UNIVERSITY OF ZULULAND

An analysis of the land rehabilitation programme of the Tronox mine: Environmental justice and the community of Gobandlovu.

By

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ORIGINALITY DECLARATION

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DEDICATION

This project is dedicated to my family. Their prayers gave me the courage to continue with this research and sustained me through the most difficult times of this academic journey, which has come to its logical conclusion.

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LIST OF ABBREVIATIONS

LSM	Large scale mining
USD	United States Dollars
DMR	Department of Mineral resources
GDP	Gross Domestic Product
MPRDA	Mineral and Petroleum Resources Development Act
NDVI	Normalised Difference Vegetation Index
EIA	Environmental Impact Assessment
EJ	Environmental Justice
DJ	Distributive Justice
RJ	Restorative Justice
IBRD	International Bank for Reconstruction and Development
GIS	Geographic Information System
LED	Local Economic Development
HDSAs	Historically Disadvantaged South African's
GHGs	Greenhouse Gasses
CM	Centimetre
KM	Kilometre
MDGs	Millennium Development Goals
RETR	Retrogade
SQMK	Sequential mann kendall
NEMA	National Environmental Management Act
KZN	KwaZulu Natal
GOSTS	Russian-"*Gosudarstvennyy standart*"

CTAE	Guinean- *"Comité Technique d'Approbation Environnementale"*
ESIA	Integrated Social and Environmental Impact Assessment
BGEEE	Guinean-*"Bureau Guinéen des Etudes et Evaluations Environnementales"*
GAC	Guinea Alumina Company
MEEF	Guinean- *"Ministère de'l'Environnement, des Eaux et Forêts"*

ABSTRACT

The aim of the study is to analyse the land rehabilitation programme of the Tronox mine at Gobandlovu. In pursuit of this aim, the objectives of this research are to (a) track the process of rehabilitation in Gobandlovu using Remote Sensing, (b) establish if the Tronox rehabilitation programme is in line with MPRDA guidelines and (c) explore the perceptions of the community of Gobandlovu towards the Tronox rehabilitation programme. To achieve these, the research utilised a mixed methods approach, in the form of the explanatory sequential design. Data was collected using remote sensing techniques to download satellite images of the study area and then later analysed using GIS software. Remote sensing techniques were used to track and detect change through the land rehabilitation process, in which yearly mean averages were downloaded and analysed on ArcMap to visualise the normalised vegetation index of the period from 2002 to 2018.The spatiotemporal yearly mean averages were then classified in ArcMap to track the change in the two classes of bare soil and vegetation over the 17 years' period (2002-2018). The second part involved the use of qualitative techniques. This was done through field observations as well as the administration of qualitative questionnaires on the residents of Gobandlovu and the officials of Tronox mine. While the results have shown that Tronox was able to rehabilitate the land it had mined on, it did not successfully fulfil the dictates of the principles of environmental justice in relation to the community of Gobandlovu. This is because most of the respondents interviewed stated that, not only were they not integrated in the whole process of mine rehabilitation, they have also not fully benefitted from the mining. This suggests that, Tronox attempted to achieve restorative justice but the same cannot be said about distributive justice.

Key words: Gobandlovu, post mine rehabilitation, environmental justice

CHAPTER ONE: INTRODUCTION AND ORIENTATION TO THE STUDY

1.1 Introduction

South Africa is globally well known for its Large Scale Mining (LSM) industry which is ranked the 5th largest in the world (Baxter 2015). With an estimated mineral base of 2.5 trillion USD, South Africa is the largest exporter of platinum group metals, chromium and manganese ores (Antin, 2013). The Department of Mineral Resources (2015) states that the mining industry has been the backbone of the country's economy for nearly 150 years and it has contributed immensely to shaping the socio-economic landscape of South Africa. The industry continues to play this role with its contribution towards the country's Gross Domestic Product (GDP), foreign direct investment, state revenue, infrastructure development and employment (Baxter, 2015; Department of Mineral Resources, 2015).

Mhlongo and Dacosta, (2016) state that as a result of South Africa's long history of mining, the country has many abandoned mines that are currently the major source of various environmental and social problems, which has led the government to come up with legislation to deal with these impacts of mining. In 2002 a new Act the Mineral and Petroleum Resources Development Act [28 of 2002] (MPRDA) was passed by the government in order to make it compulsory for mining companies to rehabilitate after operations had ceased. As a result of this Act, all mining companies are required to set aside financial provision for the discharge of their rehabilitation obligations, which can be returned to them on the issuing of a closure certificate by the state regulator (Krause, 2014). Mine rehabilitation means putting the land impacted by the mining activity to a sustainable usable condition. It recognises that the restoration of what was previously there is simply impossible even with current best practice. This definition (and implied intention) includes the concepts of minimisation of loss of land use capability and of net benefit to society (Krause, 2014).

There are various methods of tracking land rehabilitation after mining has occurred, in an attempt to monitor the recovery of the site towards the long-term post-closure land capability goals. These include, first, quality monitoring of both the shallow and deep aquifers against the parameters required by the law as stipulated in MPRDA. Second, is erosion monitoring. This takes the form of developing a representative reference

site on the disturbed footprints and undertaking visual and topographic assessments to determine erosion rate, using standard erosion monitoring techniques. This is undertaken once a year at the end of the wet season for a five-year post-closure period (Evans, 2000). Therefore, this research study tracks and analyses the rehabilitation programme of the Tronox mine in Gobandlovu, “this rehabilitation programme began at the end of 2013 - early 2014 and ended in 2018” (Tronox mine site manager, 2019).

1.2 Problem statement

Section 24(a) of the South African Constitution states that everyone has a constitutional right to live in an environment that is not harmful to their health and wellbeing (this legislation supersedes all legislation) and this is why the MPRDA was enacted (Swart, 2003). Section 24(a) of the Mineral and Petroleum Resources Development Act (MPRDA of 2002), states that mines are required to abide by the South African Constitution and Common Law which requires that mine operations and closure activities be carried out with due diligence and most importantly to care for the right of others (Swart, 2003). For the present purposes, a 2018 visit to Gobandlovu (in which there is a former Tronox mine) by the researcher led to informal conversations with the residents of the area, who were generally not happy about the status of their land after mining. This triggered to researcher to investigate if the sentiments of the residents were justified and if indeed Tronox mine met the mine rehabilitation requirements as stipulated in MPRDA. This led to this study, which tracks the rehabilitation programme of Tronox mine at Gobandlovu in terms of checking if it is on track and in line with the MPRDA. It does so using Remote Sensing algorithms/techniques, which were complemented with surveys and interview data.

1.3 Aim and objectives

1.3.1 Aim

The aim of the study is to analyse the land rehabilitation programme of the Tronox mine at Gobandlovu using the environmental justice framework.

1.3.2 Objectives

(a) To track the process of rehabilitation in Gobandlovu using Remote Sensing.

(b) To establish if the Tronox rehabilitation programme is in line with MPRDA guidelines.

(c) To explore the perceptions of the community of Gobandlovu towards the Tronox rehabilitation programme.

1.4 Significance of the study

As the study assesses the implementation of mining legislative guidelines of the MPRDA, it is anticipated that it will highlight whether mining companies like Tronox properly abide by these rehabilitation guidelines or not. This will contribute to existing information in the field of Geography and Environmental Studies in terms of showing how mining companies respond or fail to respond to their responsibilities after mine closure. It is also anticipated that the recommendations of the study could help mining companies in future in terms of addressing community needs and concerns around rehabilitation.

1.5 Outline of the study

This study is constituted of six chapters. This chapter serves as an overview of the whole research study, its addresses the overall aim and objective of the research conducted, and also gives a breakdown of the research by giving an overview of each chapter.

Chapter 2 discusses the theoretical framework which is Environmental justice. This theoretical framework corresponds directly to the core objectives of this study. Environmental justice principles are intertwined with the aim of this study and then linked to the objectives to produce a cohesive perspective.

Two environmental justice principles are used in parallel to the objectives of this study, first is distributive justice, which is concerned with the distribution of environmental goods and services across social groups. The second principle is restorative justice which is concerned with corrective actions being taken if there are instances of ecosystem degradation (Aragão and Cliquet, 2016; Stephens and Bullock, 2008).

Chapter 3 focuses on literature that guides this study. It starts from the international perspective, to the African perspective and then the South African perspective. International experience on rehabilitation is drawn from studies in Australia, Chili, Romania and Russia are used from the global front, while the African one is from Ghana and Guinea. The South African mine rehabilitation experience is derived from various sources. **Chapter 4** discusses qualitative and the quantitative approaches to the study while **Chapter 5** discusses the results of the study, with reference to the

objectives and **Chapter 6** is the conclusion of the study and suggestions or recommendations emanating from it.

1.6 Conclusion

This chapter has introduced the whole study by providing the background to the study, discussing the problem statement and outlining the aim and objectives. The chapter also provided a definition of rehabilitation and examples of it. The legislation that addresses post mine rehabilitation (MPRDA Act of 2002) was discussed and linked to the problem statement of the study as well as the aim and objectives. Finally, the chapter described the chapter outline and structure of the whole thesis.

CHAPTER TWO: THEORETICAL FRAMEWORKS

2.1 Introduction

This chapter discusses Environmental Justice (EJ) and how it is utilised as a theoretical framework in this research. The first part of the chapter defines EJ and the second part discusses its two principles, these being distributive justice and restorative justice in order to provide insights in this study.

2.2 Defining Environmental Justice

Environmental justice is a concept that links environmental health to the rights debates around access to a healthy environment. It fundamentally deals with the distribution of environmental goods and harms and looks at who bears those harms and who is responsible for creating these harms, in both a practical sense and also in terms of policy decisions (Stephens *et al*, 2008). This concept is important in this study, whose aim is to analyse the post mine rehabilitation programme by the Tronox mine, such that, issues like the pollution and environmental disturbance created by the Tronox mine, the involvement of community members in key decisions regarding the mining and rehabilitation programmes, among others, will be analysed. There are two main principles of EJ and these are distributive justice and restorative justice.

2.3. Distributive justice (DJ)

Distributive justice is a form of social justice more often associated with environmental sustainability, it requires granting everyone equal access to the benefits of the ecosystem, without discrimination based on price, economic capacity, ownership, etc (Schlosberg, 2013). With regard to the case study of Gobandlovu, South Africa has legislation that caters for environmental issues and that legislation is the Minerals and Petroleum Resources Development Act of 2002 (MPRDA) which is recognised under the constitution (Swart, 2003). The MPRDA stipulates that, all South Africans have a constitutional right to live in an environment that is not harmful to their health and have access to opportunities to benefit from the environment (Swart, 2003). This requirement goes beyond a mere proclamation of equal rights to nature, as it requires state intervention to ensure effective access by vulnerable citizens (Clough and Bell, 2016).

The principle of distributive justice entails that benefit and burden sharing activities are necessary to achieve material equality and ensure distributive fairness (Ubeda, 2014). This principle will assist the study to address objective one, which seeks to track the process of rehabilitation in Gobandlovu using Remote Sensing. The study tracks the progress of the Tronox rehabilitation programme over the period from 2002 to 2018. It evaluates if environmental burden and benefit sharing was practiced by Tronox and also if the local municipality made an attempt to protect the citizens of Gobandlovu from any environmental harms that would result from the Tronox mining activities and rehabilitation programme. In addition, the principle of distributive justice assists this study to address objective two, which analyses if the Tronox rehabilitation programme is in line with MPRDA guidelines. The research uses MPRDA guidelines that have stipulations related to issues of environmental burden sharing as well as environmental benefits sharing.

Moreover, distributive justice assists the study to address objective two. Analysis of results from the NDVI yearly mean and the other GIS data will assist this study to assess the land cover changes (whether or not land rehabilitation has occurred) in the study area. Overall, testing if redistributive justice has been attained will be done by obtaining and analysing the views of the community of Gobandlovu. It must be remembered that, redistributive justice has more to do with social justice and therefore what the people say (their perception) will provide a general idea of whether or not redistributive justice has been achieved. Although it is understood that perceptions may be subjective, they are still indicative of the views and feeling of power in terms satisfaction, happiness and anger, among others. Thus, the views of the community will be basis for assessing or testing redistributive justice in this research. This is discussed in the analysis chapter (chapter 5)

2.4 Restorative justice (RJ)

Restorative justice requires corrective actions to be taken in case of ecosystem services degradation or loss (Stephens *et al*, 2008). Corrective actions can take the form of full restoration of degraded ecosystem services or habitat creation (the creation of equivalent services through environmental engineering), both are intended to correct the negative effects by replacing lost ecosystem services with new ones (of the same or of equivalent nature) (Cotton, 2015). This principle is relevant in this research, because it provides the lens to address objectives one and two. Concerning

objective one, which tracks the process of rehabilitation in Gobandlovu using Remote Sensing, this principle is useful, because findings from the study will show whether the mining rehabilitation programme of the Tronox mine has occurred.

The researcher believes that restorative justice provides an analytical framework because, it provides a guide in terms of what to look for when one assesses the overall Tronox rehabilitation programme with regard to objective two. As already discussed the data gathered and analysed through GIS like time series analysis assists the study to project a clear picture of how this rehabilitation programme went in its different phases. In this respect, this principle will assist the study to look at the vegetation cover that was interrupted by the Tronox mine. Then the study will assess whether the Tronox mine has had corrective measure to replant that vegetation. The MPRDA guidelines will be utilised again under this principle.

Overall and given that EJ, focuses on environmental goods as well as winners and losers in the distribution of such goods (Stephens *et al*, 2008), the views of affected people are important. As a result, the general notion of EJ, will be applied to assess the perceptions of the people of Gobandlovu towards Tronox's operations in Gobandlovu. This address objective three of the study, which explores the perceptions of the community of Gobandlovu towards the Tronox mine's rehabilitation programme.

2.5 Conclusion

This chapter discussed environmental justice used in Chapter two and five as a theoretical framework to address the aim of the study. It then focussed on the two principles of EJ, the first being distributive justice and then restorative justice. Within distributive justice, the chapter addressed objectives one, two and three. The principle of restorative justice will assist the study to address objectives one and three. Testing these concepts will be achieved by intertwining the results of the study against these concepts of environmental justice.

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

This chapter focuses on the review of literature on which this study is based. It starts by discussing mining from a global context, by referring to similar mining cases from Australia, Chili, Romania, and Russia in the global perspective then Ghana, Guinea and South Africa for the African perspective. This is followed by an analysis of mine rehabilitation experiences in other contexts. Finally, the chapter discusses community perceptions of mining rehabilitation programmes.

3.2 A global context of mine rehabilitation

Mine rehabilitation is a global phenomenon, countries like Australia, Romania, Russia and Chili have laws and programmes which ensure that rehabilitation is undertaken. In Australia for example, during the initial planning of mine rehabilitation, the focus is on identifying existing groups and organisations within the community who are already engaged in similar activities (Minerals Council of Australia, 2015). Groups such as Land care, Greening Australia, farming organisations and custodians of traditional land practices possess important local knowledge which can assist in minimising the negative impacts of mining and enhance the chances of successful rehabilitation. Much of this early phase in rehabilitation planning is about establishing where there are gaps in knowledge and identifying research programs or site-specific trials to provide critical information. Consultation with key stakeholder groups at this stage can result in better targeted research and trial programs, and enhance the potential transfer of knowledge into community projects. In areas where extensive clearing has taken place, such as agricultural regions, this may result in rehabilitation programs being integrated into broader regional land management projects (Ledwaba and Mutemeri, 2018).

During operations, consultation is the second step, with the key focus being on engaging the community as well as regulators on issues such as development and review of development plans, and building the local community's capacity to assist in the rehabilitation. Seed collection and storage, nursery production of seedlings and control of invasive species should be used as activities to provide community engagement (job creation) and to develop local businesses (Minerals Council of Australia, 2015).

The third step is consultation during mine closure. Planning for rehabilitation is undertaken in the early stages of project development and is developed in the context of the overall site closure objectives. During mining, research and site trials enable the rehabilitation program to be modified to reflect site specific parameters. At closure, the final landforms are created and the progressive rehabilitation program extended to include the remaining areas of disturbance. The most important elements of the rehabilitation programme following closure are the refinement of the success criteria and the establishment of a long term monitoring program (Minerals Council of Australia, 2015).

In the lead-up to mine closure, closure criteria are needed to demonstrate the success of rehabilitation. Both regulators and the local community can play an important role in the establishment of the criteria and the monitoring methods chosen to assess performance. This is particularly important if components of the closed mine site are to be utilised by the local community. There may also be a role for the local community to play in the long-term monitoring of the success of the rehabilitation programme (Minerals Council of Australia, 2015).

Another international example around land rehabilitation after mining is Romania, This was evident after 1997, when the number of coal mines that were closed increased rapidly. The outcome of financing closure of mines is that large surfaces of land and many buildings became abandoned. Closure of the coal mines had a negative impact on the areas in which they are located. The socio-economic structures of these areas were severely affected and the degradation of the environment made these communities unattractive for future redevelopments. Even though some former mining sites were environmentally rehabilitated, contamination of many other areas still remained a major problem that contributed to the further decay of the communities where they are located (Mukhopadhyay and Sinha, 2006).

A major environmental problem that was addressed when coal mines were closed was the pollution of ground and underground water. Most of the coal was extracted through the open cast pits and the precipitation water accumulated at the bottom of these sites. In many cases, the water was contaminated with particulates, and posed a threat to underground water too. The approach to this problem was either to preserve the ponds

or to fill them with soil. If the ponds did not pose a risk for people, animals or the environment, and the level of exposure was reduced, the accumulation ponds were preserved, although access to them was restricted (Hamlin, and Cobârzan, 2006).

In other cases, filling the ponds was part of the strategy to level the terraces created through the coal extraction process. Other measures were also taken to clean the contaminated underground water. The approach was to collect the underground water, treat it for metal particulates and then discharge it into local rivers. Terraces created by the extraction of lignite had a steep slope angle, which made difficult the use of the land. Therefore, an important focus was paid on reducing the angle of the slope and on levelling the ground (Romanian Ministry of Economy and Commerce, 2006).

To the two above example can be added that of Russia. According to the Vershinina (2003) legislation requirements regarding mine closure and rehabilitation in Russia exist within regulations and federal law of the country. It is contained in legislation titles such as, subsoil legislation, land code legislation and environmental protection legislation. Top soil protection, use and conservation and rehabilitation of previously mined land is also under the state. In general, Russian legislation states that land disturbed by mining activities must be rehabilitated and mine closure should follow after a well-executed rehabilitation plan (Vershinina, 2003). There must be a detailed closure and rehabilitation plan prepared before actual mine closure. Other technically specific requirements for a successful mine closure and rehabilitation plan are as follows:

• Topsoil may be removed and stored as practical, with the topsoil's thickness determining soil fertility. If it's in the forest, the topsoil may not be removed if it is of a thickness of less than 10 centimetres.

• If the topsoil was kept for more than two years, then it should be stored for replanting and sowing, with rock stability being taken into consideration when determining the heights of the slope angles and dumps. According to the sets of standards known as "GOST's" (*Gosudarstvennyy standart)* rehabilitation has two stages, those being technical and biological. Technical includes – resloping, dumps, closing of ponds and dams, prevention of erosion, constructing a drainage system and covering the area with soil. Biological includes – planting/sowing which is determined by the final planned land use (Vershinina, 2003).

While reviewing Chilean mine rehabilitation and closure legislation, Sanzana et al. (2015) noted that Environmental Impact assessment (EIA) obligations were introduced in 1994 that did not specifically address mine closure but it did stipulate that new mining projects include the closure phase in their planning. Just like in South Africa, the milestone for Chilean legislation came in the form of updated EIA regulations (Law 19.300) in 2002, where for the first time there was a requirement for all mining operations to present closure plans to the national mining Geology service (Servico nacional de Gergia y Mineral or Sernageomin), all mining firms were required to file closure plans with relavant authorities by 2009 (Sanzana et al 2015)

Closure plans in 2009 focused on stabilising remaining mine wastes as well as safety and health issues, issues regarding environmental impact were not covered because they were considered to be outside the jurisdiction of mining Geology service (Sanzana et al. 2015). There was no requirement to indicate costs regarding closure implementation measures, which changed in November 2015 when a new Chilean law 20.511 was introduced which stipulated that mining firms establish financial assurance to the government that would be dedicated to ensuring complete compliance of closure obligations by mining firms, it obliges all mining companies under the mining authority (Brockering, 2015)

In Africa, there are also examples of countries which have engaged in successful land rehabilitation after mining. For example, in Ghana, the land reclamation, after gold mining activity, was conducted by AngloGold Ashanti Company, using a combination of physical, chemical and biological methods at the Iduapriem Mine (Tetteh, 2015). Restoration had been done on four old sites that were two, five, nine and eleven years old. The restoration involved different steps, of which are physical restoration with earthwork/slope-battering to create a more visually pleasing landscape. The addition of oxide material, added to bind the soil together and enhance soil stability, the amendment of topsoil, using poultry droppings, cow manure and fertilizers, that were spread over the oxide material (Festin, 2018). The creation of crest drains to limit the runoff of water and to control erosion, the establishment of a cover cap with *Puereria phaseoloides* and *Centrosema pubescens* to control erosion and the planting of seedlings of *Acacia mangium*, *Senna siamea, Gliricidia sepium* and *Leucaena leucocephala* followed by weeding, pruning, and fertilizer application Mensah

(2015) showed that a very long time was necessary to restore the fertility to a level similar to the original one (Festin, 2018).

On the other hand, Guinea has given priority to legislation with objectives relating to sustainable development. Some of the most important reform to legislation which have been implemented are the basic legal texts which include the Environmental Code, the Water Code, and the Code of Forests (Tivey *et al*, 2013). After its creation in 2004, the Ministry of Environments came with a revised mining code which introduced requirements pertaining to social and environmental impact assessments at the feasibility stage of mine planning (Bahamin, 2015). This code also demands full compliance with all of its legislation concerning mitigating mining impacts on the environment. Furthermore, a request for a permit by a mine must include social and environmental impact assessment in liaison with Guinea's environmental code and international standards accepted in the field. Forest species are also protected under this code. Within the context of achieving sustainability, Guinea integrates the principles of sustainable development into its policies and programs to reverse the current trend of environmental resource losses. These include the reduction of CO2 emissions. In 2009, the threshold for this was 1.93 tons/capita.22 (Tivey *et al*, 2013).

In 2013 a General Guide for Impact Studies was published, it clarifies the approval of EIA's (Tivey *et al*, 2013). The whole process of submitting and permitting procedures is managed by the Guinean environmental directorate. Formal review of the permitting documentation is undertaken by the *Comité Technique d'Approbation Environnementale* (CTAE), which is a multi-disciplinary team made up of various ministries relevant to that particular project. The Ministry in charge of an environmental department issues the final environmental compliance certificate (Tivey *et al*, 2013). For example, the Boke Mine, Rail and Port Project, also known as the Guinea Alumina Company (GAC) which is a bauxite mining and associated infrastructure project in Guinea (Bahamin, 2015) has followed the rehabilitation process. A case in point is that, in 2008 an integrated social and environmental impact assessment (ESIA) for an integrated bauxite mine and alumina refinery operations in the northern part of the concession, along with associated infrastructure, rail spurs, and port enhancements, was submitted to, and approved by, *Bureau Guinéen des Etudes et Evaluations Environnementales (BGEEE) of the Ministère de'l'Environnement, des Eaux et Forêts (MEEF) (Bahamin, 2015).*

Some of the key measures proposed by GAC based on research conducted by the Wild Chimpanzee Foundation (WCF) to reduce impacts on species affected by mining include, protecting fresh water habitats, implementing revegetation and reforestation programmes, direct environmental management measures such as reducing noise and emissions where possible; and taking into account natural habitat rehabilitation objectives as well as the needs and requirements of local communities and the Guinean authorities (Tivey *et al*, 2013).

After exploring the global and African experience on mine rehabilitation, this research now focuses on South Africa, with a specific focus on the rehabilitation programme of Tronox in Gobandlovu, Empangeni in KwaZulu-Natal.

3.3 Tracking mine rehabilitation using Remote Sensing

There are various methods of tracking land rehabilitation after mining has occurred, in an attempt to monitor the recovery of the site towards the long-term post-closure land capability goals. These include, first, quality monitoring of both the shallow and deep aquifers against the parameters required by the law as stipulated in MPRDA. Second, is erosion monitoring. This takes the form of developing a representative reference site on the disturbed footprints and undertaking visual and topographic assessments to determine erosion rate, using standard erosion monitoring techniques. This is undertaken once a year at the end of the wet season for a five-year post-closure period (Evans, 2000).

3.3.1 Change detection

In the context of remote sensing, change detection refers to the process of identifying differences in the state of land features by observing them at different times. This process can be accomplished either manually or with the aid of remote sensing software. Manual interpretation of change from satellite images or aerial photos involves an observer or analyst defining areas of interest and comparing their images from two different dates. This may be accomplished either on-screen (such as in a GIS) or on paper. When analysing aerial photographs, a stereoscope which allows for two spatially-overlapping photos to be displayed in 3D, can aid photo interpretation. Manual image interpretation works well when assessing change between discrete classes (e.g., forest openings, land use and land cover maps) or when changes are large. Manual image interpretation is also an option when trying to determine change

using images or photos from different sources (e.g. comparing historic aerial photographs to current satellite imagery) (Mishra, 2017).

3.3.2 Terrain analysis

Terrain analysis is the analysis and interpretation of topographic features through Geographic Information Systems. Such features include slope, aspect, view shed, elevation, contour lines, flow, upslope flow lines and downslope flow lines. The intention is to build mathematical abstraction of surface terrain in order to delineate or stratify landscapes and create an understanding of relationships between ecological processes and physical features, this is called classification which is how one comes to a conclusion of terrain analysis (Isioye *et al*, 2012).

3.3.3 Time series analysis

Time series analysis comprises methods for analysing time series data in order to extract meaningful statistics and other characteristics of the data. Time series forecasting is the use of a model to predict future values based on previously observed values (Li, 2018).

3.3.4 Orthophotos

Orthophotos in the form of remotely sensed images offer advantages of a conventional map product, however unlike the traditional map, Orthophotos are able to display actual ground features, not cartographic representations of those features. Their high resolution (0, 3 m) is also very helpful (Li, 2018).

3.4 Mine rehabilitation programmes and MPRDA guidelines

In South Africa the Chamber of Mines has various guidelines set for rehabilitation of previously mined land. These are discussed below, and this study will use the following guidelines;

3.4.1 Rehabilitation planning, permitting and financing

Since rehabilitation is a complex and iterative process, it requires involvement from a wide range of people to ensure smooth progress. Due to the recent developments in the mining and environmental legislative framework for authorisation in mining (which relates directly to land rehabilitation) even more complexities have arisen (Chamber of Mines of South Africa, 2007).

(a) Planning: Planning must be intertwined with the rehabilitation process, in order to integrate initial outlines based on the mine's concepts of impacts likely to occur and how they should be mitigated. As interested and affected parties come forward with comments, these initial outlines get reviewed and eventually the original plan is likely to require modification in one or two stages (Chamber of Mines of South Africa, 2007).

(b) Legal authorisation processes.

The official way in which a mine gets the acceptance of the mining activity plan by both interested and affected parties and government is through the legal authorisation process for obtaining mining rights or permit. These two groupings have the major influence in the acceptance or rejection of the mining proposal (Chamber of Mines of South Africa, 2007).

(c) Financing.

Since rehabilitation is an expensive practice, sometimes accounting for as much as 10% of the mines costs, some form of guarantee is usually required by authorities to ensure that these costs are met since they are usually incurred a period after mine closure (Chamber of Mines of South Africa, 2007).

3.4.2 Land preparation for mining

Regarding rehabilitation, the key factors to consider during the preparation for mining are, minimising the area affected by development, minimising potential future contact with toxic or materials that could pollute the environment and lastly to maximise the recovery and effective storage of profile materials that will be useful in the rehabilitation phase when mining completes (Chamber of Mines of South Africa, 2007).

3.4.3 Soil stripping

Since soil takes many years to regenerate once depleted, soil striping is very key in the rehabilitation process. All the areas that will be subjected to major disturbances must be taken note of (Chamber of Mines of South Africa, 2007).

3.4.4 Soil stockpiling

When applying stockpiling appropriate configuration is required if direct replacement is to be made. While soils placed in compact stockpiles are degraded physically and chemically in cooler/wetter climates, the drier warmer climate of South Africa does not

seem to pose the same quality reduction effects seen elsewhere (Chamber of Mines of South Africa, 2007).

3.4.5 Infrastructure removal

After mining operations are complete, certain facilities are usually surplus to ultimate land user, such as processing facilities, accommodation, and administration, transport as well as storage facilities. That is why mining infrastructure must be removed with only the reusable (e.g. offices and workshops) needing to be left uninterrupted and protected.

3.4.6 Landform changes resulting from high extraction mining, the associated environmental impacts and their remediation

If underground mining is done using long walling or pillar extraction, the back areas will be left unsupported and allowed to collapse, as a result the surface will subside. The impacts of such subsidence must be predicted by expects so that mitigation measures are taken (Chamber of Mines of South Africa, 2007).

3.4.7 Landform re-creation (spoil shaping)

Landform re-creation (spoil shaping) is the process by which the mined overburden materials are placed and moved so as to create the “desired” final topography. Cost considerations frequently prevent the full replacement of all mined-out materials back into the original excavation and, mined overburden materials must be moved and placed in an effort to create the ‘desired’ final topography. However, because of the cost implications this process is not being applied in full. This is why in many open-pit operations, the resulting topography consists of an overburden dump and an excavation (Chamber of Mines of South Africa, 2007).

3.4.8 Soil replacement

Soil replacement can commence after the final land form has been created. It is debatable as to when would be the appropriate time to replace soil and usually the recreated landform is subject to ongoing settlement for years after reshaping had been done. Theoretically this resettlement is supposed to accelerate after final pit closure because water tables are re-established, surfaces would be wet and from the consequent repackaging and compaction of deposited materials. This may result in significant surface irregularity in relation to the agreed final landform as well as impeded drainage and surface soil waterlogging issues. Early replacement of soil is a

desirable option as it's minimises the need to stockpile soil, increase stripped soil and replaced soil. Compaction has proven to be the greatest challenge to the effectiveness of rehabilitation in South Africa (Chamber of Mines of South Africa, 2007).

3.4.9 Revegetation and biodiversity re- establishment

One of the biggest challenges of mining areas are alien invasive species, that's why the key objective in the revegetation and maintenance programmes in previously mined land is the eradication or control of invasive alien species (Chamber of Mines of South Africa, 2007; Gastauer *et al*, 2018)

3.4.10 Rehabilitation monitoring

The main objective of monitoring is to ensure that agreed rehabilitation processes are followed through. Both the progress of the physical aspects of rehabilitation during the operation phase and the desired final ecosystem must be monitored carefully. Each site usually has its own varying items that should be monitored based on the closure criteria negotiated for that site (Chamber of Mines of South Africa, 2007). This review of the guidelines for rehabilitation of previously mined soil in South Africa is intended to provide a context for this study in terms of assessing which programmes have been followed and to what extent by Tronox in the area of Gobandlovu. This review starts by looking at the historical background to guidelines to mine rehabilitation. In this regard, it was noted that, in late 2000, the draft Mineral Development Bill, which was based on the White Paper on Minerals and Mining Policy, was released for public comment. The Bill introduced a new era of mineral and mining law in South Africa (Swart, 2003).

The core objectives were;

• Recognising that the mineral resources are the common heritage of all South Africans and collectively belong to all the peoples of South Africa.

• Ensure that a proactive social plan is implemented by all mining companies.

• Attract foreign direct investment.

• Ensure a vigorous beneficiation drive in the mining industry.

• Contribute to rural development and the support of communities surrounding mining operations.

• Redress the results of past racial discrimination and ensure that historically disadvantaged persons participate meaningfully in the mining industry.

• Guarantees security of tenure to existing prospecting and mining operations.

The Bill of 2000, addresses broader issues such as the transformation of the mineral industry, the promotion of equitable access to mineral resources, socio economic development and environmental sustainability. Previously South African mineral rights were owned either by the state or the private sector (Limpitlaw and Briela, 2014). This dual ownership system represented an entry barrier to potential new investors. The Bill's objective is for all mineral rights to be vested in the State, with due regard to constitutional ownership rights and security of tenure (Limpitlaw and Briela, 2014).

Then in 2002 a new Act was passed by the South African government in order to make it compulsory for mining companies to rehabilitate the land they were mining on (Marais, 2010). This Act is the Mineral and Petroleum Resources Development Act (28 of 2002), before the Act, mine closure was governed by the Minerals Act (Act 50 of 1991) (Limpitlaw *et al*, 2005). The Act has been praised by the international community as best practice (Rogerson, 2012). In relation to this Act, Krause (2014) states that all mining right holders are required to set aside financial provision for the discharge of their rehabilitation obligations, which can be returned to them on the issuing of a closure certificate by the state regulator. Further the State requires an application for a closure certificate on the closure or abandonment of the mining operation. The closure certificate can only be granted if the required documents, including a closure plan and an environmental risk report, are furnished and the environment has been satisfactorily rehabilitated. The issuing of the certificate makes the right holder eligible for a return of a portion of the financial provision once an acceptable environmental state has been reached (Krause, 2014).

Chapter two of the Act, focuses on the fundamental principles of the Act, which starts with the objectives of the Act. Section 2 (d), (f) and (h) states the following; (d) substantially and meaningfully expand opportunities for historically disadvantaged persons, including women, to enter the mineral and petroleum industries and to benefit from the exploitation of the nation's mineral and petroleum wealth; (f) promote employment and advance social and economic welfare of all South Africans; (h) give effect to Section 24 of the Constitution by ensuring that the nation's mineral and

petroleum resources are developed in an orderly and ecologically sustainable manner while promoting justifiable social and economic development (MPRDA, 2002).

The application process, whether applying for a new mining right or conversion of the 'old order' (pre-1994) mining right, requires the completion and submission of three documents, namely: mine works plan, environmental management plan and a social and labour plan. The mine works plan is a long term detailed strategic planning document describing the projected mining and production activities for the licensing period. The environmental management plan is a plan indicating how the mining operations plan to manage and rehabilitate the environmental impact as a result of mining conducted under the authority of a mining permit. The social and labour plan is a long term strategic plan focusing on Human Resources Development and Local Economic Development (LED) programmes and processes to save jobs and manage downscaling and/or closure. The Act further prescribes that the last two documents must include a comprehensive stakeholder engagement process which includes local, district and provincial government, communities directly and indirectly affected by mining operations and labour sending areas. The plan also needs to be debated and aligned to the integrated development plans of the district authority (MPRDA, 2002).

The MPRDA, Act 28 of 2002 further recognizes the need for government to promote local and rural development and the social uplifting of communities affected by mining. One objective is to ensure that holders of mining and production rights contribute towards the sustainable socio-economic development of the areas in which they are operating. A Mining Charter for broad based socioeconomic empowerment within the mining sector was mandated by the Act. The Charter sets out the major areas in which change is required, such as ownership, human resource development, employment equity, procurement, community and rural development as well as the beneficiation of minerals. It envisages to transform the industry in order that it may allow and provide for greater ownership participation; greater management control or participation; participation in procurement processes and the development of technical and managerial skills of HDSAs and the integrated sustainable socio-economic development of host communities, major labour sending areas, and of populate areas under threat of decline and abandonment as a result of past and current mining activities (MPRDA, 2002).

Section 4.4 of the Charter refers specifically to the responsibility of all stakeholders, including government, to cooperate in the formulation of integrated development plans for communities where mining takes place and for major labour sending areas. The Charter however does not have the force of the law, as it is published under section 100(2) (a) of the MPRDA, which sets the framework, targets and timetable for effecting the entry of HDSAs into the mining industry. Social and Labour Plans are the legal instrument, flowing from the Charter, that the government uses to ensure that holders of mining or production rights contribute to the sustainable socio-economic development of the areas in which they are operating, as well as the areas from which the workforce is sourced. In this document the mining operation must make explicit the approaches to human resource development (workforce skills development, career progression and achieving employment equity target) and local economic development (enterprise and infrastructure development, workforce housing and living conditions, procurement progression and the social and economic development of local and labour sending areas) that it intends to adopt. It states that the plan must be aligned with the integrated development plan of the district municipality where the mine is located and of the major labour sending areas, clearly indicating the management of down-scaling and closure of mining operations and retrenchment of the workforce and its socio-economic impacts on individuals, communities and local and regional economies. The mine must also indicate its commitment of financial resources to implement the plans (Jenkins and Yakovleva, 2005).

In October 2014, under the National environmental management act (NEMA) regulations regarding financial provision for post mined land rehabilitation, mine closure, post closure prospecting, production operation and financial assurances were stipulated in South Africa. These regulations specify what minimum content the annual rehabilitation plan must have, as well as the information from the mining company that define concurrent rehabilitation activities for the incoming year and how these activities relate to vision of closure operations as well as the objectives of the mining firm and criteria being achieved through the implementation of the plan (Failzuldayeva, 2016). Against this background of the South African legislation and its stipulations, this research will reveal whether the Tronox mine sidestepped any of these stipulations and its responsibilities pertaining to its post mine rehabilitation programme in Gobandlovu.

3.5 Impact of mine rehabilitation on the environment

Marais (2010) states that in order to gain insight into the success of this legislation in South Africa, one has to ask questions such as; has this new legislation contributed to better mine-community relations, more effective partnerships, integrated planning and Local Economic Development (LED) benefits? Marais (2013) attempts to answer these questions by concluding that although new legislation has resulted in more funds being allocated to specific local development initiatives in the Free State Goldfields, the desirability of some of the projects as well as their ability to address long term impacts of mine closure is rather questionable. The author also states that it appears as if the MPRDA Act has led to project by project approach with very little integrated planning between the role players, with the social and labour plans being little more than glorified corporate social responsibility programmes. The MPRDA (2002) affirms the State's obligation to protect the environment for the benefit of present and future generations and ensuring ecologically sustainable development of mineral and petroleum resources. Therefore, in this light this section provides a context for analysing the second objective which looks at the MPRDA guidelines to check if Tronox's rehabilitation programme respected them.

3.6 Community perceptions and mine rehabilitation programmes

In recent years, mining activities have been perceived negatively due to issues concerning their impact on the environment, such as deforestation, destruction of natural landscapes, and release of dusts, pollutants and greenhouse gases (GHGs). For instance, high metal and acid deposits from sulphur mining can lead to pollution of water sources (Ledwaba and Mutemeri, 2018), high mercury intoxication and contamination from artisanal gold mining can result in serious health hazards (Limbong *et al*, 2003; Taylor *et al*, 2005; Rajaee *et al*, 2015; Bose, 2010). Other health and safety issues associated with mining sector may include ergonomic stresses, injuries, noise, child labour, landslides resulting from mining, infectious diseases, etc. (Ledwaba and Mutemeri, 2018).

The Mining Mineral Sustainable Development Report (2002) states that mining industries significantly influence societies in which they operate. These industries are also demonstrably responsible for causing a wide range of negative environmental

and social impacts at local, regional and global levels such as disruption of river flows, degradation of land and forest resources, impacts on livelihood of local communities near mines and disturbance of traditional lifestyles of indigenous people. The mining sector in South Africa has enjoyed decades of profiteering and unchecked neglect of developmental needs of surrounding communities (Krause, 2014). Most of the communities surrounding South African mines are therefore associated with social problems that include poverty, poor health, unemployment, adult illiteracy, poor housing, family disorganization and high influx of unaccompanied migrant child labour (Krause, 2014). Recently, external forces, including globalization, the government through the Mining Charter and the MPRDA, and communities have put pressure on mining organizations in South Africa to start behaving like corporate citizens, taking social responsibility and work towards sustainable development in the areas that they operate.

3.7 Conclusion

This chapter has highlighted the literature which the study is based on, in terms of discussing mine rehabilitation programmes in other parts of the world. This provided a context for discussing mine rehabilitation in South Africa. The chapter also explained mine rehabilitation tracking tools such as change detection algorithms, terrain analysis, time series analysis and the use of orthophotos. Also discussed in this chapter are the provisions of the MPRDA of 2002 Act and how it guides mine rehabilitation in South Africa. The environmental impacts of mine rehabilitation programmes were also discussed as well as community perceptions regarding mine rehabilitation programmes. The next chapter focuses on the physical setting of the research area and the methodology used in this research.

CHAPTER FOUR: PHYSICAL SETTING OF STUDY AREA AND RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the physical setting of Gobandlovu as well as a brief profile of uMhlathuze Municipality. This is followed by an explanation of the mixed methods approach and why it was utilised in this study. There is then a discussion of the qualitative and quantitative methods and how they were used in this study. Ethical considerations around this study are also explained.

4.2 Profile of uMhlathuze Local municipality

The area of Gobandlovu is located within Esikhaleni (Esikhawini) which falls under the Municipality of Mhlathuze. The City of uMhlathuze (KZ 282) is situated on the north-east coast of the province of KwaZulu-Natal, about 180 kilometers north-east of Durban (Figure 4.1). The uMhlathuze Municipality covers 123 359 ha of land and incorporates Richards Bay, Empangeni, eSikhaleni, Ngwelezane, eNseleni, Felixton, Vulindlela, Bhucanana and Heatonville as well as the rural areas under Traditional Councils namely, Dube, Mkhwanazi, Khoza (Bhejane), Zungu (Madlebe), Somopho (Mthembu), Obuka (Biyela) and Obizo (Cebekhulu). Gobandlovu covers an area of 2.58 km² with a population of 5,271 (2,045.08 per km²) and 1,299 households with a population density of 504.00 per km² (Stats SA, 2017; uMhlathuze Local Municipality IDP, 2019).

This study was conducted in Gobandlovu, an area that is part of Esikhaleni (Mhlathuze local municipality IDP, 2019). The focus is on the rehabilitation programme of Tronox that occurred over this area. Tronox is a Global conglomerate, Its KZN Sands operation consists of a site that has been rehabilitated at Hillendale as well as the currently operating Fairbreeze Mine. The mining operation produced feed for the Central Processing Complex (CPC) in Empangeni where the concentrate was further processed to final products of rutile, zircon, high titania slag and pig iron during 2002 to 2012 (Van Jaarsveld, 2013). The rehabilitation of the residue storage facility (RSF) in 2014 to 2018 was one of the key focus areas for Tronox and was critical in achieving successful mine closure (Tronox site manager, 2019). The Tronox mine is located on the north coast of the province of KwaZulu Natal in South Africa, and it comprises of an area of 287.8 ha in size (Van Jaarsveld, 2013).

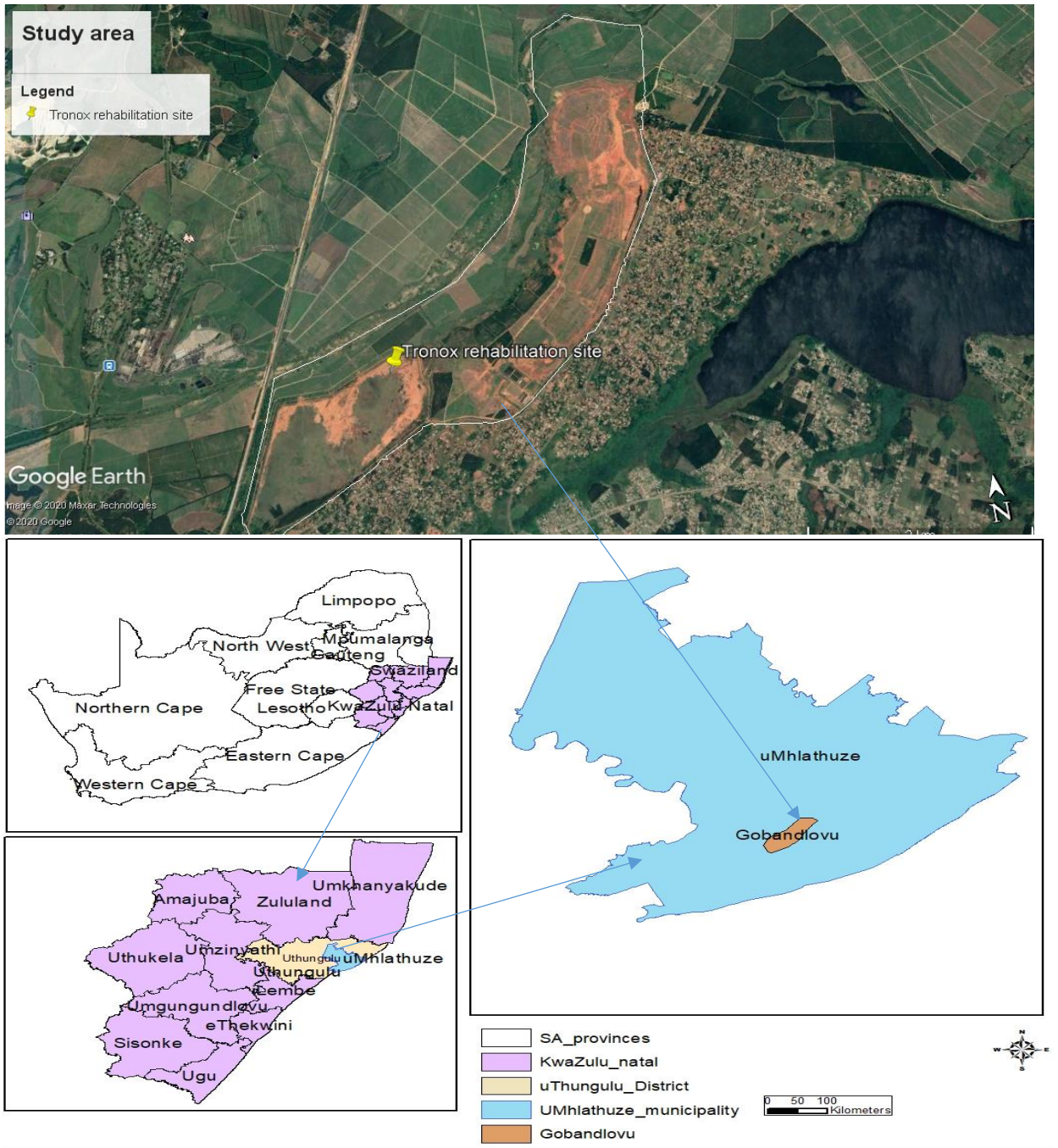

Figure 4.1: Map of study area.

4.3. Research methodology

Research methodology refers to the methods to be utilised in a study in order to successfully address the aim and objectives of that study (Creswell, 2014). It is the procedures, instruments and techniques used in combination to arrive at a conclusion that addresses the study's overall aim and prove that validity of the research (Creswell and Plano, 2011). This study adopted mixed methods, which involves combining or

integration of qualitative and quantitative research and data in a research study (Creswell, 2014).

4.3.1 Mixed Methods

Qualitative and quantitative research methods generally provide different types of information (open-ended data in the case of qualitative and closed-ended data in the case of quantitative). Further, if it is assumed that each type of data collection has its limitations and strengths and therefore the “mixing” or blending of data, provides a stronger understanding of the problem or question than each method by itself. This idea is at the core of “mixed methods research” (Creswell, 2014).

There are three basic types of mixed methods. First, convergent parallel mixed methods approach (in which the researcher collects both quantitative and qualitative data at the same time, analyses them separately, and then compares the results to see if the findings confirm or disconfirm each other) (Creswell, 2014). Second, explanatory sequential mixed methods approach involves a two-phase project in which the researcher collects quantitative data in the first phase, analyses the results, and then uses the results to plan (or build on to) the second qualitative phase. Third, exploratory sequential mixed methods approach, in which the researcher first begins by exploring qualitative data and analysis and then uses the findings in a second quantitative phase (Bell, 2015). For this research the explanatory sequential design was utilised. This method was deemed best suited to be used in this study since at first the data collection had to be collected quantitatively through GIS techniques, specifically satellite images were downloaded and analysed and then, the results of this process had to be confirmed on the field utilising 30 questionnaires under the qualitative aspect just like the explanatory sequential design dictates. Data was collected using Remote sensing techniques to download satellite images of the study area and then analysed them using GIS software. Later the research involved the use of qualitative techniques. This was done through field observations as well as the administration of qualitative questionnaires on the residents of Gobandlovu.

4.4 Research design

Figure 2.2 illustrates the explanatory sequential mixed methods approach which was used in this study. This involved first, the utilisation of satellite imagery of the study

site (quantitative), and second, interviews and questionnaires surveys were conducted on the residents of Gobandlovu.

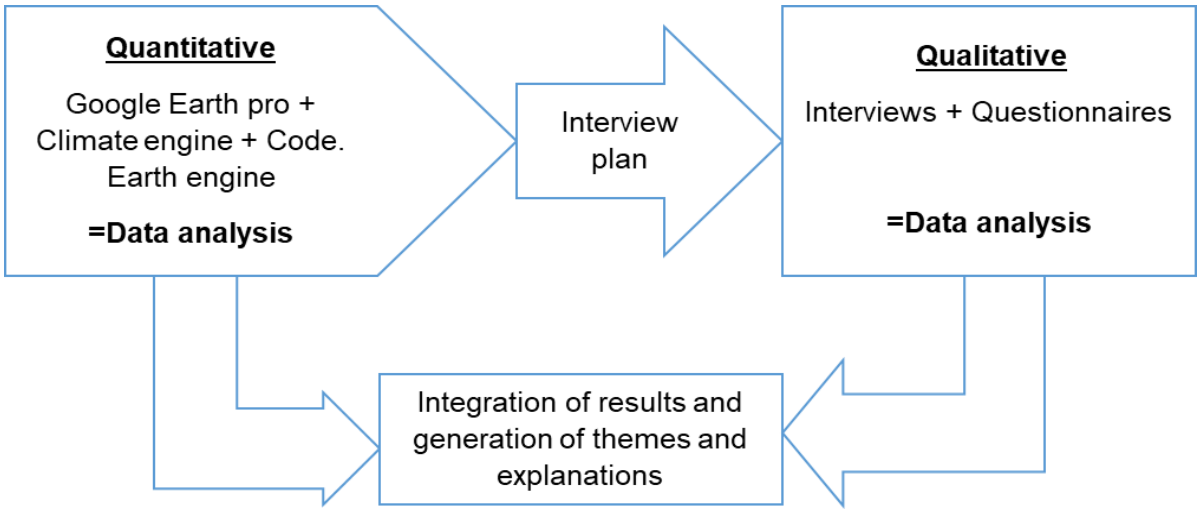

Figure 4.2: Summary of research design.

The following sections discuss in detail how both the quantitative and qualitative approach were utilised in this study in accordance with the explanatory sequential mixed methods approach.

4.4.1 Quantitative approach

Quantitative methods emphasize objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, or by manipulating pre-existing statistical data using computational techniques. Quantitative research focuses on gathering numerical data and generalizing it across groups of people or to explain a particular phenomenon (Babbie, 2010). Quantitative methods involve the processes of collecting, analysing, interpreting, and writing the results of a study (Creswell, 2014).

4.4.2 Quantitative data collection and analysis

Two quantitative methods were utilised in this study. Landsat Satellite images were downloaded online from climate engine.com, unzipped and uploaded into GIS software called ArcMap. Between April and October 2019, images starting from the year 2000 (which is the study's reference year) to 2019, were downloaded on Google earth pro. A polygon was drawn on top of the study site and then the images were saved and re uploaded to ArcMap. Then the polygon was overlaid on top of the

uploaded yearly images of the rehabilitation site in Gobandlovu. This process was repeated for all the images starting from the year 2000 up to the 2019. These steps were done in order to observe the Normalised Difference Vegetation Index (NDVI) for each image of the study site so that the vegetation characteristics of the site from the period when Tronox was still mining (2002- 2013) to rehabilitation (2014 to 2019) can be shown.

The second method involved using Code. Google earth.com. This involved the creation of a code that could be overlaid over the study area. Within this code, it was possible to clip a polygon around the study area and once again download yearly images over the study period from 2002 to 2019. In total, 17 images were downloaded and then uploaded into ArcMap software. The process was to calculate and compare the values of two classes (vegetation and bare soil), during the mining period. Images in annual succession were expected to have less vegetation values and barer soil values as mining takes away vegetation and exposes bare soil. However, during the rehabilitation period, the opposite is true since rehabilitation of post mined land requires the replanting of vegetation.

4.5 Qualitative approach

Qualitative research focuses on understanding a research query as a humanistic or idealistic approach. It is used to understand people's beliefs, experiences, attitudes, behaviour, and interactions (Creswell and Plano, 2011). Qualitative approaches to data collection, analysis, interpretation, and report writing differ from the traditional, quantitative approaches. Purposeful sampling, collection of open-ended data, analysis of text or pictures, representation of information in figures and tables, and personal interpretation of the findings all inform qualitative methods (Creswell, 2014).

4.5.1 Sampling and data collection

Purposive sampling was utilised in this study. Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources. This involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell and Plano, 2011). There is no formula for calculating sample size in qualitative research, but considerations are made by the researcher to ensure that selected cases provide adequate information

which responds to the research question (Creswell, 2014). Further, Creswell (2014), recommends a qualitative sample of between 6-30 people. In this case a sample, size of 30 respondents from Gobandlovu was made. They were selected on the basis of having lived in Gobandlovu from the year 2002 (when Tronox began mining) to 2019 (in which 2014-19 mark the post mine rehabilitation years). The assumption was made that this period of residence allowed people to be familiar with or have perception about the issues under consideration. Using GIS (ArcMap) it was determined that out of the 30 respondents, 10 lived within 30 metres to the rehabilitation site, another 10 lived within 375 metres from the rehabilitation site and the last 10 were located 750 metres from the rehabilitation site. The respondents were purposely selected in this manner so as to compare the responses of people living within different distances from the rehabilitation site, most importantly, to compare their perception regarding the impact of the post mine rehabilitation activity. A questionnaire was conducted with this sample of 30 respondents between the months of October and November 2019

Two structured interviews were organised and held with two officials. The interview with the Tronox mine's site manager was conducted in June 2019, while the interview with the official from uMhlathuze municipality fell through as the official claimed that they were not given permission by the municipality to respond to questions. The Tronox mine official was asked nine questions that were guided by the problem statement, aim and objectives of this research. Table 4.1 below summarises the qualitative sample

Table 4.1: Summary of qualitative sample.

Respondents	**Number**
Gobandlovu community members	30
Tronox site manager	01
Total number of respondents	**31**

4.4.2 Qualitative data analysis

To analyse interviews content analyses was utilised. Content analysis as defined by Maree (2014) is a systematic, replicable procedure for coding using explicit rules to compress many words of text into less context categories. The researcher first organised the qualitative data by reading through the written responses and identifying

concepts and themes. The next step was organising concepts whereby similar themes from the respondents were grouped together. The third step was sorting this data into a framework, for instance some respondents felt that they were not well integrated into the rehabilitation programme by the Tronox mine so the theme for the code of this specific response was segregated. The next step was entering this data onto Microsoft excel and SPSS to create descriptive data in the form of graphs and pie charts. In the final analysis, Figure 4.3 below summarises the whole methodology of the study as discussed in the preceding sections.

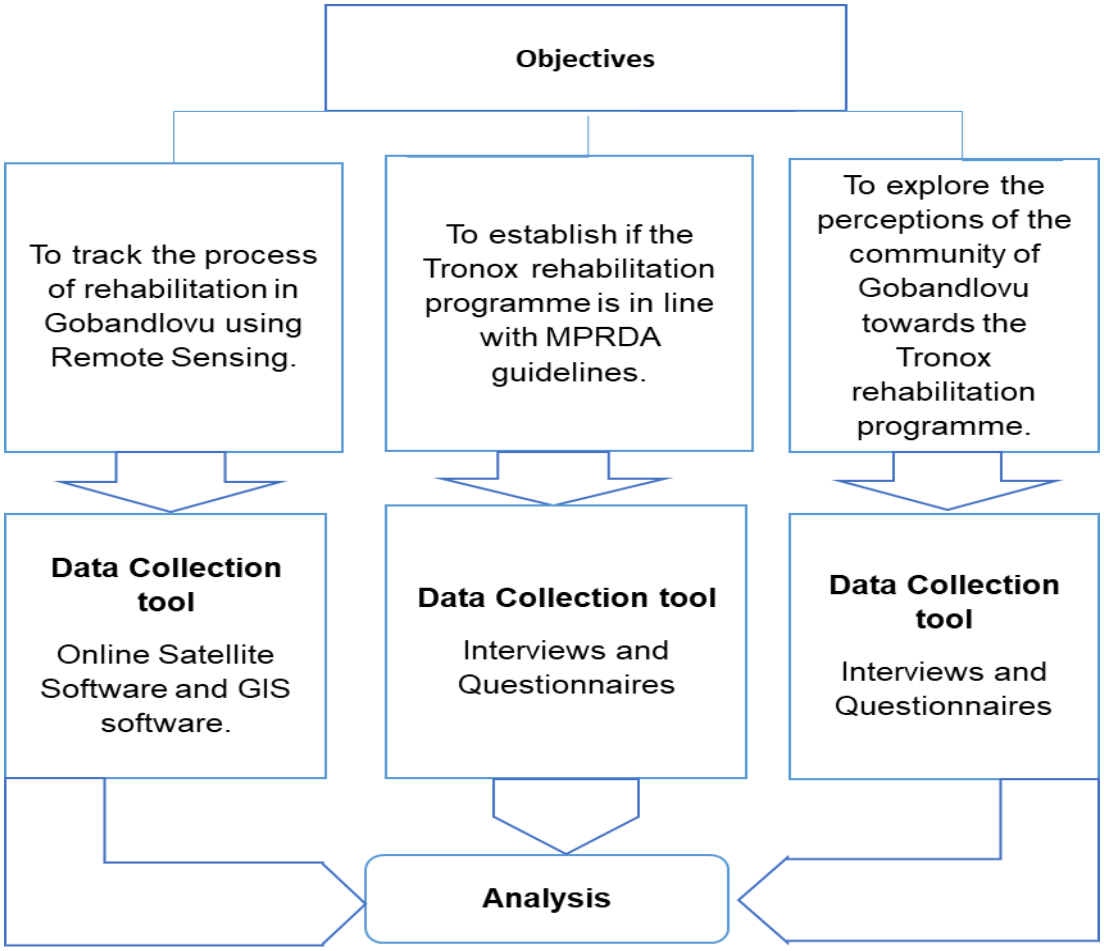

Figure 4.3: Summary of methodology.

4.6 Ethical considerations

Since the study involved human beings, ethical clearance was sought and obtained from the university. In this study all the participants were treated with respect and they willingly participated in this study and this is why a consent form was used. Informed

consent is a mechanism to ensure that people understand what it means to participate in a research study so that they can consciously decide if they want to participate. Participants were asked to willingly sign a consent form to show their willingness to contribute to the study. It was explained to the participants that their contribution was voluntary and that they could withdraw their participation anytime. In addition to this, the information which was obtained from the respondents was treated with anonymity and confidentiality.

4.7 Conclusion

This chapter described the physical setting of this study area. This was followed by a discussion of the research design and methodology in terms of the mixed methods approach and the accompanying data collection and analysis procedures, lastly the ethical considerations around this research were explained.

CHAPTER FIVE: DATA ANALYSES AND INTERPRETATION

5.1 Introduction

This Chapter builds from what has been discussed in the previous chapters. Its main focus is the analyses and interpretation of data collected both quantitatively and qualitatively. The data analysed and interpreted from this Chapter is from GIS (ArcMap), satellite images, questionnaires, interviews and site observations. After the analyses, the data was then displayed through pie charts, tables, line graphs and bar graphs. Thus, the chapter is structured as follows; the first section restates the objectives and research questions of the study, this is followed by a discussion of the demographic characteristics of the respondents so as to provide a context about the respondents. There is then the data analysis based on all three objectives. It is important to stress that the progression of the analysis follows the sequence of objectives, in which both quantitative and qualitative data is discussed for each objective in a sequential manner. Therefore, the discussion of both quantitative and qualitative data for each objective is informed by the mixed methods design discussed in the preceding chapter.

5.2 Restatement of the objectives

It is both vital and important to restate the objectives and questions of the study so as to give the reader clarity and the purpose of this study. The objections and questions of the study are as follows:

Objective 1: To track the process of rehabilitation in Gobandlovu using Remote Sensing.

Research question 1: What is the process of rehabilitation in Gobandlovu?

Objective 2: To establish if the Tronox rehabilitation programme is in line with MPRDA guidelines.

Research question 2: Is the Tronox rehabilitation programme in line with MPRDA guidelines?

Objective 3: To explore the perceptions of the community of Gobandlovu towards the Tronox rehabilitation programme.

Research question 3: What perceptions do the community of Gobandlovu have towards the Tronox rehabilitation programme?

5.3 Demographic characteristics of respondents in Gobandlovu

5.3.1 Gender distribution

The demographic characteristics of the respondents were examined in order get a better insight of the people and their perceptions of the rehabilitation programmes in the study area. Fifty (53) percent of the respondents are males while 47 percent are females.

N=30

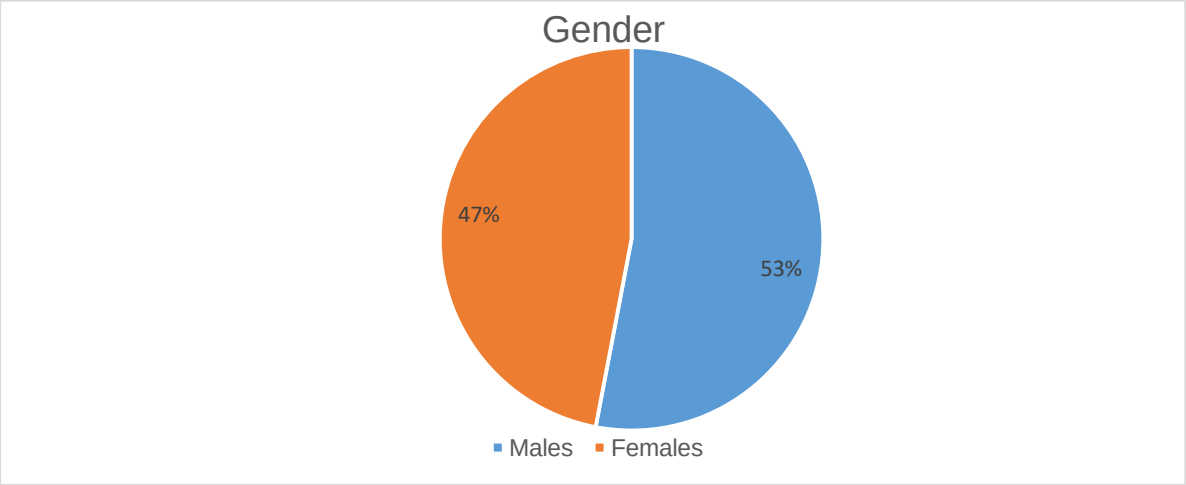

Figure 5.1: Gender profiles of research respondents in Gobandlovu.

5.3.2 Age profiles of respondents

In terms of the age characteristics of the respondents, the results show that 13 percent fall in the category of the youth (18-35 years). Those who were aged between 31 to 45 years constitute 27 percent of the sampled respondents, while 25 percent of the respondents were aged between 46 and 59 years. Those who are aged 60 years and above made up 15 percent of the respondents (Figure 5.2). The majority (87 percent) of the study sample is made up of respondents who are between the ages of 31 to 60 and above, the youngest of this group would have been 25 years old in 2013 (at the

beginning of the rehabilitation programme) meaning they would have been old enough to a good understating of environmental issues. This means the study sample is made up of respondents who are well knowledgeable to their ages and period of stay in Gobandlovu.

5.3.3 Period of stay

The results show that 87 percent of the respondents lived in Gobandlovu before the year Tronox began mining in Gobandlovu (2002). These people have continuously stayed in this place and witnessed the beginning of the rehabilitation programme in 2014 and its conclusion at the end of 2018. Three (3) percent of the respondents resided in Gobandlovu from 2002 to 2018 and Only 10 percent of the respondent started residing in Gobandlovu as from 2013 to 2018 (Figure 5.3). Since the majority of the respondents lived in Gobandlovu before Tronox's operations, they were very suitable to be a sample of this study since the assumption is that they have first-hand experience and knowledge of how things went about and the issues that came out of Tronox's presence.

N=30

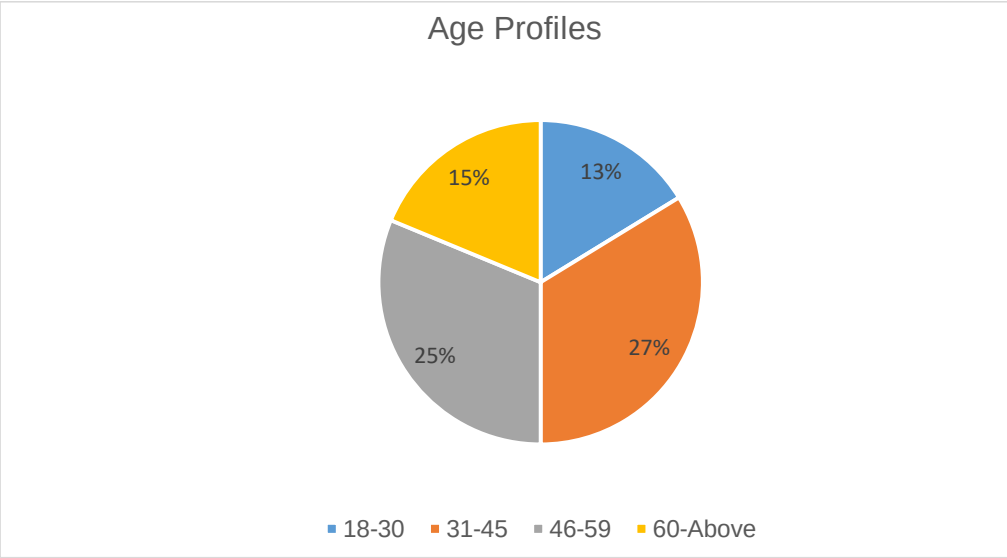

Figure 5.2: Age profiles of research respondents in Gobandlovu.

N=30

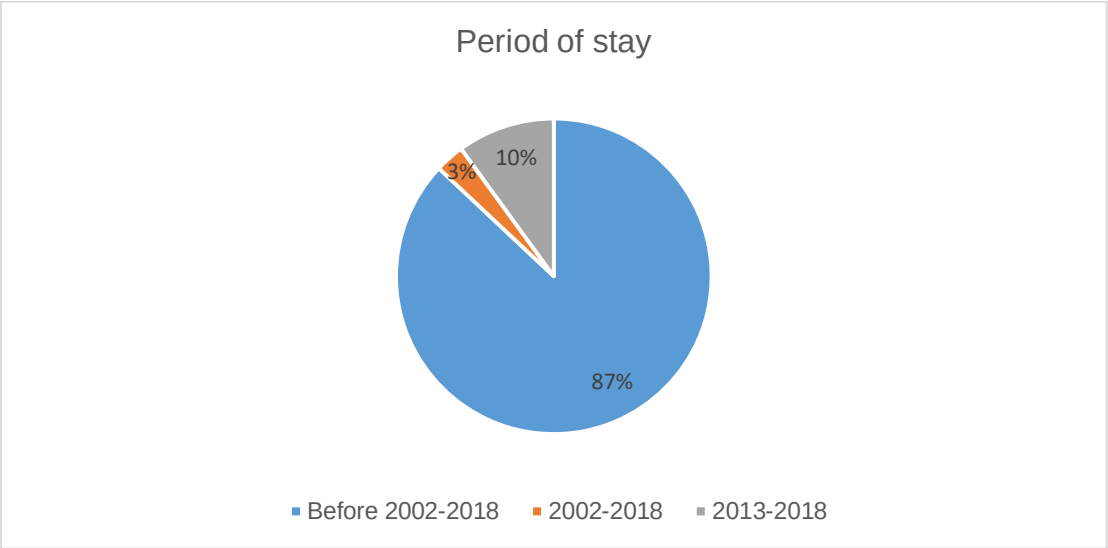

Figure 5.3: Period of stay of research respondents in Gobandlovu.

5.3.4 Education levels

The results show that all the respondents have some form of education, with the largest portion (76 percent) being made up of respondents with a high school qualification. The second highest number of respondents were those with a tertiary qualification (21 percent) and the least (3 percent) had attained primary education (Figure 5.4). This is an indication that the majority of the respondents would be capable of understanding South African legilstaion since they do have some form of education whether high school level or Tertiary level.

N=30

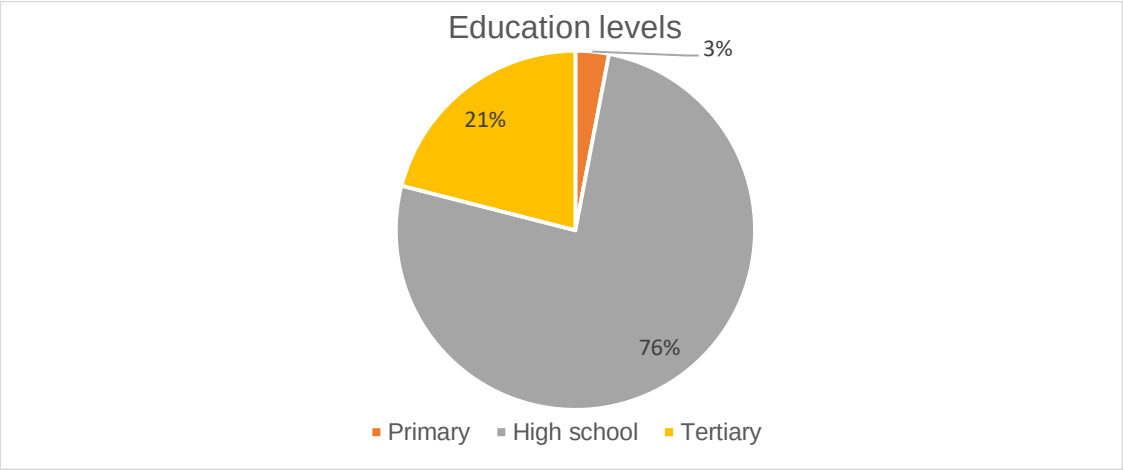

Figure 5.4: The education levels of research respondents in Gobandlovu.

5.3.5 Employment levels

Results show that, 40 percent of respondents, of respondents are unemployed individuals. Thirty eight (38) percent are employed, and 22 percent are self-employed. It would be expected that of the 40 percent respondents that stated that they are employed would be employed by Tronox at least since it is a big corporation and was operating in Gobandlovu so opening employment opportunities for the local community is to be expected.

N=30

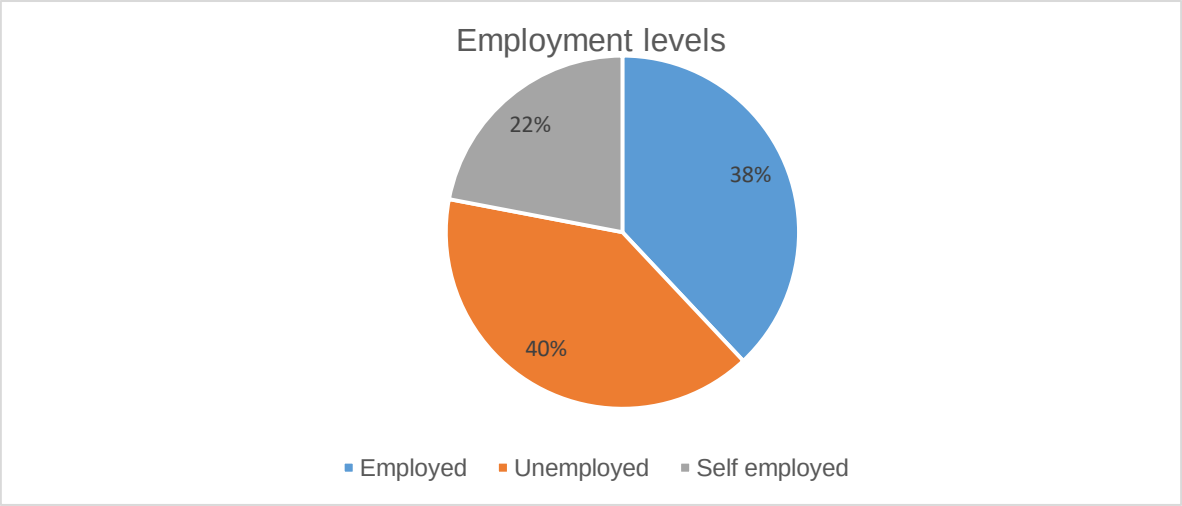

Figure 5.5: Employment status of the respondents.

5.3.6 The rehabilitation programme

The first objective of this study tracks the process of rehabilitation in Gobandlovu using Remote Sensing. For this study, Landsat satellite images were downloaded from the google earth engine (GEE) system (see: earthengine.google.com) and then visualised on Geographic Information System (GIS) using ArcMap in order to map the normalised vegetation index (NDVI) over Tronox rehabilitation site. Landsat images used in this study have a spatial resolution of 30 metres (30m x 30m). For the purpose of this study, the NDVI was calculated using relevant bands and then overplayed in the shapefile of the study area. In general, Landsat gives two to three images per month for the study area, and for the purpose of this research, these images were averaged to present each year starting from 2000 to 2019. Thus, a total of nineteen images were used in this study. These images represent a period before the beginning of the mining activity (2000), during the mining activity (2002-2013), the start of the rehabilitation

(2014) and the completion of the rehabilitation programme (2018) in the study area. Because the Landsat is sensitive to clouds, those images that were dominated by clouds over the study area were filtered out. The process of extracting these images was performed by writing instructions in JavaScript programming language in the GEE system.

In this study, eighteen Landsat yearly mean images for the period 2000 to 2018 were produced (Figure 5.6). The year 2001 was not included because it was similar to year 2000 due to no mining activities in the study site. As a first step of visualisation, NDVI was calculated and overlaid on the study area. Figure 5.6 shows the spatiotemporal evolution of the NDVI over Gobandlovu Tronox mine. In this figure, areas with higher values of NDVI which indicated healthier vegetation are represented by green colour while those which have lesser or no vegetation are represented by brown colour. During the year 2000, higher NDVI values are dominant in the study area. This period was the period before the beginning of the mining activity in the study area, hence the domination of vegetation. From the year 2002 to 2013 the NDVI values of the green colour are decreasing, which means that the soil is becoming bare due to the loss of vegetation in favour of bare soil. During this period Tronox was mining in Gobandlovu. Furthermore, from 2014 to 2018, Figure 5.6 shows that areas with high NDVI values begin to spread throughout the study map, which indicates a possible process of rehabilitation.

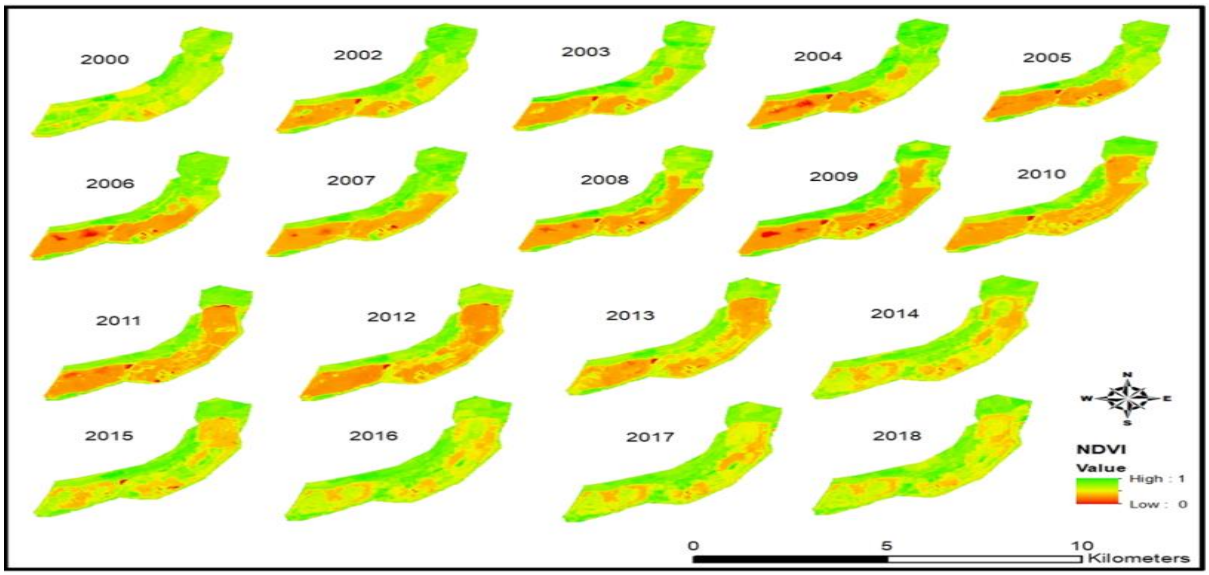

Figure 5.6: Spatiotemporal evolution of NDVI over the Gobandlovu Tronox mine.

The rehabilitation process was concluded in 2018 at the Gobandlovu Tronox mine. Therefore, in order to show the spatial map of the vegetation in the study area after the rehabilitation process was concluded, a spatial map of NDVI averaged for satellite overpasses of June 2019 was plotted (Figure 5.7). In this figure, it is apparent that the rehabilitation process is successful as the whole map is dominated by high NDVI values.

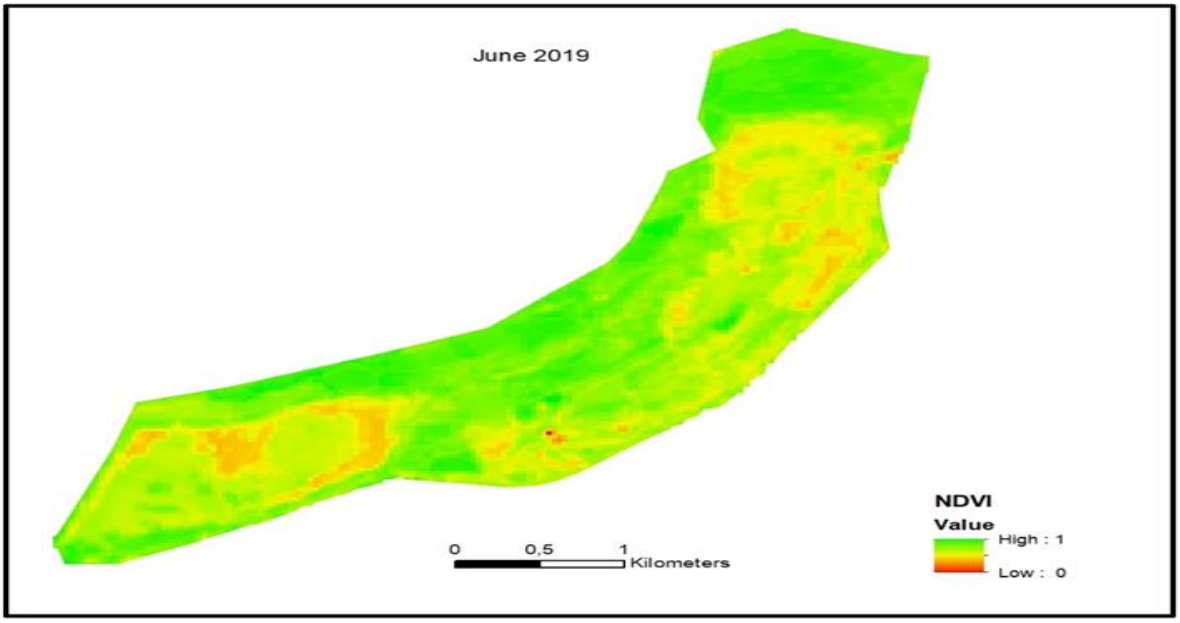

Figure 5.7: Spatial map of the Tronox rehabilitation programme in Gobandlovu, June 2019.

5.3.7 Time series of the Tronox rehabilitation programme

The monthly average NDVI time series at the Tronox mine is shown in (Figure 5.8). This was done in order to ascertain the variability of NDVI in the area over the period pre- and post-mining. In this time series, it is apparent that during the beginning of mining (2002) the trend of NDVI values show a decrease which reach its highest minimum around 2010 to 2013. Thereafter, these values start to increase in 2014 which is consistent with the beginning of the rehabilitation process. By 2016 to 2018, the NDVI values are comparable to the pre- mining period.

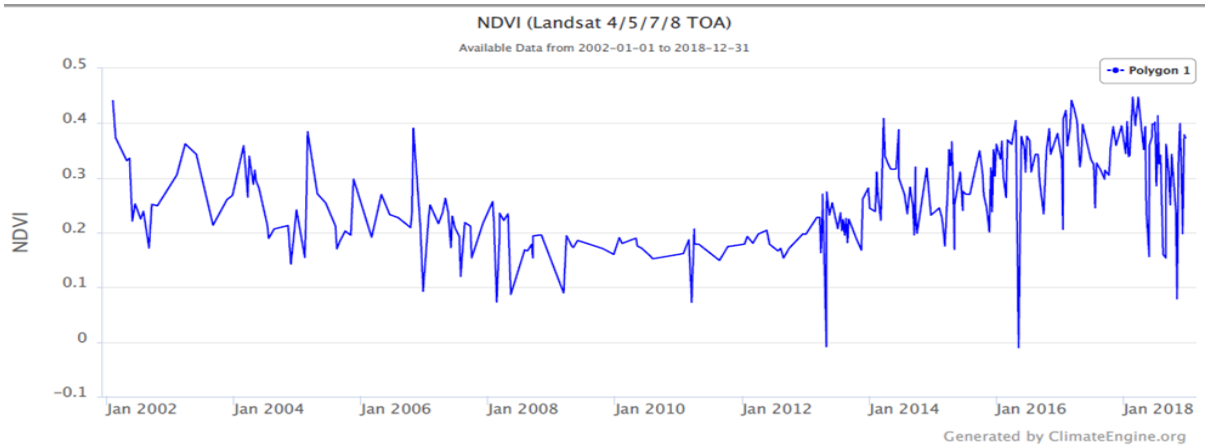

Figure 5.8: Time series of monthly average NDVI for Tronox mine for the period from 2002 to 2018.

5.3.8 Generating images that represent the NDVI

In order to investigate land cover changes, land cover classification was employed. In this study, two classes of land cover were considered, namely the bare soil and vegetation. These classes were chosen because this area is covered by vegetation and if there is any mining activity it is expected that the land cover class will change to bare soil. The classified image calculated from the yearly mean was used to represent the dominant classes per specific year starting from year 2002 to year 2018. This process was done by following the steps summarised in the figure below (Figure 5.9) which results into the yearly images shown in figure 5.10.

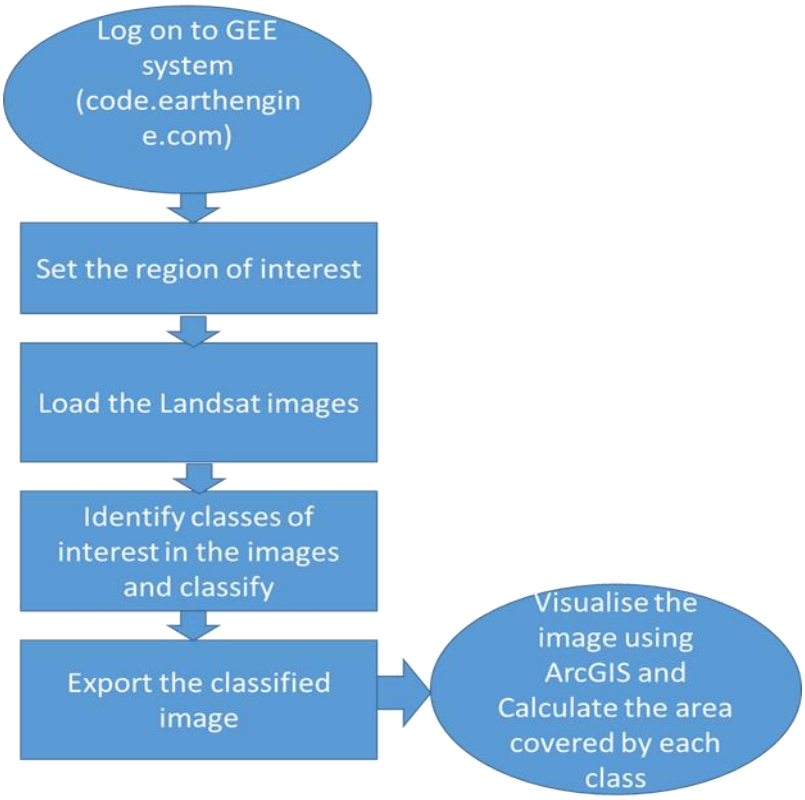

Figure 5.9: Process flow for determining the spatiotemporal yearly mean averages of NDVI.

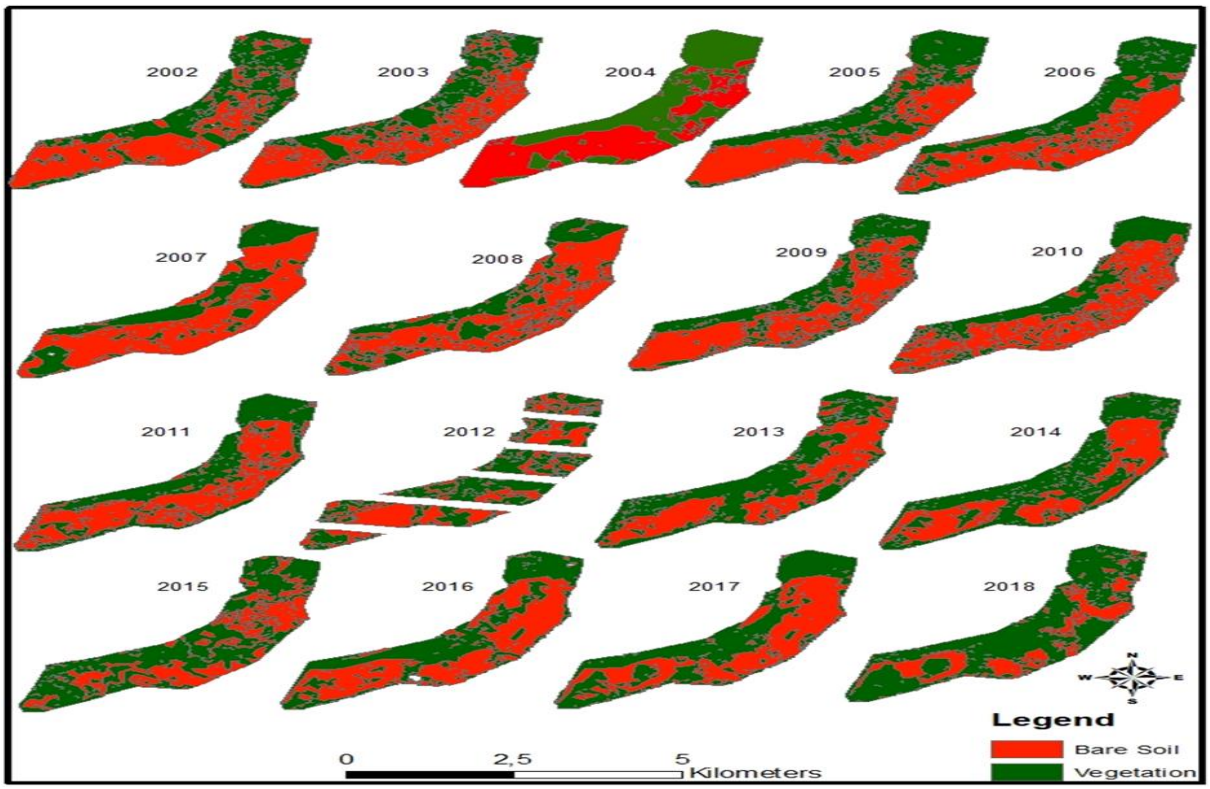

Figure 5.10: Yearly images of classification over the Tronox mine.

Table 5.1 below shows that initially (2002) the area for bare soil consistently has higher values than those for vegetation cover from 2002 to 2012. This is consistent with the fact that during this period, Tronox Mine was mining in Gobandlovu thus reducing the vegetation land cover, while exposing bare soil. From 20012 to 2018 the area of vegetation cover is greater than that of the bare soil class, which further collaborates well with the data that the Tronox Mine was reducing its mining activities in 2012-2013 in preparation for rehabilitation in 2014. Therefore, Figure 5.10 and Table 5.1 corroborate each other in that they show that the rehabilitation programme in the study area was successful as can be visualised in Figure 5.10.

Table 5.1: Bare soil and vegetation area in km^2.

Years	**Vegetation (km^2)**	**Bare soil (km^2)**	**Total in km^2**
2002	3.63	3.88	7.51
2003	3.14	4.37	7.51
2004	3.73	3.80	7.53
2005	3.64	3.88	7.52
2006	3.56	3.95	7.51
2007	2.71	4.80	7.51
2008	2.81	4.70	7.51
2009	3.22	4.29	7.51
2010	2.89	4.62	7.51
2011	3.45	4.07	7.52
2012	3.63	3.88	7.51
2013	4.05	3.46	7.51
2014	4.35	3.17	7.52
2015	4.66	2.84	7.50
2016	3.55	3.96	7.51
2017	3.98	3.53	7.51
2018	5.40	2.11	7.51

Data for a time series was averaged using the data from Table 1 (see Figure 5.11). The diagram indicates that bare soil area originally spikes upwards from 4 km^2 in 2002, it reaches its peak at 4.8 km^2 in 2007 and the drops to its lowest downward point at 2.11 km^2 in 2018. This is because in 2002 Tronox was beginning to mine, therefore exposing bare soil. In 2007 the largest portion of vegetation must have been removed which is why the area for bare soil is at its largest. The diagram also indicates that the area for vegetation begins to drop in 2002 with its lowest point being in 2007 with an area of 2.71 km^2, this is due to the beginning of the mining during this period. In 2013

it begins to peak up and its highest point is in 2018 when the vegetation cover had fully recovered.

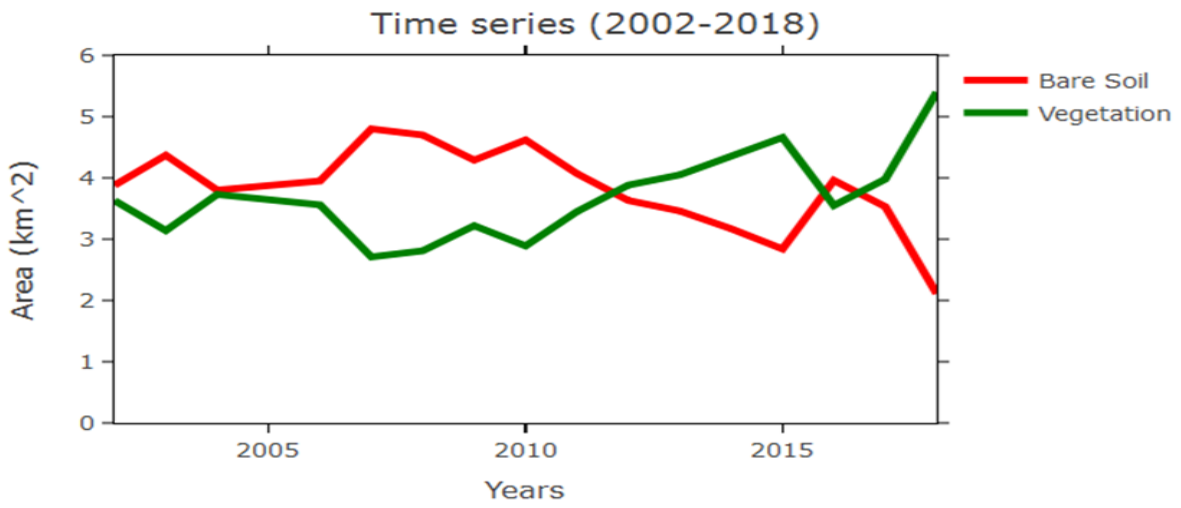

Figure 5.11: Time series of the total area of bare soil (red) and vegetation (green) at Gobandlovu Tronox Mine for the period 2002 to 2018.

To further highlight the purpose of the trends shown by the data in the preceding figures and their significance to this study, the sequential Mann Kendall non parametric test was employed. Figure 5.12 shows the sequential statistic values of forward/progressive (Prog) u'(t) and retrograde (Retr) u'(t) obtained by SQ-MK test for yearly mean vegetation and bare soil . In general, SQ-MK statistic indicates a downward trend for vegetation during early years, and a strong upward trend for vegetation in the period from 2013 to 2018, with z-scores higher than +1.96 (2018) for the forward statistic (prog). This is consistent with the earlier observation which showed that vegetation was lost during the 2002-2013 period (intense mining period). The recovery of the vegetation in the mine only started in 2013 which indicated the beginning of the rehabilitation phase. It should again be noted here that during 2018, the rehabilitation in the Gobandlovu Tronox Mine reached a statistically positive significant recovery phase.

It can be observed in Figure 5.12b that SQ-MK statistic indicates a constant retrograde trend from 2002 to 2006. This indicates that during this period mining activities were not too intense during this period. The retrograde trend goes downwards from 2007 to 2013, which is consistent with what the data has shown that mining activities were no

longer as intense. From 2013 onwards it drops further until it reaches its lowest point in 2018. This corroborates the previous data that during this period mining activities had stopped and rehabilitation had begun from 2014 and ended in 2018, thus during this period less bare soil was exposed as vegetation had regrown.

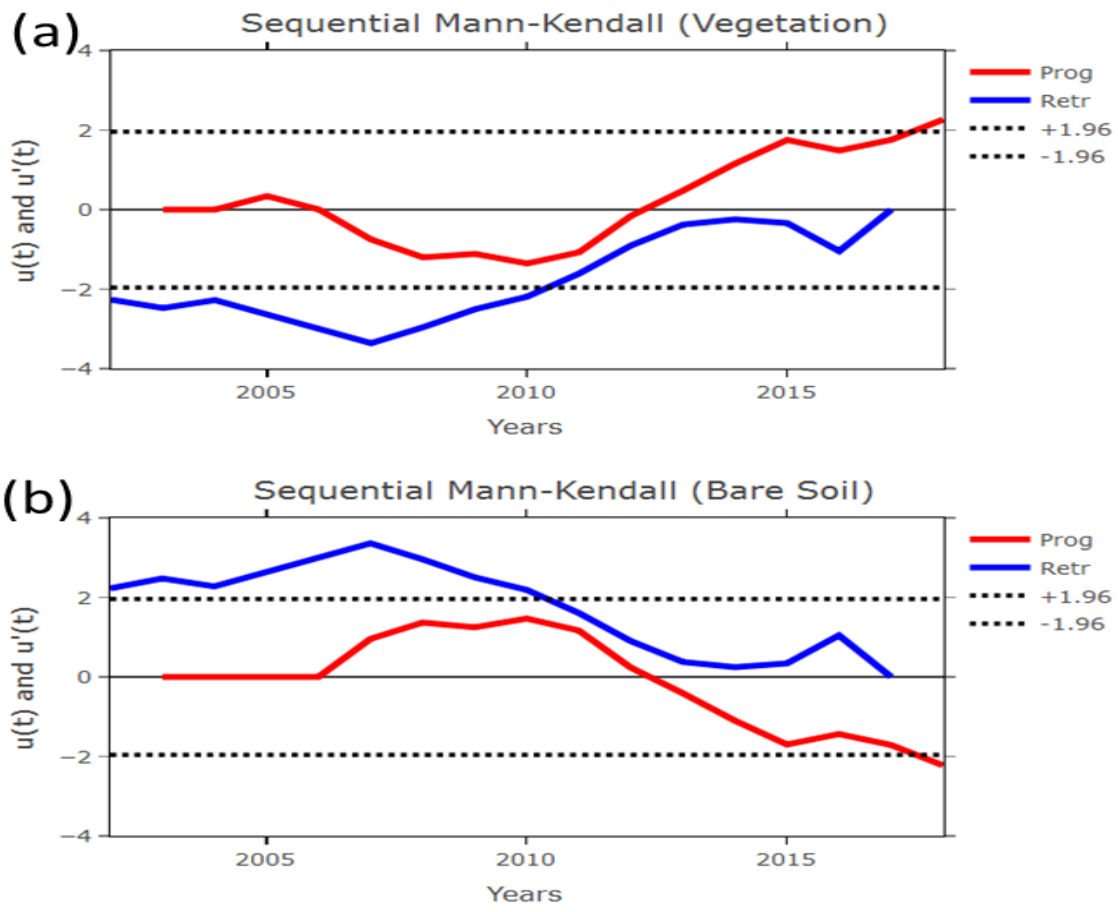

Figure 5.12: Sequential Mann Kendall (SQ-MK) indicating sequentiall statistic values of progressive (Prog) μ(t) (red line) and retrograde (Retr) μ^' (t) (blue line) obtained for the vegetation(a) and bare soil(b) data for the period from 2002 to 2018.

In order to investigate the percentage growth/decline per year of vegetation and bare soil in the study area, the Theilsen non parametric statistic method was applied. Figure 5.13 indicates the Theilsen statistic plots for (a) vegetation and (b) bare soil time series plotted for the period from 2002 to 2018. In Figure 5.13a, it is shown that the vegetation increases by 2.82%/year, with the 95% confidence level ranging from 0.47 to 15.91%. This is presumably contributed by the sharp increase of the vegetation during the rehabilitation phase which starts in 2014. On the other hand, Figure 5.13b indicates a decline of bare soil in the study area of approximately -1.86%/year, with a level of -

0.47 to -0.44% a year which is associated with the recovery of vegetation after a maximum mining activity during 2007.

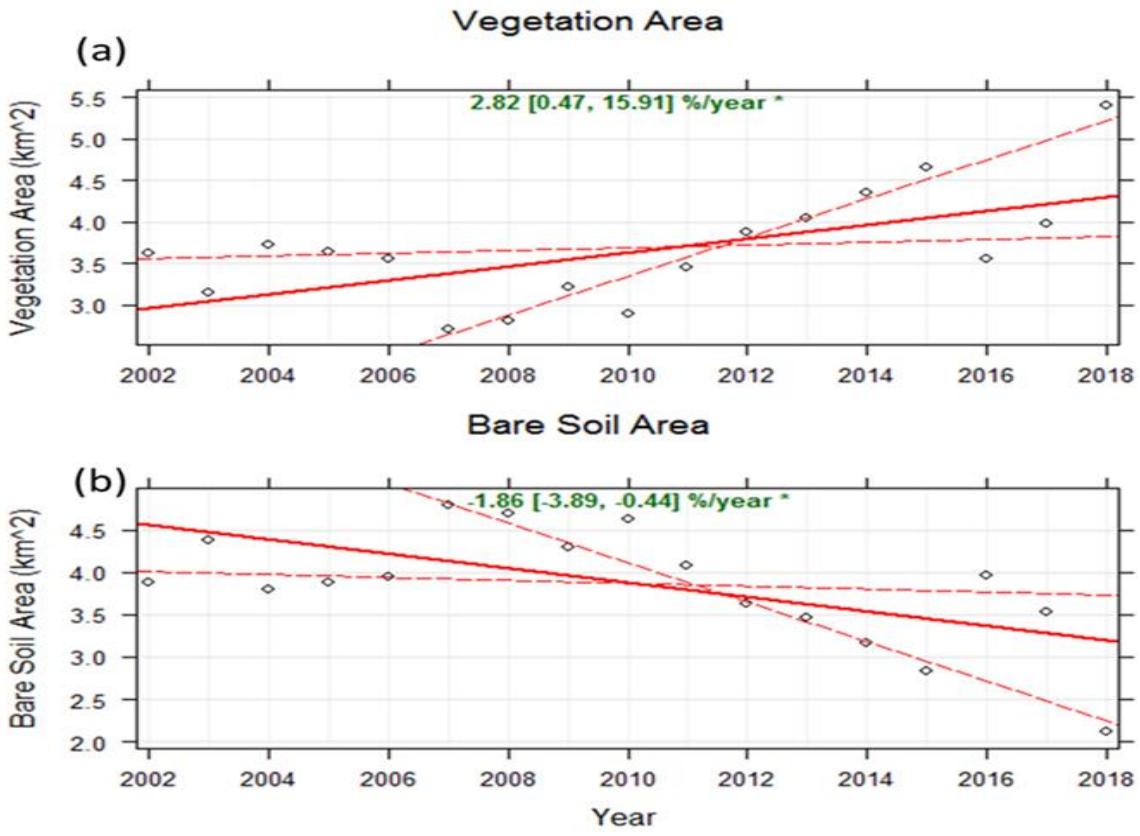

Figure 5.13: Results of the Theilsen non-parametric statistic test for the period 2002 to 2018.

5.3.9 A Brief summary of rehabilitation processes through photos

The site manager of Tronox in Gobandlovu was kind enough to share some of the rehabilitation processes that Tronox undertook through images. “Implementation of rehabilitation has several steps, first backfill, second Dune shaping, third Material deposition, fourth drying, fifth intermediate vegetation establishment and soil preparation, and sixth Planting of final target vegetation” (Tronox site manager, 2019). These images are added to give a visual interpretation of the impact of rehabilitation on the environment.

Figure 5.14: The process of backfilling the dunes with sand in 2012.

Figure 5.15: The process of dune shaping in 2012.

Figure 5.16: The process of deposition of soil moisture retaining layer in 2013.

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Figure 5.17: The process of intermediate vegetation establishment and soil preparation in 2014.

Figure 5.18: The process of soil preparation in 2015 to 2016.

Figure 5.19: Same area as Figure 5.18, this image at the end of 2018.

The discussion in the preceding section suggests that Tronox mine has respected the environmental justice principle that concerns restorative justice, which requires corrective actions to be taken in case of ecosystem services degradation or loss (Cotton, 2018). As shown by all the data from Figure 5.6 to Figure 5.19 in objective one, the Tronox mine successfully rehabilitated all the land they had mined on and replanted the vegetation required. This process also respected the MPRDA (Section 24(a) which stipulates that mines are required to abide by the South African constitution and common law which requires that mine operations and closure activities be carried out with due diligence (Krause, 2014).

5.3.10 Tronox rehabilitation programme and MPRDA guidelines

The second objective of the study evaluates if the Tronox rehabilitation programme complies with MPRDA guidelines. According to Beaukes et al (2019) Tronox KZN Sands initiated the closure process for the Hillendale Mine operations as per the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (Republic of South Africa 2002). The mine ceased production activities at the end of 2013. Over the next years (2014-2018), all activities onsite were towards achieving mine closure.

A qualitative sample of 30 respondents were purposively sampled using questionnaires in Gobandlovu. As explained in Chapter 4, section 4.5, 10 of the respondents who were sampled live within the closest proximity (30 metres) to the Tronox rehabilitation site, 10 live in the middle section (375 metres) just after those living the closest and the other 10 reside in the furthest (750 metres) part of Gobandlovu from the Tronox rehabilitation site. The respondents were sampled in this manner so that the study could represent different perspective of how Gobandlovu residents who lived at various distances from the mining site were affected by the rehabilitation programme of the Tronox mine. From the data collected and analysed the results show that from the sample of the 10 residents living 30 m to the rehabilitation site, 10 percent of the respondents believe that the Tronox rehabilitation programme is complies with legislation. This sentiment was shared by 9 percent of the respondents from the 375 m sample. Out of those living 750 m from the site, 8 percent stated that the rehabilitation programme conformed to MPRDA guidelines.

56 percent of the respondents from the 30 m sample believe the Tronox rehabilitation programme was not in line with legislation. This is the highest portion of the respondents who felt this way. Further, 50 percent of the respondents from the 375 m section stated that the rehabilitation programme was not in line with legislation. From the 750 m sample, 45 percent of them also stated that the rehabilitation programme was not in line with legislation. However, a high percentage of the respondents were not quite sure as to whether this rehabilitation programme is in line with South African legislation regarding mining or not. The lowest percentage of those who said it could be in line with legislation came from the 30 m sample (32%). Added to this were 41 percent of those from the 375 m sample, who expressed similar sentiments and 47 percent of those from the 750 m sample also answered in the same way (Figure 5.20). The researcher noted from the findings that from all the respondents, there was not a single one who could specifically name the legislation (MPRDA) that mines must abide by when rehabilitating. They had a general idea of legislation and the constitution but could not recall the MPRDA, which makes it harder for them properly voice out their complaints regarding issues caused by the Tronox mine. As per the interview with the Tronox site manager, the Tronox mine followed all the guidelines in the Chamber of Mines as well as the MPRDA (Tronox site manager, 2019).

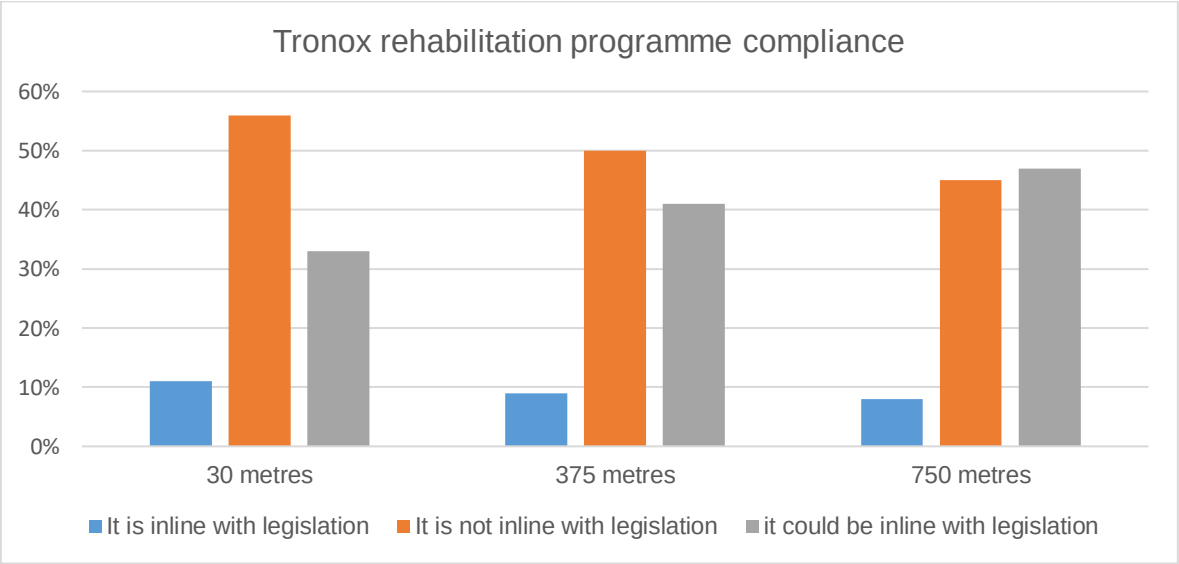

Figure 5.20: Gobandlovu community response on compliance by the Tronox mine.

While accepting that some of the community members were not fully informed about MPRDA, and also recognising that the Tronox site manager stated that Tronox

complied with MPRDA, the fact that the community were not satisfied with the whole process cannot be ignored. To this can be added the MPRDA which stipulates that, all South Africans have a constitutional right to live in an environment that is not harmful to their health (Swart, 2003). In light of this, the overall perception from the community of Gobandlovu points in the direction that, Tronox Mine did not adequately respect environmental justice regarding the principle of distributive justice, which according to Schlosberg (2013) is a form of social justice more often associated with environmental sustainability.

Furthermore, Mukhopadhyay and Sinha (2006) state that in Romania, closure of the coal mines had a negative impact on the areas where they are located. The socio-economic structures of these areas were severely affected and the degradation of the environment made these communities unattractive for any future redevelopments. Despite the fact that some of the former mining sites were environmentally rehabilitated, contamination of many other areas still remained a major problem that contributed to the further decay of the communities where they are located. This section builds from the discussion above and uses the data to show whether what is mentioned above has any similarities with Gobandlovu.

As illustrated by Figure 5.21, fifty six (56) percent of the respondents residing at 30 m to the Tronox mine rehabilitation site reported to the researcher that after the mining and rehabilitation programme started their crops are no longer as productive after the Tronox mine began operations in Gobandlovu from 2002 to 2018. According to the respondents this situation did not change even after Tronox ceased their operations in 2018. This is a belief that is also echoed by 44% of the respondents living 375 m from the site. In addition, 29 percent of the sampled respondents living 375 m from the site also said they believe their crops no are not as productive as before the mining and rehabilitation began. About 67 percent of the respondents from the sample living 30 metres to the rehabilitation site said that they experienced visible dust in their dwellings. These respondents make up the largest portion of research participants who responded this way, while 55 percent of the respondents from the 375 m section also gave a similar response. Likewise, 23 percent of the respondents (who live in the 750 m section) gave a similar response as above and they make up the smallest portion of the sample of respondents who gave this response. A majority (80%) of respondents from the 30 m sample reported that their houses developed cracks during

the process of this programme, this sentiment was echoed by 20 percent of the 375m sample while none of the respondents from the 750 m reported this statement.

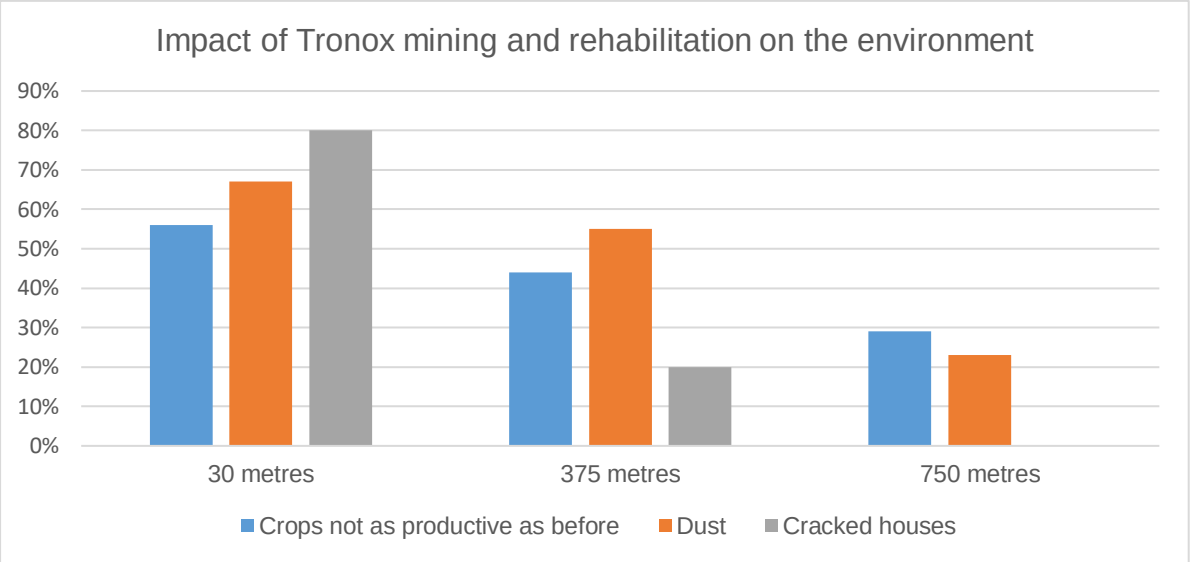

Figure 5.21: Perceived impact on the land.

Respondents pointed out that Tronox did somewhat provide corrective measures to the residents of Gobandlovu after mining and rehabilitation procedures had ceased. Those corrective measures are compensation houses for residents whose houses had issues such as cracking and to a lesser degree, employment opportunities.

Sixty (60) percent of the respondents from the 30 m sample stated that they were provided compensation houses, this is the highest statistic for this response. While there are no respondents from the 375 m sample and 750 m sample who shared the same sentiments. To the knowledge of the respondents from the 30 m sample, the reason why they are the only beneficiaries of the compensation houses is because they are located the closest to the mine therefore according to the limited information they got from Tronox, they are the only one's eligible to experiencing issues such as cracked houses. Interesting enough 40 percent of respondents from the 30 m sample state that they also had the same issues as the other 60 percent but they were not compensated and they were not given clear reasons why. As noted in Figure 5. 21, there are responses from the 375 m sample who mentioned the issue of cracked houses (20 percent), so when asked about compensation houses they stated that they have seen them in the 30 m zone but there was never any mention from the Tronox mine to build these houses in their zone.

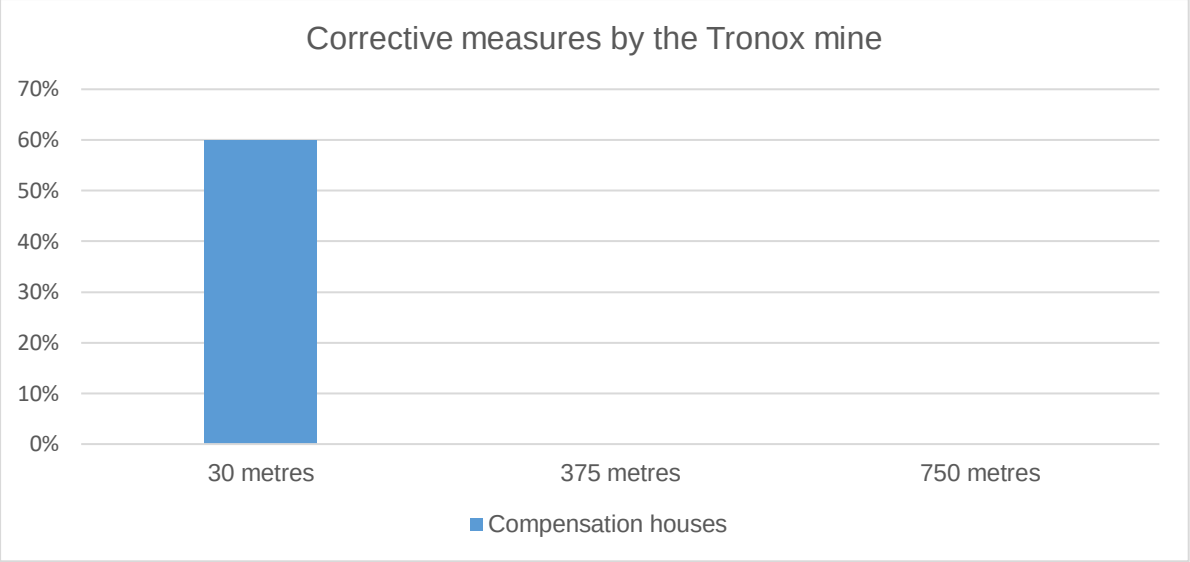

Figure 5.22: Corrective measures by Tronox.

In terms of environmental justice (restorative), the Tronox mine respected the process of rehabilitating the land (the vegetation has recovered and the bare soil has been progressively rehabilitated) it had mined on as shown by Figure 5.6 to Figure 5.19 and as discussed in Section 5.3.5. However, in terms of distributive justice it did not, as Figure 5.21 shows that a big portion of respondent for this study reported to having issues of dust and cracking in the walls around their residences and hindrances in the growth of their crops after the Tronox mine's operations from 2002 to 2018. In terms of the MPRDA, Tronox's efforts are lacking in some aspect because the MPRDA stipulates that, all South Africans have a constitutional right to live in an environment that is not harmful to their health (Swart, 2003), while the data in this section shows that the rights of the community of Gobandlovu residents were impeded since they reported that during the period when Tronox mine's operations were ongoing (2002-2018), their houses developed cracks amongst other issues. Tronox did attempt to amend the housing issue especially to the 30 m sample which had reported the most cracked houses, however complaints about this attempt still exist from the respondents.

5.3.11 Exploring perceptions of the community

The third and last objective of this study is to explore the perceptions of the community of Gobandlovu towards the Tronox rehabilitation programme. It can be observed from the results in Figure 5.22 that, seventy seven (77) percent of the respondents from the

sample living 30 m to the rehabilitation site stated that they feel that they were not integrated enough into the rehabilitation programme by the Tronox mine, the community felt left out of important decision making processes and discussions such as on issues of employment. A further 79 percent of the respondents from the sample living 375 m to the site share the same opinion as the former sample. About 81 percent of the respondents living 750 m from the rehabilitation site also share the same opinion as the other two sample groups. In addition, 23 percent of respondents from the sample living 30 m to the rehabilitation site believe that they were well integrated into this programme, while it is 21 percent of the respondents from the 375 m group share the same sentiments. Respondents from those living 750 m who stated they were well integrated into this programme make up 18 percent.

Further, 79 percent of the respondents from the 30 m sample stated they were not updated well with the proceedings of this rehabilitation programme, saying that information regarding the proceedings of Tronox's rehabilitation activities were not communicated well enough to them by the Tronox mine. Eighty one (81) percent respondents of the 350 m sample also share this answer. However, the figure rose to 84 percent from the respondents who live 750 m from the rehabilitation site. On the other hand, 21 percent of the respondents from the 30 m sample believe they are given enough updates by the Tronox mine regarding the rehabilitation programme, the figure drops to 19 percent for the respondents from the 350 m sample, and it drops even further to 16 percent for the respondents living 750 m from the site.

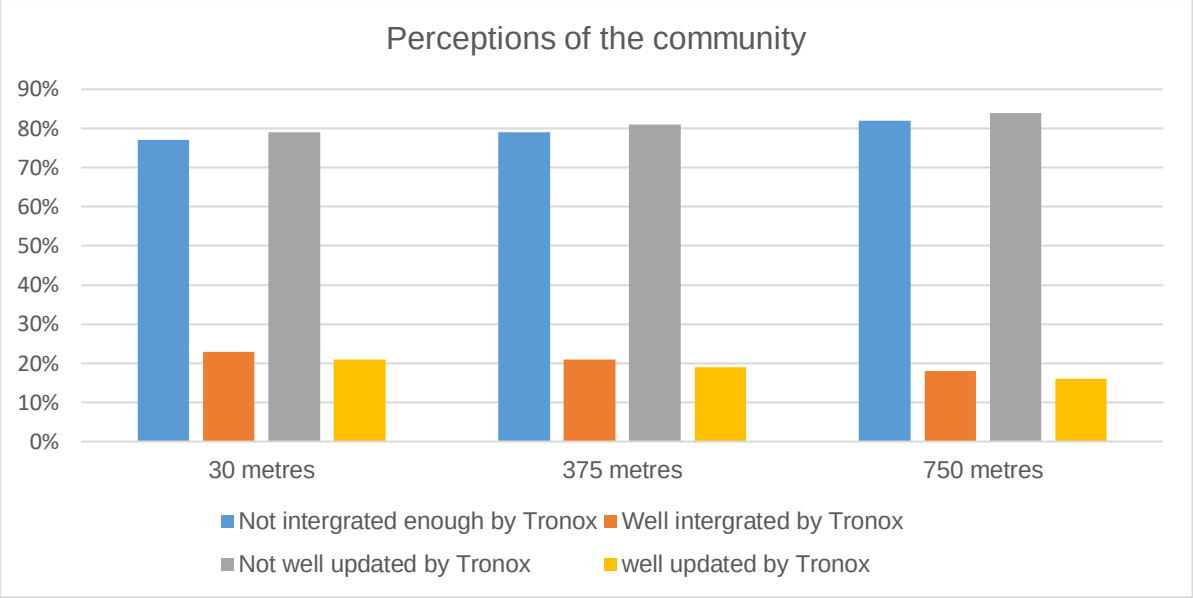

Figure 5.23: Perceptions of the community towards the rehabilitation programme of the Tronox Mine.

The key focus of engagement during the operational phase of mining should be on engaging the community and regulators in the development and review of rehabilitation plans, as well as on building the capacity of the local community to assist, where appropriate, in the rehabilitation works (Krause, 2014). It can be observed from this section's data that the Tronox mine's rehabilitation programme in the eyes of the community, did not respond to the distributive justice principle as far as community engagement is concerned among other things. Furthermore, as discussed in the data in Figure 5.22, the majority of the respondents felt that they were not well integrated and well updated. In terms of integration, a majority of the respondents stated that in general with all the operations that went on at the Tronox site in Gobandlovu they felt very isolated from the mine proceedings, while also stating that they hardly received any updates about these proceedings and plans.

5.4 Conclusion

This chapter has shown that, the rehabilitation programme by Tronox was successful, to the extent of rehabilitating the environment, but it was not perfect since it seems to be lacking in community relations and as a result does not score favourably amongst the community members of Gobandlovu. The general feeling from the Tronox mine's perspective is that the rehabilitation programme is a success, while the community of

Gobandlovu also shares this sentiment, they do however state that there is limited interaction between the Tronox mine and them.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This discussion in this chapter follows the order of objectives as presented in the preceding chapter and the final part of the chapter presents recommendations.

6.2 Conclusions

6.2.1 Tracking the process of rehabilitation in Gobandlovu using Remote Sensing

Various GIS remote sensing tools were utilised, that yielded successful results that show that Tronox did successfully rehabilitate the mining site. All the various tools utilised show area values that are projecting positively for this rehabilitation programme. These area values are low in 2013 since this was a beginning phase of the rehabilitation programme, these area values reach their peak in the year 2018. The methods which include NDVI calculation, Terrain analyses through area calculation and time series analyses all cross verify each other so that the results are balanced. The study found that Tronox followed the technical rehabilitation guidelines that are stipulated by the South African Chamber of Mines as far as rehabilitation as listed in the literature review.

6.2.2 Alignment of Tronox rehabilitation programme with MPRDA guidelines

Tronox set out to rehabilitate the land they had been mining on and they did so successfully. All the land uses that were found in the study site (before mining began) have commenced now, such as a sugar cane plantation in some parts of the rehabilitated sections. Based on interviews with the Tronox mine's site manager, there are no pending issues as far as the rehabilitation programme is concerned and all operations will stop in the coming years. However, based on the questionnaires conducted from the community of Gobandlovu, although Tronox was able to get the land back to the state it was in before mining, this came at the expense of the said community. Community members mentioned that at times during Tronox's operational years (2002 to 2018) it could get very dusty over their dwellings. As a result, the majority of residents from Gobandlovu who were sampled in the study stated that they felt their health and well-being was not respected by the mine.

As shown by the various satellite images used in this study, the vegetation that was removed has been replaced and replanted. As a result, it can be said that initially the rehabilitation programme did have destructive effects on the environment but the company did rectify that especially at the end of the rehabilitation phase (2018). With regard to the community's responses to the questionnaires, all the respondents from the sample claim that they were affected by the activities from the Tronox mine e.g cracked houses. This means that while Tronox's rehabilitation programme respected the environmental justice principle of restorative justice as far as rehab. Furthermore, the community members stated that compensation packages were not distributed adequately. For instance, some houses were built for those living closest to the rehabilitation site whose houses were effected during the mining and rehabilitation phase. However, some residents did not get this package even though they were also affected and they claim they were not given clear reasons. This means that while the Tronox mine's rehabilitation programme respected the environmental justice principle of restorative justice, it failed as far as the distributive justice principle was concerned.

6.2.3 To explore the perceptions of the community of Gobandlovu towards the Tronox rehabilitation programme

As shown by the results and findings of this study the general feeling amongst the community members is that while this big phenomenon called mining and its follow up process the rehabilitation programme happened around them, they are somewhat left out as the flow of information from the Tronox mine does not reach them adequately. The community do not have the crucial details regarding such an important activity occurring around them. From the questionnaires it was quite evident that community members lack the finer details regarding this rehabilitation programme and there is an element of mistrust and uncertainty regarding the whole process, automatically this means distributive justice has not been achieved by the Tronox mine.

6.3 Recommendations

On account of the previous discussions and the results and findings of this study, going forward the study recommends the following**:**

a. It is evident that there is very little communication between the Tronox mine and the community of Gobandlovu. Therefore this study recommends that Tronox opens some communication channel that will be dedicated to deal with the community of Gobandlovu, serving as a platform where information between the Tronox mine and the community will be shared.
b. In order to ease the level of distrust the community has for the Tronox mine, Tronox should integrate the community of Gobandlovu as much as possible when it comes to the plans that involve this mine (rehabilitation site) in the area of Gobandlovu.
c. Through a process agreed upon by both Tronox and the community, Tronox should select representatives from the community through whom they can communicate information to the community. These representatives' main function would be to seek information from the Tronox mine's officials and communicate it back to the community.

6.4 Conclusion

The chapter revealed that the biggest issue with regard to the rehabilitation programme of the Tronox mine is the issue of lack of information available to community members of Gobandlovu. The residents of Gobandlovu have indicated that they feel excluded by the Tronox mine which at times arouses unnecessary tensions, which automatically means that environmental justice and its principles have not been adequately respected by the mine, hence the study strongly recommends that Tronox KZN Sands improve their communication efforts with the community of Gobandlovu.

REFERENCES

Adler, A, Classeen, M, Godfrey, L, Turton,A,R., 2007. Water, mining, and waste: An historical and economic perspective on conflict management in South Africa. *Economics of Peace and Security Journal*, 2, (2):33–41.

Anglo American, 2013. *Mine closure toolbox version 2*. Johannesburg: Anglo American plc.

Antin, D., 2013. *The South African Mining Sector: An industry at a crossroads* .http://www.oakbay.co.za/images/South African Mining Industry.pdf (Accessed 26 February 2018).

Aragão, A , Cliquet, A., 2016*. What's law got to do with it? Why environmental justice is essential to ecosystem service valuation.* Coimbra: University of Coimbra, (22):221-227.

Auditor General, 2009. *Report to Parliament on a performance audit of the rehabilitation of abandoned mines at the Department of Minerals and Energy*. Pretoria: Republic of South Africa

Australian and New Zealand Minerals and Energy Council, 2000. *Strategic framework for mine closure.* Report no. ISR 2000/155. Canberra: Minerals Council of Australia.

Australian Government, Department of Industry Innovation & Science, Department of Foreign Affairs & Trade, 2015. *Mine Rehabilitation: Leading Practice Sustainable Development Program for the Mining industry.* Canberra. Leading Practice Sustainability Program for the Mining Industry.

Babbie, E.R., 2010. *The Practice of Social Research*. 12th ed. Belmont, CA: Wadsworth Cengage, London: Cengage learning. 52- 60.

Bahamin, P., 2015. 'A look at amendments to the Guinean mining code introduced in 2013', insideafricalaw.com, 13 August. Available at https://www.insideafricalaw.com/publications/ (Acessed on 07 July 2020)

Baxter, R., 2015. *The future of the South African mining industry.* ⟨http://www.chamberofmines.org.za/industry news/publications/presentations/send/7-2015/ (accessed on 16 September 2018).

Bell GR., 2010. *Mineral resource manager, Navachab Gold Mine. Discussion about ore types represented in tailings of TSF1*. Karibib.

Bell M.A., 2015*. Monitoring rehabilitation success using remotely sensed vegetation indices at Navachab Gold mine, Namibia.* Stellenbosch University https://scholar.sun.ac.za (Accessed on 13 March 2018).

Brockering, A, 2015. 'Law concerning the closure of mining facilities', http://www.Brockeing.cl/Law-concerning-the-closure-of-mining-facilities/ (accesssed on 05 July 2020)

Bose, 0.S., 2010. Health assessment of artisanal gold miners in Indonesia*. Science of the Total Environment*, 408 (4):713-725.

Cotton, M. 2018. *Environmental justice as scalar parity: Lessons from nuclear waste Management*, Department of environment, University of York, (2018) 31:238–259.

Clough, E and Bell, D. 2016. Just fracking: a distributive environmental justice analysis of unconventional gas development in Pennsylvania, USA. *Environmental Research Letters*, 11, (2): 56-108.

Chamber of Mines of South Africa., 2007. *Guidelines for the rehabilitation of mined land. Chamber of Mines of South Africa.* Johannesburg: Coaltech Research Association, 3-9.

Claassens, S., 2007. *Measuring rehabilitation success of coal mining disturbed areas: A spatial and temporal investigation into the use of soil microbial properties as assessment criteria.* (Thesis – PhD.Env.Sci). Potchefstroom: North-West University.

Creswell, J. W., & Plano, V. L. (2011). *Designing and conducting mixed methods research,* Thousand Oaks, CA: Sage, *2*: 28-30.

Creswell, J. W., D. 2014. *Research design, quantitative, qualitative and mixed methods approaches*, Thousand Oaks, CA: Sage, 4: 32–35.

Davis, R., Franks, D., 2014*. Costs of Company-Community Conflict in the Extractive Sector.* Corporate Social Responsibility Initiative, Cambridge, MA.

Evans, K, G., 2000. Methods for assessing mine site rehabilitation design for erosion impact*, Australian journal of soil research*, 38 (20 231-248.

Department of Mineral Resources, 2015. *Assessment of the broad-based socio-economic empowerment charter for the South African mining industry (Mining Charter)*. Republic of South Africa. Pretoria: Republic of South Africa. ⟨http://www.gov.za/documents/download.php?F=147564⟩ (accessed on 18 March 2018).

Faizuldayeva, Z, 2016. '*A comparative study of regulatory approaches to mine closure with special emphasis on the current situation in the former Soviet union'*, SRK consulting's international paper. [Online] Available at http:///www.SRK.com.(accessed on 04 July, 2020)

Festin B., 2018*.* Progresses in restoration of post-mining landscape in Africa*. Journal of Forestry Research,* 30: 381-396.

Fraser J., 2018*. Mining companies and communities: Collaborative approaches to reduce social risk and advanced sustainable development*. Resources policy, Elsevier. 55, 100-115.

Gastauer, M, Silva,J.R, Junior., C, F, C ., Ramos, S, J.,Filho, P ,W,, Neto M, S , Jose, ,A, E, F., Siqueira, O .,2018. *Mine land rehabilitation: Modern ecological approaches for more sustainable mining, Instituto Tecnologico Vale*. J. Clean. Prod. 172, 1409-1422.

Gauteng Department of Agriculture Environment and Conservation, 2008. *Mining and Environmental Impact Guide.* Johannesburg: Gauteng Department of Agriculture and Conservation, Johannesburg.

Hamann, R., 2014. Patient dialogue between mining companies and communities is tougher and scarcer that imagined: A response to Hodeg. J. Clean. *Prod*, 84, 35–36.

Haupt, S.A., 2018. *Satellite monitoring of post-mining rehabilitation and the quantification of backfill dynamics using differential SAR interferometry.* Stellenbosch University https://scholar.sun.ac.za, Accessed 26 March 2018.

Hamlin, R. and Cobârzan, B., 2006. '*Financial Incentives to restructure coal mining industry. Comparative case study of Romania and state of Michigan*', Transylvanian review of administrative sciences, 18E, 68-79.

Hilson, G., 2002. An overview of land use conflicts in mining communities. *Land Use Policy* 19 (1), 65–73.

Irvin, B. J., Slater, B,K., 1997. Fuzzy and ISODATA classification of landform elements from digital terrain data in Pleasant Valley, Wisconsin. *Geoderma*, 77, 137-154.

Isioye, O. A, Enebeli, I., Alademomi, S. A., Akomolafe, E, 2012. Terrain Analysis in GIS and Its Significance to Surface Runoff Analysis, A Study of Basawa Community in Sabon Gari L.G.A. of Kaduna State, Nigeria. Available at https://www.researchgate.net/publication/280773984 (accessed on 15 September 2018)

Jenner,L., 2018. *Landsat 8.* https://landsat.gsfc.nasa.gov/landsatdata-continuity-mission/ Accessed 18 May 2018.

Jenkins, H, Yakovleva, N, 2005. *Corporate social responsibility in the mining industry: Exploring trends in social and environmental disclosure. The ESRC Centre for Business Relationships, Accountability, Sustainability and Society (BRASS), 55 Park Place, Cardiff, CF10 3AT, UK. 14 (3-4):271–284.*

Kemp, D., Bond, C.J., Franks, D.M., Cote, C., 2010. Mining, water and human rights: making the connection. *Clean. Prod,* 18 (15), 1553–1562.

Krause, R.D., 2014. *Rehabilitation and mine closure liability, assessment of the accountability of the system to communities. Centre for Applied Legal Studies*, University of the Witwatersrand.

Ledwaba, P,F Mutemeri, N, Institutional gaps and challenges in artisanal and small-scale mining in South Africa, Centre for Sustainability in Mining and Industry (CSMI), University of the Witwatersrand, 56 :141-148.

Li S., 2018. An End-to-End Project on Time Series Analysis and Forecasting with Python, Available at: https://towardsdatascience.com/an-end-to-end-project-on-time-series-analysis-and-forecasting-with-python-4835e6bf050b (Accessed 15 May 2019).

Limpitlaw, D., Aken, M., Lodewijks, H., and Viljoen., J., 2005. *Post-mining rehabilitation, land use and pollution at Collieries in South Africa, Colloquium: Sustainable development in the life of coal Mining in South Africa. Boksburg:* The South African institute of mining and metallurgy, 3-8.

Limpitlaw, D. and Briela, A. 2014. Post-mining land use opportunities in developing countries – a review. *Journal of the Southern African Institute of Mining and Metallurgy*, (114):899–903.

Limbong, I., 2003. Emissions and environmental implications of mercury from artisanal gold mining in North Sulawesi, Indonesia*. Science of the Total Environment, 302* (1-3):227-36.

Macleod, R. D., and Congalton, R. G.1998., A quantitative comparison of change detection algorithms for monitoring eelgrass from remotely sensed data*. Photogrammetric Engineering and Remote Sensing,* 64: 207–216.

Mukhopadhyay, M.K and Sinha, I.N., 2006. A techno-economic model for optimum regeneration of surface mined land, *Environmental Geology*, 50 (1): 669–676.

Marais, A., Assessing corporal social responsibility in terms of impact on sustainable development: Anglo American PLC programmes as a case study, University of Stellenbosch. South Africa, Thesis-PhD, 15-18.

Marais , L.,2013, Resources policy and mine closure in South Africa: The case of the Free State Goldfields, Centre for Development Support, University of the Free State, Bloemfontein, South Africa, 363–372.

Massonnet, D and Feigl K.L., 1998. Radar interferometry and its application to changes in the Earth's surface. *Reviews of Geophysics* 36(4): 441.

Mausel.,P. Brondízio .,E. and Moran .,E. 2004, Change detection techniques.*International Journal of Remote Sensing,* 25 (12): 2365-2401.

Mensah, A.K., 2015. *Role of revegetation in restoring fertility of degraded mined soils in Ghana: A review. Department of Geography, Kenyatta University, Nairobi, Kenya. 7(2), 57-80.*

Mhlongo, S.E, Amponsah -Dacosta, F,et., 2016. A review of problems and solutions of abandoned mines in South Africa. *International Journal of Mining, Reclamation and Environment*, 30 (4): 279–294.

Mhlongo, S,E, Dacosta, F,A, Mphephu, N,F .,2013. In Search of Appropriate Rehabilitation Strategies for Abandoned Nyala Magnesite Mine, Limpopo Province of South Africa, Islamabad, 2 (1): 58–70.

Mishra S., 2017. Change Detection Techniques in Remote Sensing: A Review. *International Journal of Wireless and Mobile Communication for Industrial Systems*, 4 (1): 1-8.

MPRDA., 2002. *Mineral and Petroleum Resources Development Act 28 of 2002. Government Gazette No. 23922,* 10 October. Available online at: http://www.dme.gov.za/pdfs/minerals/ ACT_28_0F_2002.pdf (accessed 17 August 2018).

Minerals Council of Australia., 2015. *Mine rehabilitation in the Australian minerals industry. Guidelines for Preparing Mine Closure Plans.* Perth: Government of Western Australia,3-10.

Mining, minerals and sustainable development (MMSD) project, 2002, breaking new ground, international institute for environmental development (IIED) and world business council for sustainable development (WBCSD),University of Witwatersrand,(1):1-28.

Munro, R., 2011. *Ethics and design research at South African higher education institutions*. Design education forum of Southern Africa.www.defsa.org.za (2011). (Accessed 3 May 2018).

Pettorelli., N., Vik, J.O., Mysterud, A., Gaillard, J.-M., Tucker, C.J., Stenseth, N.C., 2005. Using the satellite-derived NDVI to assess ecological responses to environmental change, Trends Ecol*. Evolution* 20, 503-510*.*

.

Rethman, N.F.G., 2006*. A Review of Causes, Symptoms, Prevention and Alleviation of Soil Compaction on Mined Land.* Coaltech 2020, Johannesburg.

Singh A., 1989, Review Article Digital change detection techniques using remotely-sensed data*. International Journal of Remote Sensing*, 10, (6): 989-1003.

Rajaee, M. Long., R.N.; Renne., E.P.; and Basu., N,2015. *Mercury concentrations and spatial distribution in a Ghanaian small-scale gold mining community. International Journal of environmetal research and public health*, 12(09) 10755-10782.

Romanian Ministry of Economy and Commerce. '*Proposal for restructuring strategy of the mining sector*', 2006, [Online] Available at http:///www.namr.ro.(accessed 28 June, 2018)

Rogerson, C., 2012, Mining-dependent localities in South Africa: The state of partnerships for small town local development. *Urban Forum* 23 (1):107–132.

Schlosberg, D., 2013. Theorising environmental justice: the expanding sphere of a discourse. *Environ. Polit* 22 (1): 37–55.

Sanzana, E., Weeks, B., Fernandez, S., 2015. '*Closure planning for the largest copper producer in the world*',Mine closure.,infoMine inc. Canada.

Speight, J. G. 1977. *Landform pattern description from aerial photographs*. Photogrammetria.

Stephens, C., Willis, R., Church, C., 2008. *Environmental justice and health, International encyclopedia of public health:* World Health Organisation, (1): 373-382.

Statistics South Africa, 2017. Statistics South Africa, 2017. Gross domestic product. Statistical Release. P0441. 06 June, Available at: ⟨http://www.statssa.gov.za/?Page_id=1854&PPN=P0441⟩ (accessed 1 February 2019).

Statistics South Africa, 2017b. Input-output tables for South Africa [Online]. Republic of South Africa. Available at: ⟨http://www.statssa.gov.za/?Page_id=1854⟩ (accessed 5 February 2019).

Synman., K. 2001. *Inherent natural resources and agricultural potential of Hillendale eMpangeni. LRI Associates, Hilton*. Unpublished report.

Swart, E., 2003.The South African legislative framework for mine closure, *Journal of the Southern African Institute of Mining and Metallurgy, Department of Minerals and Energy, Pretoria.* Johannesburg-The South African Institute of Mining and Metallurgy. 1003(08):489-103.

Tetteh, B., 2015. Adopted practices for mined land reclamation in Ghana: A case study of Anglogold Ashanti Iduapriem mine LTD*. Journal of Science and Technology*, 35 (2) : 77-88.

Tivey, J, Campbell, R , Biensan, P, Denizot, D., 2013. 'What next for Guinean's regulation' Lexocology.com,19 July, available at http://www.Lexocology.com/ (Accessed on 11 July 2020).

UMhlathuze Local Municipality: Draft IDP Review 2019/2020,Available at http:///www.umhlathuze.gov.*za// (accessed 18 July, 2019).*

Van Jaarsveld, C*., 2013.Rehabilitation of mined land at Tronox KZN sands for Sugarcane production. Department of social, crop and climate sciences, Faculty of natural and agricultural sciences, University of Free State, Bloemfontein, South Africa, Thesis-Phd,* 56-70*.*

Vershinina, E., 2003. *Land rehabilitation requirements and practices in Russia, SRK consulting's international newsletter NO. 45. [Online] Available at http:///www.SRK.com/(accessed 04 July, 2020)*

Weber, E., 2018. *Predicting habitat quality of protected dry grasslands using Landsat NDVI phenology.* Department of Evolutionary Biology and Environmental Studies. Zurich: University of Zurich.

Ubeda, P., 2014. The consistency of fairness rules: An experimental study. *Journal of Economic Psychology,* 41(1): 88 - 100.

Xu, D., 2014. Measuring the dead component of mixed grassland with Landsat imagery. Remote Sens. *Environ,* 142 (1): 33–43.

Zhang Y and Mishra R,K., 2012. A review and comparison of commercially available pan sharpening techniques for high resolution satellite imagery: A review. *Precis.* 13 (6): 693-712.

Zhu, Z., Woodcock, C.E., 2012. Object-based cloud and cloud shadow detection in Landsat imagery. Remote Sens. *Environ*, 118, 83–94.

ANNEXURE A: QUESTIONNAIRE

I, Philani T. Phungula kindly ask for your assistance in my Masters Research based on analysing the land rehabilitation programme in Gobandlovu by willingly answering these interview questions. Be assured that all the answers you provide will be kept strictly confidential.
Consent form I……state that the research has been explained to me and that I voluntarily accept to answer the questions in this questionnaire. Signature……..

Section A: Biographical and demographic information.

1. Questionnaire Number……
2. Age……
3. Gender

Male	Female

4. How long have you been living in Gobandlovu?

   ……

   ……

5: Level of education…….

6 Indicate current status of employment with an X below

Employed	
Unemployed	
Self employed	

Section B: The process of the rehabilitation programme.

1. Are you aware of the rehabilitation programme of the Tronox Mine in Gobandlovu?

Yes	No

2. If the answer to the above question is yes please elaborate what you know about it.

……
……
……
……

3. Does the community benefit from this rehabilitation programme?

Yes	No

1. Please elaborate in relation to your answer above.

.....
.....
.....
.....
.....

Section C: Tronox rehabilitation programme and MPRDA guidelines.

1. Are you aware of any legislation that mining companies have to abide by when rehabilitating the soil they were mining on?

Yes	No

2. Please tell me the legislation you know of and its stipulation if you answered yes.

……
……
……
……

3. Do you think the rehabilitation programme by the Tronox Mine in in line with the South African legislation? Please elaborate your answer.

……
……
……
……

Section D: The impact of the Tronox rehabilitation programme on the environment.

1. Since the rehabilitation programme started at the end of 2013 until now, how has it impacted on the area you live in?

……
……
……
……

2. Are the impacts of the Tronox rehabilitation programme positive or negative in relation to where you live? Please answer and state the reason why.

……
……
……
……

2. If the rehabilitation programme has negative effects on where you live have you made a formal report to either Tronox or uMhlathuze Municipality?

Yes	No

1. If you answered yes above, what response did you get after reporting the said issues?

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……

Section E: Perceptions of the community towards the rehabilitation programme.

In general how do community members of Gobandlovu feel about this rehabilitation programme?

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……

1. Do you think that the community has been integrated enough in the proceedings on of this rehabilitation programme by the Tronox Mine?

……

……

……

……..

APPENDIX B: INTERVEW QUESTIONS (OFFICIALS)

I Philani T Phungula kindly ask for your assistance in my Masters research based on analysing the land rehabilitation programme in Gobandlovu by willingly answering these interview questions. Be assured that all the answers you provide will be kept strictly confidential.
Consent form I……state that the research has been explained to me and that I voluntarily accept to answer the questions in this interview. Signature……..

Tronox official

Section A: The process of the rehabilitation programme.

(1) Can you summarise the rehabilitation process of the Tronox Mine in Gobandlovu.

……

……

……

……...

(2) Would you say this rehabilitation programme is on track? If yes, please elaborate.

……

……

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……..

(3) Does this rehabilitation programme have any time oriented objectives that you have set for yourselves? Please elaborate.

.....

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.....

Section B: Tronox rehabilitation programme and MPRDA guidelines.

(4) Would you say this rehabilitation programme abides by the Mineral and Petroleum Resources Development Act?

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(5) How does this company ensure that it does not step out of bounds of the South African legislation (specifically the MPRDA)?

……

……

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……

Section C: The impact of the Tronox rehabilitation programme on the environment.

(6) What would you say is the impact of this rehabilitation programme on the environment?

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…….....

(7) What are the plant species used on this rehabilitation programme?

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……

Section D: Perceptions of the community towards the rehabilitation programme.

(8) Did your company inform the local community of Gobandlovu about this rehabilitation programme?

……

……

……

……

(9) How has the community reacted so far in relation to this rehabilitation programme?

.....

.....

.....

.....

APPENDIX C: ORIGINALITY DECLARATION

Full Names and Surname	**Philani T. Phungula**
Student Number	**201633153**
Title of dissertation/thesis	**An analysis of the land rehabilitation programme of the Tronox mine: Environmental justice and the community of Gobandlovu.**

I acknowledge that I have read and understood the University's policies and rules applicable to postgraduate research, and I certify that I have, to the best of my knowledge and belief, complied with their requirements.

In particular, I confirm that I had obtained an ethical clearance certificate for my research (Certificate Number UZREC 171110-030 PGM 2019/40) and that I have complied with the conditions set out in that certificate.

I further certify that this thesis is original, and that the material has not been published elsewhere, or submitted, either in whole or in part, for a degree at this or any other university, except as follows:

I declare that this research thesis is, save for the supervisory guidance received, the product of my own work and effort. I have, to the best of my knowledge and belief, complied with the University's Plagiarism Policy and acknowledged all sources of information in line with normal academic conventions.

I have subjected the document to the University's text-matching and/or similarity-checking procedures.

Candidate's signature	
Date	**02- 03- 2020**

APPENDIX D: **ASSESSMENT SHEET – MASTER'S DISSERTATION**

University of Zululand

ASSESSMENT SHEET: RESEARCH MASTER'S DISSERTATION

The following information must be completed by the Course Coordinator:

Name of Candidate: Philani Theophilus Phungula	**Date of first registration:** 2018
Degree and nature of qualification: MA Geography	**Student number:** 201633153
Title: An analysis of the land rehabilitation programme of the Tronox mine: Environmental justice and the community of Gobandlovu.	**Nationality:** SA
Supervisor: Dr I. Moyo	**Submission date to exam's office:**
Co-supervisor: Dr. S. Xulu and Dr. N. Mbatha	**Submission date to examiner:**

Name: Examiner and Institution:	**Contact e-mail of examiner**:

<u>Examiners are requested to use the following key when assessing the various aspects of the study:</u>

1	**2**	**3**	**4**	**5**
Poor (less than 40%)	Below average (40% to 49%)	Average (50% to 64%)	Good (65% to 74%)	Excellent (above 75%)

<u>Examiners are further requested to attach a report to this assessment form to supplement the comments made herein.</u>

<u>Section A</u>: Title and research focus / topic

1.	Does the title cover the topic meaningfully?	1	2	3	4	5
2.	Does the title align with the central research problem / research questions / hypothesis?	1	2	3	4	5
3.	Does the title assist meaningfully in the demarcation of the research topic?	1	2	3	4	5

Comments on Section A:

<u>Section B</u>: Conceptual and theoretical focus and quality of the literature study:

4.	Does the dissertation reveal originality of approach or involve original research?	1	2	3	4	5
5.	Does the dissertation demonstrate a comprehensive knowledge base in a discipline or field which demonstrates a depth of knowledge in the research conducted?	1	2	3	4	5
6.	Does the candidate provide evidence of an understanding of the principles and theories used in the study?	1	2	3	4	5
7.	Does the candidate demonstrate the ability to analyse and critique current research and thus advance scholarship in the dissertation?	1	2	3	4	5

8. Does the candidate show an ability to make sound theoretical judgments based on evidence which lead to epistemologically thinking?	1	2	3	4	5

Comments on Section B:

<u>Section C</u>: Methodological challenges and research process

9. Is the methodological orientation of the dissertation aligned to the theoretical conceptual orientation of the study?	1	2	3	4	5
10. Does the candidate illustrate an understanding of a range of research methods, techniques and technologies and an ability to select these appropriately for the research problem in this study?	1	2	3	4	5
11. Does the study indicate that the candidate has mastered the application of the methodological challenges?	1	2	3	4	5
12. If appropriate does the candidate show an ability to identify, analyse and deal with complex and/or real world problems using evidence-based solutions and theory-driven arguments?	1	2	3	4	5
13. Does the candidate, where relevant, demonstrate the ability to select, apply and manage appropriate statistical software, instruments and techniques in the analyses of quantitative data or research samples?	1	2	3	4	5
14. Does the study reveal efficient and effective information retrieval and processing skills?	1	2	3	4	5

Comments on Section C:

<u>Section D</u>: Conclusion, synthesis and the presentation of findings

15. Does the dissertation reveal the identification, critical analysis, synthesis and independent evaluation of quantitative and / or qualitative data?	1	2	3	4	5
16. Does the dissertation demonstrate that the candidate has shown an ability to engage with current research and scholarly or professional literature in the discipline or field of research?	1	2	3	4	5

17. Does the dissertation demonstrate an ability to present and communicate academic / professional work effectively appropriate to the context and level of the study and come to a cohesive conclusion?	1	2	3	4	5

Comments on Section D:

<u>Section E</u>: Technical and ethical requirements

18. Does the dissertation comply with the technical, language and scholarly writing requirements / standards, e.g. referencing techniques as would normally be associated with this level of research and professionalism?	1	2	3	4	5
19. Does the dissertation demonstrate ethical sensitivity as well as evidence of how the research has been conducted in this context?	1	2	3	4	5
20. Do the chapters form a meaningful and integrated unit?	1	2	3	4	5

Comments on Section E:

<u>Section F</u>: Concluding remarks:

Section G: Recommendations

Please select one of the following options:

1	That the dissertation be accepted unconditionally with a percentage mark of	**%**
2	That the dissertation be provisionally accepted on condition that the candidate makes corrections of a limited extent to the satisfaction of the supervisor, with a percentage mark of	**%**
3	That the dissertation be provisionally accepted pending more substantial corrections, to be made to the satisfaction of the examiner, or a specified person or body other than the supervisor, after which a percentage mark will be allocated. **Specify person/body:**	
4	That the dissertation be not accepted in its current form and that it must be referred back to the candidate for comprehensive revision and / or expansion, as per my attached report, after which it should be resubmitted for examination	
5	That the dissertation be not accepted and the degree be not awarded	

The degree should be awarded with distinction	**Yes**		**No**	

Section G: Consent and declaration

Should the other examiner so suggest, could you agree to the degree being awarded with distinction?

Yes ☐ **No** ☐

Do you agree to your name being divulged to a successful candidate?

Yes ☐ **No** ☐

Do you agree to a successful candidate being shown your examiner's report?

Yes ☐ **No** ☐

I confirm the content of the above assessment and that, in conducting the assessment, I was not at any stage placed in a conflict of interest situation	
Signature	**Date**

APPENDIX E: ETHICAL CLERANCE CERTIFICATE

UNIVERSITY OF ZULULAND
RESEARCH ETHICS COMMITTEE
(Reg No: UZREC 171110-030)

RESEARCH & INNOVATION
Website: http://www.unizulu.ac.za
Private Bag X1001
KwaDlangezwa 3886
Tel: 035 902 6731
Fax: 035 902 6222
Email: DlelanaM@unizulu.ac.za

ETHICAL CLEARANCE CERTIFICATE

Certificate Number	**UZREC 171110-030 PGM 2019/40**							
Project Title	**AN ANALYSIS OF THE LAND REHABILITATION PROGRAMME OF THE TRONOX MINE: ENVIRONMENTAL JUSTICE AND THE COMMUNITY OF GOBANDLOVU**							
Principal Researcher/ Investigator	T. Phungula							
Supervisor and Co-supervisor	Dr I. Moyo			Mr. S. Xulu				
Department	Geography and Environmental Studies							
Faculty	Arts							
Type of Risk	Med Risk – Data collection from people							
Nature of Project	Honours/4th Year		Master's	x	Doctoral		Departmental	

The University of Zululand's Research Ethics Committee (UZREC) hereby gives ethical approval in respect of the undertakings contained in the above-mentioned project. The Researcher may therefore commence with data collection as from the date of this Certificate, using the certificate number indicated above.

Special conditions:

(1) This certificate is valid for 1 year from the date of issue.
(2) Principal researcher must provide an annual report to the UZREC in the prescribed format [due date-24 September 2020]
(3) Principal researcher must submit a report at the end of project in respect of ethical compliance.
(4) The UZREC must be informed immediately of any material change in the conditions or undertakings mentioned in the documents that were presented to the meeting.

The UZREC wishes the researcher well in conducting research.

Professor Gideon De Wet
Chairperson: University Research Ethics Committee
Deputy Vice-Chancellor: Research & Innovation
25 September 2019

CHAIRPERSON
UNIVERSITY OF ZULULAND RESEARCH ETHICS COMMITTEE (UZREC)
REG NO: UZREC 171110-30
2 6 -09- 2019
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RESEARCH & INNOVATION OFFICE