BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF NATURAL RESOURCES

ASSESMENT OF THE IMPACTS OF ARTISANAL GOLD MINING ON THE ENVIRONMENT USING GIS AND REMOTE SENSING: THE CASE OF MASHONALAND EAST AND MASHONALAND CENTRAL PROVINCE. (2009-2020)

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APPROVAL FORM

The undersigned certify that they have read and recommended to the Bindura University of Science Education for acceptance of a dissertation entitled "**ASSESMENT OF THE IMPACT OF ARTISANAL MINING ON THE ENVIRONMENT USING GIS AND REMOTE SENSING THE CASE OF: MASHONALAND EAST AND MASHONALAND CENTRAL PROVINCE**. (2009-2020) "submitted by B1850232 in partial fulfilment of the requirements of the Bachelor of Science Honors in Environmental Science Department of Natural Resources Management

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Name of Chairman Signature Date

DEDICATION

This thesis is dedicated to my father Mathew Marira (the late) my source of inspiration for always encouraging me to soar to greater heights and being "THE PERSON". To my mother Tamari Marira, I'm grateful for your prayers that kept me going in my academic endeavor, through the good and trying times. I also dedicate this to my loving and caring brothers Mike Takavada, Takudzwa and Idaishe for their unwavering support and motivation, I appreciate you. I'm blessed to have you in my life, love you all.

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Abstract

The study assessed the effects of artisanal small scale gold mining on the environment conducted in Mashonaland East province in Mudzi district ward 14 and Mashonaland Central Province, Bindura district ward 21. The study went further to examine the adaptation and coping mechanism of the surrounding communities to the impacts of artisanal small scale gold mining. Qualitative research methodology was used in gathering relevant information from the respondents; this was done through the use of data gathering instruments in GIS and Remote sensing, interviews and also from secondary data sources. In terms of sampling methods, purpose sampling method was used, satellite images, map trends and coordinates were obtained from the selected wards. Information was also gathered from artisanal miners, mine associates as well as village heads. Results from the study implies that there are several factors that triggered artisanal mining in the selected wards and these are, droughts, massive unemployment, economic decline, abundance of gold deposits, the gold panning mind-set amongst the local people, gold rush (riches) as well as easy accessibility of gold mines. In addition, results from the study shows that artisanal small-scale gold mining results in environmental degradation. The noted and observed environmental effects of artisanal small scale gold mining include, land surface and soil destruction, erosion, land pollution, water pollution, outbreak of diseases, occupational diseases (silicosis, mercury poisoning), respiratory problems, deforestation, death and injuries.

Table of contents **Page Number**

CHAPTER 1

1:1 Background of the study.

Artisanal small-scale gold mining has appeared to have become the major economic activity in Zimbabwe during the early 21th century. Rampant economic decline, massive unemployment, recurrent droughts, legislation on small-scale gold mining (Indigenisation), as well as gold rush. Zimbabwe faced economic hardships during the period 2000 to 2008. The problems which Zimbabwe encountered during this period include hyperinflation as well as very low salaries to the workers. The World Bank (2007) pointed that this has left many households living far below the poverty datum line. During this period many families faced income hardships alongside the rising inflation rates. Artisanal gold mining appeared to be the possible solution to the majority's hardships and as a result this period has witnessed the sharp rise in the numbers of artisanal gold miners in many parts of Zimbabwe including Mudzi district ward 14. Massive unemployment is another factor that led to the rise in artisanal small-scale gold mining in many parts of Zimbabwe including Mudzi. Unemployment came as a result of the economic decline which then caused the closure of many companies and industries in the country. Moss and Busse (2006) articulates that due to the economic decline, many companies closed resulting in the retrenchment of the majority of workers. They pointed that unemployment is said to have been rise to 80% in Zimbabwe in 2008. In mudzi district, a number of families has been seen to have moved back to their rural area homesteads where the cost of living was a bit reasonable than the city life. Recurrent droughts are considered to be another factor that triggered artisanal small scale gold mining in Mudzi, agriculture cannot be depended on in this district as low rainfall is received and the soils are red therefore they require large amounts of rainfall for successful crop production, so people had to buy food thereby relying on artisanal gold mining. Legislation is another factor to be considered as a factor that triggered artisanal small-scale gold mining in Zimbabwe. Phiri (2012) noted that it can also be argued that artisanal small-scale gold mining has received a boost in Zimbabwe in the past decade from new government policies which encouraged small-scale mining through the Ministry of small and medium enterprises in which artisanal gold miners were encouraged to register claims and operate formally or legally led to the rise in artisanal small-scale gold mining in many parts across Zimbabwe including Mudzi district. Nkiwane (2012) noted that Zimbabwe since 2000 has witnessed a number of policy changes promoting indigenisation which has seen the liberalisation of mining operations with many people going into small-scale gold mining. Svotwa and Mtetwa (1997) pointed that small-scale mining sector comprises of more than 20 000 registered mining claims with about 10 % in full operation and about 300 000 unregistered illegal mines in Zimbabwe. However, diversification into artisanal small-scale gold mining although it provides some kind of source of employment and income generating to many households simultaneously it has posed a lot of environmental problems as well as causing health problems to the people residing around the area of mining and even those people who are far from the mining area but make use of water from the polluted water bodies for consumption. Noted environmental effects of artisanal small-scale gold mining include deforestation , soil erosion and siltation, land degradation as well as pollution. Soil erosion and siltation has affected mostly water systems in these areas, rivers and dams are drying up as a result of soil erosion. Artisanal miners are causing huge soil erosion due to their rudimentary methods of extracting gold as the soil is loosened and easily eroded by flowing water into the water systems. Water systems have been noted as the key area affected by artisanal small-scale gold panning legally or illegally. Phiri (2012) is of the view that gold panning processes on river banks, beds and surrounding areas discharge huge amounts of loose silt and heavy metals into the river systems. Eventually these are carried into the water bodies hence an increase in siltation and drying up of water reservoirs. The diggings by artisanal gold miners lead to land degradation. Artisanal gold miners cut down trees and also digging a lot of pits as well as destroying arable land for agricultural purposes. Pollution is another environmental effect of artisanal small scale gold mining. Four major forms of pollution are occurring as a result of artisanal mining these are Air pollution, Water pollution, Land pollution as well as noise pollution. Water pollution comes as a result of mercury use as well as cyanide use in the processes of gold amalgamation which is done by all artisanal miners which then pollutes both underground water as well as surface water in water systems (dams and rivers). Air pollution is occurring as the result of burning mercury gold amalgam on an open space which pollutes the atmosphere; this may cause respiratory diseases like bronchitis. Land pollution has become rampant due to poor management of wastes by the artisanal miners and also noise pollution as a result of explosives as well as sound from mills.

1.2 Problem statement.

This study is focusing on assessing the effects of artisanal small-scale gold mining on the environment. Artisanal mining has become a key to development of many developing countries which include Zimbabwe. There are several reasons why this activity becomes a key to development in many developing countries for example in Zimbabwe artisanal small-scale gold mining has become the major source of foreign currency. Noetsaller (1997) Nkiwane (2012) noted that in addition to the direct employment opportunities artisanal small scale contributes to the generation of substantial number of indirect jobs in other sectors of the economy as it creates demands for inputs, transportation and other services as well as benefits due to increased income and consumer spending. Due to economic decline, massive unemployment as well as recurrent droughts artisanal gold mining has become the major economic activity for many people in developing countries. This is the same scenario in Zimbabwe in the selected provinces. Due to economic decline, massive unemployment, recurrent droughts, gold rush and legislation artisanal gold mining has become the major source of livelihood as the people were forced by the harsh conditions to diversify into artisanal gold mining. However artisanal small scale gold mining is resulting in environmental degradation due to the fact that artisanal miners use poor and destructive mining methods which lead to land degradation, soil erosion and siltation, deforestation/ vegetation destruction as well as pollution to the environment which cause health problems to both human beings as well as animals and also which in the long run may hinder the basic needs for the future generations. Use of chemicals without proper disposal methods has greatly led to the demise of the environment.

1.3 Objectives

- ❖ To detect the changes on land cover over a period of 10 years (2011-2021) using GIS and Remote sensing as a result of artisanal small scale gold mining.
- ❖ To examine the extent in which artisanal small scale gold mining is degrading the environment in relation to micro-economies of the selected sites.
- ❖ To predict the future trends of environmental deterioration/ degradation.
- ❖ To provide solutions or ideas to reduce adverse impacts on the environment.

1.4 Research Questions

- ❖ What has changed on the environment with an increase in artisanal small scale gold mining?
- ❖ What are the effects of artisanal small scale gold mining on the environment?
- ❖ What strategies that can be adopted by artisanal small scale gold miners to protect the environment?

1.5 Research Design

Qualitative research methodology was used for data collection from the respondents. With this approach there is discussion of cases of the researcher's local context which is emphasized on tracing the process and sequence of events in specific settings. There is also use of direct quotations to support certain concepts, interviews, questionnaires and a great deal of analysis. It doesn't put emphasis in numbers and it uses non probability sampling methods. With this approach the setting is natural and familiar and there are field observations.

1.6 GIS and Remote sensing

Remote Sensing information was the major tool used to analyse the trends ASM quantitatively and thus helps in determining the changes associated with land cover and land use properties with reference to the multi-temporal datasets. Remote Sensing (RS) has been used to classify and map land cover and land use changes with different techniques and data sets. Landsat images in particular have served a great deal in the classification of different landscape components at a larger scale. Therefore, the main objective of the present research was to utilize GIS and Remote Sensing applications to discern the extent of changes occurred on the environment in the areas selected over 10 years' time period.

Air quality monitoring has become an important process to show how the environment is being degraded, and GIS can play a very important role here as well. A GIS integrated platform by leveraging sensors for air quality monitoring, analytics, and planning, can accurately predict the PM levels in varied areas within a city. It can also tell you which areas are the most hazardous or most dangerous for wildlife and humankind. This analysis can help the field officers to take corrective action on time to improve the air quality. Using mobile apps, the citizens can also make the authorities aware which areas need immediate attention

CHAPTER 2

2.0 Literature Review

2.1 Introduction.

This chapter will give an overview of the literature that is related to the study by defining terms the conceptual and theoretical frameworks of the available literature and also critically analysing the empirical evidence available. The chapter will also highlight the knowledge gap that researcher wants to work on. Extensive research has been carried out to determine the changes that have been brought about by interlink, interaction of man and his environment.

2.1Definitions

Artisanal and Small-Scale Mining (ASM)

ASM is a collective term embracing both small scale and artisanal mining. It covers formal or informal mining which is characterised by low capital intensity and high labour intensity and relatively simple methods for exploration, extraction and processing. ASM can involve men and women working on an individual basis as well as those working in family groups, in partnerships or as members of co-operatives or other types of association.

Environment

The natural world, including the land, water, air, plants, and animals, especially considered as something that is affected by human activity

Geographic information system

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. By relating seemingly unrelated data, GIS can help individuals and organizations better understand spatial patterns and relationships.

Remote sensing

Remote sensing is the process of detecting and monitoring the physical attributes of an area by measuring its reflected and emitted radiation at a distance, typically from satellite or aircraft.

2:3 Development of Change Detection Over Time.

Change detection refers to the process of identifying differences in the state of land features by observing them at different times (Bradley and Mustard ,2005). Change detection captures the spatial changes from multi temporal satellite images due to manmade or natural phenomenon. It is of great importance in remote sensing, monitoring environmental changes and land use –land cover change detection. Remote sensing satellites acquire satellite images at varying resolutions and use these for change detection. Timely and accurate change detection of Earth's surface features provides the basis for evaluating the relationships and interactions between human and natural phenomena for the better management of resources. I change detection makes use of multi-temporal datasets to quantitatively analyse the temporal effects of a phenomenon. Change detection emerged with the beginning of remote sensing and especially the first aerial photography captured in 1859 by Gaspard Felix Tournachon, also known as Nadar. (Singh 1989)

Change detection began as the Landsat program was launched. The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. On July 23, 1972, in cooperation with NASA, the Earth Resources Technology Satellite (ERTS-1) was launched. It was later renamed Landsat 1. Additional Landsat satellites followed in the 1970s and 1980s. Landsat 7 was launched in 1999 followed by Landsat 8, launched on February 11, 2013. Both Landsat 7 and Landsat 8 are currently in orbit and collecting data. Landsat 9 has been launch mid-2021.

Basing on journals, publications , the algebra techniques such as image differencing or image rationing were the first techniques used to characterize changes in digital imagery during the 1970s (Cracknell and Hayes, 1991; Singh, 1989; Théau, 2013). These techniques are simple and fast to perform and are still widely used today. More complex techniques were developed since then with the improvement of processing capacities but also with the development of new theoretical approaches. Change detection analysis of the Earth surface is a very active topic due to the concerns about consequences of global and local changes. This field of expertise is thus constantly progressing

Landsat satellites have the optimal ground resolution and spectral bands to efficiently track land use and to document land change due to climate change, urbanization, drought, wildfire, biomass changes (carbon assessments), and a host of other natural and human-caused changes.

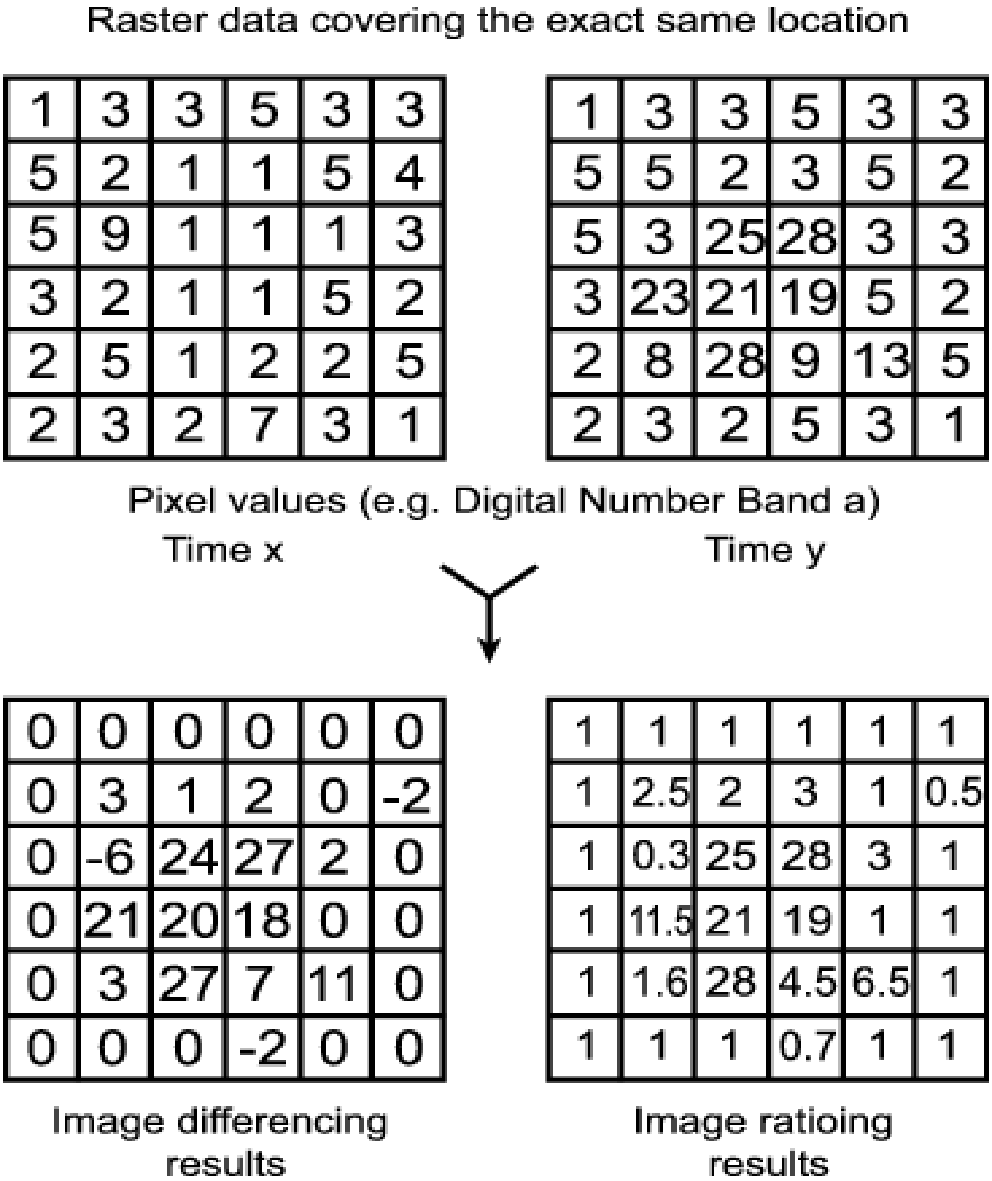
The Landsat Program's continuous archive (1972-present) provides essential land change data and trending information not otherwise available. Landsat represents the world's longest continuously-acquired collection of space-based moderate-resolution land remote sensing data. Landsat is an essential capability that enables the U.S. Department of the Interior to wisely manage Federal lands. People around the world are using Landsat data for research, business, education, and other activities.

Change detection techniques

Change detection techniques add up to seven groups namely ,transformation , classification ,geographic information systems ,algebra ,advanced models ,visual analyse and image rationing.Change detection gives a wide range of methods employed to identify , describe and quantify differences between images of the same scene at different times or under different conditions .The most familiar change detection techniques are image differencing ,principal component analysis and post analysis comparison .Image differencing and principal component analysis can provide change or non-change information whilst post classification comparison provides detailed change from a certain period to another .

Image differencing

It's an image processing technique used to determine changes between images. The difference between two images is calculated by finding the difference between each pixel in each image, and generating an image based on the result. For this technique to work, the two images must first be aligned so that corresponding points coincide, and their photometric values must be made compatible, either by careful calibration, or by post-processing (using colour mapping). The complexity of the pre-processing needed before differencing varies with the type of image.


Raster data covering the exact same location
1 3 3 5 3 3
5 2 1 1 5 4
5 9 1 1 1 3
3 2 1 1 5 2
2 5 1 2 2 5
2 3 2 7 3 1
1 3 3 5 3 3
5 5 2 3 5 2
5 3 25 28 3 3
3 23 21 19 5 2
2 8 28 9 13 5
2 3 2 5 3 1
Pixel values (e.g. Digital Number Band a)
Time x
Time y
0 0 0 0 0 0
0 3 1 2 0 -2
0 -6 24 27 2 0
0 21 20 18 0 0
0 3 27 7 11 0
0 0 0 -2 0 0
1 1 1 1 1 1
1 2.5 2 3 1 0.5
1 0.3 25 28 3 1
1 11.5 21 19 1 1
1 1.6 28 4.5 6.5 1
1 1 1 0.7 1 1
Image differencing results
Image ratioing results

Landsat Used

Sentinel 2, Landsat 4-5, Landsat 7 and Landsat 8 were used to collect data for this study. Sentinel 2 was mainly used for the 2009 period and in instances where there were no images in the Landsat 4-5,7 and 8 archives. Landsat 4-5 complimented the other Landsat were they could not provide quality images due to cloud cover or faulty sensors. Landsat 7 launched in 1999 was mainly used to obtain images for year 2014. Lastly there is Landsat 8 launched in 2013 which was used to obtain data from 2014 to 2020.

CHAPTER 3

3.1 Introduction

This part provides the information on the area where the study was conducted. This part is mainly focusing on explaining how this study was conducted, the research approaches, research design; the part also shows the total sample and sampling techniques that were employed in the whole research and why was it preferred. The chapter also shows the data collection methods that were used and it also shows the methods that were used in the presentation of data collected in the field and the reasons as to why they were used, based on the objectives of the study and the nature of data gathered in the field. This part also provides the justification onto the selection of the data collection sites, justification and sources of data that were used in the study. This section also articulates the analytical and statistical technique that was used in analysing the data collected.

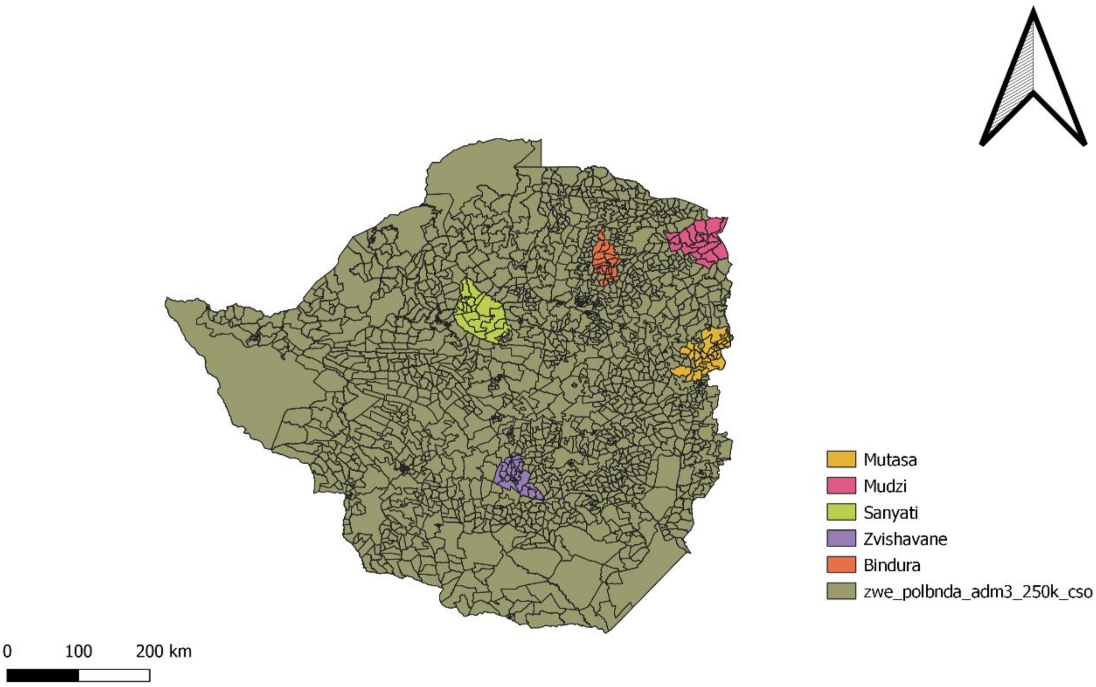
3.2 Research Design

The study was conducted using qualitative research design. According to Austin and Sutton (2014) qualitative data analysis of figures, themes, and words allows for flexibility and the researcher's subjective opinions. This means that the researcher's primary focus will be interpreting patterns, tendencies, and accounts and understanding the implications and social framework. Case study design was also used; it allows the use of multiple sources of data collection methods over time. The case study design was used for its flexibility since it allows the use of field observation and secondary data sources in data collection.

3.3 Area of the Study

The research was carried out in two provinces Mashonaland East in Mudzi ward 14 and Mashonaland Central in Bindura ward 21. The sites were deliberately selected following areas with gold deposits, where artisanal small scale mining is predominant.

Zimbabwe Map with highlighted areas of study



Data collection

The data was collected between 2009 and 2020 where the process was under the supervisor's assistance. Primary data was collected using the GIS and Remote sensing and taking pictures. Secondary data was obtained from office records, dissertations and journal by various publishers.

Methodology

The analysis mostly depended on the Landsat and ASTER images; the SPOT image was used to extract certain features. These data sets were processed using the image-processing software TNT MIPS by Micro images. The assessment included a study of the environmentally critical areas of land degradation and water pollution, as well as changes in land use. Processing Techniques Various image processing and vector GIS techniques were used for the analysis of the satellite imagery, the collected map data, and the field information (Cracknell ,2007). Sentinel 2, Landsat 4-5, Landsat 7 and Landsat 8 were used to collect data for this study. Sentinel 2 was mainly used for the 2009 period and in instances where there were no images in the Landsat 4-5,7 and 8 archives. Landsat 4-5 complimented the other Landsat were they could not provide quality images due to cloud cover or faulty sensors. Landsat 7 launched in 1999 was mainly used to obtain images for year 2014. Lastly there is Landsat 8 launched in 2013 which was used to obtain data from 2014 to 2020.

1. Georeferencing and resampling: The images used were geodetically corrected into the Transverse Mercator Projection using the Hellenic Geodetic Reference System (HGRS'87). Georeferencing was followed by image-to-image registration in order to detect changes in Landsat images.

2. Colour composites: The pseudo-colour composite RGB753 was used on the Landsat images in order to emphasize the mining areas, which have high spectral reflectance. This composite accentuated the mining areas and discriminated vegetation from barren soil.

3. Intensity hue saturation (IHS) images: The IHS transform was used to fuse the SPOT panchromatic band of higher spatial resolution with the multispectral bands of the ASTER and Landsat images so that the inherent land cover classes in the mining areas could be identified.

4. Unsupervised classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data . For classification purposes, the Self Organizing Map (SOM) ANN method was used on the ASTER image in order to discriminate all inherent land cover classes of the satellite images.

Different land cover types were mapped in the mined areas and the surface extent for each cover type was estimated.

5. Identification of areas of interest with respect to land and water surfaces: This area of interest.

6. Automated combination of the classification result of multi-temporal imagery: different resolution data were combined using data fusion techniques. This was effective for the land cover and the interpretation of geologic features because complementary information for the same target area was combined.

7. Automated conversion of raster to vector data: the raster output of the classification and/or interpretation process was converted to vector data and these data were analysed with the corresponding map data and field observations. Statistics for the classification result have been estimated related to areas. Estimates of surface area extent have been obtained. The estimates were checked in the field and proved to be accurate.

8. Collection, input, coding, storage, management, retrieval of various data: all ancillary data (raster, vector, ASCII) selected in this study were aggregated in the GIS in order to assess the natural risk caused by mining activities.

9. Processing and analysis: further processing and analysis was performed to derive information concerning changes.

CHAPTER 4

This chapter reviews and presents the results of the data collected during the survey. Adhering to the research objectives, the data obtained from the survey was carefully presented in a manner that will aid understanding. In doing so, the data gathered from the research and observations was presented under six processes in GIS and Remote Sensing, these include NDVI, band combination, supervised classification and resolution. The presentation was made through the use of maps, satellite images, tables

4.1 Estimation of NDVI

A number of Landsat images were used for the analysis of NDVI changes. The NDVI was calculated as follows: NIR –RED /NIR +RED

Where NIR is near-infrared band and RED is the red band. NDVI value ranges between −1 and +1. Vegetation indices such as NDVI (time-based) profiles were used to combine various classes as well as to identify the changes on the environment over an eleven-year period in Bindura ward 21 and Mudzi ward 14. NDVI images were classified using software QGIS 3.20.3 to compare the changes depicted.

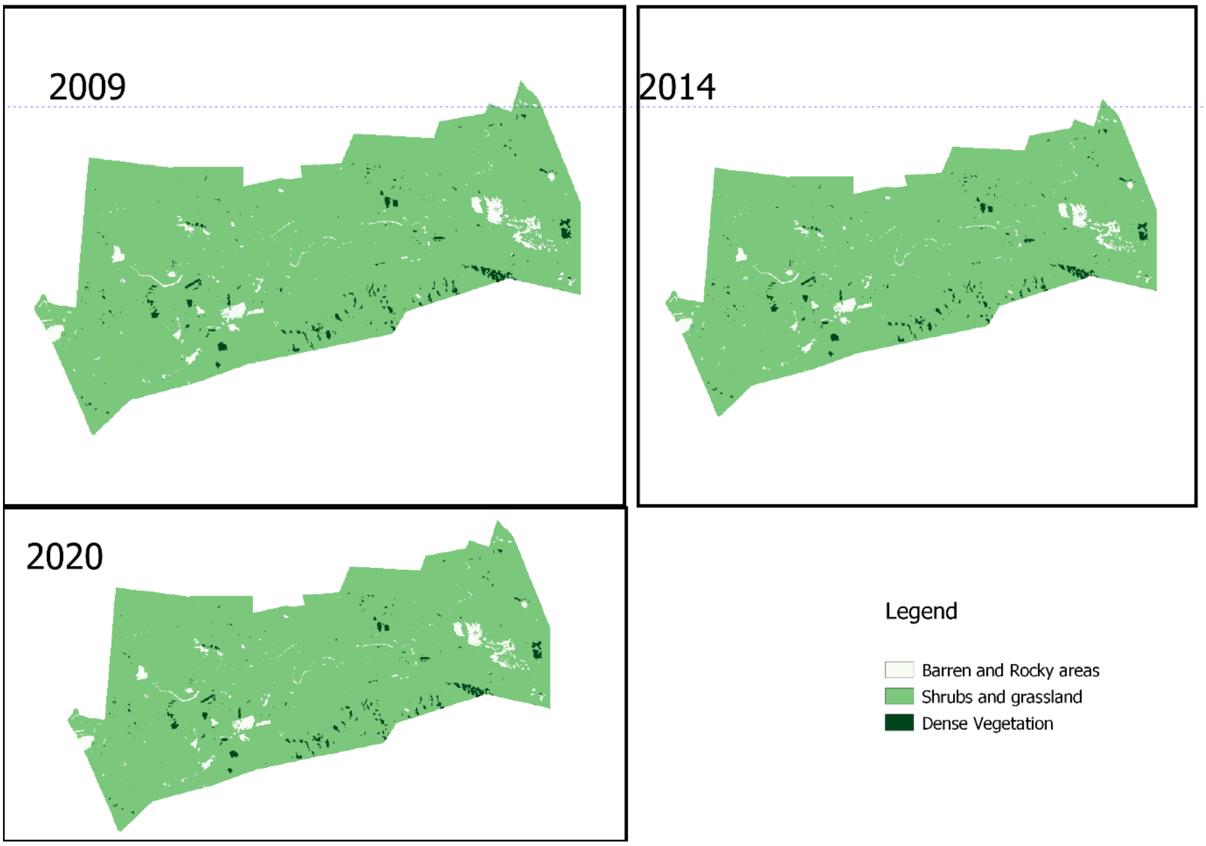


Fig 4.1 showing the NDVI for Bindura ward 21 for year 2009, 2014 and 2020

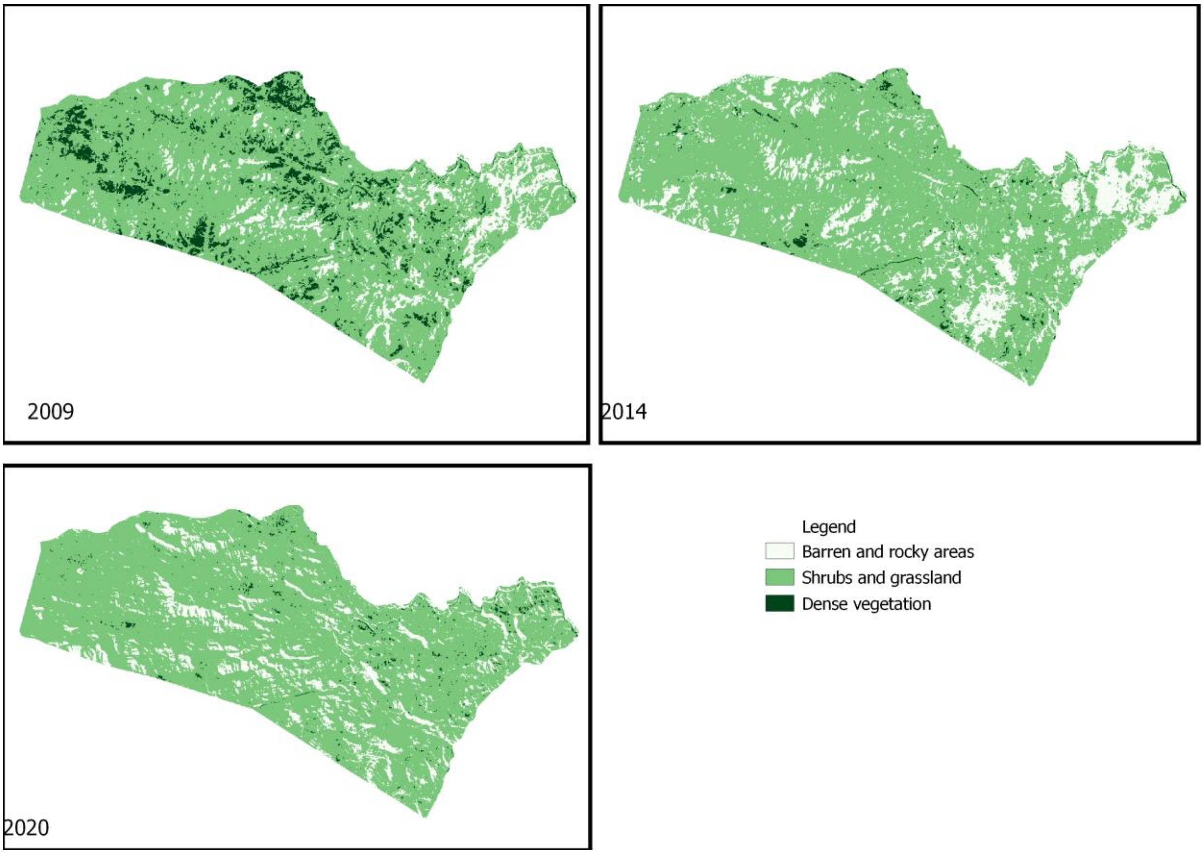


Fig 4.1.2 showing NDVI for Mudzi ward 14 for year 2009, 2014 and 2020 .

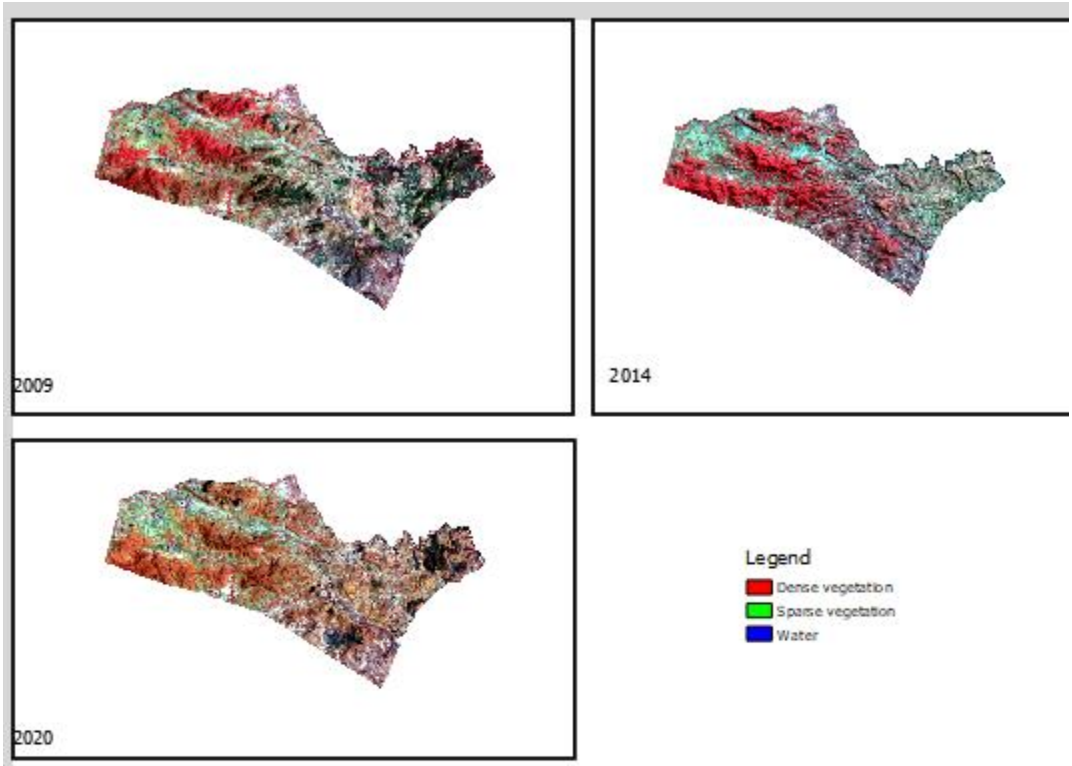


Fig 4.2 showing Mudzi ward 14 Environmental elements in False Color Composite for year ,2009, 2014 and 2020.The main aim of this image is to clearly detect the changes on the environment over time

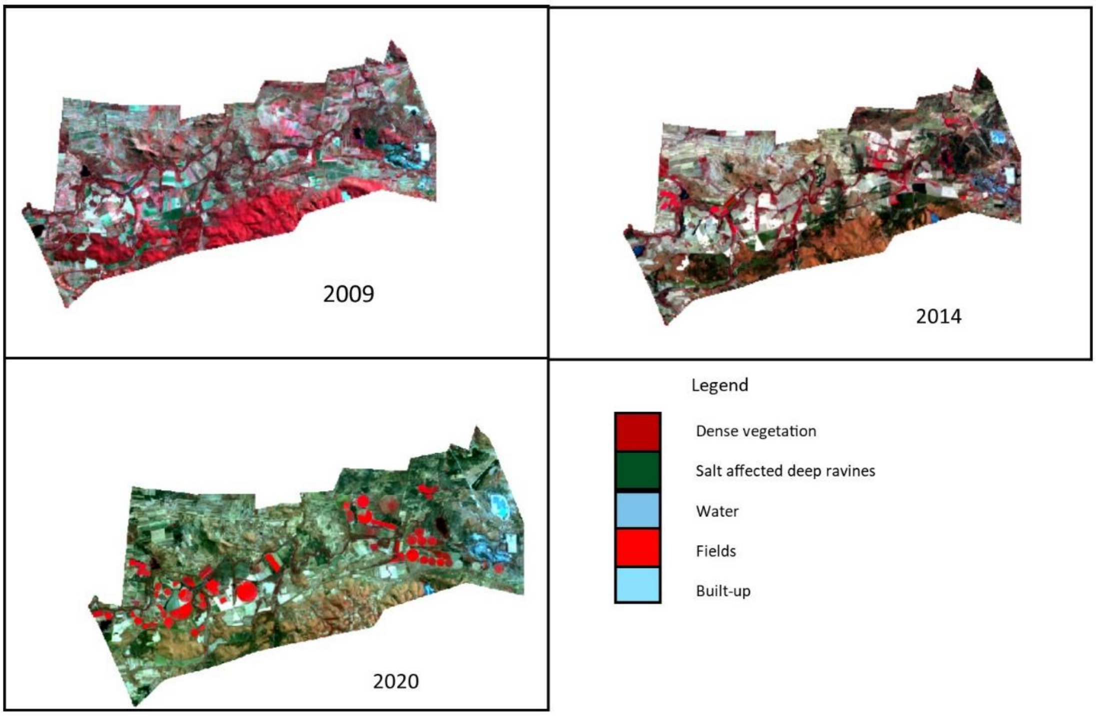


Fig 4.2.1 aboves shows the False Color Composite maps for Bindura ward 21 for year 2009 , 2014 and 2020.

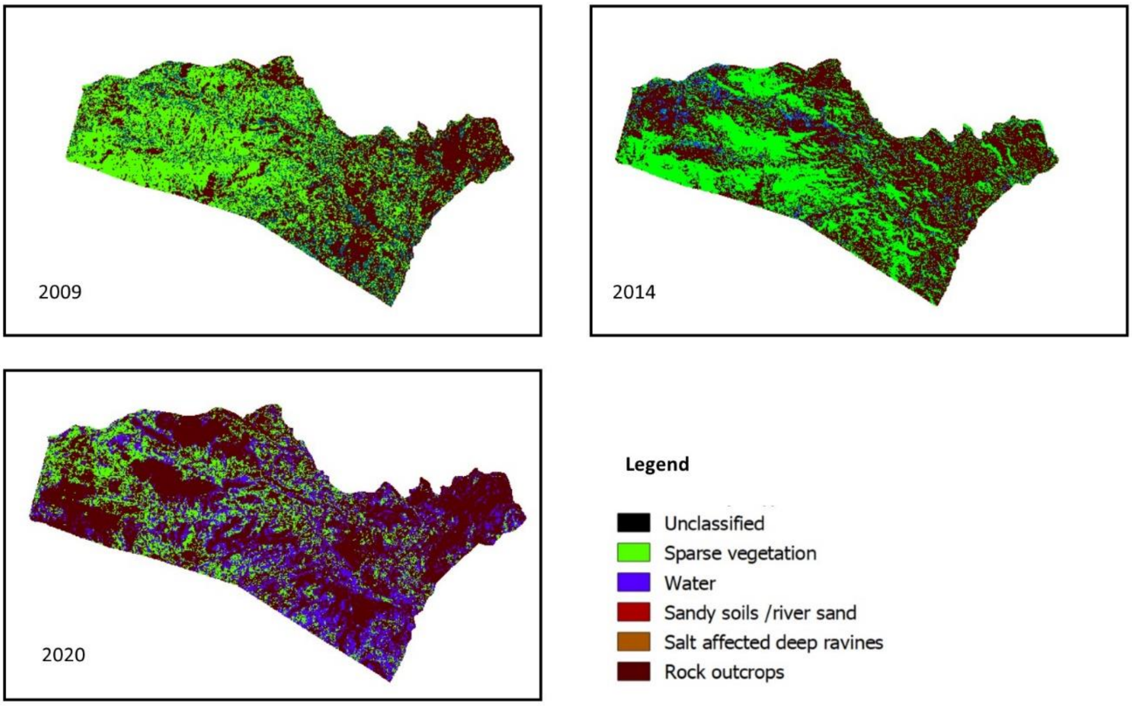


Fig 4.3 illustrates supervised classification images for Mudzi ward 14 for year 2009 ,2014 and 2020.

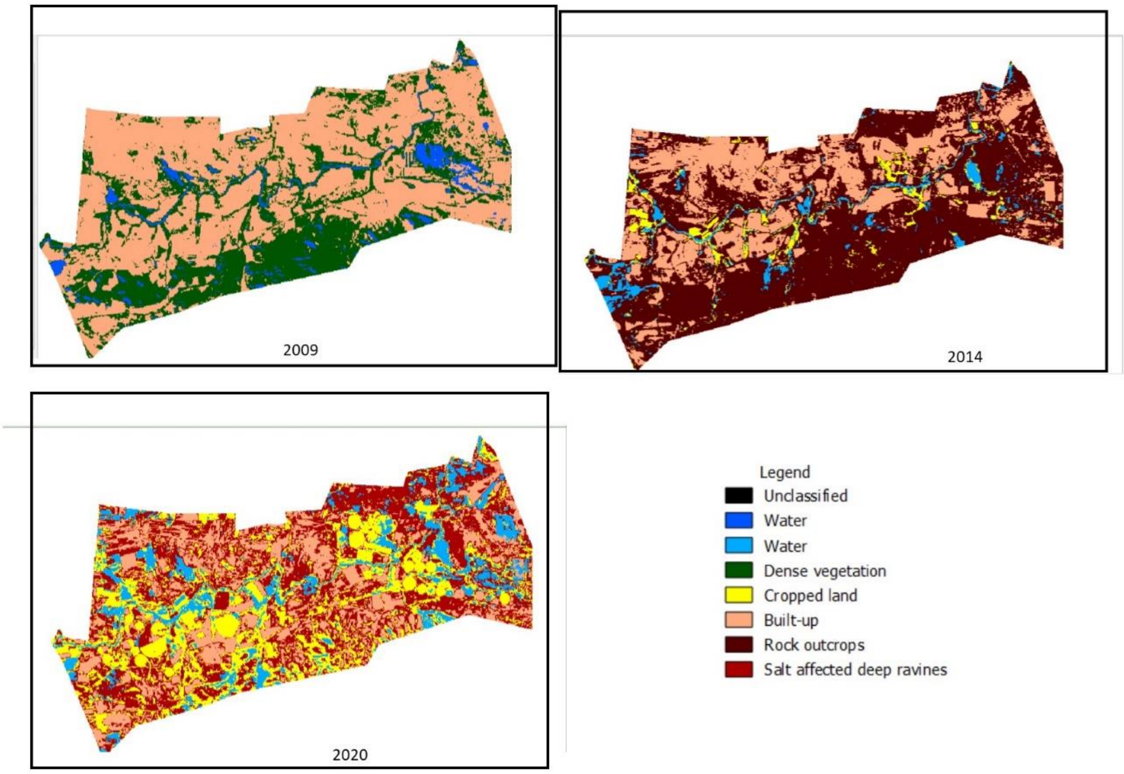


Fig 4.3.1 Depicts supervised classification for Bindura ward 21 for year 2009 , 2014 and 2020 .

Chapter 5

This chapter seeks to sum up the major findings made by the study. The summary is presented in the form of answers to the research questions of the study. False Colour Composite maps have been generated for 2009, 2014 and 2020 and these helped to present factual data and information that led to certain outcomes which will be discussed in detail in this chapter.

Land degradation

According to the satellite images in fig 4.1 and fig 4.1.2 there is a progressive loss of the intrinsic or natural quality of land. The activities of artisanal small scale gold mining in Mudzi ward 14 and Bindura ward 21, have resulted in land degradation through the deterioration of vegetation where dense vegetation is disappearing more and more. of vegetation and soil erosion; rendering affected lands less valuable in terms of their economic value for instance salt affected deep ravines which are more common in Mudzi ward 14 than Bindura ward 21. Ravines are intricate networks of large gullies with depth ranging from 3 metres or more and affected by extreme form of mass soil erosion. The major difference in the two selected areas is centred on the soil type, Mudzi ward 14 is characterised by red soils which are very fine and sticky when wet so rehabilitation on their own to their prior state takes time compared to sandy soils in Bindura which can fall back into place easily. With the rate in which gold mining is being done in these areas land will deteriorate more and more. This is worsened by the extreme summer temperatures, high wind velocity experienced in Mudzi ward 14 which makes it more vulnerable to land degradation. So the artisanal miners are accountable for this as they create the gullies /ravines.

Deforestation

Deforestation is also prominent in the areas selected for the study. Artisanal small scale gold mining in these regions has led to clearing of large tracts of forest cover, overturning of the vegetation leading to a change from dense to light vegetation cover. Consequently, mining communities in the Bindura ward 21 and Mudzi ward 14 are characterized by excessive deforestation, and this is most likely lead to desertification if artisanal progresses at this rate.

Water pollution

Findings of the study depict that rivers and streams which hitherto served as source of water for drinking and other domestic purposes can no longer be used for such purposes owing to the activities of artisanal mining. Surface water is increasing as shown on the supervised classification images as miners dig deeper on their quest to find gold belts, eventually they will reach the water table, as thy have primitive ways which they employ to manage water, it is just pumped out on to the surface. The water contains chemicals from blasting dynamites hence it's not available for use for animals or even plants as it contains more salts and corrosive elements from the gold separation processes. For the two regions (Bindura ward 21 and Mudzi ward 14) there is an increase in surface water as a result of artisanal small scale gold mining which unfortunately isn't available for other uses as it is polluted.

Shift in land use.

There is also a significant shift in land use especially for Bindura ward 21 were Agriculture is becoming more prominent, wastelands which are a product of artisanal gold mining in this regions are being turned into fields which is good progress , land will be eventually be rehabilitated .Since Bindura is in region 2A the area receives rainfall average of 750-10000mm per year which supports agriculture unlike Mudzi which is in a relatively dry receiving rainfall between 450-650 mm per year . So when the mining cycle ends land is left idol without productive uses.

Emergence of poor quality ecosystems

These are supported by the Normalized Difference Vegetation Index (NDVI) images where NDVI values are decreasing more and more, barren land, rocks , unhealthy vegetation are the prominent characteristics of these sites .

Chapter 6

RECOMMENDATIONS AND CONCLUSIONS

Land reclamation

Together with professionals in land reclamation, the District Assembly can embark on land reclamation exercises which have the potential of putting degraded lands back to a state in which they can once more be used for agricultural and construction purposes. This would involve the refilling of the exposed mined pits and trenches as well as the application of organic and inorganic fertilizers to regain the soil fertility. Furthermore, tree planting exercise could be adopted after refilling to give cover to the exposed land. In order to get the resources to finance the project, the Assembly can collaborate with the various affected communities and if possible to levy them in order to get some financial assistance. This can be done in the short term to mobilize funds. In the long term, it is suggested that, it should be considered in the registration of the small scale 68 miners that an amount would be paid by the miners towards land reclamation exercise.

Policy Formulation

Bottom-up approach in mining policy formulation, monitoring and regulation: non-involvement of the people who are to be affected by a policy has often led to best laws and policies failing to achieve their objective. It is the case in the mining sector that, most policies are made at top level for implementation without involvement of the local people. Such policies often fail as indigenes see them as an imposition and are not committed to supporting the course of such policies. As a move away from top-down approach to bottom-up approach, the researchers suggest a representation of chiefs and elders in the mining licensing process rather than as it is the case now, merely serving them with notice of grant of concession or mining license. Government should engage in dialogues with artisanal small scale miners and community leaders on the way forward rather than unsustainable approach of using military and police to ban their mining activities .

Environmental Monitoring through the use of GIS and Remote sensing

GIS "IS" and the future of every environmental monitoring system worldwide. GIS provides a valuable tool for information analysis, automated mapping and data integration. The GIS tools are easy to access large volumes of data. Remote sensing is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them. The use of GIS in EIA process is common for scoping in terms of time and money relative to the time and budgets allocated for EIA preparation and especially for scoping studies. Most of the environmental issues can be handled properly with the use of GIS techniques (Schaller, 1990). With GIS one can detect the future trends of the deterioration of the environment and the rate at which it occurs and governments can act accordingly to cope with the threatening changes accordingly.

CONCLUSION.

In conclusion, the research was done to show the changes on the environment through GIS and Remote sensing. The impact on the environment as a result of artisanal mining is largely to the negative side as there is land degradation, water pollution amongst other things discussed in the whole project. However, with proper recommendations suggested by the researcher adverse impacts on the environment can be minimised.

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