BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

EFFECTS OF ARTISANAL GOLD MINING ON WOODY VEGETATION STRUCTURE AND SPECIES DIVERSITY: A CASE STUDY OF GARATI AREA, BINDURA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HOUNORS DEGREE IN FORESTRY AND ENVIRONMENTAL MANAGEMENT.

30 MAY 2025

APPROVAL FORM

The undersigned certify that they have read and recommend to Bindura University for an acceptance of a dissertation entitled, '*Effects of Artisanal gold mining on woody vegetation structure and species diversity.*' Submitted by Munjoma Natsai Olivia**,** Registration Number **B225121B** in partial fulfilment of requirements for **Bachelor of Science Honors Degree in Forestry and Environmental Management.**

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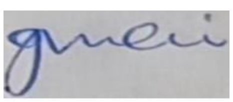

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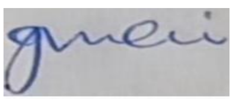
DECLARATION

I Munjoma Natsai Olivia declare that the dissertation titled Effects of Artisanal gold mining on woody vegetation structure and species diversity is my own work and all sources used have been duly acknowledged. It has not been submitted for academic purposes at any other institution before.

Munjoma Natsai Olivia 15/10/25



DEDICATION

‘’ I would like to dedicate this work piece to my late mother, whose guidance has shaped me into the person l am today, thank you Mom. My heartfelt gratitude goes to my beloved husband Christopher Munjoma, whose patience, encouragement, and love have been my rock throughout this journey. And to my precious children Jayden, Aaliyah, Delean and Alvin, who have been my inspiration and motivation. This work is a testament to the love and sacrifices of our family.’’

ACKNOWLEDGEMENTS

My heartfelt gratitude goes to my research project supervisor, Mr. A. Kundhlande, for his sterling effort in making my project successful. His knowledge, skills, patience, support and guidance made me focused and confident and without him, my work would not have been a success.

I would also like to thank Allied Timbers management for provision of time to carry out my studies and all the staff members from Cashel Estate who assisted unconditionally.

Gratitude is also extended to all my lecturers at BUSE, the likes of Mr. A. Kundhlande, Doctor L. Mujuru, Doctor A. Mureva Professor L.Jimu for their guidance, support and endless mentorship during the whole period of my studies.

I am also grateful to my fellow colleagues R. Machokoto, T.Makumbe, P. Chiwes, T. Sithole and A. Mvududu who have provided valuable feedback and encouragement during my project.

And l also acknowledge my family: my father Mr. E. Mungwari, Mr and Mrs Munyanyi, Mr and Mrs Muchemwa, Mr and Mrs Mazodze, Mr and Mrs Kafesu and Bliss Bundukutu for thei unwavering support and love.

''Above all, l would like to thank the Almighty God , the source of all wisdom and knowledge, for granting me life, strength, guidance and perseverance to complete this research project.''

ABSTRACT

This study aims on assessing the impacts of artisanal mining on structure and species diversity of woody vegetation in Garati area, Bindura, northeast Zimbabwe. Woody vegetation species data were collected, the plots were measured and divided into a total of 30 plots, sample plots were randomly selected. Square Quadrats plots of 20m by 20m were adopted for stock data collection in, 15 for the exploited area and 15 for the unexploited area. Both matured plants and saplings were recorded during the study. The study tested the hypothesis that density and diversity of the woody tree species in the mined and unmined areas. A total of 332 woody trees were recorded, 232on the unmined area and 74 on the mined area. The extent of vegetation affected by the activities of illegal small scale miners was assessed. The Simpsons reciprocal diversity index of tree species at mined area was 0.67 as compared to 0.93 for the unmined area. Common woody tree species were identified in both areas as designated by the calculated Jaccards similarity index of 0.55. However woody species density of 0.12 per $100m^2$ and 6.7 per 100 m^2 was recorded in the mined and unmined areas respectively. Shannon H diversity index for woody vegetation species diversity ($H' = 1.11$) and ($H' = 3.89$) for mined and unmined areas respectively. The null hypothesis that there is no significant difference of artisanal small-scale mining on woody tree species density is rejected at the 0.05 significant level, indicating that artisanal small-scale mining significantly affected woody vegetation cover. It is recommended that efforts should be made to reclaim the degraded lands through an effective environmental laws and forestry laws.

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LIST OF ABBREVIATIONS

DBH Diameter at Breast Height

SPSS Statistical Package for Social Science

SE Standard Error

EMA Environmental Management Agency

ASM	Artisanal Small-scale Mining
FAO	Food and Agriculture Organization
ZEGU	Zimbabwe Ezekiel Guti University
ZRP	Zimbabwe Republic Police
EMP	Environmental Management Plan
FRP	Forest Restoration Plan

1. CHAPTER ONE: INTRODUCTION

1.1 Background

Globally forest coverage is approximately 3.4 billion hectares (Cui et al., 2018), more than 850 million hectares have been degraded due to human encroachment including artisanal mining. It is estimated that 18 million acres of the forest is destroyed each year (Zhou et al., 2019). The presence of gold deposits of the Basement complex discovered in Bindura, has attracted a lot of unemployed youths, adults and small-scale mining ventures to the areas such as Garati, Bindura.

Vegetation is the base of all food chains, the producer, for it has the ability to convert solar energy into chemical energy (CNCV, 2013). Not only does it provide oxygen, rather it sequestrates carbon, one of the green-house gases thereby regulating climate. Therefore woody vegetation has great importance to the local people and the surroundings. The Garati area, in the midst of the Miombo woodlands, is suffering the scourge of artisanal mining. Artisanal mining activity, affectionately known as “chikorokoza”) in the country has resulted in environmental degradation and deterioration of biological communities.

The dominant species in the Miombo woodlands are *Julbernardia* and *Brachystegia* (Frost, 1996). Apart from wood fuel and timber, the local people also benefit from non-wood forest products such as honey, mushroom, insects, herbs and fruits (Akkinnifesi, 2006). The nation at large benefits through ecological based tourism since the Miombo woodlands are home to thousands and thousands of animal species including impala, hyena and bird species such as eagles, crows, owls.

The President along with his regional counterparts signed an agreement at the High- Level Session of the Regional Conference on the Sustainable and Regional Integrated Management of Miombo Forests, in a bid to protect these woodlands, in Maputo, on the 5^{th} of August 2022 (The Herald, 2022). This was done following the excessive cutting down of trees and burning of forests for many purposes including mining. Maintaining the vegetation structure and composition of these woodlands and their sustainable use has proven to be difficult (Munishi et al, 2010).

Artisanal mining has evolved significantly since the last two decades due to the deterioration of the economy of Zimbabwe (Mining Zimbabwe, 2018). In order to survive, the locals have turn to unsustainable mining leading to the degradation of the environment woody vegetation species structure and diversity. Gold mining has become the order of the day in Bindura area to boost their standards of living. In addition, another drawback of gold mining activities in Garati like exploitation, transportation, smelting and refining processes, as well as tailings and waste-water disposal, is the resultant heavy metals which pollute the environment (Sunga and Marinda,1998).

Various studies have been conducted on vegetation density and distribution of artisanal mining areas by several workers in different parts of Zimbabwe as well as in other parts of Mashonaland province. The Environmental Management Agency, ecosystem protection unity and the Forestry commission have also conducted researches and the Garati area has left with a gap on woody vegetation species diversity and woody vegetation structure, therefore a comparative analysis has to be conducted in order to fill in the gap left.

1.2 Problem statement

Although there is legislation, illegal gold mining is still prevailing. Environmental Management Agency illegal mining blitz and penalties are not stopping people from carrying out illegal mining activities. There is inadequate documentation on how these activities are impacting vegetation structure and species diversity in Garati area.

1.3 Justification

This study will provide information that help formulate and strengthen policies governing mining and environmental protection effectively and efficiently. This information is important for organizations whose mandate is environmental protection, such as EMA, organizations that regulate forest resources, such as Forestry Commission. The study will also help to promote sustainable utilization of forest resources, especially vegetation.

Various studies have emphasized on the need to assess the vegetation structure and species diversity of an ecosystem. Measures of vegetation structure provide information on habitat suitability, ecosystem productivity and successional pathways while species diversity provide information on susceptibility to invasion and trophic structure. The study also examines how the unsustainable exploration of minerals can have damaging and irreversible deleterious effects on vegetation.

If we are to consider the tragedy of commons by Hardin and limit to growth, important moral and ethical issues will arise. Similarly, with the rate at which illegal gold mining is taking place, the end result is doom. This study will help avoid that situation.

1.4 Aim

To assess the effects of illegal gold mining on vegetation structure and species diversity in Garati area, Bindura

1.5 Objectives

1. To determine the impacts of illegal gold mining on vegetation structure
2. To examine the impacts of illegal gold mining on vegetation species diversity
3. To come up with species evenness variations and relative abundance

2. CHAPTER TWO: **LITERATURE REVIEW**

2.1 Definition of terms

Artisanal small-scale mining (ASM) defines mining by individuals, families, groups and cooperatives with a minimal, also frequently refers as informal sector of the market (Hentschel et al. 2002).

Surface mining refers to excavation on earths above ground (open-cast mine) in order to access, producing any mineral from a natural deposit (Walle and Jennings, 2001).

Underground mining refers to excavating below the ground surface for example shaft mining (Walle and Jennings, 2001)

Forest describes an area which is greater than half hectares with average trees taller than 5 meters and a brooder canopy which is more than 10% (FAO, 1996).

Deforestation refers to the loss in vegetation through the clearing of land. It is usually occurs when massive clearance through burning and logging to create land for new activities (Boyle, 2017).

Land degradation is the deterioration or reduction in the quality of the environment owing to both human induced and natural factors (Gandiwa et al., 2014).

Woody plant species are referred to as hard stem in the sense that they produce wood as the major structural tissue (Ben-Shahar, 1998).

2.2 Effects of artisanal gold mining

Artisanal gold mining activities are maximizing daily and these have negative effects on the forests with the most abundant biological diversity in the world. Five main mining hotspots in some of the world's most richest forests, includes the the Congolean forests in Western Central Africa, tropical moist forests in the Guyanan and Andean regions in Latin America, the boreal forests in the Far East and Siberian Russia, in Northern Canada and the moist and dry forest, mountain and mangroves and lowland forests in the Pacific Rim (FAO, 1999).

Despite the fact that illegal gold mining has economic potential, it is a threat to the environment (Sunga and Marinda, 1998). A large number of the population in Zimbabwe has resorted to illegal gold mining in a bid to withstand the country's deteriorating economy. Bindura town, being part of the Basement Complex is no exception (Mining Zimbabwe, 2018). Research has it that illegal gold mining activities are poverty driven. Other driving forces include poor agricultural yields owing to climate change and the country's soaring inflation.

Peasant miners are digging up tunnels that are now encroaching farmlands, town buildings, the two universities and residential areas. This consequently has detrimental effects on livelihoods and ecosystem services which includes vegetation. One can also note that the farmers whose farms are invaded are also resorting to mining (Madava, 2012). Illegal gold mining has contributed to environmental issues such as deforestation, soil erosion, siltation of rivers, gulley formation, both surface and groundwater contamination among others (Cobbina et al, 2012).

Prime environmental issues which are triggered by artisanal mining include mercury pollution and reduction in quality of land owing to the process of gold purification (Cobbina et al, 2012; Gandiwa et al, 2014). Consequently, not only are people highly exposed to mercury in the shallow trenches in mined areas, but also are at risk of tripping and falling into the tunnels from underground mining (Mathe and Phiri, 2016).

Globally, there has been reported cases of waterlogged trenches, soil erosion; poisoning of fresh food items that can be consumed (Essumang et al., 2007), rivers and other water bodies that serves as sources of drinking water for communities in mining areas (Obiri et al., 2010). Side effects of artisanal mining to the natural environment are exceedingly extreme in less developed nations of which these constitute the majority of mineral wealth world over (Paruchuri et al., 2010).

Biophysically artisanal mining has resulted in to the disruption of different communities in the area where mining is occurring (Hilson, 2002). Water contamination has become a problem due to lack of proper waste water disposal, this has also led to a sharp increase to different water borne diseases such as typhoid. Not only affecting people but also the soil fertility is reduced leading to a high increase in acidity (Obiri et al, 2010).

2.3 Effects of illegal gold mining on vegetation structure, species diversity and abundance

The percentage of each species in the vegetation is known as the vegetation composition (Coulloudon, 1999).The spatial distribution of plants and their components on land, and of aquatic biomass is known as vegetation structure (Wessels, 2010). Also, vegetation structure refers to how the plants are arranged in three-dimensional spaces (Coulloudon, 1999).

Artisanal mining operations cause serious impacts on vegetation loss and disturbances since soil productivity will be lost when the top cover of soil is removed. Mining changes the natural outlook of the environment since it removes the protective layer thus exposing the underground unscathed material (ERM, 2013). Erosion of soil, overburden as well as ore contributes to disposition of the eroded material in water bodies resulting in changes in the drainage system which will further cause decimation of vegetation. Adding on, spills and leaks of hazardous materials can lead to extensive leaching, leading to death of herbal species and saplings (Mathe and Phiri, 2016)

The decrease in water table due to unsustainable mining has brought stress to water loving woody vegetation species such as *Ficus sycomorus* leading to relatively low distribution in the exploited areas. Artisanal mining has on the contrary given rise to pollution by heavy metals owing to activities like extraction, smelting, transportation, purification as well as disposal of tailings. To add on, this will result in reduction of the water table, thereby resulting in withering of the plants owing to moisture deficiency (Hilson, 2001).

Surface mining disturbs the outlook of enormous tracts of land creating huge quantities of waste which will be washed away into water bodies (Charis, 1994). The eroded waste can lead to tree lodging resulting to increase of dead trees in the area. Mining has detrimental effects and the extent of the damage to the environment is highly dependent upon the methods employed by the artisanal miner (Bell et al., 2001)

It is important to note that the intensity and magnitude of negative effects of mining also stems from the condition of the mine that is whether it is operating or abandoned, as well as the geology that is rock type and soil type (Bell et al. 2001). Waste rock or tailings dumps not only affect plant communities but animal natural habitats, creating imbalances in the ecosystem. Consequently, distribution of species significantly is reduced and the area in question degrades continuously, for the foreseeable future (Ruiz-Jaén et al, 2005).

Unemployed Ghanaian youths were pulled to the Nangodi area, since gold deposits had been discovered (Gyasi et al., 2006). They were undertaking strip mining, which is a type of surface mining, whereby they extracted the ore by exhuming underlying vegetation as well as rock. As a result, large tracts of vegetation were removed and buried thereby turning the natural environment devoid of trees and lifeless (Greenwood and Edwards, 1979). Greater portions of the vegetation cover in the mined areas lose its properties to be used for any other purpose (Charis, 1994). Furthermore, water which is a necessity is severely impacted by artisanal mining in Ghana, in terms of its quantity and quality aspects. Authors supporting these have it that the quality and quantity of water bodies in any given mining community is in dire state (Davis et al., 1994).

According to studies done in India's Shankargarh Forest, the area's undisturbed forest has a higher plant species richness than the area's disturbed forest (Dubey and Dubey, 2010). With the greatest IVI value in an undisturbed forest, Butea monosperma predominated the region, followed by *Flacourtia indica*. In this region the dominant species were also *Dalbergia sissoo*, *Acacia nilotica*, *Acacia catechu*, and *Prosopis juliflora*. With a 0.023 Whitford index, *F. indica* has a consistent distribution pattern. While the Whitford index for other tree species, which ranges from 0.025 to 0.05, exhibits a random distribution pattern in the mined and unmined area. In contrast, B. monosperma and *F. indica*, which grow in disturbed areas (mined area), have IVI values that are nearly identical, respectively, at 51.65 and 51.28, and they have the same structure across all areas. Based on that, B. monosperma was distributed equally as of the Whitford's index value (Dubey and Dubey, 2010).

Other studies conducted in the Jaintia Hills district of Meghalaya, in the country's northeast, the density of woody vegetation was significantly higher (1040 stems ha-1) in the unexploited area than it was in the exploited area, where it varied 515 and 646 stems ha-1. Although the density of the mined area was rich with herbaceous species (154-178 individual m-2) than in the unmined (32 individual m-2) area, the density of saplings did not differ significantly between the locations. Plants are affected differently with mining activities, shrubs and herbs are affected less by mining activities whereas tress are highly affected. Hence areas with high woody tree vegetation are ussualy affected most (.Sarma et al. 2010).

Basing on the trends of land degradation caused by illegal mining in Zimbabwe, the biophysical indicators which shows land degradation includes vegetation loss (grass, shrubs and trees), biodiversity loss, gully formation. According to the Environmental Management Agency of Zimbabwe indicated that erosion and vegetation loss has increased mostly in the Midlands province and all along the great dyke (Mkodzongi and Spiegel, 2018).

3. CHAPTER THREE: METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

3.1.1 Location

Study area; Garati area is located in a mining town Bindura in Mashonaland central, Zimbabwe. It lies between Ran mine and Zimbabwe Ezekiel Guti University (ZEGU), 17° 19' 4.6056 latitude and 31° 21' 42.4944 longitudes. Bindura is a mining town due to its basement complex. It is situated approximately 88km north east of the capital Harare. Garati area is approximately 1,4km away from the heart of the town due north east.

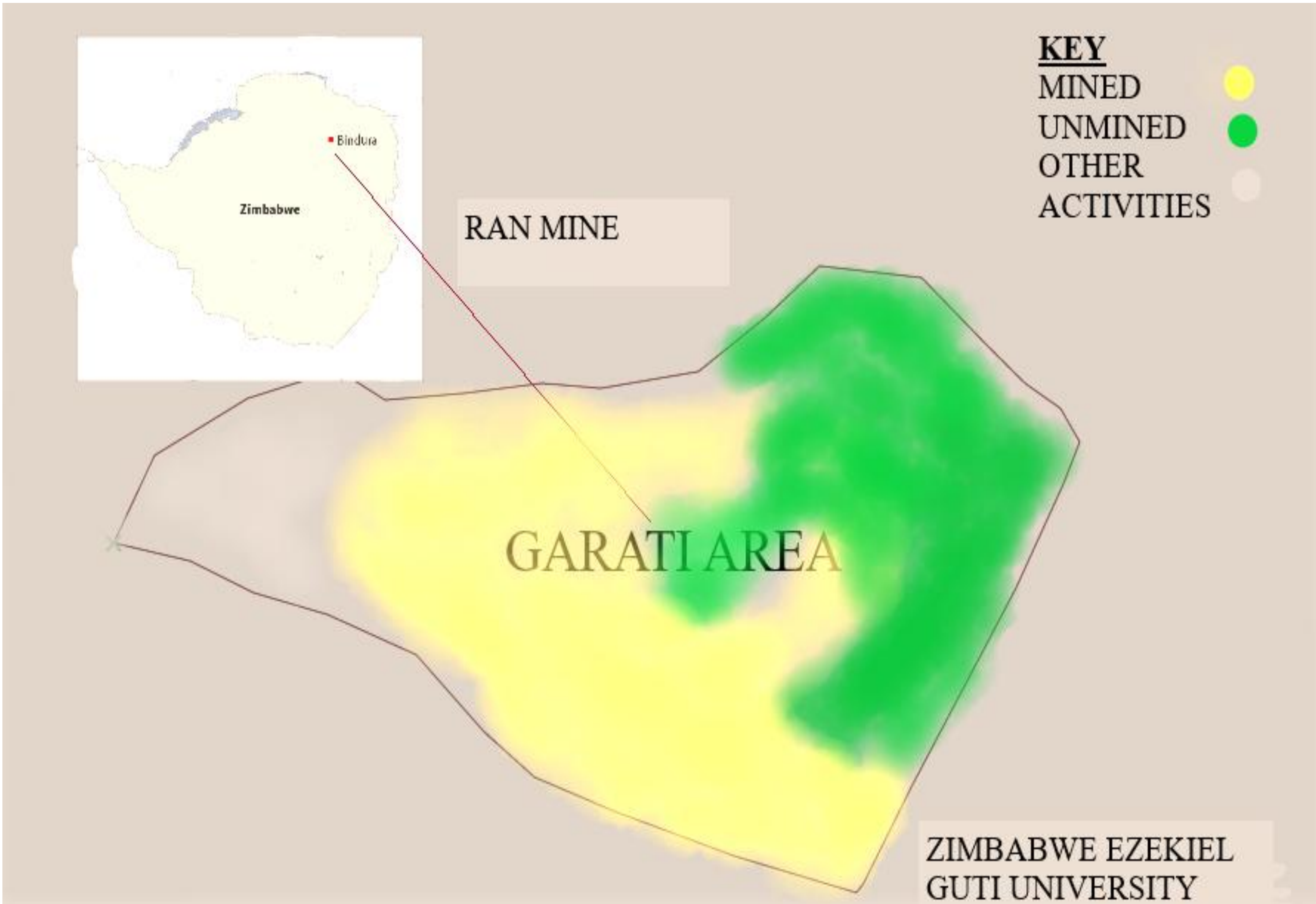


Fig 3.1 Map showing location of Garati area

Garati area is typical miombo woodland which is mainly dominated by *Brachystegia spp*, *Julbernardia globiflora, Bauhinia petersiana*, *Pilliostigma thoningii*, *Vachellia tortilis* and other important indicator species such as *Ficus sycomorus*. The area is also found in a Hyparrhernia grassland dominated by species such as *Hyparrhenia filipendula*, *Heteropogon contortus*. *Cynodon dactylon*, *Bothriochloa radicans*, Animal species area also found in the area mainly R species, mouse, lizards.

The area is one of mining claims around Ran mine. This is a claim which was given by the Ministry of Mines and Mining Development under Zimbabwe Miners Federation. The area is found on the north east of the Bindura town, along Shamva road. The area of the study lies within Zimbabwe basement complex which is characterized by patterned wet and dry seasons. The average annual precipitation is 750mm which mostly occur from December to March, also the average maximum temperature is 28.0oC and the average minimum temperature is 12.5oC, the hottest months October and November whereas June and July are the coldest (Mugandani et al., 2012)

The activities which takes place in Garati area includes urban agriculture, religious shrines (Johanne Masowe echishanu Vadzidzi vaJesu and Johanne Masowe enguwochena), illegal dumbing site for domestic waste and artisanal mining which is the major activity. Both underground mining and surface mining are practiced by artisanal miners. Extraction and processing is done on the same area.

The geological backbone of Zimbabwe is the basement complex, it consists of a large area of gneissic rocks which includes 32 linear greenstone belts and Bindura is among the 32. Greenstone belts are also known as gold belts, also the schist belt moves across via Bindura. The soils found in the area are very deep, welldrained and vertisol red loam soils with distinct horizons beneath a topsoil plentiful in organic matter (Jelsma, 1993).

3.2 RESEARCH DESIGN

A forest inventory was carried out to gather data on a variety of woody vegetation species and those which have been disturbed by artisanal mining. The survey involve the laying out of transects on the map and plots on the ground of the forest area. Simple random sampling procedure was used on collecting data. The study area was divided into two plots; the two strata were defined according to the level of exploitation. These areas include the Garati exploited area which is highly deforested (mined area) and the Garati unexploited area (unmined area).

The plots was measured and divided into a total of 30 plots, sample plots was randomly selected. Square sample plots of 20m by 20m was adopted for stock data collection in Garati area, fifteen for the exploited area and fifteen for the unexploited area. Tools used during the survey was four metal pegs, a 80meter ribbon was used to demarcate the quadrats and a 30meter tape measure was used in measuring the perimeter of the quadrat, these tools was used on measuring all plots (Zisadza-Gandiwa et al, 2013).

Woody tree species was recorded in the woody strata, trees and their samplings was recorded by their scientific name stating its distribution per hectare. Plant status (dead or alive), canopy diameter was measured and recorded, species richness and a six meter pole was used to measure tree height.

3.3 SAMPLE DATA ANALYSIS

Collected data was summarized and examined for normality using Jaccard Index to analyze species diversity similarity, Shannon-Weiner diversity Index was used to determine species diversity richness in different plots (Ludwig and Reynolds 1988). Simpson D index was used to measure species evenness across the area, SPSS was be also used to test for differences means in species height, a Diameter at Breast Height, canopy diameter and relative abundance of the areas (Gandiwa, 2011).

Observations and photographic pictures of environmental deforested and degraded lands as a result of artisanal mining were captured during the survey.

4. CHAPTER FOUR: RESULTS

4.1 Species diversity

Bauhinia petersiana, Ficus sycomorus, Vachellia tortilis, Piliostigma thonningii, Vachellia karro, and *Lantana camara* were common in all areas. The calculated density of woody vegetation richness in the mined area was 0.12/100 m^2 while unmined area recorded 6.7/100 m^2. Table 4.1 illustrate the woody species identified during the survey and their density

Table 4.1.; Woody vegetation identified during the study per hectare and their densities.

Species name	Exploited	Unexploited

Bauhinia petersiana	**2.7**	**4.2**
Vachellia tortilis	**0.6**	**9**
Senegalia nigrescens	**0**	**1.5**
Piliostigma thinningii	**2.1**	**8.4**
Mangifera indica	**0.2**	**0**
Psidium guajava	**1.8**	**0**
Azanza garckeana	**0.2**	**2.4**
Ficus sycomorus	**2.4**	**3.6**
Dichrostachys cinerea	**0**	**1.8**
Ziziphus mauritiana	**0.2**	**0.9**
Strychnos spinosa	**0.2**	**0.2**
Vangueriopsis lanciflora	**0**	**2.1**
Ziziphus mucronata	**0**	**0.4**
Albizia harveyi	**0**	**1.2**
Vachellia karro	**0.6**	**3.3**
Melia azedarach	**0**	**0.2**
Combretum collinum	**0**	**1.5**
Terminalia sericea	**0**	**2.1**
Kigelia Africana	**0**	**0.9**
Brachystegia boehmii	**0.2**	**2.4**
Julbernardia globiflora	**0**	**0.9**
Diospyros mespiliformis	**0**	**0.9**
Erythrina abyssinica	**0**	**0.6**
Lantana camara	**13.9**	**23.8**
Diplorhynchus condylocarpon	**0**	**2.4**
Flacourtica indica	**0**	**1.2**
Pterocarpus angolensis	**0**	**1.2**

The significant difference in species diversity and richness were noted across the two areas, Simpson's diversity index on the woody vegetation species diversity of the exploited area and unexploited area to be 0.67 and 0.93, respectively. On Shannon H Diversity index the highest diversity was recorded in the unmined area, the significant differences between mined and unmined sites were 1.11 for mined area and 3.89 for the unmined area. Moreover, the Jaccard index of similarity was calculated comparing the two areas, a 0.55% similarity between the two sites. The null hypothesis stated that there is no significant difference of artisanal gold mining on tree species density is rejected (P<0.08) at the 0.05 significant level, indicating that artisanal gold mining significantly affect the tree densities.

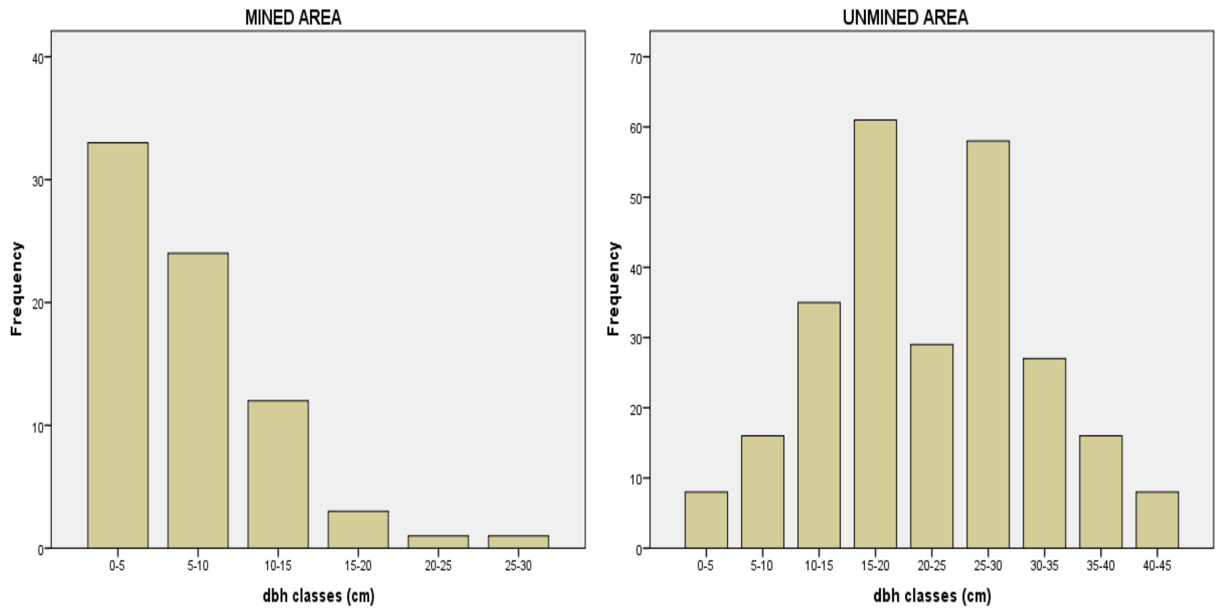
Table 4.2; Species diversity, evenness and similarity index across the two areas

AREA	SHANNON H	SIMPSON D	JACCARD
MINED	**1.11**	**0.67**	**0.22**
UNMINED	**3.89**	**0.93**	**0.77**

4.2 Vegetation structure

Unmined area DBH class of 15-20 had the highest tree species with a maximum of 60 woody plants in the area, followed by 25-30 DBH class with a total number of 57 woody plants in the area. For the lowest number of tree species DBH class of 0-5 had 8 trees and also 8 trees for 40-45 DBH class in the unmined area. The mined area which is the exploited area with an intensive deforestation had the highest number of trees on DBH class of 0-5 with a total number of 46 trees. Furthermore, the lowest number of woody tree species was on the DBH class of 20-25 with a total number of 1 tree species and DBH class of 25-30 with a total number of 1 tree species.

Fig 4.1 shows DBH classes and frequencies for the two areas



The mined area had few woody vegetation with a tall height, the height class of 3-4m had the lowest number of 3 trees. The highest number of woody vegetation was on the height class of 0-1m with a total number of 46 trees in the area. For the unmined area the number of tall trees was high, for height class 3-4m had the highest number of 50 trees. The lowest tree height was on height class 8-9 with a total number of 8 trees.

Fig 4.2; Height classes and frequencies across all areas

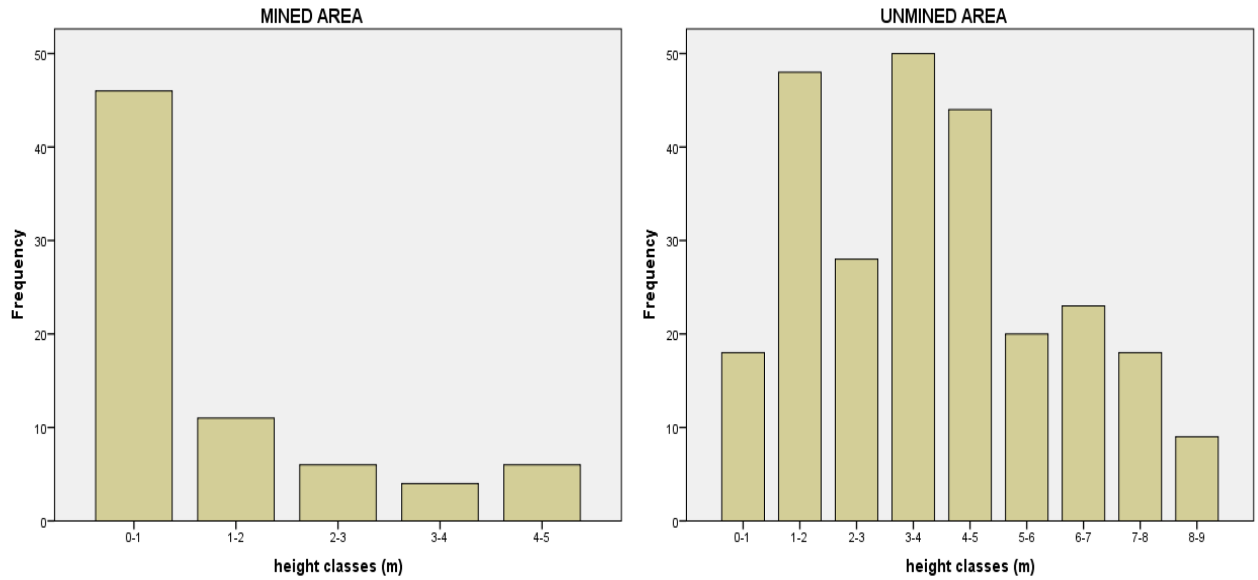


Table 4.3; Number of species, Species height, canopy diameter, dbh mean and standard errors across all areas

VARIABLE	MINED AREA	UNMINED AREA
NUMBER OF SPECIES	2.74±1.30	9.56±3.02
HEIGHT	0.86±0.16	4.36±0.13
CANOPY DIAMETER	2.18±0.25	5.43±0.19
DBH	9.45±0.61	24.63±0.59

Bauhinia petersiana had a high density across the two areas, high mature trees on the unexploited area and intensively deforested with highest density of saplings in the exploited area. *Ficus sycomorus* had the highest density in all areas, the different varies with height. *Vachellia tortilis* with the highest density in the unexploited area and lowest density on the exploited area, evidence of intensive deforestation. *Piliostigma thonningii* with a highest density in the unmined area and intensively deforested in the mined area, with a number of saplings. *Vachellia karro* had medium density on the unexploited area and lowest density on the exploited area, highly deforested. Also in the exploited area *Lantana camara* had the highest density in the unexploited area and with a highest density in the exploited area, with more saplings in the exploited area. Table 4.2 below illustrates the densities of dominants species across examined areas.

Table: 4.4: Density of dominant species per hectare across all areas.

Species	Expoited	Unexploited
Bauhinia petersiana	**2.7**	**4.2**
Vachellia tortilis	**0.6**	**9.0**
Piliostigma thonning	**2.1**	**8.4**
Ficus sycomorus	**2.4**	**3.6**
Vachellia karro	**0.6**	**3.3**
Lantana camara	**13.9**	**23.8**

Table 4.5; Shows the number of species, species height, canopy diameter, dbh mean and standard errors dominant species across all areas.

VARIABLE	MINED AREA	UNMINED AREA
NUMBER OF SPECIES	**1.03±0.49**	**2.9±1.06**
HEIGHT	**2.11±0.78**	**4.53±0.85**
CANOPY DIAMETER	**2.4±0.94**	**6.4±1.07**
DBH	**1.67±1.47**	**13.5±2.59**

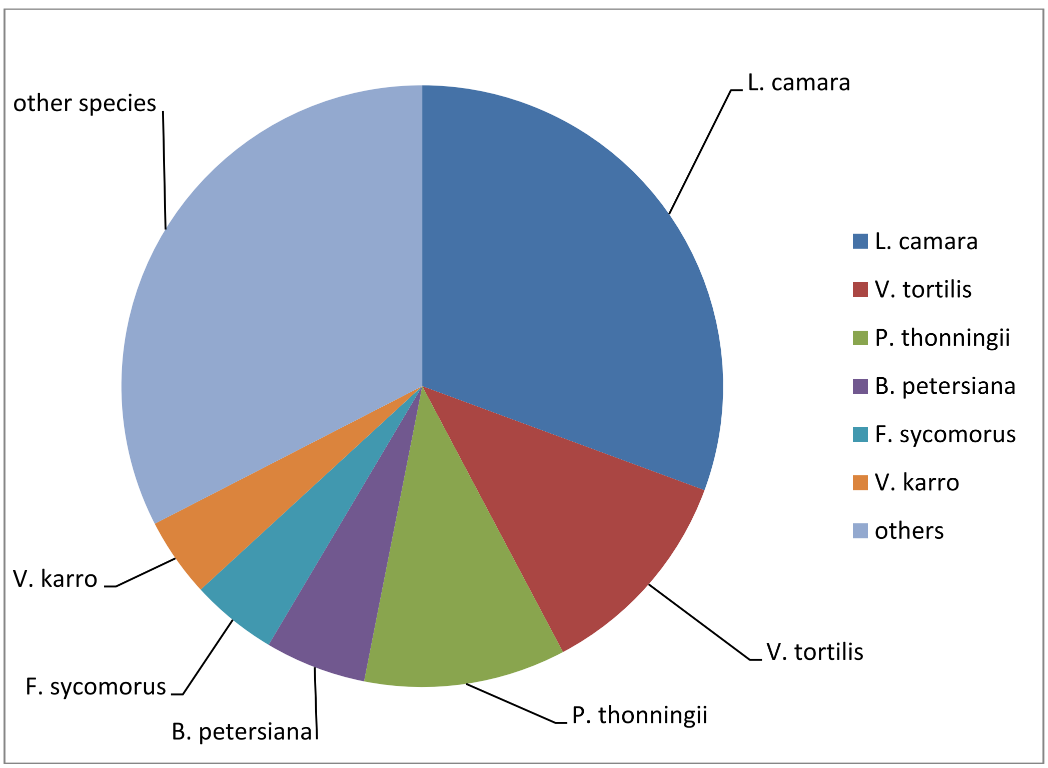
The dominant woody tree species which were found among the areas, *Ficus sycomorous* had the highest height followed by *Vachellia tortilis* and *Lantana camara* with the lowest height. Based on the dbh the *Ficus sycomorus* had the highest with few saplings. The canopy diameter was high in *Ficus sycomorus* and *Piliostigma thonningii.* Hence on the structural analysis Ficus sycomorus had the highest value in every analysis. Null hypothesis states that there is zero significant difference of illegal gold mining on dominant woody vegetation species density is rejected

(P<0.07) at the 0.05 significant level, indicating that artisanal gold mining significantly affect the woody vegetation species densities and their dominance in the area.

4.3 Species evenness and relative abundance

The species evenness indicated a degree that the exploited area recorded a lower value 0,67 and the unexploited area recorded the higher value 0,93, hence there was no evenness in woody vegetation species composition.

Fig 4.3 relative species abundance across all areas



The main dominant woody species in all area is *Lantana Camara* which has high relative abundance followed by *Vachellia tortilis* and *Piliostigma thonningii*. Species such as *Strychnos spinosa* had low relative abundance only two plants were found across mined and umined areas.

Some other species such as *Diplorhynchus condylocarpon, Vangueriopsis lanciflora, Pterocarpus angolensis* had already became extinct in the mined area and were scarce in the unmined area.

Analyzing the species relative abundance across all area, the null hypothesis that state where there is zero significant difference of artisanal gold mining on species relative abundance is rejected ($P<0.08$) at 0.05 significant level, indicating that artisanal gold mining significantly affect the species relative abundance in Garati area.

5. CHAPTER FIVE: DISCUSSIONS

5.1 Vegetation structure

The study found out a significant difference in the woody vegetation structure of the exploited area and the unexploited area in the Garati area. The woody vegetation height was high in the unexploited area and very low in the exploited area. This could be the result of cutting down of trees used in underground tunnels to support the tunnel from collapsing. In inclined shaft underground mining in order to support tunnels hard wood is to be used to avoid tunnel from collapsing. Hence this may have resulted to reduction of height of many woody tree species in the mined area, tree species such as *Pterocarpus angolensis* have hard wood which are favoured by the artisanal miners in underground mining. The matured trees are likely to be cut down leaving the undergrowth only. Woody vegetation height could have influenced by the ecological factors which includes topography and moisture variations in the area (Ben-Shahar, 1998).

Canopy diameter in some species such as *Bauhinia petersiana* were very low in the mined area and very high in the unmined, the diameter of the canopy was reduced in size due to the use of tree brunches for shade during the exploration of minerals. This also could be as a result of use of trees as building material. In Garati area thin tree brunches are used as building material by artisanal miners and vendors at the mining area. Hence through the cutting down of brunches this result to trees with a less canopy diameter. Observations which were found during the study was that the exploration process is producing much dust, dust deposits on plants leaves is capable of blocking the stomata pores which could hinder transpiration and some species was not survive the dust (Unanaomwi and Amonum, 2017)

The mined area which is the highly exploited area had high woody vegetation species on the 0-5 dbh class which is the lowest class, with a few species as going upwards classes. This could be a result of debarking by artisanal miners using tree backs as remedies for their healthy, for example during the study it was observed that people use tree barks of *Vachellia karro* to heal back pains and also they mainly use *Dichrostachys cinerea* for the same purposes, prescribed by herbalist in the area. Hence this could be the reason why the species was not found in the mining area. Unsustainable tree barking can result to reduction growth of species and this can lead to death of species if the process continues Gandiwa et al, 2013).

5.2 Woody vegetation density

Illegal mining has resulted to massive land degradation in the Garati area Bindura, these activities has resulted to degraded environment through loss of woody vegetation species and soil erosion. The results of the study had it that the invasive species *Lantana camara* is the most dominating species in both areas (mined and unmined), followed by Vachellia tortilis, *Bauhinia petersiana* and *Pilliostigma thonningii* (tree of the year 2021 by Forestry commission). *Lantana camara* is an invasive species which has become a treat to some tree species community, this plant belongs in a *Verbenaceae* family making it a woody species (Sarma, 2002).

Shannon H diversity index was very low in the mined area. This could be as a result of reduction in groundwater recharge by shaft underground mining and consequent loss of land productivity through massive degradation which led to extinction of more species in the mined area such as *Vangueriopsis lanciflora*, *Dichrostachys cinerea* but present in the unmined area (Kuffour,et al, 2018). Deforestation of *Vangueriopsis lanciflora* could have been lead to extinction due to miners' pressure to consume the fruits from the tree (tragedy of the commons). Species richness was low in the exploited area this could be as a result of massive land clearing for open cast mining in the area, whereby a large number of trees are removed in order to start exploration. Also personal observations which were made during the survey, heavy machines were used to remove vegetation, topsoil, and subsoil (Anane, 2003).

Tree density was very low in the mined area, this could be as a result of mining activities such as digging of trenches which resultant repercussions are formation of massive gullies, excessive runoff channels which leave the tree roots exposed leading to lodging of trees (Akabzaa and Darimani, 2001). Observation made during the field study, some trenches and pits were more than 10 meters deep. To add on artisanal miners, they use firewood for cooking and to warm themselves, this could be one of the reasons why the tree density is very low. The density of the unexploited area was high as the site is left untouched (Gandiwa et al, 2013). Hence the concentration of extraction process has led to the environment to go through increased land degradation and its immense economic value diminishing. However, it has been noted that the most dominant species in the miombo woodland such as *Brachystegia spiciformis*, *Brachystegia boehmii and Julbernardia globiflora* are getting extinct in the area.

Jaccard Similarity percentage was low on the exploited area in species and this might be as a result of that many species which were found in these areas were not the same and they were being affected by different type of mining, some were being affected by surface mining (open cast, strip mining, subsurface mining) and some were being affected by underground mining (shaft mining, inclined shaft mining), (Appiah-Brenyah and Antwi,2003). Hence different woody trees from different family are affected differently. Since the exploited and unexploited areas were located in a same climatic and physiographic location the species were similar in the two areas if it wasn't for the gold deposits (Sarma, 2002).

In adding on to that, the results shows that much of the woody vegetation species in the mined area are saplings and in the unmined area are full grown trees which are mature. This is due to land clearing by the artisanal miners in order for them to practice open cast mining. Out of 74 plants which were found during the study it has been noted that 45 plants were saplings. Therefore, the fear is on the unexploited area that the artisanal miners can interfere in the area as the whole area is regarded to be rich in gold deposits (Kanjilal et al. 1934-1940).

There is low woody species diversity in the mined area as compared to the unmined area from Garati. Successional species *Piliostigma thonningii* and *Bauhinia petersiana* have a great importance value in mining area due to their strength to grow in a destructed surroundings. The more importance value of herbaceous species like *Bauhinia petersiana* in the mining area suggests that it can multiply rapidly in the disturbed environments Sarma (2002).

5.3 Species evenness variations and relative abundance

The significant differences which were noted between the two areas species evenness using the Simpson D indices could be as a result of failure to regenerate, some woody species have weak fibrous roots and they easily fall if affected with degradation and leading to a decline in the number of woody vegetation species in the mined area. Some species such as *Bauhinia petersiana* were found in both investigated sites the main difference being that the mined area was rich with saplings and the unmined was rich with full grown matured woody vegetation species (O'Connor et al, 2007).

Species relative abundance in the exploited area was extremely low as compared to those of the unexploited area, distribution was clustered, random and regular. There are similar species between the two but the distribution differs with the activities occurring in that place (Mpofu et al, 2012). Illegal mining activities are a threat to woody vegetation abundance, activities such as processing of gold through the use of mercury has contributed to less distribution of woody vegetation species as plants tissue composition is easily affected. 15 species which were found in the unmined area were note present in the mined area this could be the reason leading to extinction of species such as *Albizia harveyi*, *Terminalia sericea.* Not only that, the fertile soil and soil microorganisms are removed and the rate of tree regeneration is reduced (Gyasi et al., 2006).

In addition, fruit tree species such as *Mangifera indica* and *Psidium guajava* could have been planted in the area by the miners, or seed dispersal. This could have been necessary as the two species are not easily affected by some mining activities and these species are left in-order for the miners to consume the fruits during the mining process. Hence the former tree species were not recorded in the unmined area (Luck and Daily, 2003).

5.4 Field observations

Observations and findings which were captured during the study are as follows. Different types of mining were practiced in the area which includes opencast, strip mining, shaft mining. According to Hilson, (2001) stated that open cast mining is a treat to ecosystem goods and services, hence woody species area also affected by these unsustainable practices. Some of the machinery used by the Garati artisanal miners includes caterpillars, excavator, jackhammer, picks, and shovels. As stated by Hilson (2001), some of these tools seem small but with a big impact on deforestation and loss of woody species diversity.

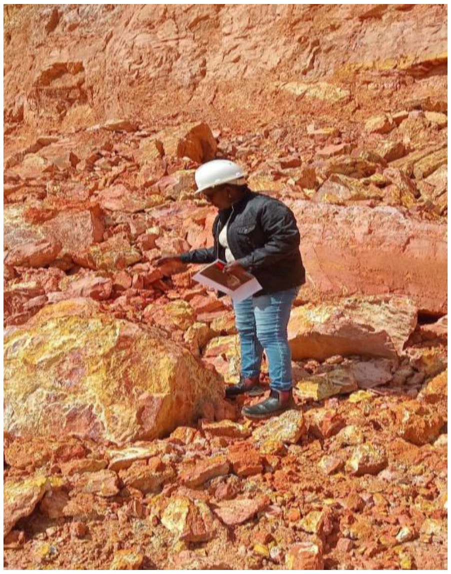


Fig 5.1; open cast mining being practiced   *Fig 5.2; machinery used on processing ore*

Not only did the extraction of minerals degrade the land, also the processing contributes to loss of vegetation cover in the Garati area. During mineral processing, the waste products pill up results tailing hill, as shown by fig 5.3. As the pilling continues the vegetation is covered bit by bit and the vegetation is left buried by the tailings (Heemskerk, 2002). Access routes to the area have followed by the removal of vegetation cover in the area, more roads are created around the area. Talking with one of the artisanal miner he stated that more roads area created as escape routes from the EMA BLITZ (EMAct 20:27, SI 7 of 2007, EIA and Ecosystem protection), hence more vegetation is removed in the mining area due to the formation of escape routes.

Fig 5.3 tailings area   *Fig 5.4; vegetation cleared for roads*

There is a clear difference between the mined and the unmined area, the vegetation colour as per the map in fig 3.1 shows the mined and the unmined area. The mined with the yellowish colour and the unmined with the green colour showing a dense forest diversity as compared with the former.

Fig 5.5; shows the mined scarce vegetation and the unmined shows the dense vegetation

6. CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Extensive artisanal gold mining of the investigated location has resulted into shrinking of woody vegetation species leading to formation of an unhealthy forest, as vegetation richness and density decreased in mined area. The disturbance which occurred during the illegal gold mining has become an enemy of progress on regeneration chance of woody vegetation species, thereby, minimizing the diversity of species in the mined area. Based on the study results, the artisanal mining activities are detrimental to woody plant diversity.

6.2 Recommendations

Therefore, to improve the woody vegetation structure and species diversity of the Garati area, to minimize the negative effects of artisanal gold mining and to enhance a sustainable utilization of the forest resources so as to save for the future generation. The following points are recommendations:

- Policies and law enforcement should be implemented effectively by the Environmental Management agency on illegal mining working hand in hand with the Forestry Commission and the ZRP.
- EMA Act 20:27 of 2007, SI 7 should be amended with heavy fines to the offenders of the environmental law.
- Forestry restoration and gully reclamation programs area supposed to be held more often so as to save the forests in the mining area.
- Artisanal miners with small scale mining license must have an Environmental Management Plan (EMP) with a Forest Restoration Plan.
- There is high need of controlling the spread of invasive plant species, for example *Lantana camara*, in both areas to avoid extinction of native species.

- There should be a regular monitoring of vegetation structure and composition in the mined area to reduce over exploitation of resource, conducting studies which estimate the volume of vegetation lost per unit area every quarter.

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