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Assessment of the Impact of Mining Activities on Land use and Land Cover Changes in Gatumba Area, Rwanda

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Abstract:- The Gatumba region is known for its mineral potential, but mining operations are still underdeveloped, and small-scale, artisanal mining practices have a negative impact on the ecosystem. An illustration of the lack of adequate environmental protection measures is provided by soil erosion, barren waste rock piles, open adits, and filthy rivers. The aim of the research is to assess the impact of mining activities on land use/land cover change in Gatumba region over the period 1998 to 2018. The specific objectives are to assess the mining activities and associated land use/ land cover changes in Gatumba region during the period of 1998 until 2018 and analyze the impact it has on land cover, to assess the spatial temporal land use/ land cover change induced by mining activities in Gatumba region from 1998 until 2018 and to analyze the relationship between mining activities and land use land cover. The results of a questionnaire survey and on-the-ground observations helped in determining the main factors driving mining operations and their negative consequences on the environment. Mostly in mining areas, the patterns of land use and land cover revealed bare soil alongside built-up, water body, woodland, and plant types. Mining areas have gradually grown from 2.85Km2 to 5.55Km2, or 3.95% of the total land area, over the course of 16 years. Moreover, gains on water bodies and bare land were built up by 0.63% and 45.43%, respectively. Contrarily, when taking into account the entire land coverage, vegetation and forests saw losses of 2.62% and 47.38%, respectively. In the central and southern regions of the Gatumba region, mining operations are common. The main factors influencing mining activities in Gatumba are the area's mining history, the mineral potential contained in a shallow and loose rock type called "pegmatite" that contains quartz veins, and the lack of other jobs that pay well. The use of spades and picks incite soil erosion from the current and abandoned mine sites, river pollution, crops and forest are damaged. In spite of continuing mining activities, local people are aware of degrading environment targeting income from minerals. Practical regulations and policies for the rehabilitation of the damaged environment are not sensitized. Therefore, the enforcement of policies and guidance to rehabilitate the degraded environment should be considered while developing professionalism mining with modern equipment.

***Keywords**:- Impact, Spatial Temporal Assessment, Mining Activities, Land use and Land Cover Changes.*

I. INTRODUCTION

Land use and land cover are crucial indicators of global environmental change that show how human activity affects the physical environment (Jimoh et al., 2018). There are a number of consequences on biophysical systems at all scales that seem to result from human modification of the Earth's land surface (Alam et al., 2020). Practically any activity that has been developed on a vast scale, such as forestry, agriculture, dams, harbors, mining, and industry, alters the natural environment (Meshesha et al., 2016).

All efforts at growth in any nation are built upon the environment. The need for a healthy, wealthy, and suitably protected environment in order to have a prosperous society (Mugiraneza et al., 2018). All human activities are considered to have an adverse effect on the environment, which includes mining, the expansion of industry, and a variety of technological developments as well as community survival (Snapir et al., 2017). Lack of environmentally friendly technologies in emerging nations has had a number of negative repercussions on the ecology (Yirsaw et al., 2016). Other types of land productivity, such as food and forest production as well as landscape profits, are always harmed by the activities of extracting land resources (Sheoran et al., 2020) . Mining is one of the resource extraction processes that harms the environment(Venkataraman et al., 2017).

Digging into the ground to obtain naturally occurring minerals is known as mining (Franck et al., 2015) Ehere are several common stages or activities involved, and each one has the potential to have negative effects on the surrounding people, the natural environment, society, and cultural heritage (MINIRENA, 2013). Irrational mining poses a major harm to the environment by reducing forest cover, accelerating soil erosion, polluting water, air, and land, and decreasing biodiversity (Padmanaban et al., 2017). Mining and processing operations discharge waste materials containing harmful components into nearby rivers, agricultural land, and communities. These releases may have an impact on human health as well as the quality of livestock and agricultural products (Case et al., 2010).

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Moreover, mining causes landslides and changes the environment.

The adjacent land use and land cover patterns are swiftly degraded and altered in mining areas for the benefit of extracting minerals. The terrain is impacted by the growth of the mining sector. Mine spoil refers to enormous heaps of overburden from mining operations and is a bad habitat from a physical, nutritional, and microbiological perspective (Sheoran et al., 2019). According to the International Council on Mining and Metals (IUCN and ICMM, 2014), the repercussions of land-use change are primarily caused by the mining sites' slow expansion. In their writings. In their publications, Sturtevant (2014) underlined how mining has changed landscapes around the world, including those in Ghana, Germany, Ghanaian forested areas of the Appalachian Mountains, and other nations. Because of diverse human activity interactions, including mining activities, emerging countries have very high rates and intensities of land use change patterns (F. Zhang et al., 2017) .

The effects of changes in land use and land cover through time and space should be monitored. The significance of mapping and monitoring changes in land use and cover has generally been accepted by the scientific community (Abbe and others, 2022). Remote sensing is an essential technique for assessing and keeping track of environmental impacts due to its technical management and refinement of space-borne imageries for their synoptic and repetitive coverage to identify the changes at various resolutions (Patel, 2019).

Data from space-borne images collected over time can therefore be utilized to inform cost-effective and good planning and decision-making (Navalgund et al., 2017). The technology has proven to be quite helpful in environmental monitoring, according to (Polster, 2015). For the purposes of monitoring mining operations generally and assessing the environmental impact of mining operations, multispectral satellite data and aerial photography data have been used. There is broad agreement among scientists on the need of mapping various land-use groups and following their evolution through time (Prakash & Gupta, 2018).

Moreover, geographical information systems (GIS) and remote sensing are crucial tools for understanding land-use trends. Mining activity's impact on land usage and land cover can be evaluated using Landsat pictures, which have been generated by (P et al., 2016) in Nigeria, in India and (Van EEDEN, 2010) also in India.

Important mineral resources that were long ago used in Rwanda and caused environmental degradation (OGMR 2010). Because of the shallow mineralized pegmatites in the Gatumba region of Rwanda's western Ngororero District, surface mining is common there. If the mineral deposit is located on the earth's surface, surface mining—also known as open-pit mining or strip mining—is carried out. (Amponsah-Tawiah & Dartey-Baah, 2011). When compared to underground mining, this approach is typically more economical and uses fewer workers to produce the same amount of ores. (Amponsah-Tawiah & Dartey-Baah, 2011) . For the purpose of prosperity and stability, the local land use and land cover patterns are now altering (Upgupta & Singh, 2017). Continuous mining operations and changes in land use and land cover must be assessed in terms of expansion and updated data to raise the environmental issue in the Gatumba region.

For the Gatumba region, a broad as well as a specific geographic temporal assessment of the effects of tin, coltan, and tungsten mining on currently existing land use/land cover patterns is necessary (Byizigiro et all. 2016). Aerial photographs, temporal remote sensing data, and other spatial datasets with information on land use and land cover can be used to support such analyses. The necessity for local inhabitants to use local resources or the need for these regions to be conserved is frequently not taken into serious consideration in the zones around protected areas.

II. PROBLEM STATEMENT

Mining operations mostly compete with agricultural land use in Rwanda, which frequently results in significant and irreversible environmental consequences (Hassan et al., 2016). Due to the legacy of subpar mining practices from the colonial and early post-independence eras, which have left behind trash dumps and deteriorated landscapes next to or near current mining operations, environmental repercussions from mining are a touchy matter in Rwanda (Barreto et al., 2017). In the Gatumba region, mining methods are still being developed, and artisanal and small-scale mining activities threaten the environment (Byizigiro et all., 2016).

According to the author, there is not enough mining activity monitoring in the Gatumba region (Byizigiro et all., 2016). Such destructive behaviors result in a chaotic and degraded environment. (Lehmann et al., 2013), Both the land use and the cover of the land are changing. One of the gaps in the monitoring of the long-term effects of mining operations is the lack of an assessment of the effects of mining activities on land use cover. In their report(Dressler et al., 2018), claimed that the sustainability principles cannot be successfully implemented without environmental policies, appropriate adaption of current environmental laws and regulations, and continuing mining without taking into account the environment and natural resources management.(Padmanaban et al., 2017).

Due to the scant attention that has been paid to such practices, no research has been done to assess the spatial temporal development of mining activities on land use/land cover change in the studied area. The objective of this study in the Gatumba region was to create a thorough methodology to assess the impact of mining activities' spatial and temporal development on changes in land use and land cover. Therefore, changes in land use and land cover were found by categorizing and analyzing Landsat imagery from 1998, 2008, and 2018. The main variables that affected the growth of mining activities were identified.

The findings of this study highlighted the significance and ramifications of future mining expansion and accompanying land use/land cover changes, helping to close the gap between artisanal and small-scale local mining activities and proactive environmental protection regulations.

III. OBJECTIVES OF THE STUDY

This study paper has a general objective and specific objectives.

➢ *General objective*

The main objective of this study was to assess the impact of mining activities on land use/land cover change in Gatumba region over the period 2000 to 2022.

➢ *Specific Objectives*

- To assess the mining activities and associated land use/ land cover changes in Gatumba region during the period of 1998 until 2018 and analyze the impact it has on land cover.
- To assess the spatial temporal land use/ land cover change induced by mining activities in Gatumba region from 1998 until 2018.
- To analyze the relationship between mining activities and land use land cover.

➢ *Hypotheses*

This study verified the following hypothesis:

- H0: There is no a significant relationship between mining activities and land use land cover changes,
- H1: There is a significant relationship between mining activities and land use land cover changes.

IV. REVIEW OF LITERATURE

➢ *Concepts on Mining Activities*

Mine exploration, development, operation, and maintenance may lead to changes in land use, and these changes may negatively impact the environment by causing deforestation, erosion, and contamination (Novianti et al., 2017). Over the world, mining results in difficulties with wastewater disposal, acid mine drainage, erosion, sinkholes, deforestation, biodiversity loss, considerable water resource usage, and pollution of soil, groundwater, and surface water. Any of these issues may have an adverse effect on specific soil pro files in the area, contaminate surrounding streams and wetlands, and raise noise and dust levels (Snapir et al., 2017).

The biological properties of the soil, the flora, the fauna, the hydrological linkages, and the surface and underground coal mining are all severely harmed. Open-pit mining involves handling, accumulating, and denudation processes (Juniah et al., 2017). Open-pit mining areas affect more than simply the vegetation, soil, and terrain because of the production of enormous holes, transit sites, solid waste, and changes in land use and cover (LULC). Although land is the most important natural resource and the primary source of all of humanity's material wealth, mining for natural resources is typically associated with changes in land use and land cover (Padmanaban et al., 2017).

Due to the loss of forest cover, deterioration of the land, contamination of the air and water, and ultimately a decline in biodiversity, mining operations are thus a significant source of economic gain for the people (Snapir et al., 2017).

Mining has led to serious environmental pollution that is dangerous for the nearby inhabitants in many developing countries due to a lack of rules and poor regulatory procedures. The effects of mining activities, according to (Ghosh, 2016), also modify the region's natural topography. Many studies have been done on mining, its consequences, and how it helps countries with abundant mineral resources prosper economically (Ghosh et al.,2016). While some studies emphasize the positive effects of mining on economic development, others concentrate on the detrimental effects of mining on the general growth of such economies.

For instance, the mining industry in Ghana produces around 40% of the country's total foreign exchange revenues and accounts for 5.7% of its GDP, according to Aryee (2001). Large areas of vegetation are removed during mining operations, and sizable pits are created to extract the rocks rich in granite and limestone. By frequently damaging the forest land and removing the fertile top soil layers, constant resource extraction causes the direct loss of the forest. This lack of fuel woods, grazing land, increased soil erosion, and air pollution are the results. This circumstance has a negative impact on the locals in the mining locations (Nzunda, 2013).

The dumping of waste boulders in an unmined area disturbs the local ecosystem, which in turn affects the biodiversity of the area and modifies its natural topography. A new mining industry, involving multinational corporations and small-scale miners worldwide, has been driven by the rise in demand for various mineral resources, such as gold, diamonds, bauxite, and coal (Bury, 2004). Ghana's gold mining operations in the various forest belts are projected to expand as a result of rising prices and demand worldwide.

➢ *Concept of Land use and Land Cover*

Land use/land cover can be classified using a variety of criteria, depending on the scientific purposes for which the classification is being developed. The classification method chosen will be based on the available data, but it will also require comprehension of the issue under investigation (R, 2017). The word "land cover change" refers to a change in the biotic or physical characteristics of a site, such as the conversion of a forest to grassland (Akabzaa, 2001). A change in land cover encompasses the entire spectrum of modifications, from minor tweaks to the current cover to complete conversion to a new cover type. These modifications could potentially take the form of structured sequences that go from modification to conversion. The ability to detect changes in land cover depends on how a class changes over time (Prakash & Gupta, 2018).

Changes in land use and land cover are two of the many facets of global change that affect the human environment, and they are both perhaps the most significant (Zhuge et al., 2019). Land use changes can either be negative, resulting in forest degeneration and a loss of production potential, or positive, resulting in an increase in value or potential (Sisay et al., 2015). Using digital change detection systems based on multi-temporal and multi-spectral remotely sensed data, the ability to detect, identify, map, and track changes in land use/cover patterns through time, regardless of the underlying reasons, has been demonstrated.

Change detection in land use and land cover can be done on a time basis, such as a decade, to analyze landscape change caused by anthropogenic activity on the land (elik et al., 2018). Changes in land usage are evaluated using remotely sensed data based on a comparison of time sequential data. Variations in surface phenomena throughout time can be recognized and measured visually or digitally (Hakorimana et al., 2018). With the extra bonus of being easy to enter data into a geographic information system, automatic change detection using satellite data can produce quick and credible estimates of changes in land-use trends across a large area (GIS).

Numerous natural and human-made processes influence how land usage and land cover change. Every accessible piece of land must be used wisely in order to improve the economic status of a certain place without further harming the bio-environment (elik et al., 2018). While driven by human behavior, land use/land cover dynamics are widespread, quick, and significant processes that affect people (Banerjee, 2017). Contemporary approaches to natural resource management and environmental monitoring rely primarily on shifting land use and cover (Ram & Kolarkar, 2013). Landsat imagery and geographic information systems are used to estimate change (GIS).

➢ *Theoretical Review*

- *Innovation Diffusion Theory*

The topic is in touch with the Innovation Diffusion Theory (IDT). IDT is a method in which a technique or invention is transferred via a definite channel continuously for a long time among individuals in the same environment (Rogers, 2017). The central objective of Innovation Diffusion Theory (IDT) is to appreciate inventions in four elements of diffusion which includes communication channels, social systems, time and innovation. The innovation diffusion theory also postulates that a person’s technology adoption behavior is entirely dependent on his or her insight regarding the relative advantage, trial ability, compatibility, innovation observability, social norms and complexity (Rogers, 2017).

In general, adoption may be regarded as an act of accepting or choosing or assuming something belongs to you. According to Rogers (2017), the adoption of an innovation is the intellectual practice of making decisions that start with hearing about the innovation to its ultimate adoption. The theory was used to guide this study where the miners go with the new technology in their mining activities to protect the environment.

- *Theory of Change*

A theory of change is a method that explains how a given intervention, or set of interventions, is expected to lead to specific development change, drawing on a causal analysis based on available evidence. A theory of change for the governments must be driven by sound analyses, consultation with key stakeholders and learning on what works and what does not in diverse contexts drawn from the experiences of the government and its partners (Mekuria, 2016).

A theory of change helps to identify solutions to effectively address the causes of problems that hinder progress and guide decisions on which approach should be taken, considering government comparative advantages, effectiveness, feasibility and uncertainties that are part of any change process. A theory of change also helps to identify the underlying assumptions and risks that will be vital to understand and revisit throughout the process to ensure the approach will contribute to the desired change (Abdullah, 2016).

First, development challenges are complex, and are typically caused by many factors and layers that are embedded deeply in the way society functions. Second, a theory of change provides a framework for learning both within and between programming cycles.

By articulating the causes of a development challenge, making assumptions explicit on how the proposed strategy is expected to yield results, and testing these assumptions against evidence including what has worked well, or not, in the past the theory of change helps ensures a sound logic for achieving change. The theory of change also helps make course corrections if the selected approach is not working or if anticipated risks materialize (Jahnke, 2016).

New learning and lessons from monitoring and evaluation help refine assumptions and inform decisions on how an approach should be adapted to deliver planned results. Adjustments to the theory of change should also be made in light of changing circumstances, especially in response to crisis and shocks, as well as part of regular monitoring. Third, the theory of change is increasingly being utilized as a means for developing and managing partnerships and partnership strategies. The process of agreeing on a theory of change establishes different views and assumptions among program planners, beneficiaries, donors, program staff, etc (Boki, 2017).

It can foster consensus and motivate stakeholders by involving them early in the planning process and by showing them how their work contributes to long-term impact. It can help others to understand and support the contribution to change, as well as strengthen collaboration with other organizations that aim to contribute to the same outcomes, leading to stronger or new partnerships and better complementarity and coordination (Kulwijira, 2017). The study is about the mining activities and the land use and land change, it is in that way the theory of change contributed to the study by showing how miners should adopt different strategies in mining based on how the land is changing and the effect on environment.

- *Empirical Review*

Richard (2022) assessed the Effect of Land-Use and Land-Cover Changes on Discharge and Sediment Yield in a Rural Coal-Mine Dominated Watershed in Kentucky, USA. The Appalachian Mountain region of eastern Kentucky is unique and contains high proportions of forestland along with coal and natural gas depositaries. Landscape changes due to extreme mining activities can eventually threaten the downstream ecosystems, including soil and water quality, resulting in excessive runoff and sedimentation. The purpose of this study is to assess the impacts of land-use and land-cover (LULC) changes in streamflow and sediment yield in Yellow Creek Watershed, Kentucky, USA, between 1992 and 2016. LULC, digital elevation model, soil, and weather data were inputted into the Soil and Water Assessment Tool (SWAT) to simulate discharge and sediment yield.

The model output was evaluated on several statistical parameters, such as the Nash-Sutcliffe efficiency coefficient (*NSE*), RMSE-observations standard deviation ratio (RSR), percent bias (*PBIAS*), and the coefficient of determination (R^2). In addition, two indices, ***P***-factor and ***R***-factor, were used to measure the prediction uncertainty. The calibrated model showed an increase in surface runoff and sediment yield due to changes in LULC in the Yellow Creek Watershed. The results provided important insights for studying water management strategies to make more informed land management decisions and adaptive practices.

Hanoi et al (2021), conducted a study on assessing Impacts of Mining Activities on Land Use/Land Cover Change Using Remote Sensing and GIS Techniques: A Case Study in Campha City, Vietnam. The present study was undertaken to analyze the process of human induced landscape transformation in the coal mines affected areas of Cam Pha, northeast Vietnam by interpreting temporal remote sensing data and using Geographic Information System.

This experiment revealed that most of the study area was dominated by forest in all the time sequence period. The forest cover has decreased about 21.3%, meanwhile having nine-fold increase in mining area from 1990 to 2020. The forest area lost during the study period was 7983.45 ha due to land cover conversion into mining area. The mining activities were also detrimental to the bare land and water body cover. The results of this study are expected to be used to support government efforts and mining managers in post-mining coal activities.

Jean et al (2021), carried out a research on spatial and temporal analysis of the land use and land cover changes in Gatumba Mining Landscape, Rwanda. The study aims to spatially and temporally analyze the land use and cover changes induced by the mining activities in Gatumba mining landscape for optimization of land use planning and management of the mined and restoring the degraded mining landscapes in Rwanda. Landsat images were used to generate the land use/cover maps for the periods of 1999, 2008 and 2015 by using maximum likelihood pixel-based classification method.

The comparison of land use/land cover maps during those periods derived from toposheet and multispectral satellite imagery interpretation indicates that there is a significant increase in bare soil, built-up areas at the rate of 0.63% and 45.43% respectively. Over a period of 16 years, mining areas has increased progressively from 2.85 Km2 to 5.55 Km2 representing 3.95% of the total land coverage. The expansion has taken place especially in central and southern part of Gatumba. It is also noted that substantial amount of the agriculture land and forest area vanished during the period of study which may be due to rapid population growth and the development of rural centers. The information obtained from change detection of land use/land cover helps in providing optimal solutions for land management, planning for the mining sites, monitoring of the related environmental effects and restoration of the degraded mining landscapes in Rwanda.

- *Research Gap*

Richard (2022) assessed the Effect of Land-Use and Land-Cover Changes on Discharge and Sediment Yield in a Rural Coal-Mine Dominated Watershed in Kentucky, USA. Hanoi et al (2021), conducted a study on assessing Impacts of Mining Activities on Land Use/Land Cover Change Using Remote Sensing and GIS Techniques

Jean et al (2021), carried out a research on spatial and temporal analysis of the land use and land cover changes in Gatumba Mining Landscape. The mining industry's human resource is the population. As a result of the continual changes in land use and cover caused by mining activities, the landscape is being degraded. Mining companies are not adhering to the policies and strategies that should be followed and direct the exploitation and rehabilitation of open pit mining communities, and no substantial action is being taken as a result. Many scholars have examined changes in land use and cover, but none have focused on how they may affect the environment or other aspects such as biodiversity, so once documented, decision-makers and planners may benefit. Mining activities' effects on land usage, land cover, and their relationship to other aspects of life that affect many people must be regularly monitored.

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➢ *Conceptual Framework*

An analytical tool with many modifications and settings is a conceptual framework. It is employed to classify concepts and arrange ideas. Strong conceptual frameworks effectively represent something real in a way that is simple to recall and use. Shields (2013) claims that the conceptual framework is a visual depiction of the independent and dependent variables. The independent variable in this study is mining activities, Land use and land change is a dependent variable with the following independent factors as sub variables: impact of mining activities on land use land cover: environmental degradation, decreased vegetation and altercation of soil profiles.

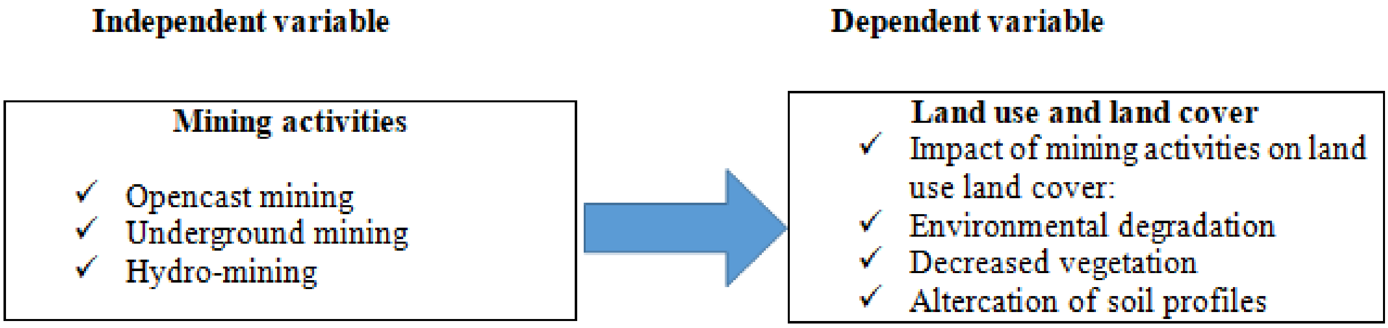

Fig 1 Conceptual Framework
Source: Researcher Compilation; 2023

V. MATERIALS AND METHODS

➢ *Research Design*

This study applied a Quantitative research method to generate quantitative data describing the impacts of mining activities and the role on land use changes and analysis of satellite images. This study will also use quantitative research methods to generate quantitative data that may help us to answer our research questions. Administrative data and raster data of satellite images was collected.

➢ *Area of the Study Physical Presentation*

The entire area within the former Gatumba mining concession is included in the research area. With a surface area of 26,000 hectares, it was one of the largest concessions that the former Rwandan government possessed. Administratively, the concession was situated in the Western United States districts of Ngororero and Muhanga. The study was carried out in 13 sectors, including Rugendabari, Kabacuzi, Kibangu, and Mushishiro in Muhanga District and Gatumba, Muhororo, Ngororero, Bwira, Kageyo, Hindiro, Matyazo, Ndaro, and Nyange in Ngororero District. The remaining areas were only partially covered, with the exception of the Ngororero sector, which was completely covered. 31,243 hectares are included in the study area.

Dominated by a mountainous topography, the study area is located in the eastern part of the Congo Nile crest, where the elevation is between 1,400 and 2,300 m above the sea level. Geographically, the study area lies between latitudes 1o 45'to 2o 03' South and longitudes 29o 32' to 29o 43' East. The area of interest is located approximately at 25 km from the town of Muhanga, and Ngororero business center is part of the study area. The main access by road is made by the Kigali – Ngororero tarmac road.

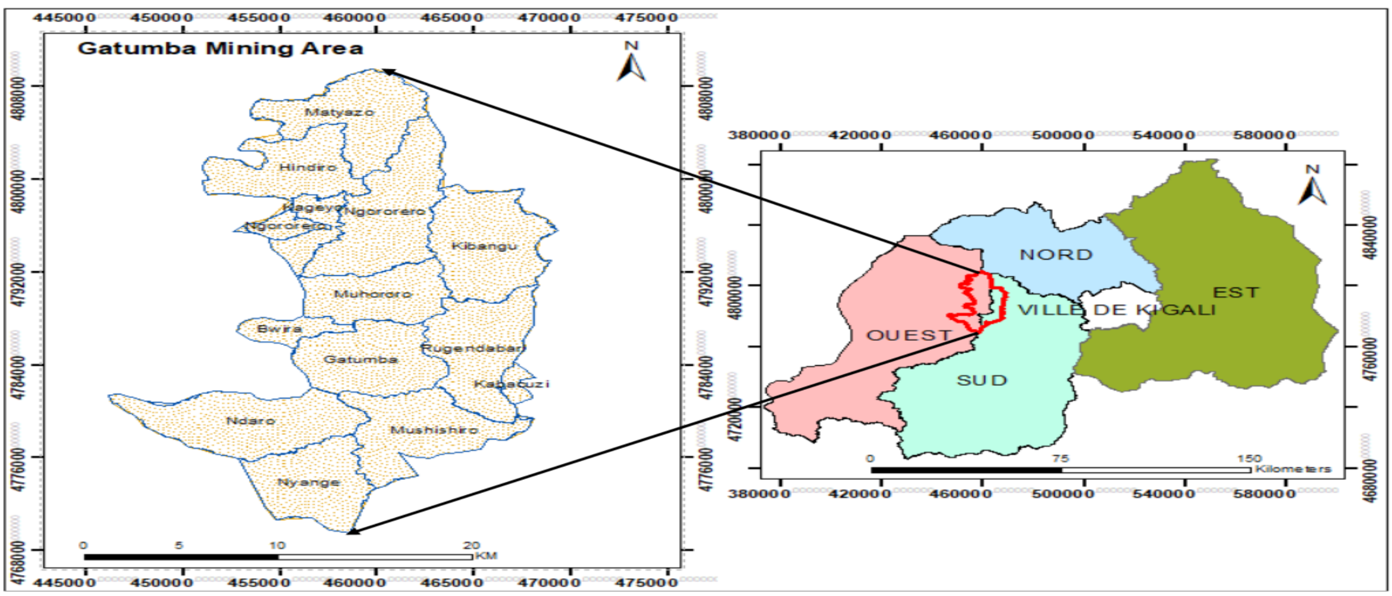

Fig 2 Location of Study Area

- *Sampling Design*

The entire study area was covered using the sampling/area frame approach. In the event of a land use/land cover survey with a large target population and a variety of sizes and types of units to sample, the selection of a sampling/area frame is simple to grasp (Taherdoost, 2020). The sampling/area frame's units are inextricably linked to a specific geographic region. The segment sampling strategy involves cutting the area into sections or segments of varying sizes and shapes (Parameshwara et al., 2021).

The Gatumba region, the subject of the study, served as the sampling area. 2 km x 2 km sample segments were utilized frequently. 109 sample segments were created and covered, so that's what it means. One common segment had a minimum sampling point of one (1) and a maximum sampling point requirement of twenty-four (24) (24). These selection points represent the actual facts on the ground. We will check and cover 82% of the total areas in order to produce reliable results. split into training and verification data, is truth ground data. In Gatumba region, 631 truth ground data (divided into training points: 145 points and verification points: 486 points) collected including 282 points for vegetation; 212 points for bare soil and built up; 133 points for the forest cover and 4 points represented water bodies.

- *Data Collection Procedures*

Field survey was the main data collection method utilized to concentrate on the second. The majority of mine locations were found and analyzed during the field survey. A frame sampling method, which was outlined later, was also used to identify, observe, and describe patterns of land use and land cover. Last but not least, accurate and precise light land use land cover class selection was made using the actual ground data. To obtain specifics of accurate ground data, handheld GPS, digital camera, sampling segment maps. The projection parameters are described in the table 1.

Table 1 Geographic Coordinate System used for Data Collection

Projection Name:	**Transverse Mercator**
Datum:	WGS 1984
Parameters	**Setting**
False Easting:	500,000
False Northing:	5,000,000
Longitude of origin:	30º
Scale factor:	0.9999
Latitude of Origin:	0º

The field work consisted of locate and find all current mine sites and abandoned mining areas in Gatumba region. For the proper future land use/land cover classification, the field observation, identification and description of the current land use/ land cover patterns was recorded.

- *Data Analysis Methods*

In order to acquire information about mining activities in the Gatumba region, a field survey was conducted that including observation, data collection, and idea gathering. Responses from the field were categorized into the four target groups of experienced mining employees and local government. the SPSS software used for data entry. Multivariate functions were utilized in the software to categorize common information and data for analysis.

All data from the local population was used to draw the conclusion that each question had a percentage response count. The results were then thoroughly studied, and a trend was found. Excel software is used to create tables, charts, pie charts, and histograms because of its versatility and the quality of the results.

The selected land use/land cover small types were grouped into generalized land use/land cover classes to generate the easily recognizable classes using the field survey data and the analysis of Landsat images. Thus, 4 significant classes were determined based on shared spectral values and physical characteristics: Mining areas, deserted land, roads, uncultivated farmland, and built-up land were all included in the "bare soil & built-up" category. The water body class included ponds, reservoirs, streams, and rivers. The vegetation class included mining regions, cultivated farms, small scrubs, pastures, and green-covered fields. The forest class included dense forest, open forest, scrub forest, and forest plantations.

The Kappa Coefficient is produced using a statistical test to measure the accuracy of a categorization. EXCEL and ArcGIS were utilized in the data analysis. Kappa essentially assesses whether the categorization outperformed simply randomly assigning values, that is, whether it performed better than random. The range of the Kappa Coefficient is from -1 to 1. Both the observed (total) accuracy and the random accuracy can be used to compute this. To determine kappa, use the formula: kappa = (total accuracy - random accuracy) / (1- random accuracy).

VI. RESULTS AND DISCUSSIONS OF FINDINGS

The chapter presents the results relate to the study which assessed the impact of mining activities on land use/land cover change in Gatumba region over the period 1998 to 2018. The specific objectives were to assess the mining activities and associated land use/ land cover changes in Gatumba region during the period of 1998 until 2018 and analyze the impact it has on land cover, to assess the spatial temporal land use/ land cover change induced by mining activities in Gatumba region from 1998 until 2018 and to analyze the relationship between mining activities and land use land cover.

- *Land use/Land Cover in 1998*

Agriculture activities dominated all other industries in 1998. The proportion of lower to higher occupiers revealed that mining activities inhabited tiny regions, followed by water bodies, bare land, and the upper class. Forestry and agriculture receive the most responses as the table 2 highlights it.

Table 2 Land use/Land cover distribution in Gatumba region in 1998

Land use/land cover classes	Area in Km^2	Percentage
Mining area	2.85	0.91
Water body	2.93	0.92
Bare soil & Built up	29.59	9.35
Forest	83.26	26.33
Vegetation	197.61	62.49
Total	316.24	100%

Source: Gatumba mining company (2023)

Using the illustration in table 4.1, the land use/land cover pattern for the Gatumba region in 1998 was evaluated. It demonstrates that 0.91% of the total area of the Gatumba region was taken up by mining areas. Water bodies made up 0.92% of the total area, while undeveloped land and built-up areas made up 9.35%. The majority of the region was covered in forest and vegetation, which is typical in rural areas. They held 26.33 and 62.49% of the total. Using accuracy tests, the methodology was confirmed, and the results show an overall accuracy (Kappa) of 82%. With our method, it is possible to reliably map the dynamics of land cover change in nearby locations.

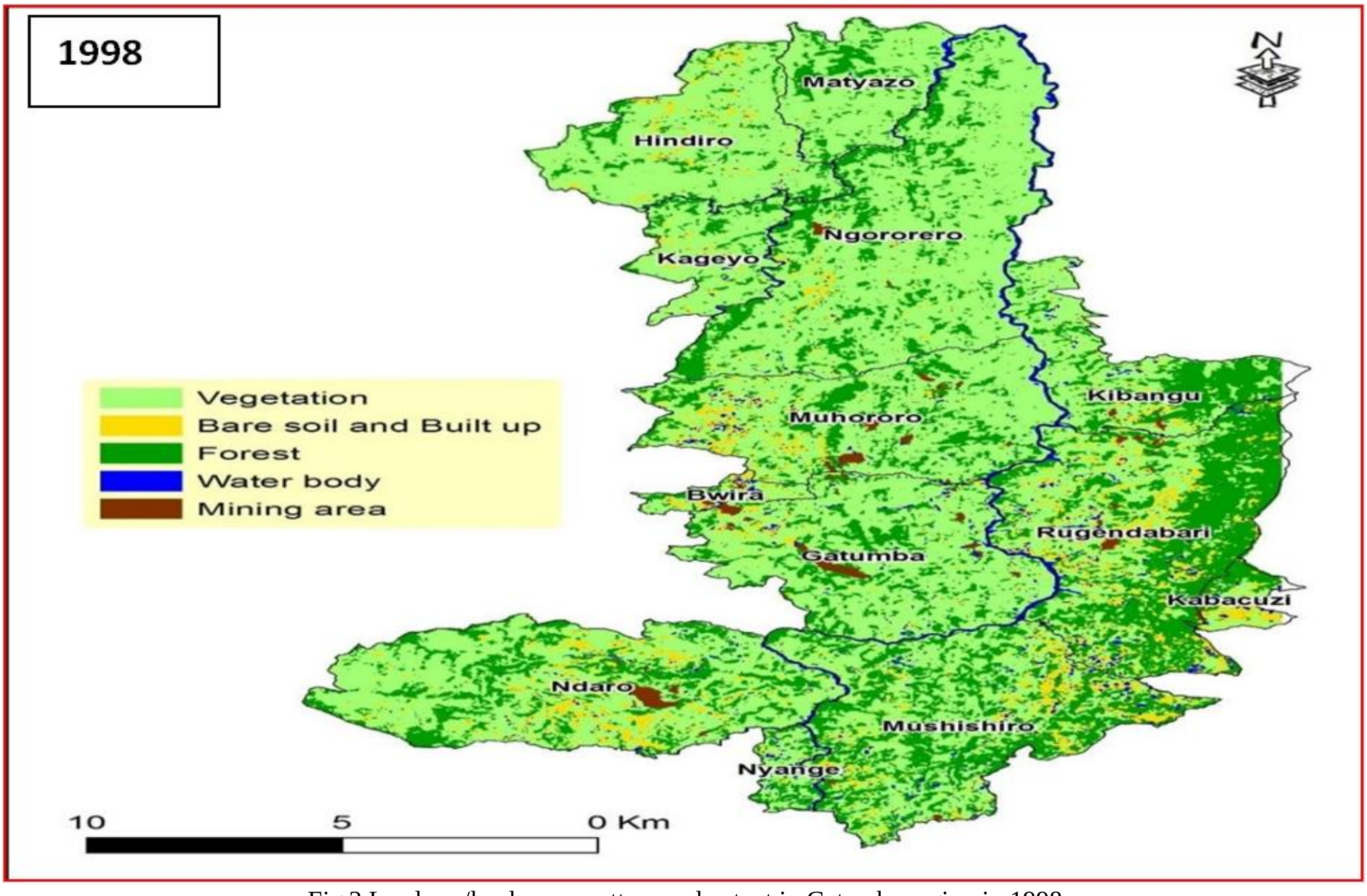

Fig 3 Land use/land cover pattern and extent in Gatumba region in 1998
Source: ArcGIS (2023)

The map's south-eastern region is primarily covered in forest, according to the distribution of land use and land cover patterns. These regions are located in the Ndiza mountains and include the Rugendabari, Kibangu, and Mushishiro sectors. A small portion of the forest is also found in the Ndaro, Kageyo, and Mattyazo regions. Agriculture, or vegetation, was done practically everywhere in the Gatumba region. Mining operations are mostly concentrated in the Gatumba, Muhororo, Rugendabari, and Ndaro areas. Other sectors are underrepresented, but there is no apparent mining activity in the Hindiro, Kageyo, and Matyazo sectors.

➢ *Land Use/Land Cover in 2008*

Table 3 Land use/land cover distribution in Gatumba region of 2008

Land use/Land cover Class	**Area in Km^2**	**Percentage (%)**
Mining area	3.25	1.04
Water body	2.16	0.68
Bare soil & Built up	94.34	29.83
Forest	75.20	23.78
Vegetation	141.29	44.67
Total	316.24	100%

Source: Gatumba mining company (2023)

The results of the categorized image from 2008 show that there were more mining areas than were counted in 1998. It took up 1.04% of the entire area of the Gatumba region after ten years. The water body was occupying the lowest value of 0.68% at this time. The next number was 23.78%, which represented the occupancy of the forest as a percentage of the territory of Gatumba as a whole. The value of bare soil plus built-up areas reached 29.83%, and the final but largest tenancy was the vegetation class at 44.67%. Compared to the situation in 1998, there was a decline in the forest and vegetation.

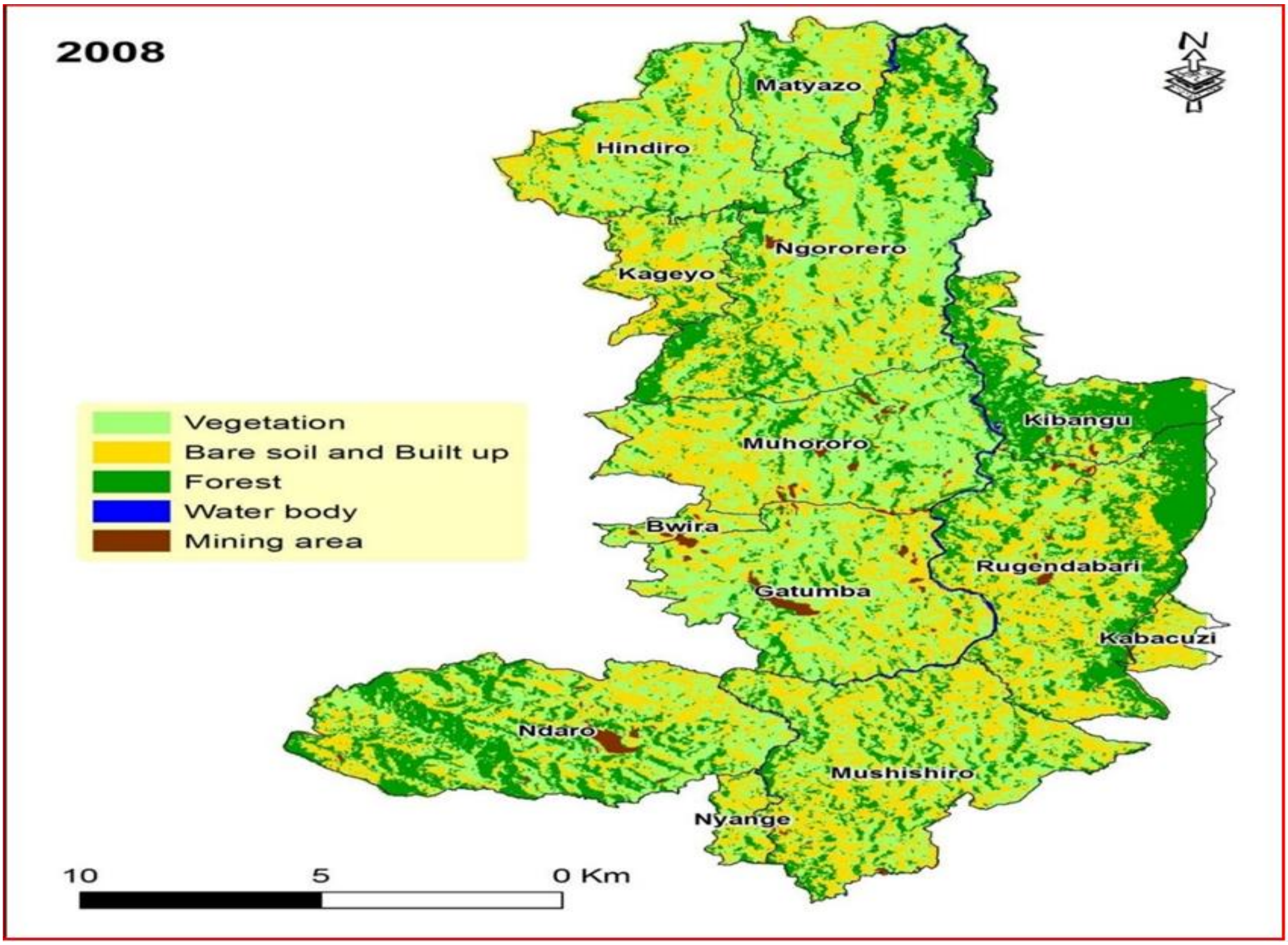

Fig 4 The land use/land cover pattern and the extent in Gatumba region in 2008.
Source: ArcGIS (2023)

Notwithstanding changes, the patterns of land use and land cover have retained their original characteristics. Together with the already existent Rugendabari, Kabacuzi, and Kibangu sectors that are heavily covered in forest, the forest occupancy decreased in the southern regions, specifically Mushishiro and Nyange sectors, but increased in Ndaro and Ngororero sectors. In addition to the already existing mine sites in Rugendabari, Ndaro, Muhororo, and primarily Gatumba sectors, mine sites increased in Bwira, Mushishiro, Kabacuzi, and Kibangu sectors. In all areas of the research region, the amount of bare soil and built-up areas has dramatically grown.

➢ *Land Use/Land Cover Change From 1998 To 2008*

When compared to the situation in 1998, the findings from a correctly categorized image from 2008 revealed a huge expansion of mining activity in numerous areas of the Gatumba region. Around current mining sites as well as a few newly discovered mine sites, the expansion is growing. The rise in mining actors in the Muhororo, Ndaro, Rugendabari, Bwira, Mushishiro, Kabacusi, and Gatumba sectors explains this development.

Table 4 Land use/land cover change from 1998 to 2008

Classes	**1998 Areain Km^2**	**%**	**2008 Area inKm^2**	**%**	**Change (1998-2008) Km^2**	**% of change**	**Remark**
Mining area	2.85	0.91	3.25	1.04	0.4	0.31	Gain
Water body	2.93	0.92	2.16	0.68	0.77	0.59	Loss
Bare soil& Built up	29.59	9.35	94.34	29.83	64.75	49.69	Gain
Forest	83.26	26.33	75.20	23.78	8.06	6.19	Loss
Vegetation	197.61	62.49	141.29	44.67	56.32	43.22	Loss
Total	316.24	100%	316.24	100%	130.3	100	

Source: Gatumba mining company (2023)

The results are described as a moderate shift in land use/land cover for the nine years between 1998 and 2008 in the Gatumba region. According to reports, 2.85Km2 of the region's total land was taken up by mining activities in 1998. The number has climbed to 3.35Km2, representing a 0.31 percent increase in land cover in 2008.

In the same time period, the area occupied by water bodies declined from 2.93km2 to 2.16km2. This indicates that between 1998 and 2008, the amount of water fell by 0.77 km2, or 0.59% of the total covering. In Rwanda, the topography and the seasons essentially dictate the type of a water body's aspect. The modest difference in water supply was caused by two factors: first, the beginning of the rainy season in September; and, second, river deviation as a result of mining activity. Little ponds that were dispersed around the countryside were frequently made by miners. Water levels in the main river bed decline when miners divert rivers in several directions. Before 1998 there were no much practices of mining activities comparable to the status of 2008 according to local leaders and Elderly people.

Yet, the area that was undeveloped and built up in 1998 was 29.59 km2, and it rose to 94.34 km2 in 2008. This growth of 64.75 km2 represents 49.69% of the total land area and is the largest one to be noted between 1998 and 2008. Aside from the 2008 image's low quality, all classes included in the "bare soil & built up" category could affect how broad it appears (buildings, roads, bright soil, uncultivated plots, grounds, etc.). Then, between 2004 and 2009, the forest and vegetation coverage in the Gatumba region continued to decline as bare soil was built up and cleared for construction purposes and charcoal manufacture. In addition, new villages were built in 9 years by immigrants who came for the mining. Around 8.06 km2 less forest was present overall in Gatumba, or 6.19% of the total area occupied by land. Between 1999 and 2008, the vegetation covering decreased by around 56.32 km2, or 43.22%, of the total land area.

➢ *Land Use/Land Cover Distribution of 2015*

Table 5 Land use/land cover change of 2015

Land use/Land cover Class	**Area in Km^2**	**Percentage (%)**
Mining area	5.55	1.76
Water body	3.36	1.06
Bare soil & Built up	60.67	19.18
Forest	50.84	16.08
Vegetation	195.82	61.92
Total	316.24	100%

Source: Gatumba mining company (2023)

The current situation resulting from the classified image of 2015 revealed that mining activities has increased effectively. In the said period, mining areas counted 1.76% of the total area. The progress of mining activities for 16 years doubled the initial occupancy. Means that in 1999 it occupied 2.85Km2 and then counted 5.55km2. This is the impressive image of mining activities evolution while the environment was still suffering. In this light the water body was covering 1.06% of the total area, which recorded an increase compared to the previous situation and bare soil & built up counts for 19.18% which lead to the decrease comparably. Forest registered 16.08% of the total area which indicated the progressive loss of cover while the vegetation counted 61.92% to imply the increase in Gatumba region.

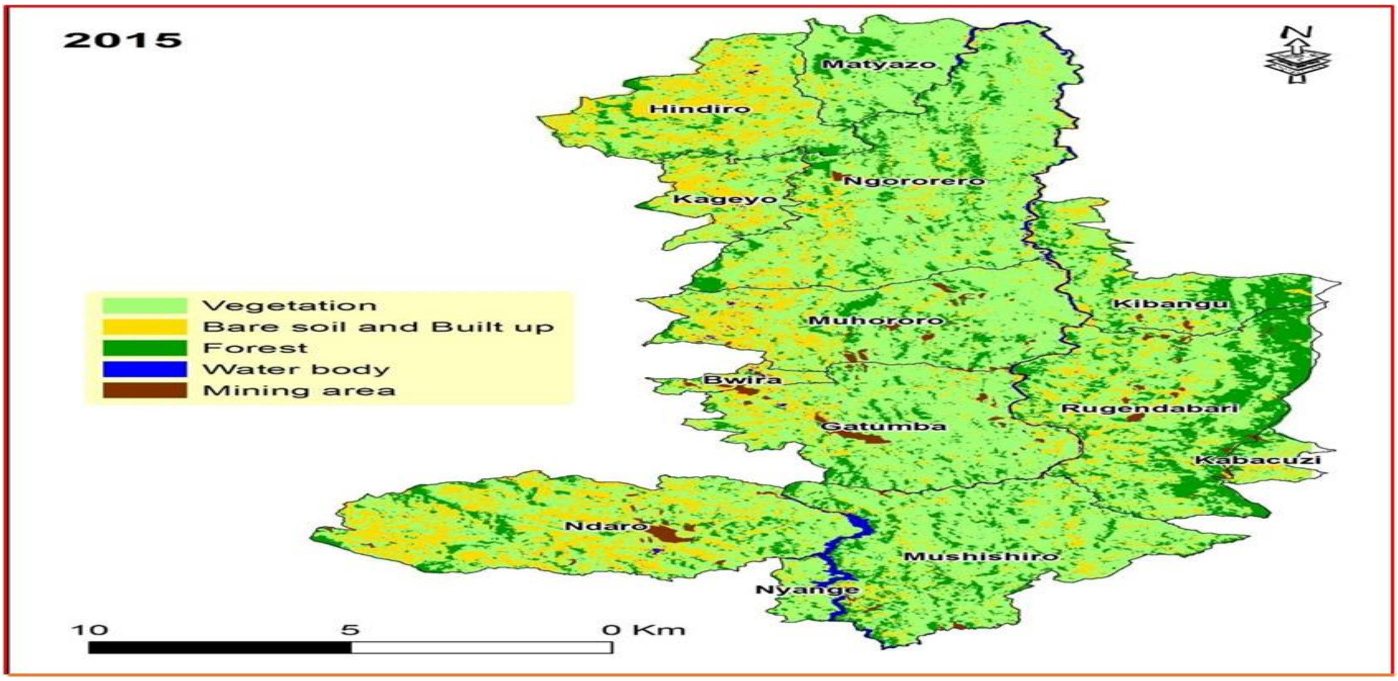

Fig 5 The land use/land cover pattern and the extent in Gatumba region in 2015
Source: ArcGIS (2023)

New pattern of water body clarify the southern concentration of water compared to the other parts of the river bed. New mine sites growth was noticed as well as new discoveries in Ndaro, Mushishiro, Kabacuzi, Rugendabari, Muhororo, Ngororero, Kibangu and Gatumba sectors. Forests were preserved mainly in Ndiza Mountains (South-East) whereas other parts of the study area hold moderate identical rates of forest cove.

➢ *Land Use/Land Cover Distribution of 2022*

Table 5 Land use/land cover distribution in 2022

Land use/Land cover Class	Area in Km^2	Percentage (%)
Mining area	5.55	1.76
Water body	3.36	1.06
Bare soil & Built up	60.67	19.18
Forest	50.84	16.08
Vegetation	195.82	61.92
Total	316.24	100%

Source: Gatumba mining company (2023)

The current scenario as seen in the 2018 categorized image showed that mining activity has effectively increased. Mining regions made up 1.76% of the total area throughout the aforementioned time. The initial occupancy was doubled during the course of 16 years of mining activity. This indicates that it was 2.85 km2 in 1998 and 5.55 km2 thereafter. This is an outstanding illustration of how mining operations developed as the environment continued to suffer. In this context, the water body represented 1.06% of the total area, representing an increase over the previous scenario, and barren soil & built up areas represented 19.18%, resulting in a comparable decline. Forest registered 16.08% of the total area which indicated the progressive loss of cover while the vegetation counted 61.92% to imply the increase in Gatumba region.

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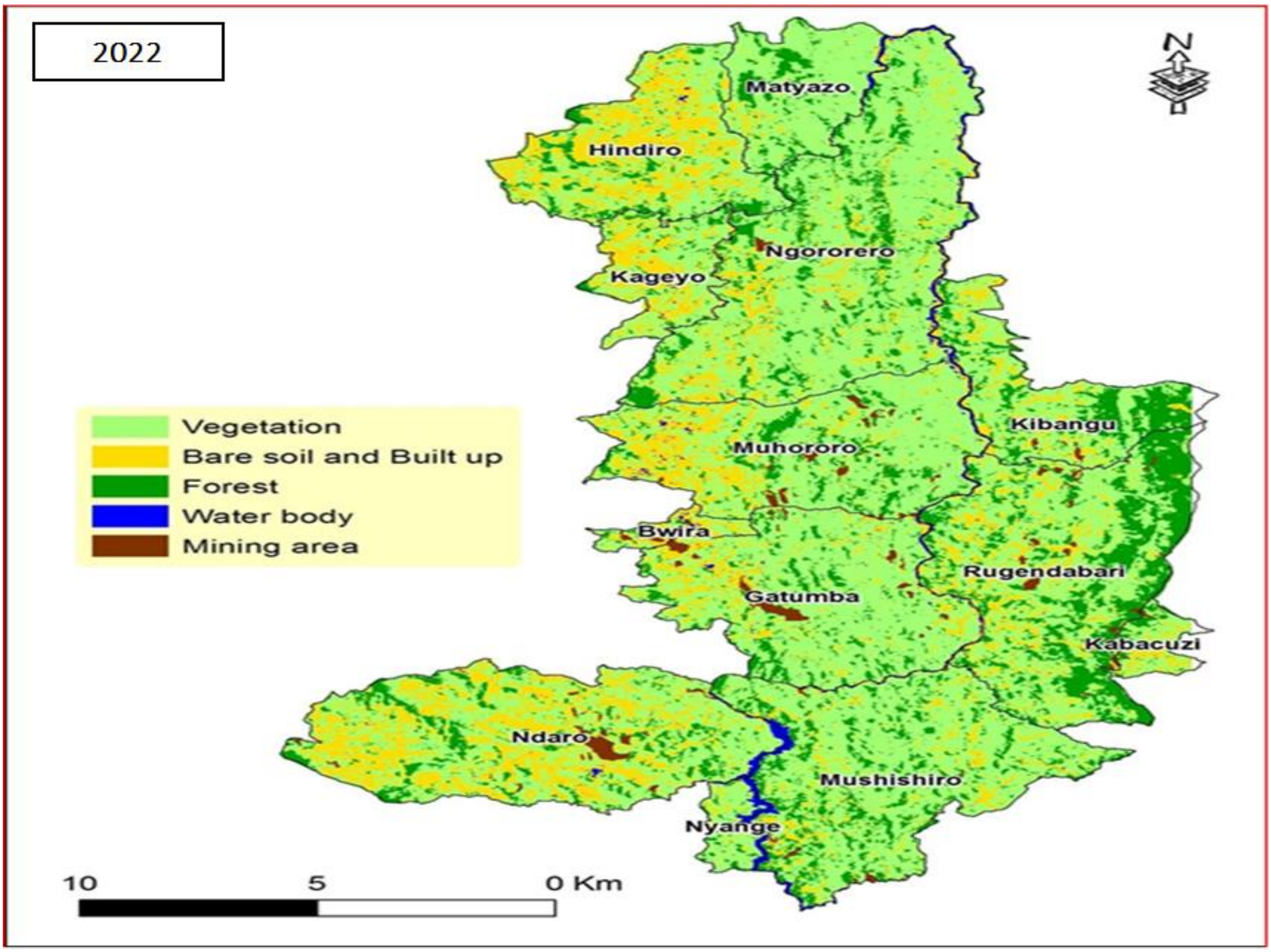

Fig 6 The land use/land cover pattern and the extent in Gatumba region in 2022
Source: ArcGIS (2023)

New pattern of water body clarify the southern concentration of water compared to the other parts of the river bed. New mine sites growth was noticed as well as new discoveries in Ndaro, Mushishiro, Kabacuzi, Rugendabari, Muhororo, Ngororero, Kibangu and Gatumba sectors. Forests were preserved mainly in Ndiza Mountains (South-East) whereas other parts of the study area hold moderate identicalrates of forest cover.

➢ *Land Use/Land Cover Change Magnitude From 2015 To 2022*

The table 8 results show an increase in magnitudes in mining areas, water bodies, and vegetation during the 2008 to 2018 period, which was a ten-year span. However, a decrease was observed in the amount of forest cover and bare soil & built-up areas.

Table 6 Land use/land cover change magnitude from 2015 to 2022

Classes	2015 Area in Km^2	%	2022 Area in Km^2	%	Change in Km^2	% of change	Remark
Mining area	3.25	1.04	5.55	1.76	2.3	1.98	Gain
Water body	2.16	0.68	3.36	1.06	1.2	1.03	Gain
Bare soil & Built up	94.34	29.83	60.67	19.18	33.67	29.01	Loss
Forest	75.20	23.78	50.84	16.08	24.36	20.99	Loss
Vegetation	141.29	44.67	195.82	61.92	54.53	46.98	Gain
Total	316.24	100%	316.24	100%	116.06	100	

Source: Gatumba mining company (2023)

Mining areas continued to increase until 2022. The magnitude of change counted expansion for mining areas by 2.3km2 representing 1.98% of the total land coverage. Gains were recorded also for the water body by an increase of 1.03% covering 1.2Km^2 of the total land coverage. Mining activities continued to pollute river water by deviating quantities and reducing the occupancy and disturb tributaries of Nyabarongo River.

Bare soil combined with built up shows a reducing magnitude from 94.34Km2 to 60.67Km2. This indicated a loss of 29.01% representing 33.67Km2 of the total land coverage. The remarked bare soil & built up changes explain the persistent gain of settlements while the fallow plots occupancies near Nyabarongo River have been cultivated recently. Also forest cover has experienced a decrease of 20.99% representing 24.36Km^2.

It was also observed that vegetation has indicated a considerable increase by 54.53Km2 representing 46.98% compared to other land occupiers. Therefore, the gain recorded by vegetation class was the loss recorded by bare soil & built up.

- *Land Use/Land Cover Change Overall Magnitude From 1998 To 2022*

The pattern of land use/land cover distribution in Gatumba region for a period of 24 years starting from 1999 to 2022, exposed substantial changes both positive and negative accordingly. Therefore, mining activities recorded progressive increases.

Table 7 Land use/land cover change overall magnitude from 1998 to 2022

Classes	1998 Area in Km^2	%	2022 Area in (Km^2)	%	Change (Km^2)	Change in %	Remark
Mining area	2.85	0.91	5.55	1.76	2.7	3.95	Gain
Water body	2.93	0.92	3.36	1.06	0.43	0.63	Gain
Bare soil & Built up	29.59	9.35	60.67	19.18	31.08	45.43	Gain
Forest	83.26	26.33	50.84	16.08	32.42	47.38	Loss
Vegetation	197.61	62.49	195.82	61.92	1.79	2.62	Loss
Total	316.24	100%	316.24	100%	68.42	100	

Source: Gatumba mining company (2023)

The overall magnitude of changes is summarized in the table 9. It shows that out of the total size of Gatumba region (316.24Km2), Mining area, water body, Bare & built up areas increased by 3.95% (2.7Km2), 0.63% (0.43Km2) and 45.43% (31.08Km2) respectively. In the same light, vegetation land decreased by 2.62% (1.79Km2) and the forest cover decreased by 47.38% (32.42Km2).

As shown by the figure 9, clarifying the variations of land use/land cover patterns, mining areas are the only class which has never get draw back but always it was increasing competing with other land use/land cover patterns.

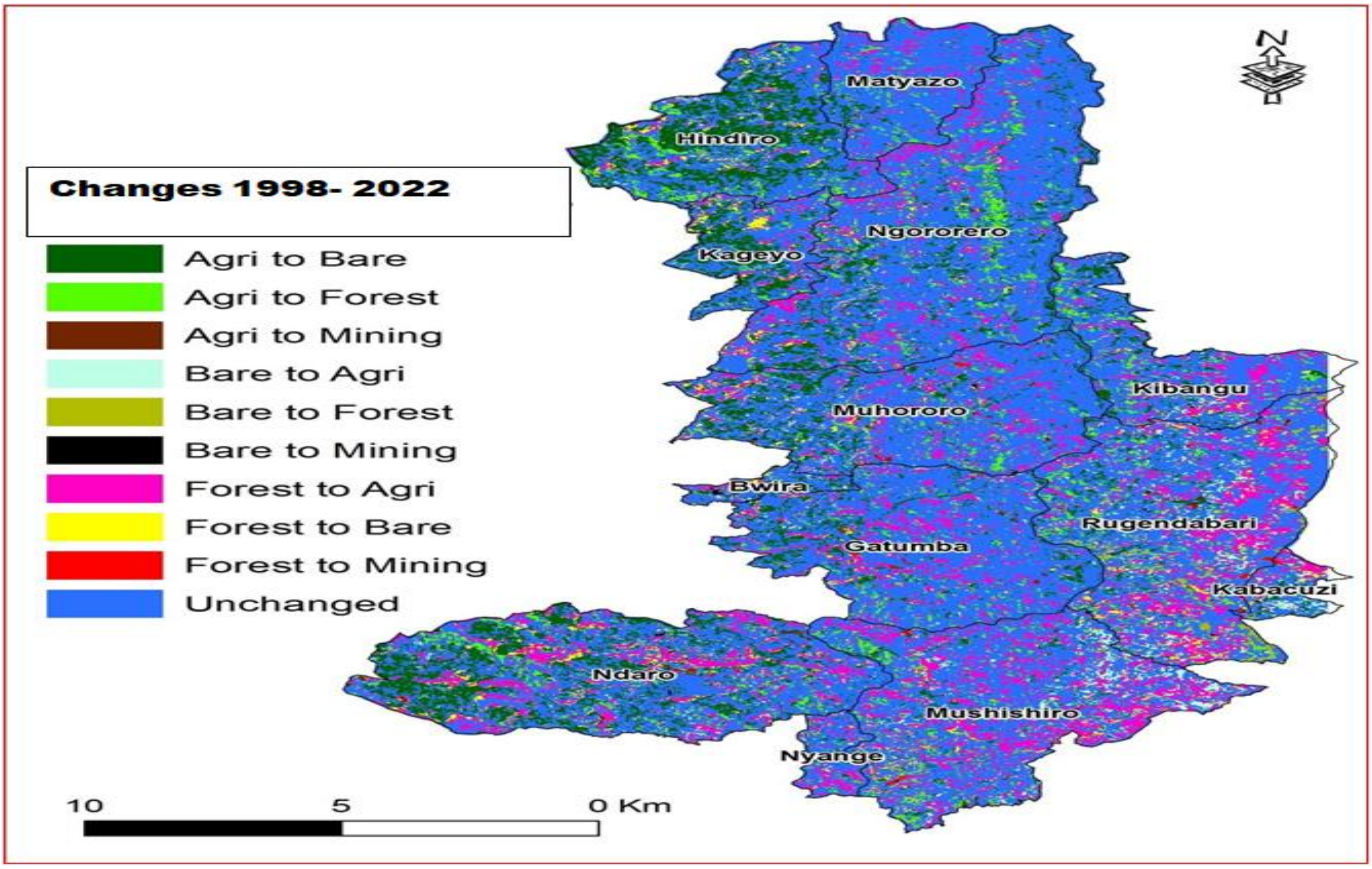

Fig 7 Land use/land cover changes map, 1998 to 2022

Source: ArcGIS (2023)

The results from all classified Landsat images show complementarities as well as a form of contrasting values among the specified land use/land cover changes and patterns. For such results, the magnitude, the significance and the implications of variability of land use patterns were explained anddiscussed in the next chapter.

➢ *Relationship between Mining Activities and Land use Land Cover Change.*

Correlations are a branch of inferential statistics that seek to explore the strength of association between the dependent and independent variable. However, correlations only give us the numerical value of the strength of this association whereby X has on Y. The study carried out a correlation to investigate the association between different land use practices responsible for land conversion and the existing land conservation measures. Highlights the findings that were generated from the computer software to show the relationship strengths

Table 8 Correlation Matrix between

	Land cover changes	**Population growth**	**Land use**	**Land cover**
Land cover changes	1			
Opencast mining	.370**	1		
Underground mining	-.167**	.228	1	
Hydro-mining	.354**	.333	.129	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

The output shows that opencast mining activities is positively correlate with land use and land cover with a Pearson correlation coefficient of 0 .370 at significance level of $p < 0.01$. This signifies that the opencast impact land use and land cover by 37%. The output also shows a negative relationship between underground mining activities and land use/cover change with a Pearson correlation coefficient of $r = -.167$ That means underground mining activities don't impact the land use/cover in the region. This level of significance indicates that the impact of land in Gatumba mining site on the land will reduce with a larger land size. The correlation output also gives a negative relationship between hydro-mining and land use/cover change with a Pearson correlation coefficient of $r = .354$,which is a significant relationship at the confidence level of 0.01.

As a result, the land use/land cover maps show dependability. The changes and patterns that have happened during the last 24 years have major implications. This tendency can be explained by the fact that mining activity in the Gatumba region resumed after 1998, with private local miners taking over. It was simple for experienced personnel who used to work for the Gatumba concession to mine independently or in groups. According to elders, because of the region's mining history, immigrant/local entering folks have come to mine and settle in the Gatumba region. Mining area tenure has more than doubled since 1998. Since 1998, it has been the only land use/land cover class that has not decreased.

Table 9 Linear Regression Coefficients

	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**	**95% ConfidenceInterval for B**	
Model	B	Std. Error	Beta			LowerBound	UpperBound
(Constant)	6.027	1.143		5.272	0.000	3.755	8.299
Opencast mining	0.890	0.368	-0.242	-2.417	0.018	-1.622	-0.158
Underground mining	0.438	0.468	-0.093	-0.935	0.352	-1.368	0.493
Hydro-mining	0.359	0.175	-0.207	-2.047	0.044	-0.707	-0.010

This is a way of predicting some kind of outcome from one or more predictor variables. The β- values tell us about the relationship between land degradation and each predictor variable (opencast mining, underground mining and hydro-mining). From the table, a negative relationship has been generated for the model with population as the independent variable and Underground mining and hydro-mining as the predictor variables for the model. Only opencast mining and land cover show a significant relationship. Regression analysis assumes that the relationship between variables is linear. It is a statistical procedure that measures the relative impact of each independent variable on the dependent and is useful in forecasting. The multiple regression formula that best describes the relationship between the variables is

Land cover changes= $\beta_0 + \beta_1$ Opencast mining + β_2Land use + β_3 Land cover= 6.027+ -.890+ .438 + 0.359

Opencast mining ($\beta = -.890$). This value indicates a negative relationship between land changes and opencast mining as a predictor variable. Therefore, as opencast mining of land reduces, land degradation will definitely reduce. Land use ($\beta = -.438$) also depicts a positive relationship meaning that reducing the number of land use on the land in the area will see a reduction in the rate of land use land cover change and land degradation other factors that contribute or lead to land degradation are held constant. A higher absolute value of Beta reflects a significant effect of the independent variable on the dependent variable whereby the equation indicates that there is uni-directional relationship between LULCC and land degradation which is characterized for relatively lower values. At confidence level of 95% or $p \leq 0.05$, land use and opencast mining are both significant. Small values for confidence level imply that it would be very unlikely for us to obtain a value of the test statistic such as the one we would observe if the research hypothesis actually were false. The lesser values of confidence level ($p \leq 0.05$) from the table output of linear regression, i.e., opencast mining ($p \leq .018$) and land use ($p \leq .044$) indicate that the sample results correspond to the research hypothesis, high population density and increased human activities in Rwamagana district are significantly related to land degradation, and therefore the hypothesis is accepted.

From the regression table, the t-test associated with the β- values for land opencast mining and land use are significant because both have values that are less than .05. level of significance. This therefore means that land opencast mining and land use of livestock in Rwamagana district (two major land use forms) as predictor variables are making a significant contribution to the model. From the model, opencast mining, [t (- 2.417) = .018, $p < .05$] and land use [t (-2.047) = .044, $p < .05$]. From the magnitude of the t- statistics, we can see that both opencast mining and land use have a similar impact on the land in the area of study. As a matter of fact, these results corroborates the outcome of the GIS maps, and the findings in the DDP that opencast mining and land use due to overstocking are the major contributors to land cover changes in Ngororero especially around Gatumba mining site.

According to the study's findings, mining activities led to changes in land use and had a negative influence on the ecosystem, including deforestation, erosion, contamination of nearby streams and wetlands, and alteration of soil profiles. The classification of several land use/land cover groups, including mining areas, water bodies, bare soil, built-up areas, forests, and vegetation, was made possible by the interpretation of satellite data. In important areas, real-world verification was carried out. According to a comparative analysis of underground mining and hydro-mining based on data from 2008 and 2018, the development of mining activities is to blame for the loss of dense forest area. There is now less vegetation.

- *Discussions*

The photos were divided into five unique classes: mining sites, forest cover, vegetation, water body, and bare soil & built up. The overall categorization accuracy is moderate, with 70.21% (1998), 69.30% (2008), and 83.20%. (2018). The corresponding Kappa values were stated to be 0.54 - 0.53 and 0.73. The trends and patterns discovered were nearly identical to those found in previous studies on land use/land cover changes in other locales. For example, (Venkataraman et al., 2017) assessed the impact of open cast mining on land use/land cover for two separate years with 95.81% (Kappa: 0.93) and 93.71% accuracy (Kappa: 0.91). Ruiz-Luna and Berlanga-Robles (2003) conducted the same experiment and discovered an accuracy of 73% (Kappa: 0.7) and 84% (Kappa: 0.72) while analyzing the land use, land cover changes, and coastal lagoon surface reduction linked with urban growth in Mexico (Byizigiro & Thomas Raab, 2016; Padmanaban et al., 2017).

Furthermore, the concept of using remote sensing data is widely accepted by the scientific community. In this study, over a 16-year period, the mining area, water body, bare and built-up areas rose by 3.95% (2.7Km2), 0.63% (0.43Km2), and 45.43% (31.08Km2), respectively. Similarly, vegetative land declined by 2.62% (1.79Km2), whereas forest cover decreased by 47.38%. (32.42Km2). According to Snapir et al., the same trend has been observed in African countries (2017).

They found that between 1975 and 2005, the degraded area/land (mine area), built-up area, and water bodies rose by 24.58%, 18.51%, and 7.57%, respectively. Whilst arable land (farm and land use land) decreased by 106.60 square kilometers (14.16%), forest reserve decreased by 264.89 square kilometers (35.18%). Mallupatu and Reddy (2013) used the same trending approach and declared that land use/land cover changes in Tirupati, India, were significant between 1976 and 2003.

There was a large increase in built-up area seen. On the other hand, agricultural land, water spread land, and forest land all decreased. Mining has increased by 11.84 km2 in Singrauli, India, over the last nine years as a result of the rapid increase in coal output. Dense forest areas are declining, while plants at overburden dumps under reclamation programs have also been going on (Pietrzykowski, 2015).

The kind tendency clarifies that, since 1998, mining actors have expanded to double the existing mined areas. Local officials attributed the increase in mining areas to the amount of mining companies, cooperatives, and mineral frauds in the Gatumba region. Mining activities were usually carried out in abandoned mine sites, but once it evolved against forest, vegetation, and barren land for one condition "new minerals deposit identified," it was performed in other areas.

Immigrants miners increased and the presence of such population affected other land uses as well. Increase of built up, reduction of forest and farming land and economy rising. Therefore, there were an increase of houses and the growth of small business centers after the resettlement of local population after the 1994 Genocide and the repatriation of population from Democratic Republic of Congo after 1998(Havugimana, 2019).

While just taking up a small portion of the land's surface, mining does have major and frequently irreversible repercussions (Snapir et al., 2017). Visible environmental degradation is occurring in the Gatumba region. It is quite simple to ruin the local ecology, but it appears to be very difficult to recover. People eventually notice a significant negative influence that is impossible to evaluate when someone refuses to engage in the circle of environmental protection. According to Ababio (2018) and Snapir et al. (2017), who put the situation in Ghana in critical terms, "Despite policies and legal frameworks like the Minerals and Mining Law. Already harmed, the environment would become even more so if proper, serious action is not taken and by which it was monitored to be done. Rivers were diverted, more polluted, and caused disease outbreaks, flooding, and land erosion. The extent of deforestation will worsen, resulting in crop losses, soil erosion, and landslides.

VII. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

The dynamic of land use/land cover patterns in rural areas express a moderate level of change which compete with mining activities. The aim of the study was to assess the evolution of mining activities over other land use/land cover patterns facilitated by remote sensing approaches. The research focused in Gatumba region, the former Government concession renowned for its tin and tantalum ores.

To achieve this, Landsat images were processed by a supervised classification, using maximum likelihood as the clustering algorithm for pixel-based classification approach. Sets of training fields were digitized for each of the classes to be evaluated to define spectral signatures. The preliminary results were assessed and resulted in moderate accuracy status. Finally, they have been validated and land use/land cover classes were forest, water body, vegetation, bare soil & built up and essentially mining areas. After a deductive calculations of magnitude for each land use/land cover class, the really occupancies were revealed. Mining areas were the only class with progressive increase compared to others. There was another decreasing trend of forest cover. Other land use/land cover classes witness up and down variations. This implied the contrasting aspect of mining activities competing with other land use/land cover patterns.

The disclosure of driving forces of mining activities was communicated via administrated questionnaire and field survey in order to retrieve the most important. Widespread mineralized pegmatite, lack of other work that pay sufficiently, good price of minerals, shallow mineralized body and the water availability were highly attractive to support mining activities in Gatumba region. In other perspective those driving forces were harmonized with different factor classes matching with mineralogy, hydrology, morphology, social and economic.

This appeared more realistic for rural areas and conditions for human interactions. The third objective was to evaluate environmental impact of mining activities and future implications on land use/land cover. The field survey and the core interview revealed the truth that poor and inadequate mining activities always antagonize with environment. In Gatumba region the environment was degraded since long time ago, whereas actual miners have tendency to look the damaged massifs as natural occurring morphology. Visibly, by the artisanal mining techniques, informal hidden practices end up by polluting rivers, charging water with debris and waste from the mine. Forests are cut, crops are neglected and the soil erosion propagates, while humans are targeting

Practically, the study evaluated mining areas progress against other land use/land cover patterns. Working with low resolution Landsat images in rural areas or green cover areas tend to be challenging without sufficient truth ground data coupled with high resolution images. The puzzling face of Landsat images could be alleviated for further similar studies undertaken in the same situation by the use of high resolution satellite images or with highly sensitive software more than Erdas Imagine.

➢ *Recommendations*

It is advised that similar research projects should be explored in the future using either more accurate satellite imagery or object-based software. This will make it possible to measure changes in mined regions over time and space with greater accuracy. The future is in danger if each generation fails to fulfill its obligation to conserve and manage the environment.

To adopt a fresh viewpoint on mining practices, it is advised that mining corporations collaborate with responsible institutions. They ought to promote environmentally friendly mining practices and environmental preservation for coming generations. This could be accomplished by educating and training local miners in sustainable mining techniques and motivating them to assess the environmental impact of their own activities. A struggle exists between organizations in charge of the environment and those who want to continue mining since there is an issue with abandoned mine sites that still contain minerals. These difficulties can be overcome responsibly and sustainably by cooperating.

It is recommended that Environment Agencies should adopt strong environment laws on mining activities and programs should be introduced to educate locals on the various aspects of mining.

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