ISSN : 0974 - 7451 Volume 9 Issue 2

Environmental Science
An Indian Journal
Current Research Paper

ESAIJ, 9(2), 2014 [71-84]

Effect of small scale gold mining on vegetation species diversity in Umzingwane district

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ABSTRACT

Small scale gold mining in Umzingwane like in other developing countries has remained artisanal in nature and is the only livelihood option in the current prevailing climatic conditions. This study examined the effects of small scale gold mining on the floristic composition of vegetation in ward 14 and 15 within the period between February 2012 and November 2012. Stratified random sampling design was used to assess and compare vegetation characteristics under two strata; undisturbed (protected area) and small scale gold mined sites. Woody tree species diversity varied significantly between a mined and undisturbed site (*t*-test, $p < 0.05$). The results also indicated less significant differences in grass species diversity ($p<0.05$). Both tree species richness and diversity decreased due to small scale gold mining while grass species were increased due to disturbance. The significant differences in vegetation floristic composition indicated that small scale gold mining operations reduce biodiversity thus; there is an urgent need to come up with sustainable policies to govern the ballooning mining sector for sustainability of the future biodiversity.

KEYWORDS

Small-scale mining;
Species richness;
Species diversity;
Biodiversity.

INTRODUCTION

Anthropogenic activities are regarded as major causes of biodiversity loss such as the destruction of vegetation cover which affects a number of ecological processes essential for life forms within the ecosystem. Mining is one such activity that has a negative impact on the environment; such impacts may include habitat fragmentation and destruction which has been regarded as the major cause of biodiversity loss and subsequently species extinction.

Small scale mining is an important economic activity for most developing countries that is likely to disturb vegetation cover and diversity. It is usually dominated by rural communities who lack appropriate knowledge, skill and equipment as well as lack of access to financial assistance[3]. In the global arena, artisanal and small-scale mining are used interchangeable. This is because it has been difficult to separate the two as both operate in small groups and use artisanal tools for operation[7]. International studies have revealed an increase in the number of small-scale miners mainly due to poverty, unemployment and food insecurity as climate extremes intensify[50].

In Zimbabwe small-scale mining is controlled and regulated by the Ministry of Mines and Mining development in accordance to the provisions of the Mines and minerals Act Chapter 21:05 of 1996. According to the annual report by the Mining Commission of Zimbabwe, there has been a noticeable increase in the number of legally registered small-scale mines that is estimated to be at between 20000 and 30000. About 12000 small-scale mines have been registered for the Bulawayo mining district. This is the area of concern which covers both Matabeleland South and North. The loss of vegetation due to mining activities is of great concern to scientists and environmentalists because vegetation destruction and disappearance results in biodiversity losses of both flora and fauna species and consequently species extinction. Ogola *et al*.[30] observed a number of environmental impacts in the Migori district where artisanal mining is practising open cast and underground operations. These include waste rock dumped randomly into heaps as tailings, dredged out and contaminated streams, disturbed vegetation and littered landscapes and open trenches visible from a distance as well as deep pits usually filled with water during rainy season. Plant growth on the wasteland is usually inhibited, and this is attributed to piling of waste dumps and acid mine drainage[30].

Studies have also revealed an increase in population pressure during non agricultural seasons that have seen many people engaging on gold panning for their livelihoods[22,30]. This puts much pressure on the environment in terms of energy resources; thus large quantities of trees are cut down either as firewood or as timber causing massive deforestation and soil erosion. Small scale mining in India is also faced with similar environmental challenges resulting from not only the destruction of the vegetation especially the trees and grasses particularly at and near the area of mining operation, but they also due to lack of strategies to regenerate environmental status or create greeneries[3]. Myers[26], noted that loss of biodiversity is a significant issue to scientists and policy makers and studies have shown that species are becoming extinct at the fastest rate known in geological history and most of these extinctions have been tied to human activities that are economically driven like mining.

The liberalization of the mining sector in Zimbabwe, has seen an increase in the number of licensed small-scale miners most of them mining gold. Recurrent droughts in the western part of the country have also forced rural communities to resort to mining for livelihood. This has seen vast tracts of land being indiscriminantly dug up in search of alluvial gold. Such activities have potentially negative impacts on the environment and especially on vegetation cover and diversity of both tree and grass species. In addition, most gold panning activities are along rivers and this has an effect on riverine vegetation and the general water systems. At a global scale, economic activities are regarded as major cause of environmental degradation and subsequently result in loss of biological diversity[48]. Thus, the concept of sustainable development is an attempt to integrate environmental policies and development strategies in harmony.

With the proliferation of small-scale mining activities in Zimbabwe, a lot of studies[13,41] have focused attention on the impact of these mining activities on aquatic ecosystems and human health. However, less emphasis has been put on terrestrial ecosystems especially the magnitude and extent of vegetation destruction and damage due to mining operations. In addition, some studies have focused on the effects of large-scale mining on terrestrial ecosystems and the contribution of small-scale mining has remained unexplored. Human induced changes in land cover influences the carbon cycle which is essential for the whole ecosystem. It is therefore, necessary to examine the effects of small-scale mining on terrestrial ecosystems and on overall long term biodiversity. Therefore, the study sort to determine the magnitude and extent of vegetation disturbance due to small-scale mining and the results may also contribute to the formulation of a sustainable mining policy in Zimbabwe.

It was within the scope of this study to address the MDG 7, which seeks to ensure environmental sustainability through promoting an integration of principles of sustainable development into every country's policies and programmes and tries to reverse the loss of environmental resources. It is more relevant to target 25 which looks at the proportion of land areas covered by forest as biodiversity gene bank.

Importance of vegetation biodiversity

Forests play a number of vital ecological, cultural, socio economic and environmental functions and these are both anthropocentric and non-use values. Some of the important roles provided by forest ecosystems include climate regulation, which is the moderation of global climate in place and time[21,23]. Forest ecosystems also play a significant role as carbon sink and the production of oxygen through photosynthesis[37]. Forest biodiversity is also important in watershed protection, provides ideal habitat for both macro and micro organisms. Most importantly, forest ecosystems provide economic benefits to food production, raw materials for other products and genetic materials that are used for the development of products. Tourism and recreation are a result of biodiversity. Forest biodiversity also provides cultural benefit for example rain making and other traditional ceremonies that take place under certain tree species[19]. As such the need to conserve the biological diversity cannot be over emphasised particularly for most developing countries like Zimbabwe which depends on natural resources for their economic and social development

Vegetation is a key aspect of the environment and forms the basis of all life forms as a primary producer[6] and plays a central role in the regulation of biogeochemical cycles such as carbon cycle and water cycle. Plants as primary producers are essential for atmospheric carbon fixation through converting atmospheric carbon to organic compounds during photosynthesis. This process of carbon sequestration prevents the release of carbon into the atmosphere. Large amounts of carbon are stored in soils and vegetation, which form natural carbon sinks[39]. Studies have revealed that forests hold about 40% of the world's terrestrial carbon stock[9]. The other most important and immediate ecosystem services provided by the forests are the provision and regulation of water resources through the hydrological cycle.

Tropical forests ecologically act as heat and humidity pumps, for transferring heat from the tropics to the temperate zones and releasing water vapour that comes back as rain[40]. Soil genesis depends on availability of vegetation. Vegetation determines the soil characteristics such as soil fertility, chemistry and other physical properties such as texture and colour which in turn determine the characteristics of the vegetation that grows as well as the overall productivity and their physiognomic structure. Vegetation also serves as habitats for both micro and macro organisms within the ecosystem and also provides food and shelter for these species[49].

Humans also depend on forests for their survival. Vegetation provides food and fruits for human consumption. Most developing countries rely on forests for energy in the form of firewood. Woody tree species are also used for carving curios and making furniture. In rural areas, farmers use wood for fencing purposes. Forest ecosystems also provide cultural services essentially in aesthetic and spiritual benefits.

Having recognized the importance of forest ecosystems in human and environmental survival, studies[9,18,23,26] have shown that the world's biodiversity is dwindling at an alarming rate. According to FAO, (2010) forests cover 31% of the total global area and it is estimated that about 13 million hectares of forest were converted to other uses in the past decade, an area that is said to be the size of Greece. It is thus, the concern of this report to investigate the extent of biodiversity loss due to small scale activities.

Causes of biodiversity loss

Historic losses of biodiversity were tied down to natural causes. There is a consensus among many paleontologists that extra-terrestrial objects, like meteorites and comets, played a significant role in past extinction events. For example, the impact of a 6-mile (10 km) wide meteorite near the Yucatan, Mexico is often cited for the demise of the dinosaurs[28]. However the current spasm is different from the past experiences. Thus, scientists concur that species are becoming extinct at the fastest rate known in geological history and most of these extinctions have been tied to human activity and these include; habitat loss and fragmentation, over exploitation, introduction of invasive species and the effects of climate change[20,21,26,33]. Myers[26], also noted that tropical forests are central to the issue of extinction because they share two unique characteristics. First, they are exceptionally rich in species, containing at least half, and perhaps two thirds of earth's species in just one twentieth of Earth's land surface. Secondly, the fact that forests are being destroyed faster than any other extensive biome.

Habit loss and fragmentation due to land use changes

Humankind has dramatically transformed much of the earth's surface and its natural ecosystems[26]. Loss of habitats and fragmentation is believed to be the most serious threat to biodiversity mostly due to massive land clearance for 'agricultural purpose necessitated by rapid population increase. Habitat loss has also been associated with mining and bush fires. Few habitats are destroyed entirely. In most cases, habitats are reduced in extent and simultaneously fragmented; leaving small pieces of original habitat persisting like islands in a sea of degraded land as such habitat fragmentation is a grave threat to species survival (Laurance, 2010).

Over- exploitation

Over exploitation especially through timber logging has resulted in loss of species as well as the reduction of population below viable levels leading to extinction. It is estimated that between 5 and 7 million hectares of tropical forests are logged annually, approximately 68 – 79 % of the area that was completely deforested each year between 1990 and 2005 (FAO, 2010). Examples of exploited plant products include fruits, nuts, worms, oil seeds, latex, resins, gums, medicinal plants, spices, dyes, ornamental plants, and genetic materials.

Introduction of invasive alien species

An Invasive alien species is a species which is either intentionally or accidentally introduced to a habitat it had not previously occupied, then establishes a population and spreads autonomously[42]. Species invasions are considered one of the main conservation threats to global biodiversity and have caused many species extinctions. The greatest impacts of invasive species are their ability to modify entire ecosystems, because such modifications usually affect most of the originally resident species.

The introduction of exotic (non-native) species can disrupt the entire terrestrial ecosystems. These invaders can adversely affect native species by eating them, infecting them, competing with them, or mating with them[42]. Invasive species tend to out-compete the native species and then dominate the habitats for example the *Lantana camara* in Zimbabwe has invaded most rangelands (FAO, 2010). In South Africa, fynbos vegetation was being threatened by the exotic species such as the Australian Acacia and Pine species threaten the survival of *Restio, Erica* species *and Protea* species[19] and this resulted in the loss of native species.

The effect of climate change on biodiversity

Populations, species and ecosystems have been observed to be responding to climate change[21,23]. The earth is believed to be warmer now than it has been for the past 40 million years Parmesan *et al*., 1999 (cited in Parmesan 2006). Estimates suggest that 18% of the species in Central America, Australia, South Africa and Europe will disappear due to climate change if the current conditions persist for the next 50 years[23,33]. The major challenge with climate change is that it is occurring so rapidly that the organisms do not have time to adjust. This is further compounded by the prevailing habitat degradation and fragmentation which gives rise to the new conditions that are often suitable for invasive species.

It is also believed that climate change has created new environs in which present species are failing to adapt thus, are naturally eliminated. Changes in temperature and precipitation have affected the species timing, where some species are now flowering earlier than usual[21]. Again, Climate change has caused species distribution shifts. Species have changed their normal geographic distribution following changes in climatic conditions Species are said to be moving pole-wards. For example, Butterflies in Europe were observed to be migrating northwards[33]. Predictions show that ranges will move north by 6.1 km per decade and spring will occur 2.3 days earlier[21]. Parmesan *et al*. 1999 in Parmesan[33], studied non-migratory butterfly species and found that 63 % of the studied 35 species had shifted their range north wards by 35 - 240 km. Species are also adjusting their breeding seasons in response to the changing climatic conditions[33], Thus, most scientists believe that there is an urgent need to address the species adaptation issue through implementing strategies based on conservation biology of adaptation.

Global trends in biological diversity

A number of species have been reported either as being locally extinct or being threatened of extinction[2]. The impact and extent of biodiversity loss in Southern Africa is of great concern because Africa is predominantly dependent on biological resources for survival. A loss of forest resources will no doubt have profound effects on the quality and quantity of benefits derived from the forests. Biodiversity loss also reduces the ecosystem resilience making them more susceptible to drought and pest and disease outbreak. Biodiversity loss has been a result of human development, for example, species rich wetlands and forests have been converted to farmlands and plantations[9,15]. Examples of biodiversity loss include Angola where the wildlife population of the national parks was reduced by 10 % of their 1975 levels in year 2000[19]. The Chisongole forest on mount Mulanje, in Malawi was reduced from 38000 ha (in 1974) to 2500 ha in 1984[9]. It is against this backdrop that environmental sustainability becomes a key aspect of biodiversity conservation. It requires maintenance of the natural capital. As noted by Smythe and Dumanski[43], this means that the source and sink functions of the environment should not be degraded. Thus, the extraction of renewable resources should not exceed the rate of regeneration and the ability of the environment to assimilate wastes, while the extraction of the non renewable resources should be minimized so as to avoid extinction of species.

The study thus, sought to test the hypothesis that small scale mining affects the vegetation species diversity and for the purposes of this study only the tree and grass species were analysed.

MATERIALS AND METHODS

Description of the study area

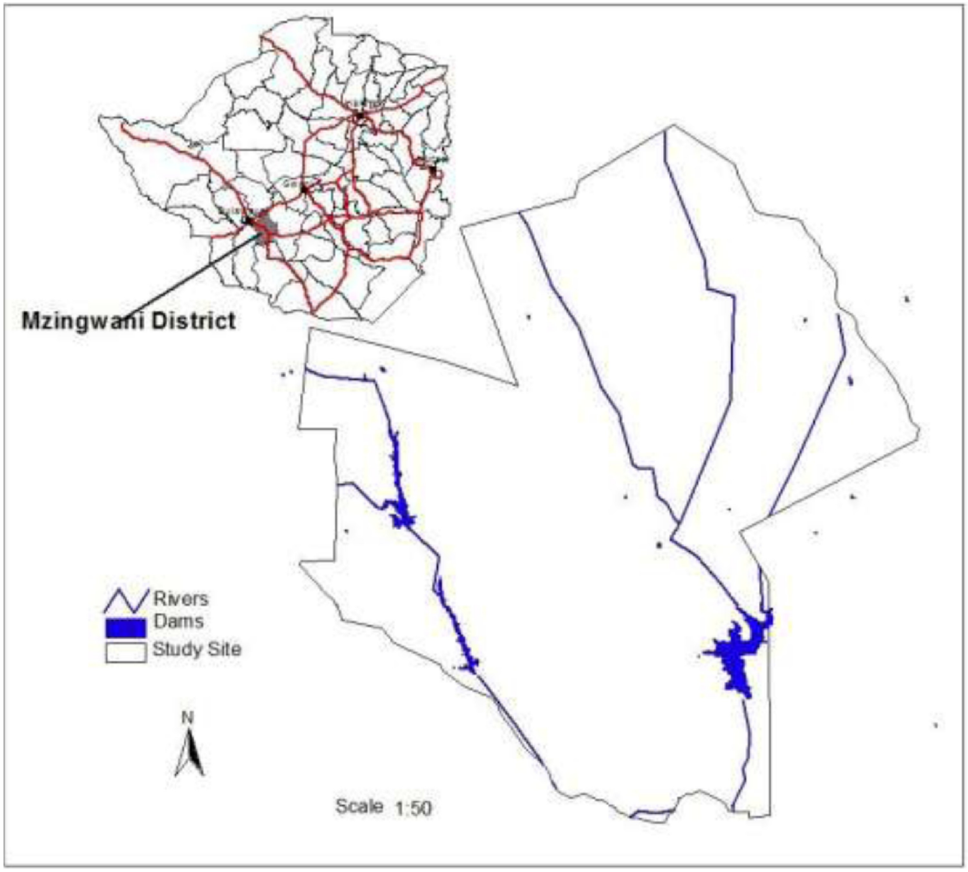
The study was carried out in Umzingwane district of Matabeleland South Province (latitude 20^0 15^1 0' and 28^0 55^1 0'). Within this location, the study focused on ward 14 (Mpisini) and ward 15 (Nyankuni) (Figure 2.1). The district covers an area of about 2820 km^2 with a total population estimated at 59569 people[4]. The district lies in agro-ecological region IV, which is a zone of low agricultural potential due to low and erratic rainfall regimes ranging between 450 - 650 mm annual rainfall while the mean monthly temperatures are relatively high at between 23 – 30 ^oC[4] (Chenje *et al.*, 1998). The area is dominated by soils of low fertility and are usually moderate to very shallow in nature and can be classified under the Armorphic order as lithosols[29]. Lithosols are soils derived from siliceous gneiss and mafic rocks and are sandy in texture. However, there are some areas that consist of brown and red clays common near rivers and on alluvial plains.

The area is about 1200 m above sea level and consists of a dissected high plateau. Umzingwane River is the major water source that passes through the area where most of illegal gold panning is concentrated[9]. Three big dams, the Upper Ncema, Lower Ncema and Nyankuni dams that supply the city of Bulawayo with water are located along Nyankuni River. The area consists of dry bush savannah type of forests dominated by the *Acacia* species such as *A. albida*, *A. ataxacantha*, *A. karoo*, *A. tortilis and A. xanthophloea*. Other common woody species include *Ziziphus mucronata*, *Euclea crispa*, *Rhus pyroides*, *Brachystegia glaucescens*, *Dichrostachys cineria*, *Terminalia sericea*, *Albizia amara*, *Burkea africana* and a number of *Combretum species* such as *C. imberbe*, *C. molle and C. hereroense.* The grass species are dominated by *Heteropogon contortus*, *Hyperrhenia filipendula* and *Elionurus dactylon.* Other prominent grass species are those that thrive under disturbed conditions such as *Pogonarthria squarrosa*, *Eragrostis viscoza*, *Eragrostis cylindri flora*, *Aristida congesa and Grewia monticola*. Species like *Eragrostis bicolour, Sporobolus pyramidalis*, *Anthephora romosa*, *Cynodon dactylon* and *Cymbopogon pospischili* are common along river valleys and mountain ranges[9]. The geology of the area is dominated by mafic rocks for example the granite rock. A mountain range called Malungwane stretches through the whole area.

Map of the study area

Methodology

The study used a stratified random sampling design to sample for tree and grass species. In addition, the study site was divided into disturbed and undisturbed area. Points were randomly generated amongst the strata in a GIS environment. The 20 generated points



were used as the centre locations of the quadrats. In each quadrat, individual tree species as well as grasses were recorded to assess tree species composition and abundance. Ten quadrats of the 20 were located in the undisturbed area while the other 10 were in the disturbed area. To sample the grass species the quadrats were further subdivided into five (1m*1m) subquadrats. Identification of tree species was aided by keys provided by Drummond[8] and Palgrave[32]. They were then confirmed using the botanic dictionary for Africa by Wild of (1965). Timberland[45] was used to distinguish acacia species while keys by Muller[25] were consulted for grass species identification.

Determination of species density

Species density was determined by using the species data collected in each quadrat (Appendix 4.1 and 4.2) to calculate the average number of individuals of a given species in relation to the total number of samples studied. This helped to infer on the most abundant species within each quadrat

$$D = \frac{n}{\Sigma q}$$

Where; D= density

N = total number of individuals of a given species

Q = sum of quadrats sampled

Determination of species frequency

The determination of species frequency was done using species data collected from 20 quadrats (both disturbed and undisturbed) sites. It was used to determine the relative presence and absence of species in a given quadrat. Relative frequency was calculated as the total number of quadrats in which species occurred/ Total number of quadrat studied *100

$$RF = \frac{\Sigma q}{\Sigma Q}$$

Where;

RF = relative frequency

Σq = total number of quadrats in which the species occur

ΣQ =total number of quadrats studied

Based on the % frequency, species are classified into 5 classes as proposed by Braun-Banquet (1948) as following;

Rare -1 - 20%

Seldom present	-21 - 40%
Often present	-41 - 60%
Mostly present	-61 - 80%
Constantly present	-81 - 100%

Determination of species abundance

Species abundance was determined by using the same species data collected from all quadrats. It was used to deduce the most occurring species as well as the most preferred species for use by the miners and was computed as total number of individual of a species divided by the total number of quadrats of occurrence.

Data analysis

All the data were first tested for normality before analysis. All the statistical analysis were done using GenStat 14th edition[34]. Diversity analysis was performed using Paleontological Statistical software package for education and data analysis (PAST) version 1.91 by Hammer and Harper[14]. Independent two sample t-test was used to test whether there is significant change in tree and grass species diversity between disturbed and undisturbed area. All these tests were considered at 0.05 % significant levels.

TABLE 1.1 : Species composition in an undisturbed site

Name of tree species	Total no. of spp	Frequency (%)	Spp Density/Quad	Abundance
Combretum molle	95	60	9.5	15.8
Combretum imberbe	27	30	2.7	9
Pterocarpus rotundifolus	13	30	1.3	4.3
Lannea discolor	8	20	0.8	4
Ozoroa reticulate	8	30	0.8	2.7
Burkea Africana	15	30	1.5	5
Pterocapus angedensis	3	20	0.3	1.5
Diplorhynchus conndylocarpon	12	30	1.2	4
Boscia angustifollia	6	20	0.6	3
Terminaria sericea	28	40	2.8	7
Peltophorum africanum	11	20	1.1	5.5
Eucla crispa	30	40	3	7.5
Doryalis caffra	3	20	0.3	1.5
Dichrostachys cineria	20	40	2	5
Sapileum ellipham	3	10	0.3	3
Albizia amara	22	30	2.2	7.3
Ziziphus mucronata	10	20	1	5
Acacia sieberana	21	20	2.1	10.5
Albizia gummifera	21	20	2.1	10.5
Commiphora caerulrea	13	20	1.3	6.5
Acacia caffra	6	20	0.6	3
Acacia karroo	58	50	5.8	11.6
Combretum hereroense	12	20	1.2	6
Bolusanthus speciosus	3	10	0.3	3
Pseudolochnostylis maprouneifolia	5	10	0.5	5
Sclerocarya birrea	3	10	0.3	3
Acacia nilotica	5	10	0.5	5
Cassia abbreviate	3	10	0.3	3
C. erythrophylum	8	10	0.8	8
Total	472		47.2	

Combretum molle **was the most abundant species in the undisturbed area with a 60% relative frequency followed by** ***Acacia karroo*** **(50%),** ***Dichrostachys cineria*** **(40%) and** ***Terminaria sericea*** **(40%).**

Appendix 1: Species composition in an undisturbed site

Undisturbed	Quadrates															
Name of tree species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total no. Of spp**	**Total no. Of quad in which spp occur**	**Total Quadrats studied**	**% Frequency**	**Density**	**Abundance**
Combretum molle	20	7	33	15	5	0	0	0	0	15	95	6	10	60	9.5	15.8
Combretum imberbe	11	0	0	0	3	0	0	0	0	13	27	3	10	30	2.7	9
Pterocarpus rotundifolus	7	0	4	0	2	0	0	0	0	0	13	3	10	30	1.3	4.3
Lannea discolour	5	3	0	0	0	0	0	0	0	0	8	2	10	20	0.8	4
Ozoroa reticulate	3	0	2	3	0	0	0	0	0	0	8	3	10	30	0.8	2.7
Burkea Africana	8	0	5	2	0	0	0	0	0	0	15	3	10	30	1.5	5
Pterocapus angedensis	2	0	1	0	0	0	0	0	0	0	3	2	10	20	0.3	1.5
Diplorhynchus conndylocarpon	7	1	0	4	0	0	0	0	0	0	12	3	10	30	1.2	4
Boscia angustifollia	3	0	0	0	0	0	0	0	0	3	6	2	10	20	0.6	3
Terminaria sericea	0	18	3	3	4	0	0	0	0	0	28	4	10	40	2.8	7
Peltophorum africanum	0	3	0	0	0	0	0	8	0	0	11	2	10	20	1.1	5.5
Eucla crispa	0	7	0	5	5	13	0	0	0	0	30	4	10	40	3	7.5
Doryalis caffra	0	2	1	0	0	0	0	0	0	0	3	2	10	20	0.3	1.5
Dichrostachys cineria	0	5	3	0	0	0	3	0	9	0	20	4	10	40	2	5
Sapileum ellipham	0	0	3	0	0	0	0	0	0	0	3	1	10	10	0.3	3
Albizia amara	0	0	0	8	7	0	0	7	0	0	22	3	10	30	2.2	7.3
Ziziphus mucronata	0	0	0	0	3	0	7	0	0	0	10	2	10	20	1	5
Acacia sieberana	0	0	0	0	0	14	7	0	0	0	21	2	10	20	2.1	10.5
Albizia gummifera	0	0	0	0	0	9	0	0	12	0	21	2	10	20	2.1	10.5
Commiphora caerulrea	0	0	0	0	0	11	2	0	0	0	13	2	10	20	1.3	6.5
Acacia caffra	0	0	0	0	0	5	0	0	1	0	6	2	10	20	0.6	3
Acacia karroo	0	0	0	0	0	19	14	11	7	7	58	5	10	50	5.8	11.6
Combretum hereroense	0	0	3	0	0	0	0	9	0	0	12	2	10	20	1.2	6
Bolusanthus speciosus	0	0	0	0	0	0	0	3	0	0	3	1	10	10	0.3	3
Pseudomaprouneifolia	0	0	0	0	0	0	0	5	0	0	5	1	10	10	0.5	5
Sclerocarya birrea	0	0	3	0	0	0	0	0	0	0	3	1	10	10	0.3	3
Acacia nilotica	0	0	0	0	0	0	0	0	5	0	5	1	10	10	0.5	5
Cassia abbreviate	0	0	0	0	0	0	0	0	0	3	3	1	10	10	0.3	3
C. erythrophylum	0	0	0	0	0	0	0	0	0	8	8	1	10	10	0.8	8
Total	66	46	61	40	29	71	33	43	34	49	472				47.2	

RESULTS

Tree species composition

A total of twenty (20) quadrats were established and 588 individual trees were recorded in the study sites. One hundred and sixteen (116) were found on the disturbed site and four hundred and seventy two (472) were recorded in an undisturbed area (TABLE 4.1) giving a mean of 11.6 for the disturbed site and 46.7 species per quadrat for the undisturbed area. This consisted of sixteen (16) species in the area practicing small-scale mining and 29 species in an undisturbed site. Species occurrence was significantly different with Sorensen (Bray-Curtis) similarity of 0.0306 ($F = 0.4885$, $DF = 9$, $p = 0.015$). However, they are species that occurred in both mined and undisturbed sites and these include (*Bolusanthus speciosus, Combretum hereroense, Ziziphus mucronata, Euclea crispa, Combretum imberbe, Acacia karroo, Lannea discolor, Dichrostachys cineria, Terminaria sericea and Pterocarpus rotundifoliu).* These common species

Appendix 2 : Species composition for small scale gold mined site

Name of tree species	Quad 1	2	3	4	5	6	7	8	9	10	Total no. Of species	Total no. Of quad in which spp occur	Total Quadrat studied	% Frequency	Density	Abundance
Bolusanthus speciosus	2	0	0	0	0	3	0	0	0	0	5	2	10	20	0.5	2.5
Combretum hereroense	3	0	1	0	0	0	2	0	0	0	6	3	10	30	0.6	2
Ziziphus mucronata	6	2	0	0	0	0	0	0	2	0	10	3	10	30	1	3.3
Euclea crispa	14	2	0	0	0	0	0	0	0	0	16	2	10	20	1.6	8
Combretum imberbe	3	0	0	0	0	2	0	0	0	0	5	2	10	20	0.5	2.5
Acacia karroo	3	1	6	0	0	0	0	3	0	4	17	5	10	50	1.7	3.4
Acacia abyssinica	0	5	0	2	0	1	0	0	4	0	12	4	10	40	1.2	3
Lannea discolor	0	5	1	2	2	3	0	0	0	2	15	6	10	60	1.5	2.5
Acacia nigrescens	0	0	2	0	0	0	0	2	0	0	4	2	10	20	0.4	2
Dichrostachys cinerea	0	0	1	0	0	0	0	0	0	0	1	1	10	10	0.1	1
Sapiteum ellipticum	0	0	0	0	1	0	0	0	0	1	2	2	10	20	0.2	1
Acacia fleckii	0	0	0	0	2	0	0	0	0	0	2	2	10	20	0.2	1
Acaci tortilis	0	0	0	0	0	2	0	0	0	0	2	2	10	20	0.2	1
Terminaria sericea	0	0	0	0	0	0	10	0	2	0	12	2	10	20	1.2	6
Ozoroa reticulata	0	0	0	0	0	0	3	0	0	0	3	1	10	10	0.3	3
Pterocarpus rotundifoliu	0	0	0	0	0	0	4	0	0	0	4	1	10	10	0.4	4
Total	31	15	11	4	5	11	19	5	8	7	116				11.6	

Appendix 3 : Diversity indices for an undisturbed site

Diversity Index	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6	Quad 7	Quad 8	Quad 9	Quad 10	Mean
Individuals	66	42	57	37	29	61	38	43	41	53	46.7
Shannon_H	1.975	1.547	1.525	1.57	1.876	1.695	1.325	1.72	1.57	1.685	1.6488
Simpson_1-D	0.8324	0.7392	0.6396	0.7495	0.8371	0.8019	0.6731	0.8112	0.7841	0.7989	0.7667
Evenness_e^H/S	0.8004	0.7831	0.5104	0.8007	0.9328	0.9079	0.7526	0.9312	0.9611	0.8984	0.82786
Menhinick	1.108	0.9258	1.192	0.9864	1.3	0.7682	0.8111	0.915	0.7809	0.8242	0.96116
Margalef	1.909	1.338	1.979	1.385	1.782	1.216	1.1	1.329	1.077	1.259	1.4374
Equitability_J	0.8987	0.8635	0.6939	0.876	0.9642	0.9461	0.8234	0.9602	0.9753	0.9402	0.89415

Appendix 4 : Diversity indices for a Small- scale mined site

Diversity Index	Quad 1	Quad 2	Quad 3	Quad 4	Quad 5	Quad 6	Quad 7	Quad 8	Quad 9	Quad10	Mean
Individuals	31	15	11	4	5	11	19	5	8	7	11.6
Shannon_H	1.532	1.45	1.295	0.6931	1.055	1.547	1.194	0.673	1.04	0.9557	1.14348
Simpson_1-D	0.7263	0.7378	0.6446	0.5	0.64	0.7769	0.6427	0.48	0.625	0.5714	0.63447
Evenness_e^H/S	0.771	0.8528	0.7299	1	0.9572	0.9391	0.8253	0.9801	0.9428	0.8668	0.8865
Menhinick	1.078	1.291	1.508	1	1.342	1.508	0.9177	0.8944	1.061	1.134	1.17341
Margalef	1.456	1.477	1.668	0.7213	1.243	1.668	1.019	0.6213	0.9618	1.028	1.18634
Equitability_J	0.8549	0.9011	0.8043	1	0.9602	0.961	0.8615	0.971	0.9464	0.8699	0.91303

constituted 28% of the total species studied.

The results on grass species diversity showed no significant difference in grass species composition between a disturbed and undisturbed area (t = 1.94, df = 18, p = 0.069). There was higher species density in a disturbed area (n = 209/quadrat) compared to the undisturbed (n = 205/quadrat).

Combretum molle was the most abundant species in the undisturbed area with a 60% relative frequency followed by *Acacia karroo* (50%), *Dichrostachys cineria* (40%) and *Terminaria sericea* (40%).

While in the mined area *Lannea discolor* was the

TABLE 1.2 : Species composition for a Small scale mining area

Name of tree species	Total no. Zof spp	% Frequency	Spp Density/Quadrat	Abundance
Bolusanthus speciosus	5	20	0.5	2.5
Combretum hereroense	6	30	0.6	2
Ziziphus mucronata	10	30	1	3.3
Euclea crispa	16	20	1.6	8
Combretum imberbe	5	20	0.5	2.5
Acacia karroo	17	50	1.7	3.4
Acacia abyssinica	12	40	1.2	3
Lannea discolor	15	60	1.5	2.5
Acacia nigrescens	4	20	0.4	2
Dichrostachys cineria	1	10	0.1	1
Sapiteum ellipticum	2	20	0.2	1
Acacia fleckii	2	20	0.2	1
Acaci tortilis	2	20	0.2	1
Terminaria sericea	12	20	1.2	6
Ozoroa reticulate	3	10	0.3	3
Pterocarpus rotundifoliu	4	10	0.4	4
Total	116		11.6	

TABLE 1.3 : Distribution of Species frequency classes

% Class	Class	Number of species in Mined area	Number of species in Undisturbed area
1 - 20	A	11	18
21 - 40	B	3	9
41 - 60	C	1	1
61 - 80	D	1	1
81 – 100	E	0	0
		16	28

TABLE 4.4 : Diversity indices recorded for an area practising SSM

Index	Mean Diversity	
	Undisturbed	Mined
Individuals	46.7	11.6
Shannon_H	1.6488	1.14348
Simpson_1-D	0.7667	0.63447
Evenness_e^H/S	0.82786	0.8865
Menhinick	0.96116	1.17341
Margalef	1.4374	1.18634
Equitability_J	0.89415	0.91303

most abundant with a relative frequency of 60% followed by *Acacia karroo* (50%) and *Acacia abyssinica* (40%). Species density was observed to be significantly different between the two sites (t = -2.36, df = 36, p = 0.02). It was higher for the undisturbed area with a total of 47.2 trees/ ha, with the highest value for the sample at 9.5 (*Combretum molle*).

Results in Table 4.3 indicate a similar frequency distribution between two sites where for both cases the highest number of species in class A (1 – 20 %) followed by the B class (21 - 40 %).However, results indicate *Acacia karroo* as the most dominant species in both sites which is a clear indication that the area is predominated by the *Acacia* species.

Tree species diversity

There was evident higher species diversity in an undisturbed area than the area where small scale mining was being practiced. The results indicated that there was a significant difference in Shannon diversity between two sites (t = -4.34, df = 18, p < 0.001). The mean Shannon diversity for the area under SSM mining was 1.435 and 1.6480 for the undisturbed area. Simpson diversity also recorded significant differences at (t = 3.54, df = 18 p < 0.002) the mean for samples in a mined site was 1.1434 and 0.7667 for the unmined site (TABLE 1.3).

DISCUSSION

Effects of small scale gold mining on tree and spe-

cies richness

The results of the study indicated a significant difference in species richness between an area practising small scale gold mining which recorded 16 species and the undisturbed having 28 tree species recorded. It was discovered that SSM reduces the number of species in an area through severe deforestation. These results are consistent with similar studies carried by Gavin, (2002) which noted a significant impact of small scale gold mining on vegetation in Ghana and reported that 15000 hectares of forest cover were affected by resident SSM activities. This deforestation is necessitated by the need for shelter, underground support props, panning dishes and for firewood as a result mining claims areas are left almost bare of vegetation particularly trees. Obara and Jekings, concur with these findings where they reported vast tracts of the forest having been deforested due to operations of small scale gold mining in Ghana.

Effects of small scale gold mining on tree and grass diversity

The study has presented strong evidence that activities carried out by small scale mining in Zimbabwe and Umzingwane in particular reduce tree species diversity and are likely to cause long term environmental disturbances related and consequences. Similar results were observed by Chiwawa, who reported that small scale mining was causing massive deforestation and estimated 100 000 hectares of land was being cleared annually and alleged that this will no doubt reduce biodiversity. However, results also indicated less significant differences in grass species diversity. This may be because disturbances promote emergence of pioneer grasses that thrive on disturbed areas such as the *Aristida* species, *Heteropogon* species and *Erogrostis* species.

Effects on vegetation species abundance and dominance

The density of trees significantly varied between the disturbed and undisturbed area. It was noted that the species density was much higher in an undisturbed area than the disturbed for the obvious reasons being that mining sites are being stripped bare of vegetation for various aforementioned reasons. This was evidenced by low species relative abundances (TABLE 1.1 and 1.2). The results also show that certain species are most favoured for example the Combretum species. It is assumed that this is due to its strength and provides good energy if used as fire wood. While on the other hand, species that dominate mined sites are those that are less important like *Lannear discolor*. This was evidenced by very high densities for *Combretum* species in an undisturbed site. It can also be inferred that other species like *Acacia* that are usually might be cleared to pave way because most of these species are thorny in nature and some are also good for fire wood accounting for their low densities within the mined samples.

Contrary to earlier research in countries like Zambia, Kenya, DRC and Ghana,[13,31,41] legalised small scale gold mining in Umzingwane does not use mercury to process gold but rather there are a number of licensed gold processors that deal with the licensed small scale miners. It can be alleged that, this practice is stipulated in their license conditions. However, the study also supports the earlier works that contend that legal small scale mining has remained artisanal in nature that simply use mainly pick and shovel operations. These results are consistent with findings by Chakravorty[3], which reported that SSM lacks machinery and thus, resort to pick and shovels to extract gold ore.

CONCLUSION

The results of this study show that Small scale mining cause significant deforestation which decreases the number of individual trees and species composition. Thus, the study rejects hypothesis that there is no significant change in species diversity between a mined and un-mined area. The study purports that if the situation is left unabated it can lead to severe land degradation in the long run. The study results also demonstrates that SSM has insignificant effects on grass species diversity and richness; rather it promotes the regeneration of pioneer grass species and the second succession shrubs such as *Dichrostachys cineria* and *Euclea crispa*. The study also revealed that SSM activities change the type of vegetation from woodland vegetation to grasslands.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor Professor J. Masaka from Midlands State University for his exceptional guidance throughout the study. I also like to thank Mr. A. Chirima from ICRISAT who helped a lot with GIS and Remote sensing guidance. I also appreciate the logistic support that I got from Lupane State University during field data collection. I would also like to thank students from the Department of Geography who helped a lot during data collection. I am greatly indebted to my husband T. Sibanda for his unwavering support without such support this study was not going to be possible. My special appreciation is directed to my family who has been the pillar of strength throughout this study. Lastly, I would like to extend my gratitude to all my friends and colleagues from Lupane State University whose moral and academic support contributed to the success of this study.

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