THE USE OF TREE LAYER TO ASSESS IMPACTS OF COAL MINING ON BIODIVERSITY IN MUKOMAWABANI AREA, MUTALE LOCAL MUNICIPALITY SOUTH AFRICA

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By

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Submitted in fulfilment of the requirements for the degree of Masters of Science.

In the

Department of Botany

University of Venda

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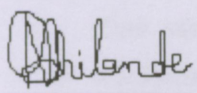
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DECLARATION

I, the undersigned: **TSHILANDE TSHILISANANI (11565269),** declare that this dissertation is my own work, and all the sources I have used or quoted have been indicated and acknowledged by means of complete references. This project work is being submitted for the degree of Master of Science in Botany at the University of Venda, Limpopo Province, South Africa (SA) and the work contained herein is original and has not been submitted at any other University for any degree.



(Signature of candidate)

08 day of July 2015

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DEDICATIONS

THIS MASTERS THESIS IS DEDICATED TO THE FOLLOWING PEOPLE:

- All the descendants of Tshililo Lydia Tshilande
- My late brother Tshilande Mulalo David.
- My kids (Nduvhokhethwa), (Ratshili. Tumiso) and (Zwoluga. Chief).

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LIST OF ABBREVIATIONS

%	Percent
^0C	Degree Celsius
1 Ml	= 1 000 Kl = 1 000 m^3 = 1 000 000 l
Cm	Centimetre
AMD	Acid Mine Drainage
DEA	Department of Environmental Affairs
DME	Department Of Mineral and Energy
DST	Department of Science and Technology
DWA	Department of Water Affairs
E	English
EMP	Environmental management Plan
EMPR	Environmental Management Programme
Ha	Hectare or 10 000 m^2
IEA	International Energy Agency
IUCN	International Union for Conservation of Nature
Ktpm	Kilo tonne per Month
M	Metre
MAD	Mine Acid Drain
Ml	Millilitre
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002)
Mtpa	Million tonnes per annum
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act (No. 107 of 1998)
NGO	Non-governmental organisation
NWA	National Water Act (No. 36 of 1998)
PA	Particulate Matter

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R	Rands
RoM	Run of Mine
SANBI	South African National Biodiversity Institute
SSA	Statistics South Africa
TDS	Total Dissolved Solids
TEK	Traditional Ecological Knowledge
V	Venda
WHO	World Health Organisation

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ABSTRACT

Coal mining results in huge damage to biological communities and landscape. Plant communities get disturbed due to mining activities and following mining the habitat becomes degraded presenting a very rigorous condition for its growth. Nutrient shortages and sandy spoils that results from colonization are a very tardy process. South Africa exploits minerals in billions of tons per year specifically in Mpumalanga, Limpopo and North West provinces. The coal has been heavily extracted since ages in South Africa including in Tshikondeni coal mine. The environment is the greatest victim of these activities, which can be gauged from the depletion of plant diversity and vegetation health status in the surrounding area. As a results many parts of the area within the mining radius have been converted from the original high plant diversity to bare ground with disperse tree distribution, mono-species domination or clumpy vegetation composition and surface fragmentation.

The aim of this study was to determine the important species within the tree layer profile of Mukomawabani plant community. The other aim was to understand the ethnobotanical utilization of tree layer in the presence of mining impacts.

The Point-Centred-Quarter method was used to analyse the tree layer of the immediate surrounding plant community adjacent to a coal mine. Thirty two points were sampled yielding 128 individual plant species since four individuals were recorded at each point. Each point was sampled 50 meters from each other. From the results obtained seven tree species namely; *Colophospermum mopane*, *Commiphora pyracanthoides, Gardenia volkensii Combretum apiculatum, Commiphora mollis, Terminalia prunioides and Grewia flava* were found to be having high relative density, relative cover, relative frequency and high Importance value. Importance determined assist in identifying the species that should be monitored in order to maintain the structure of the tree community.

Ethnobotanical utilization was documented with the use of a questionnaire. Leaves (23%), stem (23%) and roots (22%) dominated the parts utilization categories of preferred plant species. The tree layer of Mukomawabani plant community is composed of species that are very important in the structure of the vegetation and the livelihood of the local communities.

Keywords: Mpumalanga, Limpopo, Point-Centred-Quarter method, Importance value.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

South Africa exploits minerals in billions of tons per year specifically in Mpumalanga, Limpopo and North West provinces. Mining always impact biodiversity negatively and impact economy positively. However in some situation it was found that negative impacts are dominating the industry. No mine is free from environmental impacts however it is the degree or intensity of impact that differs. Suggestion has been made that a study should commence now that will help to inform us on the current and future impacts of the mine (Lloyd, 2002).

Mines are making very notable impacts on the environment and the severity of their sensitiveness depends on the life stage of the mine and its geological condition (Bell *et al.*, 2001). High impact to landscape and biological communities has been noticed (Down and Stock, 1977). Mining disturbs natural plant communities and degrade habitats. The unscientific mining of coal possess a serious threat to the environment which usually results in vegetation cover reduction, high soil erosion, pollution of water, air and biodiversity (UNESCO, 1985). Improper mine waste tilling has been problematic to landscape (Goretti, 1998).

Mining operation comes in the second position after agriculture when ranked according to the importance of their activities. Mining and civilization dates almost the same dates (Khoshoo, 1984). However the fact that mining has been practiced long ago does not make it to be immune to environmental impacts. Furthermore mining is a temporary activity even if it is important for our economy it is necessary that an independent structure should audit its compliance for the benefit of current and future generation.

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In South Africa the majority of mines are established in rural or in less advantaged area hence they boost the local, national and international economy. South Africa currently is the sixth largest coal producer in the world, with total South African production being equivalent to approximately 4% of world production. The demand for coal is expected to increase to just over 5 600 Mtce by 2035, with most of the demand growth before 2020 (IEA, 2010) Coking coal production is likely to only increase by 5% up to 2035, and brown coal production is expected to decline by 20 Mtce by 2035 (IEA, 2010)

Coal demand will always be directly proportional to environmental impacts an increase in production means an increase in environmental impacts so it is necessary that the current impacts should be studied, analyzed to prevent severe damage to livelihood. Indigenous knowledge has been a natural tool for long life survival of both fauna and flora. Sudden change or unexpected environmental changes do endanger human lives. It is therefore important to document indigenous knowledge and nature before establishing any mine as recommended by the department of mineral resources (Wood, 2011) It is necessary again to mitigate environmental impacts during mining period and it is of high value if mining reclamation uses indigenous vegetation as to match human knowledge and their surrounding environment.

Mukomawabani is an area next to Tshikondeni coal mine which is an Exxaro group. The area has been subjected to mining impacts since the mine started to operate in 1985 the impacts have been there for more than 20 years. The mine has closed in 2014 and prior to closure the mine changed its mining method from being an underground mine to an opencast which has double impacted the environment specifically biodiversity further it has opened a huge gap between human indigenous knowledge and their environment. This study aims to document indigenous knowledge in relation to vegetation and its recommendation will assist during mining reclamation processes. This research focuses on environmental impacts of South African coal mine.

1.2 Literature review

Coal is a carbon-rich sedimentary rock formed over millennia from peat, the degraded remains of plant matter. The accumulation of sufficient layers of plant material typically occurred under anaerobic (oxygen-free) conditions that limited the extent of bacterial

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decomposition, a situation provided by static water bodies such as swamps, wetlands and the margins of shallow lakes and glacial valleys. Sufficient geological and climatic stability was required for substantial accumulation of material to occur, aided by steady subsidence of the site to allow further plant growth and accumulation of submerged material (Baruya *et al.*, 2003).

In South Africa coal has been formed during Paleozoic times, collision of crustal plates caused an area of the Gondwana supercontinent to steadily subside. This created the Karoo Basin, where peat swamps developed on the margins of glaciated valleys and lakes (Baruya *et al.*, 2003). The coal deposits were subsequently affected by igneous intrusions associated with the uplift of the Drakensberg (Schmidt, undated), providing the heat and pressure to improve the coal rank in South Africa and the tendency for rank to increase from the southwest to the northeast (Baruya *et al.*, 2003), with anthracite deposits occurring in eastern Mpumalanga and KwaZulu-Natal (Council for Geoscience, 2010).

The known coal deposits of Southern Africa are hosted in the Phanerozoic sedimentary rocks of the Karoo Super group specifically formed during two periods, the Early Permian and Late Permian. The Karoo Super Group is divided into the Dwyka, Ecca, Beaufort and Drakensberg Groups, with the Molteno, Elliot, and Clarens Formations occurring between the Beaufort and Drakensberg Groups.

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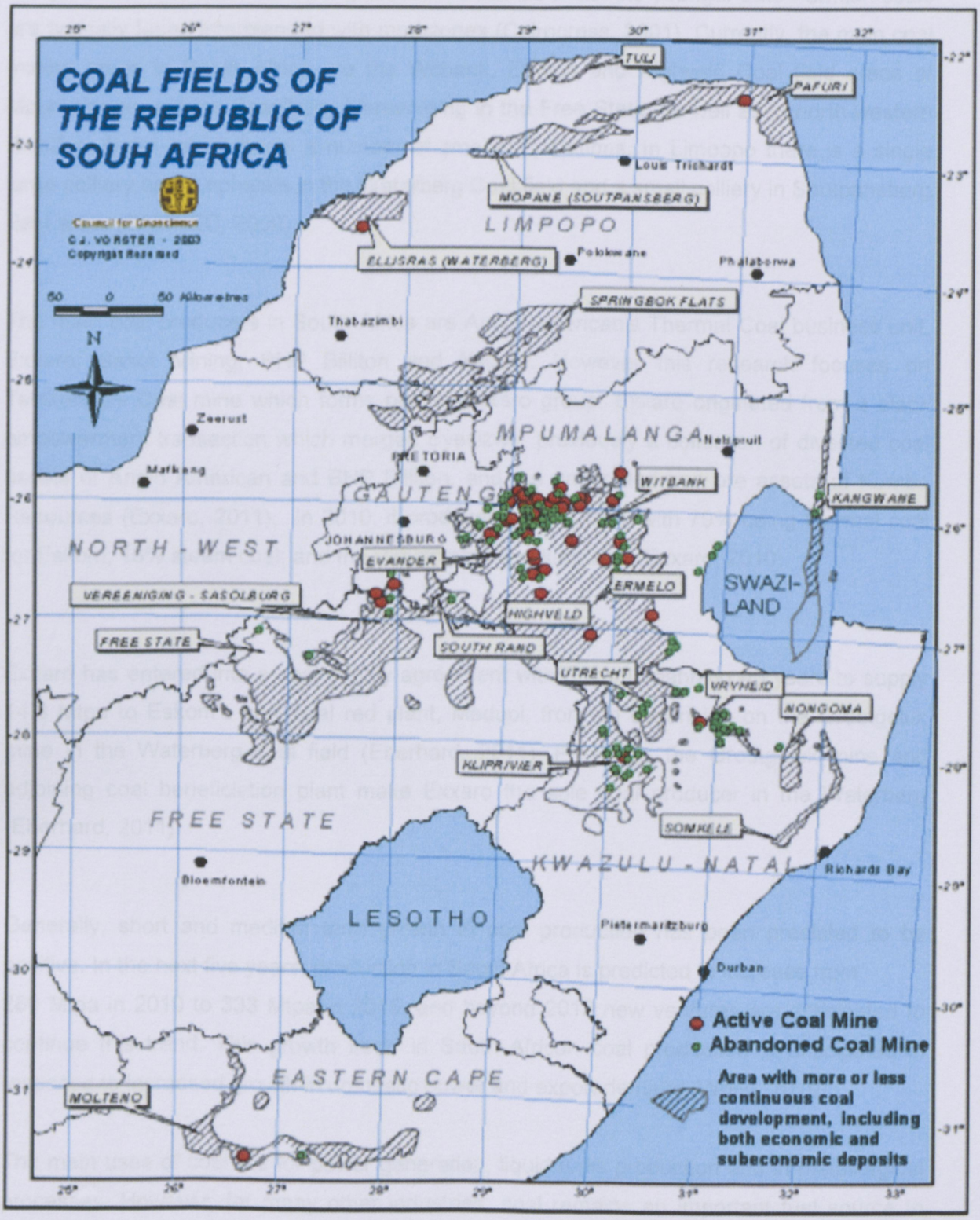


Figure 1.1: Map representing Coal fields of the republic of South Africa (Council for Geoscience 2010).

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Early Permian coals are commonly sandstone hosted whilst the younger Late Permian coals are typically found interblended with mudstones (Cairncross, 2001). Currently, the main coal mining areas in South Africa are the Witbank, Ermelo and Highveld Coal field areas of Mpumalanga, around Sasolburg, Vereeniging in the Free State, as well as in north-western KwaZulu Natal, which hosts a number of smaller operations. In Limpopo there is a single large colliery near Lephalale in the Waterberg Coal field and a small colliery in Soutpansberg East area. (SAMREC, 2009)

The main coal producers in South Africa are Anglo American's Thermal Coal business unit, Exxaro, Sasol Mining, BHP Billiton and Xstrata. However this research focuses on Tshikondeni Coal mine which forms part of Exxaro group. Exxaro originated from a black empowerment transaction which merged Eyesizwe, previously a collection of divested coal assets of Anglo American and BHP Billiton, and the unbundled iron ore assets of Kumba Resources (Exxaro, 2011). In 2010, it produced 46.7Mt coal, with 79% being thermal coal for Eskom; 16% steam coal; and the remaining 5% coking coal (Exxaro, 2010).

Exxaro has entered into a coal supply agreement with Eskom spanning 40 years to supply 14.6 Mtpa to Eskom's new coal red plant, Medupi, from an expansion on the Grootgeluk mine in the Waterberg coal field (Eberhard, 2011). Presently, the Grootgeluk mine and adjoining coal beneficiation plant make Exxaro the sole coal producer in the Waterberg (Eberhard, 2011).

Generally, short and medium term growth in coal production has been predicted to be positive. In the next five years, production in South Africa is predicted to increase from 260 Mtpa in 2010 to 333 Mtpa in 2015, and beyond 2019 new ventures are anticipated to continue this trend. This growth trend in South African coal production is anticipated in response to increased growth in domestic power and export demand (Wood, 2010).

The main uses of coal are for power generation, liquid fuels production and in metallurgical processes. However, for many other industries, coal remains an important fuel source to generate steam to provide heat and power. This is particularly the case in Gauteng and KwaZulu-Natal, where coal is relatively cheap and readily available. While coal consumption varies according to the nature and size of the industry or end-user, collectively, these other users are significant consumers of coal. Coal burning appliances used by low income households are characterized by inefficient combustion which leads to high emission rates of

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particulate matter, volatile hydrocarbons, carbon monoxide and sulphur-containing gases (H2S and SO2) (Pemberton-Pigott *et al.*, 2009).

It has been estimated that 65% of ambient pollution in Gauteng (Scorgie *et al.*, 2003) and 48% of quantifiable particulate emissions in the Johannesburg region are a result of residential coal use. Further environmental impacts include those associated with the disposal of ash. If not collected by ash collectors, ash may be disposed of in local streams or dumped on vacant land, thus resulting in the generation of leachate and subsequent pollution of land and water bodies. Local air pollution in these areas may be exacerbated by the mobilization of fine ash particles by wind (Mathee, 2004).

The likelihood of fires and burns resulting in damage or loss of property and life is increased when fires are brought indoors (Wenzel, 2006). Poor ventilation within dwellings of low income communities implies that these emissions are slow moving and affect the air quality and health of the inhabitants (von Blottnitz *et al.*, 2009). Respiratory infections resulting from exposure to indoor air pollution results in the deaths of around 2,000 children annually (Scorgie *et al.*, 2003), and the cost to treat illnesses related to air pollution amount to R 1.2 billion per annum (Bentley West and Airshed Planning Professionals, 2004).

As noted in the introduction to this section, coal mining can lead to significant environmental impacts, if not properly managed or planned for. In opencast mining, disruption of the surface is unavoidable and can adversely affect the soil, surface and groundwater and impact on the life-support function, biodiversity and subsequent land use of the local environment. Water coming into contact with overburden, open pits or exposed coal seams, may lead to the formation of acid mine drainage and surface groundwater contamination.(Ashton *et al.*, 2001)

In addition, surface mining is associated with noise, visual intrusion and dust and gas emissions. Underground mining typically involves less surface disruption, although subsidence may cause considerable land use impacts. The potential for water contamination also exists, with large volumes of groundwater pumped to the surface for the safe continuation of mining. Although appreciable volumes of pumped water may be used, the amount of water that needs to be managed and possibly treated is increased (Ashton *et al.*, 2001).

Groundwater contamination may occur when pumping stops and the aquifer is allowed to return to its normal level. Alternatively, water may be stored in underground, previously

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mined, compartments, which minimizes the risk of contamination. Subsidence may also allow air and water to enter mine workings elevating the potential for acid mine drainage formation and underground fires (Lloyd, 2002a; Miranda *et al.*, 2003).

Mining activities can increase noise above ambient environmental levels (GDACE, 2008), which can cause a disturbance to local communities and fauna. Mitigation measures to reduce noise pollution can include equipment selection, insulation, sound enclosures around machinery, as well as the installation of noise and vibration monitoring equipment (World Coal Institute, 2005).

Coal mining can have a significant impact on both surface and ground waters if not properly managed as a result of the following (1) Water consumption during mining, (2) Disruption of hydrological pathways and dewatering of active underground and opencast mining operations which result in groundwater drawdown in surrounding areas. (3) Seepage of contaminated water from overburden deposits and coal processing wastes into groundwater aquifers, Flooding of closed mine voids. (4)Possible discharge of untreated mine water into rivers, although this is regulated and strictly controlled (Oelofse, 2008).

The impact of coal mining on water quality is considered to be the coal mining industry's most significant environmental impact (McCarthy and Pretorius, 2009; Reddick, 2006). The location of South African coalfields in the sensitive upper reaches of major river systems such as the Vaal, Olifants, Usutu, Komati, Pongola and Tugela rivers is linked directly to pollution and environmental impacts related to water. It should be noted that mining is only partially responsible for acidification and increased salinization in these river systems (Oelofse, 2008).

The most significant problem facing the coal mining and coal processing sector is the formation and control of acid mine drainage (AMD). AMD is the acidic leachate (often as low as pH 2) displaying elevated iron, manganese, aluminium, sulphate and trace metal concentrations that occurs as a result of pyrite oxidation (Evangelou and Zhang, 1995). AMD affects soil layers and unsterilized acid cause harm on fauna (Hobbs *et al.*, 2008; McCarthy and Pretorius, 2009).

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AMD is one of the most common environmental issues facing the mining industry due to its significant potential for long term environmental degradation. Once it begins in mining wastes or stockpiles it may persist for tens to hundreds of years and can be difficult and costly to remediate. As such, AMD potentially represents the most serious environmental impact caused by mining, and also the industry's greatest environmentally related technical challenge (Mitchell, 1999).

Acid Mine Drainage apart from being the most potential significant immediate threat to South Africa's environment, has the potential to impact significantly on a number of economic sectors like agriculture (grain farming, stock farming, mushroom farming, food processing, etc.) and tourism (Chamber of Mines, 2009; Naidoo, 2009; Wait, 2010). AMD also carries significant health risk to communities that come into contact with contaminated water, soil or crops. It is also likely to have an impact on the coal mining industry in the form of higher costs to prevent or address the problem, or potentially as an additional externality cost (Naidoo, 2009).

Coal mine was found to be playing a role in climate change which have already been observed in South and Southern Africa (Midgley *et al.*, 2007; DST, 2010). Air temperatures over the past thirty years have increased and higher maximum temperatures have been recorded for the western and southern half of the country, and the north-west region. There are fewer frost days, particularly on the inland plateau. No strong trends have been detected in the amount of rainfall over the century. There is, however, some evidence of drying in the north-west, and wetting in the north-east since the 1950s.

Significant increases in the intensity of extreme rainfall events have been identified over more than two thirds of the country. The extent of climate change impacts going into the future cannot be stated with certainty, due to uncertainties in the degree by which emissions will continue to grow, and those around the potential feedback mechanisms associated with climate change certain effects may cause a reinforcement of other effects. To account for the uncertainty surrounding climate change, scenario analysis is used to map out the full extent of possible impacts (Boko *et al.*, 2007; Midgley *et al.*, 2007).

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Ecosystem disturbance is a problem that most of the time leads to extinction of some plant species and usually it is human induced (Coblentz, 1990) and most of the time these problem can be due to adverse or inappropriate resource use, which include poor land use and over exploitation of non-renewable and renewable resources. It can also be due to the pollution which includes all of the chemicals, nutrients and radioactive forms of pollution of air, water and soil (Macdonald, 1992). Ecosystem disturbance can be referred to any process that alters the birth and death rate of individual's percent in the patch by directly killing individuals or by affecting resource level, natural enemies or competitors in ways that alters survival (Hobbs, 1990).

There are two kinds of disturbance namely endogenous and exogenous disturbance but plants do respond differently to the two events usually native plants develop mechanism to survive environmental changes that are familiar to a certain area such as periodic flooding, cyclonic damage, wild fire, herbivore eruption and storms (Hobbs, 1992) fortunately natural communities have evolved mechanism to survive such disturbances in the form of individual species adaptations which culminate in the re-establishment of the pre-disturbance community (Fox and Fox, 1986).

But our main concern is exogenous disturbance because it is human-induced, though it may be produced by the alteration of the endogenous disturbance such as altered fires regime, flood control or drainage. Sometime may be a novel of event such as the removal of top soil, addition of fertilizers or the removal of native animals (Fox and Fox, 1986).According to Hobbs (1991), disturbance is further defined as a change in ecosystem structure caused by an external factor.

Ecosystem disturbance may be defined as a series of event that alters organism's relationship and their habitat in space and time were as ecosystem disturbance by mining is an evitable fall out of industrialization and modern civilization with high demand in fuel and energy in the world coal will always stay in high demand. Coal mines cause enormous damage to both fauna and flora, hydrological relation and soil biological systems. Site clearance during the preparation of mining and continuous trampling of soil and vegetation during mining progress results in loss of system (Relles *et al.*, 2002).

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Coal mine spoils freshly tipped has a great range of particle size ranging from large pieced of shale to silt and clay (Molyneur, 1963). These mine spoils represent or results in an extreme rigid substratum for plant growth and development colonization, establishment and maintenance of ecosystem on these spoils are highly difficult. There are several factors contributing to vegetation establishment and amongst them is acid that is caused by oxidation of iron pyrites (Chadwick, 1973). Acid continuation may results in die back of well-established vegetation (Costigan *et al.*, 1981). The other limiting factor is temperature and moisture stresses (Richardson, 1975).

Loss of soil fertility is a major factor controlling plants growth. There are other two limiting factors that limits plant establishment in mine spoils namely Nitrogen and Phosphorus (William, 1975). Soil physico-chemical characteristic like pH, Electric conductivity, soluble Ca, Mg, Na, B, caution exchange capacity, exchangeable caution, gypsum and calcium carbonate equivalents as being crucial to the prediction of plant growth potential of mine overburdens with water holding capacity and filtration rates as the other important variables (Bradshaw *et al.*,1975). Higher temperature and low moisture of surface coal mine spoils to be the important factors limiting plant growth (Bell and Ungar 1981).

Colonization of plant species on coal mine spoils is influenced by the particle size of the soil derived from the overburden and coal mine wastes (Richardson *et al.*, 1971). High clay content leads to water logged and high silt content the soil becomes compact forming crust which often restricts seedling growth, water entry and air into the soil system. pH is a major determinant in controlling plant growth in poor nutrient containing soil such as mine spoils. The average pH value of 3.5 indicates an acute acidity of the soil (Johnson and Bradshaw 1977).

Natural succession on coal mine spoils is often slow due to surface mining altering physico-chemical properties. These spoils present a special habitat where conditions are extremely unfavourable for plant growth and establishment (Kiranmay, 2005). The ecology of mined lands has been the subject of extensive study all over the world (Bradshaw *et al.*, 1986). Mining of coal causes massive damage to landscape and biological communities. The natural plant communities are disturbed by mining activities because the mining environment

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alters the climatic and edaphic complexes of the plant communities leading to a drastic reduction in the plant growth (Down and Stocks 1977).

The crude stone implements of early Paleolithic period the Egyptian pyramids, Iron and copper smelting in various civilizations and modern steel- age are testimony of mining activities of man (Sarma, 2002). Coal was known for burning and believed to produce supernatural power it was well known to Chinese before Christian era and the Greeks knew about it in the 4th century AD (Sharan *et al.,* 1994).

In England it was used as domestic fuel in the 9th century. Invention of steam engine in England and consequent industrial revolution in the 18th century brought a great input in Coal mining. The demand for Coal mining has started to increase with Coke production and when Bituminous Coal started to replace Charcoal in Iron ore smelting industries (Brown *et al*, 1975). Today coal is used in Electricity production and in heavy industries such as Iron and Steel industries (Raven *et al.*, 1993) Chemicals from Coal mines, overburden and tailing also contain high concentration of metals like Cu, Cd, fe, Hg and Zn. (Lottermoser, 2010).

South Africa produces in excess of 251 million tons of coal (Department of Mineral Resources, 2009) making it the seventh largest coal producing country in the world. Some 25% of coal production is exported internationally, making South Africa the fifth largest coal exporting country. The remainder of South Africa's coal production feeds the various local industries, including Electricity generation. The key role played by South African proven Coal reserves in the Economy is illustrated by the fact that Eskom is the 7th largest Electricity generator in the world.

The large-scale exploitation of Coal mines could help promote the development of the national Economy. However, this leads to changes in Land surfaces and in the generation of waste areas that negatively impact the environment. Coal mine waste areas require large amounts of land and pollute the atmosphere and ground water. Biodiversity in such areas decreases and the interaction between people and the environment becomes unsustainable (Bisanda, 2003).

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Air pollution caused by mining has been described in Twerefou (2009). Dust particles act as catalysts for many chemical reactions that take place in the atmosphere. Mine emissions also contaminate ground water. Mine gangue typically contains high amounts of alkali, metals, alkaline-earth metals, sulphides, and other constituents that lead to inorganic salt pollution of ground water (Liu *et al.*, 2008).

Land reclamation has been proposed as a means to restore the geomorphology and the vegetation of an ecosystem. Such efforts increase the amount of Grasslands, mixed Woodlands, Wetlands, and arable land. Accurate evaluation and monitoring of the distribution of vegetation is necessary in reclaimed sites and is central to coordinated planning of the revegetation of waste land. Coal mining has a deleterious impact on Biodiversity and impairs the production and delivery of Ecosystem services (Taylor and Kruger 1986).

Old discard dumps in South Africa are one of the greatest polluters of the environment, polluting the atmosphere, rivers, ground water and the aesthetics of the country side. Due to their elevated pyrite content, these facilities are potential causes of acid mine drainage, especially when they are inappropriately located too close to water systems. Discard dumps are also high-risk areas for spontaneous combustion, and associated emission of harmful gaseous pollutants. Furthermore, coal fines that are stockpiled can be blown into the atmosphere, thereby contributing to poor air quality (DMR, 2010).

The fine airborne matter can be carried off-site and therefore poses potential health risks to exposed local communities, and could contaminate surrounding ecosystems. Apart from degradation of the local environment, these waste facilities also represent a loss in valuable water resources through seepage and evaporation. Significant dissipative Water losses occur as a result of the high levels of water entrained in the ultra-fine slurry, as well as the subsequent use of water for dust suppression (DMR, 2010).

The respiratory problem caused by the exposure to coal dust (technically a mixture of coal dust and silica) that is currently receiving the most focus is silicosis (Chamber of Mines, 2007; Du Toit, 2010). Silicosis is an incurable respiratory disease caused by inhaling dust

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containing crystalline silica. The disease typically takes many years to develop, although intense exposure can cause acute cases (Du Toit, 2010).

Coal mines produces methane which accounts ten percent of potent green-house gas created from human activities. Methane has a global warming potential of 21 times greater than that of carbon dioxide over 100 years a threat to biodiversity. Methane is a naturally occurring product of the decayed organic matter as coal deposit are formed with an increase in depth of burial which leads to an increase in temperature and pressure over geological time (Lloyd 2002).

Methane is not the only toxic gases produced by coal mine there are some gases like arsenic, lead, mercury, nickel, vanadium, beryllium, cadmium, barium, chromium, copper, molybdenum, zinc and radium and all of these gases are dangerous if released to the environment and are common in coal mine waste(Lloyd, 2002).

Coal mine waste need to be covered or protected from light and rainfall exposure since an exposure to rainfall may results in the formation of sulphuric acid or exposure to light may results in fire and both impose a threat to biodiversity, soil and water quality. Mining activities alters landscape and that results in reduction of environmental natural values. Usually where there is mine residents are moved agricultural activities, hunting, food gathering and medicinal plants are interrupted (Taylor and Kruger 1986)

Mercury emission from coal burning are concentrated as they work their way up the food chain and are converted into methyl mercury, a toxic compound which harms both wildlife and people who consume freshwater fish (McBride,1977). Coal mining eliminates vegetation and destroys soil genetic profile and destroys wildlife habitat (Pienaar, 1963). Hence the absence of certain wildlife species can results in extinction of certain plants species. Generally mining changes the topography of an area, paleontological, cultural and other historic values are destroyed by blasting and excavating of coal.

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Dust, vibration, diesel exhaust odours, sound and smell degrades air quality in the immediate area and has an adverse impact on vegetative life mainly the waste land becomes infertile. Soil disturbance and associated compaction results in condition conducive to erosion and these leads to loss of biodiversity and productivity for agriculture and indigenous plants. Mine collapse has enough potential to affect above ground which is common in coal mines (McBride *et al.,* 1963).

Coal mines affects both fauna and flora, mobile wildlife species like game animals, birds and predators leave these areas. More invertebrates, reptiles and burrowing rodents and small mammals may be destroyed. The community of microorganism and nutrient-cycling processes are upset by movement, storage and redistribution of soil which leads to negative impacts to vegetation and since many wildlife species depends on vegetation for food and habitat either nesting or hiding from predators so, coal mine destroys vegetation and wetlands, water quality and air quality. Hence mine dumps are not inhabitable by both fauna and flora (Pienaar, 1963).

Historically, once mining operations had ceased, waste sites were simply abandoned. In light of the recognition of the severity of long-term impacts, increased legal and financial liability has shifted to operators. This has brought about the development of decommissioning, closure and rehabilitation strategies, (which may lead to subsidence) and large solid waste deposit facilities. As there is little "flexibility over the location of mineral deposits, the land required for mining can coincide with prime agricultural land (as is the case in areas of Mpumalanga). Thus, mining unavoidably competes with other alternative land uses (MMSD, 2002) and can often result in an irreversible change in land quality which now form an integral part of any waste management plan (ICMM, 2008; Stacey *et al*., 2010).

The objective of these strategies has been extended from an assurance of ecological sustainability to an assurance of environmental security for the next 1000 years (Brown and Lowson, 1999). The socioeconomic objectives of mine closure that cover health, safety, social, environmental, legal, governance and human resource considerations are described fully in Stacey *et al*. (2010). It is generally agreed that strategies for decommissioning and closure should be incorporated into the planning and design phase of process development (Stacey *et al*., 2010; ICMM, 2008; Farrell, 1998).

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Unfortunately, it is not always possible to develop the most effective strategies during planning and design as not all the variables and complexities are quantifiable at this stage. In fact, it is rare for major operational changes not to be made during the life of a mine (Farrell, 1998). Thus, an effective strategy for decommissioning and closure should be revisited and refined at regular intervals during the mine life cycle and it is termed continuous closure planning.

1.3 Rationale of the study

South Africa exploits minerals in billions of tons per year specifically in Mpumalanga, Limpopo and North West provinces. It seems to be obvious that all mines have an impact on their surroundings and very little is known on those impacts specifically in these region. Majority has focused on the economic impacts of these mines. Mine is a short term enemy of vegetation structure and sometimes it may lead to extinction of certain plant species or either promotes distribution of certain plant species. In this study it is important to trace impacts of mine on vegetation with an idea that mine can modify soil structure by disposing toxic chemicals on the ground which affect the understory plant communities allowing more light and heat to strike the ground surface which may lead to high moisture loss. Other modification may results from production of smoke which may chase away some potential pollinators and this will results in low plant production hence reducing some certain plant species distribution. Other disturbance may be from ground vibration which may discourage burrowers' insects that help to pollinate some plant species (GDACE 2008).

Furthermore mine do develop heat island which modifies local climate hence favoring certain plant species with high tolerance range. Lastly mine do scrap upper soil, fell some plants which in conclusion one can say mine do expose vegetation to multi disturbance. By multi disturbing the ecosystem you are more likely to reshape the plant community or plant distribution and mine were found to be an agent that exposes the ecosystem to multi disturbance (GDACE 2008). In this study all human induced disturbance were traced on vegetation with a general believe that any disturbance do left a trace. In short tree species distribution depends on temperature, light, soil structure, moisture, oxygen, pH, predation, competition and habitat and all listed above has been altered by mining operation. Commercial fire wood fetching, tree falling habitat fragmentation, over harvesting of trees for timber are all human induced disturbances that are facing vegetation adjacent to Mukomawabani. And this study has been done extensively to get to the root course in order

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to mitigate negative vegetation impacts and in order to help restore or reclaim where it is possible and to educate general public, motivate them and to involve them in vegetation management.

1.4 Aim and objectives of the study.

The aim of this study is to assess impacts of coal mining on the tree layer profile of Mukomawabani area in relation to its utilization by the community. To achieve the aim the following objectives were looked at:

1. To document tree species found near Tshikondeni coal mine.
2. To analyse the importance value of dominant tree species.
3. To see if mine impacts promotes invasion.
4. To assess the perception of the community on the impact of coal mining.
5. To document local uses of the recorded tree layer species.

1.5 Hypothesis

The hypothesis is that mining activities impacts negatively on subsistence utilization of resources within biodiversity of immediate surrounding areas.

1.6 Research outcomes

1. The results will be useful in decision-making processes regarding revegetation.
2. The project will serve as reference during mine rehabilitation and restoration program.
3. The research will help in documenting medicinal plant and indigenous knowledge related to documented plants.

   The research will check if indeed disturbance leads to invasion by documenting invasive species and native species.
4. The project will highlight and recommend plants that are threatened by coal mining.

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1.7 Structure of the dissertation

The dissertation is written in the format of free standing chapters and as such repetitions of certain concepts will be unavoidable. The dissertation consist of five chapters wherein Chapter 1 is the general introduction of the dissertation, followed by Chapter 2 which is about the study area, Chapter 3 being Vegetation Analysis, while Chapter 4 is about Ethnobotanical utilization of tree species and the subsequent perception by the impacts of coal mining and Chapter 5 being the general conclusion and recommendations of the whole project.

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STUDY AREA, MATERIALS AND METHODS

2.1 Study area

2.1.1 Locality

The study was conducted at Mukomawabani village. Mukomawabani is a small village found in Southern Africa (S.A) in the province of Limpopo, a province named after Limpopo river. The province is situated in the northern part of S.A. Mukomawabani is found in Vhembe District Municipality under Mutale local municipality. A local municipality that belongs to Category B in terms of Local Government structure Act (Act No 117 of 1998). Mutale municipality accounts for seven percent of the entire Vhembe District population and it is the second lowest recorded municipality in the district followed by Musina (SSA 2011).

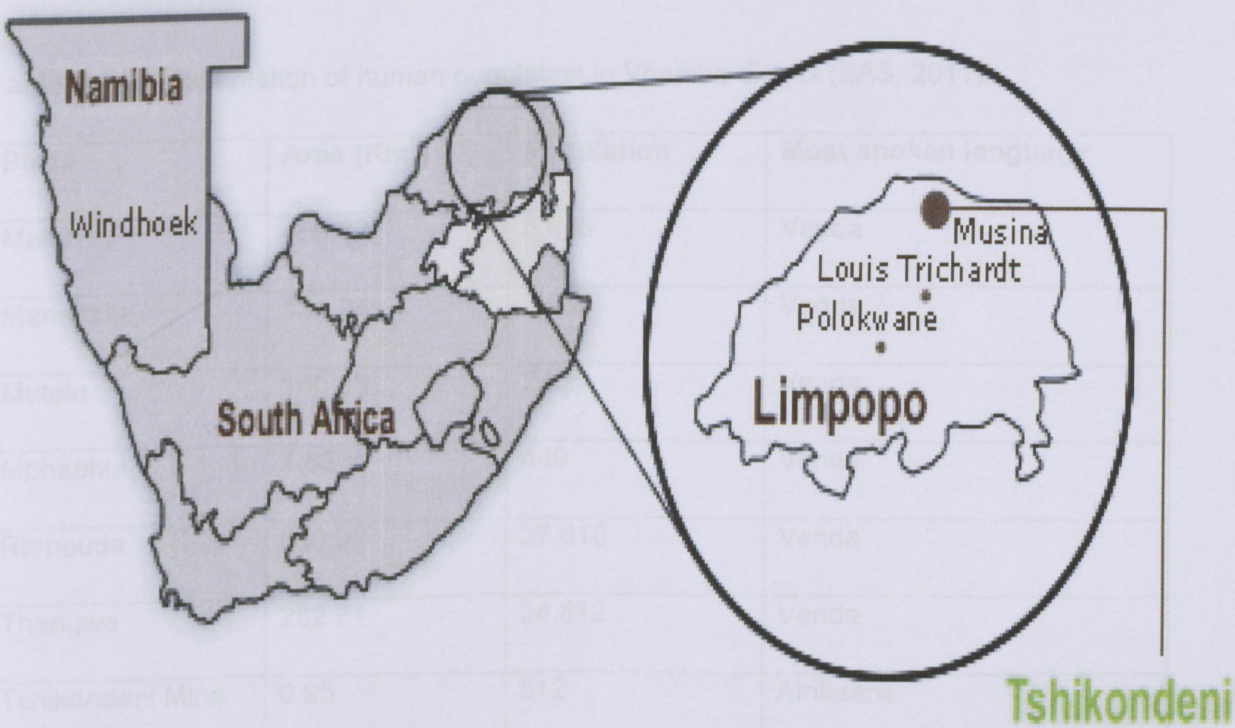


Figure 2.1: Map representing Tshikondeni coal mine (Exxaro.com); accessed November 2014.

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Mukomawabani is the nearest village to Tshikondeni coal mine which is the part of Exxaro group, South African largest coal producer with a well-balanced portfolio. Tshikondeni coal mine belongs to Mutale local municipality and the closest township to it is Masisi which is located some 140km east of Musina (formerly Messina) and 15km south of the Zimbabwe border. It is located between A.22°28'54'11"S and 30°54'46'72"E, B.22°28'43'33"S and 30°54'23'05"E, C. 22°28'44'50"S 30°54'00'05"E and D. 22°28'59'64"S 30°53'15'24"E, and E. 22°29'15'89"S, 30°53'40'87"E, the site is accessed via a tarred road, the R525 some 100km east of Tshipise (Taylor and Kruger 1986).

2.1.2 Demographical information

Mutale municipality has a total population of 91870 (census 2011). By 2011 it was found to have a growth rate of 1.033%. It has 13 wards and covers a total area of 3,886km^2 and has a density of 24/km^2 it has a racial makeup of 99.3% Black African, 0.1% Coloured, 0.1% Indian/Asians and 0.5% White (census 2011) 96.8% of the population uses Venda as their first language and 3.2% are others.

Table 2.1 Representation of human population in Vhembe district (SAS, 2011).

Place	Area (Km^2)	Population	Most spoken language
Makuya	469.38	5,948	Venda
Manenzhe	124.94	3,902	Venda
Mutele	140.96	2,229	Venda
Mphaphuli	1.83	449	Venda
Rambuda	600.92	27.610	Venda
Thengwe	282.71	24.812	Venda
Tshikondeni Mine	0.95	512	Afrikaans
Tshikundamalema	667.80	13.471	Venda

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38.2% of Vhembe District population are young people between the age of (0-14) and working age between 15 and 64 accounts to 55.6% of the population. Furthermore people over 65 accounts to 6.2% and 79.9% was found to be dependency ratio. There was a huge different in sex ratios with 82.6% of the population being females. The population growth rate has been at 1.03% between 2001-2011. However youth unemployment is very high at 62.2% with no schooling aged 20 and above accounting to 7.8% matric aged 20 and above being at 18.8%.

There are 23.751 households and amongst them 12,754 are agricultural households and four is a household average size. 54.8% households are headed by females. 87.3% of Vhembe population are dwelling formally. Only 3.8% of the population has access to flush toilets connected to sewage. The piped water inside dwelling is 5.8% and Electricity for lighting is 83.3%.

Less than 1000 persons are expected to be residing at Mukomawabani, majority are of low income. Most families depend on social grant support the educational level is very low, not many has received formal education or have formal qualification. However Tshikondeni during its maximum operation has employed 750 permanent workers which were boosting Mukomawabani local economy. Other areas closer to both Tshikondeni coal mine and Mukomawabani are Thondoni, Tshikuyu and Bileni (Batchelor, 1980).

2.1.3 Climate

Mukomawabani experiences a hot semi-arid climate with hot temperatures dominating year-round. The summer temperature may sometimes exceed 40 degrees Celsius. Average annual precipitation amounts to 372 mm (14.6 in), and is highly concentrated in the summer months from October to April and severe late-afternoon and evening thunderstorms are common. Winter is extremely dry, with almost zero precipitation typically recorded in the driest months from June to August. Clear skies and exceptionally low humidity at this time of the year enable temperatures to plunge close to freezing at night, although frost is fairly uncommon (Taylor and Kruger 1986).

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Droughts frequently occur during the winter months, and infrequently during summers when very little rain falls and drought conditions prevail. These erratic summer droughts are becoming more common as climate change continues. Mukomawabani is closer to Tshikondeni coal mine and it is for that reason the impact of the mine was assessed at that village. Tshikondeni is found in a distance less than 4.5km from Mukomawabani. Mukomawabani is at an elevation of 342 whereas Tshikondeni is found at an elevation of 377m and its geographical coordinates are between 22°30'53'91"S 30°56'30'14"E. The difference in elevation supports the flow of effluents from Tshikondeni mine towards Mukomawabani area (Taylor and Kruger 1986).

Wind blow mostly from easterly direction and Mukomawabani is on the western side of Tshikondeni coal mine. The fact that it is in the western side and to the direction at which wind blows, it exposes it to high risks of pollution. Coal dust, noise pollution and contaminated effluents are more likely to flow towards the area.

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Figure 2.2: Topographical map of Mukomawabani (Google earth 2013).

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2.1.4 Geology

The terrain is unspoilt and contains a diverse of flora. The landscape is softly undulating, and there are few points from which the mining lease area can be overlooked and even Mukomawabani itself. However, a number of hills lying alongside the border and within the Kruger National Park afford views over the mine site and Mukomawabani (McBride, 1976).

Studies have revealed that there are fourteen difference kinds of soil layers in the area, the upper most being Alluvium (quartz boulders and calcrete) followed by sandstone (course grained), Mudstone with miner coal bands, sandstone, shale with sandy and silty beds, sandstone (medium grained) shale with thin silty laminae (thin coal bands in bottom portion, main coal seam, sandstone (medium to course grained with thin shaly bands), shale and sand stone alternating with thin coal bands, lower coal seam with alternating shale and coal bands above and below, shale sandy in places, diamictite, dolerite and faulty. All above were found within a depth of 128m. Mukomawabani area is covered predominantly by sandy soils, but shallow, stony soils are found on the higher-lying areas and clayey soils occur in the valleys (Verster and Van Rooyen 1983).

The landscape has been moulded largely as a result of erosional forces, while faults and intrusions of competent dolerite dykes and sills have influenced the formation of hills and scarps. Topography is softly undulating with a few prominent ridges extending in an east-west direction (Verster and Van Rooyen 1983).

2.1.5 Hydrology

The surface hydrology is characterized by a large perennial river called the Mutale River. A river that flows from Mukomawabani through the mining lease area and to the Kruger National Park, where it joins the Luvuvhu River. However Mukomawabani is closest to Mutale River and they are less likely to be affected by pollutants discharged into the river since the river flows from Mukomawabani site towards Tshikondeni coal mine. Even though they are less affected by effluents they suffer early drought than normal due to aquifer degradation (Verster and Van Rooyen 1983).

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The study area appears to be a ground-water recharge zone. The aquifer can be classified as heterogeneous where dykes and faults determine the ground-water flow. Faults and contact zones between dykes and country rock are highly permeable and may have adverse effects on underground operations. The present water table lies 20 to 44 m below the surface. The presence of a deep regional ground-water supply is indicated, but there are significant local variations in the characteristics of the ground water. Most of the boreholes sampled do not meet the criteria for domestic water supply, and the water most suitable for domestic use occurs in the north of the mining lease area. In terms of irrigation uses, most samples display chloride and sulphate contents that are well in excess of the recommended maximum allowable limits. This is particularly true of samples from boreholes located directly north of the Mukomawabani (Verster and Van Rooyen 1983).

The high sodium content of most ground waters in the area could cause damage to the soil structure if used for irrigation purposes. The iron and chloride concentrations of a few boreholes exceed the recommended limits for the watering of livestock, but these excesses are generally not significant and the watering of livestock from groundwater sources is considered to be feasible. In the area immediately north of the entrance, most samples of ground water have excessively high concentrations of total dissolved solids (TDS). If they are to be discharged as effluent into the Mutale River, these waters would require prior treatment. Only the concentrations of chloride and iron are excessive in terms of the recommended limits for aquatic life. However, their dilution with river flow would be sufficient in most cases except during periods of low flow. The aeration of iron-rich waters would induce the precipitation of iron and so reduce the amount of iron held in solution (Verster and Van Rooyen 1983).

2.1.6 Flora

Eleven different plant communities exist within an area. Of these, forests of *Androstachys johnsonii* (Lebombo ironwood) are particularly worthy of note. Not only do they provide a unique habitat for fauna, but they are completely different in composition from other plant communities in the Bushveld (Gertenbach 1984).

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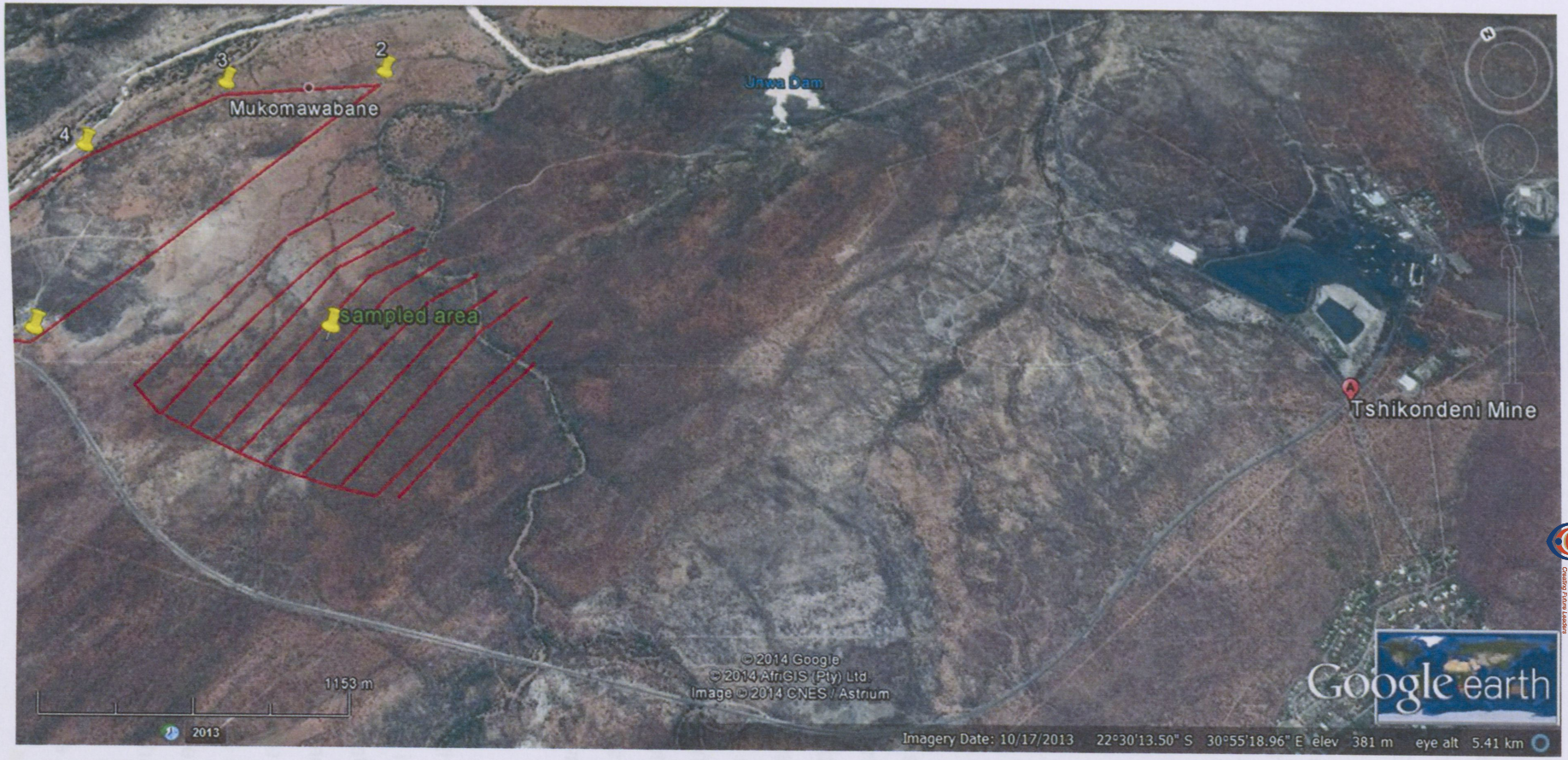


Figure 2.3: Map representing sampled area (Google earth 2013)

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2.1.7 The Socio-economic environment

North-eastern Venda has a relatively small population, and little development has occurred. The mining lease area is of considerable archaeological importance since it contains examples of the first contacts between Black populations and European traders, various Black cultural groups migrated south through the study area, and the mining lease area is largely undisturbed by recent human activities, which enhances the opportunities for archaeological research. Mukomawabani has only one primary school and no secondary or pre-school facility has been noticed during the site visit (Batchelor, 1980).

2.2 Materials and Methods

2.2.1 Sampling technique selection

Field studies of populations require adequate design and sufficient sample sizes. Choosing a sampling technique that is efficient in terms of time and money is an important consideration. It must also yield a representative sample and one that is sufficiently large to have statistical power. For many this is the funny part of population biology. Actually being in the field can yield important insight that must not be lost in the complexities of data analysis. Monitoring should be done with particular question in mind. The most important step in a population study comes at the very beginning and that is to ask the question, "will this monitoring procedure yield the data required to answer my research question?" good field data, particularly long-term data are a valuable resource (Judith and Dawn, 2003).

A thorough review of sampling methods have been conducted with an aim of choosing the most suitable and efficient data that can be analyzed and provide interpretable results. And we concluded that Point-Centred-Quarter (PCQ) method is the best suitable method for this study. However being the most suitable does not necessary mean that other methods cannot yield reliable results it only means it was suitable to our time and financial budget. As Tshikondeni coal mine is about to close officially this year (2015) it is important to assess biodiversity status on vegetation level, noting that vegetation is a heart of an ecosystem as it provides basic needs such as habitat, food for fauna, medicine, shades, recreational value, spiritual value, heritage, cultural, fuel and many more. So, the PCQ method has been identified as the most suitable method for this study. However there are many more methods

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that can be used for vegetation sampling but in this study PCQ was found to be more relevant and appropriate.

Historically there are different kinds of sampling techniques or methods that are used for vegetation sampling and they measure parameters such as population density, basal area and biomass. Even though aerial and photograph survey are sometimes used, most studies conducted previously where involving measuring different characteristics for individual trees. Though there are plenty of methods, they are all classified under two categories, namely the Plot-less and Plot–based method. Plot–based methods start with single or multiple plots (quadrants, belts) of a known area of which the characteristics of interest are measured for each plant whereas Plot-less involve measuring distance for a random sample of trees typically along a transect and recording the characteristics of interest for this sample (Kevin, 2007).

Different kinds of methods where compared to see if PCQ method was more accurate and efficient in the field on its density estimates, especially in situations wherein individuals are not randomly distributed (Engeman *et al.*, 1994). In recent years, as the PCQ method has been used more widely, variations have been proposed by Dahdouh-Guebas and Koedam (2006) to address many practical problems that arise in the field like (multi-stem trees and quarters where no trees are immediately present) and all the above reviews has made PCQ to be one of most refined method that one could rely on. One use of the PCQ method is to determine the relative importance of the different tree species in a community (Kevin, 2007).

Advantages of plot-less method is that it's faster, more efficient, require less equipment, require fewer workers, but the main being speed. This method was thought to be sacrificing the results till Strearns (1949) indicated that the method dates back least 150 years and was used by surveyors in the mid-nineteenth century making the first surveys of government land. Late 40 and early 1950 many articles appeared describing a variety of plot-less methods and comparing them to quadrants sampling. Cottam *et al.,* (1953) has compared PCQ and quadrant sampling method and derived an empirically formula that could be used to estimate population density from the distance data collected.

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Other advantages of PCQ are the fact that the resulting data cannot be tinged by subjectiveness and biasness of investigators. The results represent the vegetation as it actually exists and any other investigator could be able to employ the same methods in the same communities and secure approximately the same data. In other words this method could be used to obtain accurate estimate of population densities with the advantage that the data could be collected more quickly than quadrant data. It gives the least variable results for distance determinations, furthermore it provides more data per sampling point, and is the least susceptible to subjective bias. Beasom and Haucke (1975) compared the same four Plotless methods and concluded that the PCQ method provides the most accurate estimate of density.

An obvious factor influencing the importance of a species to a community is the number of trees present of that species. However, the importance of some number of small trees is not the same as the importance of the same number of large trees. So the size of the trees also plays a bigger role. Furthermore trees distribution throughout the community also has an effect. A number of trees of the same species clumped together should have a different importance value than the same number of trees distributed more evenly throughout the community. Measuring importance value aid clear understanding of vegetation, habitat successional stages and may enable us to predict results in different stages in which different species of trees will dominate. Importance values are one objective way of measuring this dominance. The three factors that used to determine the importance value of a species are the Relative density, Relative cover, and Relative frequency ideally, to estimate these factors, large samples should be collected (Kevin, 2007).

2.2.2 Data collection procedure

The procedure outlined below describes how PCQ data was collected along 100m transect. A 100m tape was erected on a straight line, a shorter one of 5m long was used to measure distances from the Centre to the sampled tree species, a notebook was used to record all necessary information and a calculator was used. Transect were 5m apart to avoid reputation of measurements. Where trees were highly sparse minimum distance between the points were increased to 10m. An imaginary line along transect were ran perpendicular to the transect dividing the world into four quarters, in that quarter the nearest tree to the sampled point was located. Only trees with height greater or equal to 2m were located and counted. A five meters tape was used to measure the canopy, a height rod was used to

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measure tree height and 5m tape was used to measure stem circumference at 30cm (0.3m) throughout the transect as recommended by Brokaw and Thompson (2000).

Each sampled point quarter was numbered as (I, II, III, IV) a distance from the sampling point to the centre of the trunk of the tree to the nearest 0.1m were recorded. Tree species were identified and documented, unidentified tree species were recorded as (A, B.C…Z) and were taken photos and a leaf sample were taken for taxonomic purposes. Trees with multiple trunks at 30cm, height circumference were combined to meet the minimum diameter of 12.5cm. Distances between sampled points to each tree were also summed up.

The community characteristics of vegetation between Mukomawabani and Tshikondeni coal mining were studied during the past two years 2013 and 2014. To find out the impact of coal mining on vegetation or tree layer, PCQ method was used from Mukomawabani towards the coal mining area. Structure and composition of tree layer was observed from the village towards the mining area. A 100m tape was laid down from the village towards the mining area. And 32 quarters were sampled and four nearest tree species were recorded. The total number of tree sampled ads to 128. The species found were identified with the help of reference books. A minimum of 15cm circumference was used to qualify tree for a record.

Quantitave community characteristics such as relative frequency, relative density, relative cover and importance value index (IVI) of each component were determined by following the methods as outlined by Kevin (2007).

2.2.3 Data analysis

2.2.3.1 Density

The tree density was found to be 390 per hectare but higher density was noticed adjacent to the mine and it was accompanied by low tree diversity higher density adjacent to the mine was as results of being away from human harvest. Even though mined area had greater plant density compared to the area adjacent to the village, because of the acidic pH, moisture stress and nutrient property of litter. Low grow form, sparse density and ability to tolerate low nutrient levels and low moisture conditions are probably the adaptations to the

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harsh physical nature of substrate. Low nutrient habitats are usually colonized by species with low relative growth rates. These adaptations enable colonizing species to maximize the nutrient uptake and ensure high nutrient use efficiency in low nutrient environments (Baig, 1992). Lyngdoh (1995), Das Gupta (1999) and Sarma's (2002) works lend support to the present findings.

Bradshaw and Chadwick (1980) working on the colliery spoils reported that the number of species colonizing on the mined areas was influenced by its pH. In this study we have found out that the shift in pH level has worked in favor of *C. mopane* which has resulted in high rate of establishment. The same could have happened adjacent to the village unfortunately *C. mopane* is under attack for several purposes being the most attacked tree species around the village it gives other tree species chance to establish themselves and those species were found to be of less value in terms of fuel productivity and palatability. However they were found to be valuable most of them serves as shade and wind shields this were plants like *Kirkia acuminate* and *Commiphora edulis.*

Basic Analysis

Thus:

n- represents the number of sample points along the transect

4*n* – represents number of samples or observations one for each quarter at each point

i- Represents a particular transect point, where *i = 1,…. n.*

j- Represents a quarter at a transect point, where j = *1,….4*

Rij- represents the point-to-tree distance at point *i* in quarter *j*

The absolute density λ of trees is defined as the number of trees per unit area. Since λ is most easily estimated per square meter and since a hectare is 10,000 m^2, λ is often multiplied by 10,000 to express the number of tree per hectare. The distances measured using the point-centered quarter method may be used to estimate λ to avoid having to count every tree within such a large area.

For our data $$\bar{r} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{4} Rij}{4n}$$

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Cottam *et al.* (1953) showed empirically and Morisita (1954) demonstrated mathematically that $\bar{r}$ is actually an estimate of $(\sqrt{1}/_{\lambda})$ the square root of the mean area occupied by a single tree. Consequently, an estimate of the density is given by:

Absolute density = $\bar{\lambda} = \frac{1}{\bar{r}2} = \frac{16n2}{\left(\sum_{i=1}^{n}\sum_{j=1}^{4} Rij\right)2}$ ..... (1)

$\bar{\lambda} = \frac{1}{\bar{r}2} = \frac{1}{5.06^2}$ = 0.0390 trees/m^2

There were about 390 trees in a hectare.

For our data mean distance was found to be 5.06 m.

Absolute Density of Each Species

$\lambda k = \frac{Quater\ with\ species\ k}{4n} \times \lambda$ ..... (2)

2.2.3.2 Relative Density of a species

The relative density of each species is the percentage of the total number observations of that species.

Relative density (Species k) $= \frac{\lambda k}{\lambda} \times 100$

Equivalently by making use of (2) equation

Relative density (species k) $= \frac{Quater\ with\ species\ k}{4n} \times 100$ ..... (3)

The cover or dominance of an individual tree were measured by their basal area *c*, denotes the circumference, and basal area of a tree, respectively. Since the area of a circle or circumference A $= c^2/4\pi$. In this case CCH were recorded. The first step was to compute the basal area for each tree sampled, organizing the data by species. This has been the most tedious part of the analysis. A calculator and spreadsheet were used interchangeably. For

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the data in Table 1, the basal area for each tree was obtained using the formula A $=c^2/4\pi$. For trees with multiple trunks, the basal area for each trunk was computed separately and the results summed.

Secondly the absolute cover or dominance of each species were expressed or calculated as basal area per hectare. This was obtained by taking the number of trees per species and multiplying by the corresponding mean basal area. The relative cover or relative dominance for a particular species is defined to be the absolute cover for that species divided by the total cover times 100 to express the result as a percentage. The relative covers should sum to 100% plus or minus a tiny round-off error. Note that the relative cover can also be calculated directly from the transect information.

$$\text{Relative cover (Species } k) = \frac{Total\ BA\ of\ species\ k\ along\ transect}{Total\ BA\ of\ all\ species\ along\ transect} \times 100 \quad \ldots\ldots (4)$$

2.2.3.3 Absolute Frequency of a Species

The absolute frequency of a species is the percentage of sample points at which a species occurs. Higher absolute frequencies indicate a more uniform distribution of a species while lower values may indicate clustering or clumping. It is defined as

$$\text{Absolute frequency} = \frac{\text{No.of sample points with a specie}}{Total\ number\ of\ sample} \times 100 \quad \ldots\ldots (5)$$

To normalize for the fact that the absolute frequencies sum to more than 100%, the relative frequency is computed. It is defined as;

$$\text{Relative frequency} = \frac{\text{Absolute frequency of a species}}{Total\ frequency\ of\ all\ species} \times 100 \quad \ldots\ldots (6)$$

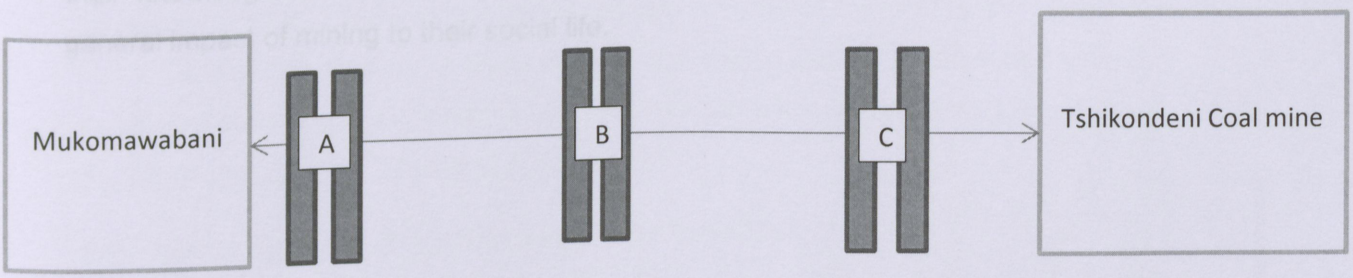


Figure 2.4: Conceptual framework of different coal mine impact zones (A, B and C).

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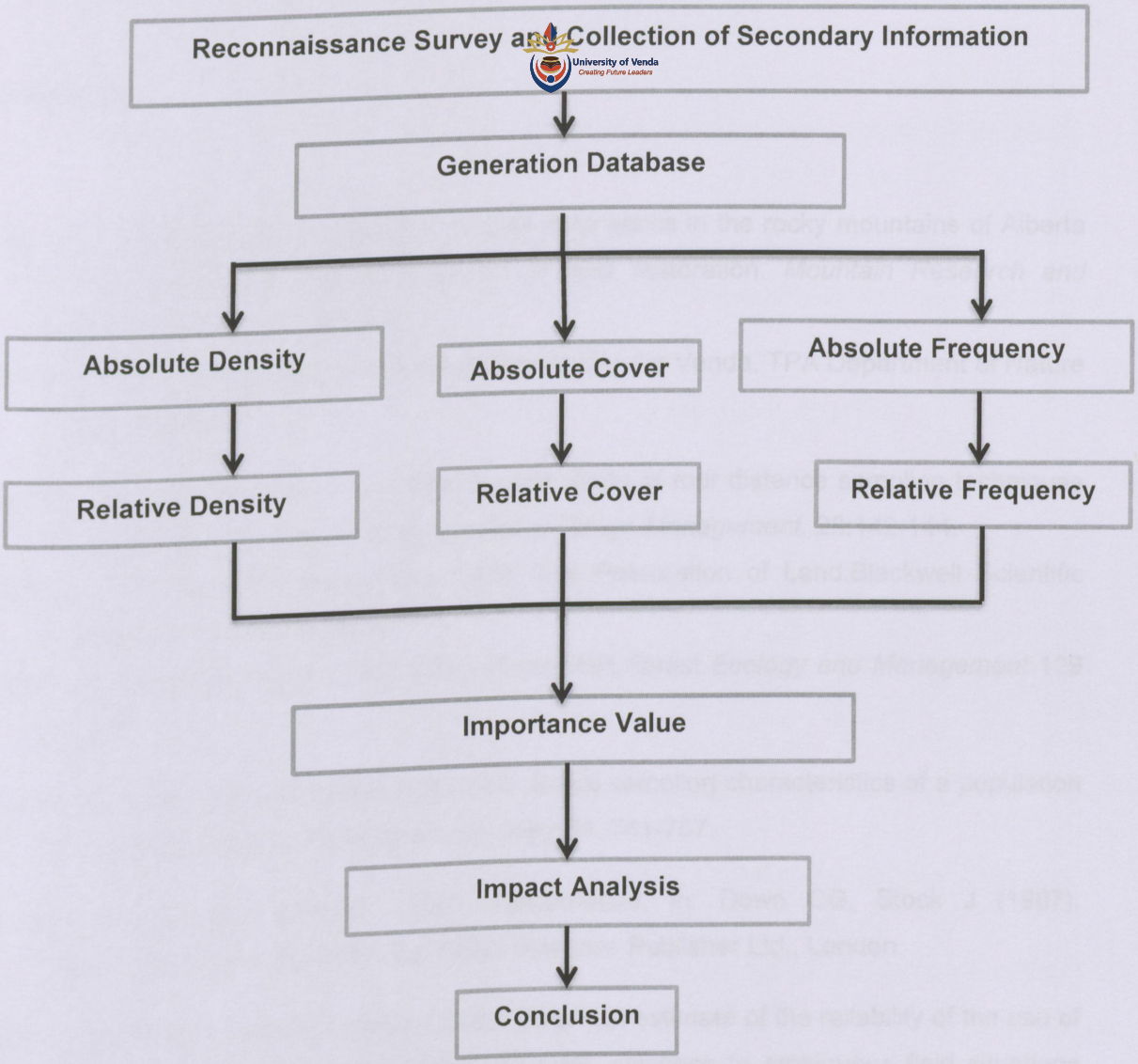


Figure2.5: Paradigm for assessment of mining impact on vegetation.

Tree species were recorded according to their importance value and the list of recorded tree was used during questioner whereby citizens were asked about tree utilization. However individuals were randomly selected and a structured formal questioner was used to assess their knowledge in order to document Traditional Ecological Knowledge (TEK) and the general impact of mining to their social life.

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CHAPTER 3

AN ANALYSIS OF TREE LAYER PROFILE USING THE POINT-CENTRED-QUARTER METHOD

3.1 Introduction

Ecosystem disturbance may be defined as an event or series of events that alters the relationship of organisms and their habitat in time and space. Ecosystem disturbance by mining is an evitable fall out of industrialization and modern civilization. Mining of coal both surface and subsurface causes enormous damage to the flora, fauna, hydrological relations and soil biological systems. Destruction of the vegetal cover during mining operation is invariably accompanied by an extensive damage and loss to the system (Charis, 1994). The disturbed and haphazardly mixed infertile, consolidated and unconsolidated materials overlying the coal seams are known as overburdens. These overburdens when dumped in unmined areas in the vicinity of the coal mines create mine spoils. Nutrient deficient sandy soils are generally hostile to plant growth. The dumping of spoils and coal destroys even the surrounding vegetation and leads to severe soil and water pollution (Kiranmay, 2005).

Mine waste has major negative effects such as, deterioration of aesthetics, reduction of land productivity, complete destruction of landscape, habitat, air and water quality. Fortunately, unlike other industries, mining is a temporary user of land, and proper reclamation can restore the productivity of land and may bring better landscape (Maiti, 2013). Therefore, establishment of tree cover in mine degraded land has the following advantages, accelerate soil-forming processes, control erosion, build up organic matter, develop microbial communities, initiate nutrient cycling and enhance overall aesthetics of the area (Josa *et al.*, 2012; Zhao *et al.*, 2012).

In mining context, reclamation often refers to the general process whereby the mined wasteland is returned to some forms of beneficial use (Cooke and Johnson, 2002), while restoration refers to reinstatement of the pre-mining ecosystem in all its structural and functional aspects, rehabilitation means the progression towards the reinstatement of the

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original ecosystem, and replacement is the creation of an alternative ecosystem (Bradshaw, 2000). Other reclamationist define it as the treatment of land with an aim of creating conditions for bringing the land back to some beneficial use, and reclamation does not necessarily mean restoring of the land to its original conditions (Khoshoo, 1988).

According to a National Academy of Science study committee, reclamation renders a site habitable to indigenous pre-mining condition organisms (NSA, 1974). Reclamation is also defined as returning a derelict site to some use (Maiti, 2013).The success of reclamation depends not only on the methods of mining, even height and slope of dumps, nature of soils, geoclimatic conditions and also on types of plant species selected and the ameliorative effects on mine soils. Mined degraded lands are reclaimed by planting drought resistant, fast growing trees without considering their ameliorative properties. Different tree species have varying degree of ameliorative effects on mine soils (Mukhopadhyay and Maiti, 2011; Juwarkar*et al.*, 2010; Mendes *et al.*, 2010; Sinha *et al.*, 2009; Dutta and Agrawal, 2003). Studies have been conducted in Inner Mongolia China on physicochemical properties improvement of a 15-year old reclaimed coal mine soils and it was concluded that different tree species have varying degree of influence on soil forming process (Yao *et al*, 2010).

Significant difference in improvement of physico-chemical properties by five exotic tree species planted in the mine soils (Jayant opencast project, Madhya Pradesh, India) were reported (Dutta and Agrawal, 2001). Successful biological reclamation largely depends on the selection of appropriate species, which have higher ameliorate capacity on mine soils. However, impact of tree species on the mine soil quality cannot be assessed by individual parameters, as most of the parameters are interlinked and difficult to interpret. Thus, integrated soil quality indices based on a combination of mine soil parameters could provide a better indication of reclamation success. Several indices have been proposed to assess soil quality but most of them are microbial in nature. Bastida *et al.* (2006), building on the approach of Andrews *et al.* (2002), suggested microbiological degradation index, whereas Sinha *et al.* (2009) derived an index based on microbial activity in the tree-rhizosphere.

Exxaro's Tshikondeni coal mine has travelled a long and unconventionally difficult road since its first production in 1984. As it walks towards the finishing line it will leave a lasting legacy (Inside Mining, 2012).The mine has been operating for a longer period which places vegetation under severe environment for too long. As a result of this, village adjacent to the

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mine has been the one witnessing the impact of the mine both positive and negative. Mine establishment and operation has converted landscape into mine spoils. Longer life span of the mine has been accompanied by large scale denudation of vegetation cover, water scarcity, air pollution, and degradation of agricultural lands.

The mitigation of negative impacts on biodiversity and ecosystem services is a legal requirement and should be taken on different forms depending on the significance of the impact and the area being affected. Mitigation requires proactive planning that is enabled by following the mitigation hierarchy. Its application is intended to avoid disturbance of ecosystems and loss of biodiversity, and where they cannot be avoided, or minimized, rehabilitation or reclamation should be an alternative (DEA *et al.*, 2013).

Tshikondeni mine is about to close it has been announced that it will officially close in 2015 however unlike other mines Tshikondeni has raised its production in 2011 after its closure proposals and announcement. All along Tshikondeni was known as an underground mine but as it was heading its closure it has introduced mini pits operations which has increased production of coal, hence double impacting the environment which was hardly copying with soil fragmentation challenges. Taking into consideration that Tshikondeni has a depth of about 400m and it supported by pillar (Inside Mining, 2012). Blasting during opencast operation has introduced a serious threat, buildings were shaken and cracked, apart from that ground surface has cracked also which has resulted in habitat fragmentation; animal community were endangered by ground surface openings. Tree species were falling and others were drying out earlier than they should; water table has been lowered acid rain became common in the area; soil could not retain moisture as it used to do.

The aim of the study was determine the tree layer profile of the vegetation of Mukomawabani. It was using the tree profile to detect environmental challenges related to coal mining specifically around Mukomawabani as influenced by Tshikondeni mine.
To achieve the aim the following objectives were looked at:

1. To determine Relative density.
2. To determine Relative cover.
3. To determine Relative frequency.
4. To determine Importance value.
5. To assess the impact of coal mining on vegetation.

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The hypothesis was that mining influences the spatial distribution, composition and condition of vegetation particularly trees layers.

3.2 **Study area**

Mukomawabani is the study site where data collection on tree layer was conducted. It is the closest village to Tshikondeni coal mine situated in the Magisterial District of Thohoyandou, in Limpopo Province, South Africa, and it belongs to Mutale local municipality the closest township to it is Masisi and is located some 140km east of Musina (formerly Messina) and 15km south of the Zimbabwe border. It is located between A.22°28'54'11"S and 30°54'46'72"E, B.22°28'43'33"S and 30°54'23'05"E, C. 22°28'44'50"S 30°54'00'05"E and D. 22°28'59'64"S 30°53'15'24"E, and E. 22°29'15'89"S, 30°53'40'87"E, the site is accessed via a tarred road, the R525 some 100km east of Tshipise (Taylor and Kruger 1986). Mukomawabani experiences a hot semi-arid climate with hot temperatures dominating year-round. The summer temperature may sometimes exceed 40 degrees Celsius. Average annual precipitation amounts to 372 mm (14.6 in), and is highly concentrated in the summer months from October to April and severe late-afternoon and evening thunderstorms are common. Study area has been discussed in detail in chapter two.

3.3 **Materials and Methods**.

The community characteristics of vegetation adjacent to coal mining area were studied during the past two years 2013 and 2014. Data on tree layer was sampled using the Point centred Quarter method described in Chapter 2 under materials and methods. Structure and composition of tree layer was observed from the village towards the mining area.

A 100m tape was laid down from the village towards the mining area. Sampling of data was done at 10m interval. The tree trend was analyzed specifically in terms of biodiversity and tree health using Excel programme. The species found were identified with the help of relevant reference books. A minimum of 15cm circumference 30cm above the ground surfaces was used to qualify tree for a record. Parameters recorded from each individual

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tree were tree name, height of tree, crown cover, basal diameter, and distance from the point to the nearest tree.

Community characteristics such as relative frequency, relative density, relative cover and importance value index of each component were determined since they are the key tools for PCQ analysis (Kevin, 2007)

3.4 Results and Discussions

Thirty-two points were sampled using PCQ method and four nearest tree species were recorded from each point. The total number of trees sampled was 128.

3.4.1 Density

The tree density was found to be 390 per hectare but higher density was noticed adjacent to the mine and it was accompanied by low tree diversity higher density adjacent to the mine was as results of being away from human harvest. Mined area had greater plant density compared to the area adjacent to the village, because of the acidic pH, moisture stress and nutrient property of litter. Low growth form, sparse density and ability to tolerate low nutrient levels and low moisture conditions are probably the adaptations to the harsh physical nature of substrate. Low nutrient habitats are usually colonized by species with low relative growth rates. These adaptations enable colonizing species to maximize the nutrient uptake and ensure high nutrient use efficiency in low nutrient environments (Baig, 1992). Lyngdoh (1995), Gupta (1999) and Sarma (2002) also made the same findings regarding low nutrient environments.

Bradshaw and Chadwick (1980) working on the colliery spoils reported that the number of species colonizing on the mined areas was influenced by its pH. In this study we have found out that the shift in pH level has worked in favor of *Colophospermum mopane* which has resulted in high rate of establishment. The same could have happened adjacent to the village unfortunately *C. mopane* is under pressure for several purposes being the most utilized tree species around the village it gives other tree species chance to establish themselves and those species were found to be of less value in terms of fuel productivity and palatability. However they were found to be valuable most of them serves as shade and wind shields this were plants like *Kirkia acuminata* and *Commiphora edulis.*

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Table 3.1: Absolute Density of each species recorded during data collection at Mukomawabani.

Species name	Frequency/quarter			Trees/ha	Relative density
Acacia karroo	1	1/128=	0.008	3.0404	0.78125
Acacia nigrescens	2		0.016	6.0808	1.5625
Acacia robusta	1		0.008	3.0404	0.78125
Acacia senegal	1		0.008	3.0404	0.78125
Adansonia digitata	1		0.008	3.0404	0.78125
Albizia anthelmentica	1		0.008	3.0404	0.78125
Boscia albitrunca	1		0.008	3.0404	0.78125
Colophospermum mopane	44		0.344	133.78	34.375
Combretum apiculatum	12		0.094	36.485	9.375
Combretum imberbe	1		0.008	3.0404	0.78125
Commiphora edulis	2		0.016	6.0808	1.5625
Commiphora mollis	9		0.07	27.364	7.03125
Commiphora pyracanthoides	18		0.141	54.728	14.0625
Dovyalis caffra	1		0.008	3.0404	0.78125
Gardenia volkensii	16		0.125	48.647	12.5
Grewia flava	5		0.039	15.202	3.90625
Kirkia acuminata	2		0.016	6.0808	1.5625
Pterocarpus rotundifolius	1		0.008	3.0404	0.78125
Terminalia prunioides	8		0.063	24.323	6.25
Terminalia sericia	1		0.008	3.0404	0.78125

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Total	128			390	100

3.4.2 Relative Density of species

The relative density of each species is the percentage of the total number observations of that species.

Table 3.2: The importance value of each species

species	Relative density	Relative cover	Relative frequency	Importance value
Acacia karroo	0.78125	0.0731	1.0653	1.91965
Acacia nigrescens	1.5625	0.2459	1.0653	2.8737
Acacia robusta	0.78125	2.5537	1.0653	4.40025
Acacia senegal	0.78125	3.967	1.0653	5.81355
Adansonia digitata	0.78125	0.6774	1.0653	2.52395
Albizia anthelmintica	0.78125	0.2534	1.0653	2.09995
Boscia albitrunca	0.78125	1.1696	1.0653	3.01615
Colophospermum mopane	34.375	28.164	27.6543	90.1933
Combretum apiculatum	9.375	4.6103	9.5726	23.5579
Combretum imberbe	0.78125	0.1169	1.0653	1.96345
Commiphora edulis	1.5625	1.4766	2.1272	5.1663
Commiphora mollis	7.03125	5.6094	8.509	21.14965
Commiphora pyracanthoides	14.0625	16.9549	13.8271	44.8445
Dovyalis caffra	0.78125	0.9211	1.0653	2.76765
Gardenia volkensii	12.5	7.1762	12.7635	32.4397
Grewia flava	3.90625	3.2116	4.2545	11.37235

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Kirkia acuminata	1.5625	0.[illegible]39	2.127	4.1134
Pterocarpus rotundifolius	0.78125	0.7359	1.0653	2.58245
Terminalia prunioides	6.25	5.7118	7.4454	19.4072
Terminalia sericea	0.78125	0.0956	1.0653	1.94215
	100	84.1483	99.9989	284.1472

From the relative density graph it can be concluded that *Colophospermum mopane* 34% has the highest relative density followed by *Commiphora pyracanthoides (14%), Gardenia volkensie (12%), Combretum apiculatum (9%), Commiphora mollis (7%), Terminalia pruniodes (6%)* and the rest has least less than *(5%).* It is clear that *C. mopane* is the key species in this area, however it is under threat since it is known to be good for fuel it is now harvested commercially to produce wood. Over harvesting could results in extinction of these tree spices. It has been endangered since the establishment of mine which has decreased the availability of Mopane worms. Mopane worms have been the pillar of Mukomawabani economy people use to harvest them for food at home and for commercial reason. The worms are known to have high protein yield which is beneficial to human health (Toms *et al.*, 2003).

Furthermore tree relative density was noticed to be low closer to the village than away from the village the reason for this maybe the fact that majority of plants with high relative density are good for fuel and for animal feed. So, during drought people fell trees for their animals to give them support that's where the closest trees in the village got preference. However people will do the same even for wood. Coal mining seems to be less threatening vegetation next to the village as compared to the citizens themselves. Even though *C. mopane* is subjected to constant disturbance or attach it seems as it overcomes that buy resprouting quicker. Its mode of resprout is supported by long tap root that enables it to tap water in deeper soil.

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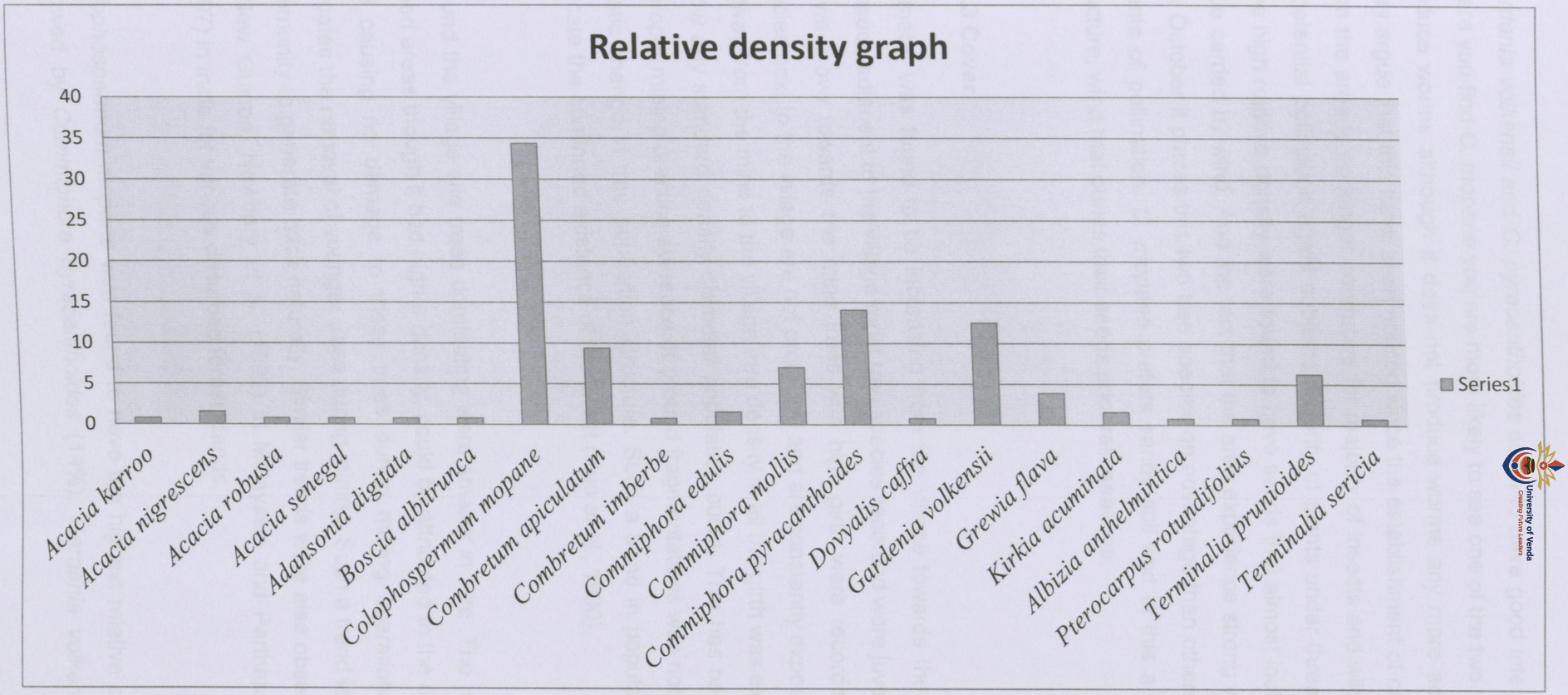


Figure 3.1: Representation of relative density.

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Gardenia volkensii and *C. pyracanthoides* seem to have good inter-action with *C. mopane* where you find *C. mopane* you are more likely to see one of the two. *G. volkensii* is known to produce worms although it does not produce worms any more according to the citizens. They argue that this have been noticed since the establishment of coal mining. According to them the area is no longer conducive for majority of insects and wild animals. The absence of potential pollination agent subjects majority of plants under threat. The two species that have high relative density were found to have seeds that almost look alike they are all easy to be carried by wind. And the fact that the area experience strong winds during September and October it places this two tree species on advantage than others that depends on other agents of pollination. *C. mopane* prefers sandy soil and in this area it is favored by soil structure, wind that buries their seeds prior rain seasons.

3.4.3 Cover.

Diameter was found to be increasing from the village towards the mining area along the transect, adjacent to the village most tree species recorded were juveniles of *C. mopane* and as we move towards the mine trees with high girth were recorded this is because tree species next to the village are not protected and are constantly exposed to harvest. However midway from the mine to the village tree density in all the girth was extremely low and did not follow any standard density diameter population curve. This has been due to rampant and improper mining practice evidence of ground fragmentations was noticed and that has led to drastic change in tree population structure. Such a trend in population structure does not indicate the continued existence of the forest (Rao *et al.*, 1990).

Around the village site trees dominating were smaller in size .The higher basal area in the mined areas though it had higher density, could be attributed to the existence of bigger trees and causing no damage to these trees during mining operations by the miners. This indicates the removal of younger trees during mining. Such a trend leads to the failure of the community to generate back naturally. Similar trends were also observed by Paijman (1970) in New Guinea, Newbery *et al.* (1992) in Malayasia and Parthasarathi and Karthikeyan (1997) in India for various disturbed forest stands.

Colophospermum mopane was found to have the highest relative cover with at least 34% followed by *Commiphora pyracanthoides* (14%), *Gardenia volkensii* (13%), *Combretum*

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apiculatum (9%), *Commiphora mollis* (7%), *Terminalia prunoides* (6%) and the rest have less than 5% relative cover each. Surprisingly not following that they were the once with high relative density and the very same reasons governing the relative density of this tree species still governs relative cover. However *Commiphora pyracanthoides* and *Gardenia volkensii* seems to be competing, their cover is almost equal or the same, without a thorough research one cannot rank them in terms of their relative covers as in *C. mopane. G. volkensii* leaves were most preferred by worms. In the absence of worms the tree is less susceptible to disturbance. Considering that the tree height is of average it was going to suffer constant disturbance by both human and animals so, the fact that it is not as good as the two other tree species in terms of fuel productivity and is less palatable to animals and its branches are disoriented as compared to the other two species mentioned above it discourages nearly all forms of disturbance if its situation where opposite.

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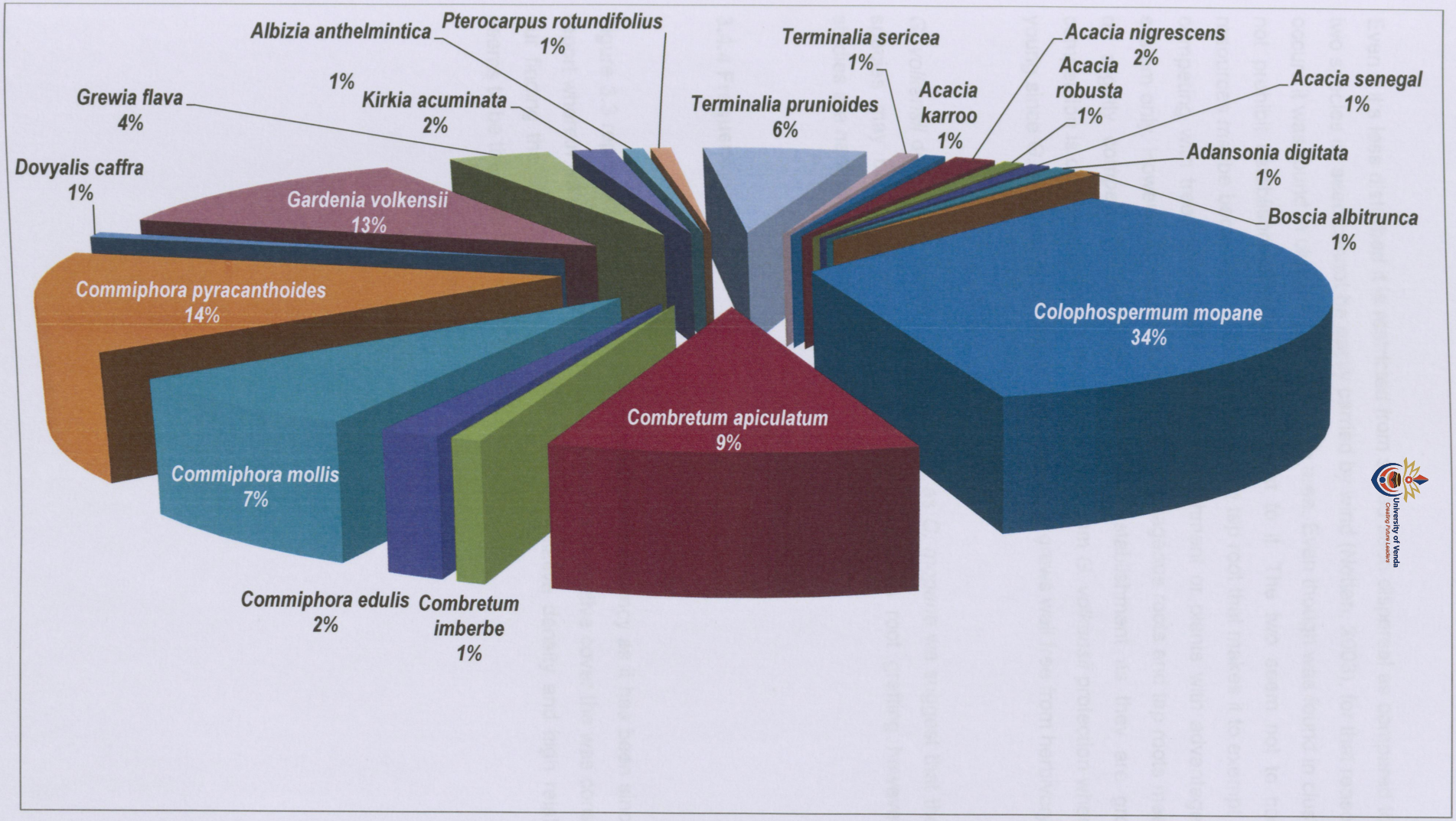


Figure 3.2: Relative Cover

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Even if it's less disturbed it is restricted from [illegible]ed seed dispersal as compared to the other two species its seed cannot be easily carried by wind (Notten, 2003), for that reason where it occurs it was found in clusters covering large area. Even though was found in cluster it does not prohibit establishment of *C. mopane* next to it. The two seem not to compete for resources maybe because *C. mopane* has a long tap root that makes it to exempt itself from competing with trees with shallow roots establishment or plants with advantageous roots system only. However *C. mopane* has both advantageous roots and tap roots meaning they do slightly compete for moisture during early establishment as they are growing the competition is decreasing and *C. mopane* benefit from *G. volkensii* protection when they are young since *G. volkensii* is not palatable. *C. mopane* grows well free from herbivory.

G. volkensii does shad leaves but not as early as *C. mopane* we suggest that the two tree species may be having mutualistic relationship such as root grafting however through studies are necessary before one can conclude this.

3.4.4 Frequency

Figure 3.3 represents tree species with high relative frequency as it has been since our first report wherein we were presenting relative density and relative cover the was consistency in our finding the very same tree species with high relative density and high relative cover seems to be the once with high relative frequency.

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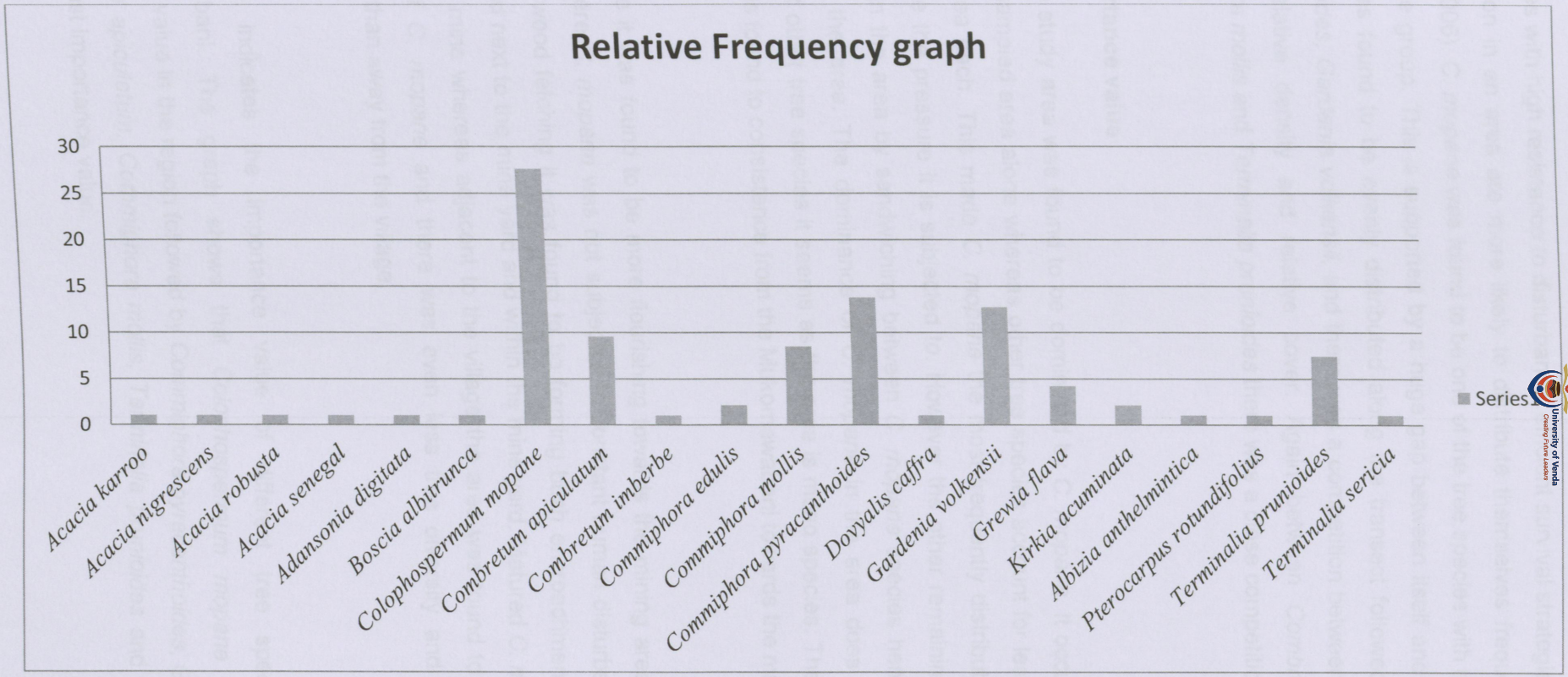


Figure 3.3: Relative frequency graph

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Tree species with high resistance to disturbance, efficient survival strategies and good mode of distribution in an area are more likely to distribute themselves frequently (Papaik and Canham, 2006). *C. mopane* was found to be one of the tree species with the above qualities amongst the group. This is supported by a huge gap between itself and other species. *C. mopane* was found to be evenly distributed along the transect followed by *Commiphora pyracanthoides, Gardenia volkensii*, and there was a competition between the two as it has been in relative density and relative cover. Again between *Combretum apiculatum, Commiphora mollis* and *Terminalia prunioides* there was a close competition also.

3.4.5 Importance value

In short the study area was found to be dominated by *C. mopane*. It occupies more than a quarter of sampled area alone whereas other tree species account for less than 15% of the sampled area each. This made *C. mopane* the most frequently distributed species in the area despite the pressure it is subjected to. However the other remaining tree species do add value in the area by sandwiching between *C. mopane* species hence bringing some diversity in the area. The dominance of *C. mopane* in the area does over shadow the presence of other tree species it seems as the area is mono species. The dominance of *C. mopane* was found to consistence from the Mukomawabani towards the mine.

Furthermore it was found to be more flourishing towards the mining area than next to the village. Where *C. mopane* was not subjected to constant human disturbance such as tree falling and wood fetching it was found to be forming bush encroachment evidence of this were noticed next to the mine yard and within the mine yard. Matured *C. mopane* was found next to the mine whereas adjacent to the village the area was found to be dominated by juveniles of *C. mopane* and there was even less tree diversity and high tree spatial distribution than away from the village.

Figure 3.4 indicates the importance value of different tree species found near Mukomawabani. The graph shows that *Colophospermum mopane* has the highest importance value in the region followed by *Commiphora pyracanthoides*, *Gardenia volkensii, Combretum apiculatum, Commiphora mollis, Terminalia prunioides* and *Grewia flava,* the rest has least importance value.

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The findings in figure 3.4 inform us about the adaptation that *C. mopane* has evolved since the establishment of the mine. It seems as it has adapted to leave in coal dust area, with bit of acid rain, high temperature low moisture, sandy, windy area and adjacent to *C. pyracanthoides, G. volkensii, C. apiculatum, C. mollis, T. prunioides and G. flava.* Above suggestion further inform us that during reclamation process a combination of this plants species should be used in order effectively reclaim biodiversity.

The high importance value of *C. mopane* was complemented by studies revealing that Mopane woodland is distributed along the Limpopo River in South Africa (Mapaure, 1994), and contributes to about 50% of the vegetation in the Kruger National Park (Fenton, 1983). The controls on the growth and distribution of *Colophospermum mopane* in southern Africa are uncertain, but seem to be influenced by edaphic (Madams, 1990; O'Connor, 1992) and climatic factors (Timberlake, 1995; Okitsu, 2005). *Colophospermum mopane* is a drought tolerant species confined to areas of low to moderate rainfall, dominated by alluvium and colluvium soils (Timberlake, 1995).

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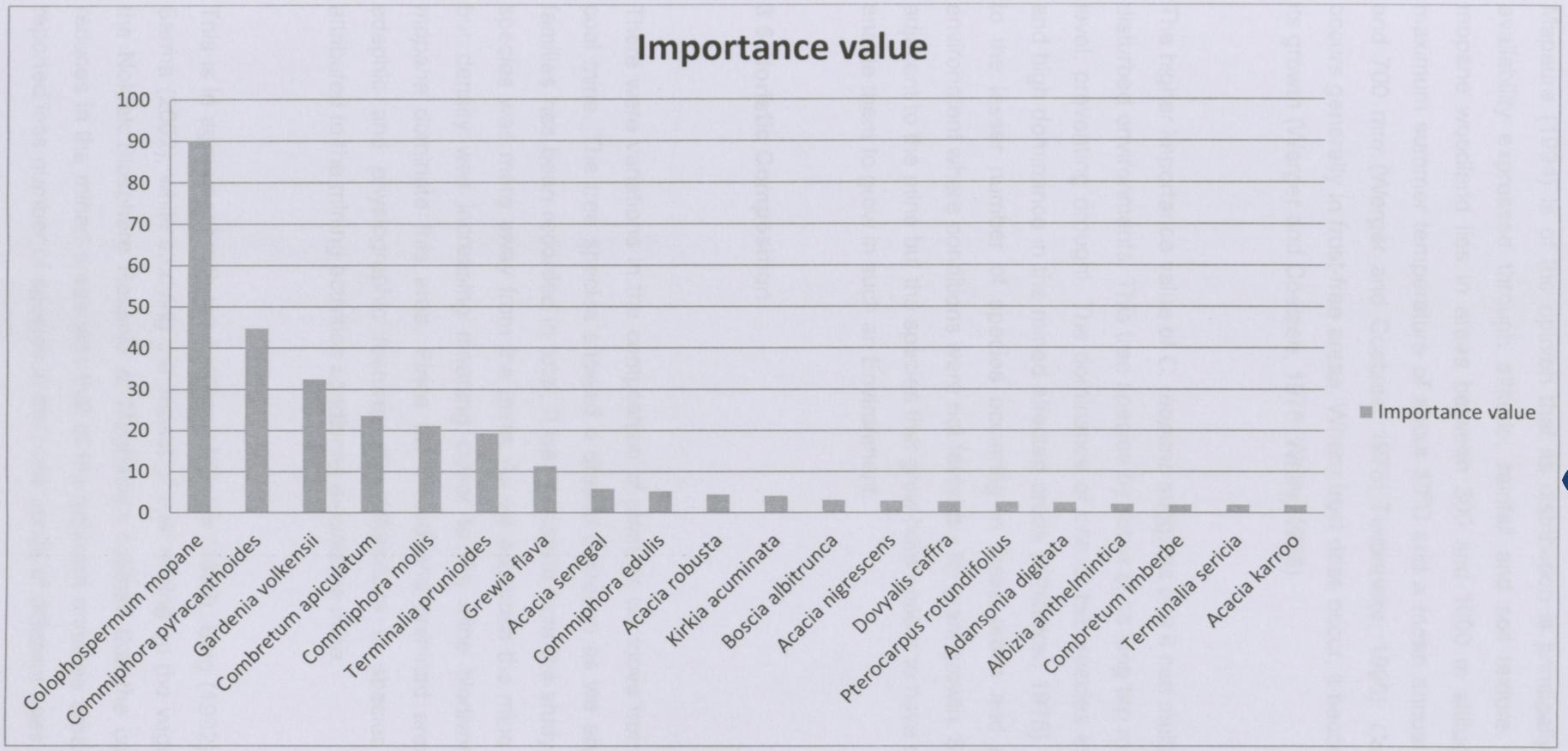


Figure 3.4: Importance value graph

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Mapaure (1994) is of the opinion that its distribution is principally influenced by moisture availability expressed through altitude, rainfall and soil texture. In southern Africa, the mopane woodland lies in areas between 300 and 1000 m altitudes, typified by a mean maximum summer temperature of about 30°C and a mean annual rainfall of between 400 and 700 mm (Werger and Coetzee, 1978; Timberlake, 1995). *Colophospermum mopane* occurs generally in frost-free areas. Where frost does occur, it becomes the limiting factor to its growth (Werger and Coetzee, 1978; White, 1983).

The higher importance value of *C. mopane* suggests that it can multiply rapidly in coal mined disturbed environments. This tree species by virtue of its long tap root can tap water in deep level, preventing drought. The dominance of one or two species explains the low diversity and high dominance in the mined affected areas (Whittaker, 1975). This could be attributed to the lesser number of species occurring in these areas and also represent a stress environment where conditions were not favorable for plant growth. Species diversity was low adjacent to the mine but the species that grow here appear to have developed tolerance that enable them to grow in such an Environment.

3.5 Floristic Composition

There were variations in the composition of plant as we move from the village towards the coal mine. The tree species showed a drastic decrease as we approach the mine eleven families has been recorded in total. It was apparent from the study that the number of tree species was more away from the mine. As we approach the mine tree species decreases but density was increasing meaning closer to the mine biodiversity decreases only *C. mopane* dominate this area. Since the mined and unmined areas had similar climatic, edaphic and physiographic features the differences in species composition could be attributed to the mining activities conditions around the mine.

This is in agreement with the findings of Gupta (1999), Baig (1992), Jha and Singh (1990). Sarma (2002), while studying the impact of coal mining on the vegetation characteristics of the Nokrek Biosphere Reserve of Meghalaya outlined that the composition of vegetation reduces in the mined areas with that of the adjacent unmined areas. Lyngdoh *et al.* (1992) reported less number of species in the mine spoils of different ages to that the unmind sites.

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Iverson and Wali (1982) observed an increase in species richness with age in reclaimed coal mine spoils.

3.6 Impact by humans on Species Distribution Pattern

Plant populations exhibit three patterns of spatial distribution, viz., contagious or clumped, random and regular or uniform. Patchiness, or the degree to which individuals are aggregated or dispersed, is crucial to the understanding of how species uses resources, and how it is used as a resource. Besides, the distribution pattern of species population is often related to its productive biology. Webb *et al.* (1967), Ashton (1972) and Austin *et al.* (1972) indicated that in the absence of major disturbance, soil and water conditions play major roles in controlling species distribution pattern. In Mukomawabani area most of the tree species showed contagious distribution pattern. In the mined areas all the component of the plant species represented contagious pattern of distribution. The contagious distribution pattern of species indicated the mosaicness of the forest stand. The contagious of the species suggests the increase in fragmentation of the natural vegetation due to mining. Similar species distribution pattern was observed by Sarma (2002) in coal mining areas of Nokrek biosphere reserve of Meghalaya.

Despite the value of mopane woodland, its resource are over utilized, mis-managed and even transformed to other land use. This has resulted in the circles of degradation surrounding the villages. The main drivers of woodland resource depletion around the villages are the result of high population pressure (Shackleton *et al.*, 2001), coupled with poverty (Shackleton *et al.*, 2000; Watson and Dlamini, 2003), lack of woodland management responsibilities and diminished power of traditional leaders (Evans *et al.*, 2000; von Maltitz and Shackleton, 2005). Lack of technical capacity to enforce conservation regulations increases the likelihood of infringement of regulations. The outcome is high pressure on local fuelwood resources (Gandar, 1983), increased distance (Mercer and Soussan, 1992) and time (Campbell *et al.*, 1993) to harvest woodland resources.

Wood for fuel is an important source of energy to over eighty five percent of southern Africa rural citizens (MacGarry, 1987; Erkkilä and Siiskonen, 1992). 84% of rural inhabitants in the woodland depleted villages and 76% in the woodland abundant villages use fuelwood as their main source of energy for both cooking and heating (Makhado *et al.*, 2009). Above Seventy percent of people in the woodland depleted village and 87% in the woodland rich

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villages are jobless and they heavily rely on the nearby woodland for power supply and construction poles. People in rural area live without income and with no affordable alternative energy sources but wood (Willis, 2004), as fuelwood is the cheapest, available and most accessible source of energy (Okello *et al.*, 2001; Mercer and Soussan, 1992; Liengme 1983) it is indeed preferable.

Colophospermum mopane wood has an energy production of about 21.570 kJ/kg (Tietema *et al.*, 1991), making it the most preferable cooking option. Although electricity, paraffin and gas are available villagers mostly use them for lighting and nothing else. The expense of using electricity is too high particularly for cooking and heating purposes. High cost of electricity other than fuelwood has increased woodland depletion in southern Africa (Banks *et al.*, 1996; Rathogwa *et al.*, 1999). More than half of the population use wood on a daily basis for cooking and heating, which is influenced by the fact that household fuelwood harvesting is a free commodity in rural areas. The use of wood especially for cooking and heating is also influenced by culture. It is widely believed among VhaVenda and Shangaan elders that porridge cooked using fuelwood have better taste than that cooked using electricity, however I believe it is the taste that they are used to it which is playing the main role in determining which porridge taste better. Wood is the first choice energy source for cooking by elders in rural areas. The preference of fuelwood particularly for barbecue "*braai*" is also popular in urban areas, which is increasing the commercialization of fuelwood. In 2014, a 10 kg pile of *Colophospermum mopane* fuelwood was sold for R10 in Mukomawabani a slightly increase from 2005 price of R8 recorded by (Makhado et.,al 2009) at the Sibasa market near Thohoyandou, Limpopo Province.

Colophospermum mopane is highly valued by villagers for fuelwood because its wood produces long-lasting coals, which Prior and Cutler (1992) attributed to high content of calcium crystals in its wood. The high quality of fire produced by *Colophospermum mopane* and its abundance due to its ability to coppice after harvesting makes it highly preferred by villagers as a primary source of energy. Drastic reduction of the surrounding woodland resources in rural areas has increased the distance travelled and time taken by women and girls to harvest fuelwood. More than 1 km is travelled by women and girls to harvest fuelwood from the surrounding woodland. In the woodland depleted villages, between one and five hours are spent by females when harvesting spent by females in the woodland abundant villages. Increased distance and time for fuelwood harvesting was also reported in most parts of southern Africa. Liengme (1983) estimated that women in Giyani, Limpopo Province, South Africa travelled between four and five kilometers, taking three to six hours to

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harvest fuelwood. This is close to an average of four hours spent by women in the Mametja village, Limpopo Province, South Africa (Twine *et al.*, 2003).

In Namibia, women travelled between eight and ten km to harvest fuelwood (Erkkilä and Siiskonen, 1992), while women in certain woodland abundant villages of Zimbabwe spent between one and seven hours (Campbell *et al.*, 1993). Long distance travelled and time spent during fuelwood harvesting limits women involvement in other socioeconomic development activities. This also results in women suffering from back pains and leg pains (Madzibane and Potgieter, 1999). This could concurrently increase the use of less preferred species for fuelwood, which is species that emits high amount of carbon and smoke particulates. This might have a negative effect on the health of fuelwood users, mostly women and girls (Terblanche *et al.*, 1994).

3.7 Conclusions and Recommendations

Extensive coal mining has led to shrinking of land base and creation of a landscape dotted with mine spoils. The pitfalls of such activities are felt in the impairment of vegetation in these ecosystems. The present study analyses the tree community characteristics in the mine affected areas and impact of coal mining on vegetation. It was found that there were more impacts adjacent to Mukomawabani (Point A) and medium impacts midway (Point B) towards the mine and low impacts (Point C) closer to the mine. Mining of coal has caused damage to the landscape and the biological communities in enormous ways. The number of tree species drastically decreased in their number due to mining.

The following tree species *Colophospermum mopane, Commiphora pyracanthoides, Gardenia volkensii, Combretum apiculatum, Commiphora mollis, Terminalia prunioides, Grewia flava* were found dominating the areas and these species can grow in the moisture stress environment. Tree diversity was lower in the adjacent to the mine. Relative density increases from the village to the mine, relative cover increases from the village towards the mine, relative frequency of certain species shows no trend along the profile but *Colophospermum mopane* had high relative frequency and it increases from the village towards the mine, importance value increase from the village towards the mine.

Even though all four aspects: Relative density, cover, frequency and importance values of sampled tree species seems to be favoring mine by indicating an increase from the village towards the mine, biodiversity was the only thing that was compromised by mining activity.

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Biodiversity was found to be decreasing from the village to the mine. Meaning coal mining favors few species and compromise the livelihood of majority of tree species hence decreasing biodiversity. This supports our hypothesis positively indeed.

Possible root courses for the above results could be as follows:
Biodiversity increasing from mine towards the village: Vegetation around the mine serves as the buffer zones absorbing multiple disturbances which has resulted species selection and by chance *C. mopane* was favored or it has manage to adapt better than other tree species hence establishing itself than others. And being away from the village has exempted it from over harvesting. Adaptation takes time however adjacent to the mine opening it's were disturbance dates longer and it is now stable. While the mine is growing older it starts to introduce disturbances away from its opening posing challenges or disturbing the ecosystem. This has been witnessed away from the mine in point B whereby tree species are drying out in numbers again surface fragmentation is common, surface fall has been witnessed, the ground pose threat to both floral and faunal communities.

In Point C closer to the village biodiversity is higher but that is not because people voluntarily wanted to conserve it. It is simply because mining impacts are relatively lower in this area. However public induced impacts are higher particularly in wood producing plants and tree species with palatable leaves. Those plants are over harvested simple because they are within a walking distance. That is the main contributing factor of lower relative density, cover, frequency, and importance value in this point. So tree species with good canopy for shade, wind shielding, and decoration potentials were left unharvest which has contributed positively in biodiversity conservation.

The present study revealed that coal mining has adversely affected the vegetation in Mukomawabani. The habitats currently do not permit proper plant growth and development. The present study led to the conclusions that tree layer can be used as a tool of evaluating mining practice efficiency. Continuous vegetation analysis could help prevent drastic habitat loss, biodiversity loss and hydrological system depletion. It is evident from the above discussion that the mining activities in Tshikondeni are detrimental to the vegetation and general environment of Mukomawabani. It is advisable and recommended that such activities has to be strictly regulated to avoid further damage and scientific mining has to be maximized to minimize vegetation damage as well as the environment. Appropriate rehabilitation measures using the native plants with high importance value in the areas is recommended. The findings of the study could be quite useful while formulating the closure or reclamation plan for the affected areas.

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Colophospermum mopane is the ideal species for fuelwood supply and poles used for construction of traditional structures. Circles of degradation are common around the villages, indicating unsustainable resource use practices. Uncertain in the management of natural resources in rural areas as a result of high rate of unemployment coupled with poverty and population growth, which has increased the demand. Land use conversion and unclear responsibility in the management of woodland has also exacerbated the situation. In the light of this study, the followings options are proposed:

I) Introduction of ways and means that could ensure better usage of woodland resources.

II) Establishment of community projects with an objective of conserving natural resources and poverty eradication in rural areas.

III) Beginning of programs that educate local people off all ages about the need for conservation and its subsequent benefits.

IV) Application of bosquet woodland management, method and season of woodland resource harvesting in rural areas.

V) Working together between stakeholders, such as traditional leaders and conservation departments in an attempt to conserve woodland resources.

VII) Committee establishment of the above-mentioned parties to take the responsibility in the management of woodland and in the administration issuing of permits, which are in line with villagers' needs and resource availability.

VIII) Fund rising to help in conservation awareness at village level and for capacity development. The awareness campaign needs to include boscage management, fire management and project management and should target females than any other group since they are mostly involved in wood utilization.

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CHAPTER 4

ETHNOBOTANICAL UTILIZATION OF TREE SPECIES AROUND MUKOMAWABANI COAL MINING AREA

4.1 Introduction

Locally and internationally the scope of indigenous knowledge as a discipline is increasing in its growth mostly to the academics. Although many scholars from European countries are still struggling to understand the meaning of the term indigenous knowledge (Battiste, 2005). According to the classifications used by Western civilization Indigenous knowledge has been revealed as an extensive and valuable knowledge system, it is further described as a knowledge passed from similar culture or from different culture and interdisciplinary source of knowledge that represent the contexts of about 20 percent of the world's population. Indigenous knowledge is logical, covering both thoughts and observations, It includes rural and the urban, the settled and the nomadic, pioneers and aliens. Other names for Indigenous knowledge or closely related concepts are folk knowledge, local knowledge, wisdom, on-formal knowledge, culture, indigenous technical knowledge, traditional ecological knowledge, and traditional knowledge (Battiste, 2005). Traditional knowledge involves all knowledge pertaining to a particular people and its territory, the nature or use of which has been transmitted from cohort to cohort. This knowledge includes all kinds of scientific, agricultural, technical and ecological knowledge, including cultigens, remedies and the rational use of flora and fauna (Daes, 1993).

Knowledge of the environment is being lost in communities around the world, and there is an urgent need to conserve this knowledge to help develop mechanisms to protect the earth's biological diversity. The United Nations *Convention on Biological Diversity* recognizes the importance of Indigenous knowledge to the conservation and sustainable use of biological diversity, acknowledges the contributions of Indigenous knowledge as innovative approaches to environmental studies, and recognizes the validity of Indigenous science. It also recognizes the value of Indigenous knowledge, innovations, and practices to scientific knowledge, conservation studies, and sustainable development (Clarkson *et al.*, 1992).

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According to the World Health Organization (WHO, 1978), traditional medicine has been used worldwide to achieve total healthcare coverage of the world's population. The use of traditional medicine in primary healthcare has been recognized as the most important factor in curing various diseases (WHO, 2002), and it has been estimated that around 80% of the rural population still depends on plants for their primary healthcare (Cunningham, 1993). Traditional medicine practices and ethnobotanical information play an important role in scientific research, particularly when literature and fieldwork data are evaluated (Malla and Chhetri, 2009).

Medicinal plants also represent the most important healthcare component of biodiversity, and they must be conserved so that they may stay for a very long time without going extinct for the production of important medicine (Rahman *et al.,* 2004). Rural people have developed unique indigenous knowledge related to the use of natural resources and this knowledge needs to be documented before it is lost (Rahman *et al.,* 2004). It is a fact that mining do boost economy of the country provided it is well practiced. Poor mining practice compromises livelihoods. The compromise my affect soil, water, biodiversity and forest resources which are critical to the subsistence of local people (DEA *et al.,* 2013).

In Vhembe District people still believe and depend in indigenous knowledge and it is widely used especially in rural area such as Mukomawabani. Traditional healers are more likely to be consulted whenever a patient feels uncomfortable. Traditional healers are believed in treating various diseases in which some of them are incurable in hospitals. People in rural area like Mukomawabani depend on their Indigenous knowledge for primary health care, as a source of fuel and fodder. Degrading biodiversity strikes imbalance in terms of knowledge versus available resources. It was found to be valuable to conserve both knowledge and resources for current and future use or to keep the two matching (Rahman *et al.,* 2004).

There are many traditional healers around Vhembe District currently practicing. However their filled of specialization do differ depending on their knowledge. Some of the categories of traditional healers are herbalists, traditional surgeon, bone setters and tradition psychiatrists apart from the above stated categories there are ordinary residence with indigenous knowledge too even if it is not medicinal related its value cannot be ignored or undermined. It was found that there is a huge loss of knowledge and where knowledge was

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not lost it was found that it is no longer relevant since it involves usage of unreliable resources such as vegetation, water, soil and etc. This research was conducted as a means of indigenous knowledge reclamation. In this study indigenous knowledge related to local vegetation, soil and water resources will be investigated and documented.

The main aim of this research was to document Ethnobotanical utilization of tree species found in Mukomawabani and to achieve the above aim the following objectives were investigated:

1. To document all tree species found around Mukomawabani.
2. To assess socio-economic impacts of Tshikondeni coal mine.
3. To document indigenous knowledge linked to documented tree species.

The hypothesis was that there is a gap between indigenous knowledge and current environmental status.

4.2 Literature review

The words "traditional" and "indigenous" are of much significance in TEK literature. Traditional refers to handing down or the continuity of beliefs, culture and knowledge in accordance with the ways of a particular group of people, which have been long established through ancient experiences, while indigenous refers to a group of people who have originated from a particular culture or customs and live naturally in an environment. Traditional Ecological Knowledge has been shown to guide and sustain the operation of customary management systems (Ruddle, 2000).

A study by (Harkes and Novaczek, 2002) showed how local institutions of resource management have been successful in managing natural resources in indigenous communities. Generally, most of these local systems often proved to be more sustainable than many western or scientific systems (Slikkenveer, 1997). A local management system in Botswana based on the use of TEK in local resource management also proved to be sustainable and had positive implications for natural resource conservation (Phuthego and Chanda, 2004). However, the structure and dynamics of these local institutions are critical

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for the implementation of management practices based on ecological understanding in any society (Hanna *et al.*, 1996).

Traditional Ecological Knowledge is place-based, geographically specific, and is most often found among societies that have engaged in natural resource use in a particular place over a long period of time (Berkes, 1999). The TEK of any community is unique, not only to that ecosystem but is also based on the culture of the people and how they view their environment. Therefore, TEK cannot be adequately used or harnessed without understanding the culture of the community from which it originates (Menzies, 2006). Additionally, TEK of any community is not static, it evolves as the people learn different things and also adapt to changing environmental conditions (Charnley *et al.*, 2007). Thus, TEK is always updated with new information while the outdated ones are deleted (Menzies, 2006). It is because of these reasons that TEK cannot be generalised or used across different regions for resource conservation or management (Charnley *et al.*, 2007).

The TEK among indigenous communities is diverse, heterogeneous and varies mostly with gender and age (Turner *et al.,* 2000). Thus it is important to understand the ways that knowledge might be differentiated within a community based on these social factors (Menzies, 2006). Age and gender are very important factors that inform resource selection and use in many local communities (Dovie *et al.,* 2008). There is thus the need to fully understand distribution of TEK based on gender and generation in order to adequately enhance its conservation (Dovie *et al.*, 2008).

TEK is usually unevenly distributed in indigenous communities due to the fact that livelihoods are mostly gender-specific. Family and ritual roles as well as social interactions also affect resource use and subsequently knowledge distribution. However, women or men may be more familiar with certain species and their uses due to their regular contact with them in their livelihoods or family obligations (Zent, 2009). There is much controversy surrounding the issue of gender and TEK. Some researchers argue that females, due to their role in communities are more involved in natural resource use and thus hold more knowledge (Begossi *et al.*, 2002) while other studies argue that males are generally more knowledgeable than females (Setalaphruk and Price, 2007; Stagegaard *et al.*, 2002; Dovie *et al.*, 2008). Although many studies have shown males to be more knowledgeable than

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females, this could be attributed to the way in which such studies are conducted, often resulting in a low level of female representation. However, the understanding of the distribution of TEK based on age and gender is inadequate (Dovie *et al.*, 2008).

Resource use may also affect the way in which TEK is distributed in any society. Just like western science, TEK is not evenly distributed in any society. Different groups or individuals have and utilize knowledge differently hence the development of local specialists and generalists (Chalmers and Fabricius, 2007). According to Davis and Wagner (2003), the assumption that all rural people equally hold TEK would be inaccurate. Specialist identification should be of high importance in TEK research because the TEK information gathered is only as reliable as the groups of individuals or knowledge holders identified and used in the study. However, it is important to involve all knowledge holding groups in any TEK research (Chalmers and Fabricius, 2007; Davis and Wagner, 2003).

The transmission of TEK is a critical process of education in any indigenous society (Ruddle, 2000). Although knowledge is the foundation of social life, the sociology of knowledge, and particularly its transmission between or among generations, remains a neglected field (Ruddle, 1993). Parents play a crucial role in the transmission of TEK in indigenous communities (Hewlett and Cavalli-Sforza, 1986). In many communities, children learn about TEK from their parents but as they grow older, the path ways through which they learn about TEK may change. Peers and personal experience become the main ways though which knowledge is learned or transmitted in the later stages of life (Eyssartier*et al.*, 2008). Hewlett and Cavalli-Sforza, (1986) identified two distinct modes though which TEK is transmitted; vertical transmission, from parents to child (inter-generational) and horizontal transmission, between individual of the same generation. Although these two modes of transmission are present in all indigenous communities, the vertical transmission accounts for most of the TEK transmitted in indigenous communities (Hewlett and Cavalli-Sforza, 1986).

The transmission of TEK in most communities begins normally as children help their parents on farms, hunts or resource gathering expeditions (Eyssartier *et al.*, 2008; Turner *et al.*, 2000). Most studies show women to play a fundamental role in the transmission of TEK at this early stage since children normally tend to follow their mothers to farms or for resource gathering, especially in the case of fuel wood and wild fruits gathering (Voeks, 2007;

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Vazquez-Garcia, 2007). Although children mostly acquire experience and TEK by participating and helping parents in resource gathering or farming, stories or folk tales that are told to children in certain communities are mostly imbedded with lessons about ecology, resource use and conservation of a community's natural environment and thus serves as another channel through which the TEK of that community is passed on to the next generation (Turner *et al.*, 2000).

Traditional Ecological Knowledge could also be transmitted through formal or informal means. A study by Knudsen (2008) showed that, though TEK transfer is mostly informal, from parent to child, there are other instances where it may be formal, not necessarily though vertical transmission (parent to child), but through formal apprenticeships. However, Ruddle (1993) suggests that the mode of TEK transfer, formal or informal should not be of high relevance since TEK transfer in either case is not done haphazardly and is carefully structured whether it is done though formal means or informal means.

Studies have shown that currently, children do not spend enough time with parents who primarily impart them with this knowledge, partly due to education or schooling at such early stages in life (Tsuji, 1996). However, language which forms an important part of the transmission of TEK has been greatly distorted with the introduction of formal education and the schooling system in many indigenous communities (Turner *et al.,* 2000; Tsuji, 1996). The introduction of western form of education has contributed to the loss of specialized indigenous language vocabulary thereby affecting the efficient transmission of TEK among children (Turner *et al.,* 2000).

A very important theme concerning TEK research is the integration of TEK with science to enhance sustainable resource conservation and management (Casimirri, 2003). TEK has been shown to complement scientific knowledge in many disciplines, especially in the area of conservation and natural resource management (Gagnon and Berteaux 2009). When TEK is successfully integrated with resource management, it can result in an increase in the efficiency of resource management especially by influencing management objectives through its various values and perspectives (Manseau *et al.*, 2005; Phuthego and Chanda, 2004).

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Traditional Ecological Knowledge may serve as a potentially valuable source of information when considered in resource management and conservation. TEK can be useful in identifying areas of concern for communities and resource users, making conservation and management more locally relevant (Rist *et al.,* 2010). In some areas, TEK has been much useful in providing information about certain species where there was none available. TEK has also been useful in providing valuable information about species abundance, uses and distribution. This is because local people mostly have a high level of familiarity with their environments and the species that may occur around them (Gagnon and Berteaux, 2009).

Traditional Ecological Knowledge can be useful to inform scientific approaches towards natural resource management and conservation as well as also serve as a base line to fill information gaps that may exist concerning certain resources (Rist *et al.*, 2010). Although very useful, little attention has been given to the relevance of TEK. Many studies have focused on the integration of TEK into science, but less attention has been paid to identifying specific areas where it is most useful and where it may be most problematic (Rist *et al.*, 2010).

Much effort has been put into comparing and contrasting TEK in order to better understand TEK in relation to science so that the two can be better integrated (Berkes, 1993). Despite the attempt of many researchers to integrate TEK and science, other researchers believe there is the need to better understand TEK as part of an entirely different worldview with its associated values, institutions and management systems (Casimirri, 2003). However, the possibility of the usefulness and integration of TEK in science and resource management is saddled with contradictory views.

The United Nations Convention on Biodiversity stresses on the need to preserve, protect and apply the knowledge of indigenous people in order to fully achieve biodiversity conservation and sustainability (CBD, 2004). However, a very important problem associated with the integration of TEK and science is the notion for scientist to consider TEK as data. There is the need to move beyond this current notion and find out how the TEK of relevant indigenous communities can form the basis for community based resource management or adaptive institutions of resource management (Casimirri, 2003).

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According to Manseau *et al.,* (2005), for TEK to be effectively integrated into resource management, it is important to respect the diverse knowledge systems that may exist irrespective of the ways in which they were acquired. This study also acknowledges capacity building of local or indigenous communities to be essential if TEK should be successfully integrated with resource management and conservation (Manseau *et al.*, 2005). However, there is the need for researchers and scientists to better understand local values, concerns and alternative management perspectives of indigenous communities in order to achieve maximum results from resource conservation and management (Casimirri, 2003).

Although useful in various aspects of science, TEK may appear inaccurate from the western paradigm because it is based on different world views and belief system. According to Charnley *et al.*, (2007), an indigenous community in America believes the forests in that community are able to survive due to their interventions. This is contrary to the scientific form of resource conservation which believes a protectionist approach to conservation is the best. It is contrasting views like these that make it difficult to integrate both TEK and science efficiently in resource management.

Another problem is that TEK in most cases is poorly documented and is eroding or disappearing in many communities and may not persist to inform scientific decisions (Charnley *et al.,* 2007). Because of the pace at which this knowledge may be eroding, certain scientists have suggested that it be documented and stored. This may not be appropriate since TEK is locally specific and dynamic (Agrawal, 1995). Thus, the documented TEK of a community may not be useful after a period of time (Charnley *et al.*, 2007).

More often than not, certain TEK holders refuse to share their knowledge with scientist because they feel it may not be used responsibly or even benefit them. This also poses a threat to knowledge integration since the integration of TEK and science is impossible unless local knowledge holders are willing to share their knowledge. Local knowledge holders will only share their knowledge if they will benefit from it. There is therefore the need for incentives which will benefit local communities such as community resource management programs it order to make them feel they are part of resource management and conservation (Charnley *et al.,* 2007).

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4.3 Study Area, Material and Methods

4.3.1 Study area

The project was carried out in Mukomawabani a village. The village is closest to Tshikondeni coal mine in Mutale local Municipality of Limpopo province in South Africa. The area is very rich in biodiversity. There are many plant and animal species that local people use for various purposes. The area is surrounded by mountains, Mutale River, Kruger national park, Makuya Nature Reserve and a number of other tourist attractions. Mukomawabani experiences a hot semi-arid climate with hot temperatures dominating year-round (Taylor and Kruger 1986).

The summer temperature may sometimes exceed 40 degrees Celsius. Average annual precipitation amounts to 372 mm and is highly concentrated in the summer months from October to April. Severe late-afternoon and evening thunderstorms are common. Winter is extremely dry, with almost zero precipitation typically recorded in the driest months from June to August. Clear skies and exceptionally low humidity at this time of the year enable temperatures to plunge close to freezing at night, although frost is fairly uncommon (Taylor and Kruger 1986). Details on study area have been discussed in chapter two.

4.3.2 Material and methods

To gather information members of the community were interviewed to assess environmental and social impacts of coal mining. All sampled tree species were listed and using a structured questioner individuals from the community were interviewed based on their indigenous knowledge and their knowledge was summarized in the table below. There was an open ended question assessing individuals understanding in relations to the environment and mining activities. The interview samples were stratified based on gender and age (youth 18-35), middle age (36-55), old age (above 56). For the purpose of this study, only people who had been staying in the village since birth or for the past 30 years were sampled. A total of 33 respondents were randomly selected. The ethnobotanical data was recorded in a note book and was analyzed using Microsoft Excel spreadsheet (2010 version).

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4.4 Results and Discussion

4.4.1 Informants profile

Individuals amongst the community were through a door to door visit interviewed since Mukomawabani is a small village. Members who were found at home willing to be interviewed were interviewed after their consent. Figure 4.1 indicates that majority of informants were female with a total percentage of 70 and males at lower 30 percent.

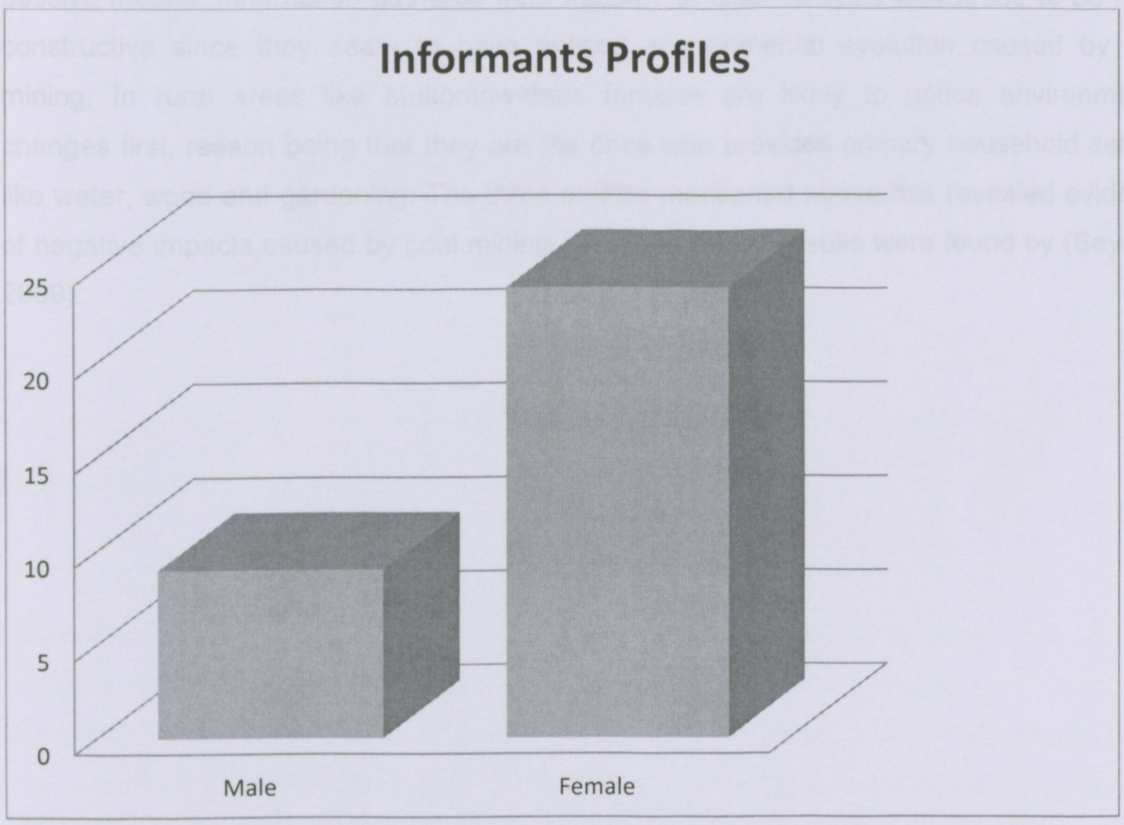


Figure 4.1: Graph representing male vs. female informants' profile.

A total of Thirty three (33) citizens were interviewed during the survey and 24 were female and 9 were males. All of them were Venda the survey was carried out the whole of 2014. Citizens were visited in their respective homes during the day and they were interviewed on all issues involving their immediate environment and its health status.

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The fact that residence were visited during the day may have contributed in these profile dominated by females. It has been observed that since males are breadwinners chances of meeting them during the day are always slim. Again chances of meeting more youth was low since they are often at school during the day.

However, with old aged informants being more knowledgeable than youths and middle aged informants. Resource use also affected the distribution of knowledge indicating that knowledge was highly dependent on resource use. Females were the main actors in the transfer of TEK in this community and the majority of this knowledge was acquired through passive means. Information gathered from majority of elder females was found to be more constructive since they seem to have noticed environmental evolution caused by coal mining. In rural areas like Mukomawabani females are likely to notice environmental changes first, reason being that they are the once who provides primary household service like water, wood and gardening. The three entities mentioned above has revealed evidence of negative impacts caused by coal mining activities, similar results were found by (Seyram, 2009).

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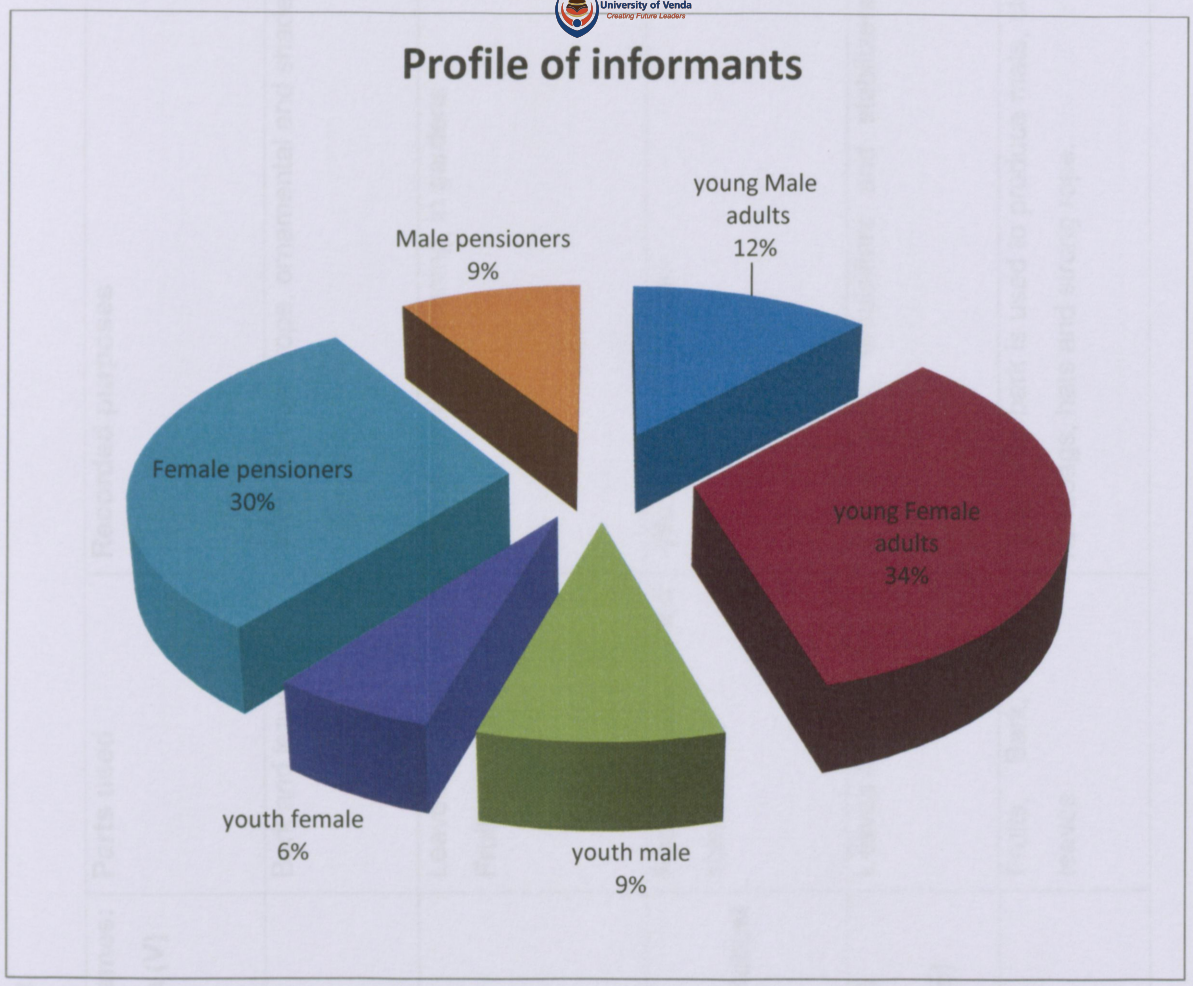


Figure 4.2: Graph representing profile of informants.

Furthermore young adult females were dominating than any other group. Figure 4.2 indicates that female pensioners holds 30 percent whereas male pensioners holds nine percent (9%), young female adults holds 34 percent whereas young male adults holds twelve percent (12%), female youth holds 6 percent and youth male holds nine percent (9%).

4.4.2 Inventory of plant use.

Informants indicated different use options of tree species identified through tree layer profiling of Mukomawabani vegetation. Parts used and other purposes were recorded in table 4.1.

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Table 4.1: List of tree species recorded from Mukomawabani in 2014.

Family	Scientific name	Common names: English (E), Venda (V)	Parts used	Recorded purposes
FABACEAE	*Acacia karroo* Hayne.	Musu (V), Sweet thorn(E)	Bark and leaves	-Wood, timber, rope, ornamental and shades.
FABACEAE	*Acacia nigrescens* Oliv.	Munanga(V) Knob thorn (E)	Leaves, bark and Fruits	-Wood, furniture, tanning, in gardens
FABACEAE	*Acacia robusta* Burch	Munanaga(V) River thorn or Robust thorn (E)	Roots, leaves and stem.	-Wood used for yokes.
FABACEAE	*Acacia senegal* Willd	Tshinangaphele (V) Three- hook thorn(E)	Leaves and Fruits	-Wood, gum, emulsifiers and stabilizers in food.
BOMBACACEAE	*Adansonia digitata L*	Muvhuyu (V) Baobab(E)	Fruits, Bark, and leaves	-The inner bark is used to produce mats, cloth, handbags, hats and strong rope.

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				- Ornamentals. - Refreshing drink.
CAPPARACEAE	*Boscia albitrunca* Gilg and Gilg-Ben.	Muthobi(V) Shepherd's tree (E)	Fruits Bark Roots	-Household utensils - Fruits are eaten fresh -Roots are used to make porridge. -Fresh fruits and pounded roots are used to make beer. -Leaves are used by cattle and game. - Coffee substitute.
CAESALPINIACEAE	*Colophospermum mopane* (J.Kirk ex Benth.) J.Léonard	Mupani(V) Turpentine tree (E)	Stem, leaves	-Host mopane worms -Leaves are eaten by live stock -Construction timber -Heartwood used as pestle for grain stamping -Firewood -Bark extracts are used for colouring leather.

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				-Inner bark used for strong cordage and twine.
COMBRETACEAE	*Combretum apiculatum* Sond.	Musingidzi (V) Red bushwillow (E)	Leaves, bark, stems	-Refreshing tea. -Leaves are browsed by game and livestock. -Build huts and fences -Sticks used for stirring porridge. -Bark extract are used for tanning.
COMBRETACEAE	*Combretum imberbe* Wawra	Mudzwiri(V) Leadwood (E)	Roots and Stem	-Food. -Ashes are used as toothpaste. -Used for fencing and grain stamping mortar. -Is used as substitute for whitewash.
BURSERACEAE	*Commiphora edulis* Engl.	Mubobobo (V) Rough-leaved Corkwood (E)	Roots, stem and leaves	-Leaves are browsed by game and cattle. -Roots are edible and are used for moisture than for food. -Used for carve household utensils. -Poles are used for ceremonial purposes.

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BURSERACEAE	*Commiphora mollis* Engl.	Muukhuthu (V) Velvetleaf corkwood (E)	Roots and stem	-Fleshy roots used for moisture. - Wood.
BURSERACEAE	*Commiphora pyracanthoides* Engl.	Mutalu (V) Common corkwood (E)	Roots, Bark and stem.	-Roots are eaten for their sweet fresh water -Gum from bark is edible but bitter -Gum from the stem is used to form lather when boiled in water and is used to wash clothes. - Extracts from bark are used as hair straightener. -Fire sticks.
FLACOURTIACEAE	*Dovyalis caffra* Hook.f.	Mutunu(V) Kei-apple (E)	Fruits, leaves	-Fruits are eaten fresh. - Making jam and jelly -Leaves are browsed by cattle and game. -Used as attractive and impenetrable hedge.
RUBIACEAE	*Gardenia volkensii* K.Schum.	Tshiralala(V) Bushveld gardenia (E)	Roots, stem and Fruits	-Firewood. -Carving turnery.

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				-Garden ornamentals.
SPARRMANNIACEAE	*Grewia flava* DC.	Murabva(V) Velvet raisin (E)	Fruits, leaves, stems and barks	-Roof blenders. -Fruits are eaten fresh. -Dried fruits ground mixed with meal to make porridge. -Fruits are fermented to make beer. - Leaves are eaten by games and livestock. -Thick branches are ideal for making hunting bows and walking sticks. -Twigs are chewed and used as toothbrushes. -Tough bark is used for rope.
KIRKIACEAE	*Kirkia acuminata* Oliv.	Mubvumela(V) White Seringa(E)	Roots	-Wind shield. - Shade -Used for furniture. -Inner bark is used for ropes -Thick roots may be tapped for fresh water

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				during emergency. -Wood.
MIMOSACEAE	*Albizia anthelmintica* (A.Rich.) Brongn	Munyasela(V) Worm-bark false thorn, Worm-cure albizia, Bitter false-thorn (E).	Roots	-Wood. - Shade.
FABACEAE	*Pterocarpus rotundifolius* Druce	Muhataha (V), Round-leaved bloodwood (E)	Leaves and Stem	-Leaves are browsed by cattle and game. - General purpose timber.
COMBRETACEAE	*Terminalia prunioides* M.A.Lawson	Mutwari(V) Purple-pod cluster-leaf (E) or Purple-pod terminalia (E).	Stem, leaves, fruits and bark	-Wood - Hut poles - Kraal fences.

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COMBRETACEAE	*Terminalia sericea* Cambess.	Mususu (V) Silver cluster-leaf or Silver terminalia (E)	Roots, Bark, stem and Leaves.	-Wood. -Timber. -Furniture. -Rope. -Hoe handles.

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From sampled tree species it was found that stem and leaves are used more often followed by roots, bark and fruits. High stem usage is encouraged by low level of employment in the area. Matured stems are cut into small pieces and packed in plastic bags. It seems as selling wood is the most reliable and easy way of making cash in the area. However over harvesting of wood is contributing to loss of biodiversity.

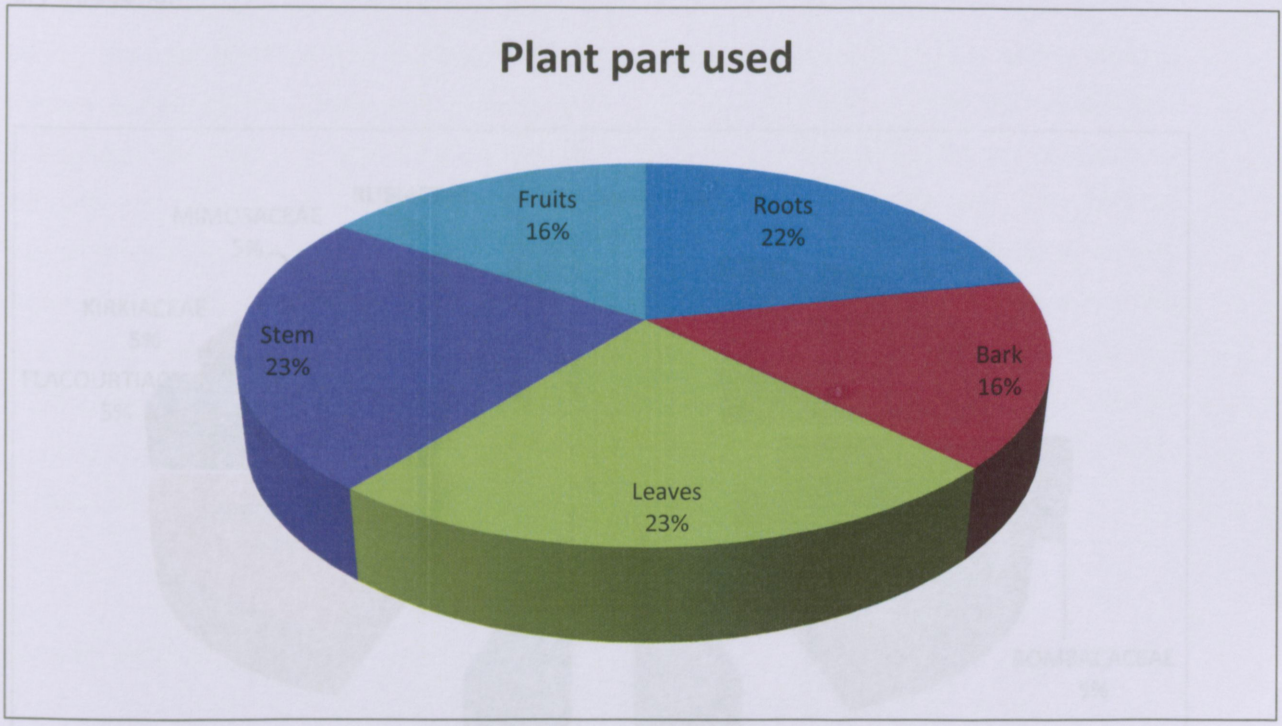


Figure 4.3: Graph representing plant parts used for various purposes.

The rate at which tree species are being harvested exceeds recovery rate. Overharvesting of stem automatically reduce seed production and number of leaves. Reduction of leaves affects micro-climate which adds in global warming. Taking into account that leaves are attached to the branches of the stem it is for that reason stem harvest is equivalent to stem harvest. Barks are often used for making ropes it was found that ropes made from barks are used once and disposed which encourage over harvest too and compromises tree health.

Selling wood seem to be the best possible and easier way that a person leaving in the area can engage to earn income. Taking into consideration that majority of plants found in the area are good for fuel, fencing and furniture.

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However more leaves are used by both animals and human beings. Most plants sampled have palatable leaves hence are preferred by animals, leaves provides shades in the area noting that Mukomawabani experiences hot long dry summer so, tree canopies provides shade to both human and animals and helps soil in retaining water. Fruits are usually used as diet by both human and animals and barks are often used either for making ropes or for medicinal purposes. Roots are used for medicinal purpose and as a source of water during dry seasons.

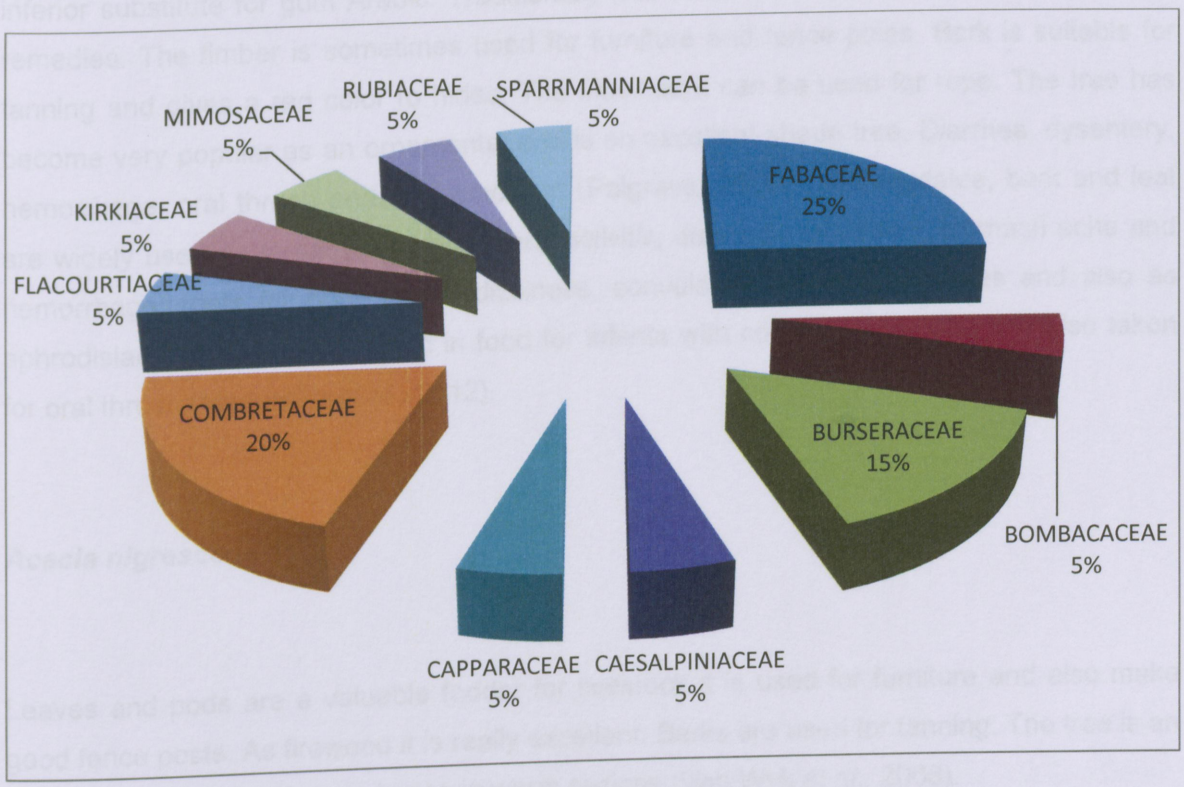


Figure 4.4: Graph representing tree families of the most recorded plants found in Mukomawabani.

Eleven families were recorded and From the graph it was found that Fabaceae family was dominating other families having 25 percent followed by Combretaceae with 20 percent and Burseraceae at third position with 15 percent and all eight remaining families had 5 percent each.

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4.4.3 Other uses and preparation techniques of recorded tree species

Acacia karroo

Flowers, leaves and pods are important fodder. Bark and leaf infusion are astringent and widely used for diarrhea and dysentery. The gum is well known as cape gum and is used as inferior substitute for gum Arabic. Traditionally it is used with colic, and in many traditional remedies. The timber is sometimes used for furniture and fence poles. Bark is suitable for tanning and gives a red color to hides. The inner bark can be used for rope. The tree has become very popular as an ornamental and is an excellent shade tree. Diarrhea, dysentery, hemorrhage, oral thrush and skin emollient (Palgrave, 2002). The exudates, bark and leaf are widely used as remedy for colds, conjunctivitis, diarrhea, dysentery, stomach ache and hemorrhage; roots for body pains, dizziness, convulsion, venereal diseases and also as aphrodisiacs; crushed root mixed in food for infants with colic; gum as food and also taken for oral thrush (Madureira *et al.,* 2012).

Acacia nigrescens

Leaves and pods are a valuable fodder for livestock it is used for furniture and also make good fence posts. As firewood it is really excellent. Barks are used for tanning. The tree is an attractive ornamental for gardening in warm regions (Van Wyk *et al.,* 2008).

Acacia robusta

In traditional medicine, root powder is applied to swellings; a root decoction is used to treat dysmenorrhea, female sterility and schistosomiasis, a stem bark decoction to treat gonorrhea, abdominal pains and skin ailments, and leaves to treat snakebites (Lemmens, 2006).

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Acacia senegal

Leaves and pods are browsed by livestock and game. The timber is not very valuable, nevertheless branches are used for poles. In northern Africa the high quality gum of this plant is commercially exploited. It is well known as gum Arabic, a useful additive, emulsifier and stabilizer in the food and pharmaceutical industries (Eckman *et al.*, 1993)

Adansonia digitata

Fruit is soaked in water to make refreshing drink. Fruit pulp is used for fever, diarrhea and spitting of blood. Barks and leaves mixture are used to treat urinary disorders and mild diarrhea. Grinded seeds are given to children as a hiccup remedy. Thinner barks are used to produce mats, cloth handbags, hats and strong ropes. Sometimes the plant is used as ornamentals (Sugandha *et al.*, 2013).

Boscia albitrunca

Fruits are eaten fresh and can be used make juice. Flower buds may pickled in vinegar and used as a substitute for capers. Roots are dried and ground into fine powder and mixed with grain meal to make porridge. They are coffee substitute pounded fresh roots are used brew beer. Roots decoctions are used in the treatment of hemorrhoids. Timber is used for household utensils. Leaves are browsed by cattle and game (Palmer and Pitman 1972; Brundin and Karlsson 1999)

Colophospermum mopane

Serve as Mopane worms host. Leaves are eaten by livestock. Bark decoctions are used for diarrhea, leaf infusions for constipation and chewed leaves are applied to wounds to stop bleeding. Gum exuding from heated branches is used to cure wounds that are slow to heal.

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It's again used as durable timber, used for fuel, bark extracts gives a pale brown color to leather. The inner bark makes strong cordage and twines (Palgrave-Palgrave.*et al.,* 1988).Mopane, is one of the most important tree species. (Liengme, 1981; 1983; Mashabane *et al.*, 2001). *Colophospermum mopane* is also used for treatment of various animals and human diseases in southern Africa (Watt and Breyer-Brandwijk, 1962; Palmer and Pitman, 1972; Madzibane and Potgieter, 1999; Mashabane *et al.*, 2001), and hosts the mopane worms, larvae of the moth *Imbrasia* (Kozanayi and Frost 2002). Other viable products harvested from mopane woodland by rural dwellers include stink bugs, termites, edible locust, edible mushrooms, honey, thatching grasses and wild fruits (Shackleton, 2005; Makhado *et al.*, 2009).

Cobretum apiculatum

Edible, dark red gum is found on some trees but is not very taste. Leaves are used for refreshing tea. Leaves decoctions do treat stomach disorders. Poles are used to build huts and fence. Sticks are used for stirring porridge. Used for firewood and leaves are eaten by livestock and game. Bark extract are used for tanning in kaokoveld (Van Wyk *et al.,* 2008)

Combretum imberbe

The gum is used as food, Roots decoctions are used to treat various ailments. Fresh leaves are placed on hot coals and smoke inhaled to treat cough and colds. Ashes are used as toothpaste. It is further used as grain stamping mortars. Ashes are used for white wash because of high lime content (Van Wyk *et al.,* 2008). Root decoction is used to treat constipation, headaches, stomachs, fever, dysentery and swellings, and as an anthelmintic for hookworm. The leaves are chewed, soaked in water and the juice drunk for chest complaints; it can also be used as an inhalant in a hot steam bath (Palgrave, 2002)

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Commiphora mollis

Fleshy roots are used as source of water to treat thirst. Leaves are browsed by game and livestock. Soft timbers are used for household utensils. Poles are used for ceremonial purposes. And can be grown from large stem cuttings. (Van Wyk *et al.,* 2008).

Commiphora pyracanthoides

Roots are edible and are chewed for fresh sweet water. Gum from the bark is said to be bitter but edible. A bark extract is used to treat gall sickness in calves. Gums from stem forms lather when boiled in water and used to wash clothes. Extracts from bark are used as hair straightener. Wood used for fuel (Van Wyk *et al.,* 2008).

Dovyalis caffra

Fruits are used to make jam and jelly and may be eaten fresh. Contains Vitamin C (Van wyk and Gericke, 2000; Wehmeyer, 1966). The juice of these fruits is squeezed onto maize and sorghum meal porridge by the Pedi people of South Africa (Palmer and Pitman, 1972, Fox and Young, 1982). They also can be cooked to make an excellent jam and jelly preserve. To neutralize the acidity they are mixed with grapes when making preserves (Venter and Venter, 1996).

Gardenia volkensii

Used medicinally as a cure for intestinal worms. Infusions of the fruit and roots are used to induce vomiting. The ash of burnt roots is rubbed into the chest to treat pneumonia, while headaches are treated by dripping an extract into the eyes or by placing a cold compress on the forehead. For earache an extract is dripped into the ear. The wood is very hard and suitable for carving ornaments, and plants are also believed to protect against lightning or

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evil spirits (Van wyk and van wyk, 1997). The roots and fruits are used as emetics; wood is used for carving, turnery, and sometimes used as garden ornamentals (Van Wyk *et al.*, 2008).

Grewia flava

Fruits are eaten fresh and can be dried for later use or can also be ground into a meal for porridge. Fruits maybe fermented to make beer or maybe distilled to produce potent alcoholic beverage. Leaves decoction can be used in expulsion of placenta retained in cow. Twigs are used as toothbrushes, thick branches are ideal for making hunting bows and walking sticks. Tough barks are used for rope (Mabogo, 1990).

Kirkia acuminata

Root grounds are used in toothache treatment, sometimes used for furniture, panels and household utensils. The inner bark is a source of fiber for low quality ropes. Thick roots may be cut off and tapped for fresh drinking water (van Wyk *et al.*, 2008) Bark extract drunk as diarrhea, cholera, dysentery and constipation medicine. Fruits juice applied to bitten part as snake antidote and fruit juice does treat wounds.

Pterocarpus rotundifolius

Leaf infusions are used to treat eye sores (van Wyk *et al.*, 2008).it can be used for furniture, shelves, picture frames, household utensils, wagon wheels and axe handles. Sap from the tree is used as eye drops to treat eye complaints. A leaf infusion is used as a wash or dropped into sore eyes. A root decoction is drunk to treat anemia.

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Terminalia prunioides

Young twigs are boiled to make tea, Barks are chewed and the sap swallowed for sore throat, cough and stomach cramps. (Van Wyk, *et al.,* 2008). The wood makes an excellent charcoal. It is used to make tool handles, house building, and wagon axles durable, even in salty water it resists borers. The rotten heartwood is sometimes pulverized and used as a fragrance for cosmetic purposes. A roots decoction is taken to treat constipation, cough and colds. The bark is chewed to treat coughs, sore throat and stomach-aches. A decoction is used to relieve postnatal abdominal pains (www.tropical.theferns.info).

4.5 Environmental and socio-economic impacts of coal mining.

Ground surface fragmentation its common around Mukomawabani, secondly water collected from rain was found to be black. Black color in water has been related to coal dust emitted from Tshikondeni coal mine. Residence are not sure whether this black coal contaminated rain water is good for plant species but they are sure it is not good for human and animal health.

Majority of plant species where showing early maturity, dwarfism and drying out which residence are claiming that plants in the area use to have long life span till the establishment of underground coal mining. Underground mining lowers water table so, it has been witnessed by early plant wilting and drying out. Furthermore coal mining has led to extinction of mopane worms in the area, according to citizen the area use to have lots of Mopane worms but some few years after the establishment of mine the worms started to get reduced in terms of availability above challenges has been predicted by (Neland, 2009).

However the most threatened species around Mukomawabani is *C. Mopane*. The same results have been noticed (Makhado *et al.*, 2009). Fruits producing plants like *G. flava* no longer produce more and big as they use to do and this has been impacting the community badly since it promotes competition between man and animals. Animals exhaust wild fruits earlier than they use to and start to feed themselves in agricultural farming fields. Such

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behaviour results in lower agricultural production lower plants yield has been highlighted by (Nel and Nel, 2009).

4.6 Conclusions and recommendations

Ethnobotanical survey concluded that the study area is experiencing high negative impacts high loss of biodiversity, underground dewatering, dust emission, poor air quality, soil quality, habitat loss, vegetation fragments, mono-species dominance, impacts on social values, impacts on public health, impacts on livelihood, impacts on climate, impacts on cultural and aesthetic resources. It seems as there is no more matching in indigenous knowledge and available resources.

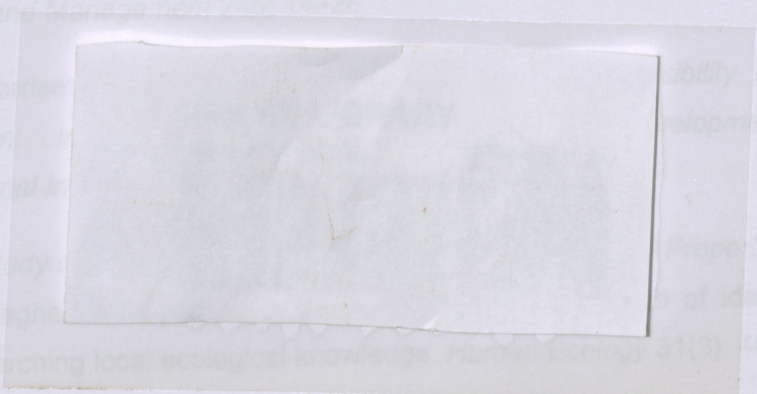
The study shows that age group and resource use are the most important factors that influence the distribution of TEK in this area. However, gender plays an important role in the transmission of knowledge. In an area where modernization is taking effect, the fact that younger people always know less and middle aged people do not necessarily know more than the youth may indicate a possible decline in TEK in the future. It is evident that less knowledge exists about rare tree species in this area. The most common species and tree species with more use values are known throughout the communities by all resource users. Knowledge on local tree species is highly dependent mainly on the abundance of the species and its use values to the people. This inference is particularly important considering the high rate of tree harvesting in this area. The continuous unregulated harvesting of trees in local communal lands may be a serious threat to the loss of not just species diversity but TEK of tress in this area.

There is therefore, a need to explore possible ways of preventing the erosion and extinction of this knowledge in order to conserve TEK and the dynamic culture of these people.
Acknowledging that the adverse effects of modernizations on TEK in these communities may be irreversible, it is important to understand the changes in community dynamics in order to implement strategies that may prevent this loss. Given that peers are effective in transmitting TEK, it is recommended that programs that target peer groups be implemented in order to ensure that TEK is passed on to the younger generation

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Furthermore research strongly recommends that the mine should support the ground as much as possible to minimize ground subsidence or falling and ground surface fragmentation which is the main contributing factors of habitat loss and biodiversity loss. A ground with lots of support will help restoring water table which will directly restore biodiversity. We further recommend that during land reclamation process plant species from Fabaceae, Combretaceae and Burseraceae families should be the once that receive more preference. Furthermore public awareness are necessary people need to be informed about the effect and consequences of overharvesting plants for any reason. Law enforcement should be maximized to ensure compliance for both members of the public and the mining company to speed up reclamation process.



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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This is the chapter that summarizes the whole project. Chapter 1 was the introduction of the whole project with the literature review. It also includes the aims and objectives of the study, hypothesis, and the structure of the thesis. Chapter 2 was about the study area, materials and methods it gives a detailed background picture of the study area and all environmental futures such as vegetation, soil, fauna, climate and human population, the methods or procedures and materials used in gathering relevant information. It further clarifies the reasons of making that method a method of choice for this study. It gives a thorough background of PCQ method, advantages and lists of materials needed for the study.

Chapter 4 was about an analysis of tree layer profile using the point-centred-quarter methods; analysis includes data collections and data analysis. The main aims of this chapter were to analyses the tree layer from Mukomawabani to Tshikondeni coal mine. And the main objective was to document tree species found between the two points. However to accomplish the aim relative density, relative cover, relative frequency and importance value were determined. And in conclusion it was found that trees were widely distributed closer to the village and the sparse decreases as we are moving towards the mine. Biodiversity was found to be higher next to the village and decreases as we are moving towards the mine.

Closer to the mine only *Colophospermum mopane* was dominating and it shows signs of encroachments. Moreover adjacent to the village more species recorded were found to produce low fuel energy and it is for that reason they are left. Half way or point B of the research area has high rate of plant dying out due to ground surface fragmentations. In short point A has high tree diversity but sparred point B has moderate tree diversity evenly distributed and high mortality rate, point C low tree diversity, dominated by one healthy mopane species which is even encroaching. Point A is more accessible by persons and they are the once putting pressure on tree diversity by constantly harvesting trees for illegal wood

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commercialization whereas point B is slightly far away and slightly unaccusable do to distance however it was found to be endangered by coal mining through dewatering and soil fragmentation. Point C serves as a buffer zone however it is working in favour of *C. mopane*.

5.2 Recommendations

This study strongly recommends re-introduction of the following seven (7) tree species which were found to have high importance value *Colophospermum mopane, Commiphora pyracanthoides, Gardenia volkensii, Combretum apiculatum, Commiphora mollis, Terminalia prunioides and Grewia flava,* during reclamation. Secondly Tshikondeni mine should support the ground surface where it is necessary to mitigate or to prevent habitat fragmentation. Thirdly uncertain in the management of natural resources in Mukomawabani area as a result of high rate of unemployment and loss of job due to mining closure coupled with poverty and population growth, which has increased the demand.

Unclear responsibility in the management of woodland has also exacerbated the situation. In the light of this study, the followings options are proposed:

I) Introduction of ways and means that could ensure better usage of woodland resources.
II) Establishment of community projects with an objective of conserving natural resources and poverty eradication in rural areas.
III) Beginning of programs that educate local people off all ages about the need for conservation and its subsequent benefits.
IV) Application of coppice woodland management, method and season of woodland resource harvesting in rural areas.
V) Working together between stakeholders and, all affected parties such as traditional leaders and conservation departments in an attempt to conserve woodland resources.
VII) Committee establishment of the above-mentioned parties to take the responsibility in the management of woodland and in the administration issuing of permits, which are in line with villagers' needs and resource availability.
VIII) Funds rising to help in conservation awareness at village level and for capacity development. The awareness campaign needs to include coppice management, fire management and project management and should target females than any other group since they are mostly involved in wood utilization

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Chapter 4 was about the ethnobotanical utilization of tree species and the subsequent perception by the impacts of coal mining. This study has revealed that there is high utilization of recorded plant species however due to sudden unexpected change in plant communities the knowledge they have its no longer valuable which supports the studies hypothesis. It was found that there is huge gap between indigenous knowledge and current environment. The fact that knowledge is no longer complemented by available resources poses challenges to traditional ecological knowledge (TEK). The study showed that age group and resource use rather than gender are the most important factors that influence the distribution of TEK in this area. However, gender plays an important role in the transmission of knowledge.

In an area where modernization is taking effect, the fact that younger people always know less and middle aged people do not necessarily know more than the youth may indicate a possible decline in TEK in the future. It is evident that less knowledge exists about rare tree species in this area. The most common species and tree species with more use values are known throughout the communities by all resource users. Knowledge on local tree species is highly dependent mainly on the abundance of the species and its use values to the people. This inference is particularly important considering the high rate of tree harvesting in this area. The continuous unregulated harvesting of trees in local communal lands may be a serious threat to the loss of not just species diversity but TEK of tress in this area.

Local people believe that TEK has declined in the community. Since the majority of the people acknowledge that this knowledge forms an important part of their culture, it is clear that its loss may not only be a loss for conservation but also result in the loss of the cultural diversity of these people. There is therefore, a need to explore possible ways of preventing the erosion and extinction of this knowledge in order to conserve TEK and the dynamic culture of these people. Acknowledging that the adverse effects of modernization on TEK in these communities may be irreversible, it is important to understand the changes in community dynamics in order to implement strategies that may prevent this loss. Given that peers are effective in transmitting TEK, it is recommended that programs that target peer groups be implemented in order to ensure that TEK is passed on to the younger generation.

This study recommends urgent reclamation of the environment in order to conserve both Indigenous knowledge and biodiversity. Furthermore we emphasize the idea of greater cooperation between villagers, traditional leaders and conservation departments in an

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attempt to conserve woodland resources particularly *Colophospermum mopane.* It is again recommended that the mine should involve general members of the public before they initiate reclamation process. There are several cracks on majority of buildings around Mukomawabani that the citizen claims they were caused by mine through blasting. A through study focusing on that is necessary. It is further suggested that Department of Mineral Resource (DMR) should engage with stakeholders to resolve this matter.

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