IMPACTS OF MINING ON LAND USE- A CASE (STUDY) OF LUANSHYA DISTRICT, ZAMBIA.

A thesis submitted in partial fulfilment of the requirement for the degree of Master of Philosophy
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ABSTRACT

Copper mining is the main driver of Zambia's economic growth and development and plays a significant role in the global supply of materials for electrical, plumbing, heating and transport equipment among other benefits. However, primary production and beneficiation of copper pose serious risks to the mining districts such as environmental pollution, landscape alterations, land degradation and social economic challenges to the host communities. This research looks at the landscape alterations in the mining district of Luanshya, and how these alterations are related to mining and other land uses. Using remote sensing and Geographic Information Systems (GIS), the landscape alterations were mapped and analysed to identify the processes causing these alterations and their impacts on land use. Secondly, stakeholder interviews were conducted to gain a deeper understanding of the mapped landscape alterations, what the approach has been to land use planning and the stakeholder roles in this planning. Analysis of the findings identifies that landscape alterations in the district have been caused by different inter-related mechanisms stemming from a number of causes. These causes include high dependency on copper mining; inadequate enforcement of environmental legislation; lack of state involvement in land use planning of mining districts; and also global factors such as commodity market conditions. As a result, boom and bust commodity cycles have had significant impacts on the wellbeing of both mining communities and the environment. These impacts are not limited to the mine sites alone but extend to entire districts. This research also identifies that while mining plays a vital role in the economic development of Zambia, adequate enforcement of environmental legislation and adoption of inclusive land use planning may stimulate sustainable development of mining districts and foster sustainable land use patterns. Furthermore, this study recommends that future land use planning must be dynamic in terms of adopting post-mining restoration of landscapes and infrastructure while also taking the direct and indirect impacts of mining into account.

Key words: Mining; Zambia; land alterations; land use; Luanshya district.

STATEMENT OF ORIGINALITY

DECLARATION

1. I know the meaning of plagiarism and declare that all the work except that which has been properly acknowledged is my own.
2. I have not allowed, and will not allow anyone to copy this work to pass it off as their own.
3. This dissertation has been submitted through Turnitin and I confirm that my supervisors have seen my report and any issues have been resolved with them.

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Kabang'u Grace Sakuwaha

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ABBREVIATIONS AND ACRONYMS

AMD	Acid Mine drainage
BSMC	British South Africa Mining Company
CACB	Central African Copperbelt
CEC	Copperbelt Energy Corporation
CEP	Copperbelt Environment Project
CSO	Central Statics Office
DA	Development Agreement
DRC	Democratic Republic of Congo
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
LCM	Luanshya Copper Mines
ICMM	International Council for Mining and Metals
IMF	International Monetary Fund
WBC	World business council
NGO	Non-Governmental Organization
SCO	Civil Society Organization
RAMCZ	Roan Antelope Mining Corporation of Zambia
RCM	Roan Consolidated Mines
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Development Project
WCED	World Commission on Environment and Development
ZESCO	Zambia Electricity Supply Company
ZCCM	Zambia Consolidated Copper Mines
ZCCM-IH	Zambia Consolidated Copper Mines- Investment Holdings

CHAPTER 1

INTRODUCTION

One of the world's most important sources of copper ore is found in Zambia and the Democratic Republic of Congo (DRC) in a region known as the Central African Copperbelt (US Geological Survey, 2013). Copper is used in electric cables and wires, plumbing, heating, pharmaceutical machinery, alloys, transport equipment and many other uses. Other important minerals from this region include cobalt silver, lead, zinc, gold (rarely) and gemstones. In Zambia, gemstone mining is mainly done by small-scale artisanal miners while copper and cobalt are mined by international companies. Since British colonial rule, Zambia was understood principally as a source of mineral wealth to support significant industrial, social, educational and governmental infrastructure (Mususa, 2014). To the surrounding communities, mining provides additional benefits of jobs, social services support and increased trade opportunities. Now 53 years after political independence, Zambia's mining industry has continued to grow and support the country's development process (International Monetary Fund, 2017). Yet, even though copper mining has many benefits for the country, it poses various risks to the surrounding environment such as pollution of water sources and air and degradation of land. Studies have shown that there are costs associated with mineral developments for resident communities, whose livelihoods are linked to the health of their environment (Limpitlaw, 2001; Sandlos and Keeling, 2009; LeClerc and Keeling, 2014). Due to Zambia's long history of mining, the impacts can be expected from both historical and contemporary mining operations.

This study investigates the relationship between long-term mining, land alterations and land use in the mining district of Luanshya in Zambia. The learnings from this study can be used to anticipate changes and assist in the development and implementation of integrated long-term land use planning of mining districts. This chapter presents the contextual background, research problem, key research questions and the scope of the study.

1.1 BACKGROUND

1.1.1 MINING AND SUSTAINABLE DEVELOPMENT

The application of sustainable development to mining has become a subject of debate in recent years. A number of interpretations have emerged, some with a focus on the non-renewable nature of mineral deposits and its implications for society (Hojem, 2014). Following the 1983 World Commission on Environment and Development (WCED), chaired by Gro Harlem Brundtland, a 1987 report named 'Our Common Future' was published. This report defined Sustainable Development as: 'Our Common Future' was published (WCED, 1987). This report defined Sustainable Development as: *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.''* The report highlighted three fundamental components to sustainable development namely environmental protection, economic growth and social equity. The concept of sustainable development focused attention on finding strategies to promote economic and social advancement in ways that avoided environmental degradation, overexploitation or pollution and side lined less productive debates about whether to prioritize development or the environment (www.kinglobal.org/catalyst.php). The World Bank later re-defined sustainable development as "development that lasts" (1992). These definitions have since invited a lot of criticisms and arguments that have furnished our current knowledge on sustainability and sustainable development (Sneddon et al, 2006).

Evidence from published literature on the mining industry and sustainability shows that the industry may understand sustainable development in a similar way as the above definitions, but it must also appreciate that many mining operations may have already compromised natural systems as attempts to generate economic growth and development have underestimated the value of the environment (Kumah, 2006). Mineral extraction is associated with both opportunities and challenges (Hojem, 2014). While mining brings significant investments in new ventures, more jobs and economic growth to a number of regions, it also faces some difficult sustainability challenges. It leaves visible footprints in its surroundings, and local communities who bear the consequences of environmental degradation have come to demand justice (Hojem, 2014).

Environmental impacts of mineral extraction and processing are long lasting and they are compounded by socioeconomic changes that occur at various stages in a mine's life cycle (LeClerc and Keeling, 2014). In Zambia, the Zambia-United Nations Sustainable Development Partnership Framework (2016-2021) recognizes land degradation as one of the major challenges hindering progress (Zambia-United Nations, 2016-2021). The Partnership Framework is a joint report by the United Nations and Zambia that affirms the United Nations' support to the Zambian government through the Sustainable Development Goals (SDGs). In response to the country's development issues, the Zambian government and the United Nations Country Team (UNCT) have partnered in pursuing eight partnership framework outcomes under three broad pillars; 1) inclusive social development, 2) environmentally sustainable and inclusive economic development and 3) governance and participation (Zambia-United Nations, 2016-2021). These outcomes are a result of an analysis of the underlying causes of developmental issues in Zambia which included environmental degradation as one of the key issues that leaves people vulnerable. Through a shared vision set out by the Sustainable Development Goals agenda, the government has set principals for integrated, people-cantered national planning that is supposed to leave no one behind (United Nations Zambia, 2017).

The government subscribes to the SDG's agenda through its medium term 7th National Development Plan for the years 2017-2021 (Republic of Zambia, 2017). The 15th SDG (sustainable ecosystems) provides for environmental protection. It aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (UN General Assembly, 2015). Furthermore, SDG 11 (sustainable cities and communities) also requires that land use planning and management systems must improve in order to make cities and human settlements inclusive, safe, resilient and sustainable (UN General Assembly, 2015). In order for the mining industry in Zambia to be sustainable and contribute to the achievement of sustainable development goals 11 and 15, the long lasting environmental impacts resulting from mineral extraction and processing must be understood and mitigated. The following section provides an overview of the mining industry in Zambia.

1.1.2 OVERVIEW OF MINING IN ZAMBIA

Globally, copper and other minerals are extracted from the earth because they are wanted or needed for various purposes. Notably, copper is sought for its thermal and electrical conductivity, high ductility and high malleability and thus easy to draw into wires and electrical equipment (Ayres et al, 2002). Zambia is among the leading producers of copper with Chile, China, USA, Canada, Russia and DRC (USGS, 2017). Ranked the 7th largest copper producer in the world, Zambia contributed about 4% to global copper output in 2017 (USGS, 2017). Most copper ore deposits in Zambia are hosted near its border with the Democratic Republic of Congo (DRC), in a region known as the Central African Copperbelt (US Geological Survey, 2013). The earliest commercial copper mining with heavy earth moving machinery is recorded at Luanshya in 1925 and since then, additional large copper mines have been established in the rest of the Copperbelt Province and more recently in the North-Western Province, sometimes referred to as the new Copperbelt (Lindahl, 2014). Several smaller copper mines have also been established in the rest of the country while small scale mining of other mineral deposits such as gemstones is taking place in various regions of the country (USGS, 2013).

Since its initial discovery, copper mining became the mainstay of Zambia's economy (USGS, 2013; Lindahl, 2014). According to the International Council on Mining and Metals (ICMM) 2014 report on Zambia, copper mining accounts for over 80 per cent of Zambia's export earnings (ICMM, 2014). Additionally, mining also contributes up to 12% to the national GDP and accounts for over 25% of the government's revenue. Mining also provides direct employment to about 1.7% of the workforce, and creates entrepreneurial opportunities and various social services such as schools, scholarships, health services, sporting, recreation facilities and agricultural support among others. Studies have found that due to the significant positive contributions of the mining sector, there is an inherent lack of diversification which makes Zambia's economic progress generally dependent and driven by mining (ICMM, 2014; Sikamo, et al., 2016; IMF, 2017). This is illustrated by Figure 1 which shows the various benefits of mining to the Zambian economy in comparison to other low and middle income mining-dependent countries in 2014.

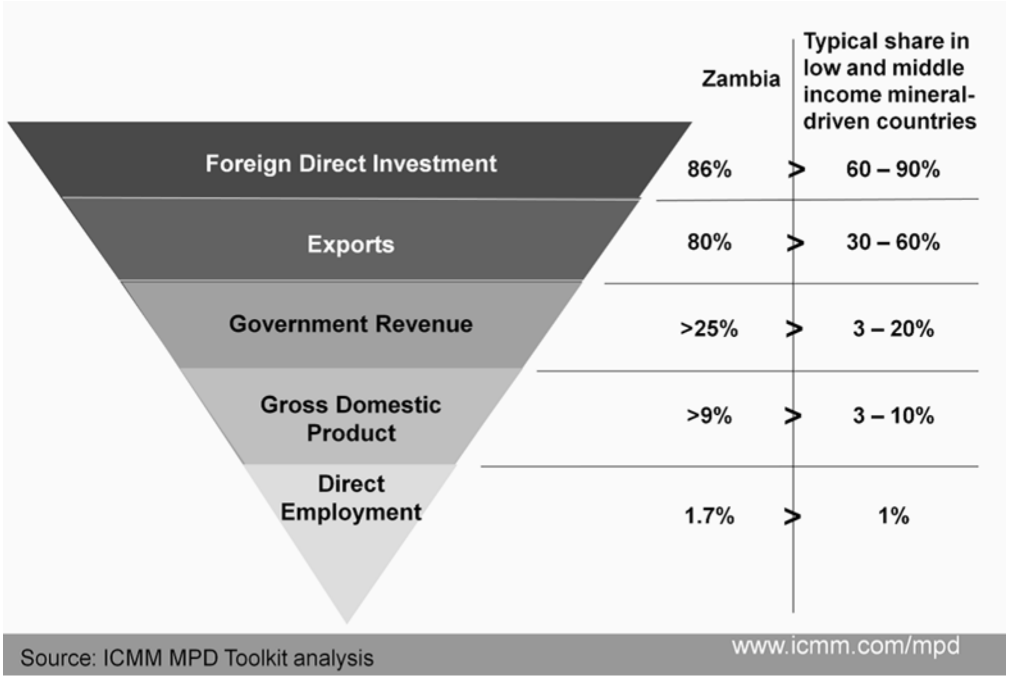

Figure 1: An overview of the macroeconomic contributions of mining in Zambia as of 2012. Source; ICMM 2014 Zambia report

Figure 1 clearly shows that the mining sector is a significant contributor to the growth and development of the Zambian economy. It also shows that Zambia depends more heavily on its mineral sector than other low and middle income mineral driven countries. However, these benefits are susceptible to volatility in the world copper price as evidenced by setbacks in 2014-2016 when the economic contributions from mining reduced in response to reduced commodity prices on the international market (IMF, 2017). Yet, despite such temporary setbacks, the mining industry continues to play a significant role in the national economy given that current copper export earnings are still high, amounting to 70% of Zambia's export earnings (IMF, 2017).

- **OWNERSHIP AND PERFORMANCE OF THE COPPER MINES IN ZAMBIA**

The mines in Zambia were initially privately controlled under the British colonial administration (Figure 2). From the first commercial mining operations in 1925 to the early 1970s, copper was on high demand as evidenced by the high prices. Figure 2 shows that copper mining contributed more than 12% to the national GDP. However, there were complaints that this abundant mineral wealth was not translating into development for the country or benefits to the general population (Mususa, 2014). This led to the formation of various labour groups calling for nationalist movements and in October 1964, Zambia won its political independence from Britain. The mines were nationalized in the early 1970s, under a socialist economic model with the creation of the state-owned Zambian Consolidated Copper Mines (ZCCM) (Mususa, 2014). ZCCM acquired the mandate of managing the portfolio of mining operations and also took up the responsibility for the provision of a wide range of social services and public goods to mine workers and their communities

(ICMM, 2014; Sikamo et al., 2016). The future of the industry was bleak, as copper output declined along with the national GDP (Figure 2).

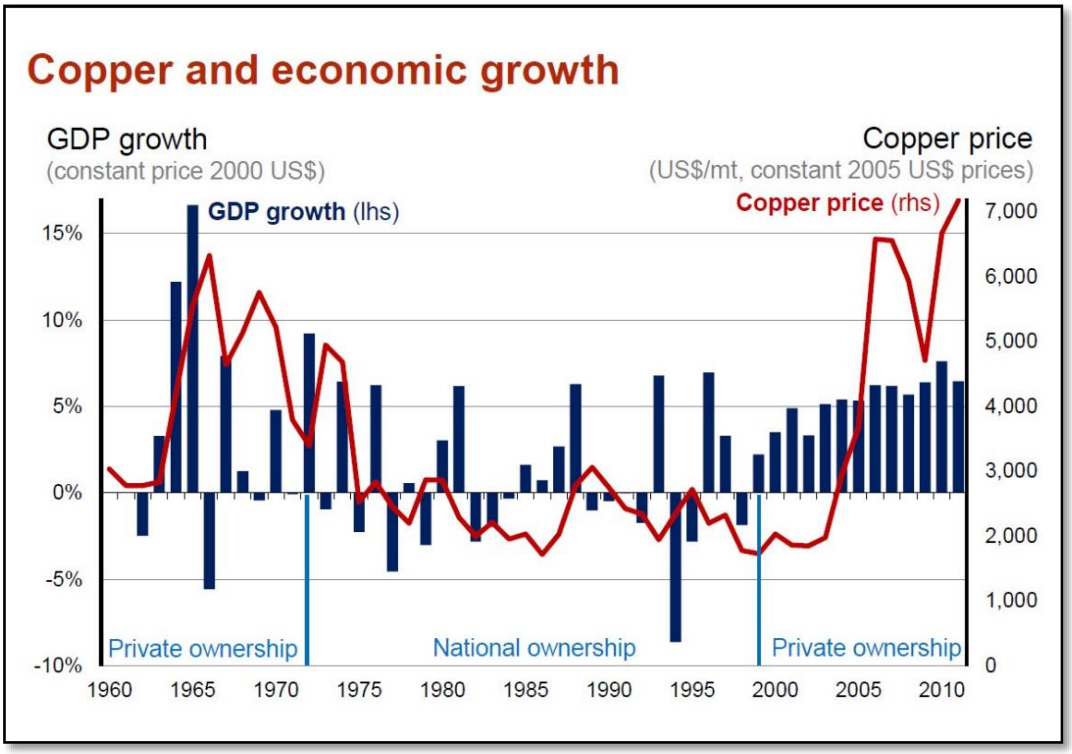

Figure 2: Zambia's GDP growth versus copper price under different ownerships. Source; ICMM 2014 Zambia report

It can be seen in Figure 2 that during the first few years following nationalization of the mines, copper prices were high and the mining industry’s contribution to the GDP remained high. However, the country’s economic policies during the copper boom were biased towards state intervention in the capture of copper-generated revenues (Meller and Simpasa, 2011). The state captured the revenues and expanded government consumption during the boom instead of diversifying. When copper prices fell sharply by 1975, the high consumption trends were difficult to reverse and the country’s reliance on copper led to heavy borrowing from international institutions (Limpitlaw, 2011; ICMM, 2014). As a consequence, we see that the GDP per capita fell significantly between 1975 and 1995 in figure 2. Furthermore, because ZCCM engaged in non-core business activities by investing in socially and economically unviable activities which required costly expansions to the workforce, the company failed to invest in exploration works to expand the ore reserves and replenish the equipment and hence there was an associated decline in copper output which magnified the effects of copper prices (Sikamo et al., 2016). During the years that the mining industry was in government control, Zambia’s annual copper production fell from just over 700 000 tons to 250 000 tons, and consequently, an average of about 2 000 mining jobs were lost every year (Sikamo et al., 2016). ZCCM’s operations became increasingly unprofitable as copper prices remained low for many years. In light of this declining economic growth, global financial institutions insisted on economic reforms which included reduced government expenditure, trade liberalization and privatization of the mining industry to reduce the role of government in price setting among other issues (Mususa, 2014).

Government decided to attract foreign investment to recapitalize the mines and in so doing, the industry was reprivatized in 1995, and big tax breaks were given to the new owners to attract new investments (Lindahl, 2014; ICMM, 2014). Whilst the privatization of the mines began in 1995, actual asset transfer only happened over the period 1998 to 2000. Generous capital allowances were given to the new owners by the government to attract increased investment and promote job creation for the country's growing population (Masinja et al., 2005; Lindahl, 2014). As a result of this privatization, large amounts of money were invested by the new owners. Shortly after privatisation of the mines, copper prices started improving. However, due to the incentives given to the private developers, government failed to capture any resources rents during the boom (Meller and Simpasa, 2011). This led to cancellation of the DAs and the establishment of a new fiscal regime for the mining sector in 2008. Royalty rates were shifted upwards (from 0.6 to 3 %), variable profit taxes were adjusted upwards and windfall tax taxes of up to 75 % for copper prices of above $7, 840 per ton (Meller and Simpasa, 2011). As a result of this shift from its commitment to respect the legal provisions of the DAs, government was challenged by the companies. Furthermore, the expected increase in economic returns form the adjusted fiscal revenues did not to materialise due to the global economic meltdown which followed in 2008 (Meller and Simpasa, 2011). In 2009, the top two bands of the graduated variable profit tax were removed and the windfall tax completely withdrawn (Meller and Simpasa, 2011). As result of its history of regular policy adjustments, Zambia's policy environment is considered not favourable in terms of attractiveness to mining investments (Meller and Simpasa, 2011; World Bank, 2011). Nevertheless, due to the new investments, annual finished production rose from a low of 250,000 metric tons per annum to over 700,000 metric tons in 2016 and 2017 with future predictions expecting this production to rise towards 1 million metric tons in 2018 (IMF, 2017).

Currently, copper mining accounts for about 70 percent of Zambia's export earnings and the recent steady increase in the world price from about US$5,700 per metric ton in December 2016 to nearly US$6,500 in August 2017 has brightened the economy's prospects and is expected to have positive spill overs to other sectors (International Monetary Fund, 2017). Even though Zambia's mines have undergone significant changes in ownership models over the past years, the overall contribution of mining to the national economy has been higher than the contribution from other sectors. Studies have shown that there is a connection between investments in the mining industry, levels of copper production, employment, and the performance of the wider economy (Sikamo et al., 2016). The 2017 analysis of the Zambian economy by IMF also shows that the average growth of the mining sector has been faster than other major sectors. Future projections hypothesise that effective revenue collection from mining can have positive spill overs to other sectors and improve the national economy (IMF, 2017). Furthermore, the International Copper Alliance (2017), predicts that global demand for copper will rise as copper is considered one of the strategic metals for the low-carbon economy driven by innovative technologies in smart energy, aquaculture, electric cars, electro mobility, energy efficiency and renewable energy with sustainable benefits to climate action. As such, the copper mining industry in Zambia needs to prepare for the increasing demand by understanding and managing the impacts.

- **LEGISLATION AND REGULATION OF THE MINING INDUSTRY IN ZAMBIA**

Zambia did not have environmental management legislation until 1990 (Chileya and Dokowe, 2014). Until then, all the large scale mining was taking place without sound environmental management. Over the years as the population of the country grew, the environmental issues became less acceptable and in 1990, government enacted the Environmental Protection and Pollution control Act (EPPCA). The environmental Council of Zambia (ECZ) was established under this Act and 7 other regulations were established to support it (www.zema.org). In 1997, the environmental protection fund was setup and regulations for environmental impact assessments, mine dumps, air and water quality, and emissions were passed.

When the mines were privatized between 1998 and 2000, the responsibility for environmental liabilities and performance in Zambia was shared between the government (GRZ), the investor or Zambia Consolidated Copper Mines-Investment Holdings (ZCCM-IH) and differed at each mine site (Masinja et al., 2005). Special arrangements were made between the developers and government at the time of privatization and relevant legislation in force at particular times was different. Each case was accompanied by a Development Agreement (DA) and an Environmental Liabilities Agreement (ELA) each with different commitments and obligations to the different parties involved in the deals (Masinja et al., 2005; World Bank Group, 2011). These deals were agreed upon in recognition that during the period of state ownership, there was very little investment in environmental management by ZCCM. The new investors were unwilling to accept legal responsibility for legacy liabilities and hence were given concessions to limit their liabilities (World Bank Group, 2011). Stability periods were also given during which environmental legislation would not be enforced and this meant the investor set the standard by which they would operate in the Environmental Management Plan (EMP) and that standard was the requirement for compliance (Masinja et al., 2005). The environmental law would only be enforced at the end of the stability period set in the DAs. Some investors such as Konkola Copper Mines and Chambishi Metals were indemnified by ZCCM-IH and government against suits arising from past ZCCM operations provided that they were operating within the agreed EMP. As such, ZCCMIH or government also carried the responsibility for any issues arising from possible legal action (Masinja et al., 2005). This represented a trade-off between the need for increased copper output/economic growth and environmental management. Such agreements have been criticised as being detrimental in the long-run as they reduce the revenue prospects of mining countries (World Bank, 2016). Studies have found that such types of stabilization clauses in contracts between investors and host states could also constrain the state's ability to protect human rights (International Finance Corporation-UN, 2009). After privatization, every mining company was mandated to prepare an EMP to submit to the Environmental Council, ECZ (now Zambia Environmental Management Authority, ZEMA) for approval within specified time frames. However, some companies did not have specified timeframes within which to complete these and the old ZCCM EMPs were adopted while time was given to the investor to prepare theirs (Masinja et al., 2005). This meant that the same poor environmental performance was carried over by the private investors as environmental issues continued to accumulate.

Revisions and improvements have since been made to the legislation, and currently, the mining industry in Zambia is mainly regulated by the Mines and Minerals Act of 2015 (Chapter 213 of the laws of Zambia). All rights of ownership in searching for mining and disposing of minerals in Zambia are vested in the president on behalf of the people (Mines and Minerals Act, 2015). Under this Act, the non-renewable nature of mineral resources is appreciated and a set of principles for mining and minerals development have been laid down as follows;

a) Minerals are to be explored and developed in a manner that promotes and contributes to socioeconomic development and in accordance with international conventions to which Zambia is a party.

b) The exploitation of minerals shall ensure safety, health and environmental protection.

c) Wasteful mining practices shall be avoided so as to promote sustainable development and prevent adverse environmental effects.

d) Citizens shall have equitable access to mineral resources and benefit from mineral resources development.

e) Development of local communities in areas surrounding the mining area must be based on prioritisation of community needs, health and safety.

Four directorates were appointed and given power by this law to regulate the industry and ensure that the laid down principles are attained. Other important legislation relevant to the mining industry includes the Mines and Minerals Act No. 31 of 1995 (MMA), Mines and Minerals (Environmental) Regulation 1997 (MMER) and the Mines and Minerals (Amendment) Act 2000. The Environmental Protection and Pollution Control Act of 1990, and its 1999 amendment address environmental issues, including those associated with the mining industry. Issues pertaining to land use planning are guided by the 2015 Urban and Regional Planning Act and the Public Health Act. Some of these legislative Acts have since gone through various repeals and have been re-defined, but they are the laws that have guided the mining industry's environmental performance in Zambia. The present day environmental status of the mining regions in the country is as a result of how these laws have been applied or enforced.

Despite all these Acts being in place, Zambia's legal and institutional framework, particularly its implementation and enforcement is still considered to be weak. Nothing in the law requires mining companies to consider community and future land use in their planning and construction. Research shows that inadequate regulatory frameworks and weaknesses in the rule of law have enabled investors and the Zambian "elite" to circumvent legal requirements (Sambo et al., 2015). Some notable issues recognised with the application and enforcement of the environmental legislation include inefficiency, low institutional capacity, duplication of efforts, lack of collaboration among various branches of government and under-enforcement of legislation (Banda and Zulu, 1998; Lindahl, 2015; GRZ, 2015; Sambo et al., 2015). Sambo et al (2015) further point out that some of the key challenges affecting sustainable land use investments in Zambia include lack of incentives, insecure customary land tenure and failure to incorporate adequate processes to uphold social safeguards such as consultation with land users in the legal framework (Sambo et al., 2015). Due to low institutional capacity to enforce the social and environmental safeguards that are established in the law, access to information on investments is limited, which in turn reduces the potential for public scrutiny and participation (Sambo et al, 2015).

1.1.3 MINING AND ITS IMPACT ON LAND AND LAND USE

Mining brings alterations to the visible characteristics of the land surface including topography, vegetation cover and water bodies (Alam, 2014). These landscape alterations occur as a result of deforestation and occupation of land by the mine workings and mine wastes. Mining-induced land alterations may subsequently result in land degradation through pollution, dewatering or stripping and hence cause a reduction in the land's ecological and economic productive potential (UNEP, 2015). According to UNEP (2015), land degradation is defined as a process that encompasses any reduction or loss in the biological or economic productive potential of the land. This reduction can be permanent or temporary and it includes soil erosion and deforestation and is usually caused by human activities, worsened by natural processes and usually magnified by climate change (UNEP, 2015). Mines contribute to land degradation throughout their life cycle, from exploration through to beneficiation and closure (Moon et al, 2006). A mine develops through a process that begins with mineral exploration and prospecting (Moon et al., 2006; Alam, 2014). During advanced exploration surveys, an area's land can be locally altered through removal of vegetation and topsoil. When there are many exploration projects happening in the same area, cumulative impacts can result in significant land alterations (Moon et al., 2006; Alam, 2014). If an exploration project is proven to be economically viable, mining facilities are established at the development stage during which more vegetation and topsoil are removed (Alam, 2014).

After development, the next stage is mining during which mineral ores are extracted from the ground either through open pit (surface) or underground operations (Calcutt, 2001; Yilmaz, 2011). Open pit or surface mining is employed when the ore bodies are low grade, relatively near surface and laterally extensive. Underground mining is done when the deposit is of higher grade and deep (Calcutt, 2001). Surface mining is generally preferred over underground mining because it is cheaper, safer and provides better ore recovery, grade control, and has fewer limitations on the operation of large machines with high capacity. Underground operations are more expensive and considerably dependent on rock conditions (Hartman, 1992; Yilmaz, 2011). However, surface mining is more damaging to the environment as it results in large scale loss of vegetation and soil cover and produces high volume wastes. Large excavations are created at open pits and most of the extracted material is piled at the surface as waste rock, overburden or slurry dumps. At underground mines, the excavations happen below the ground surface and most of the extracted material remains underground with less physical alterations to the land surface, and lower volumes of waste (Yilmaz, 2011; Alam, 2014).

Once extracted, ores typically undergo further processing to liberate and separate the valuable ore-bearing minerals from the host rock by crushing, milling and gravity separation or flotation (Ayres et al., 2002). These processes produce additional wastes in the form of slurry tailings, which are stored in tailings impoundments (Yilmaz, 2011). Consequently, mines and milling plants at open pit mines produce highly voluminous wastes which alter the landscapes of an area and degrade the land. Mines wastes are a potential source of environmental pollution, as over 90% of extracted material ends up in waste storage facilities (Ayres et al., Yilmaz, 2011). Figure 3 shows a schematic of the physical alterations at mine sites.

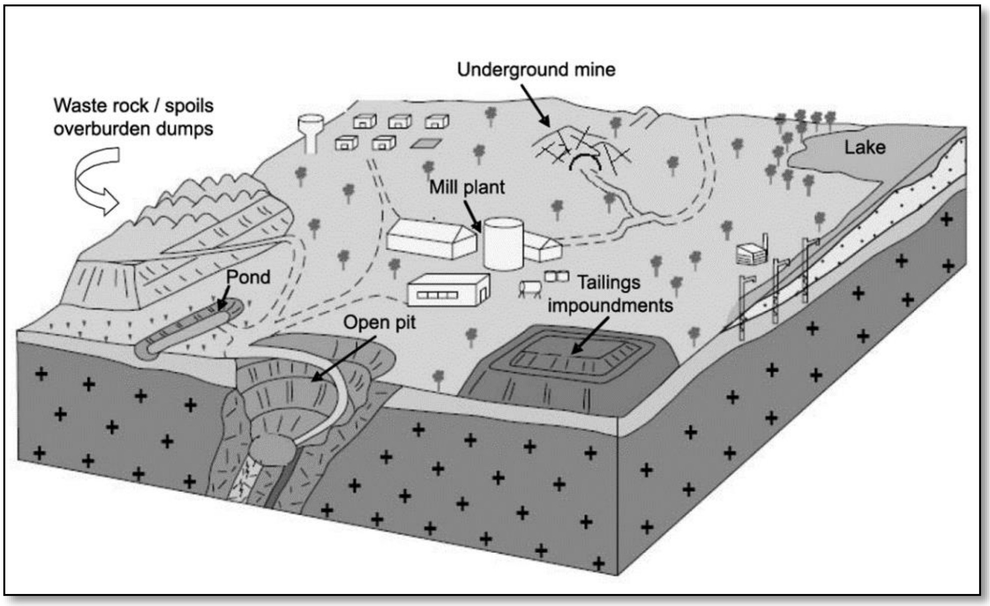

Figure 3: Schematic of mining operations set up. Source; Yilmaz, 2011

The impacts of mining operations and mine waste deposits on land can last for many years. For example, in India it was found that the cumulative effects of mining contributed to the significant loses in rain forests and rich top soil (Sahu and Dash, 2011). Other impacts include water and air pollution. In a related example in Germany, remediation of the Wismut uranium mining area in the former East Germany cost taxpayers over €6.6 billion since the 1989 re-unification. Furthermore, the treatment of the water in rivers in the nearby Schlema-Alberoda area is currently ongoing and is said to be a continuous process for many more years to come.[1]

These land alterations and waste piles impact other socioeconomic activities such as forestry, farming and urban development (Limpitlaw, 2001; Alam, 2014). A study conducted to examine the post-industrial land use in Canada's Northwest Territories found that land users continued to be influenced by the changes in the landscapes 25 years after mine closure (LeClerc and Keeling, 2014). Traditional land uses of hunting and trapping for subsistence and trade previously practiced in this area were impacted by landscape changes and introduction of wage labour. An extensive network of cut lines was bulldozed through the local forest during exploration surveys and displaced some local land users who hunted and trapped in the area. Additionally, highway construction and the process of dewatering open pits disrupted the local hydrology, causing localized flooding that also forced local land users to abandon trapping in the area (LeClerc and Keeling, 2014). LeClerc and Keeling (2014) concluded that if mining is to become sustainable, issues concerning local land use must be addressed at each stage of mining projects from exploration to mining and post closure. In a related example, a land mapping study conducted in the Iron Quadrangle (QF) mining region of Brazil showed that mining influenced land use both directly and indirectly (Sonter et al., 2014). In their report, Sonter et al. (2014) state that the processes of land use change in mining areas is different from those in non-mining areas and, as such, suggest that land use and management policies should reflect this. This means that mining regions cannot be managed the same way as non-mining regions. Additional protective and control measures must be in place to safeguard the environment for the surrounding communities that depend on it (Sonter et al., 2014).

As is the case with international studies on mining, a number of studies attest to land alterations and degradation as a result of mining in Zambia (Limpitlaw, 1998; ICMM, 2014). The landscape on the Copperbelt province in Zambia is characterized by open pits and hills of mine waste dumps (Limpitlaw, 1998). These mine waste dumps are usually located within or near population centres, thus making their potential impacts more threatening. The close proximity of mining areas and mine waste dumps to active population centres in Zambia has been criticized by Banda and Zulu (1998) as a reflection of the lack of efficient planning and enforcement of environmental regulation. Limpitlaw (2001) also notes that landscape changes in mining

[1] www.wismut.de; Bismuth News; cleaned 100 million cubic meters of water in the WBA Schlema-Alberoda.

towns of the Zambian Copperbelt sometimes happen abruptly, and the impacts can last for decades after mine closure thus threatening the ecological sustainability of those areas. This is consistent with the views of Ayres et al (2002), who express fears that the mining industry is likely to be a significant polluter in the developing countries like Zambia due to weak environmental laws, corruption or both. It is feared that companies working in countries with weak environmental laws usually perform to the low country standards thus leaving communities to bear the consequences of environmental degradation (UNECA, 2011).

Being one of the first districts in which commercial copper mines were established in Zambia, Luanshya has not been spared from mining-related land alterations and degradation. Concerns have been raised by stakeholders over the socio-economic impacts related to mining activities such as deforestation, soil degradation, dust emissions, cracking and partial sinking of land and buildings, water pollution and silting of rivers (Masinja et al., 2005). However, no studies have been conducted in this district to assess the relationship between mining and landscape alterations and the extent to which this relationship has been influenced by global economic and national governance issues.

1.2 PROBLEM STATEMENT

Although copper mining is a significant contributor to the national economy in Zambia, it has also introduced negative impacts on the environment, the landscapes and land use patterns in mining districts. Changes in the world copper prices and the weak regulatory framework may also have an impact on local development and contribute to the environmental degradation. While mining activities take place on the local level, they can also affect regional and national processes such as land use planning. This may be particularly pronounced in Luanshya district where one of the earliest commercial copper mines was established in the Copperbelt province. Studies in other countries have shown that impacts on the land can persist long after extractive operations stop, and a number of studies have been undertaken on the impacts of mining on land quality in the Zambian Copperbelt. However, to date no studies have been conducted to show the relationship between long-term mining, land alteration and community land use in Luanshya district to support effective long-term planning for mining towns both during and after the life of the mine.

1.3 PROJECT SCOPE AND OBJECTIVES

The main objective of the study is to identify the relationship between long-term mining, landscape alterations, land-use planning and community land use patterns in the mining district of Luanshya in Zambia. The specific objectives of this study are to:

1. Map the landscape changes that have taken place in Luanshya district over the past 32 years.
2. Investigate how these landscape changes relate to mining activities and other land use patterns in the district.
3. Establish what the approach to land use planning has been by the relevant stakeholders.

This study entails three main tasks;

1. Literature review and analysis. The study begins by reviewing relevant literature on the copper mining process, mine waste and the land-related impacts of copper mining, the policies and regulations governing the mining industry and land-use planning in Zambia. Sources of information include published literature newspaper articles, company reports and the publications from the Zambian government printers.
2. Landscape change mapping. The second stage involves collection of spatial land use data from Google earth, satellite images, and archive search in the study area. This was done to achieve the second objective of the study; to map the landscape changes that have taken place in the Luanshya district over the period 1984-2016.
3. Semi-structured interviews. To assess the implications of land alterations and degradation on land planning and other land uses, semi-structured interviews were conducted with representatives of key government sectors, namely agriculture, forestry and the local municipality, as well as the local mining company. Questions here were designed to obtain a better understanding of the observed changes in land use patterns in the Luanshya district and how this has been influenced by land-use planning, and the roles of different stakeholders in this planning.

It is anticipated that this project will contribute to knowledge generation to support the development of sustainable land planning and use in mining districts. However, it should be noted that while policies and regulations governing the mining industry and land-use planning have been discussed, a detailed analysis of governance and planning processes is not the central focus of this dissertation. Rather, their discussion is meant to help understand both the direct and indirect relationships between mining and land alterations, with a view to guiding improved policy and strategy development for land-use. It should also be noted further that while the indirect impacts of mining on health and socio-political and socio-economic issues are briefly discussed in this study, it is beyond the scope of this study to undertake a comprehensive analysis of the these issues. Impacts related to the alteration of the visible features of land and land use changes are the main focus of this study.

1.4 DISSERTATION STRUCTURE

This dissertation is presented in 4 chapters. Chapter 1 provides an introduction to the study, the objectives and scope of work. Chapter 2 provides a summary and synthesis of the reviewed literature in line with the first task of the study and chapter 3 presents the research questions and case study methodology. Chapter 4 presents the findings and analysis of the mapping exercise and the interviews. Chapter 5 draws conclusions and makes recommendations for alternative uses of post-mining landscapes and for future studies.

Figure 4 shows a schematic of the dissertation structure.

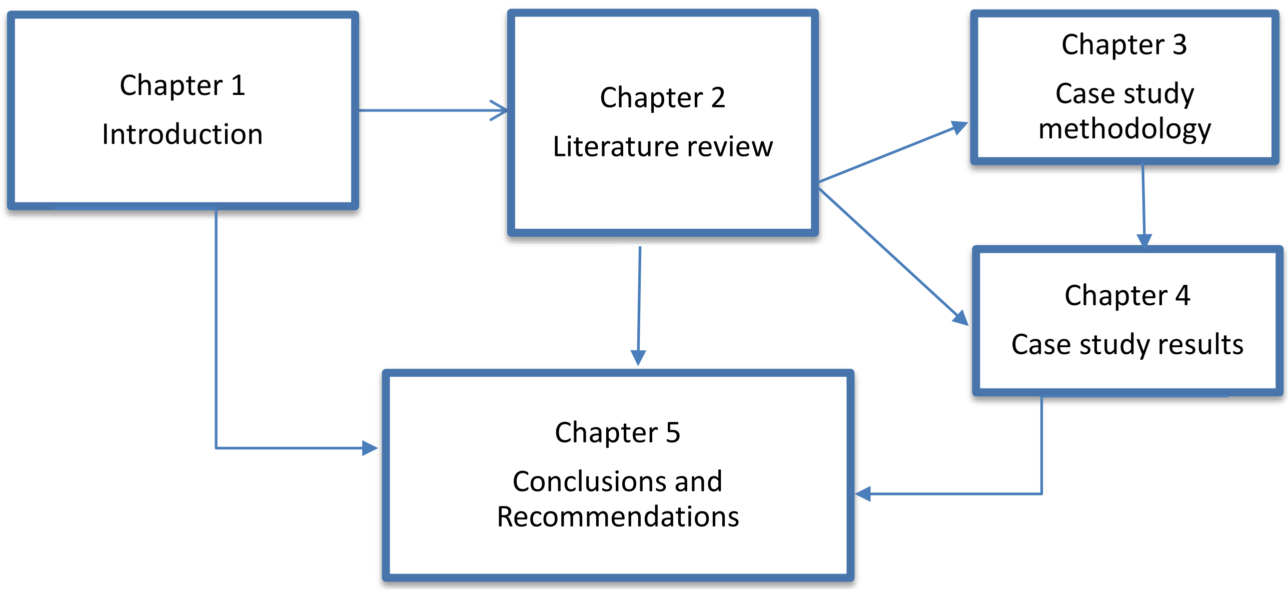

Figure 4: Dissertation structure

In line with the dissertation structure and scope of the study, the next chapter presents a review and analysis of the relevant literature.

CHAPTER 2

LITERATURE REVIEW

As noted in section 1.1.2 of the introductory chapter, copper mining plays a major role in Zambia's economy. However, copper mining and its primary beneficiation processes are also associated with generation of highly voluminous wastes which alter the landscapes and impacts local land use (Limpitlaw, 2001; Yilmaz, 2011). Other impacts include water and air pollution. The air emissions from copper smelting also contribute a significant share of global elemental sulphur which forms acid rain and degrades the land thus impacting agricultural production (UNECA, 2011). According to Ayres et al. (2002), the mining industry is likely to be a significant polluter in the developing countries like Zambia due to weak environmental laws, corruption or both. This is also supported by Sambo et al. (2015) who argue that inadequate regulatory frameworks and weaknesses in the rule of law have allowed investors and the Zambian "elite" to circumvent legal requirements. Inadequate institutional capacity to enforce the rule of law, over-dependency on copper mining and management inefficiencies have allowed companies to perform to the low country standards and, as already indicated in the introductory section, indigenous communities whose livelihoods depend on the health of their environment are the most impacted (Sandlos and Keeling, 2009; LeClerc and Keeling, 2014).

This chapter presents a detailed review of the literature on copper mining, how it relates to landscape alterations and their connection to community land use practices, consistent with the first task of the study. The chapter also reviews the policies and legislation of relevance to land degradation and use, as well as initiatives taken to mitigate land degradation in Zambia.

2.1 COPPER MINING, LAND ALTERATION AND LAND USE

There are various ways through which mining can result in land alterations and have subsequent impacts on community land use. As already discussed in section 1.1.3 of the introduction chapter, mining-induced land alterations may cause land degradation through pollution, dewatering or stripping and hence cause a reduction in the land's ecological and economic productive potential (UNEP, 2015). The impacts of mining on land start during exploration when vegetation is cleared to create access routes, trenches, test pits and boreholes (Environmental Law Alliance Worldwide, ELAW, 2010). When a mineral deposit is discovered, the project goes into development stage during which the developer constructs more roads, mine support facilities and stripping of overburden is done to create access to the ore body (ELAW, 2010). After development, impacts on land can result directly as a result of actual mining activities or indirectly as a result of community development around mine sites. Figure 5 shows some of the different ways through which mining can impact the land quality of an area.

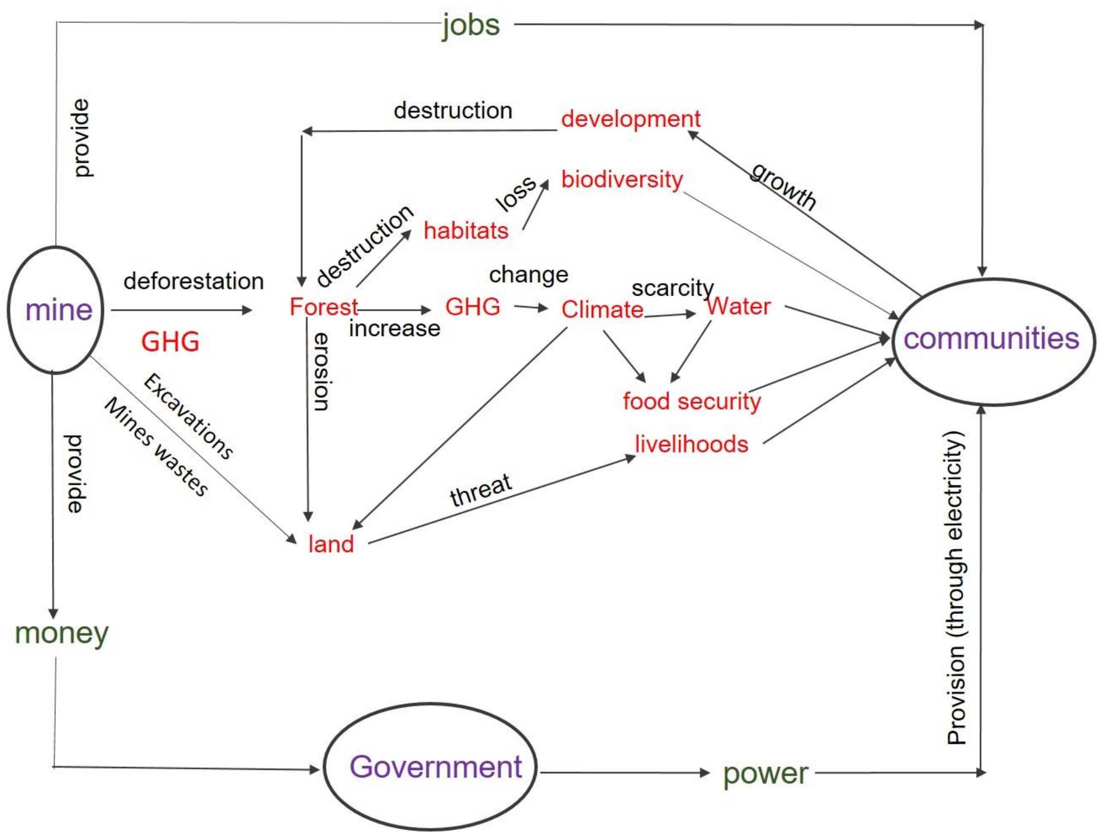

Figure 5: Illustration of some of the key impacts of mining on land through direct and indirect processes. Modified after Harrison (2015).

Figure 5 shows that mining impacts land directly through physical disturbances at mine workings such as deforestation to clear the land for excavations (for open pit mining), and the associated waste disposal areas. These excavations and mine waste disposal areas also cause visual and aesthetic impacts on the landscape while deforestation results in soil erosion and biodiversity loss through habitat destruction which consequently threatens community livelihoods and food security. Mine infrastructure and support facilities such as processing plants and offices also occupy part of the land at mine sites and may be salvaged during mine closure (ELAW, 2010). In the long run when mining stops, there are limited options for economic use of degraded lands for the communities (UNEP, 2015). Communities may try to regain usage of the land they initially lost to mining by making use of the remnant mine facilities such as water-filled open pits for domestic water supply or fishing and other previously contaminated soils for growing of crops, which pose serious health and safety issues to the communities (Lindahl, 2014).

Government benefits from mining through revenue collection and communities gain employment and entrepreneurship opportunities (Figure 5). As communities are developed, they also impact the landscape of an area through land clearing for occupation, farming or other socio-economic activities as well as through domestic and sewage waste disposal (Lindahl, 2014; Petrova et al., 2015). The following sub-sections discusses the direct (Section 2.1.1) and indirect (Section 2.1.2) impacts of mining on land.

2.1.1 DIRECT IMPACTS OF MINING ON LANDSCAPES

Mining directly impacts land quality and land use through five main activities, as outlined in Table 1.

Table 1: Mine activities directly impacting land quality and use: summarized from ELAW, 2010

Activity	Related impacts
Land acquisition and relocations	▪ Livelihood disruptions and limitations on access to land and water resources ▪ deforestation away from mine sites
Vegetation cover removal	▪ land moves towards degradation through deforestation and ▪ increase in soil erosion and siltation
Overburden removal	▪ loss of top soil by removal and mixing with overburden ▪ alteration to landscape scenery
Pumping out of water from mine workings	▪ lowering of water table ▪ land subsidence
Mine waste and emission generation	▪ land use change through storage of wastes ▪ land degradation through contamination

These activities and related impacts are discussed in the following sub-sections:

- **LAND ACQUISITIONS**

Copper mining is associated with large-scale land acquisitions which pose challenges to safeguarding the rights and livelihoods of displaced communities (Chu et al., 2015). In their study, Chu et al. (2015) established that land acquisitions in Zambia are sometimes characterised by lack of consultation with the community and inadequate legal provisions to protect the affected communities. As such, thousands of households have been impacted in Zambia. For example in 2008, Munali Nickel Mine in Mazabuka district acquired 5,100 ha of land displacing 125 families (Mukupa, 2014). Similarly, in 2013 First Quantum Minerals (FQM) Trident Mine project in Solwezi district displaced 600 households and impacted their livelihoods and food security (Mukupa, 2014). Land acquisitions do not alter the land around the mine site but alternative land is cleared away from the planned mine site to accommodate the displaced communities (Hund et al., 2017). Land acquisitions deny people access to land which is a basic natural resource upon which their livelihoods depend and can cause conflict when trying to win back access (Mwitwa and Chikumbi, 2015). Land acquisitions are also linked to inequalities among the communities, competitions and increased environmental degradation (Mwitwa and Chikumbi, 2015).

- **PHYSICAL LAND ALTERATIONS THROUGH VEGETATION AND OVERBURDEN REMOVAL**

During vegetation and overburden removal, an area loses its greenery while top soil and overburden are removed to create access to the ore body (Yilmaz, 2011). Figure 6 shows examples of physical land alteration and land degradation at mine sites.


Figure 6: Land degradation due to vegetation and soil removal during surface mining operations. Photograph on the right downloaded from www.zambiaminingphotos.com. Photograph on the right is used with permission from Lewis Tumbama.

Figure 6 shows land impacted directly though physical disturbances, which can be considered as "degraded"[2]. As a result of the deforestation caused by mining, soil erosion occurs resulting in larger areas being impacted as fine sediments (silt) continuously build-up in the river channels and may flow into the environment during flooding (Sracek et al, 2011). According to UNEP (2015), degraded lands may never be restored to their natural state or to a state usable for the community's traditional land use practices. This is supported by UNECA (2011) who point out that land degradation is a serious problem as it introduces limits to the land use options available for the communities whose livelihoods are dependent on healthy land. Large-scale land alterations associated with open-pit mining may also disrupt the natural flow of surface and ground waters (UNECA, 2011). It may lower the water table in the mine area and cause water shortages, land subsidence and fracturing which further impacts the landscape and can introduce additional health and safety risks to the mining areas (UNECA, 2011). Although the industry is increasingly using underground techniques as surface deposits become depleted, most mines in Zambia have historically employed the open pit method for exploiting low-grade and easily accessible ore deposits which has significantly altered the landscapes in the Copperbelt towns (Limpitlaw, 1998; Zientek et al, 2014).

[2] According to UNEP's definition of land degradation as a process that encompasses any reduction or loss in the biological or economic productive potential of the land including soil erosion and deforestation (UNEP, 2015)

- **MINE DEWATERING**

Since mining usually extends to depths below the ground water table, large quantities of ground water are pumped out of the mine workings to allow mining to continue (ELAW, 2010). The pumped ground water is channelled to rivers or to open pits which are no longer in use where it can form pit lakes (ELAW, 2010). Pumping of ground water results in lowering of the ground water table and can cause ground subsidence (ELAW, 2010). Water at mine sites is a resource but may also be a nuisance at the same time as it poses management challenges (Soni and Wolkersdorfer, 2014). It is frequently monitored and various water management systems have been developed to reduce the amount of mine water produced. Good practice recommends treating the water before it is discharged into the environment, but there are some instances when untreated waste waters have entered rivers and streams due to maintenance failures or faults and consequently contaminated them (Limpitlaw, 1998). In Zambia, Konkola Copper Mine (KCM) in Chililabombwe is the world’s wettest mine (KCM, 2016). Its dewatering contributes about 400,000 cubic meters of water to Kafue River per day. The water is channelled through sumps for settling and sedimentation before clean and clear water is pumped for discharge into the Kafue River (KCM, 2016). The Kafue River is the main water source for various uses in the Copperbelt province and Lusaka city and most of the mines in the province are located along this river or its tributaries (Sracek et al, 2011). Studies suggest that other mines located along this river course may also be contributing significant quantities of mine water and metals to the Kafue River (Sracek et al, 2011).

- **LARGE VOLUME WASTE STORAGE**

Mining generates wastes through three main processes; mining itself (which is the extraction of the ore from the ground); mineral processing or beneficiation (which produces a mineral concentrate out of the ore); and metallurgical processing (which generates a refined metal out of the mineral concentrate) (Lottermoser, 2007; Lèbre and Corder, 2015). All three processes produce wastes, collectively referred to in this report as mine wastes. Mine wastes include solid, liquid or gaseous emissions which are of no immediate economic value and accumulate at mine sites (Lottermoser, 2007). During mining, wastes generated include overburden and waste rock removed to gain access to the ore, as well as dust emissions. Once the metalliferous ore is extracted from the ground, it is beneficiated using techniques which involve physical crushing, gridding, sorting and the addition of reagents to separate the minerals from gangue material (Lottermoser, 2007). Mineral beneficiation generates wastes which include tailings, sludge, wastes waters and noxious gases. After mineral beneficiation, the mineral concentrate is processed further using extractive metallurgy which involves use of solvents to break the crystallographic bonds in the ore to liberate the element of interest (Lottermoser, 2007). Figure 7 illustrates the different processes through which mine wastes and emissions are generated.

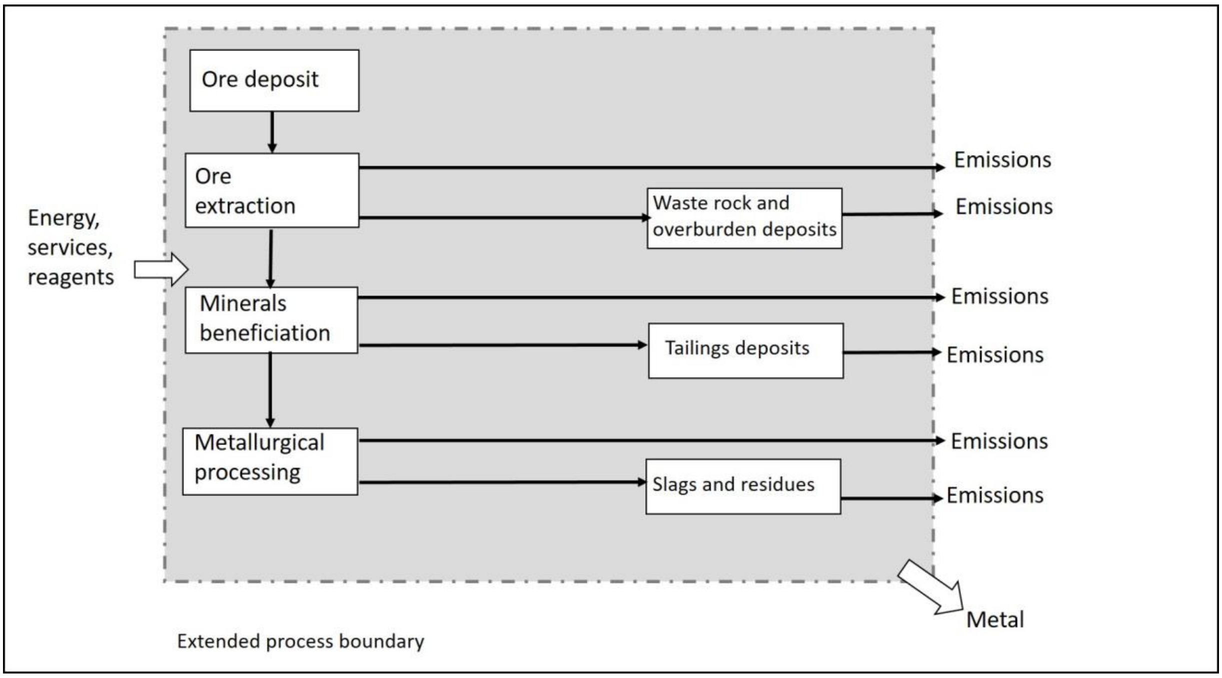

Figure 7: Link between mining and the processes through which mine wastes are generated. Modified from Broadhurst et al., 2007.

It can be seen from Figure 7 that mine wastes are generated at different stages in the mining process. As such, mine waste materials also differ and vary in their physical and chemical composition, their potential for land degradation, the processes of their management at mine sites, and their disposal. Mine wastes are conventionally stored in impoundments at mines sites where they impact the land through occupation and generation of emissions, which include dust, seepage of contaminated leachates and run-off (Bellenfant et al., 2013). Specific wastes and their land-related impacts are outlined in (i) to (v) below:

(i) Overburden

Overburden includes the soil and weathered rock that is removed to gain access to the ore deposits without blasting at open pit mines (Bellenfant et al., 2013). Overburden is usually piled on the surface at mine sites where it will not obstruct further expansion of the mining operations. Overburden generally has a low potential for land degradation, and is often used at mine sites for backfilling the open pits, landscape contouring and re-vegetation during mine closure (Limpitlaw, 1998). From the environmental point of view, overburden can support vegetation growth without artificial additives (Adamek et al, 2005). The main impact of overburden on land is its occupation of large areas of land at mine sites (Lottermoser, 2011). However, if they are left un-vegetated, overburden dumps can cause environmental issues such as dust fallout, geotechnical failures and, during the rainy season, runoff from these sites can carry sediments into the surrounding environment.

(ii) Waste rock

Waste rock is coarse wall rock material that contains minerals in concentrations considered too low to be extracted at a profit (Lottermoser, 2007; Yilmaz, 2011). The amount of mine-generated waste rock depends largely on the shape of the ore body and the mining plan. The cut-off grade distinguishes ore from waste rock and it is determined by all the factors which control the costs of the overall mining operations (Limpitlaw, 1998; Lèbre and Corder, 2015). Waste rock is often stored in heaps or dumps on the mine site, but may be stored underwater with tailings if it contains a lot of sulphide minerals and has a high potential for acid rock drainage formation. Waste rock dumps mainly impact the land by occupation and may also have a high potential for land degradation through pollution by seepage depending on their chemical composition (Yilmaz, 2011; Bellenfant et al., 2013). In Zambia, hills of waste rock material are a common feature in mining towns (Limpitlaw, 2003). Eroded material from waste rock dumps may be deposited in nearby streams or on adjacent farmlands thus reducing their economic potential.

(iii) Tailings

Tailings are finely ground rock and mineral waste products of mineral processing operations (Lottermoser et al., 2011; Yilmaz, 2011; Lèbre and Corder, 2015). Tailings cover valuable topsoil and have a high potential for land degradation as they may also contain leftover processing chemicals which can sterilize the land by seepage. They are usually deposited in the form of water-based slurries into tailings impoundments. Un-stabilized tailings impoundments can burst and spill waste into the environment (Lèbre and Corder, 2015). On the Zambian Copperbelt, tailings are usually deposited in clay-rich wetlands where long retention times allow solids to settle out and organic materials to be decomposed before they are released into the environment (Limpitlaw, 2003; Von der Heyden, 2005). As low relief areas, wetlands play an important role in trapping sediments and preventing erosion. Wetlands filter sediments and form low turbidity water that are carried by rivers in their natural state (Von der Heyden, 2005). Mining companies discharge tailings to some of these wetlands for their effective “natural treatment” capabilities. However, this practice causes degradation of the wetlands, thus endangering their role in sustaining both local communities and ecosystems (Von der Heyden, 2005). Contaminated leachates potentially generated from tailings disposal sites over many years pose threats to ground and surface waters and affects the ecological integrity of those areas (Sandlos and Keeling, 2013).

Tailings containing sulphide compounds are also a potential cause of land degradation through acid mine drainage (AMD) if they are exposed to oxygen and water (Hilson and Murck, 2000; Sandlos and Keeling, 2013; Lindahl, 2014). Acid forms when sulphide minerals weather by oxidation, and if the neutralizing capacity of the surrounding rock is too low to buffer the generated acid, the result will be low pH waters with high metal content (Hilson and Murck, 2000; Sandlos and Keeling, 2013; Lindahl, 2014). Indirectly, accumulation of metals in soil may also result from erosion and wind-borne dust particles from dry tailing dams. Studies show that erosion from old tailing dams and waste dumps contribute about 9000 tons of material into the environment per year, with a significantly larger contribution from ongoing mining operations (Masinja et al., 2005; Lindahl, 2014). Material eroded from waste rock and tailings dumps can degrade the land and impact aquatic ecosystems as it may contain heavy metal concentrations in significant quantities. A study conducted on mining-related contamination of the surface water and sediments of the Kafue River drainage system in the Copperbelt found that total metal contents in stream sediments show that the Kafue River and especially its tributaries downstream from the main contamination sources are highly enriched with respect to copper, exceeding the Canadian limit for freshwater sediments (Sracek et al., 2011). This study concludes that this sedimentation of suspended particles and the resulting high load of metals in sediments of the Kafue River may have serious environmental risks during acid spikes, especially following accidental spills from chemical plants, when a significant part of metals in sediments can be released back into surface water thus polluting it (Sracek et al., 2011).

Other direct impacts of tailing wastes include safety issues where waste dumps are overtopped. Issues of structural instability also emerge posing threats of structural damage, injury or death to the communities (CEMP II, 2005). This risk can result from both solid and slurry wastes and studies have found that the risk is highest where dwellings or paths are located close to the base of waste dumps (Limpitlaw, 1998). The high energy flow of a mixture of water and solids can be very destructive to infrastructure and can have serious consequences to flora, fauna and people present in the direct path of the flow including mine workers. A good example is the Mufulira disaster which killed 89 people in 1970 (Nellar and Sandy, 1973). On the 25th September 1970 an underground breach of a tailings dam occurred at the Mufulira Mine in Zambia. As the night shift crew were on duty the tailings dam above them collapsed causing nearly 1 million tonnes of tailings to fill the mine workings killing 89 miners (http://www.tailings.info/casestudies/mufulira.htm).

(iv) Slags

Slags are solid waste materials separated from ores during smelting and refining (Schlesinger et al., 2013; Lèbre and Corder, 2015). During smelting, the ore concentrate is mixed with other materials known as “fluxes” and then heated in furnaces until it melts (Schlesinger et al., 2013). As the molten metal-bearing minerals separate from the other materials, they accumulate at the bottom of the furnaces and are removed. The other constituents, primarily iron and silica, float to the top of the furnaces and cool to a solid substance called “slag” (Schlesinger et al., 2013). Slag has been historically considered to be waste but is largely environmentally benign by EU standards, and can be used as aggregate in concrete and road construction or used to cover tailings surfaces (Ettler, 2012). There are cases where slag dumps are re-mined due to an increase in mineral market prices and improvements in extraction technology. An example of a re-worked slag dump is the infamous “Black Mountain” in Kitwe, Zambia (Zambia Daily Mail, 2017). There are about 20 million tons of slag in Kitwe-Nkana which are being re-worked due to their high copper and cobalt content (Ettler, 2012). Mining companies historically exploited easily accessible, high-grade reserves in priority, often wasting lower-grade material. Lèbre and Corder (2015) argue that this represents mineral processing inefficiency since some valuable metals become part of the waste and can contribute to environmental legacies which can last for many years after mine closure.

(v) Mine waters and water treatment sludge

Surface and subsurface waters used in the extraction and disposal of mine wastes including process waters are also considered mine wastes when they are no longer wanted (Lottermoser et al., 2011). Where mine sites are well-managed, mine waste water is stored in settling or decant ponds and used as recycle water in mill processes and mining operations (Lottermoser et al., 2011). These ponds can occupy significant areas of land and need to be constantly managed in order to avoid seepage and leaks.

Regulations in most countries require that mine water meets specific quality standards before it is released into the environment as the heavy metal constituents are potentially toxic to both aquatic and terrestrial life (Lottermoser, 2007). As such, contaminated mine waters are treated at mine sites producing a semi-solid slurry known as sludge. Water treatment sludge consists of the solids that had been removed from the water as well as any chemicals that had been added to improve the efficiency of the water treatment process (UNEP, 2017). Sludge may be used in agricultural applications but the majority of sludge has little economic value and is handled as waste (UNEP, 2017). Its final disposal is by land filling or incineration and the heavy metals or toxic chemicals contained can degrade land and water (UNEP, 2017).

- **GENERATION OF EMISSIONS**

Much of the impacts of mining on land are associated with the release of harmful emissions from mining and mine wastes (Lottermoser, 2007). As seen from Figure 7, emissions are generated at every stage in the mining process. These emissions include particulate matter (dust), noxious gases, mine water and effluent discharge, as well as uncontrolled seepage and run-off from mine sites and mine waste dumps (Figure 8). During actual mining operations at open pits, air emissions are generated by drilling, blasting and ore handling operations such as crushing (Figure 8). A significant contribution of air emissions is also received from fugitive dust blown from waste dumps and from transport of ore and other materials on unpaved roads, and from particle fall-out from smelters (Kříbek et al., 2012). However, the largest contribution to air pollution has traditionally come from smelter fumes, containing elevated levels of sulphur dioxide and enriched with volatile metals and semi-metals, such as lead, zinc, arsenic and cadmium, as well as the major elements copper and cobalt (Lindahl, 2014; Kříbek et al., 2012). Barren areas near smelting operations have been a long lasting environmental impact of historical smelting in the Copperbelt province and there have been reports that communities located near smelters are unable to grow vegetables in their gardens (Ncube et al., 2012; Moyo et al., 2013). A study by Křibek et al. (2012) confirmed that soils in the Copperbelt areas surrounding the mines and processing plants are heavily contaminated by fine metal laden tailings deposited from the air, and also particle fall-out from the smelters particularly where smelters are active or where smelting occurred previously. In related studies, a correlation of down-wind distance from some smelters conducted on the Zambian Copperbelt found high copper-arsenic content in cassava and sweet potato (Lindahl, 2014). This study recommends that the growing and consumption of cassava and sweet potatoes in areas where contents of arsenic exceeds 5 mg/kg should be avoided to limit human exposure to the toxic metals (Lindahl, 2014).

Figure 8: Emission generation at mine sites Source: https://www.google.co.zm/search?q=mining+industry+in+Zambia-photos.

Water-related emissions include the discharge of contaminated mine water, as well as the uncontrolled seepage and run-off from mine sites and mine dumps. Mine waters may carry dissolved particulate matter, nitrogen chemicals from explosives used in blasting, or chemical additives from mineral processing and hydrometallurgical processing. These water may also interact with exposed sulphides in mine workings and mine waste dumps and become acidic (Lottermoser, 2007). In Zambia, sulphide minerals constitute a significant proportion of copper ore deposits such as chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), bornite (Cu_5FeS_4) and carrollite ($CuCo_2S_4$) in association with pyrite (FeS_2) (Zientek et al, 2014). The chemical structures of these ores are characterized by the linkage of sulphur with metals. Mining of sulphidic ores exposes the sulphides to an oxygenated environment and as such, the mine workings, waste rock dumps, low-grade stockpiles, haul roads and tailings all expose sulphides to the atmosphere or ground water (Lottermoser, 2007). Exposed sulphides become chemically unstable and a series of chemical reactions are initiated which produce metal and sulphide-rich acidic waters which degrade the land by polluting it (Lottermoser, 2007).

If mine waters are released into local streams, the dissolved constituents may precipitate and result in colourful mineral coatings in soils and floodplain sediments thus degrading them and consequently impacting crop production (Danielson and Zubkova, 2009; Lottermoser, 2007). As already stated, almost all the mining operations in the Zambian Copperbelt are located within the Kafue River catchment area (Sracek et al, 2011; Lindahl, 2014). Various concerns have been raised over the potentially contaminating mining activities along this river and mines have been reported to be responsible for discharge of heavy metal effluents into the river water (Ntengwe, 2005; Dymond, 2007; Lindahl, 2014). For some new mines in North-Western Province where rocks are naturally elevated in uranium, there are fears that run-off from these mine areas may contribute to water pollution and impact the land more severely (Lindahl, 2014). Prolonged precipitation of secondary minerals, furthermore, results in laterally extensive surface or subsurface layers which may dry out and cement to form hardpans. Hardpans prevent vertical flow of water and their surface expression causes yellow to red staining on rocks, seepage points, water bodies, sulphurous odours and vegetation failure (Lottermoser, 2007). The lack of vegetation further increases erosion rates of sulphide wastes and extends to other areas through transportation into soils and streams downstream of the mine sites (Lottermoser, 2007).

Poorly managed emissions can spread far thus contributing to soil degradation and impediment of tree and crop growth (Kříbek et al., 2012; Ncube et al., 2012). This is consistent with earlier studies which show evidence of metal contamination over large areas in the Copperbelt Province compared to natural background values and that a variety of other elements occur in elevated concentrations in addition to copper and cobalt (Ntengwe, 2005; Sracek, 2011).

2.1.2 INDIRECT COMMUNITY-RELATED LAND ALTERATIONS AND THEIR IMPACTS

Apart from the environmental impacts discussed, mine operations in a developing nation like Zambia often indirectly lead to land alterations and degradation and thereby creating social challenges. One big challenge specific to new mining districts is the rapid increase in population (UNECA, 2011; Lindahl, 2014). Since mining provides employment and entrepreneurial opportunities, people tend to migrate to the mine and its surrounding areas. As the population of these areas grow, social challenges such as land tenure security and access, road construction, river diversion and displacements of people from the mining area can all contribute to disrupting the livelihoods of local communities, alter the landscape and increase land degradation (UNECA, 2011). For example, the number of people living in Solwezi, the new mining town in the North-Western Province increased from 203,797 in 2000 to 254,470 in 2010 with projections expected at 307,730 by the end of 2017 (Central Statistical Office Zambia, 2017). The population growth is said to have followed after the mines were opened as people migrated to the new mining district in search of jobs and business opportunities.

Population growth creates high pressures on provision of basic social services such as decent housing, domestic water and sewage treatment (Lindahl, 2014). Several related studies have also shown that the biggest threat to drinking water quality in the Copperbelt is from inadequate handling of waste treatment (Limpitlaw, 1998; Masinja et al., 2005; Lindahl, 2014). There are many other places around the Zambian Copperbelt where sewage has been reported to flow directly into the environment, which apart from polluting water and land with faecal bacteria, also results in oxygen depletion for aquatic life to survive. Other social challenges include increased domestic waste generation and high prevalence of diseases including Tuberculosis (TB) and HIV/AIDS. A recent study conducted on the mining regions of Zambia found that TB is a significant health problem among miners and their communities (Chanda-Kapata et al., 2016). The TB prevalence was found to be closely associated with HIV and AIDS meaning that there was co-infection of the two conditions.

Population explosion impacts on the land primarily through the increased use of natural resources, deforestation and production of domestic wastes (Lindahl, 2014; Mususa, 2014). Increased pressures on the land and other natural resources are associated with additional environmental stresses such as loss of biodiversity, air and water pollution which further impacts arable land (UNEP, 2015). According to UNEP (2015), there is a direct link between population growth and land degradation in African countries because land use tends to intensify without accompanying conservation measures. Furthermore, global economic factors such as commodity market conditions encourage short-term intensive exploitation of land for industrial and urban development purposes (UNEP, 2015). This is consistent with the findings of the land use studies conducted by Limpitlaw (1998 and 2001) on areas surrounding the city of Kitwe and the larger Copperbelt Province. These studies showed that while there was an increase in mine waste deposits and their associated impacts on surface water and land in the 27 year period investigated, there were also other indirect means of pollution and forms of landscape alterations occurring simultaneously around the mining towns. The study concludes that mining-related land cover changes were not the only causes of changes on the Zambian Copperbelt, other activities of deforestation for farming or charcoal production were also contributing to landscape changes over large areas in the Copperbelt Province and that these were not being detected in the EIA and EMPs (Limpilaw, 2001). These studies suggest that these indirect community-related landscape changes were contributing to the failure in addressing the long term environmental sustainability of mining towns. Findings from these studies were illustrated by focusing on areas in which land was observed to have changed significantly, but did not include Luanshya district.

Based on the overall findings that different landscape alterations occur simultaneously in the Zambian Copperbelt, Limpitlaw (2001) recommends that land use planning and management policies should take indirect causes into consideration. The following section highlights the policies and legislation of relevance to land degradation and use.

2.2 POLICIES AND LEGISLATION OF RELEVANCE TO LAND DEGRADATION AND USE

This section discusses some of the policies and legislation of relevance to managing land degradation and use in Zambia. Also discussed are some initiatives taken to rehabilitate degraded lands and polluted rivers.

2.2.1 ENVIRONMENTAL REGULATION

The Zambia Environmental Management Agency (ZEMA), a statutory body originally established in 1992 under the former name Environmental Council of Zambia (ECZ), is the major environmental institution in Zambia and the lead agency with a mandate by law to; "*to regulate and coordinate environmental management, promote awareness, and ensure environmental protection through enforcement of regulations and the prevention and control of pollution in support of sustainable development so as to provide for the health and welfare of persons, animals, plants and the environment*" (www.zema.org.zm). According to the *Mines and Minerals (Environmental) Regulation (MMER) 1999,* any company wishing to undertake any developmental project in Zambia, particularly large-scale mining which may impact the environment must obtain written permission from ZEMA after undergoing an Environmental Impact Assessment (EIA) (*MMER 1997)*. The EIA process involves systematic investigations of conditions within the environment of the proposed development or project followed by an assessment of the impacts that the development or project will have on the environment. It provides prediction for the developer and planning authorities of the expected impacts.

For projects considered to have very low negative impacts on the environment (e.g. urban area rehabilitation and infrastructure development), the developer is required to prepare an Environmental Project Brief (EPB) (MMER 1997). An EPB is an EIA report consisting of a description of the baseline environment, a description of the planned project activities, reasonable alternatives and the expected benefits and impacts of the proposed project. Similarly projects expected to have significant negative impacts on the environment are required to operate with an Environmental Impact statement (EIS) (*MMER 1997)*. An EIS is an extensive evaluation of the impacts likely to arise from a project expected to significantly affect the environment. Consultation and participation are integrated to this evaluation and it is undertaken by ZEMA-approved experts. In addition to the EPB, EIA and EIS, water abstraction, forest permits and waste management licences must also be sought prior to any development activities being carried out in any area. ZEMA works with other government bodies like the Department of Water Affairs under the Ministry of Mines to regulate and manage water resources (Statutory Instrument no. 12 of 1990). Other functions of ZEMA include;

- Advising the government on policy work,
- Coordinating the implementation of environmental management in all government ministries,
- Development and enforcement of measures to prevent and control pollution,
- Development of guidelines and standards related to environmental quality,
- Promoting research and studies,
- Controlling the Environmental Impact Assessment process,
- Authorizing or inhibiting industrial projects in accordance with the law,
- Issuing permits and licenses,
- Auditing and monitoring the compliance of operating industries, and
- Raising public awareness on environmental management and pollution control.

ZEMA is meant to be autonomous and run by a board comprising members drawn from a wide range of ministries, business and non-governmental organizations. This is a powerful and deliberate setup designed to ensure sustainable natural resources exploitation but there have been suggestions that its operations are not very effective due to luck of capacity (Lindahl, 2014).

RELEVANT LEGISLATION

1. *The Environmental Protection and Pollution Control Act No.12 1990 (EPPCA);* provides for the protection of the environment and the control of pollution, for the establishment of and the powers and functions of the Environmental Management Authority and for all matters incidental to the environment including water and air (Statutory Instrument no. 12 of the 1990).

2. *The Mines and Minerals Act No. 31 1995 (MMA);* assigns the president as the custodian of the rights to minerals on behalf of the Zambian people. It also assigns various guidelines pertaining to the prospecting for and extraction of minerals resources for both small-scale and large-scale mining licenses (Chapter 213 of the laws of Zambia).

3. *The Mines and Minerals (Environmental) Regulation 1997 (MMER);* provides guidance and regulations on the preparation of Environmental Project Briefs (EPBs), Environmental Impact Assessments (EIAs), rehabilitation plans, management of dump sites, water resources management, mine closure plans, storage and handling of hydrocarbons and hazardous substances, air quality and emission standards. It also assigns powers to the minister to regulate mining and mineral exploration licenses as well as prescribes penalties for defaulters (Statutory Instrument 29 of the 1997).

4. *The Mines and Minerals Amendment Act 2000;* assigns ZCCM's environmental liabilities to the government and also those responsibilities arising at the privatized mines on the condition that the new private operators comply with the Environmental Management Plans if no special agreements have been made.

These legislative acts and regulations were implemented by sharing responsibilities between the Ministry of Lands, Natural Resources and Environmental Protection (former Ministry of Tourism, Environment and Natural Resources) the Ministry of Mines, Energy and Water Development (Lindahl, 2014). However, there were challenges in the implementation of these laws resulting from poor coordination between the two Ministries and hence their failure to effectively enforce the law (Lindahl, 2014). The following section discusses the policies and regulations pertaining to land-use planning in Zambia.

2.2.2 LAND USE PLANNING

Land use planning is defined by the World Bank as a process by which a society, through its institutions, decides where within its territory different socioeconomic activities such as agriculture, housing, industry, recreation, and commerce should take place (World Bank, 2012). For mining districts where significant land alterations take place, land use planning is important for pollution control as well as for safeguarding the health and safety of the communities (World Bank, 2012). According to the Republic of Zambia's (here after referred to as GRZ) Draft Land Policy of 2015, land is the most fundamental resource because it is the basis of human survival (Republic of Zambia, GRZ: Draft Land Policy, 2015). Land is the space on which all human activities take place and it performs basic and fundamental functions that support human and other terrestrial systems including production of food, fibre, fuel, water or other biotic materials for human use (GRZ, 2015). It also provides biological habitats for plants, animals and micro-organisms and regulates the storage and flow of surface and ground water, physical space for settlements, industry and recreation. It stores and protects evidence for historic or pre-historic record (GRZ, 2015). For these reasons, the draft land policy points out that land usage must be planned to accommodate all purposes and for control to promote health, safety and social aspects of people's lives. This section reviews the historical perspectives on land planning in Zambia as a background to the discussion and later highlights current and on-going initiatives in land use planning as a tool for degradation control.

- **HISTORICAL PERSPECTIVES**

Land use planning in Zambia was initially guided by the 1964 legislation which was inherited at the time of colonial rule from UK's 1948 Town and Country Planning Town Act (Berrisford, 2011). This Act states;

"An Act to make provision for the appointment of planning authorities, for the establishment of a Town and Country Planning Tribunal, for the preparation, approval and revocation of development plans, for the control

of development and subdivision of land, for the assessment and payment of compensation in respect of planning decisions, for the preparation, approval and revocation or modification of regional plans; and for matters connected with and incidental to the foregoing" (Chapter 295 of the laws of Zambia).

In this Act, land planning refers to the orderly development or use of land and in agreement with public interest (Chapter 283 of the laws of Zambia). Development was defined in the Act to include any new constructions, renovations to existing infrastructure, agriculture development or mining activities. Permission was required to carry out any subdivisions or developments on the land. A town planning authority was appointed to oversee all land use interests and to prepare development plans, taking into account relocations of people, industries and use of open spaces. Such plans were in the custody of the town engineer's office in each town's civic centre. However, the Act only applied to the formally developed parts of towns and cities excluding low income areas and rural or wilderness land, forest reserves and protected areas (Berrisford, 2011). In 1976, the Housing, Statutory and Improvement area Act was implemented to allow for parts of a town to be excised from the planning system of the Town and Country Planning Act to accommodate low income residential areas (Berrisford, 2011).

Planning authorities were created under the Town and Country Planning Act of 1964 and ranked according to the size of the area controlled. The lowest rank was the Town Planning Authority and above it was the Provincial or Regional Planning Authority which had the power to approve the town plans from the districts and to harmonize land use plans on a more regional scale (Town and Country Planning Act of 1964). In the case of the Copperbelt Province, the Provincial Planning Authority was required to prepare a development plan for the province but the mine towns, Kitwe, Ndola, Chingola, Luanshya and Mufulira were to be excluded from these plans (Town and Country Planning Act of 1964). The mining districts (previously referred to as mine townships) were placed outside the planning control of the legislative planning authorities and the mining companies were left to regulate their own development. This means that the government was more focused on collecting foreign exchange earnings, tax and royalty revenues and short term economic growth which has been criticised as selling the nation's resources for short-term gain because mining companies also fall prey to this type of short-term decision making (Limpitlaw, 2006). According to Mukuka (2001), and UN-Habitat (2005), government was blinded by short-lived upturns in commodity cycles such that long term risks of collaborative land use planning were not properly evaluated. This probably explains why mining towns were excluded from the formal regional land plans and their exclusion may have contributed to the uneven development of mining districts.

As a mining country, Zambia's urbanization began with the opening of the mines and subsequent development of a railway (Mususa, 2014). Yet the early mining period was not characterized by any coherent land use plans that were concerned for the welfare of local mine workers or the rest of the local population.

Male migrant labour was preferred at the mines, discouraging the presence of women and children in the townships (Mukuka, 2001; Mususa, 2014). Women and children stayed in the villages while the urban areas were developed and allocated to Europeans based on their wealth levels (Mukuka, 2001). This system later proved to be wasteful because the labour force did not develop skills. They remained inefficient and it was realized that there was need for stable labour (Mukuka, 2001). Development of African housing hence became relevant and began in the peripheries of the urbanized areas (Mukuka, 2001). As the population grew and the demand for land increased, more settlements developed by invasion of dormant areas and by illegal allocations by ruling party officials (UN-Habitat, 2005). Such occurrences proved to be unsustainable for the country as the communities who are the ultimate inheritors of mining landscapes were not properly planned for (Mukuka, 2001). The involvement of the state and the communities in land use planning has been recognised as critical for long-term planning and sustainability of mining districts after mine closure (Limpitlaw, 2006; World Bank, 2012). The existing legislation has since been reviewed and new ones developed.

- **CURRENT TRENDS AND INITIATIVES**

All land in Zambia is vested in the President who "*holds it absolutely in perpetuity in trust for and on behalf of the people of Zambia*" (GRZ, 2015). This is done with the view that land is a strategic resource and hence should be held by the highest office in the land. As a sovereign and unitary state, land and national security relate closely and therefore powers over the two are vested in the President (GRZ, 2015). However, there are opposing views that fear for abuse of office or potential for political interference if land is vested in one person (GRZ, 2015). Municipal councils are currently responsible for issues concerning land use under the guidance of the new Urban and Regional Planning Act of 2015 (which repeals the Town and Country Planning Act of 1964 and the Housing -Statutory and Improvement Areas Act of 1975), the Decentralisation Policy and the Public Health Act (Chapter 295 of the laws of Zambia).

In 2002, the Government of the Republic Zambia (GRZ) adopted the National Decentralization Policy; "towards empowering the people" (GRZ, 2002). This policy seeks to strengthen the local government (councils) where the district level is the focal point for land-use planning such that plans are locally specified and tailor-made for the local area with input from citizens. Through this policy, government devolved specified functions, authority and matching resources to Councils to facilitate effective operations at the district level. Government recognised the lack of capacities in the councils to implement this new system of government and a 10 year period was given from the time of adoption to develop the necessary capacities. The implementation of this policy is now in progress and the transfer of functions from central government to councils commenced in 2015 (Times of Zambia, 2016). Following the commencement of power transfers to the councils, new districts have been created throughout the country some of which are miningdominated. A good example is the newly created Kalumbila district which has been built by First Quantum Minerals (FQM), the country's largest mining company following successful development of its Trident Kalumbila mine project at the cost of 200M US$ (Times of Zambia, 2015). Kalumbila was a rural area, previously part of Solwezi district and now given district status by President Lungu to encourage development of new mine communities (Zambia Daily Mail, 2015).

The following section identifies the stakeholders involved in the long-term land use planning of mining districts in Zambia.

- **STAKEHOLDERS INVOLVED IN LAND USE PLANNING**

Following the formulation of the Urban and Regional Planning Act of 2015 and the Decentralization Policy, the responsibility for land administration is assigned to the Ministry of Lands through its constituent departments (GRZ, 2015). Other departments falling under a number of ministries such as Physical Planning and Housing, Valuation, Agriculture and Natural Resources and other statutory institutions also contribute to land management (GRZ, 2015). The specific functions of these institutions are broken down as follows;

- **MINSTRY OF LANDS AND NATURAL RESOURCES**

This ministry is responsible for land administration on behalf of the people of Zambia (http://www.mlnr.gov.gh). Their functions include; **l**and beaconing, cadastral survey and exploration, land surveys and mapping; control of unauthorized Settlements; environmental Policy formulation and environmental protection and pollution control**;** support and facilitation of environmental research and training**;** forestry policy formulation and development of forestry and renewable energy resources; natural resources policy formulation and **r**egistration of lands and deeds.

- **MINISTRY OF LOCAL GOVERNMENT AND HOUSING;**

The Ministry of Local Government is an important part of the decentralization sector of the national economy. The ministry is responsible for the administration of the local government system and ensuring the provision of the necessary municipal services (http://www.mlgh.gov.zm). This ministry is multi-functional in nature and oversees the implementation of delegated functions and responsibilities of the local authorities by managing the social, economic and political spheres of governance. This ministry is responsible for almost all of government's functions at the local level; to co-ordinate the local government administration, regulation and provision of social services; urban and regional planning, provision of roads; valuation of public property; support the affairs of chiefs; water supply and sanitation, provision of housing, municipal infrastructure services and support services; co-ordination and implementation of the National Decentralisation Policy.

- **MINISTRY OF FINANCE AND NATIONAL PLANNING;**

This ministry is a dominant force in the Zambian government charged with the responsibility of national financial planning, financial management and administration, including the development of national development plans (http://www.mofnp.gov.zm). This ministry supports all other government ministries by ensuring timely approval of budgets by parliament and making sure that funds are released in time for the other ministries to carry out their functions. Sometimes confusion arises in identifying the difference between the financial planning function of the Ministry of Finance and the town and country planning function of the Ministry of Local Government and Housing (Berrisford, 2011).

- **MINISTRY OF AGRICULTURE AND CO-OPERATIVES**

This ministry's main function is to provide quality agricultural goods and services and ensure food and nutrition security, thus contributing to poverty reduction (http://www.agriculture.gov.zm). The ministry is a major stakeholder in land use planning because agriculture is a very important part of any country's economy. Agriculture it employs the majority of poor people especially in rural areas (IMF, 2017). Land use planning must include agriculture production as a priority function.

- **FORESTRY DEPARTMENT**

The Forestry Department is part of the Ministry of Lands and Natural Resources and is responsible for the management of forest resources in Zambia. (http://www.ministryoflands.gov.zm). Its mandate includes management of state forest reserves and the enforcement of national regulations related to the use and harvesting of forest resources on state and customary lands. Other functions include:

- Providing guidelines and supervision for the management, restoration and establishment of forests.
- Facilitating and regulating forest industries.
- Providing extension services and supporting forestry research.

- **CIVIL SOCIETY ORGANIZATIONS (CSOs)**

Civil society organizations in Zambia are involved in various issues including governance, gender, HIV/AIDS public health, education, access to legal aid, land advocacy among others (UN-habitat, 2005). They are important stakeholders because they usually represent the interests of the general public and the poor. A good example is the Zambia land Alliance (ZLA) which is a network of civil society organizations that advocates for just land policies and laws that take into account the needs of the poor (http://www.zla.org.zm). The organization promotes secured access, ownership and control over land through lobbying and advocacy, research and community participation. However, CSOs are usually seen by government to be antagonizing rather than as partners in national governance (UN-Habitat, 2005).

- **MINING COMPANIES**

Mining is a high income-earning sector. It has been Zambia's development driver with its significant contributions to the national economy (IMF, 2017). Yet, mining is one of the main activities through which landscape alterations and land degradation takes place. Because minerals are non-renewable resources; their exploitation must take into account sustainable land use practices. Mining companies in Zambia have been left to regulate their own land planning in the past which has been seen to have contributed to the land planning issues currently facing the country (Mukuka, 2001; UN-Habit, 2005). A study conducted on the impacts of large-scale land acquisitions, displacement and resettlement in Zambia found that people in rural communities where mining usually takes place do not have secure land rights and that large-scale land acquisitions for industrial development leads to loss of access to lands which undermines the community's livelihoods (Chu et al., 2015). The writers in this study recommend that the legal framework should be strengthened to secure customary, informal and unregistered land rights to protect the affected communities (Chu et al., 2015). Mining companies should properly consult the communities during land acquisitions and take more responsibility for their land use to help to ensure that the communities around the mines are not left to unduly suffer for the loss of land (Chu et al., 2015).

2.2.3 INITIATIVES TO REDUCE ENVIRONMENTAL POLLUTION AND LAND DEGRADATION

There are various developmental projects and initiatives related to environmental pollution and land degradation in Zambia. This section highlights some initiatives directly linked to mining and the environment.

- **THE COPPERBELT ENVIRONMENT PROJECT (CEP)**

The Copperbelt Environment Project is a large scale study that was conducted from 2003 to 2011 by a consultant company (Water Management Consultants) in partnership with ZCCM-Investment Holdings and the University of Zambia. This project was sponsored by the World Bank and the Nordic Development Fund on a total budget of 42 million USD. The Canadian International Development Agency (CIDA) and the Norwegian Agency for Development Cooperation (NORAD) also contributed with funding to specific parts of the project. The program was designed to identify and address environmental liabilities associated with the mining sector in Zambia with the aim to improve future social and environmental compliance of mining companies (World Bank, 2016). The project consisted of two components; the first component was the Environmental Management Facility (EMF) aimed at addressing the legacy environmental and social impacts resulting from ZCCM-IH in accordance with Zambia's environmental laws. The second component was aimed at strengthening the country's regulatory framework to ensure that future environmental impacts of mining are addressed in compliance with stronger safeguards. This work was conducted in three phases;

Phase 1: To determine the extent and magnitude of contamination.

Phase 2: To determine pathways of human exposure to the contamination and

Phase 3: To formulate a mitigation and rehabilitation plan using models developed in phase 2.

This work has since produced a number of topical reports on different aspects of mining and the environment in Zambia. The first activity funded under the EMF was the preparation of a Consolidated Environmental Management Plan (CEMP). The plan identified issues to be addressed and provided criteria for the selection of sub-projects to be funded within the whole project. A high priority measure that CEMP pointed out was related to the geotechnical integrity of waste dumps but it was only partially met. This is because the government sold the dumps as mining rights to companies willing to reprocess them for copper but the feasibility of reprocessing has been too low, hence the geotechnical problems continue (http://projects.worldbank.org/P070962/zambia-copperbelt-environment-project-cep?lang=en&tab=results).

The highest priority was given to mitigation measures that addressed widespread public health problems and damage to ecological functions. Important sub-projects undertaken in the country included;

- Resettling villages in Mufulira, Ndola and Kitwe (4,2 million USD)
- Dredging of Luanshya River (1,0 million USD)
- Remediation of two uranium tailing dumps in Kitwe (2,2 million USD)
- Rehabilitation of Kabwe mine plant area (2,0 million USD)
- Dredging of Kabwe canal zone and removal of mine waste from Mulungushi road dump (1,6 million USD)
- Improving water supply to communities in Kabwe (2,7 million USD)

The project was closed in 2011 and the World Bank gave it a performance rating of moderately satisfactory as most objectives were not met and the budget was overrun (World Bank, 2011).

- **MINING ENVIRONMENTAL REMEDIATION AND IMPROVEMENT PROJECT (ZMERIP)**

Due to outstanding issues from the CEP, another World Bank-funded initiative termed Zambia Mining Environmental Remediation and Improvement Project (ZMERIP) was proposed by the Ministry of Mines and Mineral Development in 2015 (GRZ, 2016). The project was proposed with a view to contribute to reducing environmental health risks and lead exposure to the local population arising from mining activities in critically polluted areas of Kabwe, Chingola, Mufulira, and Kitwe districts. This project is currently in progress and is planned to be conducted through: (a) Optimizing existing financial mechanisms to identify, finance, implement and monitor feasible environmental and social measures for prioritized contaminated areas; (b) Strengthen environmental management in the mining sector through improved regulatory and institutional capacity of regulatory agencies and the local governments to strengthen environmental management in the mining sector; and (c) Targeted health interventions and improved job opportunities for affected people, particularly women and youth through collaborative partnership with local government and neighbouring communities. Expected outcomes of this project include improved capacity of the key institutions at the national, subnational and local levels. The project also includes investments for remediation of contaminated sites and environmental infrastructure improvements; enhancing Institutional capacity to strengthen environmental governance and compliance; reducing environmental health risks through localized interventions and project management (GRZ, 2016).

- **OTHER INITIATIVES**

After privatization of the mines, the new operators invested in improved modern technologies that were considered to be more environmentally friendly (Simubali and Chileshe, 2013). In their study, Simubali and Chileshe (2013) analysed the impacts of technology changes on production and environmental performance of Konkola Copper Mines before and after privatization and found that apart from improving copper production and profit margins, new technologies helped to improve most aspects of mining including drilling and blasting, loading and excavation, ore haulage, mine ventilation, mine support and dewatering efficiency as well as waste production. Ore smelting capacity was also increased with environmental improvements leading up to 96% sulphur capture (Simubali and Chileshe, 2013). This study also found that the operational and financial performance of KCM improved significantly as a result of improved technologies (Simubali and Chileshe, 2013). Further improvements were made to environmental monitoring and early warning of impending life-threatening ground movements, hence assuring a safer working environment (Simubali and Chileshe, 2013). Given the success of KCM, Simubali and Chileshe (2013) conclude that further advancements in technology can help the mining industry to achieve better environmental performance while also improving metal production.

Furthermore, capacity building initiatives have been conducted through support from the Australian Agency for International Development (AusAID) and cooperation from the International Mining for Development Centre (IM4DC) run by the University of Queensland and the University of Western Australia. Courses have were held from 2011 to 2015 to train the staff in the Mines Safety Department in Zambia in incident management as well as use of Geographical information Systems (GIS) in environmental monitoring (www.im4dc.org). An evaluation of the outcomes of these courses suggest that alumni have developed the relevant capacities for them to effectively contribute to the country's social, environmental and economic status through policy, regulation and processes and also to improve oversight for all phases of the mining life cycle (IM4DC, 2015). By adopting better approaches to mining governance and sustainability, it is expected that the country can attract better and responsible investments, achieve broad-based and equitable returns and enhance the interests of communities and the environment including protection of water and land resources from degradation (IM4DC, 2015)

Additional support for control and remediation of land degradation in the Copperbelt has been received through donor support from the Czech Republic and the Finish Department for International Development Cooperation (FINIDA) in 2004-2006 and then 2008-2010 (Czech Geological Survey, 2008). The Danish International Development Agency (DANIDA), and the Swedish International Development Cooperation Agency (Sida) and Norway (NORAD) in 2006-2010. Several studies have been conducted through this support, some of which have focused on mining and the environment and they provide some background knowledge on the extent of the problems related to land degradation and impacts on agricultural products in Zambia (e.g. Kříbek et al., 2012). Overall recommendations from these studies emphasize the need to conduct Environmental Impact Assessments (EIAs) and Environmental Management Programs (EMPs) as a tool for monitoring, reducing and preventing these mining-induced impacts on land and other natural resources.

2.3 SUMMARY AND SYNTHESIS

Even though copper mining plays an important role in the growth of the Zambian economy, mining beneficiation and metallurgical processing of copper ores are associated with physical landscape alterations and subsequently degrades the land. The impacts of mining on land start during exploration when vegetation is cleared to create access routes and to conduct other exploration text works such as drilling. During development more vegetation and top soil are lost as mine infrastructure are established. During mining, land is impacted through acquisitions and relocation of communities away from new mine sites to other areas where vegetation and topsoil are impacted to settle the displaced communities. Mining is characterised by vegetation and top soil removal at mine sites, and also creates excavations which alter the landscape scenery. Further physical impacts of mining on land are caused by dewatering of mine workings which can lower the ground water table and cause land subsidence. Mining also alters the landscapes through generation of high volume wastes and emissions which degrade the land through contamination.

During ore beneficiation and metallurgical processing, more wastes and emissions are generated which contribute to landscape alterations and land degradation by altering the soil chemistry of mine sites. Significant impacts of mining on land are associated with generation of harmful emissions at every stage in the mining processes (mining, beneficiation and metallurgical processing). From drilling and blasting at open pits, chemicals used in explosives are emitted into the air and are blown by the wind until they settle and contribute to land degradation. Since copper ores in Zambia occur as sulphides, their extraction from the ground exposes sulphides to oxygenation in the mine workings, haul roads, ore stockpiles and waste dumps. Exposed sulphides react in the presence of atmospheric oxygen, meteoric water, microorganisms and other sulphides to form acid mine drainage and secondary minerals or effloresces which may form laterally extensive surface or subsurface layers which cause crop and vegetation failure resulting in barren areas. Further contributions to air emissions may result from wind-blown dust from dry tailings and particle fallout from smelters.

Indirectly, mining can impact the land by causing social challenges of population explosions, river diversions and general lifestyle disruptions. These challenges impact land through land use changes and increased use of land-based resources. Displaced or immigrant communities contribute to landscape alterations and land degradation through deforestation for settlements and agricultural purposes, and also through domestic waste generation. These impacts on land threaten the preservation of natural resources including biodiversity, water and land. Land degradation and pollution also bring about economic costs associated with clean-up, maintenance or future land use which threatens food security and undermines the livelihoods of the communities (UNEP, 2015).

Policies and legislation have been developed to control land degradation and use in Zambia. Land use planning is particularly important in the Zambian context since land use planning in mine towns was historically controlled by the mining companies, and this has led to unregulated landscape alterations and land degradation. The Zambian government recognises that effective land use planning is not a simple undertaking due to the complex inter-relationships between mining, community development and land degradation. Action has been taken on the matter through the introduction of the Decentralization Policy which removes the mining firms as planning authorities and empowers the local governments. However, effective land use planning needs to be done in collaboration with all stakeholders and it must be based on a clear understanding of the direct and indirect impacts of mining on land degradation and land use on a district scale. Considerable donor support has been received and research conducted focusing on pollution mitigation and rehabilitation, arising from mining in Zambia. Some land use change mapping studies have also been conducted on a regional level, but no mapping studies have been conducted on district scale to show the relationship between long-term mining, land alterations, land planning and community land use practices to support effective and sustainable development of mining districts. It is important to understand this connection as it will help inform future planning for the new mining districts in North-Western Province, consistent with the National Decentralisation Policy.

CHAPTER 3

CASE STUDY METHODOLOGY

Chapter 2 presented a review and summary of the literature on copper mining and its impacts on the environment in line with the first objective of the study; to provide a review of the land-related impacts of mining and strategies for land-planning in Zambia. This case study employs landscape mapping and stakeholder interviews to explore the relationship between mining, landscape alterations and land-use planning in Luanshya district, Copperbelt Province, Zambia. In doing so, some key research questions were asked;

1) What are the landscape changes that have taken place in Luanshya district over the 32 year period between 1984 and 2016?
2) How do these landscape changes relate to mining activities and other land use patterns in the district?
3) What has been the approach to land use planning by the relevant stakeholders in the district?

This chapter presents the methodology employed in this study. A two-step approach was used to provide answers to the research questions. The first task involved mapping of the landscape changes over a 32 year period (1984-2016) in the study area. The second task involved conducting of semi-structured interviews with key stakeholders to gain more detailed insights into the observed landscape changes and the associated land uses, and also to develop a better understanding of the approach to, and stakeholder roles in land use planning in the district.

3.1 INTRODUCTION TO THE STUDY AREA

Luanshya district is located in the Copperbelt province of Zambia, 337 kilometres from the country's capital city of Lusaka and 35 kilometres south-west of the provincial capital, Ndola. The district is drained by the Baluba stream in the north, the Kafubu stream in the south and several smaller tributaries all of which drain into the Kafue river. Accounts of early prospectors and missionaries (from as early as 1850s) such as David Livingstone describe an early landscape characterized by abundant meandering rivers, large well-watered dambos (wetlands and meadows) along which villages and gardens were located before and during the early mining period (Schumaker, 2008). These areas played a key role in African agriculture and, because of these special characteristics, Luanshya came to be known as Zambia's only "garden town" with green parks and gardens before machinery and commercial mining activities were introduced to the area (Mususa, 2014).

Figure 9 shows the location of Luanshya district in relation to the whole country. More detailed maps are provided in Section 4.1 of Chapter 4.

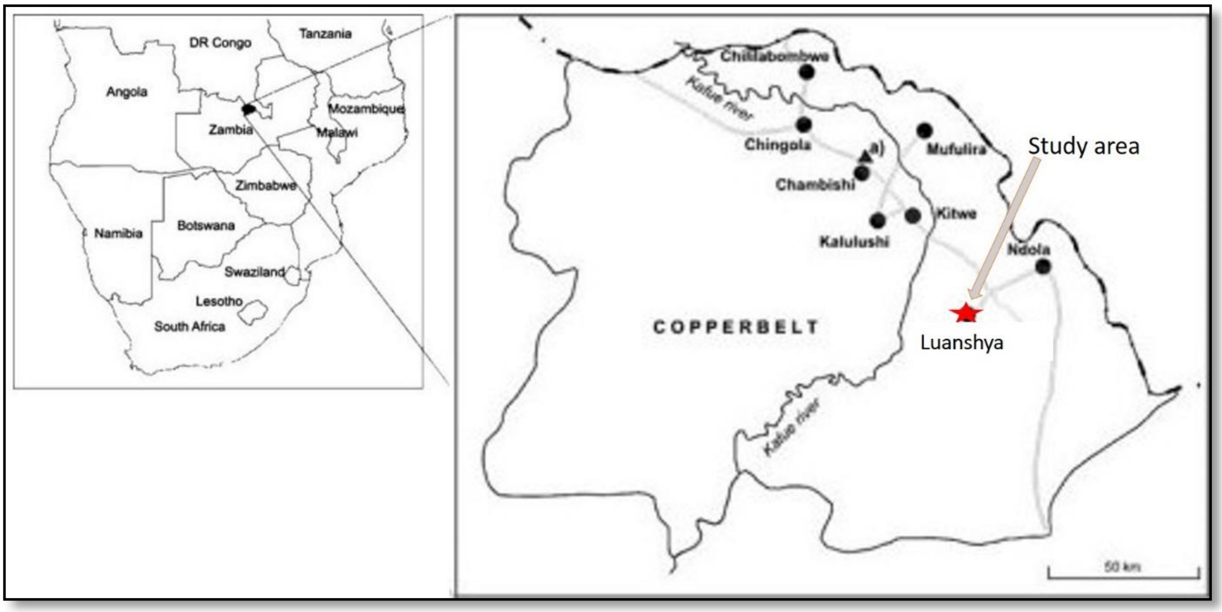

Figure 9: Location of Luanshya district in relation to the whole country

The copper deposit in Luanshya was discovered in 1902 by William. C. Collier of the Rhodesia Copper Company when he shot dead a *Roan* Antelope and its blood stained a copper outcrop near the banks of the Luanshya River (Horizon, 1958). Following Collier's mineral discovery, the Roan Antelope Copper Mines were opened in 1927 under the ownership of the British South Africa Mining Company (BSAMC). The mines in Luanshya district are now owned by Luanshya Copper Mines (LCM) under the giant multi-national mining conglomerate, China Non-ferrous Metal Company (CNMC) and are comprised of two mines, the Baluba and Mulianshi Mines. Mining is the major economic activity in Luanshya which employs the highest number of people, followed by agriculture. Farming is mainly done through farm blocks which consist of thousands of small-scale and commercial farmers and contributes to the district's GDP. Various Government ministries and public institutions also offer employment to many people in Luanshya in addition to the now growing and thriving informal sector (Luanshya Municipal Council, 2016). Luanshya also has some strategic manufacturing industries such as the Zambia Metal Fabricators Plc (Zamefa). Zamefa is a local beneficiation company which turns raw copper into finished products such as electrical cables and wires for sale on the local and export market (www.zamefa.com).

The Luanshya Mines initially had total ore reserves of 253 million tons (Luanshya Copper Mines, 2007). The ore is in the form of chalcopyrite ($CuFeS_2$), with minor amounts of bornite (Cu_5FeS_4) and chalcocite (Cu_2S). Cobalt occurs mainly as carrolite ($CuCo_2S_4$) and cupriferous pyrite (FeS_2 (Co) X) with average copper grades of 1.6% and 0.12% cobalt (Luanshya Copper Mines, 2016). During the early mining period after copper was just discovered, mining was done by underground operations until the early 2000's when near-surface copper occurrences began to be developed. During underground mining, alterations to the natural landscapes involved occupation of mine infrastructure, development of townships and occurrences of tailings and slag deposits in the southern part of the district. The ore was crushed and milled at the processing plant prior to differential flotation of copper and cobalt concentrate. The concentrates were then transported to Chambishi Metals Plc (82.2 km away) by road for metallurgical processing. Currently, more than 93% of the underground reserves have been depleted and, the rest are difficult to extract due to difficult geotechnical issues and flooding (Luanshya Copper Mines, 2016). Extracting these reserves would incur high capital and operating costs. In view of the depleting reserves, closure of the mine was first considered in 1978 (Luanshya Copper Mines, 2007). However, ZCCM kept the mine operating to keep people employed and to maintain some flow of foreign exchange. The mine was privatized in 1997 and the new developer, Roan Antelope Mining Corporation of Zambia, (RAMCZ) started operating the mine against the background of declining reserves and severe cash flow problems. This subsequently led to the company being placed into receivership in 2000. Additionally, there was a power supply cut as the mining company failed to pay their electricity bills to the Copperbelt Energy Corporation (CEC) for almost two years (Zimba, 2000; Luanshya Copper Mines, 2007). The receiver resumed production in January 2001 and operated the mine for a month until it was flooded in February by heavy storms. Following this flooding, the mine was placed on care and maintenance and eventually closed in the same year.

The underground operations remain closed since the flood, but the open pit operations commenced in the early 2000s and are active. The open pit operations have also undergone some short term closures due to financial challenges but are still active today. The present day environmental status of the mine and its surrounding areas is as a result of over 90 years of large scale mining activities. The following section outlines the spatial land use mapping methodology employed in this study.

3.2 LANDSCAPE MAPPING METHODOLODY

Land cover and use changes from different times spanning 6 and 10 year periods were mapped and compared to identify changes and how the changes relate to mining activity. These time spans were chosen because of the transitory nature of mining activities in this district as the Luanshya mines experienced cyclic periods of intense mining activity and periods of little to no mining activity. Landsat images were used in this study to identify alterations in the landscape. Landsat imagery was pioneered in 1972 with the launch of the Earth Resources Technology Satellite and it records land cover changes around the world (Masek et al., 2001). This technology employs sensors which provide calibrated multispectral measurements of land conditions which help in tracking the earth's land cover and anthropogenic activities. Landsat images enable a synoptic view of the land, and hence were used in this study because they were accessible and were found to adequately show the landscape alterations. Even though mining in Luanshya district commenced in 1927, only Landsat datasets from 1984, 1990, 2010 and 2016 were used in this study. Earlier datasets were not available as Landsat imagery is relatively new. For comparisons in the changes and quality of the landscapes, digitized spatial data based on land use mapping were used. It is not clear which year this mapping was conducted but it is assumed that it was conducted before 1984, and is hence used to infer changes in the landscape for the purposes of this research.

Table 2 shows the Landsat images used for the mapping.

Table 2: The satellite images used to analyse land cover changes in the study area

File Name	Date acquired	Satellite	Sensor	Path	Row
LC81720692015241LGN00	August 29, 2016	Landsat 8	Operational Land Imager (OLI)	172	69
LT51720692010147JSA01	May 27, 2010	Landsat 5	Operational Land Imager (OLI)	172	69
LT51720692000248JSA00	September 4, 2000	Landsat 5	Operational Land Imager (OLI)	172	69
LT51720691990172JSA00	June 21, 1990	Landsat 5	Operational Land Imager (OLI)	172	69
LT51720691984172AAA04	July 20, 1984	Landsat 5	Operational Land Imager (OLI)	172	69

Using ESRI ArcGIS software, three satellite image classification techniques are available (automatic, manual and hybrid) (Abburu and Golla, 2015). These techniques each have their own advantages and disadvantages. An automatic technique relies on the software to identify areas with similar pixel values and groups them. A manual technique employs human input and the user instructs the software to group similar features together (Abburu and Golla, 2015). Hybrid techniques combine automatic and manual methods where the automatic classifications are used to conduct the initial classifications and then manual methods are applied to refine the classifications and correct for errors (Abburu and Golla, 2015). This research applied hybrid techniques to extract satellite images based on pixel colour and intensity, with support of Google Earth images. The following steps were followed to identify the different land cover classes and land use categories in the study area:

1) Landsat images from the NASA Goddard Space Flight Centre were downloaded from the U.S. Geological Survey website. The images where then enhanced by applying the Tasselled Cap (TC) transformations as described by Zanchetta et al. (2015). These transformations are based on the

principal that combining multiple satellite data bands into a lesser number of features reduces the data volume and enhances the processor's ability to extract particular information (Abburu and Golla, 2015). The technique is used to convert the original set of data bands into a new set that bears a physical meaning in terms of surface characteristics. As such, the variation in soil reflectance is referred to as "Redness (R)"; variation in green vegetation is referred to as "Greenness (G)" and "Blueness (B)" refers to the wetness (Zanchetta et al., 2015). These three characteristics are considered to be more meaningful as they contain the greatest amount of information and hence applied to this research using a band combination of 1, 2 and 3 RGB.

2) The Landsat satellite data were manipulated by using ESRI ArcGIS 10.3 software to create a desired combination of bands. Features were mapped by grouping image pixel values into meaningful categories using hybrid classification techniques. For example, old tailings dams that are now dried up were automatically picked by the software as bare land. In this case, the tailings were manually traced with the help of Google earth imagery and added as layers to the processed image. Portions of images were then selected graphically and classified using supervised classification to cluster pixels into classes through maximum likelihood coding, a statistical approach for recognising patterns and allocating feature classes based on the probability value of the pixels (Abburu and Golla, 2015). Using this process, different land cover classes and land uses were identified and mapped. The classifications were validated by comparing to topographic maps and Google Earth images.
3) The processed images were then analysed to identify any noticeable decreases or increases in the physical elements for further interpretation. Key elements were identified and classified using visual cues from the processed satellite image with the support of mine records and Google Earth images for a given time period.

By applying these three steps, the study identified four land use categories; 1) settlements and bare land; 2) mine surface infrastructure and patches of land that have been cleared, or used for industrial purposes; 3) Mine waste disposal sites including overburden dumps, waste rock dumps and tailings impoundments and 4) Mine excavations or open pits. Similarly, land cover classes were identified and categorized into five; 1) Natural woodland or wilderness areas; 2) Crop fields and patches of deforested areas – typically areas used for small-scale clearings; 3) forests and plantations; 4) Water bodies and, 5) Other disturbed areas around the mine facilities and settlement areas. A major limitation of this methodology is that deforested areas now occurring as grasslands and patches of crop fields were difficult to distinguish from one another and hence combined. Similarly, settlements and bare lands were also hard to separate as the two attributes often occur together.

Following the mapping, a "ground truthing" exercise was conducted by visiting some sites and also by verifying the findings with the mining company, the relevant government ministries as well as with the national remote sensing centre located in Lusaka. Information patterning to the baseline environment in the study area was obtained from topographical maps and archival search at the ZCCM's Ndola facility and the Luanshya Municipal Council archives.

Major challenges encountered during the data collection phase were the lack of sufficient coherent data and conflicting land use and demographic statistics. Additionally, some of the information obtained from the government ministries was out of date. The land use statistics used in this report have been complimented by data from the remote sensing centre in Lusaka and estimations from the satellite images. Another limitation of the mapping exercise is that the mining company did not permit taking of pictures around the mine site. Pictures used in this report were obtained from previous company reports and related studies and hence the conditions of the mine sites may not represent the most current state.

3.3 INTERVIEW PROCEDURE

After the landscape trends were mapped, observations and preliminary interpretations were used to conduct semi-structured interviews with key people from relevant government sector ministries in the study area as well as the mining company. Four participants were selected to represent each key sector in the district. The interviews were conducted to obtain a better understanding of the mapped landscape changes and the associated land uses, and also to develop a better understanding of the approach to and stakeholder roles in land use planning in the district. Also assessed were the fluctuations in mining activity, the human behaviour patterns they created and the associated impacts on the land. Table 3 provides details of the interview participants

Table 3: Interview participant details

Participant No	Organization	Job Title
1	Ministry of Agriculture	Agriculture land planning officer
2	Municipal Council	Physical planner
3	Forestry Department	Forestry extension assistant
4	Luanshya Copper Mines Plc.	Head of land surveying

An interview guide was developed for this purpose and, except for the mine representative, face-to-face interactive interviews were conducted in the participant's offices. Different sections of the interview guide were designed for each different participant as follows;

1. The Municipal Council Town Planner: To obtain further understanding of the mapped landscape changes and to develop a better understand of the approach to, and stakeholder roles in, land use planning in the district. Questions were also asked to find out which other stakeholders contributed

to the land use planning process, what key legislation guided their planning, and if the legislation was considered to be sufficient.

2. The Agricultural Planner at the Ministry of Agriculture and Livestock: To get information on the Ministry's activities and the planner's experiences on their planning and use of the district land for agricultural purposes. Questions were also asked about how the mapped landscape changes are connected to agricultural activities, and also if these activities were influenced or impacted by mining.
3. The Forestry Extension Assistant at the Forestry Department of the Ministry of Lands and Natural Resources: To get information on the Department's planning and use of the district land for development of forests and plantations. Questions were also asked to gain a more in-depth understanding of the mapped landscape changes and how they are connected to mining and other land uses, and also their experiences in the management of forestry resources.
4. A representative of Luanshya Copper Mines: To obtain information on the mine's use of the district land for mining-related functions; the types and quantities of mine wastes generated; and the ground conditions around the mine. Questions were also asked to find out how the mine responds to the identified land issues.

Although limited, the number of interview participants were selected on the basis of their ability to provide expert insights into the approaches to, and stakeholder roles in land use planning. A copy of the interview guide is presented in Appendix A.

3.4 ETHICS, HAZARDS AND OPERATIBILITY OF RESEARCH TECHNIQUE

To ensure ethical compliance in the research, the proposed study underwent an ethics review by the Engineering and Built Environment Ethics Committee (EBEEiRC) prior to data collection. A copy of the review form has been made available in Appendix C. Following this clearance, an application was made to the Luanshya town clerk to get approval to approach the target people for interviews and for a voice recorder to be used. Attached to the application was an introductory letter signed by the supervisor of the research, a copy of the interview guide as well as the informed consent form.

These approvals were necessary because it was recognized that some participants would be hesitant to participate in this type of research for fear of facing disciplinary charges afterwards. The signed approval from the Town Clerk, who is the custodian of all information concerning the district, would provide them with comfort and protection. Upon getting approval from the Town Clerk, the offices of the target people were then located and each of the participants were then approached with the signed approval, an introductory letter including some simplified details about the research, the researcher, the purpose of the interview, the type of information sought as well as what the information would be used for once obtained. Once the participants understood and were happy to be interviewed and recorded, an informed consent form was then provided for their signature and the interview followed. Some participants were happy to be referenced as an information source while others preferred to remain anonymous. Nevertheless, no direct reference to participants has been made in this dissertation. Evidence of their participation will be presented in a separate anonymous form to the supervisor of the research if necessary.

CHAPTER 4

RESULTS AND DISCUSSION

Chapter 3 outlined the methodology employed in conducting this study. The methodology involved two tasks; landscape and cover mapping and conducting of semi-structured interviews designed to gain more detailed insights into the observed landscape changes, the associated land uses, and also to develop a better understand of the approach to and stakeholder roles in land use planning in the district. This chapter presents the results and analysis of the study pertaining to the current state of the environment in the Luanshya District (Section 4.1), landscape changes from 1984 to 2016 (Section 4.2) and stakeholder perspectives (Section 4.3).

4.1 CURRENT STATE OF THE ENVIRONMENT IN THE LUANSHYA DISTRICT

4.1.1 THE MINE SITES

All the mining and mine waste dumping activities have taken place in the central part of the district while all the other activities take place in the surrounding areas (Figure 10). There are several mine operations at in Luanshya district and these include Mulianshi open pit, Luanshya underground workings, the Baluba open pit, Mashiba underground operations and the Roan Basin mining operations in the district (Luanshya Copper Mines, 2017). The underground workings correspond to a surface area of approximately 900 ha of which about 600 ha have been undermined and the land surface above them are now subsiding, sinking or caving (Luanshya Copper Mines, 2017). Underground workings extend to a depth of 900m below ground surface and have a strike length of about 11km. Some small-scale mining and quarrying operations also occur at or near the main mine sites. At the time of investigation, open pits only covered 150.5 ha of the land but several solid and slurry waste dumps were also present.

In terms of overall land usage, Luanshya district covers an area of 100,761 ha (Luanshya Municipal Council, 2017). Of this, 16581.2 ha is used for mining and related activities and 2939.2 ha has already been altered by mining and related waste dumping. This signifies 18% of the district land which when compared to the total land area available in the district, the size seems small. However, due to the close proximity of the mines and waste dumps to population centres, their impacts are locally significant. There are 231.1 million tons of tailings waste and 121.6 million tons of waste rock deposits corresponding to 1836.5 ha which have not been rehabilitated (Table 4). This is a big portion of land which represents a loss of opportunity for the local population to use it for other purposes. Tailing dams take up the largest portion of the district land with 1480.7 ha. This corresponds to 74% of the total mine land and 310.8 million tons of waste (Luanshya Copper Mines, 2017). Figure 10 shows a Google earth image of the current state of the environment in Luanshya district.

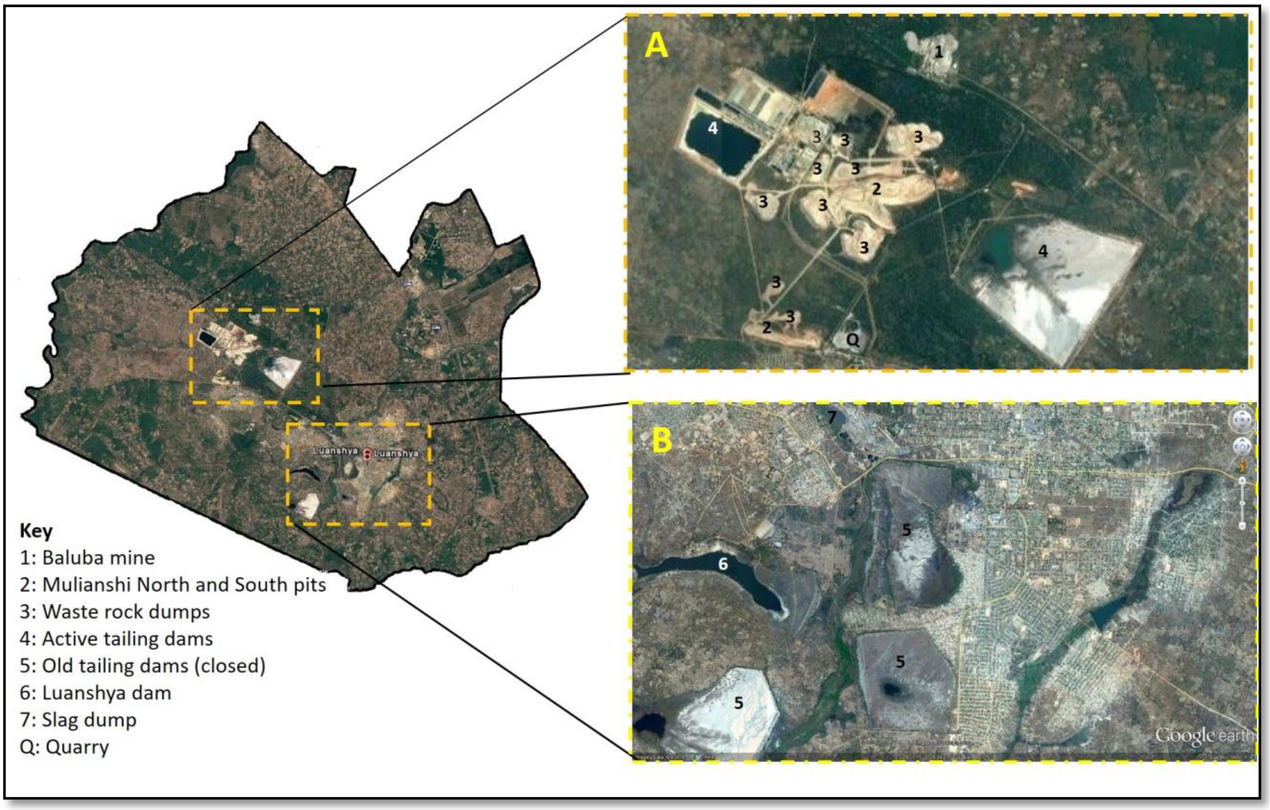

Figure 10: Google earth image showing the current state of the environment in Luanshya district. A: shows the open pit operations. B: shows the area above the underground operations.

There are several waste rock dumps of variable sizes present in the district covering a total of 355.8 ha and amounting to approximately 121.6 million tons of solid waste (Luanshya Copper Mines, 2017). Several mine waste dumps have been closed as they have reached their maximum carrying capacities, but they are not rehabilitated. Some waste dumps have been partially vegetated and, as can be seen in Figure 10, some tailings are dry but not vegetated (bottom left). Unrehabilitated tailings are not expected to naturally support vegetation growth due to their physical and chemical properties (Luanshya Copper Mines, 2007). They are characterized by fine silt content, poor drainage, and lack of organic matter, surface hardening, elevated metal content and erosion and hence unsuitable for re-vegetation in their current state. There is also a man-made water storage dam (Luanshya dam) which was created to facilitate the diversion of Luanshya River through a 1.83 m^2 diversion tunnel and emergency overflow pipes (Luanshya Copper Mines, 2007). The Luanshya River was diverted to prevent it from flowing into the underground workings and to allow for expansion of the Old Tailings Dam.

Table 4 presents an inventory of the mine workings and waste dumps in Luanshya district.

Table 4: Inventory of the mine workings and waste dumps in Luanshya district. Source; Luanshya Copper Mines, 2017.

No.	DESCRIPTION	SIZE (Ha)	Av. HEIGHT (m)	QUANTITY (Million tons)	STATUS
TAILINGS DAMS					
1	Old tailings dam	293.6	36	48	Closed
2	Akatiti tailings dam	240.4	30	44.8	Closed
3	Chonga tailings dam	280	30	6.3	Closed
4	Musi tailings dam	531.6	43	120	Active
5	Mulianshi tailings dam	135.1	25	12	Active
	Total	**1480.7**		**231.1**	
ROCK WASTE DUMPS					
1	Baluba east waste dump	9.4		1.3	Active
2	Baluba east waste dump	15.8		2.9	Closed
3	14 shaft north waste dump	16.3		3.7	Closed
4	14 shaft south waste dump	19		2.6	Closed
5	18 shaft north waste dump	3.9		0.4	Closed
6	18 shaft south waste dump	9.7		0.8	Closed
7	28 shaft waste dump	8.4		3.1	Closed
8	Muliashi north waste dump no 1	36.9		16	Closed
9	Muliashi north waste dump no 2	25.3		9	Active
10	Muliashi north waste dump no 3	20.9		6.6	Active
11	Muliashi north waste dump no 4	46.1		20.3	Closed
12	Muliashi north waste dump no 1	36.9		16	Closed
13	Muliashi north waste dump no 2	25.3		9	Active
14	Muliashi north waste dump no 3	20.9		6.6	Active
15	Muliashi north waste dump no 4	46.1		20.3	Closed
16	Muliashi south waste dump	14.9		3	Active
	Total	**355.8**		**121.6**	
OPEN PITS AND OTHER WORKINGS					
1	Muliashi north open pit	98			Active
2	Muliashi south open pit	25.2			Active
3	Baluba Central pit	-			Planned
4	Baluba East pit	27.8			Active
5	Mashiba Underground section	900			Closed
6	Roan Basin	-			Planned
7	Mine Infrastructure	51.7			Variable

Some of the closed mine waste dumps have been partly vegetated but are not rehabilitated to support alternative land uses. A summary of the actions taken and the outstanding issues has been provided in section 5.2 of chapter 5 (Table 6). The tailing surfaces are characterized by deep erosion gullies and the eroded material gets deposited into the surroundings especially during the rainy season (Figure 11). Mine infrastructure includes office space, workshops, processing plants, shafts, analytical laboratories and other mine support facilities (LCM, 2017). These cover about 52ha of the land and some of them are in deplorable states and may be characterized as waste (LCM, 2017).

Figure 11: Erosion on the old dry tailings. Pictures courtesy of Lewis Tumbama, 2008

Other mining-related land impacts in the district are surface openings and geotechnical failures related to the underground workings. According to the mining company's 2007 mine closure and decommissioning report, the ground surface above the underground workings is characterized by a number of surface openings which include shafts, vent raises (and winzes) and a portal (Luanshya Copper Mines, 2007). Over 70% of the openings are located in areas that are now caved, sinking or collapsed and hence pose serious health and safety hazards for animals and the communities living around the area. Other geotechnical issues are caused by debris flow from the rock dumps (Luanshya Copper Mines, 2007). Figure 12 shows some examples of land subsidence and caving in Luanshya district.

Figure 12: Land subsidence and caving above the underground workings in Luanshya. Source; Luanshya Copper Mines, decommissioning and closure report, 2007. Annexure 3.

More than 100m² of land around the Luanshya Mines is caved or unrehabilitated, and the only measures taken to protect the communities is posting of warning signs for people to keep away from danger (Luanshya Copper Mines, 2017). An inventory of all the ground openings and caved areas is provided in Appendix D.

In terms of aesthetics, the district is significantly impacted by the presence of mine wastes. The general scenery of the mine area is characterized by shaft headgears, water tanks and mine waste dumps. A 2007 Environmental Impact Statement report indicates that the impacts of mining extends to the other mining tenements. According to this report, some waste rock dumps are located in the neighbouring mine tenement on copper caps thus impacting other mine developments (Luanshya Copper Mines, 2007). This means that the future exploitation of the mineral resources is also impacted by the wastes from the older mines.

4.1.2 LAND USE

In terms of overall land use, 28 % of the district land is used for commercial farming. Small holdings consisting of smaller portions of land (2 ha or less) used by small scale farmers for their own subsistence take up 30 %. This class also includes emergent farmers who hold more than 2 ha of land and produce crops (maize, beans, cassava, sorghum and groundnuts), livestock and poultry for sell (Ministry of Agriculture, 2017). Natural forests take up 17 % while plantations consisting of exotic species of pines and eucalyptus take up 3 % (Luanshya Forestry Department, 2017). Built up land (consisting of urban settlements, commercial, recreational and transport infrastructure) takes up 3%. The remaining 1% of the district land remains as open spaces and consists of wetlands and streams. Figure 13 shows how much land is in use for different functions in the district.

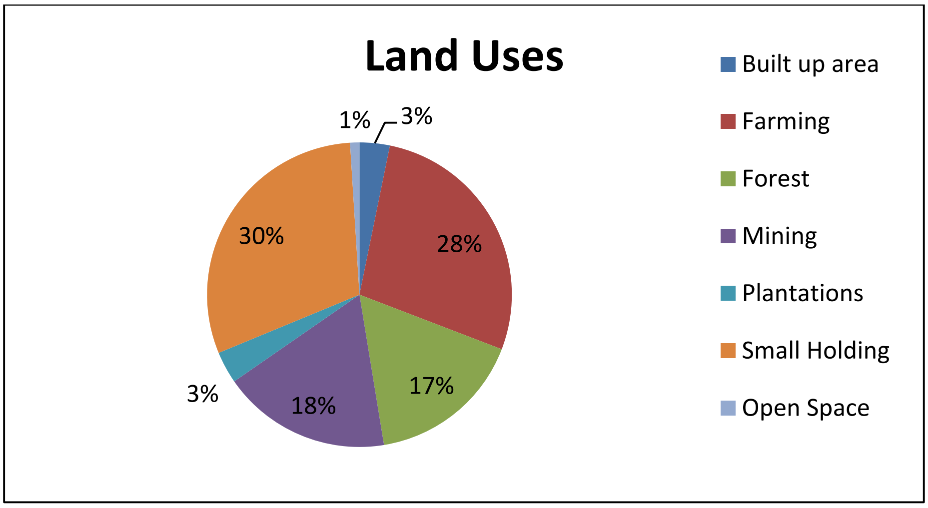

Figure 13: Chart showing the current land uses in the study area. Values obtained from the Luanshya Municipal Council (2017), the Ministry of Agriculture (2017) and the Luanshya Forestry Department, 2017.

Mining and its related functions take up 18% of the district land and of this, tailings take up the largest share with 74% used for tailings disposal (Figure 14).

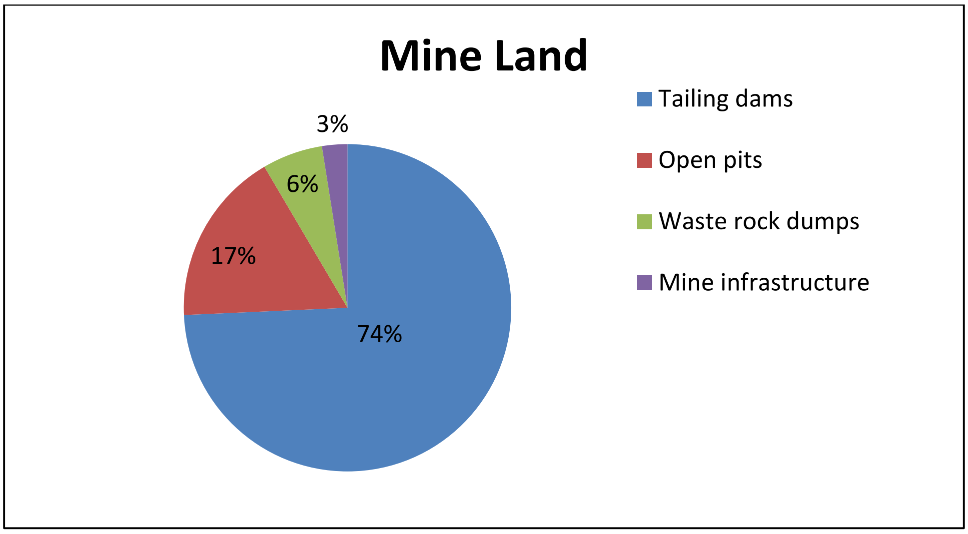

Figure 14: Percentage land proportions taken up by different mining functions. Source; Luanshya Copper Mines, April 2017

4.1.3 DEMOGRAPHY AND POPULATION DISTRIBUTION

In terms of demographics, the population distribution of the district is such that there is a there is greater concentration of townships around the mining areas than the areas in the peripheries of the district (Figure 15). Initially, the district consisted of 5 formal townships; 3 in the mine area and 2 in the municipal area (demarcated by the red dotted line). Due to the influx of people in search of mining jobs, several informal settlements developed around the peripheries of the district by illegal takeover of idle land and forests (Luanshya Municipal Council, 2017). With time, most of the illegal settlements became formalised or relocated and now the district has 28 recognised townships (locally referred to as wards), and those located near the mines are more densely populated (Figure 15). All the townships are now managed and serviced by the Municipal Council following the changes in the ownership of the mines and the adoption of the National Decentralization Policy (Luanshya Municipal Council, 2017). In terms of social issues, rapid population growth remains a challenge and the allocated public resources for service provision are thought to be to too little to meet the demand (Luanshya Municipal Council, 2017). This is coupled by over-dependence on and crowding out of the mining industry for economic growth. Figure 15 distribution of townships in the district

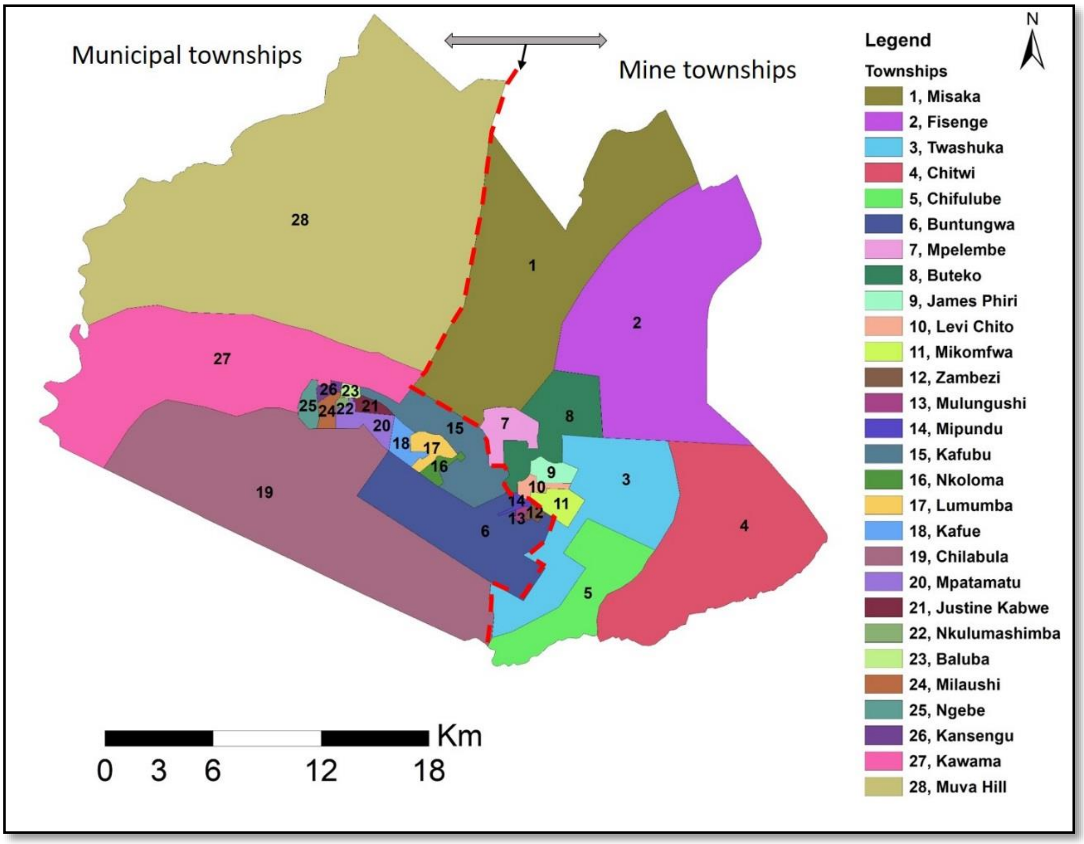

Figure 15: Townships of Luanshya: Modified from https://earthworks.stanford.edu/catalog/stanford-yc436vm9005. The red dotted line represents the boundary between municipal and mine townships

These factors have led to the development of a mono-based economy but there is hope that decentralization will improve service delivery if it is implemented correctly (Luanshya Municipal Council 2017). Generally, as with the whole Copperbelt region, Luanshya district has experienced cyclic periods of rapid social and economic rejuvenation after going through periods of debilitating economic depressions. Currently, the district is characterized by high urban poverty that has persisted since the mines' privatization, followed by retrenchments and withdrawal of social welfare provisions (Luanshya Municipal Council, 2017). The Luanshya Municipal Council (LMC) has a motto; "*improvement and maintenance of quality life of its communities through the effective and efficient provision of service of acceptable quality.*" Yet, they are faced with a lot of challenges due to heavy dependence on government grants to finance the day to day operation of the Municipality (Luanshya Municipal Council, 2017). Poor coordination of development activities is another challenge facing the municipality and the council attributes this to the absence of an integrated developed plan, and lack of development partnerships and cooperation with other stakeholders. The following section presents the landscape changes observed from the mapping.

4.2 MAPPING OF LANDSCAPE CHANGES

As already stated in the methodology chapter, a 32 year period from 1984-2016 was investigated in this study. Even though mining in Luanshya started in 1927, land cover and use data before 1984 was not used due to lack of availability. As such, a land use classification map showing the original forest reserves (pre-1984 map) has been included in the discussions to facilitate comparisons in the alterations and quality of the landscapes. This map was obtained from the Luanshya Municipal Council but the year these classifications were made is unknown. However, since it shows the original forests (dark green areas), we assume the classifications are pre 1984, and it is used to infer changes in the landscape for the purposes of this research.

The mapping results generally show that the landscape alterations in the district involved simultaneous processes caused by mining and community-related activities. The first mechanism consists of mining activities and the associated mine wastes, while the second mechanism consists of community activities. The main attributes identified from the mapping are dark green patches representing forests and plantations; red patches representing bare land and settlements; blue patches representing water; cream white patches representing tailings dams; and brown patches representing open pits. The remainder of the light green patches represent deforested areas and crop fields. Deforested areas are those previously densely vegetated now largely converted to grasslands and patches of crop fields (Figure 16).

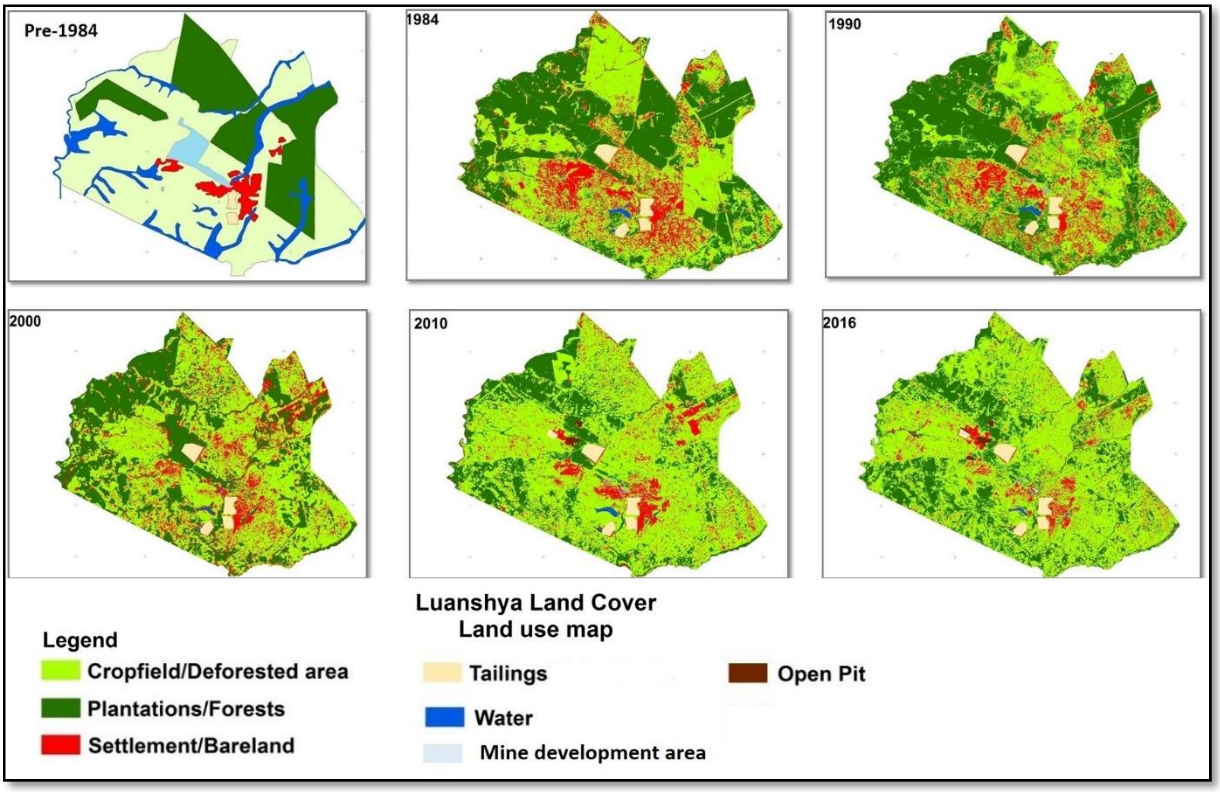

Figure 16: Progressive land cover changes in Luanshya district between 1984 and 2016. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 1984, 1990, 2000, 2010 and 2016

Figure 16 shows that the landscape in Luanshya has changed drastically over the 32 year period investigated. The first period under investigation is the 1980's during which the mines were under government control after 37 years of private control. The second period under investigation is the 1990's during which the mining industry went into decline and subsequent reprivatisation at the end of the decade. During this decade, changes observed relate to community activities as impacts from mining remained almost constant. The third period investigated was the early 2000's during which mining activities picked up under private ownership. The fourth and final period investigated was the 6 year period between 2010 and 2016 to establish the current state of the landscape and how the changes are related to mining activities or other land uses in the district.

4.2.1 BASELINE ENVIRONMENT

As already stated in section 3.1 of the methodology chapter, early explorers and prospectors describe an early landscape characterized by dense forests and wetlands which led to Luanshya being referred to as a "garden town" before commercial mining was introduced. This garden-like nature of the district is also illustrated in Figure 17, and according to the council, the transformation of Luanshya from a garden town into what it is today is traced from 1902 when copper was discovered near the Luanshya River (Luanshya Municipal Council, 2017). However, during the early 1920s, there were a number of malaria-associated deaths among the miners (Schumaker, 2008). Malaria expats saw the wetlands and gardens as sources of malaria and considered them "sick". They described them as "*sluggish, chocked and winding tortuously through broad floodplains*" (Schumaker, 2008). They were later "cured" by burying them under tailings, while others were drained, reshaped or oiled as part of the malaria control programmes with little attention to their agricultural uses (Schumaker, 2008). Yet, even when filled with slimes, the altered dambos transfigured the landscape, as in the 1952 description of Luanshya by Kenneth Bradley, a colonial administrator and author: ". . . *you may, perhaps, lift your eyes from all this present industry and there, down the valley, lies a silver plain. But it is not a plain, it is the tailings from the flotation plant, and you may get some satisfaction from reflecting that no slag-heap could shine so beautifully or, if it comes to that, could so mold itself to the landscape".*[3]

Figure 17 shows a map of the district with different land cover and land use categories before 1984.

[3]Bradley, Copper Venture, in African Highway: The Battle for Health in Central Africa (London, John Murray, 1953), compiled by Sir Malcom Watson from reports and articles written by the people involved in the various stages of the Copperbelt malaria control programme.

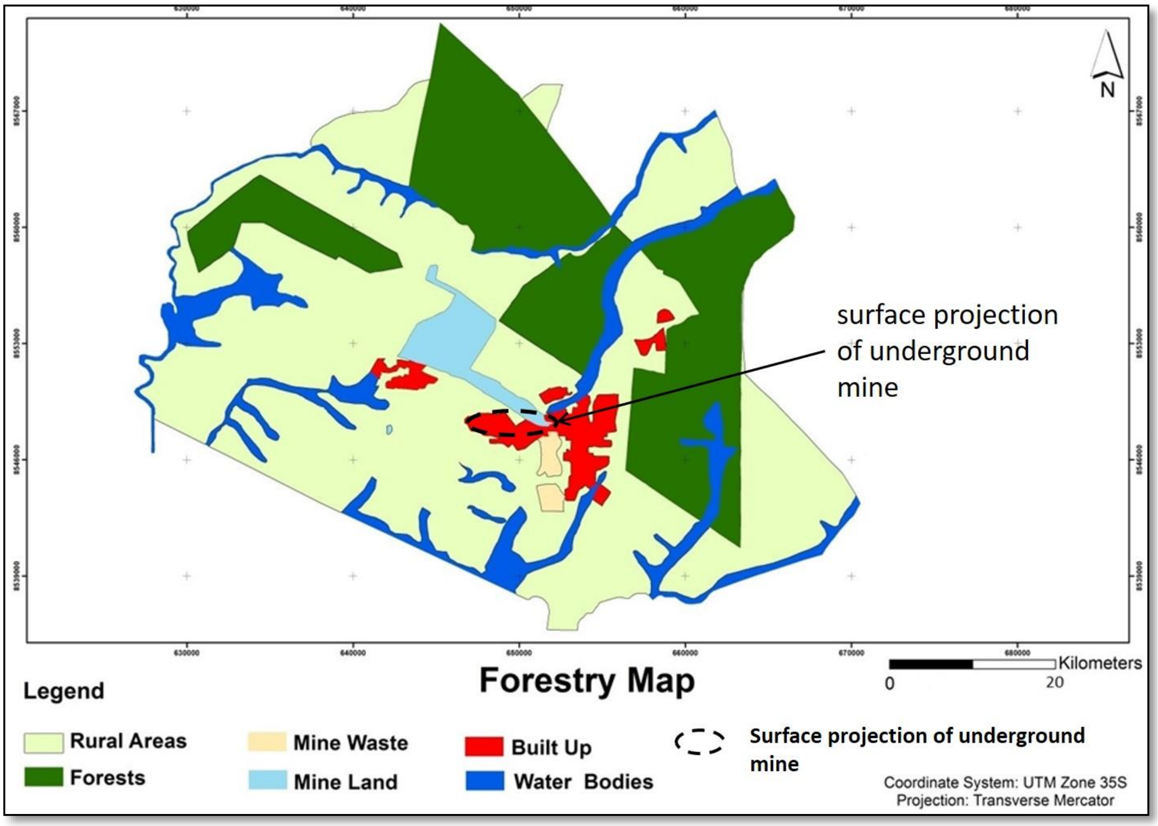

Figure 17: Map of Luanshya district showing the state of the environment before 1984. Modified after the Luanshya Municipal Council, Year unknown

The dark green areas in Figure 17 show the forest reserves and plantations as originally designated, while the lighter green areas show the rural or wilderness areas characterized by natural woodlands. Although not shown in the map, wilderness areas also include farm lands. The deep blue areas correspond to the water bodies (wetlands, rivers and dams). The build-up areas correspond to residential, commercial and industrial infrastructure. Following the commencement of mining, another portion of the land in the centre of the district was held as mine land (light blue patch), for continued mineral explorations and future mine expansions, while the cream patches were used as tailings impoundments.

4.2.2 LAND COVER CHANGES

Various elements in the landscape have been identified based on differences in colour, shade and pattern. Figure 18 shows the land cover map at the start of the period under investigation.

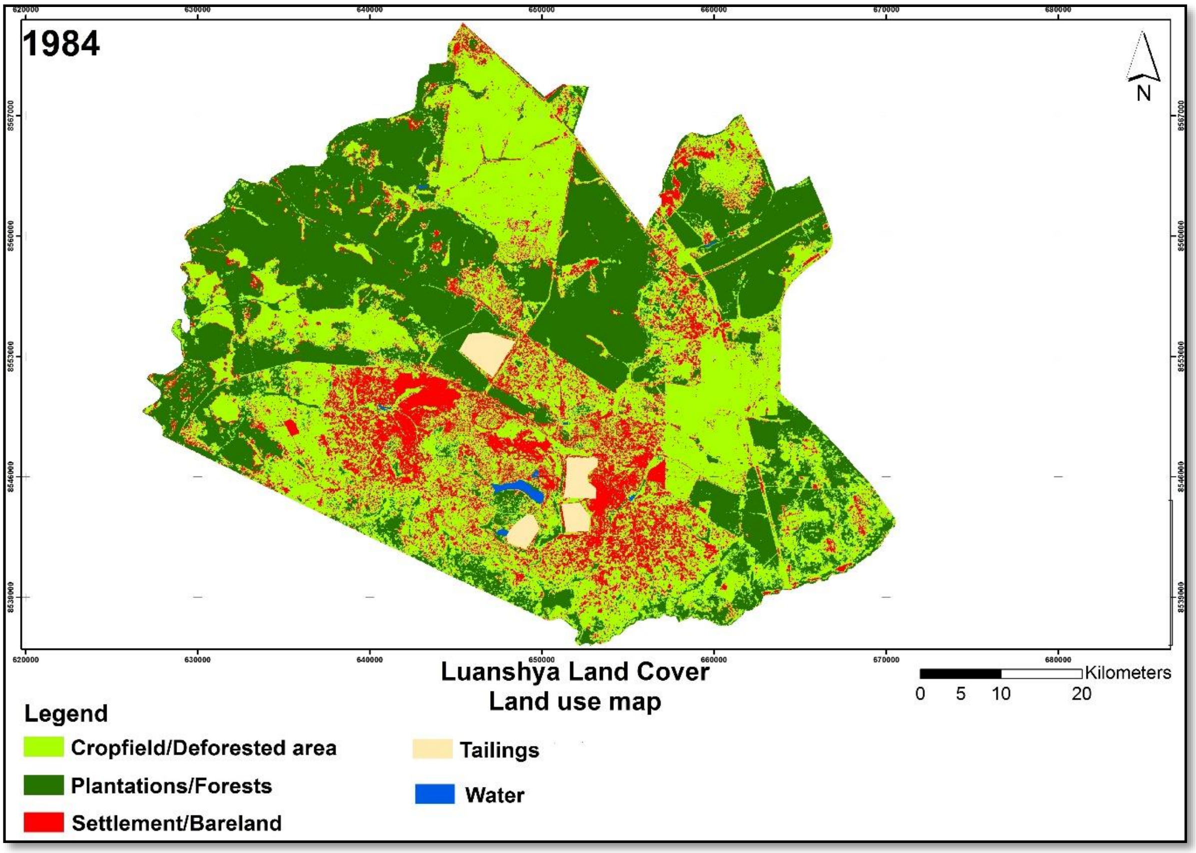

Figure 18: State of land cover at the start of the investigated period. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 1984

It is apparent from Figure 18 that there was high concentration of red patches in the southern half of the district. This may be attributed to the high influx of people to the district such that settlements evolved around the mines and other parts of the district. According to literature reports, the mine had been nationalised in the early 1970s with the creation of ZCCM and a number of social services and public goods were being provided to the mine workers and their communities (ICMM, 2014; Sikamo, et al., 2016). As a result, Luanshya district experienced an influx of people and the population of the district grew from 96,242 in 1969 to 129, 589 in 1980 representing a 2.7% annual growth rate[4]. Figure 18 also shows that a significant percentage of the natural forests and plantations were still thriving but deforestation is observed from the patchy forest areas characterized by crop fields and treeless grasslands. In terms of mining activity, there were no open pits yet during this time as only underground operations were taking place. There were no waste rock dumps at this time but there were 4 large tailings deposits on the land surface.

Ten years later in 1990 (Figure 19), some patches of previously deforested areas had regenerated but greater portions of the forests had been cleared. Similarly, settlements and bare patches of land had spread out to other parts of the district.

[4] Zambia Central Statistical Office: online data portal

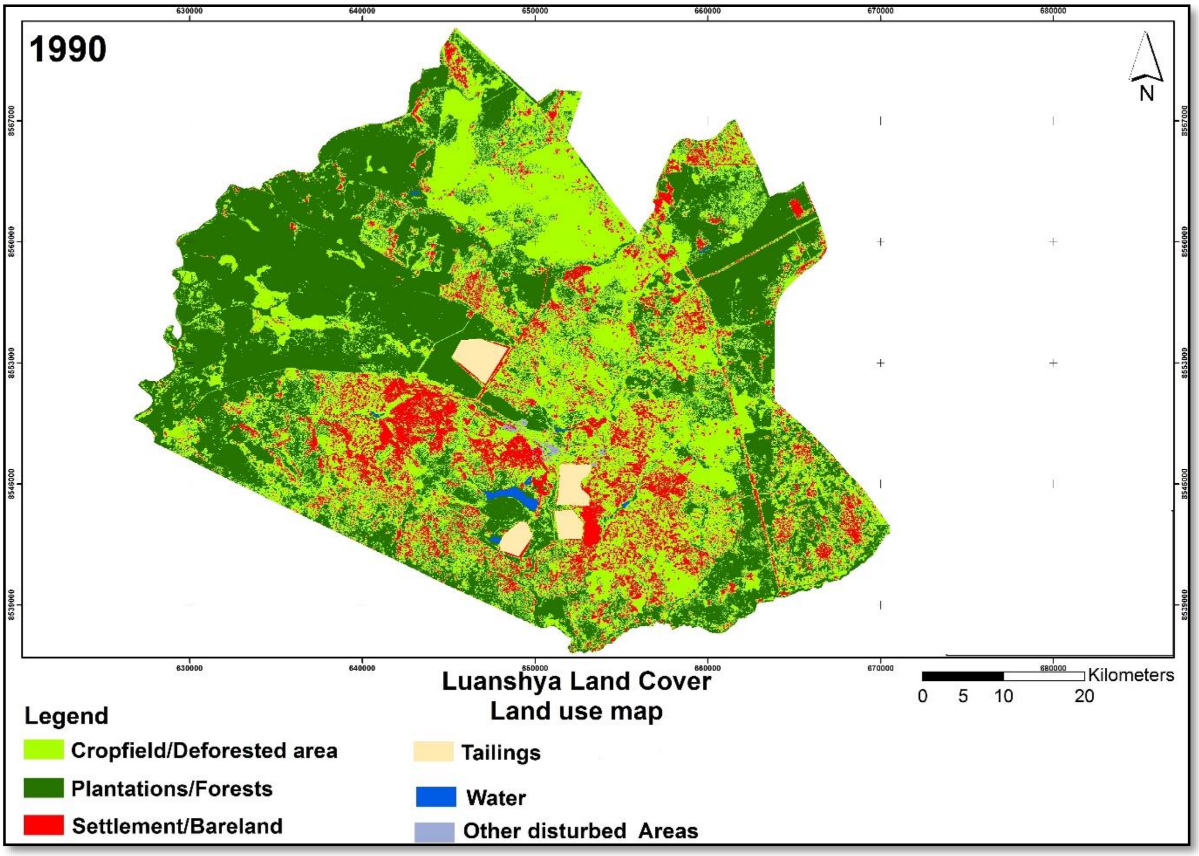

Figure 19 : Land cover status in 1990. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 1990.

There are no observable increases in mine waste deposits between 1984 and 1990 as mining activities had slowed down in response to low commodity prices. The industry in Zambia faced financial challenges which led to reductions in copper production, during the period 1980 to 2000 (Sikamo et al., 2014; ICMM, 2014). Despite the slowdown of mining activities, there were reported geotechnical issues relating to the tailings impoundments, land degradation through ground subsidence and silting of the Luanshya River during the Copperbelt Environment Project (2005). It also worth noting that until 1990, there was no environmental management legislation in place yet in Zambia and hence the lack of sound environmental management (Chileya and Dokowe, 2014). The light blue areas attributed as "other disturbed areas" consist of a slag dump and processing infrastructure. The main observable physical alterations from the mapping during this period were human-induced deforestation and spreading of settlements to other parts of the district. The population of the district at this time was 141,929, up from 129,587 in 1980. This represents only 0.9% annual population growth rate, down from 2.7% experienced during 1969-1980 and below the national average of 2.9% at that time[5].

[5] Figures obtained from the Zambia Central Statistical Office online portal

The next 10 year period leading to 2000 was characterized by similar changes as the period before it. Copper production and prices had declined further. The mine became privatized in 1997 but copper production had not improved yet. Figure 20 shows the land cover changes in 2000.

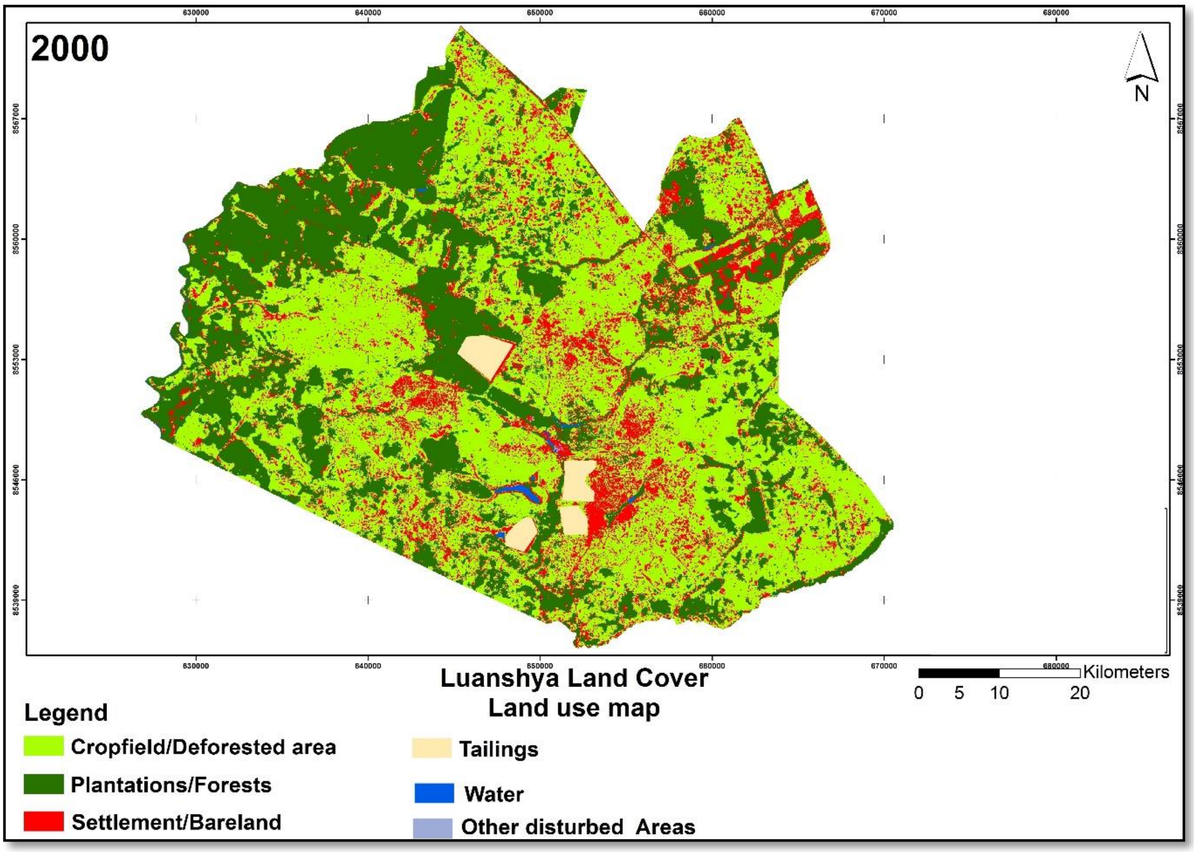

Figure 20: Land cover status in 2000. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 2000

Figure 20 shows that mine waste deposits remained constant in 2000 as copper production stayed on the decline path as the known copper reserves were getting depleted as well (Luanshya Copper Mines, 2007). As already noted in section 3.1 of the methodology chapter, when the mine was privatized in 1997 and the new developer, Roan Antelope Mining Corporation of Zambia, (RAMCZ) had resumed mining operations against the background of declining reserves and severe cash flow problems. Furthermore, the mine suffered a power supply cut as electricity bills accumulated (Zimba, 2000; Luanshya Copper Mines, 2007). This subsequently led to the company being placed into receivership in 2000. Despite the stoppage of mine operations, there is an observed dramatic increase in deforestation during this period as forests were largely converted into grasslands and sparsely vegetated agricultural areas. Due to the issues faced at the mine and its subsequent placement into receivership, significant retrenchments also followed (Luanshya Copper Mines, 2007). According to the 2000 national census, Luanshya district had a population of 155,979 and an estimated 5,000 former miners and their families in 2000.[6] This figure represents 3% of the total district population which previously depended on mine wages for their livelihood and now seeking alternative means.

This may explain the increase in deforestation as former mine workers went into farming and unlicensed quarrying of construction material while others started producing firewood and charcoal to supplement the energy shortages. These observations are also consistent with literature reports of the Copperbelt Environment Project, (2005) and Mususa (2014), whose studies note that the practice of making a living through other means was common among Copperbelt residents after losing their mine jobs. The CEP further notes that a number of the mining workforce tended to migrate to other districts in search of new opportunities. Socio-economic consultations of the CEP conducted during 2004-2005 in some selected communities of the district also found that cracking and partial sinking of buildings were common above the underground workings (Masinja et al., 2005). Also reported were air pollution resulting from dust emissions from the old tailings impoundments and smelter emissions; flooding and erosion from the tailings resulting in crop failure; open geological sampling pits; occurrence of illegal settlements and high poverty rates. These problems were attributed to inadequate enforcement of legislation, non-compliance to legislation by the mining company. The high poverty rates were attributed to withdrawal of welfare services by ZCCM and lack of new opportunities to cushion the job losses (Masinja et al, 2005). Figure 21 shows further land cover changes in 2010.

[6]Zambia Central Statistical Office

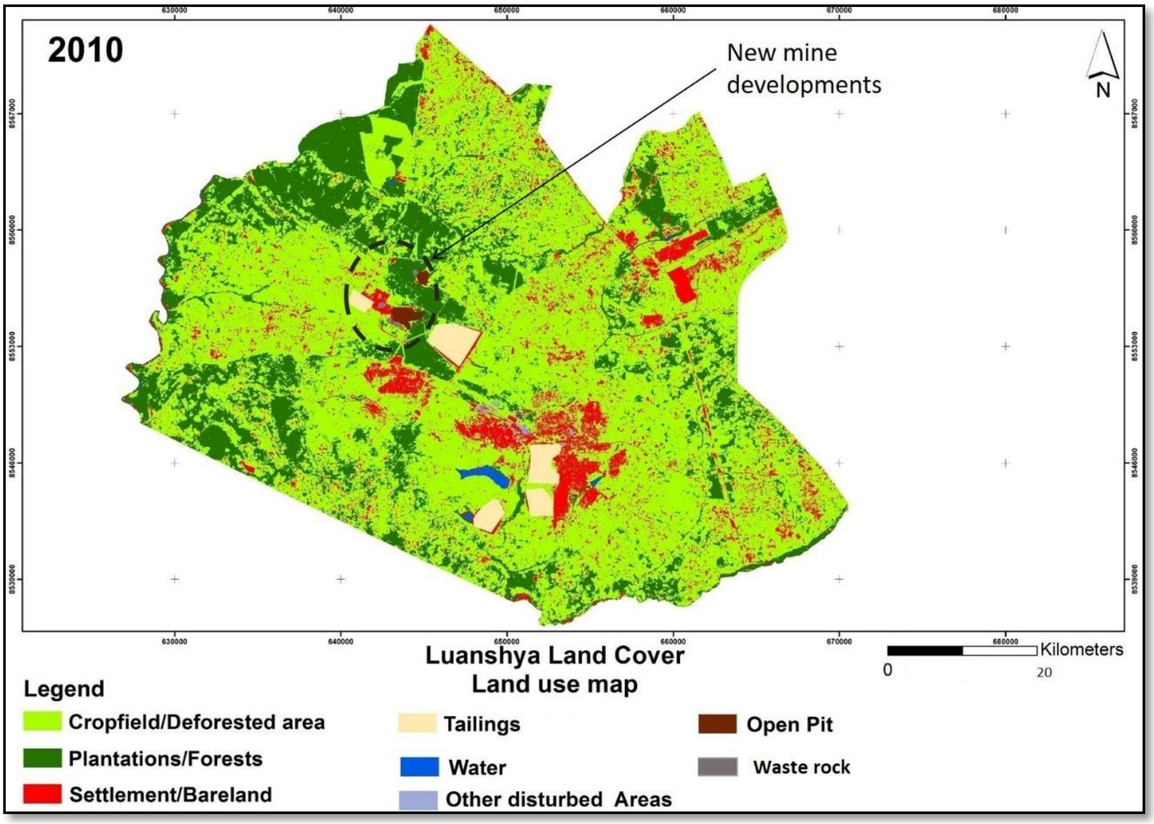

Figure 21: Land cover status in 2010. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 2010.

In 2000, new mine operations appeared along with additional mine waste dumps (Figure 21). According to literature, this was during the period after the mines were reprivatized so the mining sector was opened up to foreign investment (Sikamo et al., 2014). The mining industry was also experiencing resurgence in copper prices during this time which brought about a boom in new investments. It was this inflow of revenue that enabled new mine operations to start and in Luanshya, as evidenced by the appearance of new mine workings (circled). These new operations brought with them an increased land use by the mines as more land was cleared to pave way for additional mine infrastructure and mine waste dumps now visible in the 2010 map (Figure 21).

According to the EIS report of these new mine operations (Luanshya Copper Mines, 2007), the company acknowledges that while the new developments would bring new opportunities to the area, they also point out that there would be negative impacts. The negative impacts recognised included reduction in air quality (from dust and plant emissions), disruption of movement patterns, economic displacement of small-scale farmers and displacements of some community's recreation and social facilities including tennis courts, swimming pools, a day care centre among others (Luanshya Copper Mines, 2007). New plant infrastructure and a heap leach pad were also established during this period which required removal of vegetation. Water bodies were also being impacted such that some previously flooded historical underground workings were being de-watered to allow mining to continue. The mine dewatering produced sulphate-laden water from the mine which was channelled to the rivers thus contaminating them (Luanshya Copper Mines, 2007).

Unfortunately, the mining industry experienced declines in the copper prices once again between 2010 and 2016 and the Luanshya mines faced financial and operational challenges including flooding which led to closure of the underground operations in 2015 (Luanshya Copper Mines, 2017). With closure of the underground operations, more people lost jobs as the mine embarked on labour cuts during this time in a bid to save on costs. At the time of this data collection, the population of Luanshya was estimated at 113, 365, down from 153,117 in 2010.[7] Based on the reduction in population, some former mine workers are thought to have migrated to other districts in search of new opportunities while others took on farming and unlicensed charcoal production to sustain their families. Lack of alternative economic opportunities besides mining leads to migration of people to other areas. Urban to rural migration also contributes to increased pressures on natural vegetation as families look for new ways to diversify their income sources through farming and sale of charcoal (Vinya et al., 2011).

During this period, the country also experienced serious power shortages as the state-owned Zambia Electricity Supply Company (ZESCO) failed to generate enough power to meet the national demands (International Growth Centre, IGC, 2016). Based on this information, some of the deforestation observed in Luanshya in 2016 (Figure 22) may be attributed to the power shortages. ZESCO failed to generate enough electricity due to the reduced water levels in the Kariba dam caused by low rainfall in 2014 and 2015 thus triggering a power deficit. As a consequence, daily load shedding hours became extended (up to 8 hours in certain parts of the country) and more people went into charcoal burning to sustain their families and supplement their energy needs (IGC, 2016). The situation is also compounded by the heavy reliance on, and failure to diversify the energy sector from hydroelectric power which is already insufficient to counteract the effects of climate change (Tembo et al., 2015; Samboko et al., 2016; Kachapulula-Mudenda et al., 2018). Generally, Zambia has a low electrification rate and, even for the electrified population, households are heavily reliant on charcoal and firewood for cooking and heating due to the unreliability of hydroelectric power for household use and the socio-cultural influence on household energy habits (Tembo et al., 2015; Kachapulula-Mudenda et al., 2018). These factors contribute significantly to land cover change and land degradation.

Figure 22 shows the landscape changes in 2016.

[7] Zambia Central Statistical Office; online portal

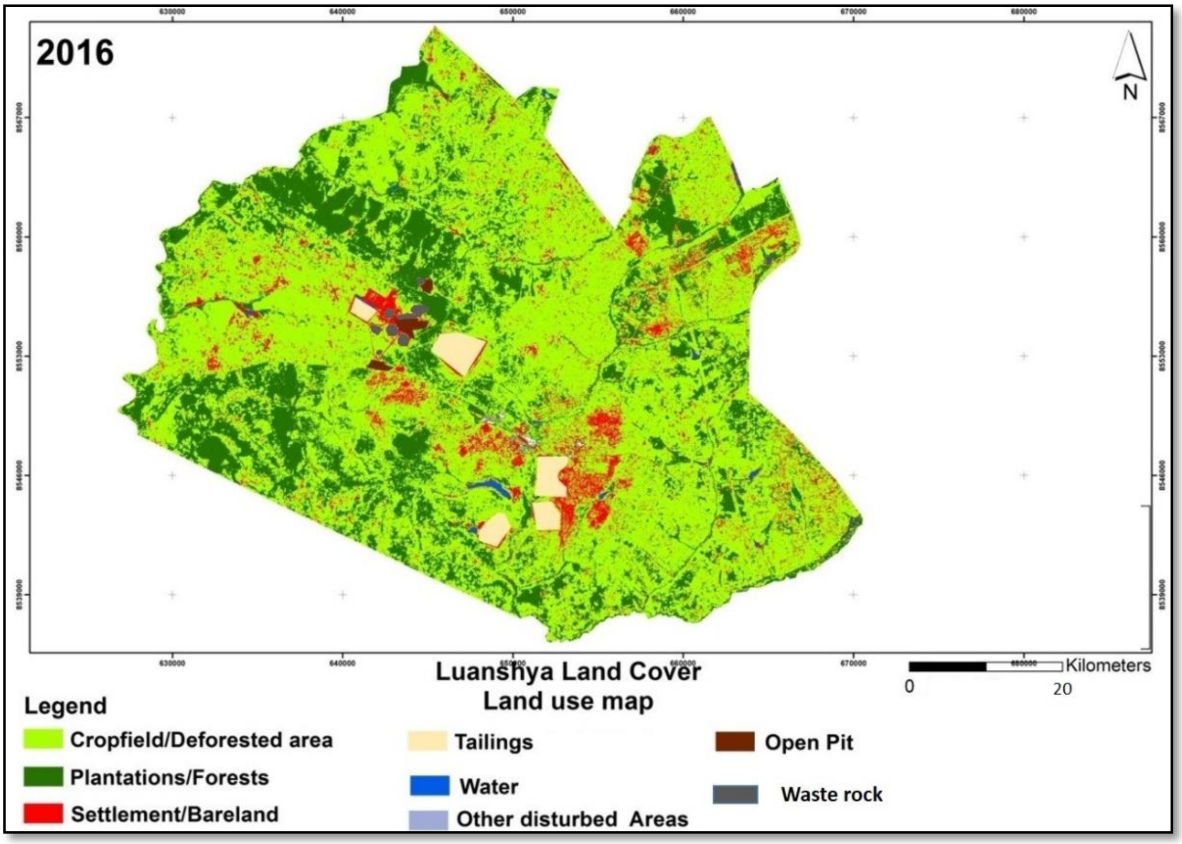

Figure 22: 2016 land cover map. Modified after NASA Goddard Space Flight Centre and U.S. Geological Survey, 2016.

Figure 22 shows that even though the mines were privatized and mining activities peaked, deforestation seems to have worsened as dark green patches continued to decline. There also seems to be fewer settlements scattered around the district as there was some formalization of illegal settlements and control.

4.3 INTERVIEW RESULTS

As already stated in the methodology chapter, this study involved two tasks; land cover and use mapping; and conducting of semi-structured interviews. The interviews were conducted with relevant stakeholders from the Ministry of Agriculture, the Luanshya Municipal Council, the Forestry Department and the Luanshya Copper Mines to obtain more understanding of the mapped landscape changes and the associated land uses. The interviews also set out to develop a better understanding of the approach to land use planning in the district and stakeholder roles in this planning.

4.3.1 MINISTRY OF AGRICULTURE

When asked to confirm how much of the district land is classified as agricultural land, the interview participant from the Ministry stated that previously, almost all of the land in the district was classed as mining land while wilderness or undeveloped land was reserved for mine expansions.

"Only 500 ha were reserved for agricultural purposes and this share of land became increasingly insufficient as the population of the district grew with time. "

As such, the Ministry of Agriculture (MoA) were failing to meet the demand and this led the local people to start illegally farming on idle land previously reserved for mining expansions.

"*People started squatting and farming on idle mine lands and were sometimes forcibly removed from these lands by mine authorities until the government intervened through the Ministry of Lands*. *With the help of the Ministry of Lands, the Ministry of Agriculture had to go to the mining company to request for a larger share of land to be legally allocated for farming purposes. Following government's interventions, 25,500 ha of the land in Luanshya corresponding to 30% is now classified as farming land. Even with this share of land subsistence farmers only get allocated 2 ha each which is not enough for them ".*

The interview participant from the mine also confirmed that cases of community members encroaching on mine lands are very common.

"Yes we have a challenge with people encroaching on mine land, some portions of the mine land have actually been officially given up to the communities for their use."

The patches of deforested areas observed in the maps were attributed to inadequate management as informal takeover of idle lands by the communities makes it hard to monitor and manage land users. Also due to the land restriction for mining, the Ministry has not experienced cases of agricultural land being taken over by the mines.

"Actually, it's the other way round, since Luanshya is primarily a mining district, most of the land in Luanshya was held for mining and now the mine has been giving back some of the land which it does not need to the Ministry for farming purposes."

The process followed in this case requires approval by the council and then by the Ministry of Lands.

"*Since all land in Zambia is vested in the president, we go through the council to the Ministry of Lands with plans which are then approved and land is officially allocated to us*."

In terms of land quality for agricultural production, the interview participant confirmed that soil degradation is also an issue for some farm lands located near the smelters as the sulphur emissions were causing crop failure. The smelter is now closed but some areas in Roan, Mpatamatu and Chibula townships have been impacted by smelter emissions. The other threat to land degradation is created by the small sizes of farm plots allocated to people.

"*We normally encourage farmers to practice crop rotation to help preserve the soil's productivity but the plots are not big enough to allow that. Most farmers cannot even afford fertilizers so they practice shifting cultivation where they move to other areas when their land becomes unproductive."*

In terms of collaboration with the mines to plan for land use, there was acknowledgement that the Ministry of Agriculture collaborates with other stakeholders and contributes to land use planning.

"We are part of a working committee which comprises of the council, the office of the president and Zambia Environmental Management Agency. However, we do not have enough resources to carry out our work properly."

The view on mining as partners in agricultural development was mixed as the land restrictions created by holding most of the district land for mine expansions makes agricultural planning a difficult process.

"I would say yes and no, mining is a partner in agricultural development but too much land was held for it and now we have to keep going to the mine to request for land to be given to us, it's not a good process."

4.3.2 FORESTRY DEPARTMENT

The department is charged with the responsibility of protecting, conserving and managing forest resources in the district. However it was established during the interview with a representative of the district Forestry Department that the Department is not active in regulating the forestry land in the district. This is attributed to the lack of funding as the department depends on the central government for resources and funding which they have not received in over 15 years. Forest areas have changed dramatically but maps have not been updated to reflect the changes.

"*We make plans on paper but we do not carry out field monitoring due to lack of resources. We have lost big portions of forests to the communities and to mining. For example, the Kafubu Botanical Reserve was lost to mining despite it containing special indigenous vegetation species. We simply have no control."*

The situation is made worse by lack of a clear process to follow when forest lands are converted to other uses.

"Usually there is no word, forests are not converted in a transparent manner, especially when mining is involved. Mining is usually given higher priority over forests because it employs a lot of people so decisions are sometimes made without involvement of the Forestry Department. Even other government sectors overlook us sometimes when they feel that we will deter their activities. For example, we have heard of the Ministry of Agriculture issuing fertilizers to farmers who are illegally farming in forest areas."

Plantations are semi-autonomous and therefore not threatened like forests. Table 5 shows the state of the forests in the district.

Table 5: State of forests in Luanshya district. Source, Forestry Department, 2017

Number	Name of forest	Size (ha)	Comment
1	Muva forest reserve	3216	Stocked but more than three quarters of it has been deforested and partly occupied by illegal settlers.
2	Masansa forest reserve	1149	Used to grow exotic plantations of pines and eucalyptus. Semi-autonomous.
3	Kafubu botanical reserve	63	This area was reserved for its natural biodiversity but has been lost to mining.
4	Maposa forest reserve	8 982	Occupied by illegal settlers

There was a strong feeling that the Forestry Department were side-lined and sometimes forest officials are scared to go out and monitor the forests for fear of being victimized. Some of the forests have since been declassified and given to the local people for farming and settlement without the involvement of the Forestry Department.

"*Some people have been issued land in the forests for settlement or farming without consent or knowledge of the Forestry Department. We are just in the shadows and sometimes politicians are involved. They may even pick you and say we have come with these people, they will not do anything to you. So, how can a forester go against the higher powers unless they want to get in trouble? We had the Maposa forest reserve which has been given away in portions to the people without any notice from the state. So, as far as we are concerned, it's still a forest reserve but obviously its functions have changed.*"

4.3.3 MUNICIPAL COUNCIL

The Luanshya district corresponds to the administrative extents of the local government's planning boundaries as initially defined by the Town and Country Planning Act (chapter 283 of the laws of Zambia). This was confirmed by the town planner who also pointed out the Ministry of Agriculture's plans extend beyond the Luanshya district boundaries into other districts. From the interview, it was established that the district has faced difficulties with land use planning since the 1920s when council townships started developing independently of the mining townships (Luanshya Municipal Council, 2017). According to the district profile, the town planning challenges were recognised early and a director of town planning was appointed to try and resolve the challenge. Following this, the first ever unified town plan was prepared in 1928. The development of the mine was accompanied by the development of two main townships; Roan, a municipal township and Luanshya, a mine township. The development of the townships took place between 1931 and 1936 under the administration of the colonial government through the District Commissioner, who was an employee of the British Overseas Military Administration (BOMA). In 1954, Luanshya was elevated to full municipality and the Council was granted the right to appoint a mayor.

Because the development model has been such that mining was given priority over other land uses, the district does not have an integrated land use plan.

"*We do not have an integrated land use plan, different land users all have separate land use plans focusing only on those activities because everyone planned in isolation."*

A lot of land around the mines was reserved for mining purposes and future mine expansions while the rest of the land outside the designated forests was divided into farm blocks which were later developed into townships. The mine townships were developed independently from government townships but the latter was given municipal status in 1954. Mine townships developed in an organised fashion with regular street patterns and the mines provided funds for construction and maintenance of drainages, recreation facilities, domestic waste disposal, and other services to residents. With time, when the mine experienced closures due to economic constraints, all the townships were placed under the administration of the council. Currently, the planning boundaries of the council correspond to the geographical boundaries of the whole district and all the planning is done around the already existing plan left behind by the mining company (Luanshya Municipal Council, 2017). The only exception is the portions of land habited by people who have been re-settled by mining; these are planned for by the resettlement office located in Ndola.

In terms of other stakeholders contributing to the land use planning, the interview participant confirmed that all key government sectors present in the district contributed.

"*The Forestry Department and the Ministry of Agriculture contribute. As you may be aware the mining company also have a role to play since they were the initial land use planners in Luanshya. There is also an NGO called Green Space Initiative which advocates for preservation green spaces though they do not have physical presence in the district. Before the Decentralization Policy was adopted, all the sectors made their plans in isolation, now all the planning authority except those under the mandate of the defence forces has been given to the council. The main exception is people who have been displaced by industrial development, they are planned for by the resettlement office situated in Ndola."*

As it is with the other stakeholders, the council has never lost land meant for its activities to mining; however, there are some problems created by allowing the initial land planning to be controlled by mining.

“It all started with the mines, all the land in the district belonged to the mines. The central business district was developed without consideration for settlement needs. The land in the peripheries of the mining company’s area of interest was divided into farm blocks which were later developed into townships. These were the only areas the council had planning control over. As the demand for settlement areas grew, we had to find dormant areas to allocate people.”

Despite the planning challenges currently faced, there is a general feeling that mining has been a partner in developing the district.

“The mines have done a lot for Luanshya, now it’s up to us to take it further. During government control of the mines, some systems stopped running smoothly, all we need is the political will to do our jobs well. For example, we are ready to charge people for garbage, but when there are uprisings, people tend to get their way. The planning in the past was not done with the proper planning concepts so you will find that some areas are purely residential with no service facilities such as clinics, markets or police posts. Sometimes, due to lack of consultation, some newly built infrastructure has been rejected by the end users because it fails to meet their standards and resources which went into constructing them have gone to waste.“

In terms of legislation, it could not be confirmed whether the legislation was adequate or not as the restructuring process is still on-going. However, it was acknowledged that collaboration among all the relevant stakeholders will be critical.

“*The right tools have been provided to us but it’s up to us to make it work. There are a few gaps in the legislation but we can make it work with the right political will and cooperation with each other.”*

4.4 SUMMARY AND SYNTHESIS

After more than 90 years of episodic commercial copper production, the landscapes in Luanshya district have been significantly altered. The alterations result from both underground and surface mining and also from human activities. Mining has directly impacted 18 % of the district land through vegetation removal, excavations, waste generation and other mine-related uses. Of all the mine uses, tailings impact the largest share of land, covering 1480.7 ha of land with 231.1 million tons of wastes. Underground mine workings also use a large share of land, taking up 900 ha and even though these workings occur below the ground surface, their direct impacts on land are significant as areas above these workings are now sinking, collapsing or caving. These geotechnical challenges impact future land use as there are serious safety issues associated with their rehabilitation.

Open pit operations only cover 52 ha of the land surface, but they are also directly related to a further 355.8 ha of land covered by waste rock dumps. Waste rock dumps amount to 121.6 million tons of solid mine waste and impact the land through their occupation and related dust and emissions into the environment. They also cause aesthetic pollution especially since a greater percentage of the district population live in close proximity to the mine sites. The presence of the mines in the district is also associated with social challenges which impacts the operations of the local authorities in the district. Mapping of the landscapes changes between 1984 and 2016 shows a correlation between mining and landscape alterations which vary based on the level of mining during the different time spans. Mine-induced landscape alterations have also been accompanied by indirect community-related alterations. Evidence of human activity is provided by the continued deforestation and increase in cultivated land or grasslands throughout the 32 year period investigated.

The period of intense mining activities during the 1980s when the mines were nationalised were associated with higher annual population growth of 2.7 % between 1969 and 1980. This slowed down to only 0.9 % in the subsequent periods but the human-induced impacts occur throughout. Periods of low or no mining activity were characterized by higher human-induced impacts on the landscapes. This is because the closure of the mines or scaling down of mine activities were associated with retrenchments and hence created a population of former mine workers and their families who previously depended on mine wages for their livelihoods and now needing alternative means. As such, there are observable increases in deforested areas and bare lands in the district as more people involved themselves in charcoal production, quarrying and agriculture. However, not all the observed deforestation can be connected to mining as the household energy habits (high dependence on charcoal and wood fuel) and the power deficits impacting the whole country also play a role in promoting deforestation.

The stakeholder interviews provided further insights into the mapped landscape alterations and confirm the connection between mining, landscape alterations and community land use. It was also established from the interviews that there is a contribution to the landscape changes resulting from lack of an integrated land use plan and lack of cooperation among key stakeholders. Stakeholders have historically planned for their activities in isolation from each other and as such, each sector planned and conducted their developmental activities without consideration for other land uses. The impacts are worsened by illegal community activities and unlawful land takeovers by the communities. Furthermore, due to the limited land use planning by the mining company, some areas developed without the necessary social facilities to cater for community social, health and educational needs.

Another significant contribution to the observed landscape alterations stems from the lack of empowerment of the Forestry Department which has largely led to uncontrolled deforestation in the district. It was established from the stakeholder interviews that significant portions of forests have been lost to both mining and the communities. The interviews further highlight a general prioritization of mining over other land uses in Luanshya and, because the mines are so centrally located, their impacts are locally significant. Even though the stakeholders recognise mining as a partner in development, there is also a recognised need for better collaboration in the land use planning among stakeholders.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to investigate the impacts of copper mining on land use in Luanshya district of the Copperbelt Province in Zambia. The main objective was to identify the relationship between long-term mining, landscape alterations and community land use. The study was conducted with a view to detecting and comparing changes in the landscapes between different dates to infer increases or decreases in the landscape quality. In order to accomplish this objectives, three research questions were asked and a methodology involving 3 main tasks was employed. The first task involved a desktop study of relevant literature on copper mining and beneficiation processes, mine wastes and their impacts on the environment, the Zambian copper mining industry and mining legislation as well as publications from the Zambian government printers. The second task involved collection of spatial land use data from Google earth, satellite images, and archive search to map the landscape changes that have taken place over a 32 year period from 1984 to 2016 in Luanshya district. The third and final task involved conducting of semi-structured interviews with representatives of key government sectors, namely agriculture, forestry, the local government, as well as the mining company to gain further understanding of the landscape changes and how the changes are connected to mining and other land uses in the district. This chapter consolidates the findings, draws conclusions and makes recommendations for future studies land use options applicable to areas characterised by mine wastes.

5.1 KEY FINDINGS

As already pointed out, this study set out to investigate the relationship between long-term mining, landscape alterations and community land use. In doing so, three research questions were asked and the key findings are presented in this section.

1) What landscape changes have taken place in Luanshya district over the 32 year period between 1984 and 2016?
2) How do these landscape changes relate to mining activities and other land use patterns in the district?
3) What has been the approach to land use planning by the relevant stakeholders in the district?

In order to answer these questions, a land cover mapping process that integrates company records, satellite data and Google Earth images were employed. The images were processed using a combination of manual and supervised classifications in ESRI Arc 10.3 software to generate land cover maps. Further investigations that considered other factors such as stakeholder activities, policy responses and the district's land use planning strategy were conducted. These investigations provide a deeper understanding of the processes causing landscape alterations, and also how these processes were related to mining and other land use patterns in the district. Figure 23 shows the differences in state of the environment in Luanshya district at the start and end of the period under investigation.

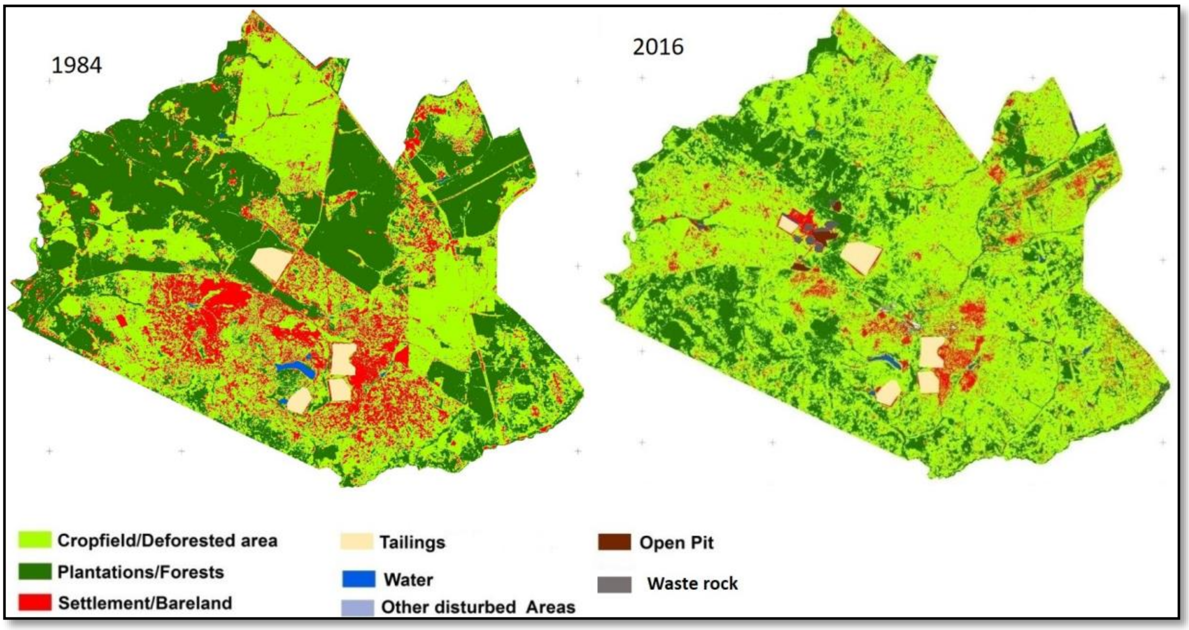

Figure 23: Map comparing the state of the environment in Luanshya district in 1984 and now (2016). Modified after the Luanshya Municipal Council, NASA Goddard Space Flight Centre and U.S. Geological Survey, 2016.

As a result of the landscape mapping, the main changes identified in Luanshya district are the physical alterations to the landscape scenery due to vegetation removal, mine excavations; storage of large volume mine wastes on the land; land subsidence and caving and also deposition of fine tailings material resulting from erosion of old tailings dumps. Additionally, other indirect means of land alteration were identified and these are related to human activities. Unlike mining which takes place in relatively localized areas, human-induced landscape alterations have impacted a larger percentage of the district land. Evidence of this has been shown by the continued deforestation throughout the 32 year period investigated in this study and also from the spreading of settlements and bare lands away from the mine sites. This is consistent with Limpitlaw (1998) who points out that mining is not the only activity causing landscape alterations in Zambian mining districts. Human activities of deforestation, settling and farming also contribute significantly to the landscape alterations in these districts.

The stakeholder interviews also confirm these findings and identify that the landscape alterations have been caused by both mining and community activities. The greatest contribution to deforestation is from community-related activities through timber harvesting, farming, charcoal production and settling.

Community-induced alterations also spread faster than the mine-induced alterations and hence need to be addressed. However, community activities are indirectly related to mining due to the fact the needs of the mine were considered in higher priority at the expense of other land uses and this attracted undesirable community land use practices. Being a mining district, Luanshya was previously outside the planning control of the legislative land planning authorities in accordance with the old Town and Country Planning Act of 1964. As such, mining was the priority land use in this district and the initial land planning was conducted by the mining company. This planning was mainly dictated by the needs of the mining sector and as a result, the district has no integrated land use plan. As a consequence, the district has developed unevenly with destructive community responses whereby idle lands and forests have been illegally taken over by the communities. This has had negative impacts on the forests and is a major contributor to the failure by the Forestry Department to manage the forests in accordance to their mandate. Furthermore, the approach to land use planning in the district has been such that each institution planned for their land use functions in isolation from other institutions without much consideration for other land uses.

However, global factors such as changes in the commodity prices have impacted both the mines and the communities. Additionally, national factors such as high dependence on mining, changes in mine ownership dynamics, ineffective policy responses, power deficits and poverty have also played a role in the observed landscape alterations in Luanshya district. Therefore, the process of landscape changes in Luanshya district is as a result of an interaction of inter-related causes. Notably, the inadequate involvement of the state in the development process of the district has had negative consequences on Luanshya and, as pointed out in background section of the introductory chapter (section 1.1.1), if the mining industry is to contribute to the sustainable development of mining districts, it must aim to meet SDG 11 (sustainable cities and communities) and SDG 15 (sustainable ecosystems). This requires that land use planning and management systems are designed to make cities and human settlements inclusive, safe, resilient and sustainable (UN General Assembly, 2015).

5.2 SYNERGIES AND OVERLAPS WITH EARLIER STUDIES AND INITIATIVES

A follow up on some of the initiatives to reduce the impacts of mining on the Copperbelt mining districts (discussed in section 2.2.3) identifies some overlaps and on-going issues. A sub-project of the Copperbelt Environment Project conducted social-economic consultations in selected townships of the Luanshya district between 2001 and 2011. These consultations were designed to identify issues affecting public health and ecological damage in the district (Masinja et al., 2005). As a result of these consultations, an extensive list of issues and mitigations measures were suggested. However, follow-ups on the suggested actions identified that almost all the actions suggested were either not implemented or did not adequately address the causes of the issues and hence the issues continue. Table 6 highlights some of the identified issues, the proposed actions and the outstanding issues in those actions taken.

Table 6: Social-economic issues, actions taken and outstanding issues

IDENTIFIED ISSSUES	RECOMMENDED ACTION	ACTIONS TAKEN AND OUTSTANDING ISSUES
Loss of mine jobs and emigration of skilled labour	Establish markets for trading and attract new investments to the district	Action partially implemented but lack of individual capacity to cope with changes not addressed.
Increased deforestation	Re-vegetation	No action taken, deforestation still high
Illegal settlements	Legalization and upgrading of illegal settlements	A number of illegal settlements were legalized but the action did not address the full extent of the issue as some settlements still occur in undesignated places
Encroachments on mine lands	Sensitization	Cause of issues (poverty) not addressed, hence the issue is on-going
Air pollution from smelter emissions	Close the smelter	Action implemented
Water pollution and siltation of streams	Dredging of rivers and implement monitoring programmes	Only the Luanshya River was dredged but the cause of the problem was not addressed, i.e. inadequate management of mine and sewer effluents
unprotected openings on the ground surface	Rehabilitation	Some shaft openings were closed but most openings remain open
Food pollution	Sensitization of communities	Action partially implemented and the cause of issue not addressed e.g. community ignorance and inadequate mine waste management
Land subsidence/ sinking	Rehabilitation	No action taken
Flooding and erosion from tailings	Sensitization and provision of alternative land to the communities	Cause of the issue not addressed, i.e. inadequate management of tailings dumps
Dust emissions from old tailings dumps	Vegetation of tailings impoundments	Action only partially implemented
Soil degradation	Liming of polluted soils	No action taken
Diseases (Malaria and HIV/AIDS	Sensitization	Action not implemented

These gaps were not only limited to Luanshya district but to all the mining districts on the Copperbelt Province (Masinja et al, 2005). As a result of these gaps in the actions from the CEP, there is an on-going follow-up Mining Environmental Remediation and Improvement Project (ZMERIP). This projects has been under implementation by the Ministry of Mines and Mineral Development since 2015 but it does not include Luanshya district. The project only covers Kabwe, Chingola, Mufulira and Kitwe (GRZ, 2016).

5.3 CONCLUDING REMARKS

Copper mining has been central to the socio-economic development of Zambia with significant contributions to the national GDP, employment opportunities and other positive benefits. However, mining has also come at a cost to the country as the interests of the mining companies have been given priority over community land use needs. Historically, there has been little protection of the environment to avoid land degradation through deforestation and pollution. Mining and environmental legislation were implemented much later from the time mining started and hence there has also been little protection of local communities. The initial land use planning was left to the mines and vast amounts of land were reserved for mining activities. As a result of this dependency on the mines and inadequate governmental regulation and involvement in land use planning, boom and bust commodity cycles have had a significant and inter-related impact on the well-being of both mining communities and the environment. These impacts are not just in the immediate areas but extend to entire districts. Studies to date have focused on remediation of pollution due to mining activities in the immediate vicinity of mines, but little appears to have been done to restore forests or natural habitats in broader areas which have been affected by mining and related community activities.

This study identifies that the landscape alterations in Luanshya district are as a result of an interaction of different inter-related mechanisms. While mining plays an important role in the local economy, sustainable development requires that environmental legislation and land use policies are tailored to anticipate and address these different mechanisms. This study explores the impacts of mining on land in the former garden district of Luanshya in an attempt to inspire sustainable land use planning of mining districts and future research. This study also identifies an opportunity for mining to make positive contributions to Luanshya district though mine closure planning that considers integration of post-mining landscapes and community land use needs. This may also possibly mitigate the loss of mine jobs and reduce the risk of socio-economic collapse of this mining district and also support the social acceptability of future mining projects by communities in Zambia.

5.4 RECOMMENDATIONS

Ore deposits do not last forever, they ultimately get depleted. Mining should therefore be conducted with consideration for the needs of society during and after mine life. In order to support the sustainability of Luanshya and other mining districts in Zambia, some recommendations have been are proposed.

1) ADDITIONAL INTERVENTIONS

i. Efforts should be made to transform post-mining landscapes and restore degraded land to a state capable of supporting different alternative land uses that natural landscapes are able to provide. Alternative land uses to be considered may include plantations, settlement, agriculture or eco-tourism. Other options such as construction (residential, commercial or educational facilities) and conservation (for wildlife habitats) could be considered.

ii. Given the high dependency of communities on bioenergy and the financial challenges faced by the Forestry Department in monitoring and managing forests effectively, there is need to recognise the availability of reliable (and cheap) remote sensing tools to combine ground initiatives with remote sensing technology for monitoring forests and other land resources. This may also entail an exploration of the potential for bioenergy and strengthening of linkages between the Forestry Department, communities and other government stakeholders such as the Ministry of Energy so as to ensure optimal intervention in the supply, management and use of forests as an option for renewable energy.

iii. While the decentralisation policy has devolved the local planning functions to the council, future land planning must be collaborative and inclusive to allow for greater co-operation of all the different stakeholders including government departments, mining companies, communities and other businesses, while also focusing on post-mining transformation of landscapes and mine infrastructure. These plans also need to take direct and indirect impacts of mining into account and must be dynamic in terms of adapting to the boom and bust cycles of mining, the impact that this has on mining companies, on communities and on land.

iv. The learnings from this study should be used for future land use planning for the new mine districts in the North-Western province where new mining operations are taking place. In line with the National Decentralization Policy, land use plans should be tailor-made where the land use needs of the community are put into consideration. For example, since most mines occur in remote districts where there may be an infrastructure deficit, mine infrastructure should be developed with a view on potential community use after mine closure.

v. Consideration should be made in the on-going follow-up projects under the Mining Environmental Remediation and Improvement Project (ZMERIP) to include the Luanshya district as there are a number of outstanding issues from the previous works (outlined in Table 6).

2) FURTHER STUDIES

i. Future studies should consider undertaking a more detailed review of the available legislation in order identify possible ways of how mining and its impacts may be subjected to land planning regulations.

This kind of study may require some background knowledge in law and hence may be best suited for a student specialising in law studies.

ii. Further studies should include an analysis of the economic benefits derived from the diverse land uses and how to raise awareness among the land users about the value of the everyday cultural, economic and environmental services provided by land resources. Raising awareness about the economic benefits (and costs) may help promote stakeholder buy-in and participation in collaborative land use planning and environmental protection.

iii. Since a great amount of research has already been done on the impacts of mining on the environment in the Zambian Copperbelt, future research should consider why remedial actions that have been proposed as part of the previous studies have not been implemented, or have not been successful.

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Appendix A: Interview Guide

SECTION 1: To the Ministry of Agriculture

1. How much of Luanshya's land is classed as farming land?
2. How much of this farm land falls under;
   a) Commercial farming?
   b) Subsistence farming?
3. Have there been cases where farm lands have been given up to allow for mine developments, expansions or waste dumping?
4. If yes to question 3 above, how much of this land was given up and what process was followed?
5. Was the process followed in 5 considered satisfactory?
6. Does the ministry of agriculture collaborate with the mine and other sector ministries to harmonize plans as it updates plans for agricultural land? Provide details.
7. According to your experiences, does mining influence the ministry's planning and use of land for agriculture? Provide details of your response.
8. Would you say mining is a direct threat to farm lands? Provide details of your response.

SECTION 2: To the Forestry Department

1. How much of the Luanshya district's land is classified as
   a) Forest land?
   b) Plantation land?
2. Is the forestry department active in planning and regulating these lands? Provide details.
3. Have there been cases where parts of forests or plantations been lost to allow for mine developments or other land uses?
4. If you answered yes to question 5, what process is normally followed?

5. Does the Forestry Department collaborate with the mine, the council or other sector ministries in the district to plan for their use of land for forests and plantations? Provide details.
6. From your experiences, do mine activities influence the department's land use plans? Provide details.
7. Would you consider mining to be a partner or a threat to the success of forests and plantations? Provide details of your response.

Section 3: To the Municipal Council (Town Planner)

1. Are the council's planning boundaries the same as the district geographical boundaries?
2. If no to question 1, how are the planning boundaries defined?
3. What land use classes are the council mandated to plan for?
4. Does the mine area fall within the authority of the town planning bureau?
5. If no to question 4, does the council collaborate with the mine to harmonise the land use plans?
6. Have there been cases where land planned for other uses has been given up to allow for mine developments or waste dumping?
7. If yes to question 6, what process was followed?
8. According to your experiences, to what extent would you say mining influences the council's land use plans? Provide details.
9. Is the council always consulted and involved in the process when the mine expands its land usage?
10. Which key legislation guides the town planning process?
11. Would you say the town planning legislation is adequate for the land planning function of the council?
12. If no to question 12, what would you suggest to improve the functionality of the town planning legislation with regard to land use planning?

SECTION 4: To Luanshya Copper Mines Plc.

1. What is the official status of the Luanshya mines?
2. What factors led to the current status of the mines?
3. How much of Luanshya district's land is classified as mine land?
4. How much of this mine land is taken up by;
    a) Mined areas?
    b) Waste rock and overburden dumps?
    c) Tailings facilities?
    d) Slug dumps?
    e) Mine infrastructure?
5. Does the mine consult or collaborate with the town panning department at the council and other government ministries present in the district to plan for the mine's land use? Provide details.
6. Have there ever been complains from other land users about the mines' use of the district land?
7. If yes to question 6, are there procedures in place to deal with such complaints?
8. Are there plans in place to rehabilitate these lands used by mining activities?
9. What are the estimated costs of rehabilitating these lands?
10. Would you say rehabilitation will be adequate to enable these mine lands to be used for other purposes after closure of the mine?

Appendix B: Informed consent form

Impacts of mine mining on land use- a case (study) of Luanshya town, Zambia.

I, the undersigned, confirm that (please tick as appropriate):

1.	I have understood the objectives of the project, as explained by the researcher.	
2.	I am clear about my level of participation in the project.	
3.	I voluntarily agree to participate in the project.	
4.	The procedures regarding confidentiality have been clearly explained to me.	
5.	I agree to the audio recording of this interview.	
6.	I understand that other researchers may have access to this data if they agree to preserve the confidentiality of the data and to the terms specified in this form.	

Participant:

Name: ……………………

Organisation: ……………......

Role: ……………………….

Signature: …………………

Date: ………………………

Researcher:

Name: ………………………

Signature: …………………

Date: ………………………

Appendix C: Ethics Clearance for the semi-structured interviews

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form**before**collecting or analysingdata.The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook**(available from the UCT EBE, Research Ethics website) priorto completing this application form: http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf

APPLICANT'S DETAILS		
Name of principalresearcher, student or external applicant		Kabang'u Sakuwaha
Department		Chemical Engineering
Preferred email address of applicant:		kabangusaku@gmail.com
If a Student	Your Degree: e.g., MSc, PhD, etc.,	MPhil
	Name of Supervisor (if supervised):	Dr Jenny Broadhurst
If this is a researchcontract, indicate the source of funding/sponsorship		N/A
Project Title		Impacts of mining on land use- a case (study) of Luanshya town, Zambia.

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Kabang'u Sakuwaha		**26 Dec 2016**

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Click here to enter text.		15/02/2017 Click here to enter a date.
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduateresearch (Including Honours).	Click here to enter text.		Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	R Behrens Click here to enter text.		18 Jan 18 Click here to enter a date.

Appendix D: Surface openings in the Luanshya Mine area.

Source: Luanshya Copper Mines Plc.

NO.	DESCRIPTION	COMMENTS	SIZE (m^2)	STATUS
1	50 Winze	Good ground - in Footwall	1.5 x 3	Open
2	304 Winze	Caved Area	1.5 x 3	Caved
3	12 Service Shaft	Caved Area	2.0 x 6	Plugged
4	468 Man Way	Main way to 170L (Footwall)	1.5	Open
5	472 Ventilation Raise	Caved Area (# Pillar Raise)	1.5 x 3	Caved
6	474 Ventilation Raise	Caved Area (# Pillar Raise)	1.5 x 3	Caved
7	482 Ventilation Raise	Caved Area	1.5 x 3	Caved
8	486A Ventilation Raise	Caved Area	1.5 x 6	Caved
9	26 Ventilation Shaft	Good ground - in Footwall	5	Open
10	14 Service Shaft	Good ground - in Footwall	4.5 x 4.5	Temporary Seal
11	15 Service Shaft	Hanging wall	4.5 x 4.5	Plugged
12	16 Service Shaft	Good ground	4.5 x 4.5	Open
13	17 Service Shaft	Good ground - in Footwall	4.5	Temporary Seal
14	914 Ventilation Raise	Good ground - in Footwall	4.5 x 4.5	Open
15	20 Ventilation Shaft	Good ground - in Footwall	4.5	Open
16	1100Ventilation Winze	Good ground - in Footwall	4.5	Temporary Seal
17	22A Ventilation Shaft	Good ground - in Footwall	4.5	Open
18	22 Ventilation Shaft	Good ground - in Footwall	4.5	Open
19	18 Service Shaft	Good ground - in Footwall	6.5 x 4.5	Temporary Seal
20	1166 Ventilation Raise	Good ground - in Footwall	1.5 x 3	Open
21	1166A Ventilation Raise	Good ground - in Footwall	1.5 x 3	Open
22	1164 Ventilation Shaft	Good ground - in Footwall	1.5 x 3	Open
23	24 Ventilation Shaft	Good ground - in Footwall	5	Open
24	28 Service Shaft	Good ground - in Footwall	7	Temporary Seal
25	SS48 Ventilation Shaft	Good ground - in Footwall	5.5	Open
26	Muliashi Portal	Good ground - in Footwall	40 x 265	Temporary Seal

27	SS51 Ventilation Shaft	Good ground - in Footwall	3 x 4.5	Temporary Seal
28	Muliashi Service Shaft	Good ground - in Footwall	5	Temporary Seal
29	Beaty shaft	Good ground in footwall	1.5 x 3	Plugged
30	3 Shaft	Good ground in footwall	1.5 x 3	Open
31	92 Winze	Caved area	1.5 x 3	Caved
32	108 Winze	Caved area	1.5 x 3	Caved
33	132 Winze	Caved area	1.5 x 3	Caved
34	136A Winze	Caved area	1.5 x 3	Caved
35	136 Winze	Caved area	1.5 x 3	Caved
36	2 Shaft	Caved area	1.5 x 3	Caved
37	8 Shaft	Caved area	1.5 x 3	Caved
38	83 Winze	Good ground in footwall	1.5 x 3	Open
39	10 Shaft	Caved area	1.5 x 3	Caved
40	9A Shaft	Caved area	1.5 x 3	Caved
41	206 Winze	Caved area	1.5 x 3	Caved
42	206A Winze	Caved area	1.5 x 3	Caved
43	208A Winze	Caved area	1.5 x 3	Caved
44	9 Shaft	Caved area	1.5 x 3	Caved
45	171 Winze	Caved area	1.5 x 3	Caved
46	173A Winze	Caved area	1.5 x 3	Caved
47	175A Winze	Caved area	1.5 x 3	Caved
48	7 Shaft	Caved area	1.5 x 3	Caved
49	177B Winze	Caved area	1.5 x 3	Caved
50	179A Winze	Caved area	1.5 x 3	Caved
51	181A Winze	Caved area	1.5 x 3	Caved
52	203 Winze	Caved area	1.5 x 3	Caved
53	436 Winze	Caved area	1.5 x 3	Caved
54	532 Winze	Caved area	1.5 x 3	Caved
55	576 Winze	Caved area	1.5 x 3	Caved
56	574 Winze	Caved area	1.5 x 3	Caved
57	247 Winze	Caved area	1.5 x 3	Caved
58	349 Winze	Caved area	1.5 x 3	Caved
59	214 Winze	Caved area	1.5 x 3	Caved
60	212 Winze	Caved area	1.5m x 3	Caved

61	216 Winze	Caved area	1.5 x 3	Caved
62	230 Winze	Caved area	1.5 x 3	Caved
63	260 Winze	Caved area	1.5 x 3	Caved
64	1 Shaft	Caved area	1.5 x 3	Caved
65	553 Winze	Caved area	1.5 x 3	Caved
66	620 Winze	Caved area	1.5 x 3	Caved
67	660 Winze	Caved area	1.5 x 3	Caved
68	664 Winze	Caved area	1.5 x 3	Caved
69	714 Winze	Caved area	1.5 x 3	Caved
70	710 Winze	Caved area	1.5 x 3	Caved
71	764 Winze	Caved area	1.5 x 3	Caved
72	780 Winze	Caved area	1.5 x 3	Caved
73	808 Winze	Caved area	1.5 x 3	Caved
74	16A Vent shaft	Caved area	1.5 x 3	Caved
75	818 Winze	Caved area	1.5 x 3	Caved
76	838 Winze	Caved area	1.5 x 3	Caved
77	866 Winze	Caved area	1.5 x 3	Caved
78	868 Winze	Caved area	1.5 x 3	Caved
79	882 Winze	Caved area	1.5 x 3	Caved
80	898 Winze	Caved area	1.5 x 3	Caved
81	924 Winze	Caved area	1.5 x 3	Caved
82	37B Winze	Caved area	1.5 x 3	Caved
83	38A Winze	Caved area	1.5 x 3	Caved
84	1072 Winze	Caved area	1.5 x 3	Caved
85	1098 Winze	Caved area	1.5 x 3	Caved
86	1116 Winze	Caved area	1.5 x 3	Caved
87	1134 Winze	Caved area	1.5 x 3	Caved
88	1196 Winze	Caved area	1.5 x 3	Caved
89	1246 Winze	Subsidence area	1.5 x 3	Open

APPENDIX E: Weathering reactions of sulphide minerals and formation of secondary minerals.

Source: Lottermoser, 2010

Mineral undergoing weathering	Chemical reaction
1. Complete oxidation of Fe-rich sulfides	
Pyrite and marcasite	$FeS_{2(s)} + 15/4\,O_{2(g)} + 7/2\,H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + 2\,SO^{2-}_{4(aq)} + 4\,H^+_{(aq)}$
Pyrrhotite	$Fe_{0.9}S_{(s)} + 2.175\,O_{2(g)} + 2.35\,H_2O_{(l)} \rightarrow 0.9\,Fe(OH)_{3(s)} + SO^{2-}_{4(aq)} + 2\,H^+_{(aq)}$
Chalcopyrite	$CuFeS_{2(s)} + 15/4\,O_{2(g)} + 7/2\,H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + 2\,SO^{2-}_{4(aq)} + Cu^{2+}_{(aq)} + 4\,H^+_{(aq)}$
Bornite	$Cu_3FeS_{4(s)} + 31/4\,O_{2(g)} + 7/2\,H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + 4\,SO^{2-}_{4(aq)} + 3\,Cu^{2+}_{(aq)} + 4\,H^+_{(aq)}$
Arsenopyrite	$FeAsS_{(s)} + 7/2\,O_{2(g)} + 3\,H_2O_{(l)} \rightarrow FeAsO_4 \cdot 2\,H_2O_{(s)} + SO^{2-}_{4(aq)} + 2\,H^+_{(aq)}$
Fe-rich sphalerite	$(Zn,Fe)S_{(s)} + 3\,O_{2(g)} + H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + SO^{2-}_{4(aq)} + Zn^{2+}_{(aq)} + 2\,H^+_{(aq)}$
2. Precipitation of Fe^{3+} and Al^{3+} hydroxides	
Iron hydroxides	$Fe^{3+}_{(aq)} + 3\,H_2O_{(l)} \leftrightarrow Fe(OH)_{3(s)} + 3\,H^+_{(aq)}$
Aluminium hydroxides	$Al^{3+}_{(aq)} + 3\,H_2O_{(l)} \leftrightarrow Al(OH)_{3(s)} + 3\,H^+_{(aq)}$
3. Dissolution of secondary minerals (Fe^{2+}, Mn^2, Fe^{3+}, and Al^{3+} sulfate and hydroxysulfate salts)	
Halotrichite	$FeAl_2(SO_4)_4 \cdot 22\,H_2O_{(s)} + 0.25\,O_{2(g)} \rightarrow Fe(OH)_{3(s)} + 2\,Al(OH)_{3(s)} + 13.5\,H_2O_{(l)} + 4\,SO^{2-}_{4(aq)} + 8\,H^+_{(aq)}$
Römerite	$Fe_3(SO_4)_4 \cdot 14\,H_2O_{(s)} \leftrightarrow 2\,Fe(OH)_{3(s)} + Fe^{2+}_{(aq)} + 8\,H_2O_{(l)} + 4\,SO^{2-}_{4(aq)} + 6\,H^+_{(aq)}$
Coquimbite	$Fe_2(SO_4)_3 \cdot 9\,H_2O_{(s)} \rightarrow 2\,Fe(OH)_{3(s)} + 3\,H_2O_{(l)} + 3\,SO^{2-}_{4(aq)} + 6\,H^+_{(aq)}$
Melanterite	$FeSO_4 \cdot 7\,H_2O_{(s)} + 0.25\,O_2 \rightarrow Fe(OH)_{3(s)} + 4.5\,H_2O_{(l)} + SO^{2-}_{4(aq)} + 2\,H^+_{(aq)}$
Jurbanite	$Al(SO_4)(OH) \cdot 5\,H_2O_{(s)} \rightarrow Al(OH)_{3(s)} + 3\,H_2O_{(l)} + SO^{2-}_{4(aq)} + H^+_{(aq)}$
Jarosite	$KFe_3(SO_4)_2(OH)_{6(s)} + 3\,H_2O_{(l)} \rightarrow K^+_{(aq)} + 3\,Fe(OH)_{3(s)} + 2\,SO^{2-}_{4(aq)} + 3\,H^+_{(aq)}$
Alunite	$KAl_3(SO_4)_2(OH)_{6(s)} + 3\,H_2O_{(l)} \rightarrow K^+_{(aq)} + 3\,Al(OH)_{3(s)} + 2\,SO^{2-}_{4(aq)} + 3\,H^+_{(aq)}$