IMPACT OF ARTISANAL AND SMALL-SCALE GOLD MINING ON VEGETATION COVER IN BUKOMBE-MBOGWE FOREST RESERVE AND SURROUNDING VILLAGES, GEITA REGION, TANZANIA.

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN PROJECT MANAGEMENT AND EVALUATION OF SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA.

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EXTENDED ABSTRACT

Vegetation cover in Bukombe-Mbogwe Forest Reserve (BMFR) has been impacted negatively for decades due to Artisanal and Small-scale Gold Mining (ASGM). The study aimed at examining the impact of artisanal and small-scale gold mining activities on vegetation cover in Bukombe-Mbogwe Forest Reserve and surrounding villages. The study employed cross-section research design with 138 respondents using remote sensing, questionnaire survey, key informant interviews, field observations and focus group discussions. Landsat images of three window periods of 1984, 2002 and 2020 were analysed qualitatively using Normalized Difference Vegetation Index (NDVI) and quantitatively using supervised classification of Maximum Likelihood (ML) algorithm techniques. Descriptive and content analysis were conducted for quantitative and qualitative data respectively employing Microsoft excel for results presentation. NDVI median value decreased from 57% with dense vegetation to 34% with shrubs and grasslands indicating decrease in vegetation quality. There was a quantitative decrease in dense vegetation by 20.78% and bare-land by 23.17%; and quantitative increase in sparse vegetation by 37.46% and built-up land by 6.49% from 1984 to 2020. Relative abundance of tree species most used in ASGM decreased led by *Pterocarpus chrysothrix* (Mkurungu) with relative abundance of 0.3% of which it is in a threat to extinction. Environmental trainings to artisans were inadequately provided by 22% indicating low level of awareness on vegetation cover conservation. Therefore ASGM has negatively impacted vegetation cover in the study area. There is need for increasing protection against human intrusion in BMFR by employing joint forest management and establish an environmental management plan for BMFR.

DECLARATION

I, **Placidia Pancrace**, do hereby declare to the Senate of Sokoine University of Agriculture that this research is my own original work done within the period of registration and it has neither been submitted nor is it being concurrently submitted to any other institution.

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……. ……

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(Supervisor)

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AUTHOR CONTRIBUTION STATEMENT

The author confirms sole responsible for the study conception and design, data collection and analysis, results and discussions, and manuscript preparations.

LIST OF PUBLISHED PAPERS

Vegetation cover changes due to artisanal and small-scale gold mining in Bukombe-Mbogwe forest reserve in Geita Region, Tanzania.

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DEDICATION

The accomplishment of this research is dedicated to my parents (Pancrace Theonest Shwekelela and Domitina Michael Kyaruzi) together with my siblings (Diana, Datius and Pius). They have all been in touch with me at priceless cost and time throughout my study period.

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LIST OF ABBREVIATIONS

ASGM	Artisanal and Small-Scale Gold Mining
ASM	Artisanal and Small-scale Mining
BMFR	Bukombe-Mbogwe Forest Reserve
DOS 1	Dark Object Subtraction
EMP	Environmental Management Plan
ETM	Enhanced Thematic Mapper
FGD	Focus Group Discussion
FYDP II	Five Years Development Plan II
Ha	Hectare
ISODATA	Self-Organizing Data Analysis Technique
JFM	Joint Forest Management
LGM	Large-scale Gold Mining
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
ML	Maximum Likelihood
NDVI	Normalized Difference Vegetation Index
NIR	Near-infrared reflectance
OLI-TRIS	Operational Land Imager and Thermal Infrared Sensor
PA	Producer’s Accuracy
PFM	Participatory Forest Management
QGIS	Quantum Geographical information system
RED	Visible red reflectance
RGB	Red, Green and Blue
RMO	Regional Mining Office

ROI	Regions of Interest
SCP	Semi-automatic Classification Plug-in
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
TFS	Tanzania Forestry Services
TM	Thematic Mapper
UA	User’s Accuracy
USGS	United States Geological Survey

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Mining is one among the major contributors to any county's economy due to the high price value of minerals specifically gold. This is because gold is easily marketable and is less affected by government instabilities (Jianwei *et al.,* 2019; Oloko *et al.,* 2021). It involves either Large-scale Gold Mining (LGM) or Artisanal and Small-scale Gold Mining (ASGM) differentiated by the type of technology used and gold produced (Butancur-Corredor e*t al.,* 2018; G'afurovich *et al.,* 2020; Cano and Kunz, 2022). LGM is associated with high technological tools leading to high production of gold unlike ASGM that is associated with poor technological tools hence low gold production (Verbrugge and Geenen, 2019; Worlanyo *et al.,* 2022; Mestanza-Ramon *et al.,* 2022).

ASGM is a labour intensive gold mining practice associated with the use of low technological tools and poor working conditions practiced with the view of obtaining gold faster from gold ores (Verbrugge and Geenen, 2020; Cortes-McPherson, 2020; Mholongo and Akintola, 2021; Martinez *et al.,* 2022). ASGM is a good source of income improving people's livelihood in most rural areas throughout the world. There are about 150 million artisanal operators globally of which about 100 million of the artisans depend on it for their survival (Stoffersen *et al.,* 2019; Kyaw *et al.,* 2020; Kyaw and Sakakibara, 2022). During ASGM in different mining phases of construction, operation and after mine closure vegetation is degraded in need of mining ground (Githiria *et al.,* 2020; Bakobie *et al.,* 2020; Kimijima *et al.,* 2022). This leaves the land bare accelerating soil erosion and increasing soil infertility since the fertile grounds are washed away by wind and water (Worlanyo and Jiangfeng, 2021; Sari *et al.,* 2022).

ASGM has contributed to the growth of industrial sectors in most developed countries despite of its impacts to the environment like in Indonesia and Australia (Abdurashidovich, 2020; Harianja *et al.,* 2020; Kimijima *et al.,* 2022). There has been soil degradation in the areas where vegetation cover was cleared thereby decreasing soil fertility and nutrients due to erosion. This has led to less effectiveness of rehabilitation methods like restoration of the degraded soils after mining closure in the European countries like Philippines (Tsang *et al.,* 2019; Orlovic-Leko *et al.,* 2022; Espiritu *et al.,* 2022).

In Africa, thousands of unemployed youths mine for fortunes as a way to easily get rid of poverty (Brottem and Ba, 2019; Achina-Obeng and Aram, 2022). They normally use the means at their disposal for mining, irrespective of the impacts of their activities to the vegetation cover and their own health (Bansah *et al.,* 2018; Beda *et al.,* 2021). These issues have been accelerated due to improper mining methods, inefficient technologies, lack of technical training and lack of regulatory enforcement (Otamonga and Pote, 2020).

Bukombe-Mbogwe Forest Reserve (BMFR) is at a threat particularly deforestation due to the continuous ASGM activities surrounding it (IPP Media, 2019). The surrounding villages are also at risky on their vegetation cover as a result of the on-going ASGM activities. There is little research conducted on the impacts of ASGM activities on the vegetation cover. There have been limited studies focusing on BMFR's forest condition based on health-related problems in Shinyanga Region, and education in Mbogwe District (Bakengesa *et al.,* 2013; Alex, 2014; Erasto, 2019). This study contributed in addressing the impacts that arises due to ASGM activities in BMFR and surrounding villages in order to come up with solutions such as the use of modernized machineries.

1.2 Overall Problem Statement

Bukombe-Mbogwe Forest Reserve has been experiencing continuous deforestation reducing its coverage. Reports revealed that, 0.47 kha hectares of BMFR had been lost from its original 28.7 kha following severe deforestation of about 13% of its land cover in 2010 due to ASGM activities. Over 30 hectares of the forests were lost in favour of pits and logs for construction (IPP Media, 2018, 2019, 2020). This is because a great interest in mining was gold extraction and less concerned on safeguarding the vegetation cover especially among artisans who lack technical expertise (Morgane *et al*., 2018). This led to serious vegetation cover problems extending to surrounding villages.

ASGM are legal activities recognized by the Mineral Policy of Tanzania following their positive contribution to the economy through taxation (Veiga *et al*., 2014). However this activity is accompanied by land degradation, mercury contamination, cyanide release and pollution on vegetation cover (Black *et al.,* 2017). However, there were a few researches regarding vegetation cover problems faced by surrounding villages and BMFR due to ASGM (Bakengesa *et al.,* 2013; Alex, 2014; Erasto, 2019). This study intended to examine the vegetation cover impacts that villages surrounding BMFR face due to ASGM activities conducted.

1.3 Justification of the Study

This study was conducted due to the persistence of degradation in Bukombe-Mbogwe Forest Reserve (BMFR) and surrounding villages. Several studies in the area have focused on human health and education with a few of them on current state of BMFR and surrounding villages. Vegetation cover is essential in reducing high temperatures on the earth’s surface; it reduces soil erosion by increasing soil compatibility. It is also the habitat for most terrestrial animals acting as source of food preserving the natural

ecosystem. The current study contributed further to knowledge on the impacts ASGM activities have on vegetation cover in BMFR and surrounding villages.

The accomplishment of this study helped to set measures on proper forest protection against further destruction and to prevent further harm to surrounding villages above threshold. This aided in ensuring vegetation cover conservation for sustainable co-existence of mining and local villages in Mbogwe District. This also facilitated compliance with Sustainable Development Goals (SDGs); goal number 15 on life on land, and the Five Years Development Plan III (FYDP III) to ensure the improved vegetation cover for productive purposes and sustainably. Knowing the extent of forest degradation attributable to ASGM aimed to preventin further degradation and extinction of the forest species and associated biodiversity. This is by setting stricter rules and regulations like by providing licenses of vegetation cover conservation before mining commenced.

1.4 Objectives of the Study

1.4.1 General objective

The overall objective of this study was to examine the impact of Artisanal and Small-scale Gold Mining activities on vegetation cover in Bukombe-Mbogwe Forest Reserve and surrounding villages.

1.4.2 Specific objectives

The specific objectives of the study were to:

i. Explore the extent of vegetation cover change of Bukombe-Mbogwe Forest Reserve before and after Artisanal and Small-scale Gold Mining commenced.

ii. Examine the strategies used by Artisanal and Small-scale Gold Mining in conservation of vegetation cover in Bukombe-Mbogwe Forest Reserve and the surrounding villages.

iii. Determine the presence of indigenous forest tree species after Artisanal and Small-scale Gold Mining commenced.

1.5 Research Questions

The study intended to address the following research questions:

i. How has BMFR transformed due to the on-going ASGM activities?

ii. What measures has ASGM put in place following the impacts of mining activities on BMFR and surrounding villages?

iii. What tree species are endangered due to the availability of ASGM activities?

1.6 Theoretical and Conceptual Framework

1.6.1 Theoretical framework

The theories that guided this study were conservation theory by Gifford Pinchot of 1890 and disturbance theory by Joseph H. Connell of 1978. Conservation theory viewed natural conservation was triggered by wise use of resources available unlike for disturbance theory that viewed natural conservation as total restriction of human intrusion to natural biodiversity. The study employed conservation theory as there are human intrusions in BMFR and in order to conserve it for the future generation's benefit it should be wisely used. This is through having entry permits from TFS within the forest reserve. Due to over exploitation of resources from BMFR needed to employ total restriction of human entry in BMFR by employing disturbance theory's technique. This is important in order to allow natural regeneration to take place within the forest reserve. Hence these theories were used in complementary within the study.

1.6.2 Conceptual framework

This study consisted of background variables, independent variables as intermediate variables and dependent variables (Figure 1.1). Due to human intrusion in BMFR and availability of endangered tree species within the forest reserve there was need to hypothise the triggers (background variables). These included the characteristics which a particular individual had like age, employment and economic status that would influence conservation of vegetation cover. Age is an indicator of knowledge, maturity and experience; economic status is an indicator of wealth; education is an indicator of the ability of an individual to read and understand different publications and participate in different innovations and employment is an indicator of accumulation of wealth and having access to a variety of activities. The technology used during ASGM and the level of vegetation cover sensitivity also had indirect influence on the conservation of vegetation cover. In order BMFR to be conserved there was need to identify how wisely resources are used based on the triggers. They had increasing impact on vegetation cover conservation when the outcome results were positive and decreasing impact when the outcome results were negative. The independent variables each had its own impact on ensuring the increase or decrease of vegetation cover conservation.

The extent of vegetation cover change in BMFR was helpful in establishing the relationship between ASGM activities and the variation of vegetation cover in BMFR. This involved knowing the coverage of BMFR in hectares, vegetation health, and vegetation density. These parameters were studied based on disturbance theory calling for the need of total restriction in BMFR in order to allow regeneration of forest reserve to take place. These factors had either increasing or decreasing impact on vegetation cover conservation. They increased conservation when the resulting impact was positive and decreased conservation if the resulting impact was negative.

The strategies used during ASGM activities had either increasing or decreasing influence to vegetation cover conservation. They involved ways ASGM gold activities are conducted in terms of chemicals used and handled and disposal form of effluents. Transportation facilities involved use of heavy trucks leading to destruction of rural roads and access to environmental trainings were examined. Implementation of these strategies indicated they dealt with the vegetation cover conservation. The absence of these strategies indicated there was little or no vegetation cover conservation.

The presence of tree species in the study area with time variation before and after ASGM activities commence was studied in order to know trees that have extinct and more vulnerable since ASGM activities commenced. The availability of all the tree species in there abundance, density and health that were present before ASGM to date hypothesised no negative impact to conservation. There unavailability to date hypothesised ASGM activities had negative impact to vegetation cover conservation.

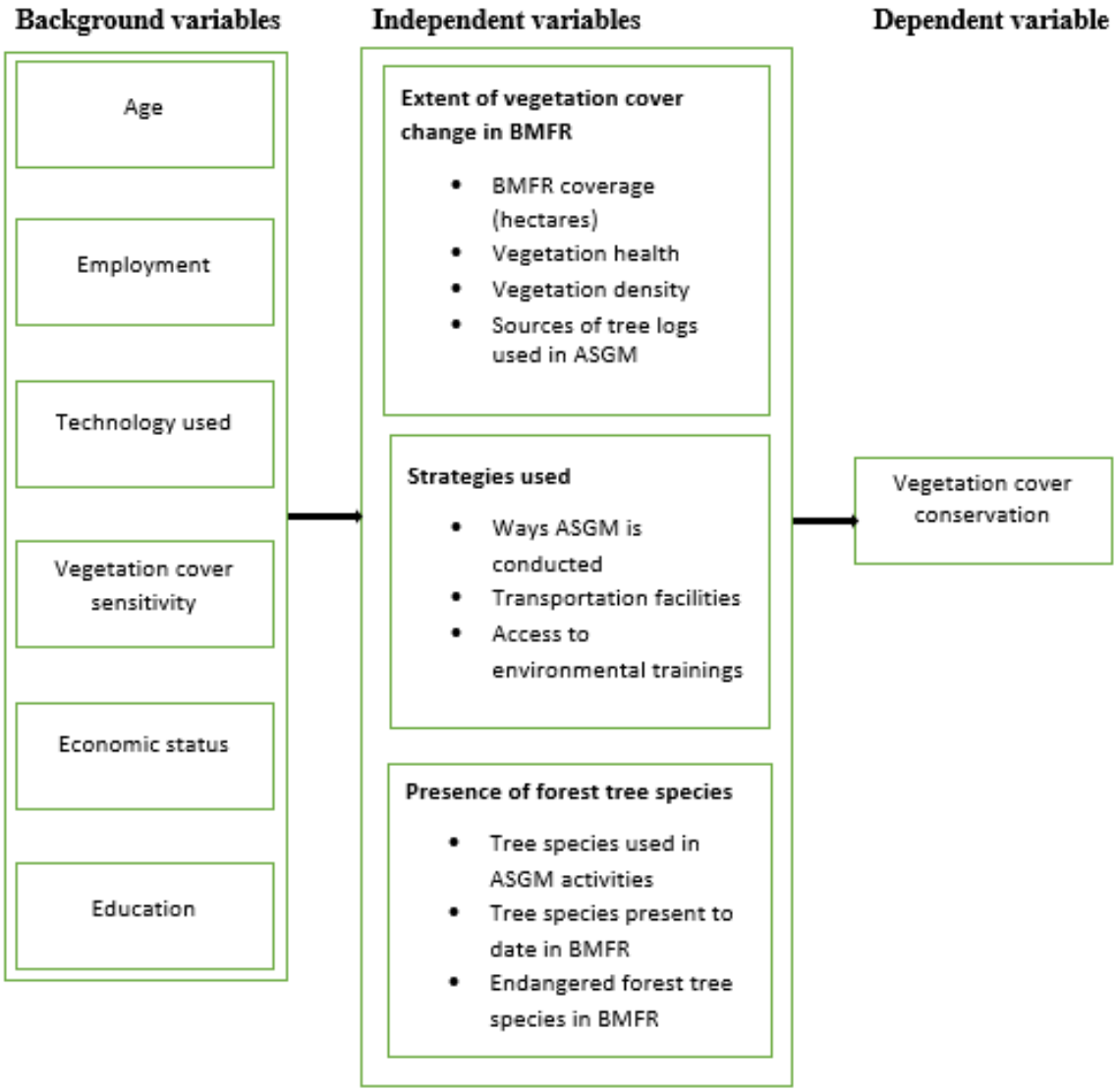

Figure 1.1: Conceptual framework (source: Author).

1.7 Study Limitations

The study was limited by unwillingness of some respondents to provide reliable information when requested, language barrier as others used Sukuma language only and unavailability of the management plan of Bukombe-Mbogwe forest reserve. These were overcome by doing participant observation and residing within their premises in order to understand the meaning behind their languages. .

1.8 Description on the Organization of the Dissertation

The dissertation is organized in form of guideline for authors in Tanzania Journal of forestry and nature conservation (chapter two) and the sub Saharan journal of social sciences and humanities (chapter three).

CHAPTER TWO

Vegetation Cover Changes due to Artisanal and Small-Scale Gold Mining in Bukombe-Mbogwe Forest Reserve in Geita Region, Tanzania

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CHAPTER THREE

Impact of Artisanal and Small-scale Gold Mining on Tree Species in Bukombe-Mbogwe Forest Reserve in Mbogwe District, Tanzania.

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The material contained in this chapter is submitted to the sub Saharan journal of Social Sciences and Humanities

Abstract

Bukombe-Mbogwe Forest Reserve (BMFR) has continuously experienced decrease in its tree species. This has been accelerated by the availability of Artisanal and Small-scale Gold Mining (ASGM) within the district. This study aimed at determining tree species variations within the forest reserve and surrounding villages due to ASGM activities. A total of 138 respondents were randomly selected of which 120 were involved in questionnaire survey and 18 participants in key informant interviews. Participant observations, 3 focus group discussions (1 from each village), and literature searches were also employed. Content analysis was employed for qualitative data and descriptive analysis for quantitative data and Microsoft excel was used for presentation. The study found out that forest tree species decreased in abundance after ASGM commenced. *Pterocarpus chrysothrix* (Mkurungu) tree speciesis near to extinct followed by *Brachystegia microphylla* (Mgela), and *Afzella quenzensis* (Mkora) species. Environmental trainings were inadequately provided of which 78% of the respondents indicated that there were no trainings and 22% there were trainings. Mine closure plans were ineffective of which 1.7% had restoration plan, 24.1% had plans to plant trees, and 74.2% had no plans. Therefore; ASGM has negatively contributed towards conserving forest tree species in BMFR. There is need for increasing protection against human intrusion in BMFR to allow natural regeneration to take place and establish an environmental management plan for BMFR.

Key words: Tree species, Gold mining, Bukombe-Mbogwe, Forest reserve, Impact.

3.0 BACKGROUND INFORMATION

Artisanal and Small-scale Gold Mining (ASGM) is a mining practice associated with limited capital investment employing low technological tools with poor working conditions leading to low production of gold (Mutagwaba *et al*., 2018). It is practised mostly with the view of obtaining wealth faster by rural community occupants, nomadic people and farmers. They contribute positively towards increasing foreign exchange earnings and employment opportunities (G'afurovich *et al.,* 2020; Asare *et al.,* 2022). Despite its benefits, it is still encountered with deprived quality of life within mining sites and surrounding areas (Umirzoqov, 2020).

There are about 40.5 million men and women involved in ASGM with more than 150 million people dependants on it for sustaining their livelihoods globally. This is due to the rising price value of gold and increased difficulty of earning a living from alternative activities (Hentschel *et al.,* 2002). The need for tree logs used during mining activities has made nearby forests to be invaded and exploited like in Peru (Diringer *et al.,* 2019). This has increased deforestation rates within forest reserve areas and decreased tree species abundance reducing carbon sequestration like in the Amazon forests (Espejo *et al.,* 2018).

Despite the benefits of ASGM to the economic growth and raising people's living standards in Africa. It is accompanied by negative impacts to the environment due to high interest of miners being in gold recovery other than environmental sensitivity (Adesipo *et al.,* 2020). There are about 54 million people whose livelihoods are dependent on ASGM activities as a rush type activity especially in the rural context (Hilson, 2016). In other parts of Africa like in Congo, Ghana and Nigeria despite licensing of artisans, they are reported to contribute in exploitation of forest tree species in need of tree logs and timber

used during mining (Girmay, 2018; Nkubai *et al.*, 2019; Adesipo *et al.*, 2020; Akomaning *et al.*, 2021; Takyi, 2021).

Artisanal and small-scale gold mining is recognized legally through provision of mining licenses for individual firms contributing positively to government revenue through taxation in Tanzania (Machacek, 2019; Kinyondo and Huggins, 2020; Mtasigazya, 2021). Most communities where ASGM is conducted there is usually a large transformation of inhabitants from being farmers to miners (Britwum, 2022). This leads to increase of human population within and around mining sites of which nearby forest tree species are extracted for mining activities there by degrading the forest. This has happened like in North Mara (Massay and Kassile, 2019). Due to ASGM, forest tree species are removed in search of gold and in use of its resources. Restoration of degraded areas like through reforestation and afforestation attributable to mining has been ineffective due to severe degradation (Roman-Danobeytia *et al.*, 2021).

Bukombe-Mbogwe Forest Reserve (BMFR) has been experiencing continuous degradation that is accelerated by the presence of ASGM activities within Mbogwe District. This has led to the decrease in tree species present within the forest reserve. The decrease is accompanied by the need of logs for pit construction in mining areas around Mbogwe District and other districts in Geita Region. In the early 1980s Resolute mining limited from Australia owned the mine sites and they were interested in gold recovery rather than environmental conservation. They extracted and used trees only from BMFR for pit construction and timber within the mine sites especially at Nyakafulu mine site till the late 1990s (Michael, 2019). At this time tree species (*Eucalyptus paniculata*) started to be used in complementary to cover up the deficiency of endogenous tree species from BMFR. From 2016, gold mining sites were provided and owned by Tanzanians and at this

time the rate of destruction increased since most people were interested at having their own pits for obtaining gold. There was high rate of degradation and deforestation hence decrease in tree species within the forest reserve (Sophia *et al.*, 2018).

The overall objective of this study was to examine the impact of artisanal and small-scale gold mining on tree species in Bukombe-Mbogwe Forest Reserve. Specifically, it aimed at determining the presence of indigenous forest tree species after ASGM commenced, examine the availability of environmental trainings during ASGM, and examining plans after mine closure.

3.1 Theoretical and Conceptual Frameworks

3.1.1 Theoretical framework

The theories underlying the study were conservation and disturbance theory. Conservation theory by Gifford Pinchot based on resource conservation ethics. He viewed conservation as a way of wise use of earth's resources for the benefit of the present and the future generation. The wise use of public land of which is not subjected to total restriction of the land for various activities. He is against exploitation of land resources with emphasis of sustainable use of resources preserving it for the future generations. However the theory was criticized by Muir that believed human actions would likely harm the nation's landscape. He emphasized on total avoiding of human activities in conservation areas. It follows that, due to the need of full filling human needs for survival, humans are allowed to a certain extent to have access to conserved resources. In this study, due to the need for continuous survival, humans are extending further to the restricted areas exploiting the forest tree resources. The need for gold is becoming a threat to BMFR and to the villages surrounding it hence studied.

Disturbance theory based on natural biodiversity as essential for the sustainability of life on earth. However, it is hindered by human activities in search for a living (Turner *et al.*, 1993). Due to these disturbances, there has been different temporal and spatial changes on naturally occurring vegetation to various communities. Due to such human disturbances, it is very important to know the species that are vulnerable to the disturbance in order to avoid their extinction. It is expected for the natural biodiversity to renewal, but when disturbance exceeds their ability to renew may lead to a global concern.

3.1.2 Conceptual framework

The conceptual framework explained the relationship among the background variables at the left, the independent variables at the middle, and dependent variable at the right (Figure 3.1). The conceptual framework hypothesized the characteristics of a particular individual such as age, education, employment, economic status, technology used in ASGM would influence conservation of tree species. Age is an indicator of knowledge, maturity and experience of an individual on conservation issues. Economic status is an indicator of wealth as it is believed that there will be money earned from the activities conducted. Education is an indicator of the ability of an individual to read and understand different publications and participate in different innovations. Employment is an indicator of income level alleviation. They may have increasing or decreasing impact ensuring BMFR and surrounding village tree species are conserved. They had increasing impact on tree species conservation when the outcome results were positive and decreasing impact when the outcome results were negative. The independent variables each had its own impact on ensuring the increase or decrease of tree species conservation hence studied.

The presence of tree species in the study area with time variation after ASGM activities commenced was studied. This was helpful in knowing the trees that have extinct and

endangered since ASGM activities commenced. If there were no endangered tree species in relation to ASGM indicated positive impact to tree species conservation in the study area. And if there were endangered to near extinct tree species indicated ASGM had negative impact on the study area.

The strategies used during ASGM activities may have either increasing or decreasing influence to tree species conservation. This included availability of environmental trainings; measures taken after tree harvesting and area for disposal of tailings were examined. The availability of implementation of these strategies meant they dealt with the tree species conservation. The absence of these strategies implied there were little to no conservation of tree species in the study area.

Availability of plans after mine closure acted as an indicator of environmental consciousness to the conservation of tree species within the study area. If there were plans (planting trees and restoration) after mine closure this indicated ASGM had positive impact to conservation of tree species and vice versa.

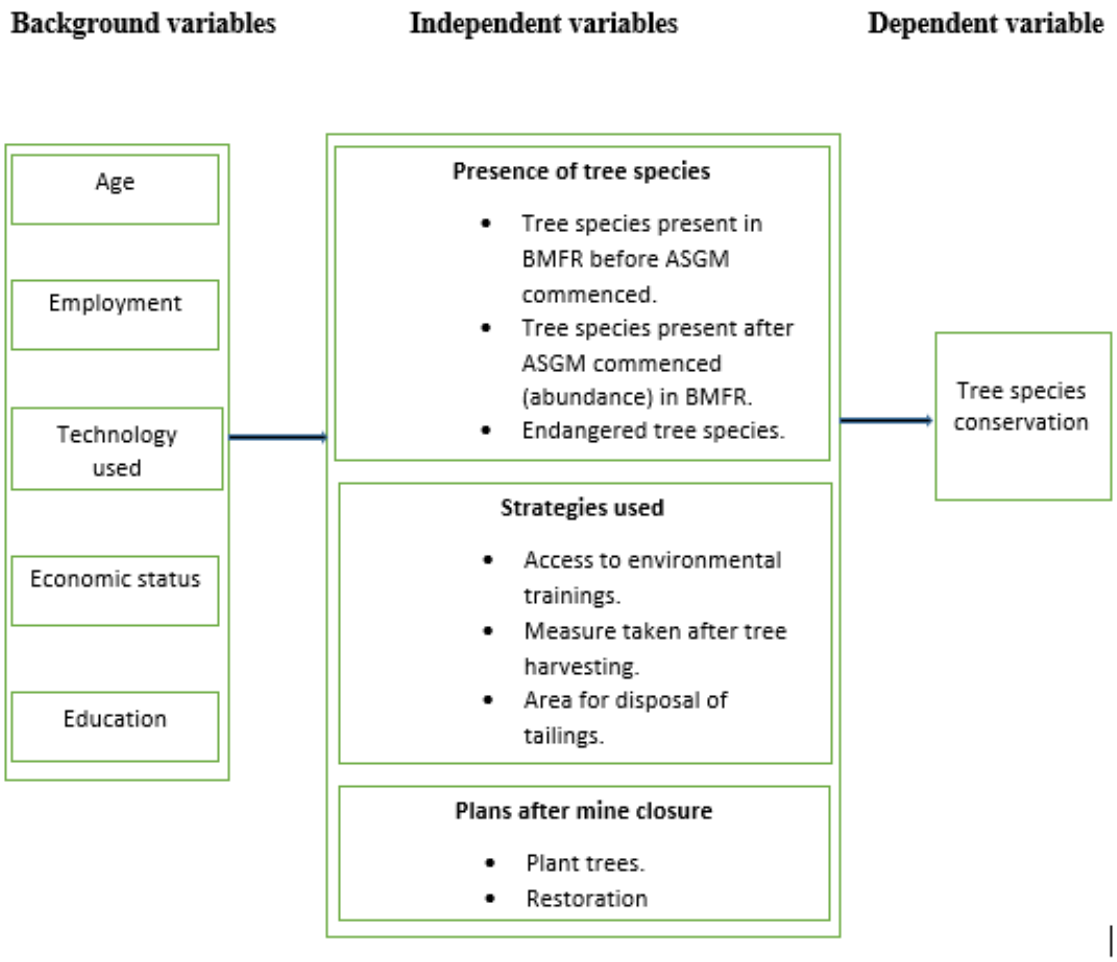

Figure 3.1: Conceptual framework of the study

3.2 Materials and Methods

3.2.1 Description of the study site

The study was conducted at the Bukombe-Mbogwe Forest Reserve (BMFR) and the surrounding villages, located in Mbogwe District, Geita Region (Figure 3.2).

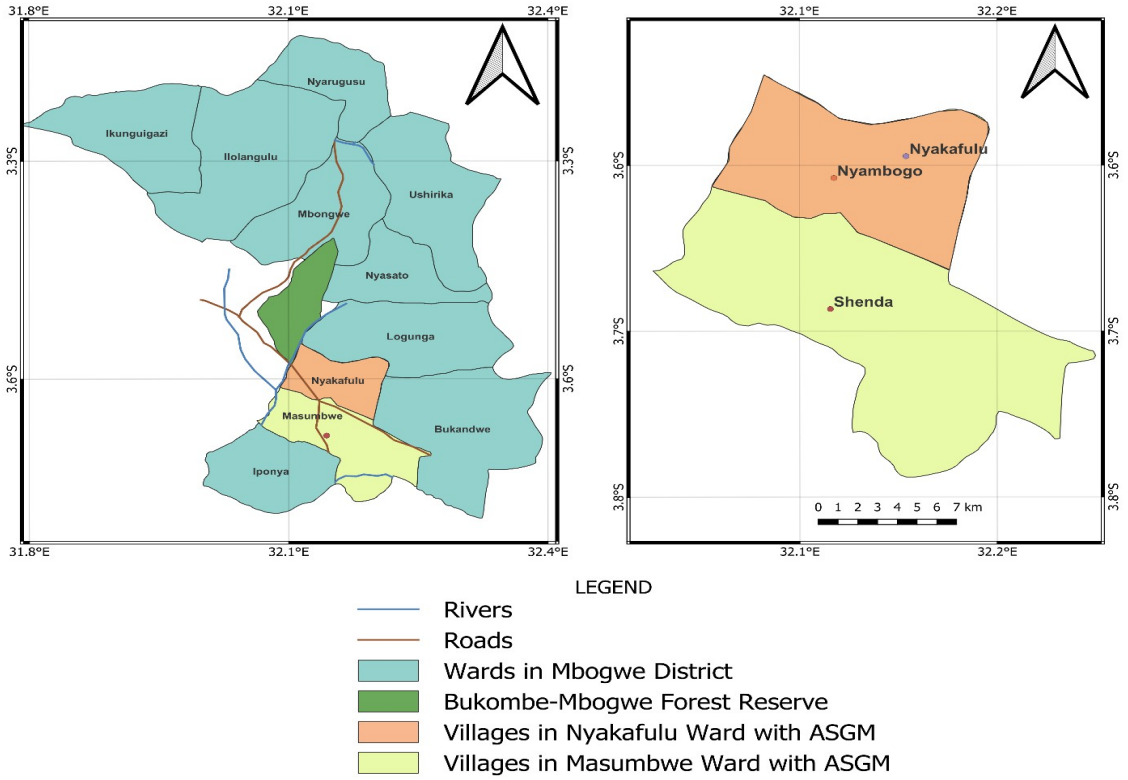

Figure 3.2: Location of the study area (QGIS Version 3.16)

The study involved Nyakafulu and Nyambogo Villages in Nyakafulu Ward and Shenda Village in Masumbwe Ward because there were ASGM activities conducted surrounding BMFR.

3.2.2 Data Collection

3.2.2.1 Ecological data

This was conducted in Bukombe-Mbogwe Forest Reserve in Mbogwe District of Geita Region. It firstly involved visiting the district forest office and obtaining the list of tree

species that were dominant within the forest reserve before ASGM commenced. This was secondly followed by going to the field accompanied by the representative from the council that was detailed on identifying and differentiating different tree species within the forest reserve in order to determine tree species present to date (2022) by determining their relative abundance. Thirdly, six plots were randomly selected each of one hectare then tree species with reference to the list provided were counted in each plot and the average was determined. This was done by obtaining the total number of single specie divided by the number of plots studied. Lastly, relative abundance was obtained for each specie within the forest reserve. Relative abundance was used as a relative measure of how common a species is relative to other species. It is used to show the relation of one species to other tree species within the ecological boundaries (MacArthur, 1960).

$$\mathbf{P_A = n_o / n_T}$$

Where; $\mathbf{P_A}$ = Relative abundance, $\mathbf{n_o}$ = Total number of individual species and $\mathbf{n_T}$= Total number of species population.

This was followed by conducting three focus group discussions within the three villages in order to obtain more details on the kind of tree species used during gold mining. This involved artisans and non-artisans known to reside for about 15-20 years within the study area. Lastly, the district environmental officers provided details on the kind on tree species that are endangered and are highly used within mine sites within and outside the district.

3.2.2.2 Socio-economic study design, sampling and data collection

The study employed cross-section research design of mixed approach (qualitative and quantitative methods) because it can collect multiple data within a narrow time span

hence less cost involved (Bryman, 2016). Sample households were purposively selected involving artisanal and small-scale gold mining from the study villages. This was followed by systematic random sampling technique of which the studied sample was selected from village registers. This was done by selecting the first household purposively and the rest were selected after every 6 interval in order to minimize selection bias guided by the formula (k = N/n) whereby; k is the interval size for selection, N is the total population and n is the required sample number (Fite *et al*., 2018). The sample size was 138 determined by using Cochran formula (Israel, 2012);

$$n=\frac{Z^2 \times pq}{e^2}$$

Where; *n* = required sample size; Z = Confidence level at 95% (standard value of 1.96); p = Estimated proportion of an attribute that is present in the population; q = 1 - p; e = Marginal of error at 5% (standard value of 0.05)

Therefore,

$$n=\frac{(1.96)^2 \times 0.1(1-0.1)}{0.05^2}=138$$

Questionnaire surveys were involved of which 40 questionnaire guides (open and close-ended) were provided to each village totalling to 120. These were used to collect information related on the availability of environmental trainings within ASGM firms

including knowing the actions for the solid tailings and measures taken after tree harvesting. This also involved knowing the kind of tree logs used during mining and the availability of tailing storage facilities within the mining firms. The study also involved one Focus Group Discussion (FGD) of seven participants from each village with a facilitator totalling to three FGDs involved. This is because FDGs is encouraging with participants ranging from 5 to 12 informants (Dodds and Hess, 2020). These aimed at collecting information related to the commencement of ASGM within the villages in relation to conservation of tree species in BMFR, community perception of the status of BMFR if mining activities keep on operating for decades within the district and plans taken after mine closure. Checklists for key informant interviews were provided to Mbogwe forest officer (1), Mbogwe environmental officers (2) and Mbogwe mining officers (2), village leaders (5), ASGM representative leaders (8). These provided baseline information regarding transformation of forest tree species in relation to the period since ASGM activities commenced within the district and awareness of the government support if any during mining. Secondary data were collected from the Regional Mining Office (RMO) and environmental office in Mbogwe District Council Office (documentary review). Literature searches from published and unpublished official sources in the internet and libraries related on this study were also employed. Furthermore; participant observation was involved by living with indigenous people and obtaining more insights regarding on how ASGM is conducted in relation to tree species used from BMFR with pictures taken for more clarity. This provided more details on reasons why indigenous tree species from BMFR are preferred to other tree species.

3.2.3 Data analysis

Data collected through household survey was corrected, processed and analysed using Statistical Package for Social Sciences (SPSS) version 20 and Microsoft excel for

presentation were quantitative and qualitative variables were analysed. Qualitative data collected though verbal discussions held by different respondents during focus group discussions and key informant interviews were analysed using content analysis basing on the themes. Quantitative data were analysed descriptively computing individual variables through frequencies, percentages, averages, minimum and maximum values.

3.3 Results and Discussion

3.3.1 Presence of indigenous forest tree species after artisanal and small-scale gold mining commenced

The most dominant tree species were *Brachystegia spiciformis* (7.0%), *Pterocarpus chrysothrix* (7.0%), *Brachystegia boehmii* (7.0%), *Pterocarpus angolensis* (6.8%), *Strophanthus eminii* (6.7%), *Pericopsis angolensis* (6.7%), *Afzella quanzensis* (6.7%). Next to these were *Terminalia sericea* (6.7%), *Sterculia africana* (6.6%), *Combrentum zeyheri* (6.6%), *Acacia rovumaeas* (6.6%), *Annona senegalensis* (6.6%), *Brachystegia micropylla* (6.6%). Most rare tree species included: *Commiphora ugongensis* (6.3%) and *Combretum molle* (6.1%) as presented in Table 3.1.

Table 3.1: Tree species present in BMFR before the commencement of ASGM activities in the study area

Tree species botanical name	Common names	Local names	Frequency (N)	Percent (%)
Acacia rovumaeas	Wattles	Mtundwa	104	6.6
Afzella quanzensis	Pod mahogany	Mkora	106	6.7
Annona senegalensis	Wild custard apple	Mtopetope	104	6.6
Brachystegia boehmii	Prince of wales feathers	Myenze	110	7.0
Brachystegia microphylla	Chikuni	Mgela	104	6.6
Brachystegia spiciformis	Spiciformis	Mtundu	111	7.0
Combretum molle	Velvet-leaved comretum	Mlama	97	6.1
Combretum zeyheri	Zeyheri'sbushwillow	Mlamamweupe	104	6.6
Commiphora ugongensis	Corkwood	Mkongoro	100	6.3
Pericopsis angolensis	East African afrormosia	Mbanga	106	6.7
Pterocarpus angolensis	African teak	Mninga	107	6.8
Pterocarpus chrysothrix	Mukula	Mkururngu	110	7.0
Sterculia africana	Mopopaja	Moza	104	6.6
Strophantus eminii	Emin'sstrophanthus	Mvelevele	106	6.7
Terminalia sericea	Silver terminalia	Mzima	105	6.7
Total			**1578**	**100**

Brachystegia spiciformis tree species are of different types and were dominant throughout making them the most dominant species followed by *Pterocarpus chrysothrix*, and *Brachystegia boehmii*. *Combretum molle* species were present in scarcity amongst all tree species available in BMFR.

In this study relative abundance was used to show the presence of species variation within BMFR. This has enabled to know the species that are abundant and those that are almost extinction (Table 3.2).

Table 3.2: Relative abundance of tree species in BMFR

Tree species botanical name	**Common names**	**Local names**	**Number of trees per ha.**	**Relative abundance (P_A)**
Acacia rovumaeas	Wattles	Mtundwa	25	0.082
Afzella quanzensis	Pod mahogany	Mkora	7	0.023
Annona senegalensis	Wild custard apple	Mtopetope	30	0.098
Brachystegia boehmii	Prince of wales feathers	Myenze	10	0.033
Brachystegia microphylla	Chikuni	Mgela	8	0.026
Brachystegia spiciformis	Spiciformis	Mtundu	15	0.049
Combretum molle	Velvet-leaved comretum	Mlama	40	0.131
Combretum zeyheri	Zeyheri'sbushwillow	Mlamamweupe	28	0.092
Commiphora ugongensis	Corkwood	Mkongoro	35	0.115
Pericopsis angolensis	East African afrormosia	Mbanga	11	0.036
Pterocarpus angolensis	African teak	Mninga	12	0.039
Pterocarpus chrysothrix	Mukula	Mkururngu	1	0.003
Sterculia africana	Mopopaja	Moza	30	0.098
Strophantus eminii	Emin's strophanthus	Mvelevele	26	0.085
Terminalia sericea	Silver terminalia	Mzima	27	0.089
Total			**305**	

Table 3.3 shows endangered forest tree species since the commencement of ASGM activities, 14.4% of respondents agreed on the *Pericopsis angolensis,* 14.8% *Pterocarpus chrysothrix*, 14.7% *Brachstegia microphylla*, 14.7% *Afzella quenzensis*, 14.4%

Pterocarpus angolensis, 14.4% *Brachystegia boehmii*, and 12.5% *Brachystegia spiciformis*.

Table 3.3: Endangered tree species in BMFR after ASGM commenced

Tree species botanical name	Common names	Local names	Frequency (N)	Percent (%)
Afzella quanzensis	Pod mahogany	Mkora	108	14.7
Brachystegia boehmii	Prince of wales feathers	Myenze	106	14.4
Brachystegia microphylla	Chikuni	Mgela	108	14.7
Brachystegia spiciformis	Spiciformis	Mtundu	92	12.5
Pericopsis angolensis	East African afrormosia	Mbanga	106	14.4
Pterocarpus angolensis	African teak	Mninga	106	14.4
Pterocarpus chrysothrix	Mukula	Mkurungu	109	14.8
Total			**735**	**100**

BMFR is denominated with miombo woodland species making it susceptible to changes in tree variation if over exploited. *Pterocarpus chrysothrix* was the leading tree species that has been degraded and is expected to extinct within BMFR if no further protection measures are taken. It was exploited for timber and pit logs within the mine sites. This is because it is best preferred in mining during exploration and mine closure due to its quality characters (Zulu *et al.*, 2020). It is more resistant to water penetration when in the ground and not affected by underground and above ground microbes (Moonga and Chileshe, 2019). Due to its superiority characters it was more exploited than other tree species illegally like in Zambia of which it is almost to extinct. It is one among most valuable tree species in monetary terms hence extracted highly and sold for profit making (Phiri *et al.*, 2015). Followed by *Afzella quanzensis* and *Brachystegia microphylla* were used and still used currently specifically for logs within mine pits making them to be included in the group of endangered tree species. *Brachystegia spiciformis* had the lowest

percentage value due to the different types (Mtondo, Mtondolo, Mtundu, Mnembela, Mputu, and Msima) trees found within this group of tree species in BMFR.

BMFR was dominated by *Brachystegia spiciformis, Combretum molle, Terminalia sericea, Strophanthus eminii, Brachystegia boehmii, Sterculia africana, Commiphora ugongensis, Combretum zeyheri, Acacia rovumaeas, Pterocarpus angolensis, Pterocarpus chrysothrix, Pericopsis angolensis, Annona senegalensis, Brachystegia microphylla,* and *Afzella quenzensis* (Tanzania forest service agency, 2020). All these tree species were abundant and plenty dominating BMFR even before the declaration in 1954 as a forest reserve. They have a tendency of regenerating naturally and may take up to about100 years to mature for extraction (Marc *et al.,* 2019). Mbogwe forest officer stated that *"there is total restriction of human activities in BMFR despite human encroachment in need of logs for mining, timber, and firewood."*

All tree species present in BMFR are still present despite the fewer number of tree species present in abundance (0.003-0.115). Mbogwe forest and environmental officers stated that "*there is no tree species that has extinct to date."* There are some trees that were highly degraded in the past decades following the need of logs for construction purposes in mine sites. Despite the government posing total restriction on the entrance and any human activity still illegal activities were conducted. Due to the availability of gold in Mbogwe District and the need to have mine pits, many logs were obtained from BMFR. It was mentioned by the District forest officer that "*indigenous forest tree species were only trees used for pit construction till late 1990s following high rate of decrease of trees.*"

From BMFR most of its natural trees were cut for gold mining activities making the forest currently to have middle class diameter trees ranging from 157mm to 455mm (Gi-Young

et al., 2013). The tree species that were reported to be highly used in mine pits included *Brachystegia spiciformis, Pterocarpus angolensis, Pterocarpus chrysothrix, Pericopsis angolensis, Brachystegia microphylla,* and *Afzella quanzensis.* All these are now endangered tree species and if not well protected are likely to extinct. *Pterocarpus crysothrix* is a tree species that is highly endangered and is likely to extinct from BMFR in near years if not protected.

The high need of indigenous forest tree species was accompanied by their characteristics of not shedding their tree barks even in the presence moisture content. This made them to be highly exploited for use in mine pit construction mostly at Nyakafulu gold mine (Makumbe *et al.,* 2020). These tree species despite their scarcity they are still preferred and used in mine pits like in Shenda mine site including *Brachystegia spiciformis, Pterocarpus angolensis,* and *Pterocarpus chrysothrix.*

ASGM pits extend to about 30 meters and above for shallow mine pits and to about 80 meters for deep mine pits due to the increase in excavation and gold being at greater depths (Hilson *et al.,* 2019; Aliyu *et al.,* 2019). Nyakafulu mining site posed many mining pits and each day it was estimated not less than three trucks of logs were imported. Due to the scarcity of indigenous forest tree species, most tree logs used were from *Eucalyptus paniculata* tree species in construction of mine pits to date (Siqueira-Gay *et al.,* 2020). *Eucalyptus paniculata* tree species are currently used as an alternative since they can grow and mature within a short time before harvesting as compared to the miombo woodlands. These tree species are unfavourable for the safety within mine pits as the shed there barks in the presence of moisture leading to collapse of mine pit and deaths of the people in the mine pits. It is from this fact that tree species were highly degraded from

BMFR and used during mine sites endangering their survival in the near future. Plate 3.1 shows pit constructed with *Brachystegia spiciformis* tree species.

Plate 3.1: Pit constructed using *Brachystegia spiciformis.*

3.3.2 Availability of environmental trainings during ASGM

From the results obtained, about 22% of the respondents agreed on the availability of environmental trainings and 78% denied. This is because the trainings are most on gold recovery other than conservation of the tree species. Trainings were provided by a group called "*Tunza mazingira Mbogwe*" and paid by respective ASGM firms.

There was high response (78%) on the absence of environmental trainings of which this was accelerated by interest they possess. Artisans are more interested at obtaining gold at whatever cost possible with no concern to the environment. It was stated by the district

environmental officer that "*environmental trainings are provided when there are special interests regarding on the payment that is to be provided by ASGM firms and the trainings are taken into consideration and employed at least in gold mine plants.*"

Disposal of tailings is also an issue indicating whether education is provided on the safety of humans and environment. Tailings after gold recovery from the ore within mine sites were disposed in various ways depending on the time and money available. From the results, 5.8% of tailings are transported to tailing storage facility for treatment, 71.7% are piled on open areas and 22.5% were taken to gold mine plants for leaching processes. Tailings were least taken to tailing storage facility due to it being expensive for treatment, which is unaffordable for most artisans (Figure 3.3).

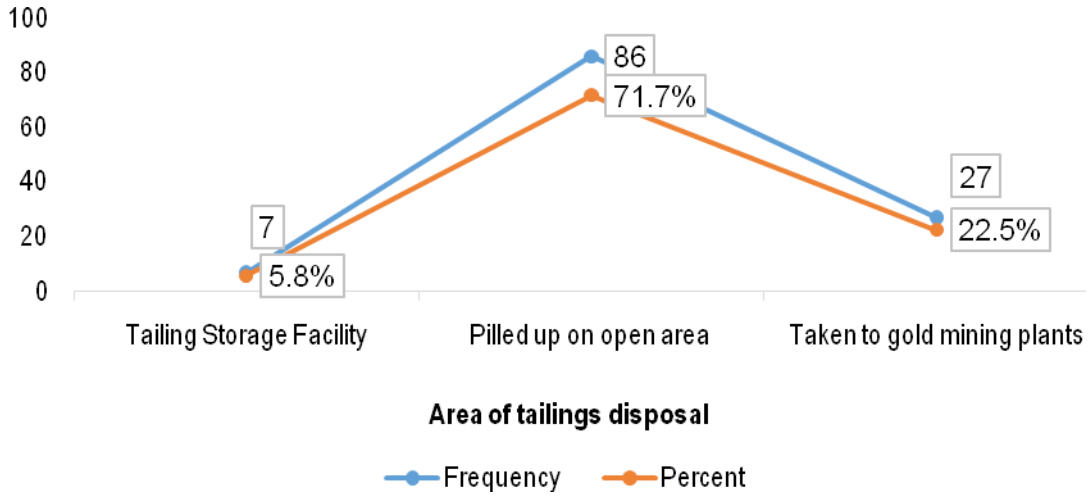

Figure 3.3: Area for disposal of tailings after gold recovery

There is need to ensure tree species are maintained in order not to alter climate variability and change. Since tree logs were used in mine sites there was need of knowing actions taken after cutting down of trees. Tree logs obtained from BMFR cannot be replaced by human actions since they do natural regeneration when there is no human disturbance.

From the responses obtained, 31.7% declared that afforestation was conducted 9.1% reported that reforestation was conducted in the sites where deforestation of *Eucalyptus paniculata* was done. It was stated by the district environmental officer that "*Eucalyptus paniculata tree species were owned by private institutions like schools and churches and make business from them."* Most respondents (59.2%) said there were no plans yet on the actions taken after tree extraction from their sources. Nyakafulu mining site was the leading in the importation of logs hence the leading mine site in deforestation (Figure 3.4).

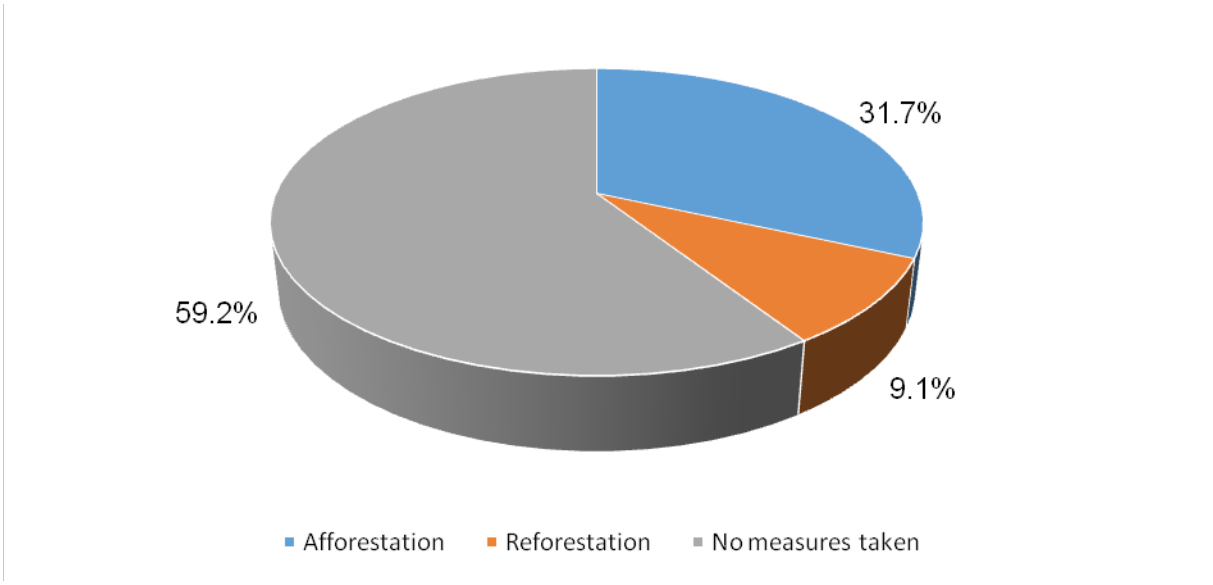

Figure 3.4: Measures taken after tree harvesting during ASGM

Environmental trainings and monitoring are compulsory and need to go in complementary to ensure safety of the environment. In mining, there is a challenge of monitoring and supervision on what is to be done after education is provided. Inadequate monitoring of the trainings provided leads to continuous environmental degradation (Keegan *et al.*, 2020). Monthly trainings and workshops are necessary to be provided to the artisans in order to promote more awareness (Louisa and Justin, 2018).

The environmental office authorized an environmental group (Tunza mazingira Mbogwe) to provide trainings. The trainings were ineffective since they were provided on the basis of the firms that pay more money for trainings conducted other than conservation as seen from results by 22%. There were no follow ups to ensure what has been taught is put into practice hence continual degradation. Mine pits were constructed on the basis of predictions and belief of availability of gold. If not available, pits were left bare uncovered weakening the upper soil and making pits to collapse (Plate 3.2).

Plate 3.2: Abandoned mine pit at Nyambogo mine site.

In this study, 5.8% of the respondents agreed on tailings to be taken to the tailing storage facility (tailing dam) for treatment after leaching process. About 71.7% of the respondents agreed that tailings were piled up in open area after gold recovery. This was done in mine rashes and the duration of the pilling up depended on the amount of tailings available. It may take up to six months to a year for solid tailings remaining on bare land before there transportation to the mine plant for leaching purpose. The long duration of the tailings

containing hazardous chemicals like mercury on bare land exposes them to rain and wind leading to pollution of far villages (Reginawanti *et al.*, 2018).

Vegetation cover is cleared as the first step to obtain gold from its ore. Clearance of vegetation (trees and grasses) leaves the soil bare there by facilitating erosion and further degradation. It is expected after cutting down trees, afforestation or reforestation to be conducted for sustainability. Forests are cut down for the need of timber leaving it bare and reducing its ecological cycle (Johanna and Stephen, 2021). The district forest officer stated that "*there is no law that allows entry and extraction of forest tree species from BMFR, the only allowed entry is when there is need for electricity poles to pass through towards adjacent villages."* There is high rate of deforestation in BMFR and since it is a miombo woodland, it only depends on natural regeneration for survival. In the past decades, there were many indigenous trees that have currently disappeared due to the high need of such trees used as logs for mining activities (Plate 3.3). There is no reforestation done in BMFR because the nature of miombo woodlands is natural regeneration hence left bare (Reuben *et al.*, 2019). Because of the need of logs during mining and the insufficiency of natural tree logs, most mining sites are currently outsourcing logs from the planted forests, mainly of *Eucalyptus paniculata*.

Plate 3.3: Tree logs at Nyakafulu mine site

3.3.3 Plans after mine closure

Mine closure in this study referred to the period of time when the ore-extracting activities of a mine have ceased. This calls upon for final mine closure and mine reclamation for completion. From the results provided by the respondents, 24.1% agreed on the plan to plant trees in the mine leaching plantations in order to ensure the landscape is retained even though not to the extent it was before. There was 1.7% of response on the option of restoration planning to return the area at the state it was before mining. The majority of the response (74.2%) indicated no plans were in place after mine closure (Figure 3.5).

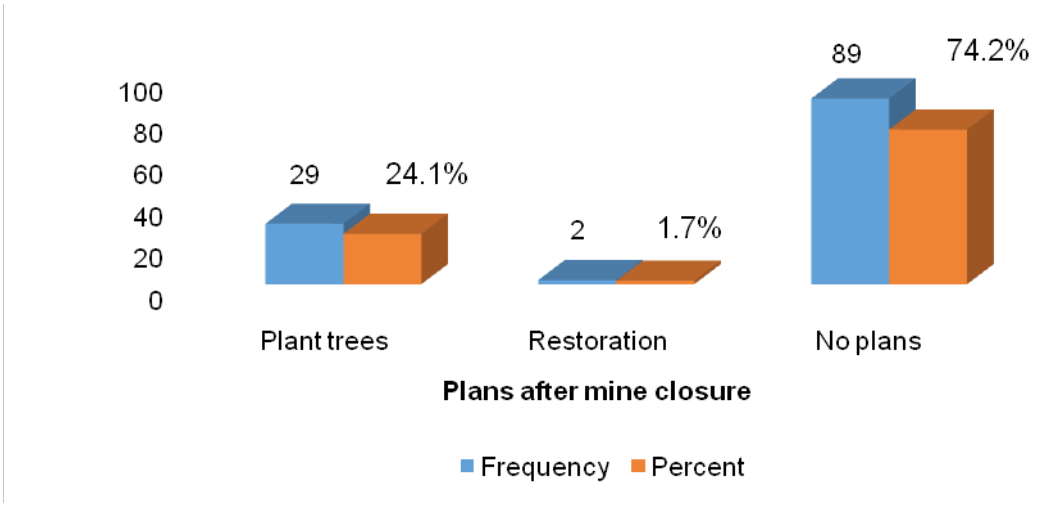

Figure 3.5: Mine closure plan of ASGM

The use of hazardous chemicals during mining in particular mercury and cyanide needs mine closure plan to avoiding further environmental degradation. Mercury is recognized as lethal, insistent and transportable contaminant hence should be well managed (Eisaku *et al.*, 2020). Formalization of ASM is reported to have limited connection with environmental conservation. This is followed by the nature of miners due to their nomadic nature, lack of funding, limited capacity, and usage of license for wealth gaining in Tanzania (Abel and Christopher, 2021). Mining is accompanied with ecosystem disturbance and rehabilitation is essential and this is by first restoring the soil quality. Soil quality is expected to deteriorate due to the use of toxic chemicals like mercury and cyanide (Sabrina *et al.*, 2021).

This study found out that there was high percentage of no plans yet set on what should be done after mine closure. This was because of high availability of gold and it is not expected to deplete in the near future as stated by mining officer. In mine pits, gold may either increase or decrease depending on the direction of gold ores. Pits are left bare open without closure or being filled if gold is not found. There is need of preparing

Environmental Management Plan (EMP) after mine closure to ensure the safety of human and environment specifically within mine lashes. Vegetation cover is degraded before and during mining and it is expected to be restored (Chenaimoyo, 2020).

It was stated by the environmental officer that "*there are mine closure measures set in mine plants before the construction phase begins of the plants an EMP is prepared for the safety of the environment left after closure, different plants are expected to be grown for phytoremediation.*" These include sunflower, *Ficus benjamini*, arundinaria and alphina for absorption of chemicals spilled by the tailings. The rest of the mine site will be rehabilitated particularly the areas developed with holes. They will be gently backfilled by using the waste rocks and soil and trees will be planted so as to restore lost vegetation. Furthermore, other openings will be gentle backfilled by using the top soil so as to allow self-regeneration of vegetation.

3.4 Conclusions and Recommendations

Findings of this study have proved ASGM has contributed to the decrease in tree species variation in Bukombe-Mbogwe Forest Reserve. Indigenous forest tree species were many before ASGM activities commenced than when ASGM commenced. This resulted to making *Pterocarpus crysothrix* tree species in threat to extinction. Other endangered tree species included *Brachystegia spiciformis, Pterocarpus angolensis, Pterocarpus chrysothrix, Pericopsis angolensis, Brachystegia microphylla, and Afzella quanzensis.* There is need to increase protection against human invasion of these tree species to allow natural regeneration. Environmental trainings during ASGM are not conducted on regular basis and they depend on profit making other than awareness creation in mine firms. This calls for the government to provide seminars regularly on good ways of tree logs utilization with follow-ups. There are no strict plans put after mine closure endangering

community life afterwards. There is need to have a plan for mine closure to avoid environmental and health problems that may arise in the future. If there are no strict measures imposed towards protection of forest species in BMFR, indigenous species are likely to extinct. Since it takes decades for indigenous trees in BMFR to mature, it is essential to preserve and protect those undergoing natural regeneration.

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CHAPTER FOUR

4.0 GENERAL DISCUSSION

The study aimed at determining the impact ASGM has on vegetation cover in BMFR and surrounding villages. The study examined vegetation cover change in terms of quality and quantity change. Presence of tree species variation were also studied within BMFR from 1984 to 2020 and analysed descriptively for quantitative data and using content analysis for qualitative data.

Vegetation cover changes of eighteen year window period were obtained for three phases which are 1984, 20002 and 2020. The quality of vegetation greenness and density were obtained and it was seen to decline with time using NDVI technique. In 1984 NDVI median values were 0.57 and decreased to 0.46 in 2002 and 0.34 in 2020. This indicated that vegetation health and density was persistently decreasing. This was facilitated by the availability of ASGM activities that commenced since the early 1980s. At this time period only one mine site Nyakafulu mine site was established and mining had not yet been intensively carried out making the vegetation quality in BMFR to be good in1984. After intensification of gold mining activities in Mbogwe District with increase of many deep mine pits, this made extraction of tree logs for pit construction, soil washing and building construction to increase leading to decrease of vegetation health in BMFR. At this time population had increased due to the movement of people within the district in search for fortune specifically gold in 2002. This was followed by persistence decrease in vegetation quality in BMFR in 2020 due to increase in privatization of mine pits to Tanzanian residents.

Using LULC classed dense vegetation was 15355.08 ha by 1984 as there were minimal interactions within the district and mining activities had recently commenced in 2002 dense vegetation decreased to 6587.55 ha due to overexploitation of tree logs for mining purposes. In 2020 dense vegetation decreased to 8492.7 ha due to the increase in new mine site like Shenda mine sites and population increase accompanied by over exploitation of forest resources from BMFR. At this time sparse vegetation increased from 3112.47 ha in 1984 to 14 178.78 ha in 2002 and increased to 15 507 ha due to population increase and increased in cleared land for gold excavation and agricultural purposes. Bare-land areas in the study area decreased from 14303.7 in 1984 to 10426.05 ha in 2002 due increase in settlement and infrastructures like roads for easy transportation during gold mining and movement of people. There was decrease in bare land areas to 6636.78 ha in 2020 due to increase n privatization of mine pits in mine sites hence more clearance of vegetated field. Built-up areas increased from 319.95 ha in 1984 to 1898.82 ha and increased to 2454.66 ha in 2020 due to increase in mine field sites within the district. ASGM activities are accompanied by clearing of vegetation there by increasing the risk to erosion and infertility of soil were about 1 389 km^2 were cleared from Atewa Forest Reserve in Ghana (Jan, 2019; Anton *et al.,* 2020).

Relative abundance of tree species was seen to vary depending on the kind of tree. it was evidenced that the tree species mostly preferred within the mine sites are decreasing rapidly from BMFR. This is because indigenous forest tree species have high ability to resist penetration of water and moisture and do not shade their barks alongside. This has made them to be preferred most and harvested most since artisan’s first interest in gold searching for increasing their livelihood other than environmental conservation. It was reported that *Pterocarpus chrysothris* tree species had the lowest relative abundance of 0.003 as it is resistant to attack of underground and above ground microbes followed by

Afzella quanzensis with relative abundance of 0.023 and lastly *Brachystegia microphylla* with relative abundance of 0.026. These were highly preferred and extracted from BMFR than others as there more resistant to water penetration increasing the safety of miners during mining. Forest tree species tend to decrease like in Ghana due to various activities including ASGM from 1973 to 2015 with increase in bare land by 16.9%. The forest cover decreased by 37% dense forest with increase of light forest in 20% (Adapong *et al.,* 2022). *Combrentum molle* tree species had the highest relative abundance since it is not used during mining activities making it dominate within the forest reserve. "*This is because it is believed to be associated with ritualism purposes and it chases away gold from mine pits*" as stated during FGD with artisans.

The strategies used in ensuring conservation of vegetation cover were limitedly employed increasing degradation. It was reported that most of the tailings (71.7%) were piled on open areas for a range of 6-12 months leading to infertility of soil and nearby land. Measures taken after tree harvesting were not taken into consideration as from the respondents there were no measures put in place by 59.2%. This is because the primary interest of ASGM is gold other than environmental conservation like in Burkina Faso (Adama *et al.,* 2017). This was accompanied by availability of many abandoned mine pits if gold was not present or they were filled with water like at Nyambogo mine site. Awareness creation in ASGM is affected by limited mining experts who are expected to keep on educating miners on safe mining practices (Jean-Paul and John, 2020). There are no campaigns that will educate on technological, vegetation cover and health and safety impacts during ASGM activities. This tends to increase ignorance of the impacts of their activities and destroying more the vegetation cover as they are interested more at profit making (Kinyondo and Huggins, 2020). Due to the increasing trends of negative mining impacts during ASGM, this revealed there was low awareness provided for vegetation

cover protection like in Ghana (Edwoa, 2019). Plans after mine closure were inadequately implemented as there were no plans by 74.2%. This increased the risk of degradation to taking place even after mine closure. Hence there is low awareness on environmental conservation among artisans in the study area.

CHAPTER FIVE

5.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 General Conclusions

Finding of this study have proved that artisanal and small-scale mining have impacted negatively on vegetation cover conservation in Bukombe-Mbogwe Forest Reserve (BMFR) and surrounding villages. Vegetation cover in BMFR has decreased in its health evidenced from the decrease of NDVI values from 57% in 1984 to 34% in 2020. There were no strict strategies employed during ASGM to ensure vegetation is conserved. Furthermore; indigenous forest tree species have persistently decreased and others are almost extinction like *Ptrerocarpus chrysothrix* with relative abundance of 0.3%.

5.2 General Recommendations

Due to the decrease in vegetation cover within the forest reserve, there is need to increase protection by employing a participatory approach of joint forest management. This will enable the government and local people in adjacent villages to be in charge of conserving the forest reserve and enable natural regeneration to take place. Since there is no environmental management plan for BMFR, the Tanzania Forest Service Agency is advised to create one which will enable to know the status of the forest reserve. There is need to ensure environmental trainings are provided in regular basis by employing seminars from the district environmental office. This will ensure vegetation cover is preserved and maintained against negative impacts of artisans during mining. In order mining activities by keep on operating without further explaining tree species from BMFR. This may be achieved by having large plots of land that are planted like commercial trees in specific *Eucalyptus paniculata* to provide space for natural regeneration to take place within BMFR.

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APPENDICES

Appendix 1: Questionnaire for Artisanal and Small-Scale Gold Mining (ASGM) firms

Household survey questionnaire for ASGM firms

A. Registry information

Firm's name	Ward	Village	Residence: *a)Native b)Foreign*

B. Information on extent of vegetation cover change of Bukombe-Mbogwe Forest Reserve (BMFR)

a) What chemicals are used during gold mining activities? (circle the most appropriate answer)
   i. Mercury
   ii. Cyanide
   iii. Any other chemical

b) What is the land coverage of ASGM operation site in hectare?

……..

c) Where are logs for constructing mining pits obtained from? (circle the most appropriate answer)
   i. Bukombe-Mbogwe Forest Reserve
   ii. Separate area with trees planted specific for ASGM activities
   iii. None of the above mentioned

d) What is the status of roads since ASGM activities have commenced in the surrounding village? (circle the most appropriate answer)

i. Damaged

ii. Increased wideness

iii. Well maintained

e) Are there actions put forward for the trees that are cut down during mining? If yes, what are they?

i. …….

ii. ……

iii. …….

f) How are used chemicals handled after gold recovery for the safety of the vegetation cover? (circle the most appropriate answer)

i. Treated after gold recovery

ii. Untreated after gold recovery

g) Is there any tailing dam? (circle the most appropriate answer)

i. Yes

ii. No

h) Are tailings treated in order to reduce impact of chemicals present before disposal (circle the most appropriate answer)

i. Yes

ii. No

i) Are there plans put forward after decommissioning of ASGM for vegetation cover safety? If yes, what are they?

i. …….

ii. …….

iii. …….

j) Do the leaders provide access to regular environmental training? (circle the most appropriate answer)

   i. Yes

   ii. No

E. Information on determination of the presence of tree species after ASGM

a) What tree species where present before ASGM activities stated operation?

b) What tree species are most prone to destruction due to ASM activities?

c) Are there any indigenous species that have extinct due to ASGM activities? If yes, what are they?

d) What tree species are present to date since ASGM activities commenced?

e) Is there any decrease on the number of indigenous tree species? (circle the most appropriate answer)

   i. Yes

   ii. No

f) How is the decrease (if yes)?

   i. High

   ii. low

g) Why do you think there is a decrease?

h) Where are effluents displaced after gold recovery? (circle the most appropriate answer)

   i. Tailing dam

   ii. Piled up

   iii. Left bare on the ground

THANKS FOR YOUR PARTICIPATION

Appendix 2: Checklist for village and council leaders

1) What was the area (ha) coverage provided for conducting ASGM?
2) Who are responsible for training the miners on how to conduct safe ASGM?
3) How many artisanal and small-scale miners are involved in mining activities?
4) When did ASGM activities commence in Mbogwe District?
5) Is there any financial support from the government for conducting ASGM activities?
6) Is the productivity of land still the same or has it changed since ASGM activities commenced?
7) The rate of biodiversity of trees and animal species and birds is it the same from the commencing of ASGM or has it changed?
8) Is there any erosion encountered within the village as a result of ASGM activities?
9) How many times has education been provided on vegetation cover conservation since you have started mining? (Circle the most appropriate answer)
    i. Once
    ii. Twice
    iii. More than twice
    iv. Never
10) What other vegetation cover problems do you face due to ASGM operations? Just list at least three (3).
    i. .....
    ii. …….
    iii. ……..
11) Is there any success experienced on vegetation cover change since ASGM commenced? (circle the most appropriate answer)
    i. Yes
    ii. No

12) To what extent has the change been successful?

    i. High

    ii. Low

13) What is the effect of the success to the vegetation cover in BMFR and surrounding villages?

    i. Positive

    ii. Negative

THANKS FOR YOUR PARTICIPATION

Appendix 3: Focus group discussion

Checklist for focus group discussion

a) How did you first perceive the commencing of ASGM activities in relation to vegetation cover conservation?
b) What do you know about the change of vegetation cover of Bukombe-Mbogwe Forest Reserve (BMFR)?
c) How has BMFR changed since ASGM activities commenced?
d) Looking back; how has ASGM activities contributed to conserving the vegetation cover around BMFR?
e) What do you know on the impacts of the chemicals used during mining on the vegetation cover?
f) What was the vegetation cover condition before ASGM commencing?
g) Are there any local groups amongst that are responsible to ensuring ASGM activities are well conducted to conserve the vegetation cover of the BMFR and the surrounding villages?
h) What do you think might happen to BMFR if ASGM is to continue after a decade?
i) Do you think there is any importance of replacing trees after they are cut down?
j) How do you think mercury should be handled and displaced during and after ASGM activities respectively?
k) Looking back; has the number of birds reduced around the mining site?
l) Is there any importance of ensuring education is regularly provided on how ASGM activities are to be done for vegetation cover conservation?
m) Specifically, which tree species have decreased before and after ASGM commenced?

THANKS FOR YOUR PARTICIPATION