part of the community being studied to overcome problem of alienation. Basing on this context participants observation involved assessment of land cover status, forest disturbances and technology used in exploitation of mining and general environmental condition. Observation facilitated drawing attention on the association between mining activities and land cover/use status. It is always essential to keep ones eye open when visiting community and to check what you are told against what you see (Mafupa, 2006). Participant observer is described as the one who seeks to go beyond outward appearances and probe the perceptions, motives, beliefs, values and attitudes of the people studied (Njana, 2008).

3.2.4.3 Focus group discussion

Focused group discussion (FGD) is a technique guided by a checklist due to limitations of human memory this was used to ensure that important issues were not forgotten. It is a tool used to ensure that importance issues were not forgotten. The team for FGD comprised men and women. A total of 30 participants were involved in three villages, comprising 18 men and 12 women. Involved members were village government, Village Environmental Committees, influential people, religion leaders, income generating groups and local elders.

Key informant was also consulted whereby intensive strategic information sampling was used by people who were thought to have most and relevant information was consulted for discussion. In this study discussion were held with members from various disciplines experienced in the study area. These included: Mining Project Managers, District Forest Officer (DFO), District Trade Officer (DTO), Ward Executive Officer (WEO), Ward Agricultural Extension Officer (WAEO), Ward Clinical Health Officer, Head Teachers, and. This was done to fill in gaps of missing information and help to clarify issues which arose from formal interviews. Discussion included historical trends of land cover changes in relation to mining activities, community perceptions about forest degradation and socio economic activities as guided by a checklist (Appendix 3).

3.2.5 Secondary data

Published and unpublished information were collected from different sources such as, Sokoine National Agricultural Library, internet search/sources, village, ward offices and Mbozi District Council.

3.3 Data Analysis

3.3.1 Image processing

The methods for the images processing involved three stages which are pre-processing, image rectification/georeferencing and image enhancement. The steps involved are summarized in (Fig. 3).

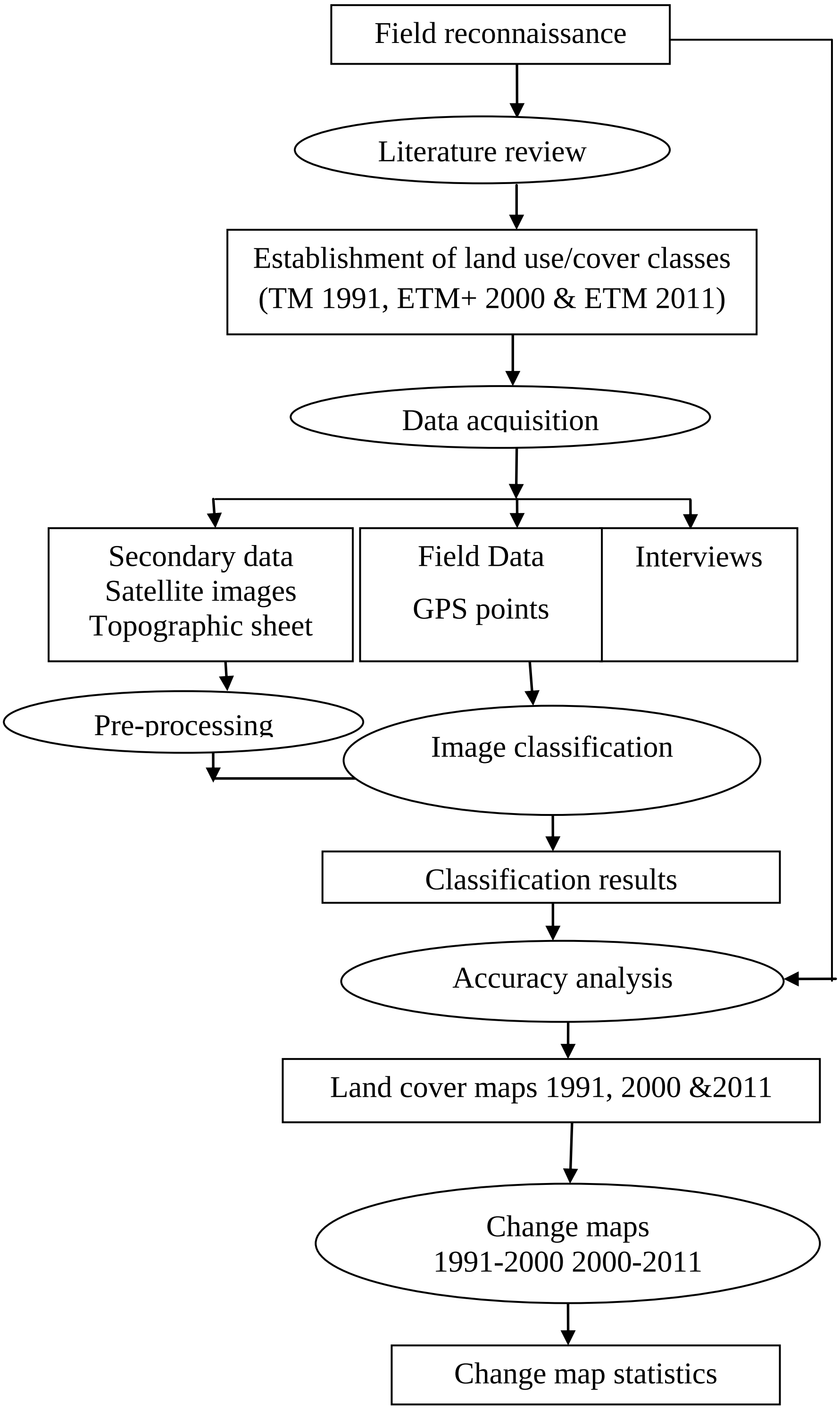

Figure 3: Image analysis flow chart

3.3.2 Image pre-processing

The methods for the images analysis used both visual and digital image processing. Before extracting data from the image, the process called image preparations were done first. Pre-processing procedures was adopted as an initial stage of refining and rectifying digital image flaws and deficiencies including georeferencing, resampling and image enhancement. At this stage images were evaluated to see their potentiality for the purpose of classification and change detection.

3.3.3 Image rectification/Georeferencing

Image reprojection is a process in which images are transformed and rectified to a standard projection of a particular area. Image rectification was carried to correct for distortions resulting from the image acquisition process. This was one to ensure accurate identification of temporal changes and geometric compatibility with other sources of information. Since the landsat images acquired were already geo-referenced from World Geodetic System (WGS84) images reprojection were coded to the co-ordinate and mapping system of the national topographic maps, i.e. UTM co-ordinate zone 36 South, Spheroid Clarke 1880, Datum Arc 1960 in which Mbozi District is located. Three rectified images were extracted from the full scenes using sub set command in ERDAS Imagine software version 9.1 to sub scenes followed by rectification, special attention was done for satellite images as being the major sources of data for the research.

The geometric correction include correcting the data for sensor irregularities and geometry variations, earth rotation effects, panoramic distortion curvature of the earth atmospheric refraction, relief displacement, variations in platform altitude and velocity and panoramic effects related to the imaging geometry (Kashaigili and Majaliwa, 2010).

3.3.4 Image enhancement

Image enhancement involved mathematical operations that are applied to digital remote sensing input data to improve the visual appearance of an image for better interpretability of subsequent digital analysis (Lillesand *et al.,* 2004). In order to reinforce the visual interpretability of images, a color composite (Landsat TM bands 3, 4 and 2) Red, Blue and Green were applied for visual interpretation. However, Band 4, 5 and 3 were used for classification of land cover/use. All images processing were carried out using ERDAS Image software Version 9.1.

3.3.5 Preliminary image classification

Supervised classification process involved selection of training sites on the images, which represent specific land cover classes to be mapped. Maximum Likelihood Classifier was performed. Training sites were generated by automated areas for each land cover classes derived from colour composite. Training was an iterative process, whereby the selected training pixels were evaluated by performing an estimated classification (ALARM command). Training samples were refined until satisfactory result was obtained. Relationships between spectral classes and different surface materials or land cover types were determined after classification by analysis of the spectral properties of each class.

3.3.6 Shape and size of the classified map

The boundary used for extracting subset from the preliminary landsat imagines was based on the forest boundary in which mining activities were taking place. The base map of three villages surrounding Marmo forest was extracted from the topographical map of Tanzania produced during the period 1987. The extracted sub map of the study area was superimposed in the three villages surrounding Marmo forest namely Songwe, Nayala and

Senjele. Each image was overlaid with the forest boundary so as to extract the area of interest. The extraction process is known as image subset using ERDAS Imagine program.

3.3.7 Ground truthing

Ground truthing was done in order to verify and modify land covers described in the preliminary image interpretation and it was guided by a sub map produced from landsat images of 2011 used as a base map for field surveys. Land cover/use types identified from the landsat images of 2011 were counterchecked in the study area. Hand held GPS was used to locate coordinate of points of areas with different types of land cover/use. Visual image interpretation was used for getting information about land use/land cover from satellite data. Various photographic and geotechnical elements such as tone, texture, shape, size, association, drainage, landform, soil and vegetation were used to identify and delineate the different land use/land cover classes. The assessment was based on the physiognomic types (physical) attributes, at each of the sample sites, the recognizable features on both the ground and the color composite print out was done by locating easily observable features such as roads, grassland, farms, mining patches and natural boundaries. Local people were involved to give some information on land cover and associated changes in the forest. In some areas photographs were taken to support what has been observed on the ground. Data regarding land cover variations and location were recorded in the field form directly from the site (Appendix 4).

3.3.8 Image classification

Supervised classification using Maximum Likelihood classifier was chosen to classify the images, as prior knowledge of the study area was available in hand. The method groups together features in specified classes based on the likelihood of the spectral signature of each feature to the sample set representing a specified class. The process involved selection of training sites (Area of interests) on the image, which represent specific land classes to be mapped. Selection of the training sites is one of the most important aspects of the classification process; ideally a training site must be homogeneous and should be a representative of the overall land covers/uses. In the training sites pixels were used to represent what is recognized as a discenable pattern, or potential land cover class. The training sites were generated by on-screen digitization of selected areas for each land cover classes identified on color composite (Kashaigili and Majaliwa, 2010). Essentially it is a visual tool that gives an overview of where the classes will be assigned in the image and whether additional classes are required. The objective was to produce thematic classes that resemble to actual land cover types on the earth's surface (Kashaigili and Majaliwa, 2010). Once an entire image has been classified into different categories, based on the spectral signature extracted from the training sites, the next step was to evaluate accuracy. It was important not to misidentify a land cover/use in a training site because it would lead to misclassification during accuracy assessments (Sheoran, 2005).

3.3.9 Accuracy assessment

The idea for accuracy assessment of classification results came from the facts that no classification maps were completed until their accuracy had been assessed and deemed sufficient for the intended purposes. An error matrix for current Landsat classified images ETM 2011 was employed. The error matrix was performed by verifying classified and observed cover classes to assess the reliability of the results (Appendix 5). Error Matrix is a square array of numbers laid out in rows and columns that express the number of sample units assigned to a particular category relative to the actual category as verified in the field. The columns normally represent the reference data, while the rows indicate the classification generated from remotely sensed data. Furthermore, an error matrix was used as a starting point for a series of descriptive and analytical statistical techniques whereby, an overall accuracy which was computed by dividing the total corrected sum of the major diagonal by the total number of pixels in the error matrix and this was performed to obtain the overall percentage accuracy. Accuracy assessment's objective was to detect and refine bias of thematic classified maps (Congalton, 1991).

3.3.10 Land use and vegetation cover change detection analysis

In the context of this study, post-classification change detection method was used to assess land cover and land use changes. Image from different dates were classified and labeled. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different time (Mas, 1999). The area of change was then extracted through the direct comparison of the classification results (Lyoba, 2009). Change detection method normally uses overlay technique in ERDAS IMAGINE 9.1 computer software, the method has been found to be the most suitable for detecting land cover changes Kashaigili, 2006). The approach identifies changes by comparing independently classified multi-date images on pixel by pixel basis using a change detection matrix (Kashaigili, 2006). The matrix analysis produces a thematic layer that contains a separate class for every coincidence of classes in multi-date dataset (Kashaigili, 2006). This resulted into a matrix table from the overlay of maps of different dates. The table was then exported as DBF table and further processed in excel to quantify change detection matrices.

3.3.11 Assessment of the rate of cover change

The estimation for the rate of change for the different covers was computed based on the following formulae (Kashaigili and Majaliwa, 2010).

$$\% \, Change_{year\ x} = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{\sum_{i=1}^{n} Area_{i\ year\ x}} x\, 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$Annual\, rate\, of\ change = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{t_{years}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\% \, Annual\, rate\, of\ change = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{\sum_{i=1}^{n} Area_{i\ year\ x}\, x\, t_{years}} x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where;

Area $_{i\ year\ x}$ = area of cover i at the first date, Area $_{i\ year\ x+1}$ = area of cover i at the second date

$\sum_{i=1}^{n} Area_{i\ year\ x}$ = the total cover area at the first date and

t_{years} = period in years between the first and second scene acquisition dates.

3.4 Forest Inventory Data Analysis

Inventory data were analyzed by using Microsoft excel and Paleontological Statistics software (PAST). ANOVA was used to test the difference in structure between the two strata (mining and non-mining).

3.4.1 Height estimation/ diameter equation

Two models based on height (Ht) and diameter (D) were fitted using regression to obtain a better fit model for estimation of height for unmeasured trees. The better fit model was selected based on the standard error (E) and Coefficient of Determination (R^2). Equation (5) was used for height estimation as it has higher value or r^2 and low standard error (Table 2).

Table 2: Selecting the best model for height/ Diameter equation for tree species with dbh ≥4cm Marmo forest

Model	Equation a+ b	R^2	SE	Remark
H = a + b (D)	3.12 + 0.13	0.41	0.41	Not selected
LnH = a + bLn (D)	0.69 + O.35	0.51	0.27	Selected

$$Ln(H) = a + bLn(D) \quad \text{.. (5)}$$

Where;

H = Estimation of tree height

a and b are constants with 0.69 and 0.35 values respectively

D (cm) Diameter at breast height.

3.4.2 Stocking parameters

For the purpose of this study stocking parameters include: stem density (N), basal area (G) and volume (V) of the forest. Computation of stocking parameters proceeded as follows:

3.4.3 Density (Number of stems/ha)

Number of stems was determined by summing up number of trees in each plot divided by number of plots and plot area to give number of stems per ha (Equation 6).

$$N = \frac{1}{n}\sum \frac{ni}{a} \quad \text{..(6)}$$

n_i = number of trees counted

n = number of plots

a = plot area in ha.

3.4.4 Basal area

Stand basal area is the sum per hectare of cross section areas of all trees estimated at breast height (Malimbwi, 1997). Therefore, basal area (m^2/ha) was calculated from measured stems diameter at breast height (1.3 m) for all wood individual in all plots (Equation 7).

$$G = \sum \frac{Gi}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where;

G=average basal area per ha of the stand (m^2ha^{-1}),

Gi= basal area of the i^{th} plot (m^2ha^{-1}),

n= number of sample plots.

3.4.5 Volume

The total tree volume was calculated according to (Malimbwi, 1997).

$$V = 0.0001 di^{2.032} h^{0.6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where

V= volume (m^3),

d_i= diameter at breast height (cm),

h = tree height (m).

3.4.6 Species diversity

This study used Shannon-Wiener Index (H'), and Simpson's Index (ID) indices to assess tree and shrub species diversity of the two strata (Equation 9 and 10).

$$H' = -\sum_{i=1}^{s} pi * \ln pi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where;

H' = Shannon Wiener Index of diversity,

s = Number of species in the sample,

Pi = Proportion of individual species i^{th} and

ln = Natural logarithm (Kent and Coker, 1992).

$$Ds = \frac{N(N-1)}{\sum ni(ni-1)} \qquad \ldots\ldots (10)$$

Where;

Ds = Simpson index of diversity,

N = the total number of individuals of all species,

ni = the number of individuals of species i^{th}.

3.5 Social Economic Data Analysis

3.5.1 Qualitative data analysis

Qualitative data were subjected into content and structural-functional analyses. Content analysis is a set of methods for analyzing the symbolic content of any communication. The basic idea is to reduce the total content of communication to some set of categories that represent some characteristics of research interest (Singleton *et al*., 1993) cited by Njana (2008). Through this method, the data collected through verbal discussions with key informants were analyzed in details whereby the recorded dialogues were broken down into smallest meaningful units of information or themes and tendencies. According to Kajembe and Luoga (1996), the technique helps the researcher in ascertaining values and attitudes of the respondents thereby generating themes and tendencies. Qualitative data results were used along with the output generated from quantitative data (descriptive and inferential statistical analyses) to triangulate and enrich the understanding on the perception of local communities on impacts of mining activities on land cover and forest structure.

3.5.2 Quantitative data analysis

The collected data were sorted, coded and entered in the Statistical Package for Social Sciences (SPSS) version 16.0 software in conformity with the objectives of the study. Descriptive statistical analysis included: frequency distribution, tables, histograms, pie-charts and percentages were used to summarize the results from the household's questionnaires.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Land Cover Changes during the Period of 1991-2011

Temporal and spatial variation of different land cover changes as a result of mining activities and other drivers of land cover changes in Marmo forest were studied. The results of land use/ land cover analysis are graphically represented in maps, bar diagram and tables (Table 3, Fig. 4, 5 6 and 7). The analysis shows the land use/ land cover maps of the study area for the years 1991, 2000 and 2011 respectively. Seven land cover classes namely settlement, bush land, cultivated land, forest, grassland, mining area and woodland were identified. The land use/land cover categories delineated in the study area revealed the changes in land use /land cover statistics (in hectare and percentages) that have taken place during the period between 1991- 2011 are due to expansion of mining activities.

Results in (Table 3 and Fig. 7) indicate variation in land cover classes in the period of three years (1991, 2000 and 2011). In 1991 the area cover was 567.55 ha (22.20 %) for forest, 529.94 ha (20.73 %) for woodland, 397.91 ha (15.56 %) for bush land, 409.09 ha (16.00 %) for grassland, 0.47 ha (0.02 %) for cultivated land, 651.24 ha (25.47 %) for settlement and 0.77ha (0.03 %) for mining. In 2000 the area covered by forest, woodland and grassland decreased by 265.13 ha (6.24 %), 265.26 ha (10.37 %) and 265.13 ha (10.13 %) respectively. Bush land increased up to 688.12 ha (26.91 %), cultivated land increased to 557.67ha (21.81 %) this show significant increase of cultivated land. Settlement decreased 326.09 ha (12.75 %), and mining area increased up to 295.26 ha (11.55 %), this imply that, mining operation was actively initiated during this period. Results show comparative great loss of vegetation cover for the period of 9 years (1991-2000).

The trend of mining activities might be associated with negative impact on land cover and forest structure at Marmo forest. Since mining operation is the function of time which results into direct and indirect effect on different land uses.

Table 3: Land cover 1991, 2000 and 2011

Land covers	Land cover 1991 Area (Ha)	(%) coverage	Land cover 2000 Area (Ha)	(%) coverage	Land cover 2011 Area (Ha)	(%) coverage
Settlement	651.24	(25.47)	326.09	(12.75)	367.20	(14.36)
Bush land	397.91	(15.56)	688.12	(26.91)	807.62	(31.59)
Cultivated land	0.47	(0.02)	557.67	(21.81)	530.12	(20.73)
Forest	567.55	(22.20)	265.13	(10.37)	0.13	(0.01)
Grassland	409.09	(16.00)	265.26	(10.37)	263.44	(10.30)
Mining area	0.77	(0.03)	295.26	(11.55)	517.44	(20.24)
Woodland	529.94	(20.73)	159.43	(6.24)	71.01	(2.78)
Total	2556.96	(100.00)	2556.96	(100.00)	(2556.96)	(100.00)

The land cover classified during the period 2011 indicates the considerable increase of area under bush land to 807.62ha (31.59 %), cultivated land to 530.12ha (20.73 %) and mining to 517.44ha (20.24 %) while settlement, grassland, woodland and forest recorded significant decrease to 367.20ha (14.3 6%), 263.44ha (10.30 %), 71.01ha (2.78 %) and 0.13ha (0.01 %) respectively. The overall trend indicates that, forest and woodland areas were decreasing as increasing mining area increase. This has been due to rampart and random clearing of forest areas for mining purposes, which have resulted into drastic changes and results in significant reduction of vegetation cover. Similar case was reported by Garry (2001) in the Suriname forest Ghana that the area deforested by mining may seem relatively small, but given the slow forest recovery and the concentration of mining in selected areas, small scale gold mining is expected to reduce local forest cover and ecosystem services in the regions where mining activities are taking place.

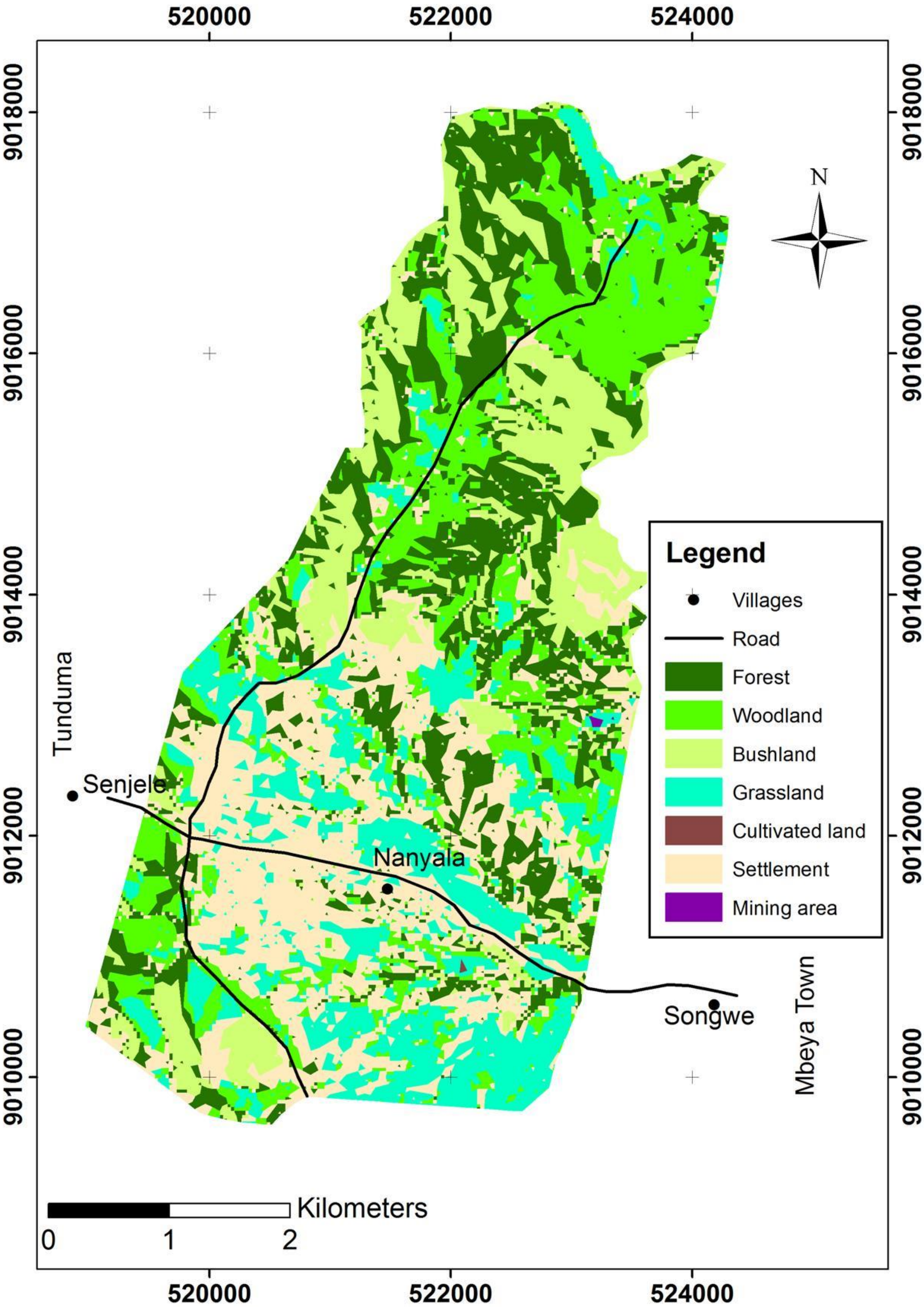

Figure 4: **Land cover/ use map for Marmo Forest in Nanyala ward 1991**

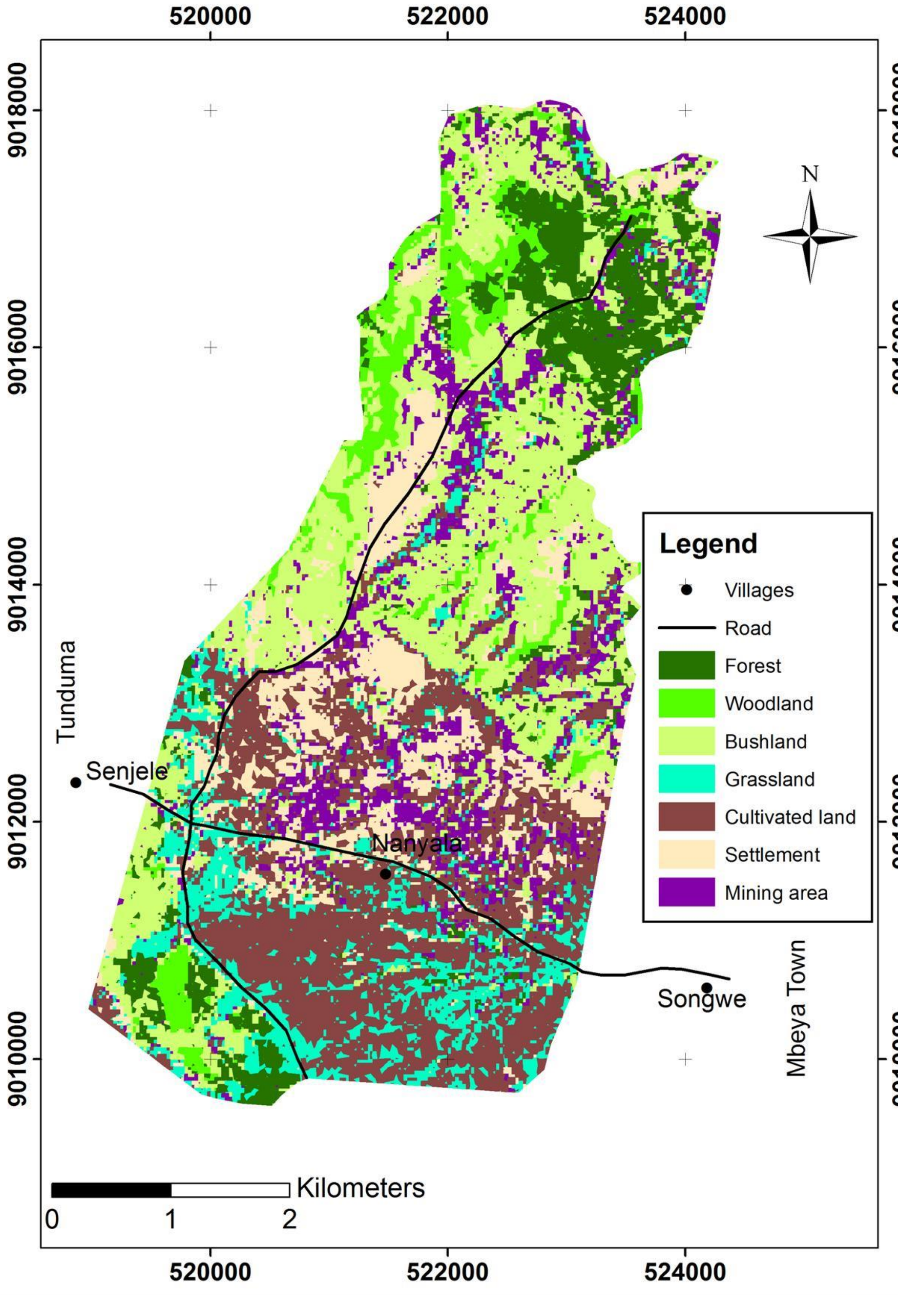

Figure 5: Land cover/ use map for Marmo Forest in Nanyala ward 2000

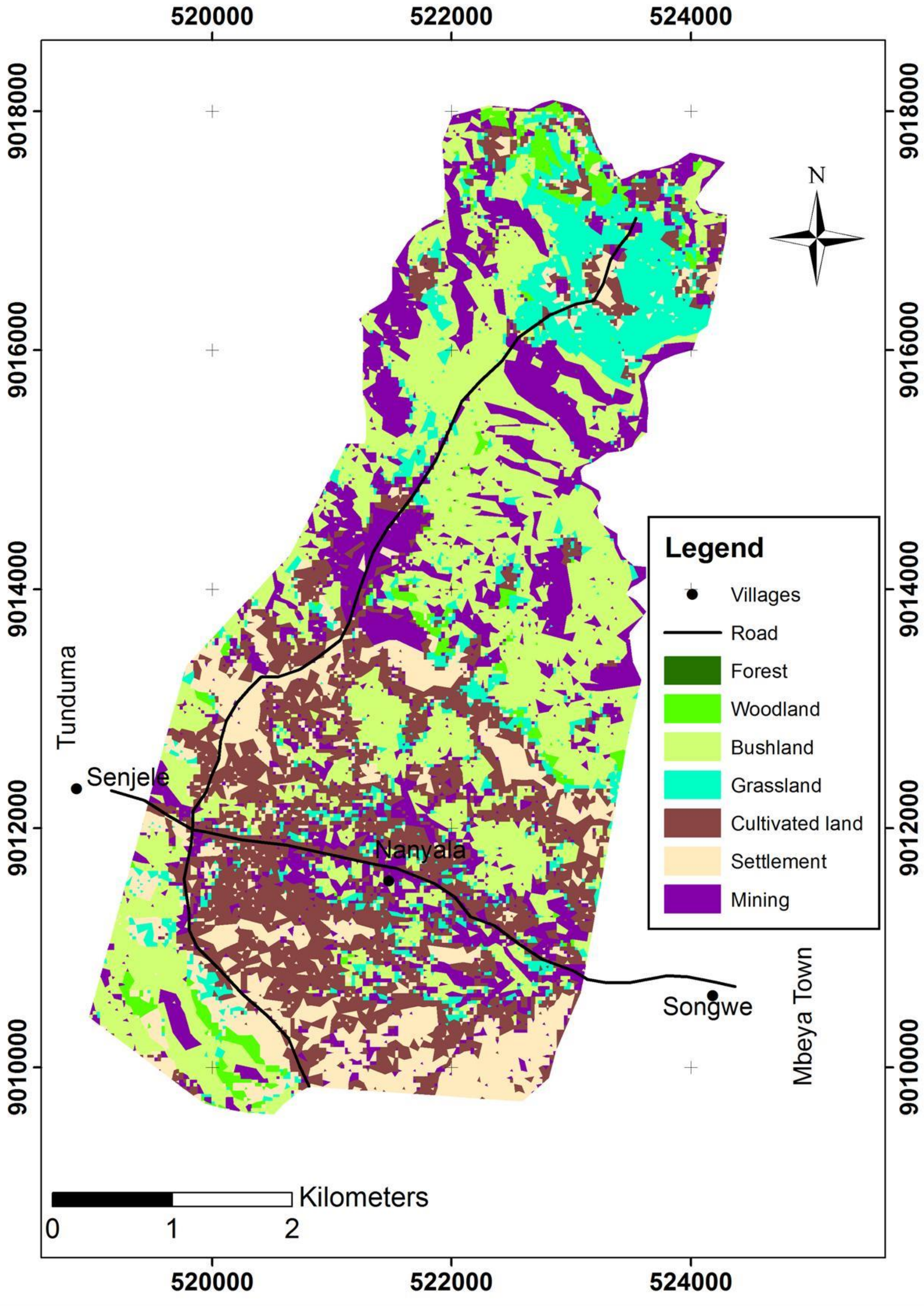

Figure 6: Land cover/ use map for Marmo Forest in Nanyala ward 2011

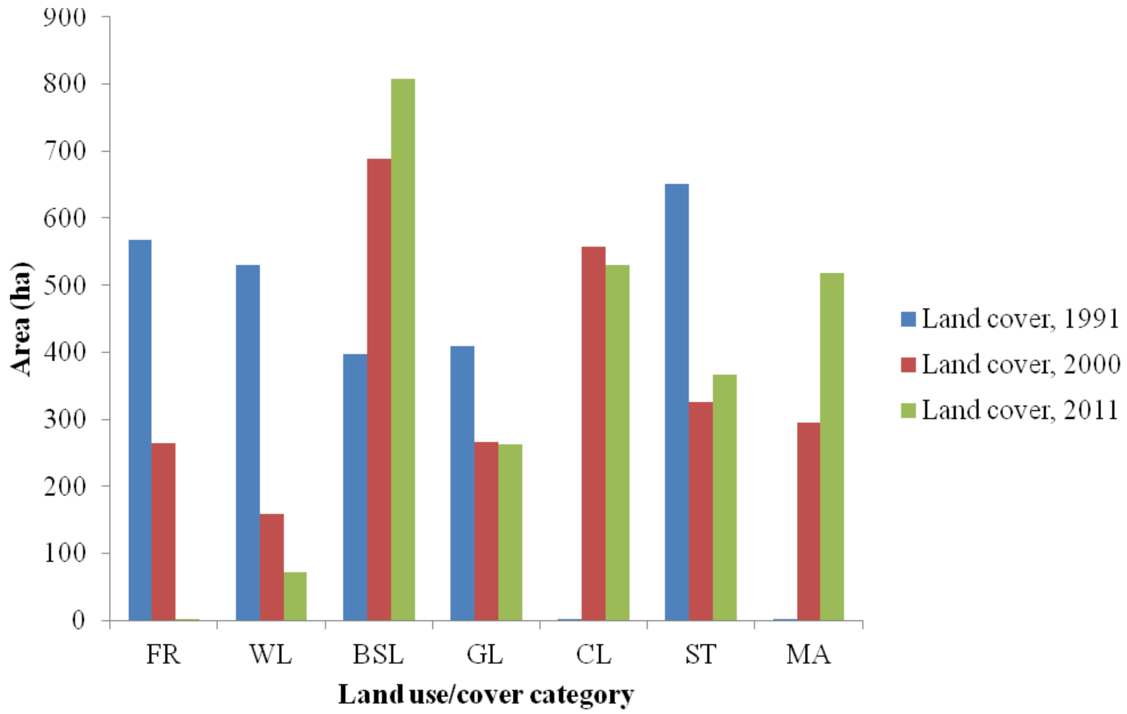

Figure 7: Land use/ cover distribution for Marmo forest 1991, 2000 and 2011

FR=Forest, WL= Woodland, BSL= Bush land, GL=Grassland, CL=Cultivated land, ST=Settlement, MA= Mining area

4.1.1 Cover area, changed area and the rate of change between 1991-2011

Results of cover area, changed area and the rate of change between 1991 and 2000, between 2000 and 2011 are presented in Table 4 and 5 respectively. From 1991 to 2000 there was tremendous decrease of settlement area in Marmo forest from 651.24 ha to 326.09 ha (-12.75 %), and 2000-2011 settlement increased from 326.09 to 367.20 ha (1.61%). In 1991-2000 forest area decreased from 567.55 ha to 265.13 ha (-11.83 %) and 2000-2011 persisted enormous forest decreased from 265.13 ha to 0.13 ha (-10.36 %). Deforestation was noted to occur when native vegetation was being cleared to provide room for mining operation and for residential use. Woodland decreased from 529.94 to 159.43 ha (-14.49 %) between 1991 and 2000 and from 2000-2011 it decreased from 159.43 ha to 71.01 ha (-3.46 %).

The trend of decrease reflects that human disturbances especially mining operations which resulted into forest cover changes. Grassland experienced a continuous loss from 409.09 ha to 265.26 ha (-5.62 %) between 1991 and 2000 and between 2000 and 2011 it showed slight decrease from 265.26 ha to 263.44 ha (-0.07 %). Farm expansion and mining perhaps favors regeneration of grassland after land disturbance. For example bush land, during the period of 1991 was 397.91 ha (15.56 %) increased to 688.12 ha (26.91 %) area change was 290.21 ha (11.35%). From 2000-2011 it continued to increase up to 807.62 ha (4.67 %), this was probably caused by mining and other anthropogenic disturbances includes grazing, agriculture, firewood collection, charcoal burning and cutting trees for polls and construction materials. From 1991-2000 land cover for mining signified remarkable increase from 0.77ha to 295.2 6ha (11.52 %), also from 2000 to 2011 mining activities increased up to 517.44 ha (8.69 %). This accelerated depletion of general land cover this implies that, mining operation and human population is actively degrading the vegetation cover. In1991-2000 cultivated land accounts for an increase from 0.42 ha to 557.67 ha (21.79 %), and 2000-2011 cultivated land decreases up to 530.12ha (-1.08 %) this might have been caused by mining expansion.

The reason for this heterogeneous change might be associated with the mining activities since mining projects are linked to both direct and indirect changes in land covers which have significant effects on different land use in which forest is the greatest victim. The current study result is supported by Singh *et al.* (2010) reported a gradual decrease and threat to vegetation present in the area where mining was prominent. Sarma (2005) found that due to extensive coal mining, large areas of Jaintia-hills District of Meghalaya, northeast India were degraded and resulted in unfavorable habitat conditions for plants growth.

Table 4: Cover area, changed area and the rate of change between 1991 and 2000

	Land cover in 1991		Land cover in 2000		Land cover change (1991-2000)			
Cover class	Area (ha)	% cover	Area (ha)	% cover	Area change (ha)	% cover change	Annual rate of change (hayr-[1])	%Annual rate of change (%/yr)
FR	567.55	22.2	265.13	10.37	-302.42	-11.83	-33.60	-1.31
WL	529.94	20.73	159.43	6.24	-370.50	-14.49	-41.17	-1.61
BSL	397.91	15.56	688.12	26.91	290.21	11.35	32.25	1.26
GL	409.09	16.00	265.26	10.37	-143.83	-5.62	-15.98	-0.62
CL	0.47	0.02	557.67	21.81	557.20	21.79	61.91	2.42
ST	651.24	25.47	326.09	12.75	-325.15	-12.72	-36.13	-1.41
MA	0.77	0.03	295.26	11.55	294.49	11.52	32.72	1.28
Total area	2556.96	100.00	2556.96	100.00				

FR=Forest, WL= Woodland, BSL= Bush land, GL=Grassland, CL=Cultivated land, ST=Settlement, MA= Mining area

Table 5: Cover area, changed area and the rate of change between 2000 and 2011

	Land cover in 2000		Land cover in 2011		Land cover change 2000-2011			
Cover class	Area (ha)	% cover	Area (ha)	% cover	Area change (ha)	% cover change	Annual rate of change (hayr-[1])	%Annual rate of change (%/yr)
FR	265.13	10.37	0.13	0.01	-264.99	-10.36	-24.09	-0.94
WL	159.43	6.24	71.01	2.78	-88.43	-3.46	-8.04	-0.31
BSL	688.12	26.91	807.67	31.59	119.49	4.67	10.86	0.42
GL	265.26	10.37	263.44	10.30	-1.82	-0.07	-0.17	-0.01
CL	557.668	21.81	530.123	20.73	-27.55	-1.08	-2.5	-0.1
ST	326.08	12.75	367.19	14.36	41.11	1.61	3.74	0.15
MA	295.26	11.55	517.44	20.24	222.18	8.69	20.20	0.79
Total area	2 556.96	100.00	2 556.96	100.00				

FR=Forest, WL= Woodland, BSL= Bush land, GL=Grassland, CL=Cultivated land, ST=Settlement, MA= Mining area

Table 4 indicates the annual rate of change (hayr^{-1}) and percentage rate of change (%/year) from 1991-2000. The analysis shows an increase in the cultivated land, mining and bush land area at a rate of 61.91 hayr^{-1} (2.42 %/yr), 32.25 hayr^{-1} (1.26 %/yr) and 32.25 hayr^{-1} (1.26 %/yr) respectively. This increase signifies continual loss of the land cover while woodland, settlement, forest and grassland are diminishing by the rate of -41.17 hayr^{-1} (-1.61 %/yr), -36.13 hayr^{-1} (-1.48 %/yr), -33.60 %/yr (-1.31 %/yr) and -15.98 hayr^{-1} (-0.62 %/yr) respectively. Forest and woodland depict negative trends of change throughout the period of 9 years (1991-2000). The main drivers for this forest degradation might be the expansion of mining activities and other anthropogenic activities such as charcoal burning, uncontrolled bush fires, fuel wood collection and agricultural expansion (focused group discussion). Furthermore, cultivated land, mining and bush land area were increasing on the expenses of the forest, woodland, grassland and settlement. Similar case was reported by Peterson and Heemskerk (2001) who studied deforestation and forest regeneration in small-scale gold mining in the Amazon, and attributed the rate of deforestation of 48 up to 96 km^2 per year to the developments in Ghana. The author further argued that, even though deforestation produced by small-scale gold mining is relatively minor compared to other land uses in the Suriname forest but their impact is more severe.

Table 5, entails the annual rate of change (hayr^{-1}) and percentage rate of change (%/yr) of the area between 2000 and 2011. Mining land, bush land and settlement were increased by the rate of 20.2 hayr^{-1} (0.31 %/yr), 10.86 hayr^{-1} (0.42 %/yr) and 3.74 hayr^{-1} (0.15 %/yr) respectively while forest, woodland, cultivated land and grassland were diminished in the consecutive years at a rate of -24.09 hayr^{-1} (-0.94 %/yr), 8.04 hayr^{-1} (-0.31 %/year), -2.5 hayr^{-1} (-0.1 %/year) and grassland -0.17 hayr^{-1} (-0.01 %/year). This analysis confirms the occurrence of forest and woodland degradation in Marmo forest. Grasslands are seen to occupy quite large area. This is due to the fact that, they form part of abandoned mining area. Most of the grassland was observed to dominate on areas adjacent to the mining and agricultural areas. Similar observation was reported by Rwamugira (2008) who found that a forest cover decreased by 352 ha from between 1991 and 2000 resulting into a total loss in forest for 24 %. This was equivalent to annual rate of decreasing of 39 ha/yr (2.7 %). Lyoba (2009) reported that, the land degradation in refugee's settlement in Ulyankulu, for the period of 1978, 1984, 1994 and 2006 years cultivated land and grassland increased in areas while woodland and forest decreased in area, It was further argued that, population increase is the major drivers of land use changes.

4.1.2 Change detection matrix of different land cover/use 1991-2011

4.1.2.1 Land cover changes 1991-2000

Table 6, presents the land cover changes detection matrix from Landsat satellite imagery of 1991-2000. The results indicate the fluctuation of land cover classes in the study area as follows: settlement was converted into bushland, forest, cultivated land, woodland, grassland and mining by 36.69 %, 21.08 %, 15.13 %, 11.72 %, 3.07 % and 0.73 % respectively, while 11.58 % of settlement remained unchanged. About 44.74 % of grassland changed into cultivated land,10.81 % changed to mining area, 8.04 % changed to bush land, 5.92 % changed to forest, 0.32 % transformed to woodland and 15.40 % remained unaffected. Forest cover was converted to woodland, settlement, grassland, bushland, mining and cultivated land by 42.15 %, 13.78 %, 9.93 %, 8.82 %, 8.63 % and 6.89 % respectively. About 9.79 % of the forest remained intact. Also 23.75 % of woodland was converted to grassland, 13.48 % converted to bushland, 11.81 % converted to settlement, 9.40 % changed to cultivated land and 2.37 % converted to mining and 9.62 % remain unchanged. The result justified that, forest and woodland has almost perished and is severely and negatively impacted than other land cover classes.

Consequently, bush land was converted to woodland, mining, grassland, settlement, forest and cultivated land by 45.97 %, 23.03 %, 9.72 %, 8.72 %, 5.53 % and 3.72 % respectively while 3.30 % remain unchanged. About 81.50 % of mining area was converted to bushland, 14.01 % was transformed into settlement and about 4.49 % was converted to forest, whereas there was no cover change from mining area to bush land, forest, wood land and grassland. Moreover, 95.36 % of cultivated land was converted to bushland, 4.36 % changed to cultivatedland, and there was no change from cultivated land to settlement, forest, grassland, mining area, and woodland.

Table 6: Change detection matrix of different land cover/use 1991-2000

	Land cover in 2000 (ha)							
Land cover in 1991(ha)	FR	WL	BSL	GL	CL	ST	MA	Total (ha)
FR	55.56	239.22	50.06	56.37	39.13	78.21	48.99	567.55
	(9.79)	(42.15)	(8.82)	(9.93)	(6.8)	(13.78)	(8.63)	(100.00)
WL	50.96	156.73	71.44	125.84	49.82	62.57	12.57	529.94
	(9.62)	(29.57)	(13.48)	(23.75)	(9.40)	(11.81)	(2.37)	(100.00)
BSL	22.02	182.93	13.15	38.66	14.79	34.71	91.65	397.91
	(5.53)	(45.97)	(3.30)	(9.72)	(3.72)	(8.72)	(23.03)	(100.00)
GL	60.23	32.91	183.04	24.23	62.99	44.24	1.45	409.09
	(14.72)	(8.04)	(44.74)	(5.92)	(15.40)	(10.81)	(90.35)	(100.00)
CL	0.00	0.00	0.45	0.00	0.02	0.00	0.00	0.47
	(0.00)	(0.28)	(95.36)	(0.00)	(4.36)	(0.00)	(0.00)	(100.00)
ST	137.27	76.33	238.92	20.01	98.51	75.42	4.77	651.24
	(21.08)	(11.72)	(36.69)	(3.07)	(15.13)	(11.58)	(0.73)	(100.00)
MA	0.03	0.00	0.62	0.00	0.00	0.11	0.00	0.77
	(4.49)	(0.00)	(81.50)	(0.00)	(0.00)	(14.01)	(0.00)	(100.00)
Total	326.09	688.12	557.67	265.13	265.26	295.26	159.43	2556.96

Note: Numbers in brackets are percentages (%)
FR=Forest, WL= Woodland, BSL= Bush land, GL=Grassland, CL=Cultivated land, ST=Settlement, MA= Mining area

4.1.2.2 Land cover changes during 2000 and 2011

This period consists of land cover changes detected from Landsat imagery. Based on the changed detection matrix for different land use cover between 2000 and 2011 the results from Table 7 revealed that, about 37.36 % of cultivated land was converted to bush land, 29.34 % changed to forest, 17.40 % converted to woodland, 11.46 % converted to settlement, 0.38 % converted to mining while 4.07 % of cultivated land remain unchanged. Grassland cover was converted to bushland, forest, woodland, settlement, cultivated land by 31.47 %, 21.47 %, 21.35 %, 16.34 %, 6.72 % and 2.65 % respectively while grassland was completely perished.

The analysis indicates that about 33.91 % of settlement was converted to bushland, 22.54 % to woodland, 15.40 % to forest, 6.26 % to cultivated land, 0.61 to mining and 21.28 % of the settlement remained unchanged, while there was no cover change from settlement to grassland. Forest classes were converted into cultivated land, woodland, settlement, mining, bushland and grassland by 35.39 %, 28.68 %, 13.60 %, 6.97 %, 5.08 % and 0.04 % respectively, while 10.23 % of the forest remain unchanged.

About 39.78 %, of mining area was switched to bush land, 18.03 % to cultivated land, 9.25 % to grassland, 7.30 % to bare land, no cover change occurred from mining to forest and 22.01 % remained unchanged. Woodland area was converted to settlement about 43.32 %, 5.46 % to cultivated land, 1.68 % to forest, 1.42 % to bushland, 1.34 % to mining, 0.01 % to grassland and 46.77 % remained unchanged. Generally the results indicate the significant loss of the bush land areas in three years. This might be attributed to expansion of mining activities in the study area; there is no doubt that mining activities has antagonistic association to the vegetation cover. Mining activities has substantial long-term effects on the forest stock disintegration in Marmo forest where mining is concentrated. The massive continual vegetation depletion that is accompanied by expansion of mining greatly slows regeneration and produces vegetation cover differently compared to un-mined forest area.

Table 7: Change detection matrix of different land cover/use 2000-2011

Land cover	Land cover in 2011 (ha)							
in 2000 (ha)	FR	WL	BSL	GL	CL	ST	MA	Total
FR	27.12	76.03	13.48	0.12	93.84	36.06	18.48	265.13
	(10.23)	(28.68)	(5.08)	(0.04)	(35.39)	(13.60)	(6.97)	(100.00)
WL	2.67	74.56	2.27	0.01	8.71	69.07	2.14	159.43
	(1.68)	(46.77)	(1.42)	(0.01)	(5.46)	(43.32)	(1.34)	(100)
BSL	45.07	312.37	58.78	0.00	72.68	170.69	28.53	688.12
	(6.55)	(45.39)	(8.54)	(0.00)	(10.56)	(24.80)	(4.15)	(100.00)
GL	56.96	56.64	83.47	0.00	17.82	43.34	7.03	265.26
	(21.47)	(21.35)	(31.47)	(0.00)	(6.72)	(16.34)	(2.65)	(100.00)
CL	163.60	97.05	208.32	0.00	22.68	63.91	2.09	557.67
	(29.34)	(17.40)	(37.36)	(0.00)	(4.07)	(11.46)	(0.38)	(100.00)
ST	50.22	73.51	110.58	0.00	20.40	69.40	1.98	326.09
	(15.40)	(22.54)	(33.91)	(0.00)	(6.26)	(21.28)	(0.61)	(100.00)
MA	21.55	117.45	53.22	0.00	27.31	64.98	10.75	295.26
	(7.30)	(39.78)	(18.03)	(0.00)	(9.25)	(22.01)	(3.64)	(100.00)
Total	367.20	807.62	530.12	0.13	263.44	517.44	71.01	2556.96

Note: Numbers in brackets are percentages (%)
FR=Forest, WL= Woodland, BSL= Bush land, GL=Grassland, CL=Cultivated land, ST=Settlement, MA= Mining area

4.1.2.3 Variations on detected changes and interpretation

Assessment of the detected changes during the period between 1991, 2000 and 2011 Table 3 shows settlement cover was 651.24 ha, 326.09 ha and 367.20 ha respectively. The reason behind is that during 2000s eviction of the local communities living closer to the mining area was done in order to pave the way for infrastructures development involved in mining activities. However the current situation indicates that settlement is increasing following demographic changes. This is caused by natural growth and immigrants who come to look for job opportunities as a result tend to stimulates population expansion. These migrants are not only employed in the mining projects but some are engaged in small scale limestone processing, petty trade, farming activities and casual laborers. Area occupied by grassland decreased due to conversion of grassland into bush lands, cultivated land and mining. The tremendous increase of population in the study area results into demand for natural resources for survive, this has also caused depletion of land covers and forest resources.

4.1.2.4 Results of accuracy assessment

The result of error matrix shown in Table 8 indicates an overall map accuracy of 88.89 %. The accuracy entails the probability of reference pixels being correctly classified. Ground survey observed some plots being affected by mining and other human activities; this has resulted into decreasing classification accuracy. The most common way to represent the classification accuracy of remote sensed data is in the form of an error matrix (Congalton, 1991). An error matrix is a very effective way to represent accuracy in that, the accuracies of each category is plainly described along with both the errors of inclusions (omission error) present in the classification (Congalton, 1991).

Table 8: Results of accuracy assessment using error matrix

		Ground reference data							
	Classification	FR	WL	BL	GL	CL	ST	MN	Row total
Classified field data	FR	8	1	0	0	0	0	0	9
	WL	0	5	0	0	0	0	0	5
	BL	0	1	5	0	0	0	0	6
	GL	0	0	0	8	1	0	0	9
	CL	0	0	0	0	4	1	0	5
	ST	0	0	0	0	1	4	0	5
	MA	0	7	5	0	1	0	14	15
	Column Total	8	7	5	8	7	5	14	54

Note: *FR = Forest, Wl = Woodland, BL= Bush land, GL= Grassland, CL = Cultivate land, ST = Settlement, MA = Mining area*

The overall accuracy assessment classification is 88.89% however; this does not mean that each category was successfully classified at that rate.

4.2 Forest Inventory

4.2.1 Impacts of mining activities on forest stock

4.2.1.1 Number of stem

Table 9 shows the mean stems per hectare of un-mined stratum was 151.31 ± 7.6 (SE) and the mean stems for mined stratum was 25.01 ± 6.27 (SE) per hectare. The difference of stems per hectare for the two strata was statistically significant ($p<0.05$) implying the difference between mean number of stem per hectare in un-mined and mined strata. This scenario substantiate that, more numbers of stems was observed in the un-mined than mined forest area, suggesting that there was higher forest disturbances in mined stratum than un-mined stratum. This significant difference could be attributed by extensive anthropogenic activities (mining activities) in mined stratum than un-mined stratum. Thus, it is no doubt that, mining activities has severe impact in forest stock than other types of disturbances.

Table 9: Stand Parameters un-mined and mined forest

Stand parameters	Forest strata		p-value	Significance
	Un-mined	Mined		
Mean number of stem N/ha	151.31 ± 7.6	25.01 ± 6.27	< 0.001	√
Mean basal area	2.50 ± 0.26	0.21 ± 0.01	< 0.001	√
Mean volume	9.61 ± 0.19	0.51 ± 1.18	< 0.001	√
Shannon wiener (H')	1.29±0.16	0.36 ± 0.08	< 0.001	√
Simpson index of diversity (SD)	0.66± 0.03	0.22 ± 0.05	< 0.001	√
Evenness	0.83± 0.01	0.96 ± 0.01	< 0.05	√

The results from this study reported less number of stems per hectare compared to other studies in miombo region. Mafupa (2006) found a total of 722 ± 60 (SE) stems per hectare for undisturbed stratum and 150 ± 43 (SE) stems per hectare in the disturbed stratum of the forest reserve. The study conducted by Malaisse (1978) cited in Mafupa 2006 reported that number of stems per hectare ranged between 520 and 645 in Katanga Democratic

Republic of Congo. Also Peterson and Heemskerk (2001), studied deforestation and forest regeneration following small-scale gold mining in the Amazon reported that, the vegetation that appears following mining does not resemble the vegetation in adjacent old-growth forest in quantity and quality. The findings suggest that, the regeneration of forest on mined sites is extremely slow and large areas of mined sites remained bare ground and dominated by grass. Sarma (2005) also reported that, mining activities results into massive damage to landscape and biological communities eventually the number of trees and shrub species reduced due to mining activities.

Tree diameter class (4-9 cm) was dominant and much higher in mined than in un-mined site. The Mean number of stems per hectare was found to decrease with increasing diameter from lower ≥4 cm to higher ≥20 cm class, both in the mined and un-mined strata (Fig. 8). But more species composition was observed in un-mined compared to the mined stratum.

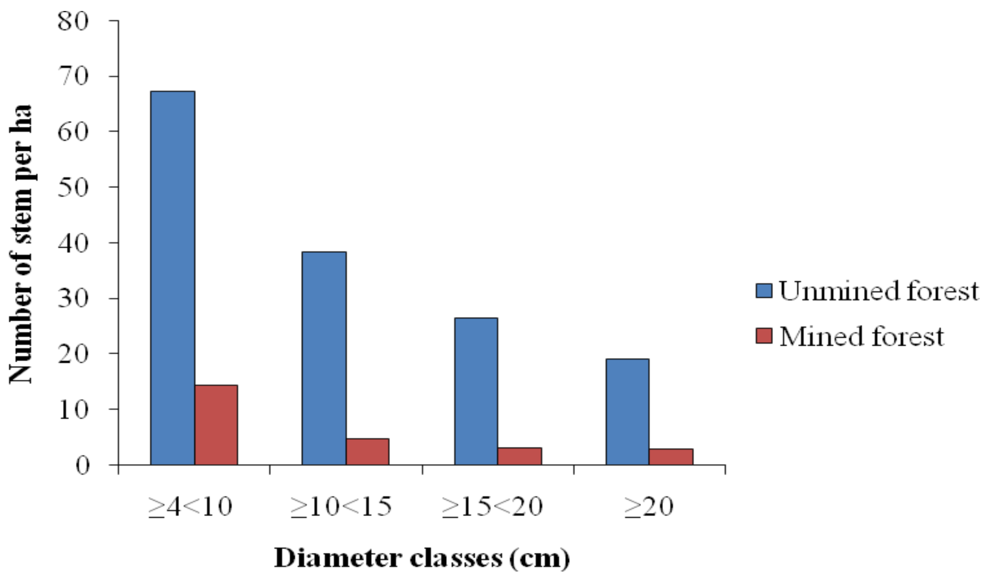

Figure 8: Distribution of stems per hectare in diameter classes in both mined and un-mined strata

4.2.1.2 Basal area

The results show that mean basal area in un-mined area was 2.50 ± 0.26 (SE) m^2/ha and mined area 0.21 ± 0.01 (SE) m^2/ha. The analysis of variance showed significance difference ($p< 0.05$) between mined and un-mined forests (Table 9). This shows that un-mined forest had larger mean basal area than mined forest thus implying the presence of forest deforestation in mined than un-mined area. Moreover, the distribution of basal area decreased as diameter classes increased from 4cm both in mined and un-mined forest area. However, the basal area plot against diameter class didn't show a normal J shaped expected in natural forest, this explains that both strata were poorly stalked (Fig. 9). Mafupa (2006) found that mean basal area per ha of 11.24 ±0.76 m^2/ha in undisturbed stratum and 2.44 ± 0.48 m^2/ha in the disturbed stratum of Igombe river forest Reserve Miombo woodland in Tabora. However the results obtained indicates less mean basal area compared to the above findings entailing severe forest degradation intimidating the sustainability of Marmo forest.

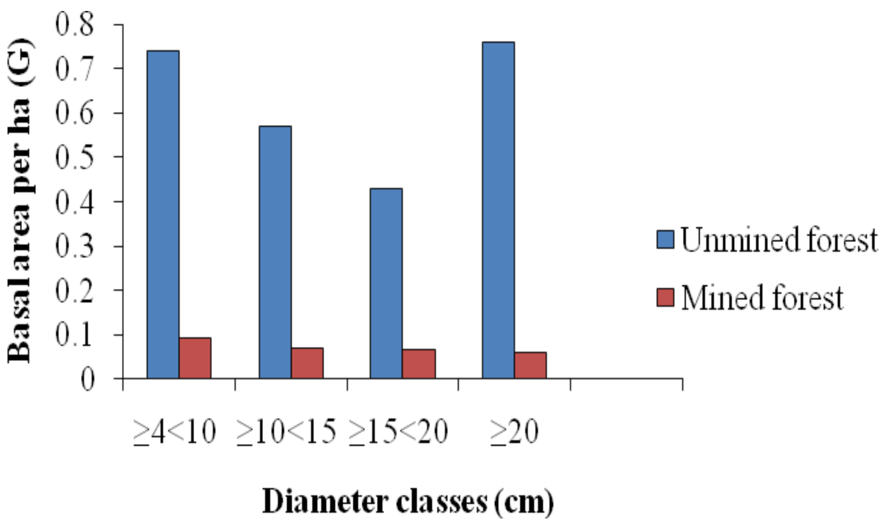

Figure 9: Mean basal area per ha distribution by diameter classes for mined and unmined strata at Marmo forest

4.2.1.3 Volume

Comparative results substantiated that mean standing volume for un-mined area was 9.61 ± 0.19.18 (SE) m^3/ha and that of mined area was 0.51 ± 1.18 (SE) m^3/ha, the results tested at ($p<0.05$) shows significant statistical difference between mean volume of un-mined and mined area (Table 9). This implies that, mean volume in un-mined was higher compared to that of mined area. Thus, mining activities could not be overlooked on recent degradation of Marmo forest.

4.2.1.4 Impact of mining on tree species diversity and richness

Results indicate that, the Shannon wiener index of diversity (H') in un-mined and mined area were 1.29 ± 0.163 (SE) and 0.36 ± 0.08 (SE) respectively ($p<0.05$). This result shows that, there was relatively high species diversity in un-mined than mined strata (Table 9). The finding shows significant differences in diversity between the forest areas. This is explained by the fact that the number of species observed in un-mined area was high and were evenly distributed and hence contribute more to the diversity index. Thus the general Shannon-wiener index of diversity for this study was found to be 1.65. This means that the diversity of the area was very low, as the value H' ranges from 1–5, with H' = 5 considered to be highly diverse and H' less than 2 was considered to be low diverse (Rwamugira, 2008). Low diversity of the area could be explained by expansion of mining activities that creates severe disturbances on forest structure and species composition in the study area.

Species evenness in un-mined forest area was 0.83 ± 0.01(SE) and mined forest area was 0.96 ± 0.01(SE). Species evenness was statistically significant different at ($p<0.05$) between un-mined and mined areas (Table 9). Un-mined forest indicate less proportionality in species distribution compared to mined forest which showed high proportionality but less dominance of species distribution. Results revealed comparatively slight diversity difference between two forest strata, signifying that, even in un-mined strata there might be occurrence of forest disturbance resulted from human activities like firewood collection, poles harvesting, charcoal marking, grazing and seasonal bushfire (Personal observation). The results align with the study conducted by Rwamugira (2008) on impacts of mining in Ruvu Catchment Forest Reserve, who reported that, Shannon Wiener diversity index was lesser in the mined than in un-mined area. Sarma (2005) in the study of Impact of coal mining on plant diversity and tree population structure in Meghalaya, North East India reported lower Shannon-Wiener diversity index for tree and shrub species in mined compared to un-mined areas.

4.2.1.5 The Index of Dominance

Basing on this study the results show that, index of dominance was 0.66 ± 0.03 (SE) and 0.22 ± 0.05 (SE) in un-mined and mined forest respectively, these values were significant different at $p<0.05$ (Table 9). The greater the value of dominance the lower the species diversity in the forest community and vice versa (Rwamugira, 2008). The lower the value of the mined stratum shows that each species relatively contributes evenly to the community and the high value in the un-mined forest is an indicator that there are more tree species in this stratum that dominates others. These includes *Terminalia sericea*, *Combretum adenogonium*, *Combretum molle, Commiphora africana*, *Erythrina abyssinica*, *Sterculia quinqueloba*, *Terminalia mollis and Lannea schimperi.* The imbalance in species distribution in two strata might be caused by forest destruction in the mining sites. The observation aligns with the study conducted by Kijazi (2007) who reported index of dominance of 0.96 and 0.05 in closed canopy and degraded forests respectively in Chome catchment forest reserve. Zahabu (2001) in Kitulangalo area observed the higher species richness in forest reserve compared to the public land.

Mafupa (2005) obtained the index of dominance of 0.08 for undisturbed forest and 0.13 for disturbed forest in Miombo woodlands of Igombe river forest reserve.

4.3 Socio- Economic Characteristic of Respondents

4.3.1 Sex and age of respondents

Majority of the respondents were men 55 (61.1 %) and 35 (38.9 %) were women. The reason for women being fewer was due to the fact that, the interview was administered to the head of households where male headed household formed majority of the respondents. Age is an important parameter since different age groups perform different sets of activities in most societies. Overholt *et al.* (1991) in a study of gender analysis framework found that, age is a function of knowledge and experience as well as a measure of maturity of individuals. Ages of the respondents at the household level were considered and the results in Table 10 show that, majority of the respondents were adult ranges 40-60 years (53.3) followed by youth ranges 18-39 years (46.3 %), and old aged group >60 years (21.1 %). This shows empirically that the respondents interviewed were mature in age and were likely to observe, understand and evaluate the impacts of mining activities to the environments.

4.3.2 Education level

Understanding education levels of respondents is the key important aspect in assessing their skills and knowledge in judging and reasoning different issues. The results expose that, majority 60 (66.7 %) of the respondents have primary school level, 22 (24.4 %) attended informal education, 7 (7.8 %) acquire secondary education and only 1 (1.1 %) attended adult education (Table 10). Kajembe and Luoga (1996) reported that, education creates awareness, positive attitude, values and motivation, and is perceived as one of the factors that influence an individual’s perception and decision making on a particular development. Thus, education promotes better management of household resources and reduces pressure on the easily accessible natural resources.

Table 10: Social economic characteristics of three villages at Nanyala ward

Parameter	Frequency (N = 90)	Percentages of respondent
Age of respondents		
18-39	42	46.7
40-61	48	53.3
Sex		
Male	35	38.9
Female	55	61.1
Level of education		
Informal education	22	24.4
Adult education	1	1.1
Primary education	60	66.7
Secondary education	7	7.8

4.3.3 Main household's income generating activities

The results in Table 11 show the sources of income for households in the study area were agriculture (87.8 %), mining (7.8 %) and livestock keeping (4.4 %). Mining activities can contribute to household income direct or indirectly for example by promoting petty business and selling of agricultural products. The finding shows few respondents to have access in mining activities as a source of income. This is probably due to education level, capital and mining laws and regulations which do not favor local community to have access and owning mining license. The results are in line with Kitula (2006) study in Geita District who found that, mining communities were involved in diverse economic activities including agriculture, mining, subsistence business activities, and livestock rearing. Msokwa (2008) reported that, few of the respondents (16 %) raised their household income through the mining activities; this has been through employment opportunity in the mine and in the Agroforestry project facilitated by the mining company.

Table 11: The main household income activities of respondents

Household	Frequency (N= 90)	Percentage of respondents
Agriculture crops	78	86.7
Livestock keeping	1	1.1
Mixed farming	4	4.4
Mining activities	7	7.8
Total	90	100

4.3.4 Household land size

The findings of household land size in Table 12 shows that, majority of the respondents 37 (41.1 %) have land size range of 1-2ha, 31 (34.4 %) own land size in range of 2-4 ha, 17 (18.7 %) own land <1ha and 5 (5.6 %) own land size > 5 ha. This implies that majority of the farmers are small scale and of peasant in nature. Mining activities especially limestone has mainly impacted land which was previous used for agriculture causing scarcity of arable land. This has caused land holdings to be highly fragmented such that one household may have different plots in different location of the village.

Access to land in Nanyala ward pose a great challenge due to population growth account for 47 (52.2 %), soil infertility 28 (31.1 %) and mining activities 15 (16.6 %). Focus group discussion provided the evidence of current increase of population growth in the three villages which contribute to the scarcity of land. Moreover, land protected for mining activities especially limestone might have played a greater role on land scarcity by locking up access of potentially usable land as revealed by the focused group discussion.

Table 12: Household land size and reason for land shortage in Nanyala ward

Accessibility to land	Frequency (N= 90)	Percentage of respondents
Size of land		
<1ha	17	18.7
1-2 ha	37	41.1
2-4 ha	31	34.4
>4 ha	5	5.6
Land scarcity		
Population growth	47	52.2
Soil infertile	28	31.1
Mining	15	16.6
Total	90	100

4.3.5 Land acquisition and availability

Findings in Table 13 indicates deferent ways of obtaining land in Nanyala ward; purchasing account for 36.6 %, inheritance from their ancestors account for 35.6 %, village offer account for 20.0 % and 7.8 % through clearing natural forests. Farm encroachment in Marmo forest is highly practiced by local farmers which possibly contributed to vegetation cover change apart from mining activities (Personal observation).

Table 13: Land acquisition system in Nanyala ward

System of land acquisition	Frequency (N= 90)	Percentage of respondents
Inheritance	32	35.6
Buying	33	36.7
Village offer	18	20.0
Clearing natural forest	7	7.8
Total	90	100

4.3.6 Land use before mining activities

Results shown in Table 14 indicates that, majority of households 30.0 % reported that current area under mining activities was previous used as forest land, 21.1 % used for grazing land 14.4 % for agriculture, 4.4 % for settlement and 1.1 % for rituals while 28.9 % of the respondents have little knowledge of the land use before mining activities. One old resident Mr. Halison Mswima lamented that, establishments of the mines in their land have led to serious depletion of dependent natural heritage, forest resources is almost perished because of the ongoing mining activities.

Table 14: Land use before mining activities at Nanyala ward

Land use	Frequency (N= 90)	Percentage of respondents
Mining	27.00	30.0
Grazing	19.08	21.2
Agriculture	12.96	14.4
Settlement	3.96	4.4
Rituals	0.99	1.1
Don't know	26.01	28.9
Total	90	100

Note: *FR= Forest, GR= Grazing, AGR= Agriculture, ST= Settlement, RT= Rituals and DN = Don't know.*

4.3.7 Perception of local people on drivers of land cover change

The perception on what has caused the land cover change in Nanyala ward was as follows; majority shows 50 % mining activities, 27.8 % charcoal burning, 11.1 % uncontrolled bush fires, 6.7 %, fuel wood collection and 4.4 % agricultural expansion (Fig. 10). Human interaction on the land resources has caused tremendous change of land cover in Marmo forest but the most threatening activities is the exploitation of mining.

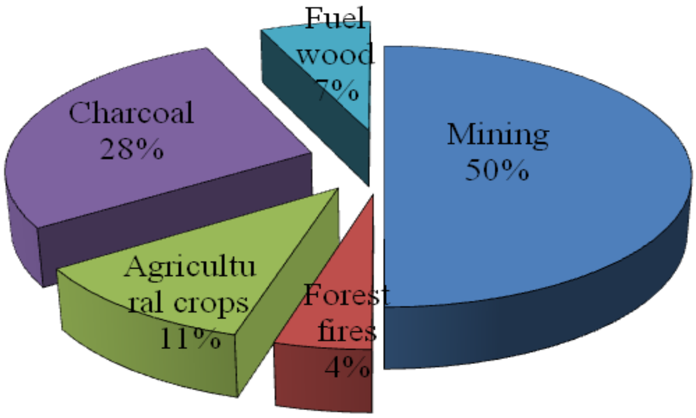

Figure 10: Activities causing land cover change in Nanyala ward

4.3.8 Perception on effects of limestone and granite activities to the environment

Table 15 shows community perception on effects caused by mining activities to the environmental degradation, limestone activity accounted 59 (65.6 %), granite accounted 13 (14.4 %) and 28 (20 %) of the respondents were not aware to the type of mineral posing threat to the environment. This might be due to the fact that, extraction of limestone is done in areas where the quarry is dug from the surface downward creating pits on the earth surface. Local limestone processing requires logs for burning limestone ($CaCO_3$), this has caused tremendous extinction of mature trees in the surrounding villages. Nevertheless, the lime processing dealers have opted to look for alternatives of exploiting mature trees from faraway villages for burning the limestone. The most preferable tree species for burning limestone are *Brachystergia spiciformis, Combretum molle, Jubernadia globiflora, Parinari curitedifolia* and *eucalyptus sp*. Therefore, the ongoing limestone burning process has caused potential forest degradation both onsite and offsite.

Table 15: Comparative effects of limestone and granite mining activities

Type of mineral resource	Frequency (N= 90)	Percentages of respondent
Limestone	59	65.6
Granite	13	14.4
Don't know	18	20.0
Total	90	100

In addition, limestone processing usually is done by burning in the constructed pits with an average size of 3 m x 3.5 m or 10.5 m^2. The entire process consumes a large amount of big logs which are used for burning rocks. Another significant effect of lime making is that, the excavated pits are often abandoned after completion; the study area had low vegetative cover, associated with scattered small trees which therefore make it susceptible to disturbances (Plate 1).

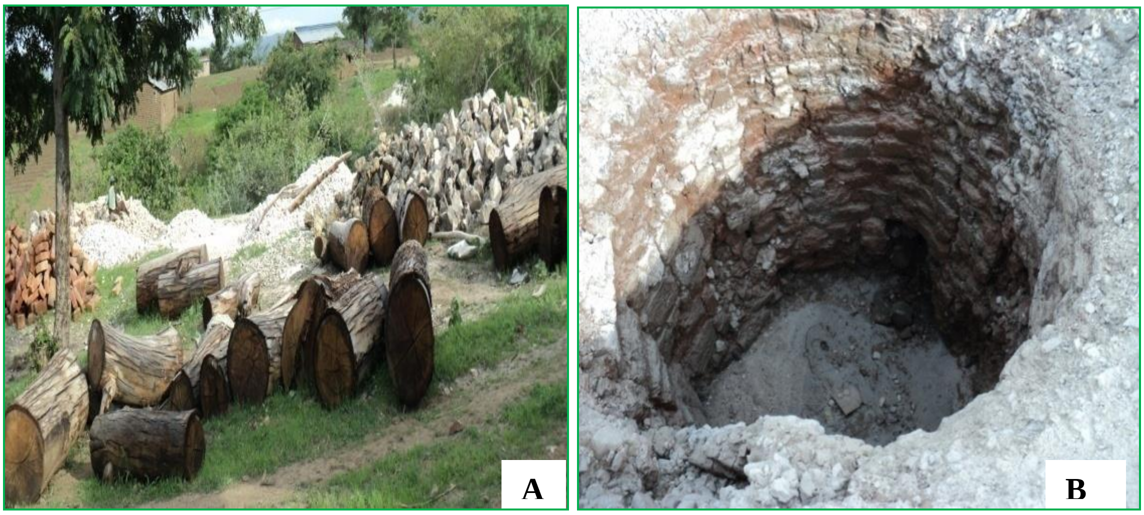

Plate 1: Logs (A) and pit (B) used for burning limestone

The process of granite exploitation involves the use of heavy equipment for stripping the overburden and overlaying vegetation, cutting, loading and transportation of the cut blocks. Although the marble chips are mostly outcropped, vegetation is usually cleared off in order to expose the outcropping marble rocks that are lateral drilled and cut to remove the top weathered part for quarrying to take place. This process continues as the quarrying process expands laterally due to exploitation of the marble to the determined economic depth. Extensive construction of quarry and supportive infrastructure for movement of vehicles is associated with negative interaction of land covers in Marmo forest leading to the total disruption of the landscape and existing vegetation. Given the topography of the area, this has caused some areas to remain bare and formation of extended gullies.

The letters from each photography describes the following phenomena (A) a site photo showing heavy machines (caterpillar) stripping the overburden rocks cutting and reshaping the blocks, (B) a site photo showing reshaped blocks ready for transporting to the Marmo head office at Iyunga street Mbeya region and (C) a site photo identifying grader clearing off vegetation in order to expose the outcropping marble rocks (Plate 2).

Plate 2: **Impacts of marble granite extraction on land cover change in Marmo forest**

Dumping of the granite waste rocks destroys surrounding vegetation and leads to severe land degradation (Plate 3). Due to extensive granite activities large areas of Marmo forest have been degraded and have resulted into unfavorable habitat conditions for plants growth. The weak enforcement of environmental laws and poor coordination from national, regional, district and local levels gives mining companies the freedom to open and abandon mines indiscriminately without due consideration for reclamation (Plate 3).

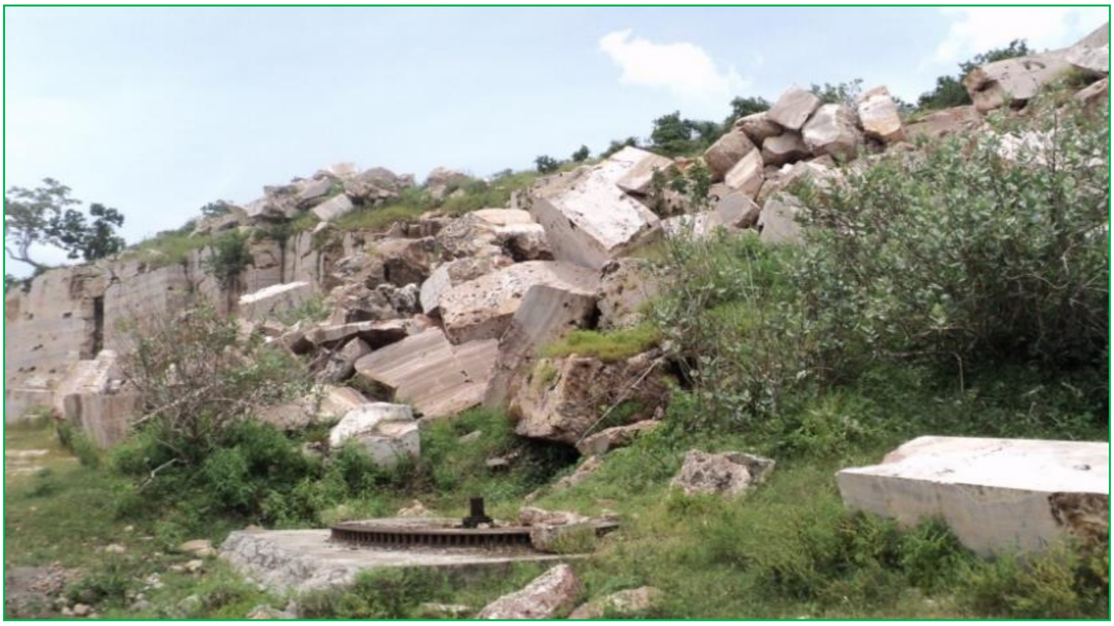

Plate 3: Abandoned rocks on land cover on Marmo forest

The study align with Sarma (2010) who reported that, indiscriminate and unscientific mining, absence of post-mining treatment and management of mined areas makes fragile ecosystems more vulnerable to environmental degradation, hence leading to large scale land cover changes. Kitula (2002) reported that uncontrolled mining and abandoning of pits, cause destruction of land beyond economic and technical reclamation. Berhe (2004) in Calfornia observed that Landmines had threatened the fragile natural environment by changing the land cover through abuse of biotic resources and habitat destruction once landmines are left in the ground. Similarly, Msokwa (2008) was reported that, open cast methods used by gold excavation destroyed the natural forest reserve in Geita District through removing trees during excavation process.

4.3.9 Community perception on importance of mining activities

Perceptions of local people on importance of mining activities is influenced by factors such as customs and beliefs that might affect critical stream opinion on stream of benefits, lifestyle and change of household income status of the communities due to the investment by the mining in their area (Msokwa, 2008).

Results in Table 16 have shown that about 70 % of the household interviewed gain benefits from mining activities while 25.6 % of respondents claimed not to benefit and 4.4 % of respondents knew nothing on the importance of mining activities. Moreover, Focus group discussion argued that, mining company namely Marmo E-granite and Jambo lime have supported the communities through building a dispensary center, school classrooms and provision of school furniture in Nanyala ward. Contrary to the findings reported by Msokwa (2008) in Geita who observed that, communities surrounding gold mining company did not perceive positively the tangible benefit accrued from gold company. Also Mnyika (2006) reported that, local people in Kahama District did not appreciate social services (road network, health services, building school and water supply) from mining investors, since the services offered reflects to facilitate the investor's projects.

Table 16: Community perception on importance of mining

Responses on benefit	Frequency (N = 90)	Percentage of respondents
Yes	63	70.0
No	24	25.6
Don't know	4	4.4
Total	90	100

4.3.10 Community opinions for improving land cover change

The respondents suggestions on the improvement of the present state of the land cover included tree planting 54 (6 %), implementation of environmental bylaws 17 (16.7 %), education in planting trees 16 (17.8 %) and closing the mining activities 5 (5.6 %) (Table, 17). This aligns with the Forest Policy of 1998 and Environmental Management Policy of 1997 which emphasize the need of active and effective participation of local people in conservation and management of the natural resources. Kajembe *et al.* (2003) argued that, collaboration with local communities is the best, most viable, effective, and long lasting way in addressing and solving problems of forest degradation in order to improve forest conservation and sustainable management.

Table 17: Possible alternatives for improving land cover change

Alternatives	Frequency (N= 90)	Percentage of respondents
Planting trees	54	60.0
Awareness raising	16	17.8
Bylaws enforcements	17	16.7
Closing the activities	5	5.6
Total	90	100

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present study has revealed that a considerable portion of the forest cover was converted into non forest during the period of 1991-2011 at Marmo forest in Nanyala ward. Since 1991 mining activities has been increasing and the area affected by mining is increasing from year to year posing a serious threat to the environments. This results into reduction of land cover and forest structure in Nanyala ward.

The comparative analysis from satellite images of 1991-2011 show that area covered by forest and woodland has significantly reduced from 567.55 ha (22.20 %) to 0.13 ha (0.01 %), and 529.94 ha (20.73 %) to 71.01 ha (2.78 %) respectively. Mining area has increased from 0.77 ha (1991) to 517.44 ha (2011). Average number of stem per hectare in un-mined forest area was found to be 151.31 ±31 (SE) and in mined forest area was 25.01 ± 6.276 (SE) ha^{-1}. The mean basal area for un-mined forest area was found to be 2.50 ± 0.26 (SE) m^2/ha and in mined forest area was 0.21 m^2/ha ± 0.01 (SE) while the mean volume for un-mined forest was 9.61 ± 0.19 m^3/ha and 0.51 ± 1.18 m^3/ha for mined forest area. Shannon-Wiener Index of Diversity in un-mined and mined forest area were 1.29 ± 0.63 (SE) and 0.36 ± 0.08 (SE) respectively, indicating high species diversity in un-mined forest area. It has also been observed that, the main drivers of land cover/use change are mining activities accounted 50 %, followed by charcoal burning 7.8 %, uncontrolled bush fires account 11.1 %, fuel wood account 6.7 % and agricultural expansion accounted for 4.4 %. Moreover, the finding show that the majority 70 % of the household interviewed perceived to gain benefits from mining activities while 25.6 % of respondents claimed not to benefit and 4.4 % of respondents knew nothing on the importance of mining activities. Limestone production was perceived to have more adverse effect to the environments compared to the granite extraction, reason behind is due to application of un-recommended level of technology during lime extraction and processing. The most preferable tree species for burning limestone are *Brachystergia spiciformis, Combretum molle, Jubernadia globiflora, Parinari curitedifolia* and *eucalyptus sp*. Therefore, the study reveals that human interaction on the land resources has caused tremendous change of vegetation cover during the period of 1991 to 2011 in Marmo forest. This has resulted in the drastic changes in the land cover dynamics and degradation of forest stocking.

5.2 Recommendations

i Comprehensive Social and Environmental Impact Assessment (SEIA) should, therefore, be undertaken prior to the project implementation. Since mining activities started operation without conducting EIA, The study suggests conducting environmental auditing and mitigation studies against these damages. Regular inspections should be executed to keep these activities of mining under control as stipulated in Environmental Management Act No 20 of 2004.

ii Mbozi District management authorities should institute management practices in three villages adjacent to mining, such as planting of local trees species. This could be a solution to overcome the present problems of forest degradation which will save the future sources of energy and ecosystem resilient in the study area. This also complies with Forest Policy of 1998 which stipulate that forest/tree cover shall be increased through afforestation, proper management and law enforcement.

iii Negative effects of mining activities include depletion and destruction of finite resources like vegetation cover and forest structure. The activities jeopardize the natural resources needed for future generation. Therefore, it is important to evaluate how the community will be affected after closing the mines and to propose the ways of ensuring their sustainability after mine closure. Also, the law enforcement to the project owner should be adhered as stipulated by the Environmental Management Policy of 1997, Act No 20 of 2004, Forest Policy of 1998, and Mining Policy of 1997 to ensure sustainable exploitation of mining and sustainable conservation of Marmo forest.

iv For limestone production company should identify potential alternative sources of energy to be used (Electricity and coal) or establish forest plantation to substitute indigenous trees for burning limestone ($CaCO_3$) and cooking.

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APPENDICES

Appendix 1: Attached field form for forest inventory

Plot no …… Transect No …… GPS (X) Easting …. GPS (Y) Northing …… Plot area …… Forest stratum name ………

Tree No	Local name	Botanic name	DBH	HT	Tree species with radius dbh			
					≥4<10cm	≥10<15cm	≥15<20	>20cm

Appendix 2: Household interview schedule

A. General information.

1. Name of enumerator ……………………………
2. Date of interview ………………………………
3. Village name ……………………………………
4. Sub village name ………………………………
5. Ward name ……………………………………
6. Division name ……………………………….
7. District name …………………………………
8. House identification No ………………………

A. Socio-economic characteristics of respondents

1. Name of head of household (respondent) ………
2. Sex (1) Male (2) Female …………………………
3. Age ……………………………………………………. Years
4. Ethnic group …………………………………
5. Marital status:

1. Single ……………..……………….

2. Married ……………………………

3. Divorced …………………………..

4. Widowed …………………………

6. Highest Education level reached

1. Non formal education
2. Adult education
3. Primary education
4. Secondary education
5. Others (specify) ……………

C. Social economic activities

1).What are the main household income activities?

(1) Agriculture crops

(2) Livestock farming

(3) Mixed farming

(4) Wage employment (5) Small business (6) Mining dealers

2). Do you own land?

(1) Yes………… (2) No ………………………

3). what is the size of your land?

(1) (1) Below 1ha (2) 1 – 2 (3) 2- 4 (4) 5 and above

4). Is the size of land you have enough ………………………

5). If not why? …………………………………………………

6). How was the land acquired?

(1) Inheritance (2) Buying (3) Village offers (4) Clearing natural forest

E. Community perception on impacts of mining land use / land covers change

1. What was the land uses before mining activities

   (1)Grazing (2) Forest (3) Settlement (4) Agriculture (5) Rituals (6) Grassland

2. What is the present state of the forest cover near the village 1 Good 2 Bad?
3. How do you assess degradation due mining activities?

   (1) Low (2) Moderate (3) High (4) Excessive

4. Out of the following factors, what do you think is mostly causing forest cover change?

   (1) Mining activities (2) Forest fires (3) Agricultural activities (4) Charcoal

5. Pole and timber cutting (6) Fuel wood (7) Livestock
6. Compare the land use/ cover at present (2011) and before the mining activities 1991 1. Healthier at present, 2. Worse at present 3. The same, 4. Don't know

7) Do you think is there any important to plant trees for regeneration in mining site?

   1 …. Yes ………2 No …………..

8. Is mining activity an important activity? 1Yes …. 2 No …………
9. How do you comment on level of benefit obtained from mining at your area

   (1) Satisfactory (2) Unsatisfactory (3) Don't know

10. Do you think mining activities are dangerous to the environments?

    (1) Yes (2) No

11. What are your comments regarding to mining impacts on land use and land cover?

Thank you very much for participating in this very important group discussion

Appendix 3: Checklist for key informants

1) When did you start mining activity?

2) What environmental impacts occurred due to mining activities?

3) What are the impacts of mining project to the environment?

4) What is the present state of the forest cover around the mining area?

5) After the Decommissioning of the mining projects what was the agreement on the rehabilitation of mining projects

6) What are the potential mitigation measures to address the problem regarding to the mining impacts.

7) Thank you very much for your participation

8) How many authorized miners (by mining department) currently are conducting mining in Mbozi District?

9) What are the potential negative environmental impacts of mining project?

10 What might be the causes of all these changes?

11) What are the management strategies to combat mining activities and associated impacts?

Thank you very much for participating in this very important group discussion.

Appendix 4: Attached field form for ground truthing form

ID	Site location	Easting	Nothings	General feature/ description
1				
2				
3				

Appendix 5: Accuracy assessment

S/N	Easting	Northing	Classified	Observed
1	522621.24	9010787.85	Mining	Mining
2	522621.25	9011238.47	Grassland	Grassland
3	521851.45	9011313.57	Mining	Mining
4	522133.08	9011313.57	Settlement	Settlement
5	521194.31	9010994.39	Bushland	Bushland
6	520499.61	901125.81	Cultivated land	Settlement
7	520161.65	9011069.49	Cultivated land	Cultivated l
8	529973.9	9010374.79	Forest	Forest
9	529448.18	9010487.45	Woodland	Woodland
10	520161.65	9009924.18	Woodland	Woodland
11	529523.28	9012120.27	Settlement	Settlement
12	522902.88	9011670.31	Grassland	Graasland
13	522996.76	9012120.99	Settlement	Settlement
14	522546.47	9012609.08	Settlement	Settlement
15	521382.66	9012965.82	Bushland	Bushland
16	521438.39	9013059.69	Bushland	Bushland
17	521628.146	9013660.52	Mining	Mining
18	521119.207	9014223.78	Mining	Mining
19	521006.55	9014937.25	Grassland	Grassland
20	521119.207	9014111.12	Mining	Mining
21	521588.59	9014017.25	Woodland	Woodland
22	522884.107	9014073.57	Mining	Mining
23	52334.72	9014073.57	Bushland	Bushland
24	523034.31	9014355.21	Mining	Mining
25	522245.96	9015256.48	Woodland	Woodland
26	523484.92	9016157.66	Grasland	Grasland
27	523991.04	9016946.23	Grassland	Grasland
28	522959.21	9016570.74	Mining	Mining
29	523315.94	9016570.72	Mining	Cultivated land
30	524029.41	9017378.67	Woodland	Woodland
31	522020.43	9017791.13	Grassland	Grassland
32	521475.94	9015538.06	Mining	Mining
33	522020.43	9017396	Grassland	Cultivated land
34	523278.39	9017340.52	Forest	Forest
35	522658.8	9015688.27	Mining	Mining
36	522245.73	9015200.1	Forest	Forest
37	521964.11	9015988.68	Grassland	Grassland
38	522433.494	9013942.14	Forest	Forest
39	522114.31	9014542.97	Bushland	Bushland
40	422564.92	9015838.47	Mining	Mining
41	521569.82	9014505.41	Mining	Mining
42	521438.39	9013698.01	Mining	Mining
43	522790229	9013059.69	Mining	Mining
44	523184.515	9012196.02	Cultivated land	Cultivated land
45	5228090.04	9011294.79	Forest	Forest
46	522151.86	9010055.61	Cultivated land	Cultivated land
47	520086.55	9011069.49	Cultivated land	cultivated land
48	521626.14	9015162.55	Grassland	Grassland
49	520011.45	901820.51	Settlement	Cultivated land
50	521663.69	9013960.92	Forest	Forest
51	522546.14	9011820.51	Forest	Woodland
52	521663.69	9013960.93	Forest	Forest
53	521701.24	9011933.166	Cultivated land	Cultivated land
54	522320.84	9015406.63	Forest	Forest

List of Tree species in mined and unmined strata in Marmo forest

Un-mined			Mined area		
Local language (Nyiha)	Botanic name	Frequency	Local name	Botanic name	Frequency
Ilamailyanavuli	*Combretum molle*	*45*	*Ilamailyanavuli*	*Combretum molle*	2
Mlamailyantanda	*Combretum adenogonium*	*54*	*Mlamailyantanda*	*Combretum adonogonium*	10
Ichisya	*Terminalia sericea*	*76*	*Nahaumba*	*Lannea schimperi*	3
Ipulula	*Terminalia mollis*	*26*	*Itukutu*	*Bauhinia thonningii*	3
Nahabhumba	*Lannea schimperi*	*20*	*Ibanku*	*Ozoroa Insignis*	10
Ininga	*Pterocarpus angolensis*	*1*	*Ipumbambuzi*	*Senn asingueana*	3
Itukutu	*Bauhinia thoningii*	*19*	*Igunga*	*Acacia tortolis*	2
Itanji	*Dombeya rotundifolia*	*7*	*Ibhale*	*Lonchocarpus bussei*	1
Ibanku	*Ozoroa insignis*	*3*	*Itonto*	*Commiphora africana*	2
Ipumbambuzi	*Sennasingueana*	*4*	*Iwawa*	*Cussonia spicuta*	3
Igunga	*Accacia tortilis*	*5*	*Itonto*	*Commiphora mollis*	3
Ng'enenge	*Diospyros fischeri*	*6*	*Ilangali*	*Euphobia triculii*	1
Ibhale	*Lonchocarpus bussei*	*6*	*Intulembe*	*Diplorhynoclms condylocarpus*	3
Itonto	*Commiphora africana*	*33*	*Sehawanga*	*Albizia harveyii*	6
Isebhe	*Erythrina abyssinica*	*24*	*Ipangala*	*Dichrostachy scinerea*	7
Iwawa	*Cussonia spicata*	*17*	*Mchese*	*Accacia albida*	6
Myela	*Sterculia quinqueloba*	*21*			
Itonto	*Commiphora mollis*	3			
Itukutu	*Afzelia quanzensis*	6			