College of Science and Technology

School of Architecture and Built Environment

Masters of Geo-Information Science for Environment and Sustainable Development

(MSc. GI-ESD)

Environmental Impact Assessment (EIA) as a Response to Environmental Problems in Mining Sector in Rwanda, Case Study of Gatumba Sector in Ngororero District

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August 22nd ,2025

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Certification

This is to certify that, the thesis entitled " **Environmental Impact Assessment (EIA) as a Response to Environmental Problems in Mining Sector in Rwanda, Case Study of Gatumba Sector in Ngororero District**" written by Miss Mediatrice NSHIMIYIMANA has been done under my guidance and supervision.

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Declaration

I declare that this master's thesis entitled **"Environmental Impact Assessment (EIA) as a Response to Environmental Problems in Mining Sector in Rwanda, Case Study of Gatumba Sector in Ngororero District"** has not been previously submitted for any academic degree or examination at another higher education institution. Additionally, I have properly indicated and acknowledged all the sources I have utilized or quoted by providing complete references.

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Approval

It is hereby confirmed that this master's thesis entitled "Environmental Impact Assessment (EIA) as a Response to Environmental Problems in Mining Sector in Rwanda, Case Study of Gatumba Sector in Ngororero District" submitted by Mediatrice NSHIMIYIMANA has been assessed and accepted for the award of the Degree of Master of Geo-Information Science for Environment and Sustainable Development, in the School of Architecture and Built Environment.

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Miss Mediatrice NSHIMIYIMANA

TABLE OF CONTENT

List of Tables

List of Figures

List of Acronyms and Abbreviations

AMV	African Mining Vision
ASM	Artisanal and Small-Scale Mining
BMDC	Burera Minerals Deposits Company
CIP	Chief Inspector of Police
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPU	Environmental Protection Unit
GIS	Geo-Information System
IISD	International Institute for Sustainable Development
INTOSAI	International Organization of Supreme Audit Institutions
LULC	Land Use Land Cover
MINIRENA	Ministry of Natural resources
NEPA	National Environmental Protection Agency
NISR	National Institute of Statistics of Rwanda
NLA	National Land Authority
PRG	Power Resources Group
RDB	Rwanda Development Board
REMA	Rwanda Environment Management Authority
RMB	Rwanda Mining, Petroleum and Gas Board
RNP	Rwanda National Police
RNRA	Rwanda Natural Resources Authority
SDG	Sustainable Development Goals

Abstract

The livelihoods of millions of households in developing nations are supported by mining, with artisanal and small-scale mining (ASM) playing a particularly important role, the environmental deterioration it causes can be minimized through the implementation of appropriate mitigation measures. Governments tried their best in introducing tools such as EIA that can help for environmentally friendly mining. However, the negative impacts persist. This study focuses on Gatumba sector an area degraded by mining since the colonial period. The research aims to:1) describe major environmental problems caused by mining activities in Gatumba Sector,2) assess the extent to which Environmental Impact Assessment (EIA) addresses these environmental problems, and 3) propose strategies for improving the effectiveness of EIA in mitigating environmental impacts of mining activities in Gatumba Sector. A survey of 150 households shows that 68% report increased mining over the past five years. The most frequent impacts include soil erosion and landscape degradation (38%), soil bareness (30%), vegetation loss (14%), deforestation (10%), seasonal flooding (4%), and waste management issues (4%). These findings were confirmed through spatial analysis using the Revised Universal Soil Loss Equation (RUSLE) integrated with GIS and remote sensing. Results show annual soil erosion ranging from 1,415 to 97,845,376 tons/ha/year. Land use/land cover (LULC) analysis (2017–2025) revealed forest loss of 154.4 ha and an increase in bare land by 94.8 ha. The study found that while EIAs are legally required and provide a framework for predicting impacts, their implementation and monitoring remain weak. A majority of participants believe that mining activities are not well regulated. Finally, the findings indicate that respondents view the government as the most appropriate actor to take the lead in environmental management. The following main actions should be undertaken by different stakeholders involved in mining activities: reforestation, encouraging environmental compliance, extending explorations works to determine mineral reserves, and investing in a massive capacity building of mine operators on various environmental aspects. RNRA/RMB are also recommended to specialize oriented inspections.

Keywords: *Artisanal and Small-scale mining, Land, Environmental compliance, EIA, compliance*

Chapter 1. Introduction

1.1. Background Information

Mining, an activity which involves excavation of the surface and subsurface for the purpose of exploiting and processing minerals (Kazindu, et al., 2020), one of the world's oldest industries, has played a crucial role in economic development, ranking as the fifth-largest global industry today (Amponsah-Tawiah, 2011).The World Bank states that mining, particularly artisanal and small-scale mining, ensures the existence of millions of families in rural areas of developing countries; about one hundred million people (workers and their families) depend on artisanal and small-scale mining (world Bank, 2009). While mining provides such significant benefits to communities and drives global civilization, these benefits are often overshadowed by significant negative effects on the environment, as well as the health and safety of mine workers and surrounding communities (Cao, 2007; Kazindu, et al., 2020).

Mining activities, particularly artisanal mining, inevitably impact the environment and the communities surrounding mining sites (Danielson & Lagos, 2001). One of the most critical consequences is land degradation, which includes the loss of fertile topsoil, deforestation, and the disruption of natural landscapes due to excavation and the dumping of waste materials (Hilson, 2002). Open-pit and surface mining disturb large tracts of land, often leading to permanent changes in topography and the loss of productive farmland (Cooke & Johnson, 2002; Reetsch, et al., 2008), In particular, overburden materials are often mixed with topsoil, creating substrates that are low in organic matter, lack nutrients, have poor water retention capacity, and may contain toxic elements, thereby rendering the land unstructured and unfit for agriculture or habitation (Kinimo, et al., 2018).The deterioration of land is further exacerbated by inefficient and wasteful mining practices, poor rehabilitation efforts, and the absence of effective monitoring mechanisms (Mansaray, Tang, & Bangura, 2019).

A long time ago, the impact of mining activities on people and environment was hardly noticed, while the economy derived from mining activities was of the first importance (Limpitlaw & Briel, 2014). Depleted mines were often abandoned, leaving behind barren landscapes with minimal economic value that continued to harm the environment (Limpitlaw & Briel, 2014).

Countries such as Canada, Australia, and South Africa have demonstrated that with strong regulatory oversight, mining can be carried out in ways that reduce environmental harm and contribute to post-mining land recovery (Buxton, 2012). Driven by growing awareness of environmental issues, many governments now require mining companies to comply with environmental impact assessments (EIA), enforce waste management protocols, and implement land reclamation plans as part of project approval and closure procedures (Hilson & Murck, 2000).

Environmental Impact Assessment (EIA) began in the United States with the enactment of the National Environmental Policy Act (NEPA) in (NEPA, 1969), which came into effect on January 1,1970. NEPA marked the first formalized process requiring federal agencies to assess the environmental effects of their proposed actions before making decisions. This legislation was a response to increasing public concern over the environmental degradation associated with rapid industrialization and development during the 1950s and 1960s. NEPA introduced the Environmental Impact Statement (EIS), a detailed document that evaluates the likely environmental consequences of major federal projects. It set a precedent for environmental governance worldwide, and many other countries have since adopted similar procedures based on the EIA framework pioneered in the U.S. (Glasson, et al., 2012).

In a few high-income countries such as Canada, Australia and New Zealand; the preliminary development of EIA took place in years 1973-1974. However, there were some developing countries as well, which introduced EIA relatively early, like Columbia in 1974 and Philippines in 1978 (Sharma & Hategekimana, 2018). In many developed countries, the legal and institutional frameworks for Environmental Impact Assessment (EIA) are now well established, with sufficient institutional capacity, trained personnel, and technical resources in place to support effective implementation. Attention has increasingly shifted from establishing basic EIA systems to enhancing their quality, transparency and integration with strategic planning processes (Morgan, 2012).

According to Africa Progress Panel (2013, p. 86), in their effort to mitigate environmental degradation in the Artisanal and Small Scale Mining(ASM) sector, the African Union(AU) with the help of international community has launched the Africa Mining Vision(AMV) in 2013, which aims at creating “a transparent and inclusive mining sector that is environmentally and socially responsible in its member states”. It is in this context that most governments, donor institutions and companies have adopted internationally recognized environmental impact assessment (EIA)and social Impact Assessment (SIA)tools that identify potential negative impacts in advance.

In developing countries, the EIA processes are hindered in many ways. For instance, many developers have a wrong view on EIA as costly and time-consuming constraint delaying the development. On the other hand, EIA benefit the developers because it creates a parallel framework for considering location, design issues and environmental issues (Morgan, 2002). Development cooperation agencies and international organizations continue to support capacity building in lower-income regions, focusing not only on legal reforms but also on strengthening institutional effectiveness and fostering local EIA expertise to ensure sustainable development outcomes (Morgan, 2012). There is a significant gap between the best practice thinking represented in the research and practice literature and the application of EIA on the ground.

1.2. Problem Statement

Mining started in Rwanda in 1926 by the Belgian colonizers (Bizimana, et al., 2021). Mining is among highly practiced activities in Rwanda and the biggest source of export revenues after tourism (RDB, 2019)**.** The sector contributes significantly to Rwanda’s economic growth and development. In 2024, the sector generated about $1.7billion, providing income and employment to approximately 76,866 people (RMB, 2024); 14,000 people are employed in quarries; 773 sites are under exploration and/or exploitation. Artisanal and small-scale mining (ASM) is predominant, counting for around 80% of the mining activities of the country’s mineral production (IISD, 2017). However, mining activities degrade the environment, undercutting the industry's ability to help reduce poverty and bring about economic change (REMA, 2012).

In Rwanda, mining activities lead to land degradation, and loss of arable land, ultimately affecting agricultural resources (Byizigiro., 2016). Landslides, soil erosion, floods, deadly accidents and other related disasters are linked to mining operations worldwide, but particularly in Rwanda which happen to be mountainous (REMA, 2012). The legacy of poor mining practices during colonial period in the 1930s and post-independence periods in Rwanda has exacerbated land degradation.

Gatumba area, known for its abundance of tantalum and tin ores, has undergone significant mining activities since the 1930s. Semi-industrial mining operations ceased in 1985, leaving behind quarries and altered landscapes. Due to active mining leases, no remediation efforts were undertaken, perpetuating land degradation (Reetsch, et al., 2008); for example, abandoned mines, waste dumps, and degraded mountainous massifs expose the landscape to erosion and pollution (REMA, 2012).

At the national ranking, the colonial Gatumba mining region which spans nine sectors in Ngororero District and four in Muhanga District; Ngororero district stands out as the area most at erosion risk, with 85% of its 58,003 hectares classified as erosion-prone; Muhanga district follows closely, with approximately 82% of its 53,352 hectares similarly at risk (GoR, 2022). This high vulnerability is further aggravated by abandoned mines, unmanaged waste dumps, and severely degraded mountainous terrain, all of which intensify both erosion and environmental pollution threats.

To recognize the needs to undertake economic investments in ways that promote sustainable development, the Government of Rwanda through Rwanda Environment Management Authority (REMA) requires that all projects be subjected to environmental impact assessment (EIA) in line with its long-term vision of a green economy and sustainable development. It is important to recognize the potential environmental impacts that mining activities have on various components of the ecosystem, and the specialized nature of EIA in mining activities (REMA, 2012).

REMA being responsible for EIA and SEA, from 2009 the Rwanda Development Board (RDB) has been mandated by REMA to implement the EIA procedure in Rwanda, specifically scoping and review. All applications for EIA certification must be addressed to the Rwanda Development Board (Kabera, 2017). EIA is mainly used to prevent or mitigate the adverse effects of major development projects. In Rwanda Ministerial Order N ° 004/2008 of 15/08/2008 outline the works, activities and projects that must undertake an environmental impact assessment (Nkundabose, et al., 2020). Among three categories of the Rwandan EIA procedure guideline, mining is under Impact level 3 (IL-3) for which full EIA is required (Sharma & Hategekimana, 2018).

Despite its importance, the implementation of EIA in Rwanda encounters several challenges—particularly in the mining sector. These include weak institutional capacity, limited technical expertise, and inadequate enforcement mechanisms (Morgan, 2012). Byizigiro et.al (2020) report that in the Gatumba region, mining methods are still evolving, and artisanal and small scale mining activities threaten the environment; According to Kazindu et.al (2020), mining companies in districts like Ngororero often failed to follow basic environmental standards such as collecting and storing topsoil or installing traps. The soil in these mining sites was in mess state near the mining pits and surrounding areas, it is evident that when it rains the soil end up flowing down in nearby rivers, exacerbating land degradation. If not addressed, the environmental impacts of mining can persist long after operations have ceased. Effective management of mining sites during and after exploitation is therefore essential for sustainable resource development (Bizimana, et al., 2021).

Recent studies have been conducted in Gatumba mining area by various scholars (Bizimana, et al., 2021; Byizigiro., 2016; Byizigiro, et al., 2020; Nsengiyumva, et al., 2023). Bizimana et al. (2021) assessed spatial temporal land use/land cover change to help optimize land management options, planning for mine sites, monitoring environmental effect of mining. Byizigiro (2016) assessed geomorphic processes associated with small-Scale open cast mining and mitigation measures in Gatumba Mining area; one of the findings was that insufficient monitoring of mining activities and degraded terrains in the Gatumba region complicate rehabilitation; with mining technique still evolving while artisanal and small-scale mining activities were posing environmental risks and the lack of proper oversight further exacerbates these issues. Byizigiro et al. (2020) were alleviating some environmental impacts resulting from Artisanal and Small-scale Mining.

On the other hand, Nsengiyumva et al. (2023) evaluated environmental impacts of mining activities in Gatumba mining area. To my knowledge though, none of the above studies assessed specifically EIA as a Response to Environmental Problems in Mining Sector.

1.3. Research objectives

1.3.1. General objectives

The general objective of this study is to assess Environmental Impact Assessment (EIA) as a Response to Environmental Problems in Mining Sector in Rwanda, Case Study of Gatumba Sector in Ngororero District, and propose strategies for improving the effectiveness of EIA.

1.3.2. Specific objectives

1. To describe major environmental problems caused by mining activities in Gatumba Sector.
2. To assess the extent to which Environmental Impact Assessment (EIA) addresses these environmental problems.
3. To propose strategies for improving the effectiveness of EIA in mitigating environmental impacts of mining activities in Gatumba Sector.

1.4. Research questions

1. What are the major environmental problems caused by mining activities in the Gatumba Sector?
2. To what extent does the Environmental Impact Assessment (EIA) address these environmental problems?
3. What strategies can be proposed to improve the effectiveness of EIA in mitigating environmental impacts of mining activities in the Gatumba Sector?

1.5. Significance and Motivation of the Research

The legacy of unsustainable mining practices from both the colonial and post-independence periods in the Gatumba mining area has left severe and lasting impacts on the land.

Abandoned mines, disturbed ground, unmanaged waste dumps, and degraded mountainous slopes have significantly contributed to environmental deterioration, making the landscape highly vulnerable to land degradation. The sector's rugged topography has amplified these impacts, leading to frequent flooding, accelerated soil erosion, and significant loss of productive land.

Recognizing these environmental challenges, Rwanda operationalized the Environmental Impact Assessment (EIA) in 2006 to ensure that projects, including mining, are evaluated and managed in an environmentally responsible manner. This study is driven by the urgent need to examine how effectively the EIA addresses environmental problems in the mining sector, with a specific focus on the case of Gatumba Sector in Ngororero District.

The significance of this study lies in its potential to address the need to understand the effectiveness of Environmental Impact Assessment (EIA) as a tool for mitigating environmental problems caused by mining in Rwanda, with a focus on the Gatumba Sector, the findings will inform policymakers, environmental regulators, and mining operators on the strengths and gaps in the current EIA framework.

This study is motivated by the recognition of both the economic value and the environmental consequences of mining activities, observed through extensive experience in the mining sector and a solid background in Mining Engineering. This dual perspective highlights the critical need to balance resource exploitation with environmental sustainability. Pursuing advanced studies in Geo-information for Environment and Sustainable Development further emphasizes the importance of bridging this gap to promote sustainable mining practices.

1.6. Conceptual Framework

The relationship between components of the conceptual framework, in Figure 1, visually indicates how they are interconnected. Practically, contextual factors can influence environmental impact of land mining sites, however with mitigation measures and compliance, environmentally friendly mining can be achieved (Akabza & Darimani, 2001).

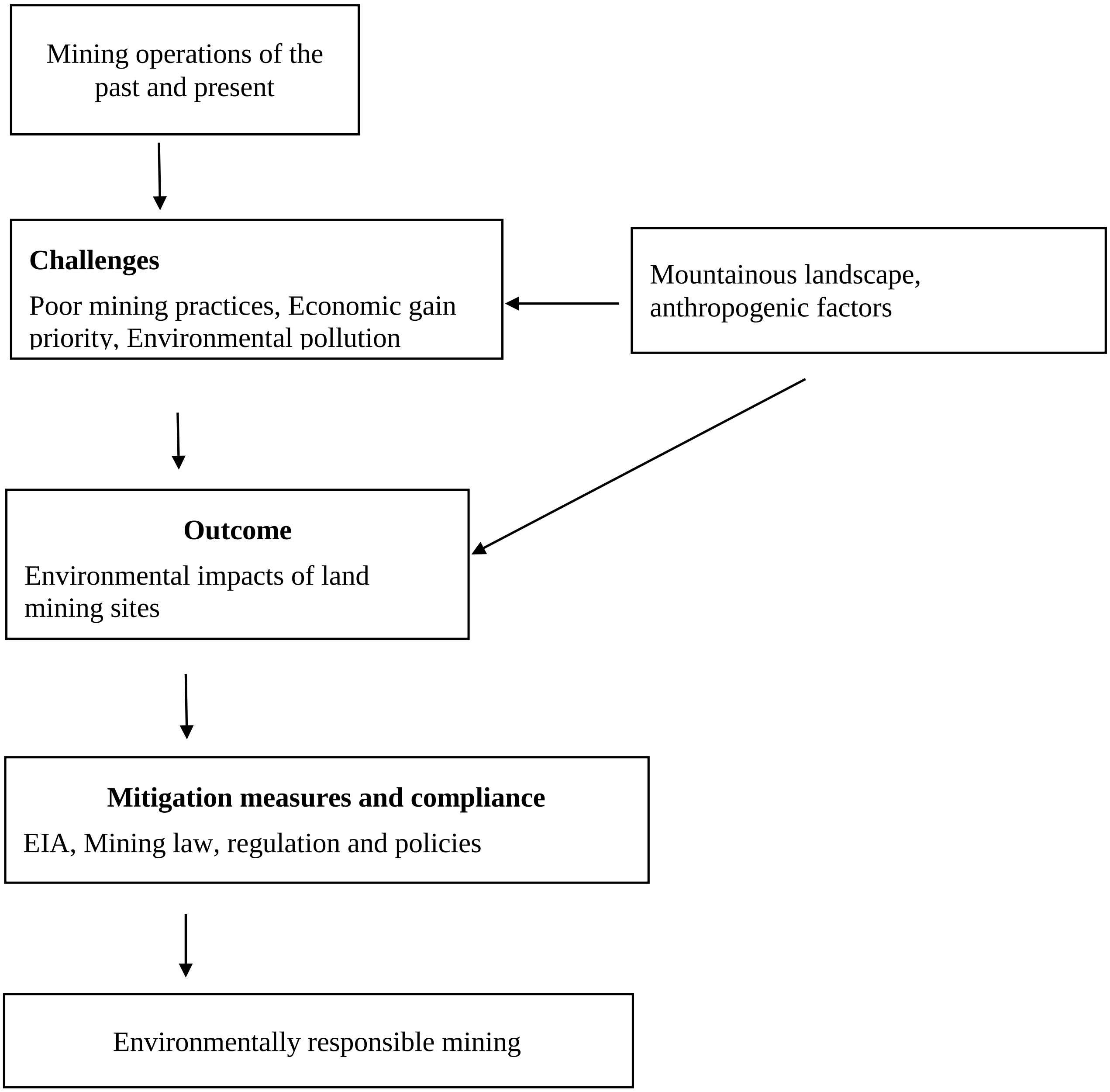

Figure 1: Research Conceptual Framework

Source: Akabza and Darimani (2001)

Mining operations, both historical and contemporary, have frequently been marked by detrimental practices motivated by economic gain, often leading to substantial environmental pollution. When combined with the difficulties posed by mountainous terrain and human-induced factors, these practices have resulted in severe land degradation at mining sites.

However, when these activities are informed by thorough Environmental Impact Assessments (EIA) and supported by the enforcement of mining laws, regulations, and policies, they can facilitate a shift towards environmentally responsible and sustainable mining practices.

1.8. Structure of the Research

Following the introduction which covers background information, problem statement, research objectives, research questions, research hypotheses, motivation and significance of the research, conceptual framework, the remaining are structured as below.

- Chapter two primarily consists of a literature review, delving into pertinent theories and concepts forming the foundation of this research
- Chapter three outlines the methods employed to collect necessary data
- Chapter four presents the primary findings of the research, discussing the result in detail.
- Chapter five concludes the study and recommendations based on the research findings.

Chapter 2. Literature Review

The literature review chapter provides a comprehensive overview of existing knowledge and research relevant details about how mining has been a threat to the environment especially on land, it begins by discussing mining and environment background, the chapter then addresses the impacts of mining on land and the introduction of EIA.

2.1. Types of Mining

2.1.1. Artisanal and Small-Scale Mining (ASM)

Artisanal and small-scale mining refers to informal or semi-formal mining activities carried out by individuals or small groups using manual tools and fundamental techniques to extract minerals, often from surface or near-surface deposits. It typically operates outside of formal regulatory frameworks or with minimal oversight and involves low capital investment, limited mechanization, and labor-intensive processes (Hilson, 2002). While ASM contributes significantly to poverty reduction and local economic development particularly in mineral-rich regions, it is frequently associated with environmental degradation, unsafe working conditions, and lack of access to technical knowledge and financial resources. ASM is a significant source of livelihood in many developing countries, contributing to local economies and rural employment, particularly in mineral-rich regions (World Bank, 2019).

2.1.2. Surface Mining

Surface mining is a method of mineral extraction that involves the removal of soil, vegetation, and overburden (rock and soil above the mineral deposit) to access mineral resources located near the Earth’s surface. This method is preferred and widely used around the world because of its low cost, ease of operation, and effectiveness in mining shallow ore deposits (Hartman & Mutmansky, 2002). Surface mining encompasses several sub-methods, including open-pit mining, strip mining, and quarrying, depending on the type and geometry of the mineral deposit. The process begins with site clearing, followed by drilling and blasting (if necessary), and the excavation of overburden and ore using heavy machinery such as excavators, haul trucks, and bulldozers. The mined materials are then transported to processing plants for crushing, screening, or concentration. Unlike underground mining comes at the cost of significant land disturbance, deforestation, and potential soil erosion (Bell, et al., 2001).

In tropical and mountainous regions like Rwanda, the removal of vegetation cover and disruption of natural drainage patterns during surface mining increases the risk of land degradation, sedimentation, and flooding (Lottermoser, 2010). Surface mining sites in Rwanda are vulnerable to landslides and gully formation during heavy rains, especially when reclamation and drainage systems are absent. Moreover, surface mining often lacks post-mining land rehabilitation, leaving behind degraded, unproductive land that negatively affects both ecological functions and community land use.

2.2. Evolution of Environmental Concerns in the Mining Industry

In the late 20th century, particularly during the 1970s and 1980s mining's environmental impacts, such as land degradation, deforestation, and water pollution, became global concerns (Hilson, 2002). The period saw growing awareness of industrial pollution and environmental degradation, driven by scientific research, media coverage, and advocacy from environmental organizations. Landmark events, such as the 1972 United Nations Conference on the human environment in Stockholm and the publication of reports like The Limits to Growth, highlighted the consequences of unsustainable resource extraction. Perhaps one of the foremost approximation to the clamor for a wider global environmental negotiation was the 1972 UN Stockholm conference on environment which provided the Stockholm Declaration, that reported growing evidence of man-made harm in many regions of the earth (Amadi, et al., 2016). Additionally, high-profile mining disasters, such as mercury contamination in Japan's Mina Mata Bay (Avenell, 2017) and acid mine drainage in the U.S, underscored the long-term ecological damage caused by mining activities. As a result, governments and international bodies began implementing stricter environmental regulations, requiring mining companies to adopt more sustainable practices and mitigate their impact on ecosystems.

In the 21st century, environmental concerns in the mining industry have evolved significantly, driven by increasing awareness of climate change, biodiversity loss, and resource depletion. Key issues include greenhouse gas emissions from mining operations, large-scale deforestation, and the destruction of ecosystems due to open-pit and mountaintop mining.

Water contamination from tailings dams, acid mine drainage, and heavy metal pollution have also become major concerns, particularly after disasters like the 2015 Sam Arco dam collapse in Brazil (Agurto-Detzel, et al., 2016).

The demand for critical minerals used in renewable energy technologies, such as lithium and cobalt, has intensified scrutiny over sustainable mining practices and ethical sourcing. New mines are increasingly squeezed between communities or placed where they damage current developments of society values, in particular the growing value ascribed to environment and life quality, makes unavoidable that future mining depends on achieving better conservation of the environment, long- term management of natural resources, and fair social- economic impacts in the life of local communities combined with improved safety in mining activities (Carvalho, 2017).

2.3.1. Land Degradation and Land Use Conflict

Land degradation, a part of environmental degradation, refers to the reduction or loss of the biological or economic productivity of cropland, pastures, forest and woodlands. It is any process that lowers the productivity of land, assuming other factors such as technology, management and weather remain constant (Wainaina, et al., 2022). Land degradation is one of the most noticeable manifestations of mining and related activities. Mining is an extractive industry which, by withdrawing the raw materials, creates anthropogenic landforms such as mine pits, soil tips and subsided lands leading to land degradation (Goswami, 2014).

Despite mining's advantages, many groups and communities worry that it comes at too great cost to the natural world, specifically in terms of access to clean water, biodiversity loss, soil fertility, agricultural land, community fragmentation and economic losses (Bermúdez-Lugo, 2013).Unfortunately in most regions of earth, the underground geological resources (minerals) are superimposed by above ground biological resources (forests) (Naveen, 2012). Mining is essentially a destructive development activity where ecology suffers at the altar of economy (Chauhan, 2010). Numerous studies have shown that the government and other major players in the mining industry reap the vast majority of the benefits while the local community takes the hit (Dontala, et al., 2015).

Land use competition, conventionally, the availability of land and other natural resources is crucial to the economic stability of rural areas.

Millions of people rely on agriculture and ecological products and services provided by communal lands (Sherbinin, et al., 2008), but mining expansion reduces the lands accessible for agricultural production and raises land use competition in minerals-endowed countries, sustainable land management is a critical concern in agricultural and mining zones (Moomen, 2017).

Additionally, mining-related soil contamination may impact extensive regions, lowering cultivable land (Aragón & Rud, 2016). Surface mining accounts for the disturbance in the agricultural land base does away with plants and soils, disrupts the flow of ecosystem services and leads to the permanent loss of farmland as well as the degradation of agricultural lands beyond short-term reclamation for intensive post-mining agricultural purposes. The degradation of agricultural lands drives farmers from sustainable livelihoods to alternative income-generating businesses (Botchway, 2018). The land surrounding mine sites is crucial to the survival of the indigenous people that live there, but industrial mining necessitates a disproportionate amount of space for its activities (Hilson, 2002).

2.3.2. Soil contamination, landscape change and pollution

Mining activities causes different changes (Larondelle & Haase, 2012), with negative impacts on landscapes (Benidire, et al., 2020). The mining sector takes up much real estate, and its environmental effects are more profound than any other type of earth disturbance (Danielson & Lagos, 2001). The greatest environmental hazard resulting from the underground mining methods is subsidence, uncontrolled ground movement can occur during regular mining activity or years after mining has ceased (Namin, et al., 2011). The most important physical landscape changes are deforestation and vegetation removal, changes in relief, deposition of mining wastes (spoil and tailings), construction of supporting infrastructure, increased erosion rates, suspended materials in surface water systems, and increased rate of soil and rock instability (Žibret, et al., 2018).

Informal mining usually ends into disturbance of the water table leading to topographic disorder, severe ecological imbalance and damage to land use patterns in and around mining regions (Naveen, 2012). Mining can affect soils over large areas, causing deleterious effects on soil properties and components, such as degradation of soil structure and horizons, disruption of soil microbial communities' structure and nutrient cycles (Benidire, et al., 2016).

Mining is one of the main sources of heavy metal environmental pollution worldwide. Either through mineral extraction or waste dumps large quantities of volatile elements and toxic dust particles are released into the environment (Namin, et al., 2011), although minerals are naturally present in the environment due to outcrop weathering and erosion, mining and related activities can produce increased levels of certain elements in the environment that exceed natural levels up to 1,000 times (Žibret, et al., 2018).

Waste dumps can cause large-scale local environmental impacts, due to their chemical nature, mainly related to a very low content of organic materials, a low nutrient content and a very high concentration of metals, mining deposits create a hostile environment which inhibits plant growth (Probst, et al., 2009) without a vegetation cover, these materials become very vulnerable to water and wind erosion and thus become a continuous source of pollution of the surrounding environment. Therefore, the lack of surface-protecting vegetation cover leaves contaminated materials exposed to wind and water erosion (Sheoran, et al., 2010).Indeed, the soils around mining sites are very often heavily affected by multi-metal contaminants (Cd, Cu, Zn and Pb) thus making the use of the land strictly limited (Wainaina, et al., 2022) contributing to serious pollution of aquatic and terrestrial ecosystems (Jordán & D'Alessandro, 2004).

2.4. Toward Sustainable and Responsible Mining Practices

Accomplishing sustainable mining has become increasingly important owing to the growing negative effects of mining on the environment and communities. Traditional mining practices are characterized by high resource consumption, high pollution and low efficiency. This has raised concerns among researchers about supplying scientific remedies to these issues. It has been suggested that additional measures are needed to compensate for traditional mining to achieve sustainable practices. As a result, mining companies have increasingly focused more on implementing green innovations (Jiskani, et al., 2023). Mining is, thus, a vast field of human activity that will go on to respond to societal needs, such as to fixing and improving the techno sphere, but today with the additional responsibility that comes with knowledge: to make responsible management of the resources and keep healthy ecosystems capable to support human society with life quality, today and in the future (Carvalho, 2017).

In mining method selection it is important to remember that no one method is able to meet all of the requirements and conditions (Bitarafan & Ataei, 2004), rather the appropriate mining method is the one that is technically feasible for the ore geometry and ground conditions, while also being a low operation cost and environmental impacts. This means that the best mining method is the one with the least environmental problems. The mining engineer must balance all of the input parameters (such as environmental criteria) and select that method that appear to be the most suitable. Potential environmental hazards in mining activities can and should be accounted for in the mining method selection during feasibility and prefeasibility study of projects. However, this doesn’t guarantee that all potential hazards can be avoided (Namin, et al., 2011). It is therefore necessary to minimize environmental effects and hazards. This allows mining designers to minimize any future adverse environmental effects before the starting of any activities.

Establishing a balanced link between “mining of mineral resources, environmental protection, and sustainable mining development” is crucial for resource development in the 21st century, since the environmental issues and geological problems arising from the growth and usage of the mineral industry have become increasingly apparent, with some consequences being quite severe (Yu, et al., 2015). From corporate viewpoint, a key aspect to the success of mining is to obtain, besides the official and legal mining permit, also the social license from community, that is, their consent and adhesion to mining in their region. Corporate responsibility of mining companies has developed also to share the wealth from mining with communities, and this has been achieved through investment in building infrastructures for the region, such as schools and hospitals, and minimizing the impacts. The future for mining is, therefore, dependent from adhering to good mining practices in order to preserve the environment everywhere and also to take social responsibility in the development of the region and contributing to life quality of the community (Carvalho, 2017).

2.5. Environmental Impact Assessment (EIA) in mining Sector

Normally, there is no one complete, valid definition of EIA (Noble, 2006), it often defined as a tool, a methodology and a regulatory requirement but it is primarily a process. According to Adebe,et al (2007),Environmental Impact Assessment (EIA) is a process which attempts to identify, predict and mitigate the ecological and social impacts of development proposals and activities.

Environmental Impact Assessment (EIA) was introduced as a formal process in the late 20th century to evaluate the environmental consequences of development projects, including mining. Its origins trace back to the United States with the National Environmental Policy Act (NEPA) of (1969), Several global conferences have shaped the evolution of EIA in the mining sector. The 1972 United Nations Conference on the Human Environment in Stockholm emphasized the need for environmental regulations in industrial activities which set the foundation for assessing environmental impacts before project approval. By the 1980s and 1990s, many countries had adopted EIA regulations, making it a standard requirement for mining projects worldwide (Weaver, 2003). The 1992 Earth Summit in Rio de Janeiro further reinforced EIA as a critical tool for sustainable development, leading to the adoption of Agenda 21, which encouraged environmental governance in mining.

The 2002 World Summit on Sustainable Development in Johannesburg highlighted the need for corporate accountability and responsible mining practices, further strengthening the role of EIA in the industry. More recently, the 2015 Paris Agreement and the UN Sustainable Development Goals (SDGs) have pushed for stronger environmental policies, influencing stricter EIA compliance in mining operations. The process involves assessing potential environmental risks, proposing mitigation measures, and engaging stakeholders, including local communities and environmental organizations.

To date, the EIA is an important tool in environmental management in many developed and developing countries. However, the functioning of the EIA is very different in developing countries. Some countries have clear regulations, others have guidelines and others have unplanned procedures (Nkundabose, et al., 2020).

2.5.1. EIA as a Response to Environmental Problems in Mining Sector

The EIA helps the stakeholders with the identification of the environmental, social and economic impacts of a proposed development before a decision is taken on whether to proceed or not. Particular attention is given to EIA practice to preventing, mitigating and offsetting the significant adverse effects of proposed undertakings according to INTOSAI (2010). EIA also helps to assist decision-making and to attain sustainable development. The effectiveness of EIA depends on several factors, among which the quality of EIA guidelines, EIA reports and implementation and follow-up of EIA recommendations are of particular importance (Abebe, et al., 2007).

The challenges posed to environmental assessments of mining projects are twofold. First, to ensure that environmental, social and health costs of the proposed mining project are given adequate consideration in determining the economic viability and acceptability of alternative project scenarios. Secondly, to ensure that adequate control, mitigation or protection measures are incorporated in proposed mining project design, implementation and mining decommissioning plans.

2.5.2. EIA Process in Rwanda

The EIA in Rwanda takes reference from the 2005 Organic Law determining the modalities of protection, conservation and promotion of environment and the latter is mainly enforced through the REMA 2006 guidelines and procedures for EIA to ensure environmental compliance. The 2014 law on mining and quarry operations leads the regulatory framework of mining activities in Rwanda (Nkundabose, et al., 2020).

According to Rwanda's Organic Law under article 67, Environmental Impact Assessment (EIA) is outlined as follows: "Every project, including programs and policies that may have an impact on the environment, must undergo an environmental impact assessment before receiving authorization for implementation." The consecutive steps in the EIA process are as follows:

- The first step of the EIA process is a developer submitting an application for EIA of a proposed project to the Authority (which is Rwanda Development Board) in form of a Project Brief whose purpose, is to provide sufficient information on the project to enable RDB and Lead Agencies establish whether or not the proposed activities are likely to have significant environmental impacts, and also enable to determine the level of EIA required (screening). If adequate mitigation measures are identified in the Project Brief, the need for conducting full EIA may be waived and a project may be approved with minimal implementation conditions (REMA, 2012).

- Screening is the initial process undertaken to determine whether the proposed project warrants preparation of an EIA. The types of projects requiring EIA are identified from the screening process in accordance with Law No. 4/2005, Law No.38/2008 and the categories of projects according to IL 1, IL 2 and IL 3 categories respectively. All mining projects at exploitation level or involving excavation and located on hillsides are under IL3 projects which undergo through a complete EIA process (REMA, 2012).

- Scoping aims to identify the main environmental problems, alternatives that need to be addressed in environmental impacts and eliminate unnecessary ones. The developers (or their EIA experts) consult lead agencies and all relevant stakeholders. Following this step, REMA approves the terms of reference (ToR) for conducting an environmental impact assessment. For each project, identification of the possible alternatives is key. By alternatives identification, Project location and process technologies must be considered. Mitigation plan along with an Environmental management plan (EMP) is required for guiding the developer in environmental conservation (Nkundabose, et al., 2020).Wood (2003) noted that, where scoping does take place, it is often directed towards meeting developing country pollution control requirements, rather than addressing the full range of potential environmental impacts from a proposed development.

- Environmental Impact Study and Report (EIS) is a research and investigation phase of the EIA process conducted by an EIA expert approved by REMA because their expertise suited to the scope of the proposed study. This stage is a three-step process as follows: In step 1, potential impacts of a project and their magnitude are identified. Also included in this step is the Analysis of Initial State. Impact Level 3 (IL-3) projects start the Environmental Impact Study process at step 1 while IL-2 projects start the process at Step 2. IL-1 projects are not subjected to Environmental Impact Study, instead they go directly to the Decision-making and Authorization stage. IL-1 projects are however subjected to a period of public review during which stakeholders may submit written views to the Authority (REMA, 2006).

- After a developer has reviewed the EIA report and, if necessary, written an addendum, these documents, which should be signed by the EIA experts, are submitted by the developer to REMA. In case the project is approved, an EIA Certificate of authorization will be issued to the developer, which permits implementation of the project in accordance with mitigation measures in the EIA Report and other necessary conditions that the authority might consider necessary (REMA, 2012).

- Implementation and Operation order (IOO) is issued by the Director in charge of EIA within REMA to the developer. This document is legally binding and authorizes the developer to implement a proposed project, subject to terms and conditions to be met during project implementation and operation. REMA is the final decision-making agency with power except when there is any appeal (REMA, 2012).

- If the Authority rejects a proposed project after reviewing an environment impact report, the developer can abandon the project, improve and resubmit a revised EIA report or appeal to the Minister for environment. In case the developer successfully appeals against the Authority's decision, a revised Record of Decision will be issued to the developer by the Authority (REMA, 2012).

- EIA certificate of authorization is issued after a proposed project is approved, this document is legally binding and authorizes the developer to implement a proposed project, subject to any terms and conditions stipulated. Except in cases of appeals, the Authority is the final decision-making agency with power over issuance of EIA Certificates of Authorization.

- Environmental Auditing and Monitoring consist of collection and documentation of environmental data respectively. The step of environmental monitoring and auditing is in responsibility of both the authority and the developer, or an EIA Expert contracted by a developer (REMA, 2006).

During auditing and monitoring, the Authority aims to ensure that mitigation measures and recommendations of the environmental impact study are implemented to avoid adverse environmental impacts, and restoration costs a developer would incur if environmental degradation occurred. Developers shall undertake self-auditing according to national Audit Guidelines and Regulations.

Upon project completion or when seeking relocation, a developer should prepare a decommissioning plan and submit it to the Authority for approval. Note that the decommissioning plan should include, all proposed engineering works, mitigation activities associated with the removal of project facilities and proposed restoration measures but not forgetting to assess existing environmental conditions. The figure 2 summarize the EIA process in Rwanda.

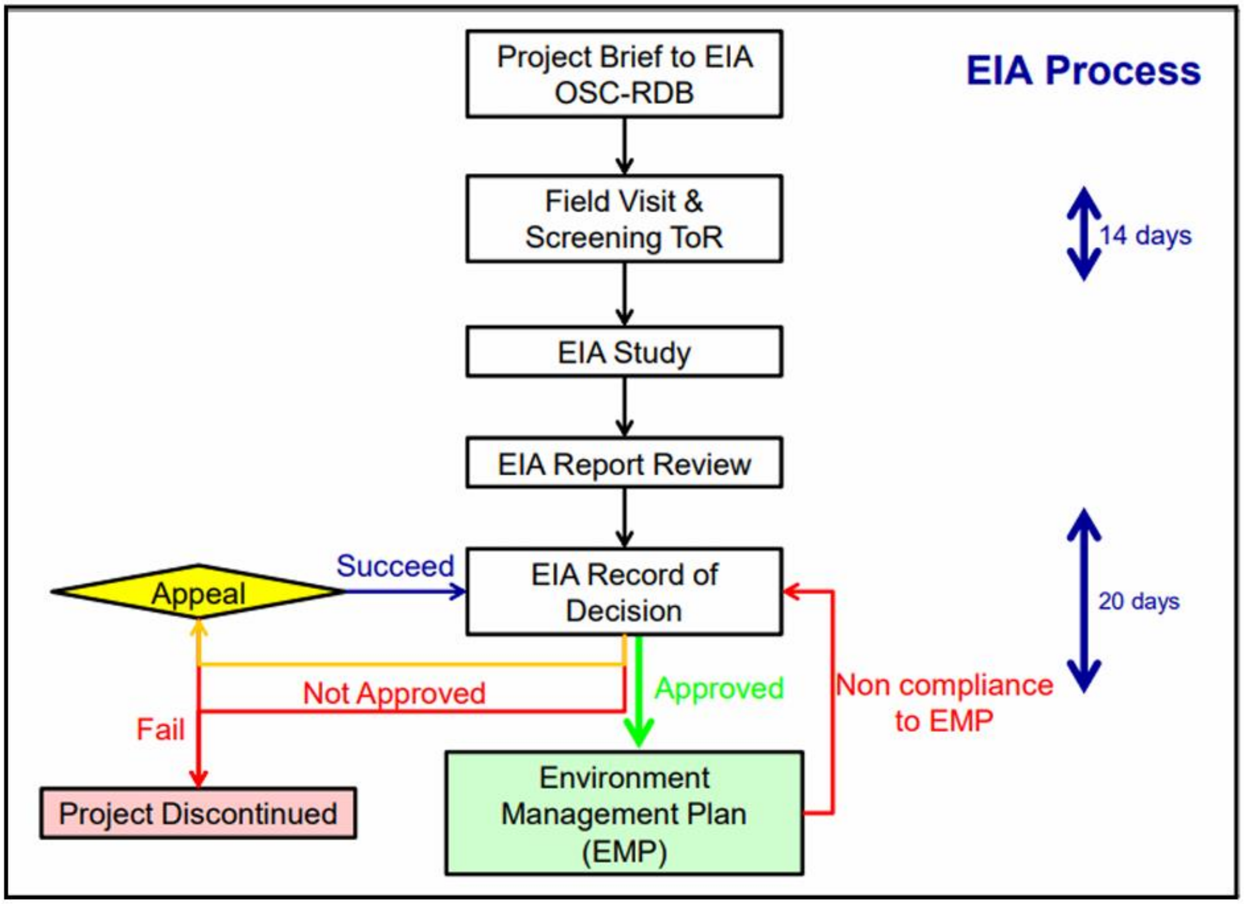

Figure 2 : Summary of EIA Process in Rwanda

Source: REMA (2006)

2.5.3. Policy Frameworks in Mining Sector in Rwanda

- **National environment and climate change policy (2019)**

This policy whose objectives include integrating environmental considerations into planning and decision making, ensuring rehabilitation and restoration of mining-affected areas provides the foundational framework for environmental governance in Rwanda. It mandates that all development activities likely to impact the environment including mining undergo Environmental Impact Assessments (EIAs) and Environmental Audits before implementation. The policy promotes the "precautionary principle" and "polluter pays principle", ensuring that mining operators take responsibility for environmental degradation (MINEMA, 2019).

- **Law no. 48/2018 of 13/08/2018 determining the offences and penalties in environment protection.**

This law reinforces the implementation of EIA by prescribing penalties for non-compliance. Any mining operation initiated without conducting an EIA or implementing mitigation measures faces legal sanctions, including suspension or revocation of licenses (Republic of Rwanda, 2018).

- **Law no. 58/2018 of 13/08/2018 governing mining and quarry operations**

This mining-specific law aligns closely with environmental policies by requiring that all mining and quarry operators conduct EIAs prior to obtaining operational licenses. The law obliges operators to submit a detailed EIA report, prepare and implement an environmental Management Plan (EMP) and monitoring environmental performance (Republic of Rwanda, 2018).

- **Vision 2050**

Rwanda's long-term development vision places sustainability and environmental protection at the center of its economic transformation agenda. Vision 2050 encourages the integration of scientific environmental assessment tools (including EIAs) to mitigate the environmental risks of industrialization, particularly in mining (Republic of Rwanda, 2020).

Chapter 3. Methodology

This chapter presents details of applied methods and techniques, and present the tools used for data collection and statistical and spatial analysis. The techniques employed in this study encompass literature review, questionnaire surveys, interviews, and an examination of the case study.

3.1. Study Area Description

Located in the western part of Rwanda, Gatumba Sector is one of the 13 sectors that make up Ngororero District in the Western Province. It shares its borders with sectors Muhororo, Bwira and Ndaro within Ngororero District, and touches to the boundary of Muhanga District of the southern province. Administratively, Gatumba Sector is subdivided into several cells and villages, forming a part of the decentralized local governance system in Rwanda. The sector covers a surface area of approximately 43.5Sq. km and has a population of around 24,952inhabitants, with a population density of 573.6 inhabitants per Sq. km, based on the most recent estimates by the National Institute of Statistics of Rwanda (NISR, 2023).

Gatumba sector is a part of one of the biggest Gatumba mining concessions ever held by the former Rwandan government. Gatumba sector consist of six cells which are Kamasiga, Cyome, Rusumo, Karambo, Ruhanga and Gatsibo. The sector consists of seven mining sites owned by five mining companies which are PRG, BMDC, GEOSAMI, Ruli Mining Trade Ltd and Crystal. The study area is located in the eastern region of the Congo-Nile Crest with a predominantly mountainous topography. The region is between 1,400 and 2,300 meters above sea level. The area of interest is located approximately at 25 km from the town of Muhanga. The main access by road is made by the Kigali – Ngororero tarmac road.

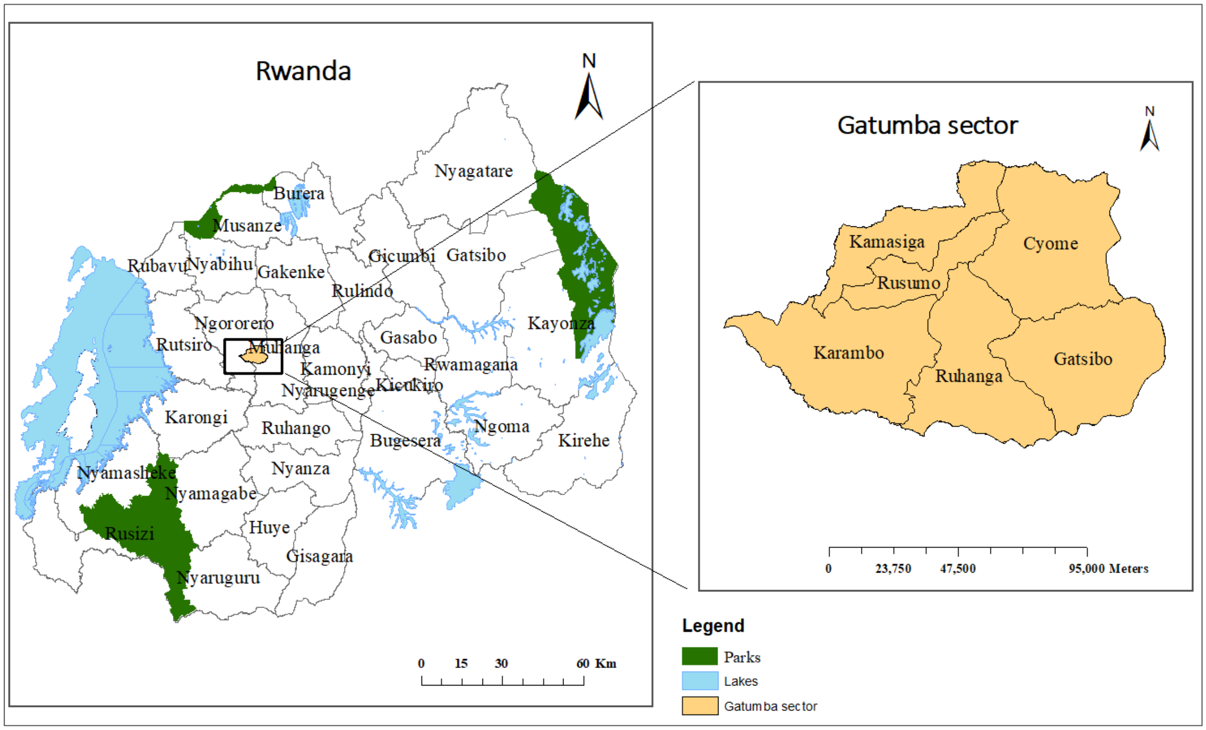

Figure 3: Location Map of Study Area

Source: NLA (2022)

3.2. Data collection methods

This part offers the guidelines, methods and procedures used for data collection of the empirical data. The methods used consisted in literature review, empirical research including field observation, sample size determination for survey questionnaire and interviews.

3.2.1. Secondary Data Collection

Literature review helped to understand concepts of environmental degradation; I consulted publications on environmental management, environmental policy and law, documents on environmental impact of mining, policy and legal frameworks on mining and documents from different institutions, such as Rwanda Mines petroleum and Gas Board (RMB) to identify concessions of companies. I also consulted documents from Rwanda Environment Management Authority (REMA) and Rwanda Development Board (RDB) for model EIA terms and conditions and EIAs of one existing mining company to evaluate compliance with EIA.

3.2.2. Primary Data Collection

3.2.2.1. Field Observations

Direct field observations were performed to get insight of the entire study area identifying types of land use such as mining, agriculture, commercial, industrial, residential and different environmental impacts resulting from mining activities as main or direct causes. The technique helped also to observe infrastructure development and characterize the study area. My smart phone was used to take some pictures for specific sites, while notebook and pen were useful for field notes.

3.2.2.2. Household Questionnaire Survey

Questionnaire is the main data collection tool that was used in this study. Primary data were collected through questionnaire survey addressed to 150 households from six cells of Gatumba sector, with priority given to those located in proximity to mining sites. It is worth noting that the local community category will include people serving in the mining companies. The questionnaire focused on challenges encountered in relation with land degradation due to mining activities.

a. Targeted Population

Table 1 : Targeted Population for Quantitative Household Survey (N=6572)

Name of sector	**Name of cell**	**Targeted Population=Number of HHs in cell**
Gatumba	Kamasiga	1060
	Rusumo	974
	Cyome	1517
	Gatsibo	887
	Ruhanga	1126
	Karambo	1008
Total		6572

Source: Field survey, (June2025)

b. Sampling

A purposive sampling technique was used to determine the number of households to survey. This is because it was not possible to survey the whole population in Gatumba sector. The purposive sampling technique was applied to select respondents who provided information of this research. This technique was used because it allows the researcher to determine the respondent who could provide the best information to achieve the objectives of the envisaged study (Kumar, 2005).

c. Sample Size Determination

According to recent data, Gatumba Sector has an estimated total population (N) of 6572 households, spread across an area of 43.5 square kilometers, with 415 hectares (4.15 km^2) (NISR, 2023)allocated across seven land-based mining concessions.

To compute a statistically valid sample size from this finite population, Yamane's formula (1967) was applied. This formula is commonly used when the population size is known, and a specific margin of error is acceptable.

$$n = \frac{N}{1 + N(e)^2} \qquad \text{(Equation 1)}$$

Where:

- n = required sample size
- N = total population (6572 households)
- e = margin of error (expressed as a decimal)

Let's assume that the margin of error is approximately 8% which is acceptable for community-based research in rural or semi-urban settings where a balance between statistical precision and practical constraints is needed.

Sample size=150 households

% of households in a cell= (Nbr of households in a cell×100)/Nbr of population (Equation 2)

Sample size within a cell= (% of household× sample size)/100 (Equation 3)

Table 2: Sample Size for Quantitative Household Questionnaire (n=150)

Sector	**cell**	**Households**	**% of households**	**Sample size**
Gatumba	Kamasiga	1060	16	24
	Rusumo	974	15	22
	Cyome	1517	23	35
	Gatsibo	887	13	20
	Ruhanga	1126	17	26
	Karambo	1008	15	23
Total		6572	100	150

Source: Field survey, (June2025)

3.2.2.3. The interviews

The interview questions were addressed to 5 mine operators and 3 technical staff of the government lead agencies in charge of overseeing the environmental protection. Thus, two types of questionnaires were designed to target the two mentioned categories. Questions towards mine operators were focusing on the current level of environmental strategy implementation, the internal organization and readiness of the mining companies to implement EIA and challenges they are facing in that process (See appendix 2). For lead agencies, questions were structured to have information on the capacity of each targeted lead agency to be on top of the situation about the supervision of the environmental strategy implementation in the ASM sector (See appendix 3).

3.3. Data analysis and Interpretation

The computer interface (Microsoft Office 2016) was used to write the thesis and data entry. The used research methods helped in the successful collection of primary and secondary data and guided their compilation and analysis, with MS excel data were summarized in tables and figures.

Spatial data acquisition and processing was performed using Geo-information technologies (Remote Sensing and GIS tools), especially GIS software was also used for processing, analyzing, and spatial data visualization.

3.3.1. Descriptive Statistics

Descriptive statistical analysis was employed to summarise and interpret the fundamental characteristics of data in this study.This approach facilitated the presentation of concise yet insightful summaries of the sample and its associated measures .Given the research studies often produce extensive datasets encompassing multiple variables and numerous respondents, the application of descriptive statistics was essential for systematically organizing and simplifying complex data.By reducing large datasets into comprehensible summaries, descriptive statistics enhanced the clarity and interpretability of the findings.

3.3.2. GIS-based Environmental Modeling

3.3.2.1. LULC Analysis

Land Use and Land Cover (LULC) Analysis refers to the process of identifying, mapping, and quantifying the physical features present on the Earth's surface (land cover) and the human activities or purposes associated with them (land use). This analysis was typically carried out using remote sensing data (landsat imagery) and Geographic Information Systems (GIS) through classification techniques that categorize satellite imagery into thematic classes which are forest, cropland, built-up areas, water bodies, bare land and range land.

Land Use Land Cover (LULC) analysis in the context of the environmental impact of land mining in Gatumba Sector was instrumental in understanding the spatial and temporal effects of mining activities on the local environment. Through baseline mapping, the 2017 LULC status of Gatumba was established, serving as a reference point for evaluating subsequent changes after comparison with 2025 LULC. Change detection techniques were then applied to identify and quantify alterations forest and bare land, revealing significant shifts attributable to mining operations.

This enabled impact assessment, linking observed changes such as deforestation, expansion of bare land to land degradation, soil erosion. spatial correlation was achieved by overlaying LULC maps with the locations of mining sites, helping to assess the proximity and magnitude of disturbances.

Ultimately, the results provided decision support, offering spatial evidence to guide environmental management, land reclamation efforts, and policy recommendations aimed at restoring degraded areas and mitigating future impacts.

3.3.2.2. Soil Erosion Analysis

For analyzing the effects of soil erosion, the study has employed the Revised Universal Soil Loss Equation (RUSLE) model,the model calculates the average annual soil erosion loss by considering the five factors.

A = R×K×LS×C×P **(** Equation 4) where,

A: stands for the average annual soil loss;(tons/ ha/ year)

R: is the rainfall erosivity factor ((MJ mm ha/h1/ year)

LS: refers to slope length- steepness factor;(dimensionless) K: represents the soil erodibility factor; (tons ha h /ha/ MJ/mm)

C: represents the Cover and management factor, (dimensionless, ranges from zero to one)

P: denotes the conservation support practices factor (dimensionless, ranges from zero to one)

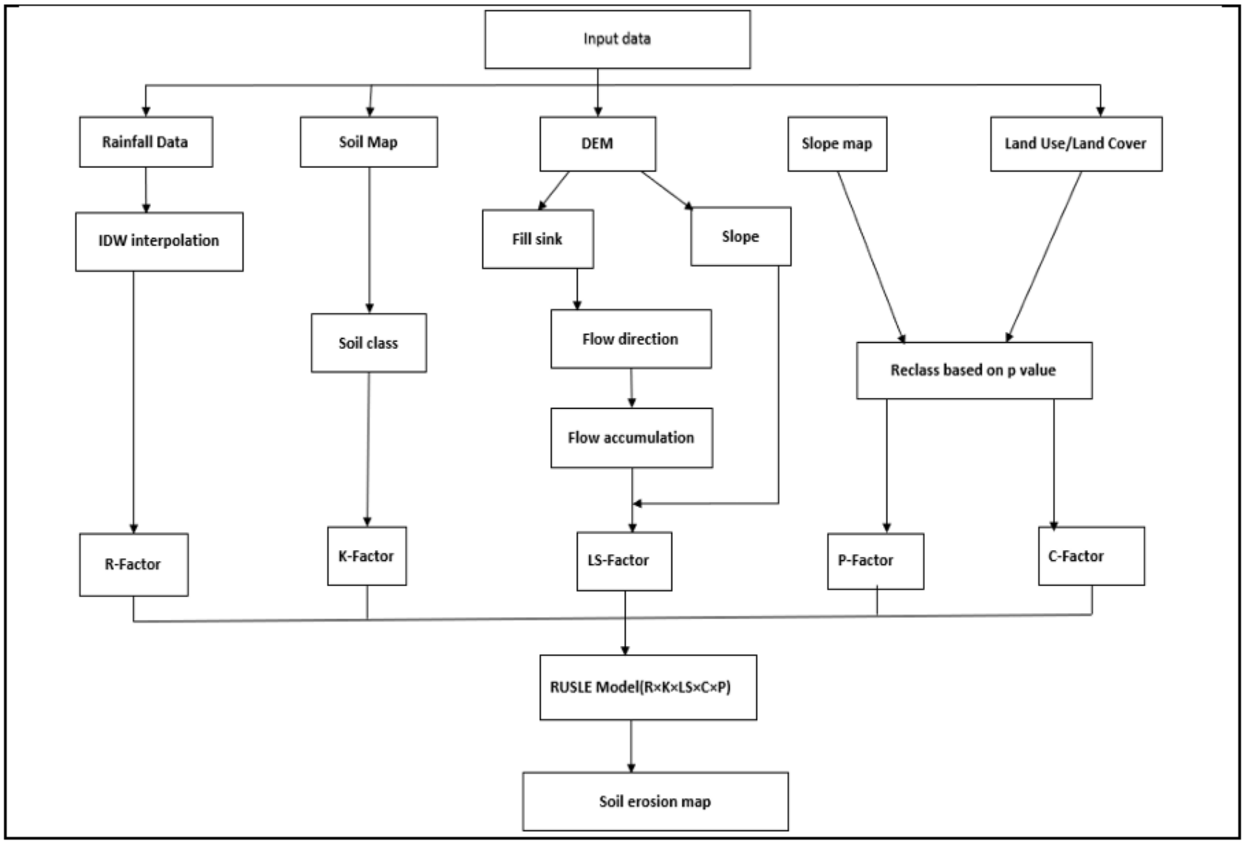

Figure 4: RUSLE Model Flowchart

Source: Kebede et al., (2021)

i. Rainfall Erosivity (R-factor)

The rainfall erosivity factor (R-factor) in the RUSLE model quantifies the impact of rainfall on soil erosion. It represents the potential of rainfall to cause erosion by considering the intensity and volume of rainstorms. Higher values of the R-factor indicate greater erosive potential. This factor is calculated using historical rainfall data, including the amount and kinetic energy of rainfall, to assess how rainfall contributes to soil detachment and transport. The R-factor is crucial for understanding the influence of precipitation patterns on soil erosion rates in a specific area.

The rainfall erosivity(R-Factor) was determined based on average rainfall from Gatumba Sector, which varies between 306mm and 2332.8mm. The R-Factor values calculated range from 698 MJ mm/ha/h to 737 MJ mm/ha/h. The patterns of average rainfall in the Gatumba sector show the distribution of high values in Ruhanga cell and low values in Kamasiga cell.

However, these R-Factor variations impact the soil loss amount because of anthropogenic activities, especially the most intensive activities of mining.

$R=(0.526\times P)-8.12$ (Equation 5)

R is the R factor in MJ mm ha/h1/ year

P is the rainfall raster in mm/year

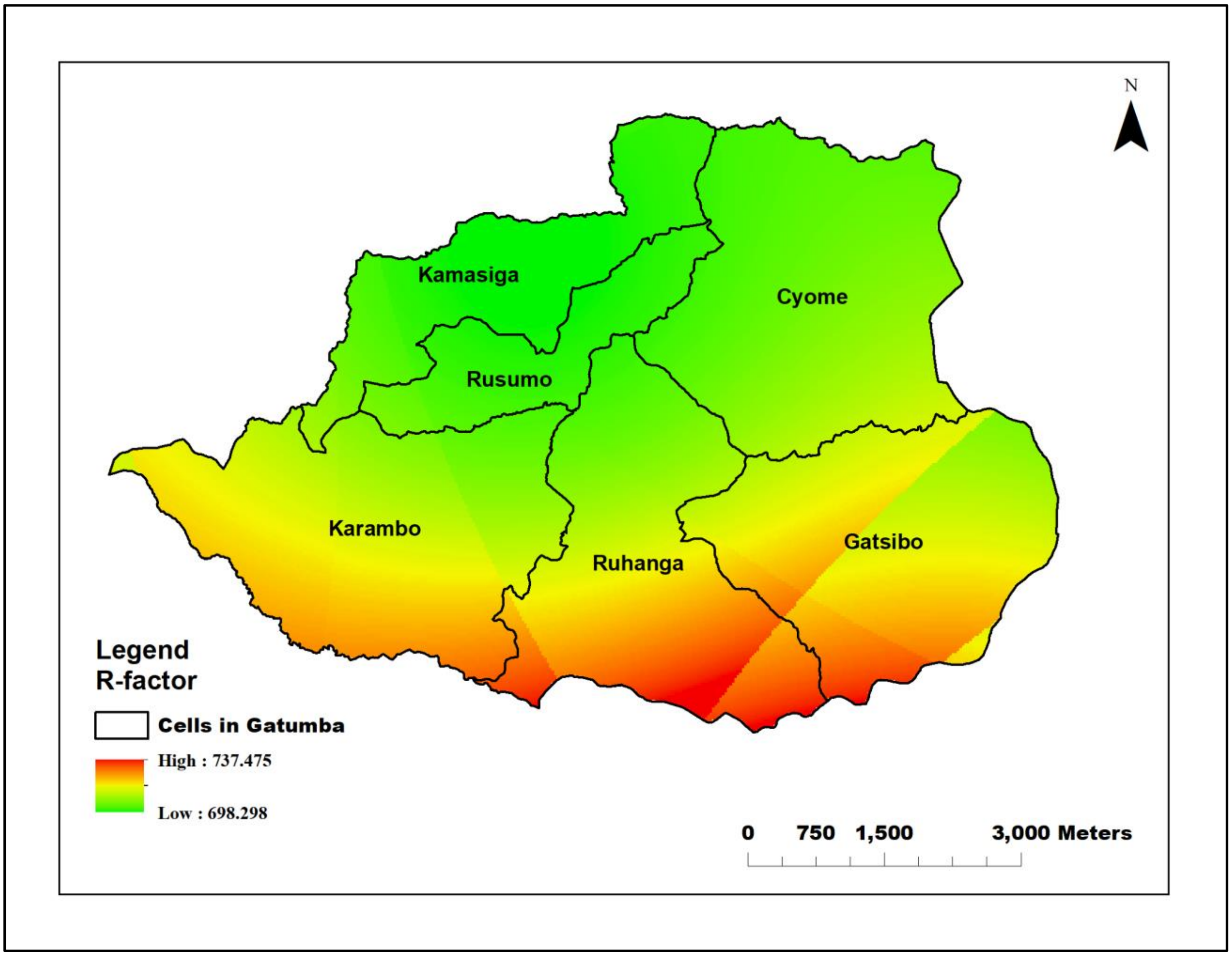

Figure 5: Rainfall Erosivity (R-factor) of Gatumba sector

Source: RMA (2024)

ii. Soil erodibility (K-factor)

K factor measures the erodible-ness of soil as affected by soil properties. It characterizes the long-term reaction of the soil to heavy erosive precipitation events.

Soil erodibility in Gatumba sector depends on soil content, which refers to the amount of sand, coarse grain, clay-silt content, and carbon content. The high amount of coarse-grain sand reduces soil erodibility, the high clay-silt ratio reduces soil erodibility, and high carbon content also reduces soil erodibility. The high K factor is the tendency of soil erosion to occur. The Gatumba erodibility ranges from 0.040 to 0.129 t.ha.h/ha/MJ/mm. K is measured tonnes · hectare · hour per hectare · megajoule · millimeter.

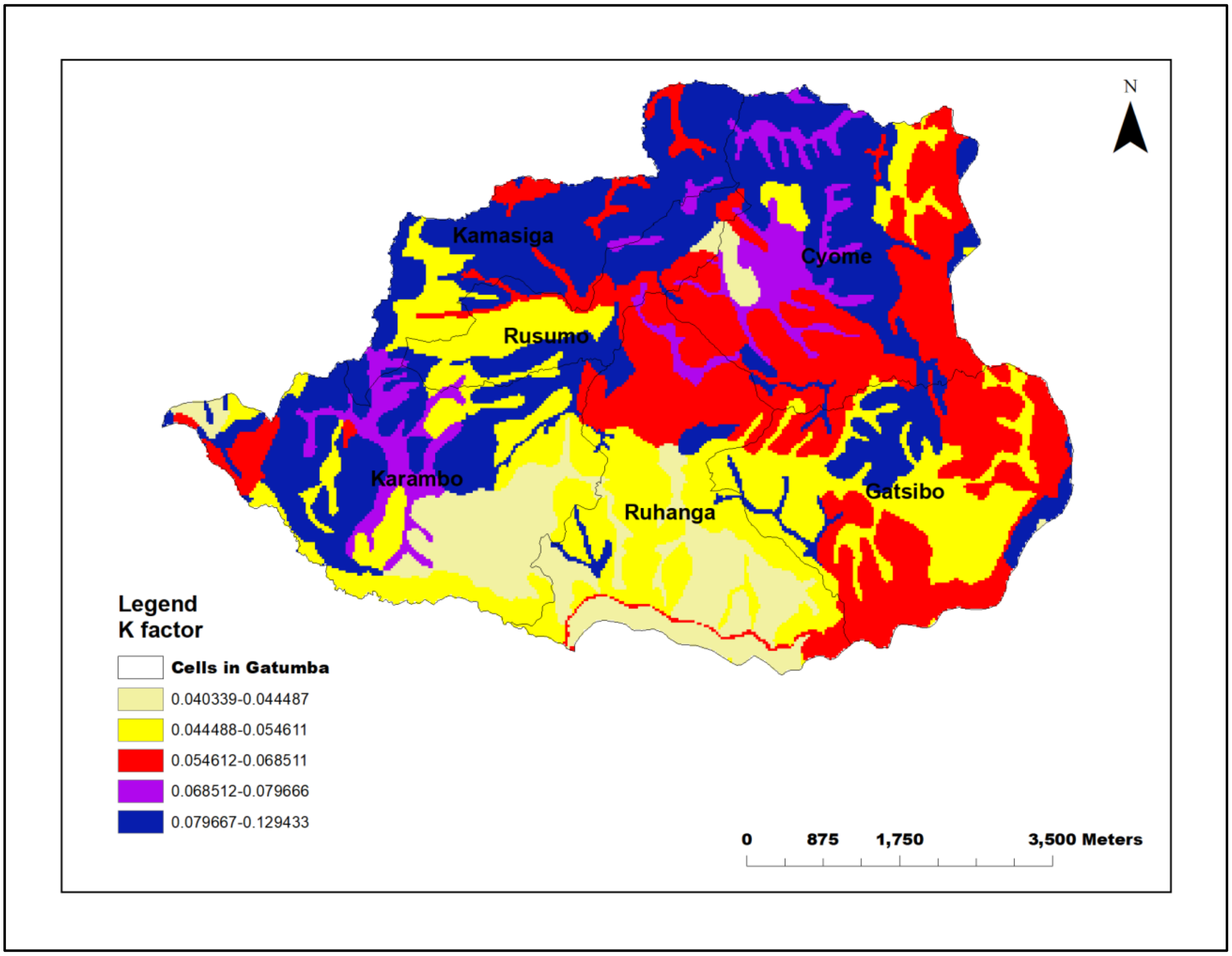

Figure 6: Soil Erodibility of Gatumba sector

Source: NLA (2025)

K Factor: [F_orgC]*[F_sand]*[F_silt] *[F_clay]*0.1317(Equation 6)

iii. Slope Length Steepness Factor (SL)

The Length and Slope factor in the RUSLE model characterize the influence of topography on erosion. The slope length (L) and slope steepness (S) factors are integral in determining the impact of topography on soil erosion rates.

The slope length factor (L) represents the horizontal distance from the point where runoff begins to the point where either the slope decreases enough for deposition to start, or the runoff enters a well-defined channel.

The SL-factor is computed in ArcGIS software using the equation (Equation 7) developed by (Mitasova, et al., 1996). The computation of this factor needs factors like flow accumulation, flow direction, slope steepness, and a digital elevation model, as well as tools like the spatial analyst in GIS software.

LS= {FA*(Cell size/23.13)} ^0.4*{Sin (Slope of DEM*0.01745)/0.09} ^1.3*1.6 (Equation 7)

Where: LS= Slope length and Steepness factor

FA= Flow Accumulation

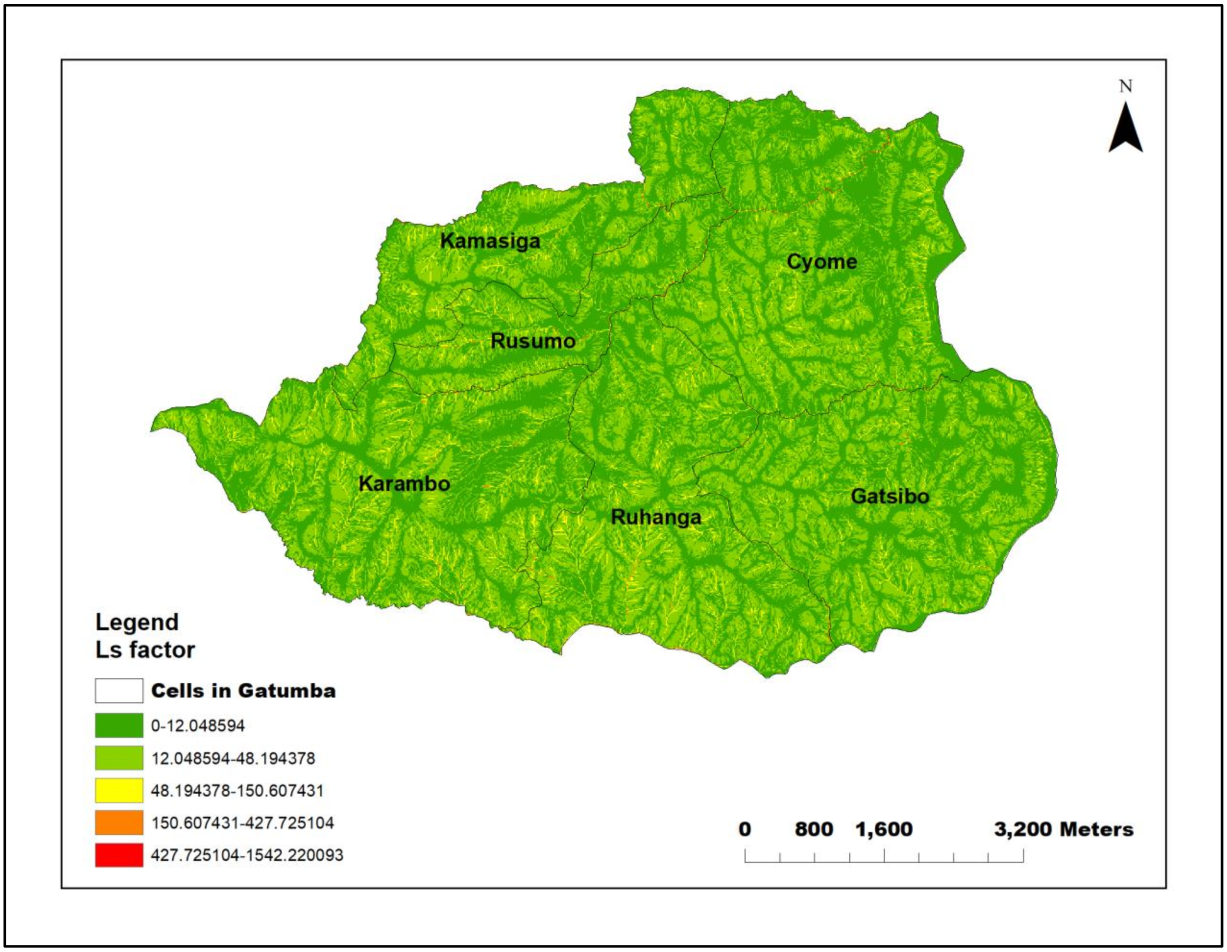

Figure 7: Slope Length Steepness Factor of Gatumba sector

Source: NLA (2025)

Where LS = combined slope length and slope steepness factor; cell size from DEM of 10m resolution, and sin slope = slope degree value in sin. The LS factor value in the study area varies from 0.00 to 1542. The computation shows that the majority of the study area has an SL-Factor value less than 48.

iv. Cover Management Factor (C)

The vegetation covers and management factor reflects the impact of ground cover, including crops and their associated management practices in agricultural settings, as well as trees and grass in non-agricultural areas, on reducing soil erosion. Ground cover helps to diminish the erosive force of raindrops before they reach the soil surface. As vegetation cover increases, soil loss decreases.

The vegetation covers and management factor reflects the impact of ground cover, including crops and their associated management practices in agricultural settings, as well as trees and grass in non-agricultural areas, on reducing soil erosion. Ground cover helps to diminish the erosive force of raindrops before they reach the soil surface. As vegetation cover increases, soil loss decreases (Tian, et al., 2015). Therefore, the type of vegetation and crop cover plays a crucial role in controlling erosion and runoff rates. Effective management of vegetation residues and plant remnants can significantly limit soil erosion.

Table 3: Value of C Factor according to Land Use

Land Use Type	**C Factor**
Agriculture	0.24
Built-up	0.15
Forest	0.01
Wetland	0.24
Waterbody	0

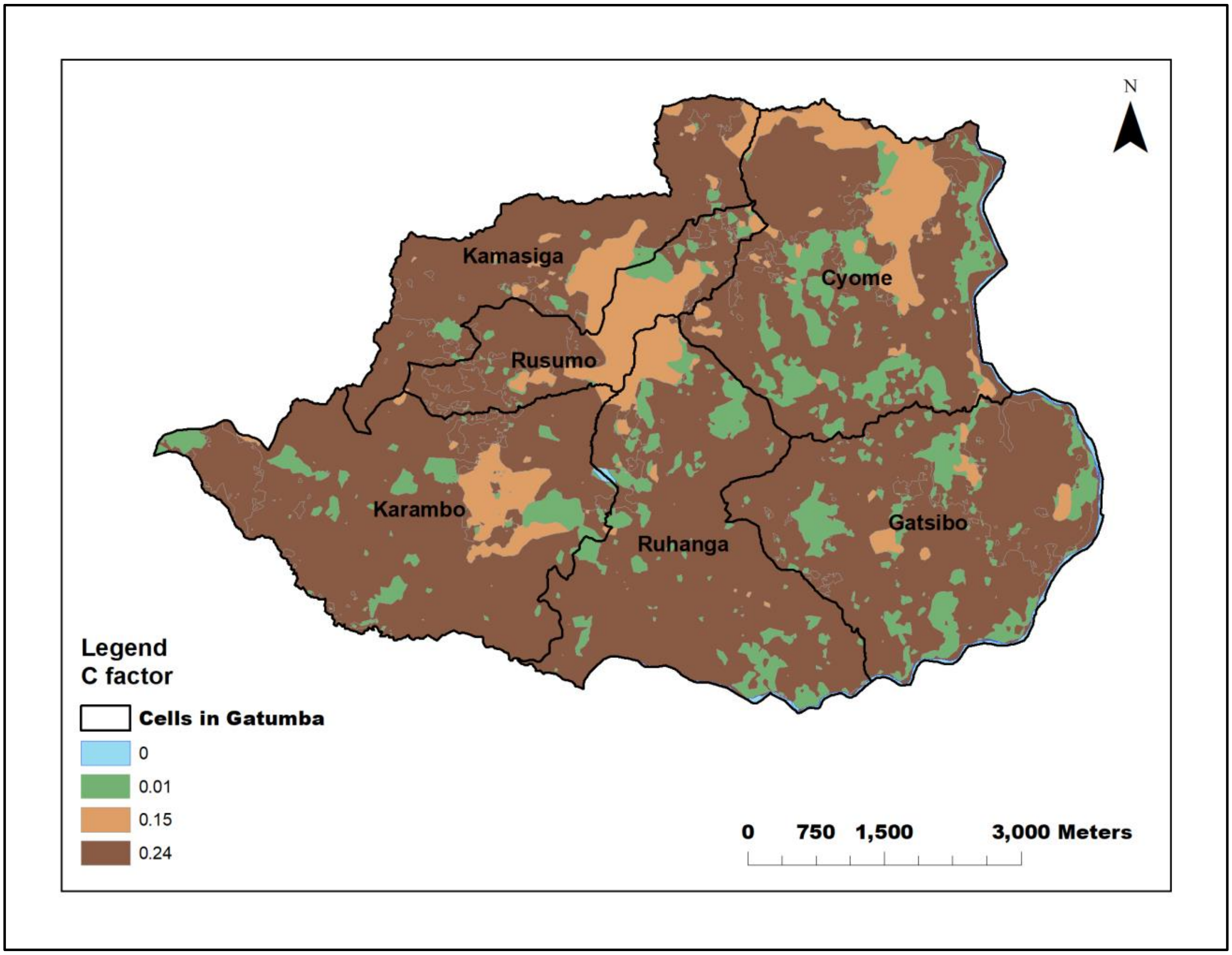

Figure 8: Cover Management Factor of Gatumba sector

Source: NLA (2025)

V. Conservation Support Practice Factor (P)

In Gatumba Sector of Ngororero District, the **P factor** in the RUSLE model reflects the extent to which soil conservation and erosion-control measures are implemented in a predominantly mountainous landscape. The sector's steep slopes naturally predispose the terrain to high runoff velocity and severe soil loss, a situation further aggravated by artisanal mining activities that often remove vegetation cover, disturb soil structure, and create unprotected spoil heaps. In many mined or cultivated areas, there are few engineered support practices such as terracing, contour farming, or properly maintained drainage channels, meaning P values may approach **1.0**, indicating minimal erosion reduction.

Where smallholder farmers or rehabilitation projects have introduced hillside terracing or contour planting, P values can be significantly lower, reflecting reduced erosion potential. However, given the prevalence of artisanal mining without formal land reclamation, the overall P factor across much of Gatumba remains high, underscoring the need for targeted conservation interventions to stabilize disturbed slopes and mine tailings.

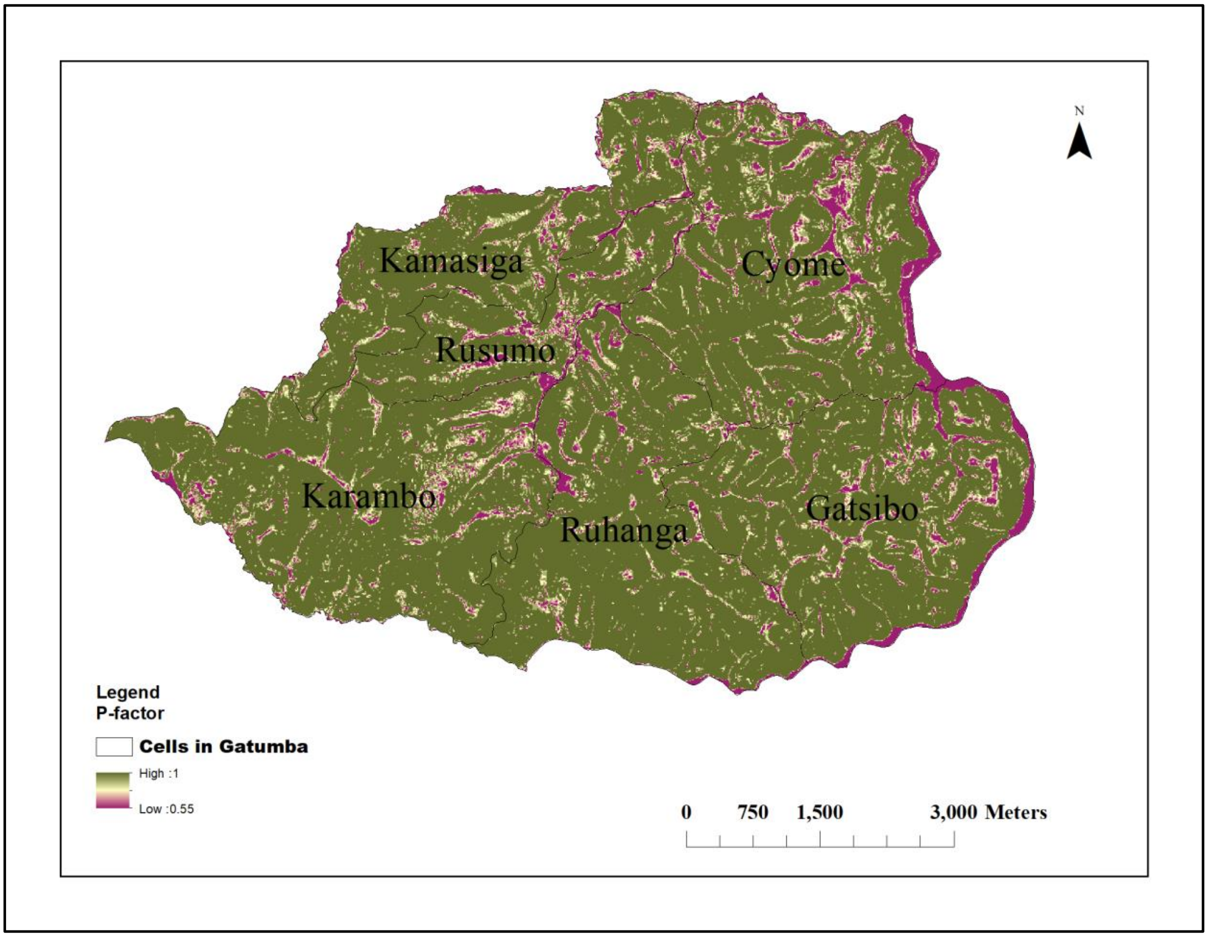

Figure 9: Conservation Support Practice Factor of Gatumba sector

Source: NLA (2025)

Chapter 4. Results and Discussions

This chapter focuses on the presentation, interpretation, and analysis of the research findings. The first section provides background information, including details about the respondents' gender, their categories. Subsequently, the chapter delves into other three sub-sections namely: major environmental problems caused by mining activities in Gatumba Sector, the extent to which Environmental Impact Assessment (EIA) addresses these environmental problems, strategies for improving the effectiveness of EIA in mitigating environmental impacts of mining activities in Gatumba Sector.

4.1. Information on Respondents

4.1.1. Gender

As shown in the following table, it was observed that most of the respondents were male, accounting for 61.3% (92) of the respondents while female respondents accounted for 38.7% (58). In general women interest in mining sector was improved but it remains a bit low.

Table 4: Respondents' Gender Distribution per cell

	Gender Distribution		
Cell	**Female**	**Male**	**Total**
Kamasiga	10	14	24
Cyome	15	20	35
Rusumo	6	16	22
Ruhanga	10	16	26
Gatsibo	7	13	20
Karambo	10	13	23
Total	**58**	**92**	**150**

Source: Field survey (June2025).

4.1.2. Categories of Respondents and Response Rate

In all cells of Gatumba sector, 150 individuals responded to our survey making 100% of the sample of 150 members of the public selected from 6 cells of Gatumba sector. Additionally, 5 Mine operators and 3 technical staff from the government lead agencies in charge of overseeing the environmental protection were interviewed.

4.2. Existing Mining Activities in Gatumba sector

4.2.1. Licensed Mining Activities in Gatumba Sector

Gatumba sector is a part of one of the biggest Gatumba mining concessions ever held by the former Rwandan government. Gatumba sector consist of six cells which are Kamasiga, Cyome, Rusumo, Karambo, Ruhanga and Gatsibo. The sector consists of seven mining sites owned by five mining companies namely PRG, GEOSAMI, BMDC, Ruli Mining Trade Ltd and Crystal.

Table 5: Legal Mining Sites and their Corresponding Surface Area in Gatumba Sector

Exploiting Mining Company	Legal Mining Site	Surface Area in Hectares
PRG	Muriro	62.3
PRG	Ruhanga	50
GEOSAMI	Gatare	83.2
BMDC	Ngurugunzu	22.5
Ruli Mining Trade Ltd	Mburabuturo A	47
Ruli Mining Trade Ltd	Mburabuturo B	50
Crystal	Rugunda	100
Total Area		**415**

Data Source: RMB (2024).

The density of mining activities in Gatumba Sector can be assessed by examining both the spatial distribution and the intensity of mining operations relative to the sector's land area and population. Out of 4350 hectares (43.5 square km) of Gatumba sector 415 ha are concessions of authorized mining activities reflecting 9.5% of Gatumba sector's land.

Although this may seem relatively small in terms of geographical spread, the concentration of extractive activities within the area is high, particularly being artisanal mining that pose real threats especially at the local level. Especially considering the artisanal nature of operations, which typically rely on manual labor, informal processing techniques, and minimal mechanization. These sites are often situated close to human settlements or agricultural lands, increasing their environmental footprint beyond their physical boundaries. Moreover, mining activities are becoming an escalating threat as they continue to expand over time, with significant encroachment into populated centers, thereby intensifying their socio-environmental impact.

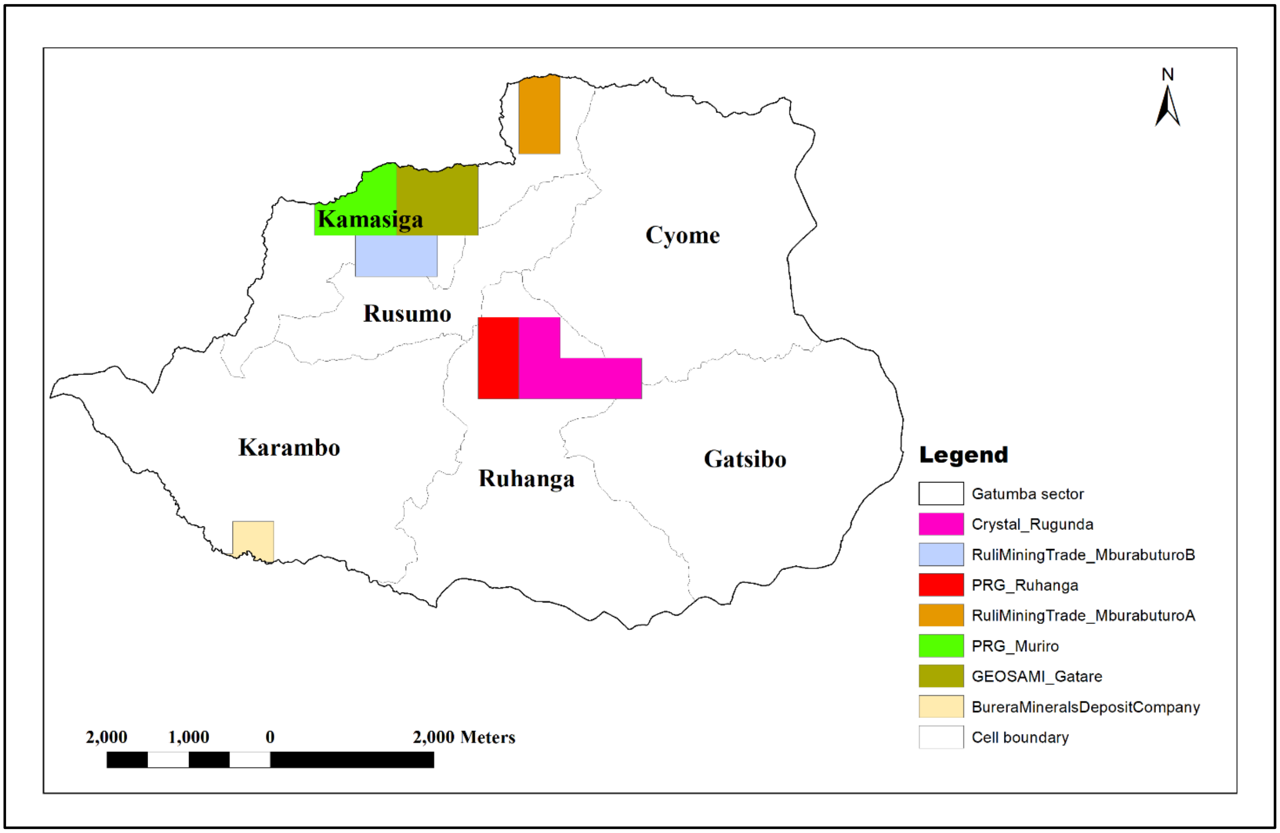

Figure 10: Spatial Distribution of Licensed Mining Sites in Gatumba Sector

Source: RMB (2024)

4.2.2. Illegal Mining Activities in Gatumba Sector

During the field visit, the first impression may confirm that mineralized terrains which are neither well monitored by mining companies nor currently occupied by mining companies are greatly invaded by illegal mining activities, local residents have reported that illegal miners trespass on their land, sometimes under threat or pressure.

When representatives of mining companies in Gatumba sector were asked why they do not monitor their entire concession thereby allowing illegal mining activities to occur they explained that they try their best to monitor their entire concession, but more activities being conducted in more mineralized and more productive zones, inadvertently leaving the less mineralized areas vulnerable to encroachment by illegal miners. In August,2020, seven men were arrested in operation against illegal mining activities, the suspects were caught mining coltan and cassiterite in a stream. The Rwanda National Police (2020) reported that "According to Chief Inspector of Police (CIP), the Police spokesperson of the Western region, 'the operation was conducted between 11AM and 12:30 following information from local residents, who reported the unlawful acts.

4.2.3. Impacts of Mining Sites proximity to residential areas on local communities

The survey reveals that certain environmental impacts are specific to residents living near mining sites, while others are more widespread and also affect those living far away, among residents living near mining sites, the majority acknowledged that proximity to mining activities offers job opportunities. However, they also expressed concerns about the disturbances and inconveniences caused by living so close to active mining operations. Respondents living near mining site experience common effects; For example, 30/42 and 25/42 who live in less than 1Km from mining sites claimed to experience soil erosion and vibration respectively;31/42 respondents who live in less than 1 km from mining sites claimed a restricted access to their land. Respondents from all residents claimed that mining activities leads to water pollution or reduced water availability.

Table 6: Impacts of Mining Sites on Residential Areas

Reported Common Effects	Frequency	Local People' Perceptions
Soil erosion	30	"Mining disturb drainage patterns".
Vibration and structural damage to houses	25	"Cracks have developed on my house wall".
Restricted access to land or resources	31	"We can't farm near the site anymore".
Employment opportunities from mining	100	"My son got a job in the mine".
Water pollution or reduced water availability	130	"The stream is no longer clean for drinking".

Source: Field survey (June2025) .

4.2.4. Evolution of Mining Sites near Local Populations' Residences in Last 5 Years

Regarding trend in mining activities in the last five years 102 (68%) respondents reported an increase in mining activities in around their residence, 12 (8%) respondents reported a decrease in mining activities around their residence, while 36 (24%) respondents reported no change in mining activities around their residence.

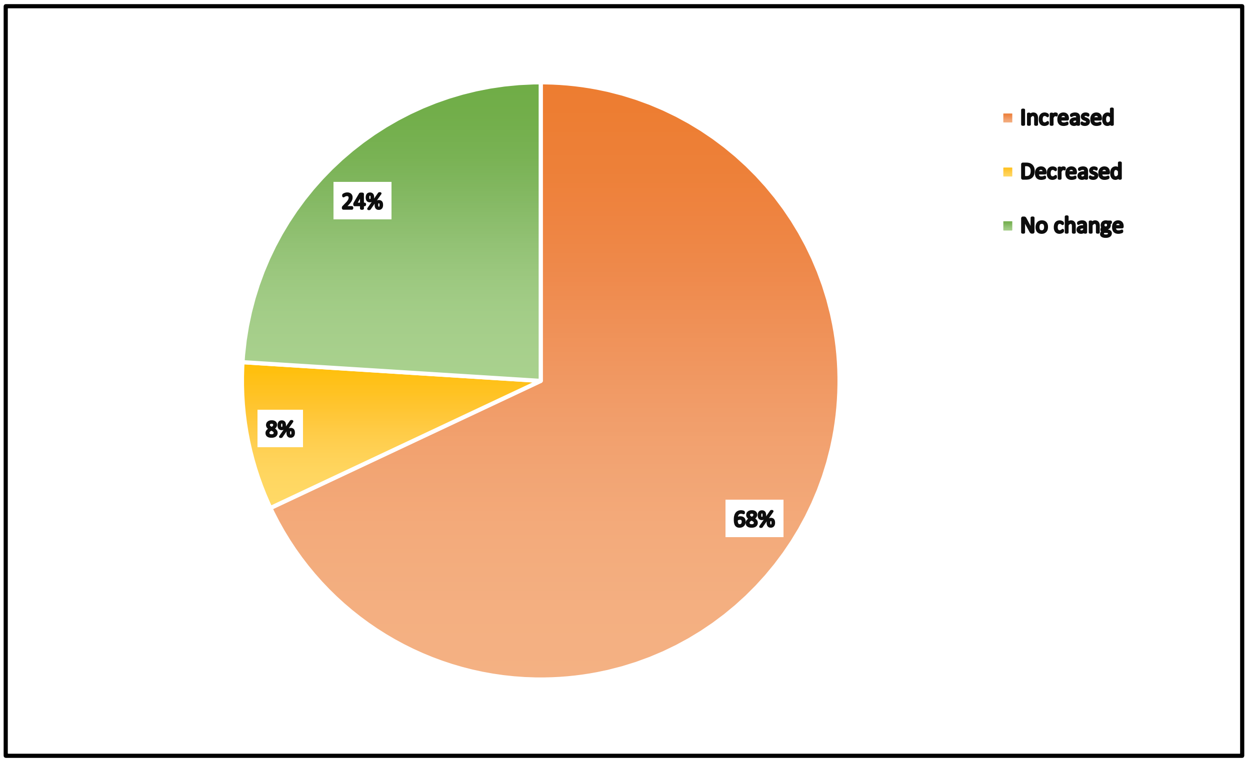

Figure 11: Evolution of Mining Activities near Local Populations' Residences in Last 5 Years

Source: Field survey (June2025)

4.3. Environmental Challenges related to Mining Activities in Gatumba Sector

The environmental condition of Gatumba Sector, located in Ngororero District, reflects a long history of unsustainable land mining practices, dating back to the colonial period. Over the years, both small-scale and industrial mining activities have intensified in the area (Bizimana, et al., 2021), leaving a significant and visible impact on the local ecosystem. Due to limited regulation in the past, the land has undergone widespread physical degradation, and many of the natural features have been permanently altered, below we discuss environmental challenges on land in Gatumba sector.

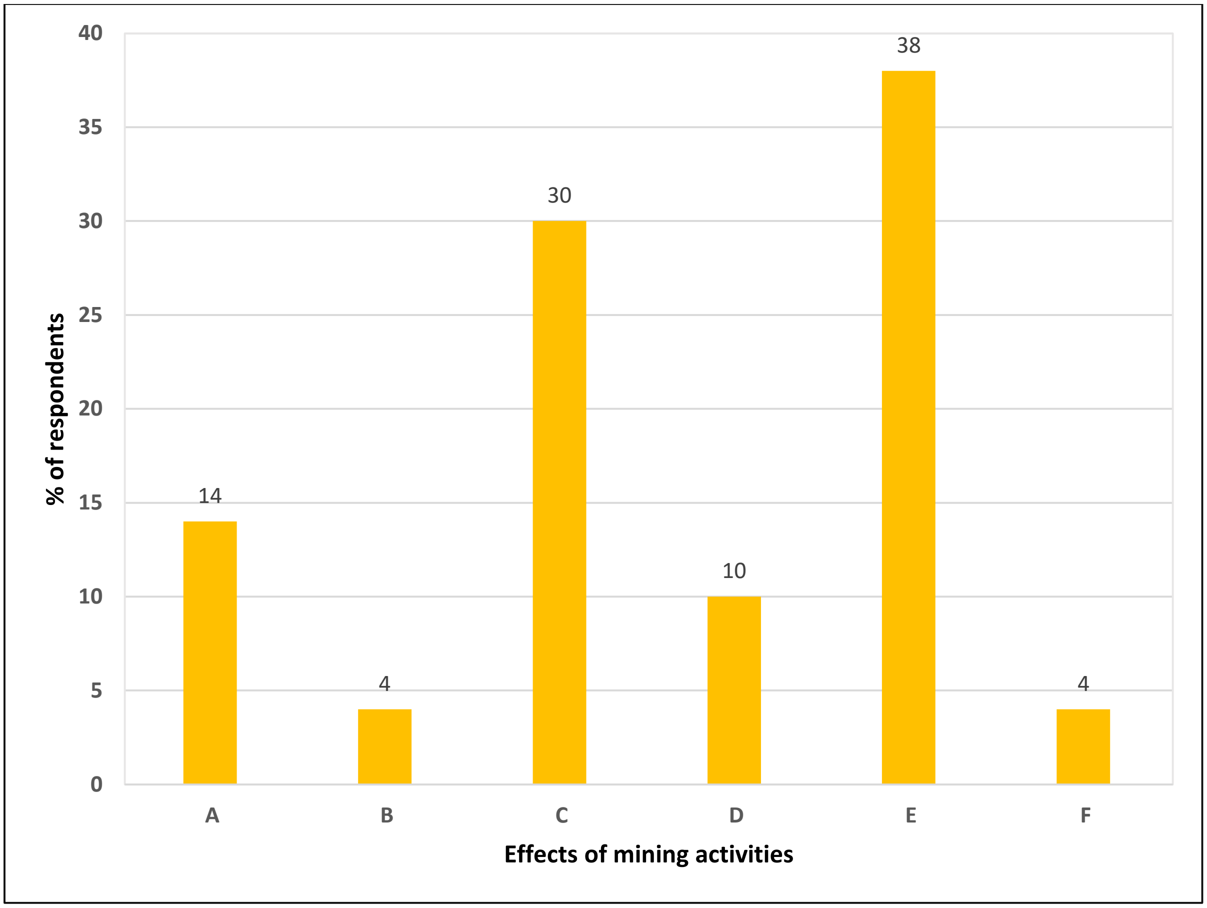

Figure 12:Environmental Challenges related to Mining in Gatumba Sector

(A: Loss of vegetation cover, B: Seasonal flooding on land, C: Barren soil, D: Deforestation, E: Soil erosion and landscape degradation & F: Waste management challenge)

Source: Field survey (June2025).

The Figure 12 above illustrates respondents' perspectives on the dominant environmental challenges they recognize. Soil erosion and landscape degradation were identified by 38% as the most pressing issue, followed by barren soil (30%), loss of vegetation cover (14%), deforestation (10%), seasonal flooding (4%), and waste management challenges (4%) as effects of mining activities.

4.3.1. Indicators of Mining-induced Environmental Impacts in Gatumba sector

4.3.1.1. Land Use and Land Cover Change

A land use and land cover (LULC) change analysis conducted in Gatumba Sector between 2017 and 2025 reveals significant environmental transformations, largely attributed to the expansion of mining activities in the region. The most notable change observed is the dramatic loss of forest cover, which decreased from 1,325.4 hectares in 2017 to 1171 hectares in 2025 an overall reduction of 154.4 hectares, representing a 38.2 change. This decline is a clear indicator of deforestation, likely resulting from artisanal and small-scale mining operations. The environmental consequences of this deforestation are profound, including biodiversity loss, increased soil erosion, disruption of hydrological cycles, and a decline in carbon sequestration capacity.

Another significant change is the increase in bareland, which grew from 479.5 hectares to 574.3 hectares an addition of 94.8 hectares. This suggests that large areas of land have been cleared or degraded due to mining operations. Bareland typically indicates exposed, unproductive land surfaces, which are vulnerable to erosion and often contaminated by mining residues. Such areas are associated with landscape degradation and become unsuitable for agriculture or habitation unless extensive rehabilitation efforts are undertaken.

Built-up areas have also expanded notably, increasing from 950.5 hectares in 2017 to 1,015hectares in 2025. This trend likely reflects increased human settlement due to labor migration linked to mining activities. The increase in impervious surfaces can intensify surface runoff, reduce groundwater recharge, and contribute to pollution through improper waste disposal and poor sanitation systems.

Between 2017 and 2025, bare land in Gatumba Sector increased from 479.5 hectares to 574.3 hectares, reflecting a clear trend of land degradation linked to mining activities. According to (Byizigiro, et al., 2020), mining in the Gatumba region is still dominated by evolving, largely unregulated artisanal and small-scale methods, which pose significant threats to the environment. Similarly, (Kazindu, et al., 2020) observed that mining operations in areas like Ngororero often neglect fundamental environmental practices such as topsoil preservation and sediment control.

As a result, soils around mining pits are left in poor condition, and during rainfall, eroded materials are washed into nearby rivers, accelerating land degradation. This pattern of environmental harm is not only immediate but can also persist long after mining activities cease.

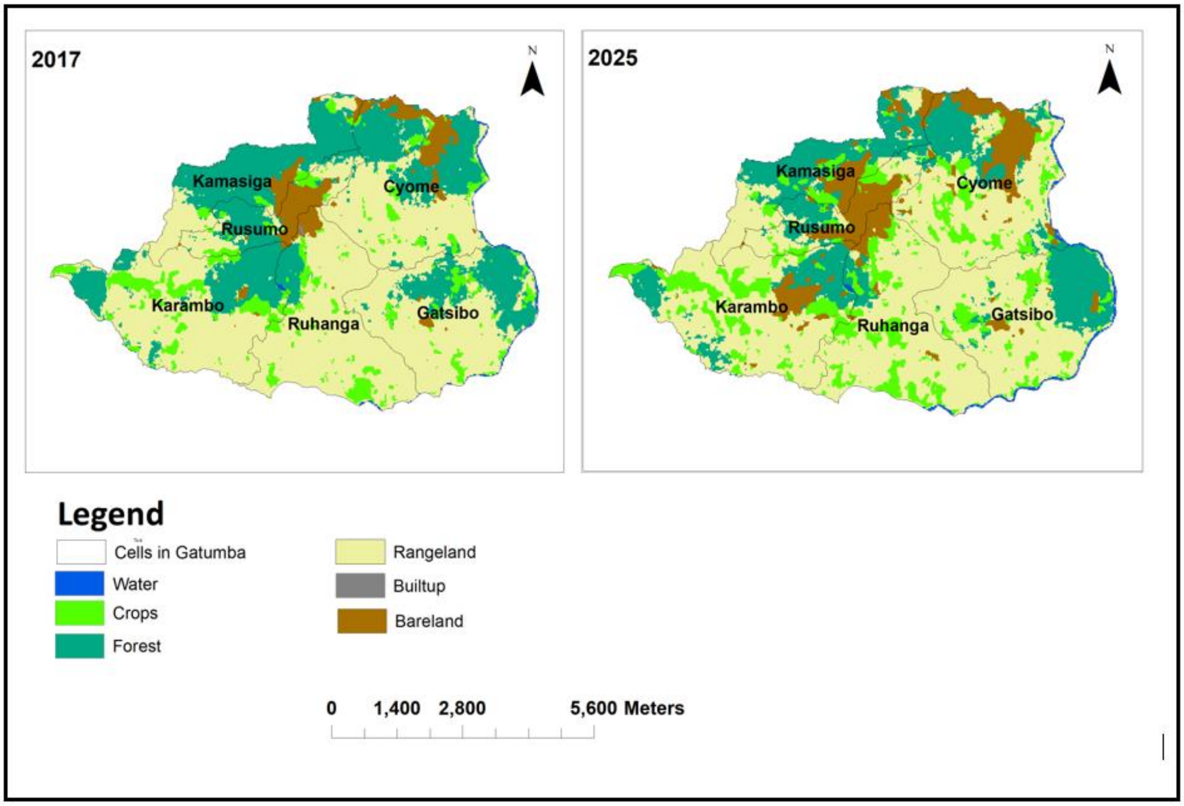

Figure 13: Land Use and Land Cover Change from 2017 to 2025

Source: USGS (2025).

Table 7: Land Use and Land Cover Change from 2017 to 2025 in Gatumba sector

Classes	2017 area in Ha	%	2025 area in Ha	%	Change in Ha	% of change	Remarks
Built up	950.5	21.9	1015	23.3	64.5	16.0	Gain
Forest	1325.4	30.5	1171	26.9	154.4	38.2	Loss
Water	79.5	1.8	79.7	1.8	0.2	0.0	Gain
Bareland	479.5	11.0	574.3	13.2	94.8	23.5	Gain
Rangeland	517.4	11.9	560	12.9	42.6	10.5	Gain
Crops	997.7	22.9	950	21.8	47.7	11.8	Loss
Total	4350	100	4350	100	404.2	100.0	

Source: USGS *(2025)*.

4.3.1.2. Soil Loss

The soil loss in Gatumba sector is estimated by the RUSLE model by considering different parameters such as soil types, topography, vegetation cover, rainfall pattern, and soil erosion management practices. The RUSLE parameters are computed in the ArcGIS software and generate a distribution of soil loss across the Gatumba sector. Then the amount of soil loss across the Gatumba sector was determined by an empirical formula that combined rainfall erosivity factor, soil erodibility factor, slope length factor, cover management factor, and supportive practices (R, K, C, SL, P). So, the mean annual soil erosion rate in the Gatumba sector is estimated in the range from 1,415 to 97,845,376 tons/ha/year.

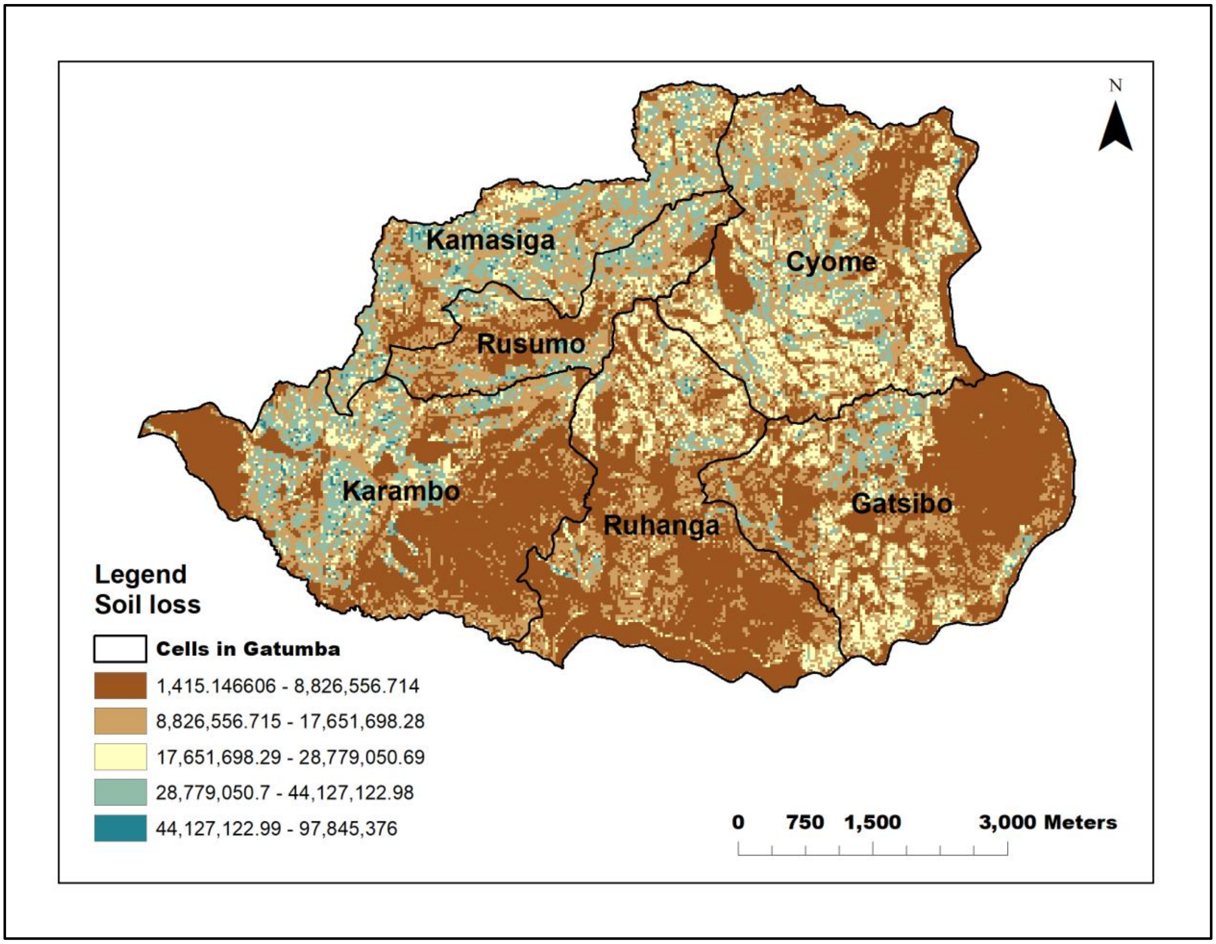

Figure 14: Average soil loss in Gatumba Sector

Source: NLA *(2025)*

Table 8: Level of Soil Loss in Gatumba Sector

Level of Soil Loss	**Area in Ha**	**%**
Very high	17.4	0.4
High	556.8	12.8
Moderate	165.3	3.8
Low	1600.8	36.8
Very low	2005.35	46.1
Total	4350	100

Source: NLA (2025)

Classification of Gatumba soil loss shows that low to modelate soil loss occupy most of the area with 46% and 37% approximatively, but yet there are distinct pockets about 13% at higher classes and a small yet critical very high class with 0.4%. Topography and climate amplify soil loss. The Western Province is mountainous with deeply incised valleys and high rainfall, conditions that raise baseline erosion risk even before mining disturbance. Mining practices intensify these natural drivers. In Gatumba and comparable ASM settings, vegetation removal, topsoil stripping, oversteepened pit walls and waste rock/tailings dumps create bare, unconsolidated surfaces that are highly erodible. Un-engineered haul roads and drainage diversions concentrate overland flow, triggering riling and gullying; tailings and fine mine wastes are easily mobilized into streams, increasing turbidity and sediment delivery downstream.

Figure 15:Environmental Impact of Mining in Gatumba Sector

Source: Field survey (June2025).

4.4. Effectiveness of EIA in Identifying and Mitigating Key Environmental Risks

4.4.1.EIA Mitigation on Impacts

Gatumba Sector with active mining operations collectively spanning approximately 415 ha Rwanda's Environmental Impact Assessment (EIA) framework demonstrates comprehensive legal coverage of the major environmental challenges posed by mining, including loss of vegetation cover, seasonal flooding, barren soil, deforestation, soil erosion, landscape degradation, and waste management difficulties. Under Law No. 48/2018 on Environment and its implementing regulations (including Ministerial Orders from 2008), mining projects are required to prepare full EIAs that include detailed baseline studies, mitigation plans, and environmental management plans (EMPs) tailored to impacts such as habitat clearance, hydrological disruptions, soil fertility loss, erosion control, and pollutant containment (Republic of Rwanda, 2018).

The mining sector-specific EIA guidelines further prescribe mitigation design measures including progressive rehabilitation, topsoil stockpiling and re-spreading, drainage structures such as sedimentation ponds and diversion channels, slope stabilization techniques (e.g., contour ripping, benching, mulching), as well as dedicated waste and tailings management systems, including environmental bonding to finance closure and reclamation. These components align technically with the identified challenges in Gatumba: restoring vegetation (A), controlling runoff and flooding (B), preventing soil infertility (C), limiting deforestation (D), minimizing erosion and landscape degradation (E), and containing mine waste (F).

Nevertheless, while the EIA framework is robust in design and regulatory intent, its effectiveness in implementation within Gatumba appears more constrained. Literature from Rwanda—especially within small-scale and artisanal mining contexts similar to Gatumba highlights persistent issues of incomplete topsoil management, delayed or patchy rehabilitation, inadequate maintenance of drainage works, and insufficient control of waste and dusty tailings. These shortcomings frequently culminate in barren land not quickly revegetated ongoing soil erosion, gully formation, and sedimentation of streams (REMA, 2012) .

4.4.1.1. Loss of Vegetation Cover

Environmental Impact Assessments (EIAs) are designed to identify and evaluate potential impacts of development activities, including the loss of vegetation cover. In the case of mining projects, EIA can be highly effective in mitigating vegetation loss when it includes a detailed baseline assessment of existing flora and recommends avoidance of ecologically sensitive areas. Mitigation measures such as buffer zones, restricted clearing, and reforestation plans are often proposed (Glasson, et al., 2012). However, the effectiveness depends largely on enforcement and post-approval monitoring. In many developing regions, EIAs are conducted but not rigorously followed up, which reduces their potential to prevent widespread vegetation loss (Morgan, 2012).

4.4.1.2. Seasonal Flooding on Land

EIAs can play a preventive role in addressing seasonal flooding by requiring hydrological studies before project implementation. These studies can assess how land use changes, especially due to deforestation and increased impervious surfaces, may alter drainage patterns and exacerbate flooding. An EIA can recommend proper stormwater management systems, preservation of wetlands, and maintenance of natural waterways (Morris & Therivel, 2009). However, the success of these measures depends on whether they are implemented in full and maintained regularly. In many cases, EIAs highlight flooding risks but fail to prevent them due to weak institutional capacity and lack of compliance by project developers (Ahmed & Ahmad, 2019).

4.4.1.3. Barren Soil

The development of barren soil, often a result of vegetation removal and poor land rehabilitation post-mining, can be anticipated during the EIA process. A well-prepared EIA includes a soil quality baseline and suggests land restoration or reclamation strategies such as topsoil preservation, controlled excavation, and post-mining revegetation (Akabza & Darimani, 2001). While EIA has the tools to address this issue, actual mitigation is often poor if there is no binding obligation or funding allocated for land restoration. Thus, while EIAs can theoretically prevent the development of barren land, practical outcomes often fall short without strict enforcement and community involvement (Hilson, 2002).

4.4.1.4. Deforestation

Deforestation is one of the most visible impacts of mining and land conversion. EIAs are meant to assess the scale of anticipated tree loss and propose mitigation measures like afforestation, biodiversity offsets, or limiting operations in forested zones. However, in practice, many EIAs either underestimate deforestation impacts or lack viable mitigation strategies. In regions where governance is weak or corruption is present, deforestation continues even after EIAs are conducted. Therefore, while EIAs offer a framework to prevent or reduce deforestation, their real-world effectiveness hinges on the transparency and rigor of the approval and monitoring process (Hilson & Murck, 2000).

4.4.1.5. Soil Erosion and Landscape Degradation

Soil erosion and overall landscape degradation can be minimized through EIA recommendations such as terracing, proper slope management, vegetative cover maintenance, and erosion control structures. EIAs can identify vulnerable areas and prescribe engineering and biological control measures before mining begins. Nevertheless, the effectiveness of these recommendations often varies. If an EIA is rushed or not adequately enforced, erosion control may be insufficient, leading to long-term degradation. Thus, EIAs can be very effective when properly executed, but this potential is frequently undermined by gaps in enforcement and funding for mitigation (Adhikari, et al., 2015).

4.4.1.6. Waste Management Challenges

Mining activities generate significant solid and liquid waste, often leading to contamination if poorly managed. EIAs are critical in assessing waste generation and proposing management strategies such as designated waste disposal sites, tailings management, and pollution control systems. In some cases, EIAs also require the development of environmental management plans that include monitoring protocols. However, the challenge remains in ensuring compliance and continuous monitoring. Inadequate implementation of waste management recommendations is common, especially when there is a lack of technical capacity or accountability. Therefore, while EIAs provide strong preventive mechanisms, their success depends largely on post-approval oversight (Lottermoser, 2010).

In summary, Environmental Impact Assessments have strong potential to mitigate or prevent the major environmental impacts associated with mining activities, including vegetation loss, flooding, soil degradation, deforestation, erosion, and waste management issues. However, their real-world effectiveness is often limited by weak enforcement, inadequate follow-up, and limited community participation. Strengthening the EIA process, ensuring transparency, and holding developers accountable are key to realizing the full protective benefits of EIAs.

4.4.2. Environmental Compliance in Degraded Lands due to Mining Activities

Mining activities in many areas remain inadequately regulated and poorly controlled, a reality clearly reflected in the firsthand experiences of local communities. Residents living near mining concessions frequently observe visible signs of environmental degradation, with land degradation and water pollution being the most common and alarming impacts. These consequences are especially severe in regions where artisanal and small-scale mining is active, as such operations often bypass formal environmental compliance mechanisms. For instance, erosion has become a major concern in several mining zones, leading to the loss of fertile topsoil and threatening agricultural productivity. Despite the existence of environmental laws, only 8% of local respondents believe that mining activities are sufficiently regulated, pointing to a widespread perception of weak enforcement of existing environmental regulations.

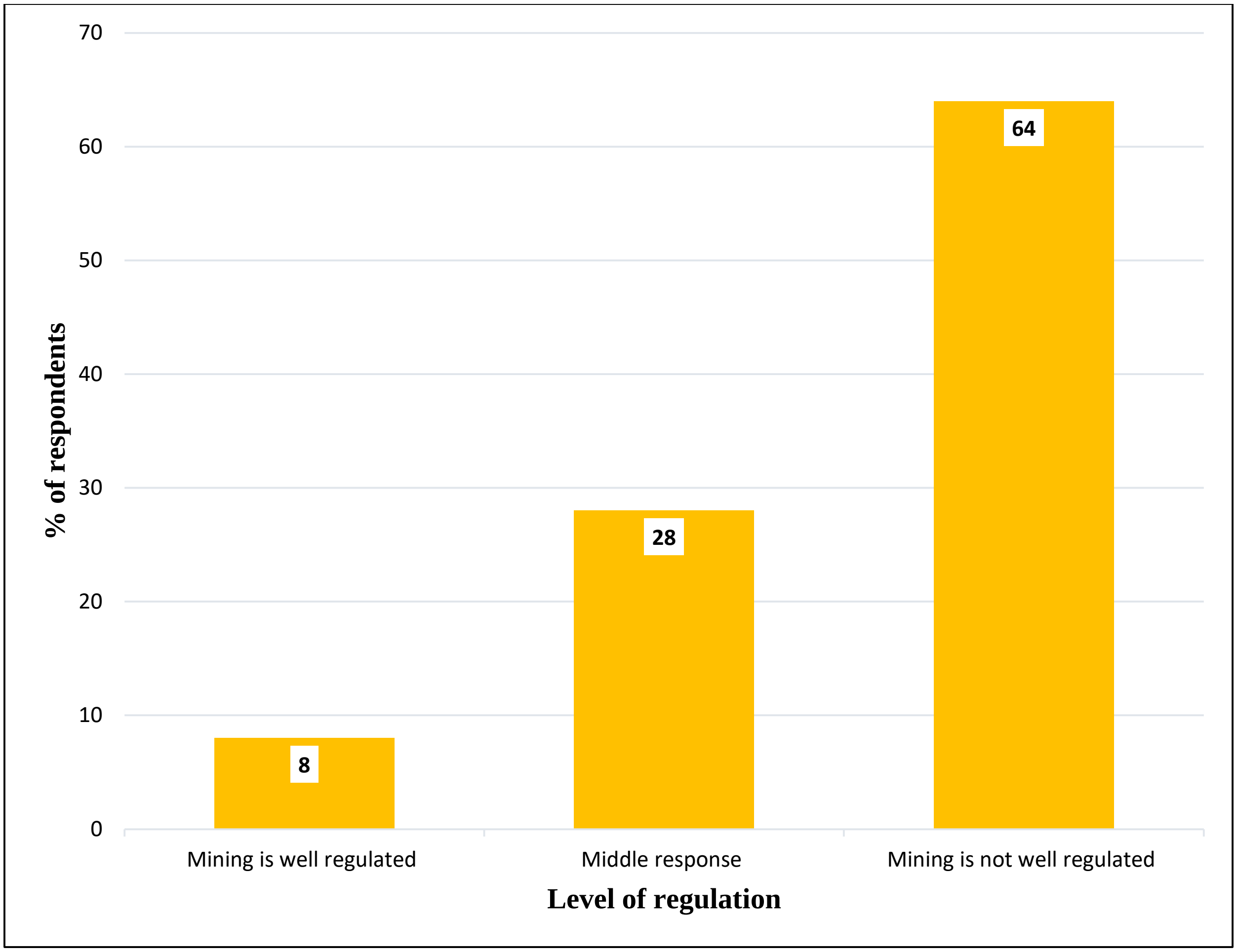

Figure 16: Level of Mining Regulation in Gatumba Sector

Source: Field survey (June2025).

Although mining companies claim to conduct Environmental Impact Assessments (EIAs), interview to 5/5 mine operators reveal that monitoring and follow-up actions are inconsistent. REMA Director in charge of environmental regulation admit himself that inspections are often irregular, largely due to limited resources such as funding and staffing. As a result, even where regulations exist, they are not effectively implemented on the ground. In some cases, mining companies have made efforts toward environmental protection, such as initiating reforestation projects and setting up waste containment systems, but these actions are minimal compared to the scale of environmental damage caused by their operations.

The imbalance between production efforts and environmental responsibility has led the majority of local respondents to perceive mining companies as environmentally irresponsible.

Local communities situated near mining areas often don't understand the legal framework around expropriation, but most remain unaware of their broader rights as residents affected by mining operations. This lack of awareness leaves them vulnerable and often powerless in the face of environmental and social disruptions. Although local government authorities attempt to advocate for community interests, they are frequently outmatched by the influence and financial power of mining company owners. When environmental issues arise, they are rarely resolved promptly or fairly, exacerbating tensions between communities and mining firms. Overall, the combination of weak enforcement, irregular oversight, and community disempowerment has allowed land degradation and other environmental harms from mining to continue unchecked in many regions.

4.4.3. Implementation Gap between EIA and Field Practices

In interview with mine operators 100% said that there is a gap between what they promised through EIA and field practices for the following reasons.

Firstly, the terrain on which the mine operates is relatively steep, thus making it difficult to manage. It does not make it easy for the control of erosion.

Secondly, less importance is paid by the mine owner on the EIA report that was produced with the purpose of complying with the application formalities for mining license while it should be a reference document to guide miners on most of aspects of environmental protection.

Thirdly, the mining companies representatives declared that the fall of mineral price at the international market does affect the way EIAs are implemented as they do not get the necessary fund to invest in the environment due to low business return.

They further specified the below as part of the main challenges to the full implementation of EIA in the majority of mine operators as they consider the implementation to below.

- Low number of mine inspectors,
- No specialized skills in environment by mine inspectors,
- Low level on environmental awareness among ASM,

- Gap in the enforcement of mining and environmental regulations,
- Lack of enough knowledge on EIA/EMP by RNRA/RMB inspectors,
- Lack of EMP/EIA only oriented inspections, as the usual ones combine all aspects of mines including mineral production and their tracking, mines corporate responsibilities, taxes, etc
- History of mining in Rwanda: Whereby some miners engage in mining business only by speculation without a real commitment and understanding of the sector: thus, with no care on the environment.

4.4.4. Environmental Inspection towards Mining Activities

The REMA Director in charge of environmental regulation and pollution said that, despite their team of 8 staff, being in charge of monitoring the environmental across all sectors of the district, they always try their best to follow up issues of compliance in the mining (see http://rema.gov.rw/index.php?id=19); According to him, REMA does not have enough human resources to ensure their employees conduct at least two visits per year to all mines. He emphasized that presently REMA is doing joint inspections with RNRA/RMB and the Environmental Protection Unit of the Rwanda National Police, to guarantee that a mine found to not be compliant is held responsible immediately.

The Director from REMA mentioned the following facts as the main barriers for ASM Companies to be fully compliant:

- Lack of a sense of responsibility and unclear structure of mining operations: in many cases, the concession owners leave all mining operations in the hands of local community living near it. With almost no basic mining techniques and no environment consideration, these people will only chasse mineral veins. The owner will only go to site to collect and pay per kilogram of mineral production that have been processed.
- Lack of knowledge on environmental protection, there is need to be a strong team on the field in charge of environmental management.
- Transfer of the profit from mining to other sector: While mining is a long-term project, some ASM operators do not have any long vision of their mining businesses, since they are not able to determine the mineral reserve and deposit within their concession, and investment in the environment to enable a proper mining of the discovered reserve

- Lack of commitment to implement EIA.

4.5. Remedial actions for environmental management in mining Sites

4.5.1. Remedial Actions for Community Affected by Mining Activities

Despite the continued economic importance of mining in the area, it is evident that environmental management and restoration efforts have been limited or weakly enforced**.** There is an urgent need for stronger environmental regulation, rehabilitation of degraded sites, and community sensitization to mitigate further damage. Without sustainable practices, the long-term environmental effect on land of Gatumba Sector may outweigh the short-term economic benefits gained from mining.

Survey responses suggest a strong desire among respondents for remediation. The most recommended actions are illustrated in figure 10

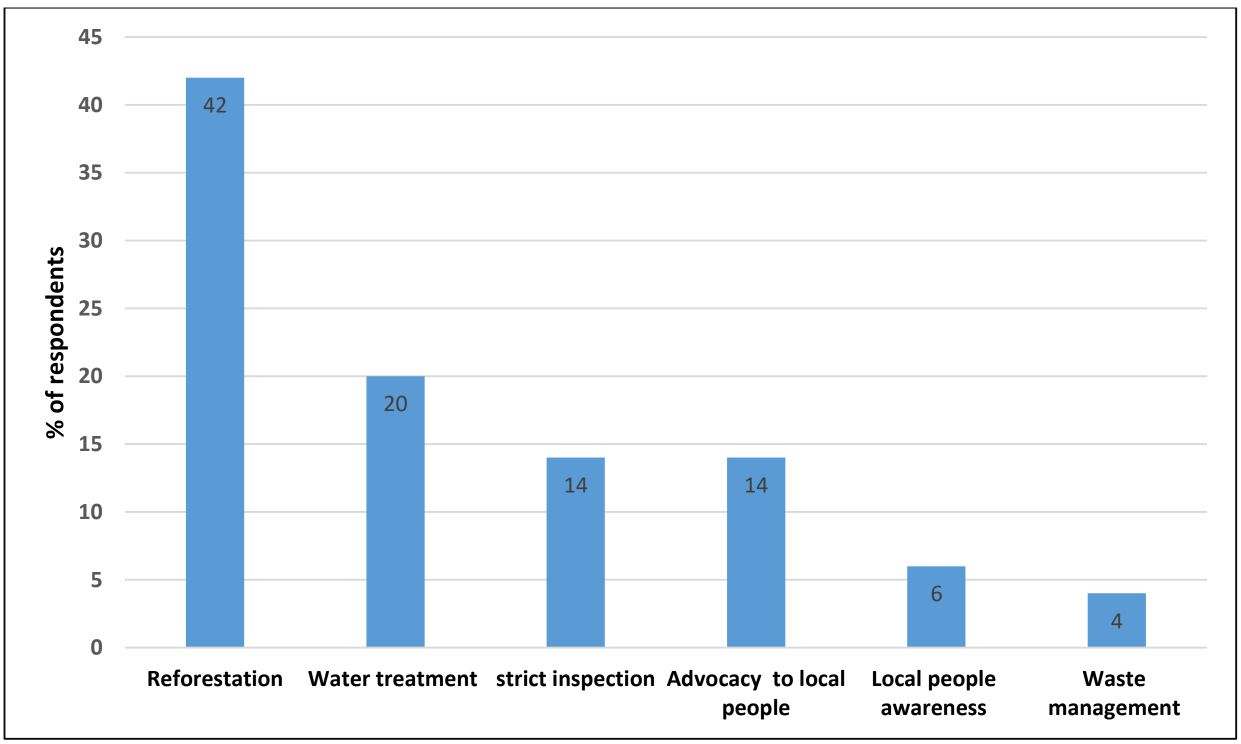

Figure 17: Remedial Actions for Community Affected by Mining Activities

Source: Field survey (June2025).

About 42% of respondents believe that reforestation would be the most required remedial action, 20% are for water treatment, 14% for strict inspection, 14% for advocacy to local people, 6% believe in raising local people awareness and 4% believe waste management as the most required remedial action.

4.5.2. Leading for Environmental Management

Approximately 20% of local residents reported a lack of understanding regarding their rights and responsibilities, noting that they are often overshadowed or overruled by the influence and decisions of mining companies. There should be advocacy that would help in resolving concerns to local people and a way of raising local people awareness about their rights.

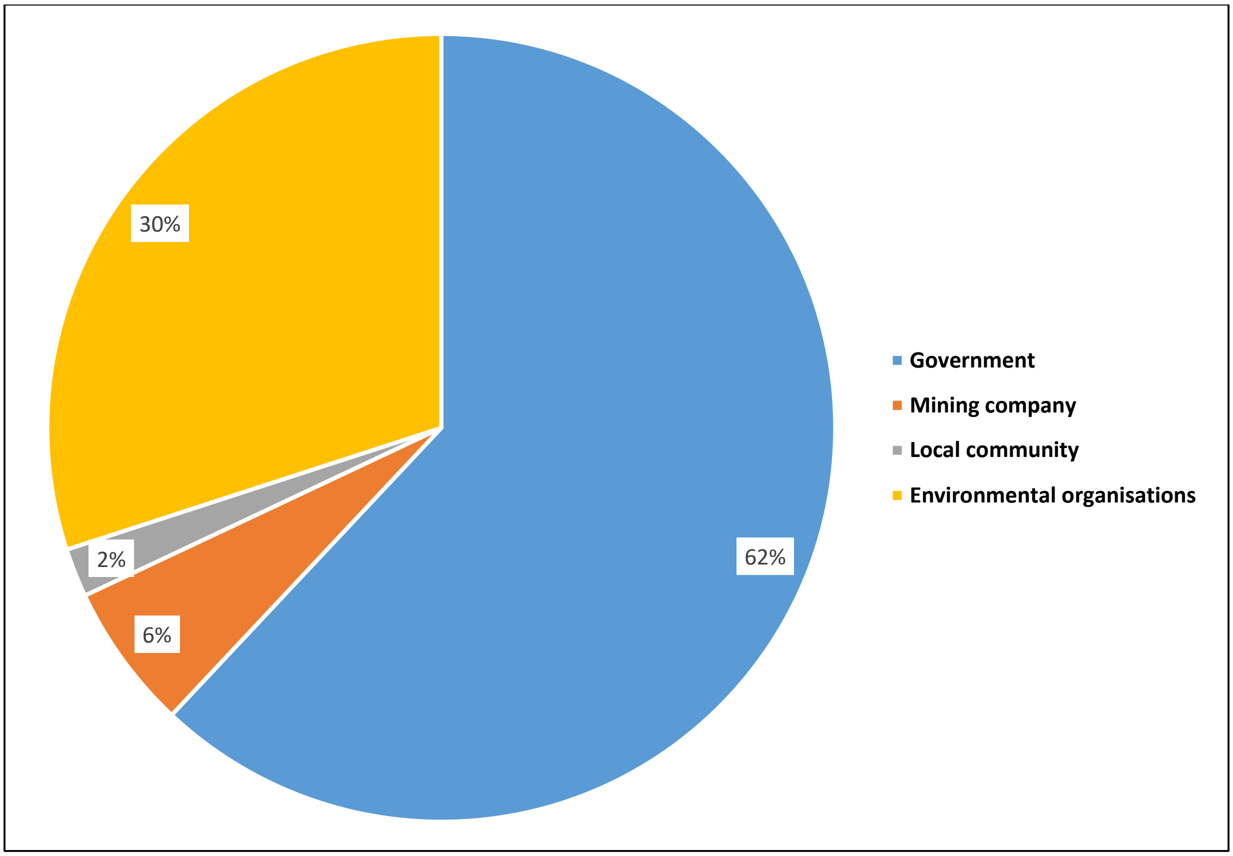

Figure 18: Leading for Environmental Management

Source: Field survey *(June2025)*.

Respondents were asked who would take a leading role in managing environmental impacts of mining: about 62% of respondents believe in government, 30% believe in environmental organizations, 6% believe in mining company and 2% believe in local community to take the leading role in managing environmental impacts of mining.

According to feedback from residents in mining-affected communities, local people believe that government authorities should play a leading role in managing the environmental impacts of mining. They feel that the government has the power and responsibility to enforce laws, monitor mining activities, and ensure that companies meet environmental standards. Community members have expressed their support for stricter environmental policies that regulate how mining companies operate, especially in relation to land and water use.

4.5.3. Issuance of Appreciation Certificate and Award for Environmental Compliance

During interview the Natural resource officer at Ngororero district, concurred with the idea of continuing to organize annual events whereby ASM which performed well in terms of environmental standards should publicly be recognized by GoR and be given appreciation certificates or award. This will create and spur competitions and innovation in environmentally friendly mining operations. The financial resources should be arranged by lead institutions including RNRA/, REMA, and other key environmental partners.

4.5.4. Specialize RNRA/RMB EIA oriented inspections

It is more strategic that the above institution organizes only EIA oriented inspections to systematically check the progress being made on the implementation of each EIA/EMP planned activity and investment being incurred as well encountered challenges. The RNRA/ Mine Inspector informed that during an inspection of an ASM, the inspector(s) conduct a wide range of verifications including human rights, labor conditions, land conflicts, presence of women and children, level of investment, census of miners, checking of mineral production records, holding meetings with local government leaders, socio-corporate responsibilities, general health and safety issues, tax payment, environmental status, etc.

In this type of mine inspection, it is obvious that environment compliance is not given enough attention, thus, a pressing need for mine administration to consider conducting only environmental oriented inspections.

However, according to the RNRA/Mine Inspector, mining companies are generally aware of their environmental responsibilities, as evidenced by the relatively acceptable conditions observed during scheduled inspections.

4.5.5. Government investment in deep and small-scale exploration activities

The RMB field officer at Ngororero district estimates that miners do not intentionally invest in EIA implementation and divert the accumulated benefits to other businesses, simply because they do not see any sustainable benefits (as they see the mineral reserves and deposits that can be mined in certain number of years), would be removed by investing in deep exploration work by the government. The very promising concession could be sold to ASM companies that are ready to fully comply with the environmental standards. It is already known that mining exploration is a very costly activity and demand highly skilled people; thus, it considered to be driven by and under government means. Therefore, it would be part of state effort to modernize and professionalize mining activities.

4.5.6. Compensation of nearby Landowners prior to the Issuance of any Mining License

Currently, it is not mandatory for miners to acquire all required land before the issue of the license by the government. To actively reduce land conflicts between concession owners and residents near the site as well as preventing any environmental damage due to mining operations taking place in the proximity of settlements, the mining authority should make it mandatory to anyone (individual, enterprise or company) intending to acquire an exploitation license to prove the availability of a piece of land that has been secured before the grant of the license to ensure a smooth start of mining operations. The acquisition should be done either by compensating residents, purchase, or leasing. The minimum size should be set by the mining authority to allow enough space to install basic mining infrastructures such store/office, space for digging tunnels/pits/shafts, bathrooms, space for mineral washing, wastes disposal, and other preliminary mining activities.

If well enforced this will be an additional element that would help identify and challenging those acquiring mining license by speculations, less sensitive to environmental concerns. Thus, paving way for a continuous improvement and moderation of the artisanal mining sector as per MINIRENA vision.

Chapter 5: Conclusion and Recommendations

5.1. Conclusion

This study underscores the escalating environmental impact on land caused by mining activities in Gatumba sector, where soil erosion and landscape degradation (38%) soil bareness (30%) loss of vegetation cover (14%), deforestation (10%), seasonal flooding (4%) and waste management challenges (4%) severely affecting ecosystems and local livelihoods. These impacts are not uniformly experienced; communities living closest to mining sites, bear a disproportionate burden. The spatial distribution of mining activities in Gatumba Sector shows a significant concentration of both licensed and unregulated operations.

Seven active mining sites, managed by five different companies, cover 415 hectares, which is approximately 9.5% of the sector's total land area, although the geographic coverage may seem moderate, these sites are frequently situated near residential and agricultural zones, resulting in a disproportionately high environmental impact on land. In addition to large scale operation the sector consists of mountainous topography. Field observations and local testimonies have also revealed a widespread occurrence of illegal mining in mineral-rich areas that are unmonitored by licensed operators. Residents reported frequent land encroachments, and law enforcement data confirmed multiple arrests related to unauthorized mining. Moreover, indicating the deep integration of mining activities into the local landscape.

Despite the existence of legal and institutional frameworks intended to promote environmental compliance, mining activities in Gatumba remain largely unregulated or poorly enforced. 64%% of surveyed residents believe that mining operations are not well regulated. Commonly reported environmental issues include soil erosion, deforestation, landscape degradation, and water pollution, particularly in areas engaged in artisanal and small-scale mining. Interviews with mining operators and REMA officials uncovered discrepancies between Environmental Impact Assessment (EIA) commitments and actual practices in the field, often due to challenging terrain, weak monitoring systems, insufficient funding, and limited awareness or training among mine inspectors and operators.

These systemic gaps have permitted mining activities to continue with minimal environmental accountability, leading to significant degradation and heightened tensions between communities and mining firms.

With regard to the extent to which EIA addresses these problems, the study found that while EIAs are legally required and provide a framework for predicting impacts, their implementation and monitoring remain weak. In many cases, mining projects in Gatumba did not fully comply with the recommended mitigation measures, such as topsoil preservation, controlled excavation, tailings management, and post-mining land rehabilitation. Moreover, community awareness of EIA processes was found to be very low, further limiting its effectiveness as a tool for environmental protection. Thus, although EIA has the potential to mitigate mining-related impacts, its current practice in Gatumba Sector falls short of ensuring environmental sustainability.

To tackle these challenges, local respondents and institutional stakeholders proposed a variety of remedial actions. The most frequently recommended solution was reforestation (42%), followed by water treatment, stricter inspections, and public awareness initiatives. Additionally, respondents expressed a strong preference for government-led environmental management, citing its ability to enforce laws and protect community interests, they feel that the government has the power and responsibility to enforce laws, monitor mining activities, and ensure that companies meet environmental standards. Key strategic proposals include mandatory land acquisition prior to license issuance, government investment in deep exploration to minimize speculative mining often carried out without a clear understanding of mineral locations, specialized EIA-focused inspections, and public recognition of compliant artisanal and small-scale mining (ASM) operators. Together, these measures provide a framework for transforming Gatumba's mining sector from an environmentally harmful industry into a model of sustainable and responsible land use.

Finally, the study proposed strategies for improving the effectiveness of EIA in Gatumba. These include strengthening institutional monitoring and enforcement, ensuring adequate technical capacity for follow-up inspections, enhancing community participation and awareness in EIA processes, and integrating gender-responsive and socially inclusive approaches to rehabilitation.

5.2. Recommendations

- To ensure stronger environmental compliance among mining companies, it is essential to increase staffing levels at REMA and, enabling more frequent and effective inspections.
- To make EIA department independent, directly under REMA supervision (not under supervision by RDB). This improve the effectiveness of EIA processes and to avoid the risk of being influenced by the investment and business department in RDB

Drawing on the challenges of this study, the below salient recommendations would contribute to enhance the status of environmental compliance of ASM operations:

- Raising awareness of local people about their rights and offices that would help resolve issues
- To ensure sustainability of ASM mining and improvement of their operations/conditions through credible investments, the Government should invest in long term and deep exploration studies to determine mineral reserves in ASM sites.
- It would be more beneficial if the Government looks into the feasibility of making it mandatory for ASM to undergo at least two environmental audits per year by capitalizing on the capacity of accredited and independent local environmental experts to conducts the audits; as part of the solutions on the small of environmental/mines' inspectors.
- Priority should be given to continuous provision of specific environmental capacity building to ASM owners and staff as a way of increasing their ownership on environmental issues.

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Appendices

Annex 1: Household Questionnaire Survey for Local Community

A. Identification

Date: ……………………………………………………………………...

Name of respondent: …………………………………………………..

B. Questions

Section A: **Personal Data**

1. **Age:** ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56+
2. **Gender:** ☐ Male ☐ Female
3. **Do you live nearby mining companies or work for mining companies?**

   ☐ live nearby mining companies ☐ work for mining companies ☐Both

4. **How long have you been living in this area?**

   ☐ Less than 1 year ☐ 1-5 years ☐ 6-10 years ☐ More than 10 years

Section B: **Spatial Distribution of Mining Activities**

5. **How close is the nearest mining site to your home?**

   ☐ Less than 1 km ☐ 1-3 km ☐ More than 3 km

6. **How many mining sites do you know in your area?**

   ☐ 1-2 ☐ 3-5 ☐ More than 5 ☐ Not sure

7. **What types of mining activities are present in your area?** (Select all that apply)

   ☐ Open-pit mining ☐ Underground mining ☐ Artisanal mining ☐ Other: ____________

8. **Have local mining activities increased or decreased in the last 5 years?**

   ☐ Increased ☐ Decreased ☐ No change ☐ Not sure

9. **How are mining activities affecting residential areas?**

Section C: **Environmental Compliance and Challenges**

10. **Do you find that mining activities sufficiently regulated and controlled?**

    a. ☐ Yes ☐ No

11. **Have you observed any negative environmental impacts caused by mining?** (Select all that apply)

    ☐ Water pollution ☐ Air pollution ☐ Deforestation ☐ Land degradation ☐ Noise pollution ☐ Health issues ☐ Other: _____________

12. **Do you know any law or regulations related to mining activities?**

    ☐ Yes ☐ No

    If **yes which law……………..**

13. **Which steps are taken by the local government or mining companies to address these environmental issues?**

14. **Have you ever reported an environmental issue related to mining?** ☐ Yes ☐ No

    -If yes, what was the issue?

15. **Do you find mining companies environmentally responsible?** ☐ Yes ☐ No

    -If yes what might be your reason?

16. **What are the biggest environmental challenges caused by mining in your area?** (Select up to 3)

    ☐ Lack of waste management ☐ Water contamination ☐ Soil erosion ☐ Air pollution ☐ Health risks ☐ Other: _____________

Section D: **Proposed Remedial Actions**

17. Is land degradation from mining increasing or decreasing?

☐ Yes ☐ No

Justify your response……………………………………………………………………..

18. What actions do you think should be taken to reduce the environmental impact of mining? (Select all that apply)

☐ Reforestation ☐ Waste management improvements ☐ Stricter government regulations ☐ Water treatment solutions ☐ Advocacy to local people ☐Local people awareness

19. Who should be most responsible for managing environmental impacts of mining?

☐ Government ☐ Mining companies ☐ Local communities ☐ Environmental organizations ☐ Other: _____________

20. Would you support stricter environmental policies for mining companies?

☐ Yes ☐ No ☐ Not sure

-If yes why?

21. Would you be willing to participate in community environmental initiatives?

☐ Yes ☐ No

Annex 2: Interview Guide to Mine Operators

A. Identification

Date: ……………………………………………………………………..

Name of respondent: ……………………………………………………..

Responsibility in the company…………………………………….......

B. General Questions

1. What are the major environmental concerns your company faces?
2. What measures does your company take to mitigate the environmental impact of mining?
3. Have you faced any penalties for non-compliance with environmental regulations? What was the exact reason?
4. Have community members ever raised concerns about environmental damage? If yes, how were these addressed?
5. Why environmental issues persist despite regulations?
6. What are the main challenges your company faces in complying with EIA regulations?
7. What role should the government play in improving environmental management in mining sites?

Annex 3: **Interview Guide for Senior Government Staff in charge of Environmental Supervision and Inspections of Mines**

A. Identification

Date: ……………………………………………………………….

Name of respondent: ………………………………………………..

Position as government staff in charge of environmental supervision and inspections of mines:

Contact/e-mail:……………………………………………………………………

B. Questions

1. Are there differences in environmental compliance between artisanal, small-scale, and large-scale operations in the area?
2. How often are inspections carried out at mining sites in Gatumba or similar areas?
3. What are the most common regulatory violations or non-compliance issues of land mining observed during inspections?
4. Have penalties or sanctions ever been imposed on companies violating environmental laws? If so, how effective are they as deterrents?
5. Have there been public complaints or documented cases of environmental harm reported by local communities?
6. Why do environmental issues persist despite regulations? (e.g., lack of enforcement, poor waste management, limited resources?)
7. What additional strategies do you think should be implemented to reduce the environmental footprint of mining operations?
8. What advice would you give to enable EIA implementation as planned?
9. Do you believe current inspection systems are sufficient to detect and respond to environmental violations? If not, what are the main limitations?
10. Have there been any government-led remediation or rehabilitation programs in response to environmental degradation from mining?

11. What challenges does your institution face in effectively supervising mining-related environmental issues (e.g., lack of personnel, funding, political influence)?
12. Are there gaps in the current laws or policies that hinder effective environmental protection in mining zones?
13. Do you have any final comments, suggestions, or insights that could help strengthen environmental management in mining regions like Gatumba?