University of Venda
Creating Future Leaders

An Assessment of Household Energy Use, Emissions and Deforestation in the Thulamela Local Municipality

By

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A research dissertation submitted to the Department of Geography and Geo-Information Sciences in fulfilment of the degree of Masters of Environmental Sciences in the School of Environmental Sciences, University of Venda.

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DECLARATION

I, Uhunamure Solomon Eghosa, hereby declare that this dissertation submitted to the Department of Geography and Geo-Information Sciences for the award of Master's in Environmental Sciences degree at the University of Venda, has not been previously submitted for a degree at this or any other institution. This is my work in design and execution, and all reference materials contained herein have been duly acknowledged.

Signature ____________________ Date: _________________

DEDICATION

To Victoria Oghogho Uhunamure and in memory of my late father and friend, Pa Francis Uhunamure.

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To my mom, my brothers (Sunnyson, Alex, Owen and Innocent) my sisters (Felicia, Florence, Mercy, Vivian), and my nieces and nephews, thank you, love always.

ABSTRACT

Fuel wood is regarded as a major source of energy around the world, particularly in developing nations. Most rural communities around the world, consider forests as the repository of stored energy. The high dependence on forests as a source of fuel wood has a major impact on vegetation because trees take a long time to regenerate to maturity, hence high dependence leads to deforestation. Fuel wood is used for household needs, such as cooking and heating and its uses contribute to the emissions of Green House Gases (GHG) such as CO_2, CH_4, and Black Carbon amongst others. The study assesses household energy use, the amount of carbon dioxide emitted from the combustion of fuel wood, the extent of de-vegetation and strategies to ensure sustainable energy provisions in the case study areas. Primary and secondary methods were used to collect data. The data were analysed using Statistical Package for the Social Sciences (SPSS 21.0), showing the frequency distribution, measures of central tendency and chi-square to determine the extent of fuel wood used in relation to electricity. The primary data were collected through personal observations, field surveys, interviews and questionnaires, while secondary data included the 2011 South Africa Census data and remote sensing images, which with the aid of GIS, were used in mapping the vegetation change.

Key words: Deforestation; Emissions; Energy; Greenhouse Gases; Fuel wood.

Table of Contents

Contents **Page**

University of Venda
Creating Future Leaders

List of Figures

List of Tables

List of Abbreviations

AC - Average Consumption

CO_2 - Carbon dioxide

CO - Carbon monoxide

CH_4 – Methane

DME- Department of Minerals and Energy

EF - Emission Factor

FAO- Food and Agricultural Organization

FEF- Forest Energy Forum

g C - Grams of Carbon

IEC- International Energy Agency

IPCC- Intergovernmental Panel on Climate Change

Kg- Kilograms

LPG- Liquefied Petroleum Gas

NGO's- Non-governmental Organizations

NO - Nitrogen Oxide

OECD- Organization for Economic Co-operation and Development

RSA - Republic of South Africa

SSA- Statistics South Africa

SSA- Sub-Sahara Africa

UNCED- United Nations Conference on Environment and Development

WEC- World Energy Council

WHO- World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

Global forestland declined by 0.22% each year during the 1990s (FAO, 2009). Forest loss has been particularly significant in developing countries, which have experienced a total loss of forest area equal to 13.7 million ha/year in 1990–1995 (FAO, 2001). Forest resources in the form of fuel wood have contributed importantly to the total primary energy supply of developing countries (FAO, 2001). In 1995, a total of 3,350 million m^3 of wood was harvested worldwide, 63% of which was used for energy production (FAO, 2009). Worldwide, fuel wood consumption represents 3% of total energy used in industrialised countries and an average of 33% in developing countries. It also covers about 60% of final energy used in Africa, 34.6% in Asian countries; Canada and the United States, 11.8%; Latin America, 11.7%; and Europe, with 8.5% (WEC/FAO, 2009).

Biomass is known to provide food, fuel, feed, feedstock, fibre and fertilizer to mankind, which are known as the “6F”. At present, biomass is the world’s fourth largest energy source after coal, oil and gas, providing about 13% of the world’s energy consumption, with nearly half of the world’s population of 2.5 billion people in developing countries depending on traditional fuels (wood, dung, and crop residues) for their cooking and heating (Hall *et al.,* 1999). IPCC, Shell, IEA, and the UNCED predicted that after the year 2020, biomass and some other renewable energies will play a significant and increasing role in the world’s future energy mix (Bernades *et al.,* 2003).)

In most developing countries, fuel wood is primarily used for domestic energy, both in urban and rural environments. However, the detrimental impacts due to fuel wood use on human and environmental health, have made many governments seek the reduction of its use through the provision of alternative and potentially cleaner energy, with electricity being the most dominant form. Surprisingly, there are few studies pointing to changes in fuel wood use even with the introduction of electricity, most especially in rural areas of Africa (Madubansi and Shackleton, 2006). For domestic uses, the primary source of energy throughout the developing world is biomass, which contributes about 10.52% of total energy use (IEA, 2006). The most important form of biomass is fuel wood, although in areas where fuel wood is scarce due to natural or human factors, other forms of biomass, such as crop residues and dung become prevalent (Bhatt and Sachan, 2004; Shackleton *et al.,* 2004). In the developed world, there is interest in biomass as a source of energy, and as renewable energy (Bernades *et al.,* 2003).

In Sub-Saharan Africa, the staple energy forms for most rural, peri-urban and urban communities are fuel wood and charcoal. These also constitute part of the energy used by small-scale enterprises like bakeries, brick-making industries and fish-smoking businesses (Sheya and Mushi, 2000; Brouwer and Falcao, 2004). As a source of energy, wood has been used in numerous ways by mankind, however, cooking and heating are the most common uses (Munalula and Meincken, 2009). The contribution of fuel wood to the total energy expended varies normally from one region to the other and is mainly determined by the developmental level and its availability in the region (Munalula and Meincken, 2009).

In several of the developing countries, it is estimated that fuel wood still accounts for up to 90% of the total energy consumption because of the unaffordable costs of other energy sources, as well as the increasing scarcity of wood resources. In such areas, firewood has become a tradable commodity (Eberhard, 1990). The factors that influence the extent of wood use as energy include the availability and accessibility of electricity, household income level, degree of urbanization, cultural and traditional norms. In South Africa, especially in rural areas, most people use wood for energy purposes more than for anything else. The choice of fuel wood is normally governed by the availability, accessibility, burning duration, maximum temperature, the ash and energy content (Raliseo, 2003).

Depending on the settlement patterns, generally, fuel wood collection is from communal forests and agricultural fields around the homestead or village. The collections are preferentially of dead and dry branches, but as the demand continues to increase, it begins to exceed the available deadwood resources, leading to live woody stems and branches being cut and dried for fuel wood, which over time brings about woodland degradation (Grainger, 1999). Concerns about this and the assumption that fuel wood harvesting would result in widespread deforestation have therefore created a gap between demand for fuel wood and the available supply which gave rise to what was referred to as the ''Fuel wood Crisis'' in the global energy planning arena in the 1970s which projected that entire developing nations were going to have insufficient woodland in the future. (Eckholm, 1975; De Montalambert and Clement, 1983). Studies have shown that the consumption of fuel wood as a major source of energy has outstripped the mean annual increase in tree stock by up to 200 percent (Boahene, 2008).

However, the introduction of electricity in rural areas has had little or no bearing on the demand for fuel wood. Up to 95% of households with access to electricity still use fuel wood as their primary energy choice for cooking and heating (Davis, 1998; Madubansi and Shackleton, 2006; Thom, 2000). Households, preferentially invest their limited financial resources into fuel wood rather than electricity in order to meet their domestic energy needs (Davis, 1998; Thom, 2000). This preference is linked to various socio-economic factors such as the prohibitive costs of monthly electricity tariffs (relative to household incomes) and the costs of purchasing appliances that need to be maintained efficiently using electricity (Williams and Shackleton, 2002).

The cost of electricity relative to the financial income earned by these households is a major factor preventing these households from switching exclusively to electricity (Williams and Shackleton, 2002). Madubansi and Shackleton (2006), found that rural households tend to incorporate electricity into their domestic energy mix, primarily using electricity for lighting even though subsidised electricity tariffs resulting as free basic allowance are granted to them by the national electricity provider, ESKOM (Davis, 1998; Thom, 2000).

In rural areas, where the majority of the households relies extensively upon fuel wood as their basic energy source, (Sheya and Mushi, 2000; Vermeulen *et al.,*2000; Kituyi *et al.,*2001; Brouwer and Falcao, 2004; Shackleton *et al.,* 2004) its widespread use has been linked to a number of environmental problems, including deforestation, biodiversity loss, climate change and land degradation. The presences of these environmental problems have detrimental consequences on the sustainability and livelihood security of the people (Sankhayan and Hofstad, 2001). The consequences may be manifested as a decrease in human well-being that can be measured in both social and economic terms, such as longer distances walked for fuel wood collection (Brouwer and Falcao, 2004).

In South Africa, for instance, energy policies have been designed and developed by the post-apartheid government to widen access to adequate and affordable energy for urban and rural households However, this has not hindered the people from harvesting fuel wood as a source of energy (Davies, 1998). The Department of Energy has embarked on as electrification programme in most rural areas of South Africa. The Department of Science and Technology and energy stakeholders such as the NGO's and other organizations have joined forces to come up with strategies to reduce the over-exploitation of natural resources, to alleviate poverty, and empower people. They have come up with the Green Economy strategy that aims at addressing issues such as climate change and global warming and improving the lives of rural communities (DME, 2003).

1.2 Statement of the Research Problem

Energy is a fundamental focus of development and it forms the central part of social, environmental and economic challenges in any country. Globally, most governments are now looking at locally available, renewable and alternative energy options in order to address the issues of climate change and the need for the provision of cleaner energy and security. Fossil fuel combustion contributes greatly to carbon dioxide emissions, which is the main greenhouse gas that has been linked to climate change. Reliance on fossil fuels to meet energy requirements is recognized, but as concern about climate change grows, there is a need for the provision of alternative energy, preferably energy that is renewable.

Fuel wood is only regarded as a renewable energy if used sustainably whereby new trees are planted to replace the ones that are used. Fuel wood forms part of the energy mix in most rural households, but in time, the rural poor will run out of fuel wood due to trees been harvested in an unsustainable manner. The use of fuel wood also contributes to the emissions of greenhouse gases as dry wood contains carbon, which is released when burnt or decayed, thereby increasing the contribution of emissions from domestic biomass burning to the global atmospheric trace budgets. The excessive and continual harvesting of fuel wood has greatly contributed to deforestation, as many trees are cut down in the process of obtaining fuel wood. This poses a threat to the surrounding environment as it does not allow for appropriate planning and sustainable management of the biomass resources which sustain the majority of rural dwellers.

Information on fuel wood consumption is necessary to enhance a better understanding of the sources of the atmospheric trace gases and to construct a credible assessment of its consumption. It is important to investigate the environmental problems associated with the extraction and use of fuel wood as a source of energy because the assertion that many communities that rely on fuel wood, are those far from stable electricity supply. Provisions of alternative and modern energy will ensure better, healthier and cleaner energy services as well as help save the remaining woodlands.

1.3 Research Aim and Specific Objectives

1.3.1 Research Aim

The aim of this study is to assess household energy use, degree of emissions and the impact of deforestation in the Thulamela Local Municipality.

1.3.2 Specific Objectives

To achieve the main aim of this study, the following specific objectives were pursued:

- To examine the socio-economic profile of the respondents in the study area;
- To examine the extent of fuel wood use in relation to electricity use in the Thulamela Local Municipality in the four case study villages;

- To calculate the amount of greenhouse gases emitted from household fuel wood use in the study area;
- To determine the extent and the rate of deforestation in the study villages; and
- To evaluate strategies for ensuring sustainable energy provisions for the Thulamela Local Municipality.

1.4 Research Questions

- What is the socio-economic profile of the respondents in the study areas?
- What is the extent of fuel wood use in relation to electricity use in the Thulamela Local Municipality from the four case study villages?
- What is the amount of greenhouse gases emitted from household fuel wood use in the study areas?
- What is the extent and rate of de-vegetation in the studied villages?
- What strategies may be recommended to ensure sustainable energy provision for Thulamela Local Municipality using the four villages as case studies?

1.5 Delimitation and Description of the Study Area

1.5.1 Delimitation of the Study

The main focus of this study is to assess household energy use, emissions and deforestation in the Thulamela Local Municipality, using Altein, Botosoleni, Makovha and Thenzheni as case studies. The study only focuses on fuel wood used in relation to electricity in the study areas; specifically, the amount of carbon dioxide emitted from the combustion of fuel wood, and fuel wood harvesting as a factor of deforestation.

The greenhouse gases considered in this study are carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide (NO) and methane (CH_4). Global warming, which leads to climate change, is caused by the emission of greenhouse gases such as carbon dioxide, methane, nitrous oxide and other chlorofluorocarbons. Carbon dioxide (CO_2) is a very significant component of the atmosphere because of the total greenhouse gas emitted, 72% is carbon dioxide thus making it the biggest cause of global warming. Carbon dioxide is released into the atmosphere through natural processes such as respiration and volcanic eruptions, as well as through human induced activities such as deforestation, land use changes, burning biomass and fossil fuels. Carbon dioxide remains in the atmosphere for about 100-200 years where its concentration increases, and in turn raises the average temperature of the earth.

Other activities such as the use of cow dung, crop residue and paraffin as sources of energy will not be considered and the cutting of wood for art or medicinal purposes or the clearing of the vegetation for residential or other development purposes will also not be considered.

1.5.2 Description of the Study Area

The Thulamela Municipality is in the Vhembe District, which is located at the northern tip of South Africa in the Limpopo Province. Figure 1 shows the map of the study area.

1.5.2.1 Location

The Thulamela Local Municipality is located at the eastern tip of the Vhembe District of South Africa in the Limpopo Province. It lies approximately between longitudes 22° 45' 24.24"S and latitudes 30° 35' 53.36"E. The Thulamela Municipality is part of the Vhembe District made up of former Venda homeland and part of the former Ganzakulu. There are four municipalities in the District; namely, Thulamela, Musina, Mutale and Makhado.The municipality borders Mutale Municipality in the north-east and Makhado Municipality in the south-west. The research will be conducted in four villages in the municipality which are Altein, Botsoleni, Makovha and Thenzheni.

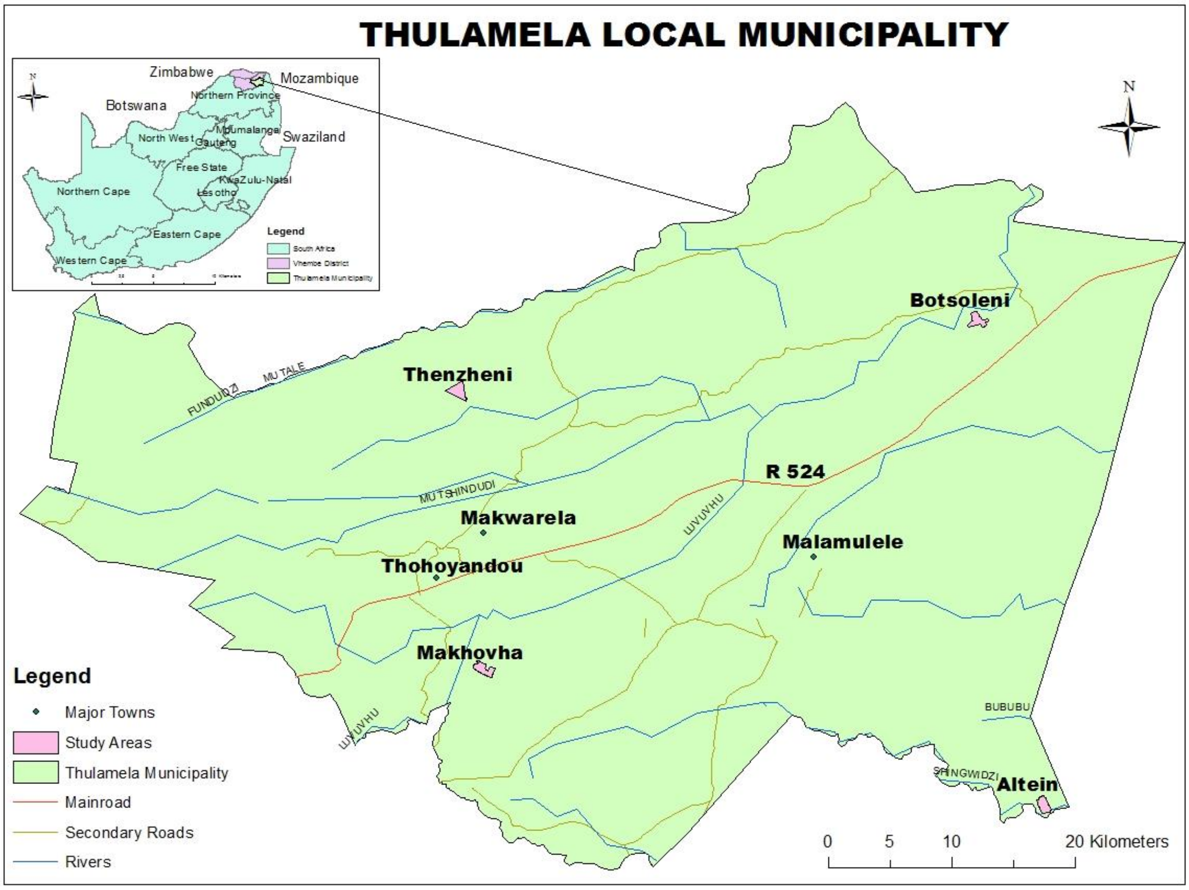


Fig 1.1: Map of Thulamela Local Municipality showing the study areas.

1.5.2.2 Climate

The Thulamela municipality falls within the sub-tropical type of climate, with average rainfall ranging from 300-1000 mm per year (Kabanda and Munyati 2010). Most of the rain falls in the summer months (between October and March). However, the mountainous areas receive an enormous amount of rainfall yearly, with an average value of about 1329 mm (M'Marete, 2003). Annual evaporation increases gradually from 1400 mm in the west to 1900 mm in the east.

Daily temperatures vary with an average range between 17° and 27°C in the summer and 4° to 20°C in the winter. Parts of the municipality can be extremely hot during summer with temperatures as high as 45°C. The average seasonal humidity within the area is about 80% during the summer, while during winter, it is about 38% (Kabanda and Munyati, 2010).

1.5.2.3 Topography and Drainage

The Thulamela topography is gently undulating with prominent mountains. The municipality is composed of granite gneiss of the Precambrian age, which is referred to as golden plate gneiss. This is a high grade metamorphic rock which is not easily eroded. The present day landscape has been moulded largely as a result of erosional forces, while faults and intrusions of competent dolerite dyke sills have influenced the formation of hills and scarps (Mucina and Rutherford, 2006).

The Thulamela Municipality is well-drained by dendritic perennial rivers such as the Mutale, Mushindudi, Mutangwi and Tshinane, as well as the Luvuvhu River. All the rivers empty their water into the Limpopo River, which is also a border between South Africa and Zimbabwe. Also located within the municipality, is a major dam called Phiphidi Dam, which supplies, portable water to the municipality household as well as water for agricultural activities.

1.5.2.4 Soil and Vegetation

The area is mainly covered by soils derived from quartzite and sandstones, which are generally shallow, gravelly, well-drained with low nutrient and is acidic in nature (Mucina and Rutherford, 2006). Soils of basaltic origin and diabase dykes are fine-textured, clayey and of considerable thickness. Soils of Aeolian Kalahari are fine-grained, the areas along the northern slope are devoid of soils; they are mainly rocks (Brandl, 2002). The general soil types within the municipality are sandy soils, silty sands, loamy soils and clayey soils which are found within the river valley.

Diverse plant communities are found within the area, of these species, forest of Lebombo ironwood are worthy of note. Several grasslands with scattered trees, baobab trees, short open woodland and bushes of different kinds cover the entire municipality. There are finger grasses, herbaceous plants, wooded plants, grasslands and farmlands within the area. Tables (1.1, 1.2, 1.3 and 1.4) are common herbs, grasses, shrubs and trees found in the vegetation.

Herbs

Table1.1: Herb species associated with the vegetation

Scientific name	**Common name**
Bidenspilosa	Black jack
Melisa afficinalis	Balm
Stureiamontana	Savory

(Source: Mucina and Rutherford, 2006).

Grasses

Table 1.2: Grass species associated with the vegetation

Scientific name	**Common name**
Cynodondactylon	Couch grass
Heteropogeoncontortus	Spear grass
Paspalumdilatum	Common paspalum

(Source: Mucina and Rutherford, 2006).

Shrubs

Table 1.3: Shrub species associated with the vegetation

Scientific name	**Common name**
Xinenia Americana	Blue sourplum
Maytenusheterophylla	Common spike thorn
Psidiumguajava	Guava
Antidesmavenosum	Tassel berry

(Source: Mucina and Rutherford, 2006).

Trees

Table 1.4: Tree species associated with the vegetation

Scientific name	English name	Local name (Venda)	Local name (Tsonga)
Parinaricuratefolia	Mobola plum	Muvhula	Mbulwa
Brideliamicrantha	Mitzeeri	Munzere	Nxuva
Acacia ataxantha	Flame thorn	Muluwa	Molele
Combretummolle	Velvet bush willow	Mugwiti	Xinkhavi
Dispyoslycioides	Transvaal blue bush	Muthala	Chugulu
Eucleadivinorun	Magic guarri	Mutangula	Nhlangula
Selerocaryabirrea	Marula	Mufula	Nkanyi
Annona senegalensis	Wild custard apple	Muembe	Muyembe
Acacia karro	Sweet thorn	Muugna	Munga
Brachylaena discolour	Brown ivory	Mufhata	Nyiri
Combretum mossambicensis	Knobby tree	Gopogopo	Xikayi
Bauhinia galprini	Pride-de-kaap	Mitswiriri	Ntswiriri
Dichrostachyscineria	Sickle bush	Murenzhe	Ndengha
Barchemiazeyheri	Red ivory	Munie	Nyirani
Combretuminbrebe	Leadwood	Muhiri	Mondzo

(Source: Mucina and Rutherford, 2006).

1.5.2.5 Population and Economic Activities

The Thulamela Municipality is home to 47.7% of the total people living in the Vhembe District and have a total population of about 618,462 people, of which 54.9% are females and 45.1% are males with a population growth of 0.62% per annum. The total land mass is 5,835km^2 with a population density of 110km^2, have an unemployment rate of 43.80%. The total household in the municipality is 156, 594 which spreads across about 228 villages and composed almost entirely of the Venda tribe (Statistic South Africa, 2011). The municipality is labelled as a category "B" local municipality because it is characterised by few towns with communal land tenure and a village system with scattered groups of dwellings which are typically located in former homelands and has about 90% of its population living in tribal or rural areas (Statistics South Africa, 2011).

The house types are comprised of clay walls and thatched roofs as well as cement walls and corrugated iron roofs. The settlements are like in many other former homelands, with unequal access to basic amenities and unequal distribution of land resources as well as inadequate infrastructure, high unemployment rates and few job opportunities. Most of the households depend on pension, government grants, and remittances from family members who migrate to urban centres to work, which has resulted in a low quality of life in the municipality. The household wealth is relatively lower when compared to other municipalities in South Africa (Aaron and Muelbauer, 2006).

The people in the municipality are renowned for agricultural practices in both commercial and subsistence in nature. The major land uses of the area are agriculture and mining. The sub-tropical climate that prevails over the area gives rise to conditions favourable for the cultivation of tea, coffee and other tropical fruits. Sunflowers, cotton, maize and peanuts are grown on a large scale, while tropical fruits such as bananas, pineapples, mangoes and oranges are also cultivated. Livestock farming, which includes cattle ranching and game, is also paramount in the municipality. Part of the Kruger National Park lies within the municipality.

However, the villages vary in terms of population sizes, number of households and spoken language (Statistics South Africa, 2011).

- Altein: population 1759, 490 households and Xitsonga language.
- Botsoleni: population 1787, 518 households and Xitsonga language.
- Makovha: population 2083, 516 households and Tshivenda language.
- Thenzheni: 1844 population, 500 households and Tshivenda language.

1.6 Significance and Justification of the Study

South Africa, like many other countries, is faced with the challenge of giving its citizens, particularly those in rural communities, an accessible and affordable energy supply that will on a larger scale be environmental friendly. Fuel wood is a cross-cutting issue; it cuts through sectors such as energy, agriculture and forestry. Its complex nature has left fuel wood issues unattended mainly due to the involvement of multiple players. The Thulamela Local Municipality is characterised by natural forest and people extract fuel wood in order to meet their household needs for cooking and heating as well as for commercial purposes. The municipality may face a problem of deforestation as a result of fuel wood harvesting. Trees are crucial to the environment due to their ability to sink carbon. The problem of climate change also promotes the protection of trees.

Unsustainable harvesting and combustion of fuel wood aggravates global climate change. However, since climate change is mainly a result of the burning of non-renewable fossil fuel, which emits carbon dioxide and other greenhouse gases, a switch to sustainable, alternative and renewable energy could mitigate climate change. Fuel wood can aggravate or mitigate climate change and there are possible measures to limit its negative impacts. Given the importance of fuel wood, both as a source of energy and a sink for greenhouse gases (GHGs), it is striking how little attention is paid to it. There is general agreement that collecting fuel wood contributes to forest degradation, particularly in Africa, and especially in the drier forests of Sub-Saharan Africa.

The importance of this research is motivated by the fact that evidence abound that fuel wood constitute a major energy source in the Thulamela Local Municipality, especially for domestic purposes and the continual use of fuel wood as a source of energy will continually contribute to the deforestation of the municipality’s vegetation and also increase the amount of greenhouse gas emissions. The results of the study will form a good basis for preliminary discussions and assist decision makers (local authority) to make meaningful future interventions in the management of forest, combating emissions as well as government developmental agendas by contributing to the aims and objectives of the government policy such as in the area of sustainable and renewable energy by Eskom in atmospheric emissions control.

1.7 Operational Definitions

The various terms that might appear repeatedly in this thesis are defined below.

- **Biomass -** It is a renewable energy resource, it includes all the water as well as land based vegetation and trees and waste biomass such as municipal solid wastes (Balat and Ayar, 2005).
- **Charcoal** - Converted from wood through the process of pyrolysis which involves the slow heating of wood in the absence of oxygen (de Miranda *et al.,* 2010).
- **Firewood** - Is used directly after harvesting and does not undergo any conversion (de Miranda *et al.,* 2010).
- **Fuel wood -** Includes the free gathering of wood in various forms such as scrap wood, wood wastes from construction sites, woodcraft, lumber yards, forest, landfill or garbage sites including non woody biomass (FAO, 2004).

- **Primary fuel wood -** Any woody biomass fuel that originates directly from fell trees (FAO, 2004).
- **Wood fuel -** Wood fuel in this thesis denotes both fuel wood otherwise known as "firewood" and charcoal (FAO, 2004).
- **Household** –According to Statistics South Africa, A household is a group of people who live together and provide themselves jointly with food and other essentials for living, but it can also be a single person who lives alone (Statistic South Africa, 2001).
- **Socio-economic factors –** It is the social and economic experiences and realities that influence a person's personality and lifestyle (Statistics South Africa, 2001).

1.8 Organisation of the Thesis Outline

The organization of this dissertation is presented in six chapters as follows: Chapter 1, consists of the Introduction and overview of forest resources, a statement of the research problem, research aim and objectives, delimitation of the study, description of the study area, significance and justification of the study and conceptual framework. Chapter 2 is a review of literature relevant to the study. Chapter 3 entails the research methodology, which includes the research design, sampling method, method of data collection and analysis as well as ethical considerations. Chapter 4 focuses on the presentation and analysis of the results. Chapter 5 gives a detailed discussion of the study findings and chapter 6 provides the key conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This section gives an overview of literature, including the nature and significance of rural energy; energy emissions in the environment; environmental and health impacts of energy production and utilization; energy consumption patterns; the use of remote sensing to detect vegetation change due to deforestation. Also, literatures on mitigation strategies are also evaluated.

2.2 Nature and Significance of Rural Energy Use

Energy is one of the basic and fundamental requirements that sustains human life. However, most people in rural areas do not have enough access to efficient and affordable energy resources. The vast majority of rural people are dependent on traditional fuels such as wood, dung and crop residues, and often use it with primitive and inefficient technologies. For many, a combination of these, rarely allows for the fulfilment of basic human needs such as nutrition, warmth and light, let alone the possibility of harnessing energy for productive uses which might begin to allow them to break the cycle of poverty (WEC, 2003).

Tropical Africa largely depends on fuel wood for about 90% of its total energy supplies (Boahene, 2008). The use of fuel wood is still far cheaper than most alternative forms of fuel available, for instance by 1970 constant prices, charcoal did not show any trend in price increment (Boahene 2008) and even if the price of fuel wood was to increase, the demand would not drastically reduce due to the unavailability of substitutes (Boahene, 2008). More so, the extent and uses of fuel wood as energy and its consumption rates are influenced by a number of factors amongst which include climate, altitude, demand and household sizes (Kituyi *et al.,* 2001).

There are many facets of poverty in developing countries and one of such facets is how to cope with limited means and lack of efficient household energy technologies. In most rural communities in Sub-Sahara Africa (SSA), poverty can mean, among other things, having to rely primarily on wood and or dung for cooking and heating. For these rural communities, in order for them to meet their household energy need and demand through fuel wood, the majority of the rural based and urban poor clear large tracks and areas of land with its vegetation while creating degradation and deforestation as devastating ecological consequences. Estimations have shown that Africa is experiencing a net loss of about 5 million hectares of tropical forested land every year (Awino, 1999).

SSA therefore, thrives on a very fragile environment, threatened by deforestation, biodiversity loss and rampant soil erosion amongst other environmental consequences.

According to Masekoameng *et al.,* (2005), like in many other developing countries, rural areas in South Africa are less privileged in terms of social services and infrastructure compared to urban centres. Where services are available in these areas, they are normally of low quality and limited. Even the energy consumed in the rural areas is mainly from the traditional sources such as fuel wood and cow dung. With a fairly large population living in the rural areas, this has led to problems of deforestation and soil erosion.

A study conducted by (Broadhead *et al.,* 2001), for Food and Agricultural Organization (FAO), has shown that developing countries, particularly Africa are dependent on fuel wood as a major source of energy. While other regions of the world show a steady decline in the use of fuel wood, the demand in Africa is projected to increase tremendously till about 2030. Figure 2.1 shows the projected global trends in wood fuel consumption.

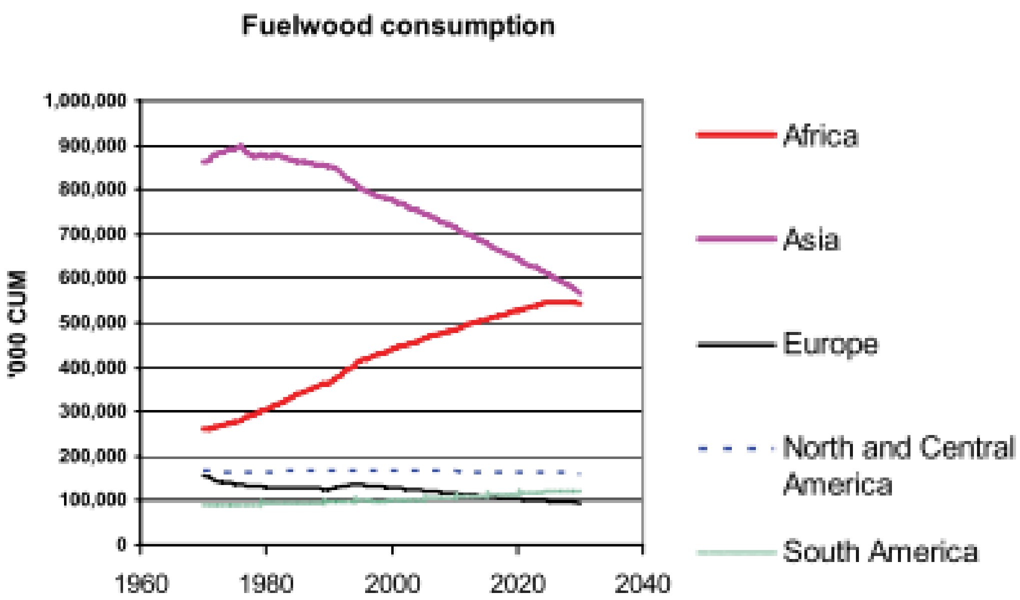


Figure 2.1: Global fuel wood consumption in past trends and future prospect for utilization of wood for energy 1960 –2040 (Broadhead *et al.,* 2001).

According to the best available figures, the use of energy in households in developing countries totalled 1 090 Mtoe in 2004, representing almost 10% of world primary energy demand. Biomass use in households of developing countries alone accounts for almost 7% of world primary energy demand (IEA, 2006).

Predominantly, there are variations in the level of consumption and the types of fuels used as a source of energy and a precise breakdown is difficult to attain, but energy use in households in developing countries is mainly for cooking, followed by heating. Because of geography and climate, household space and water heating needs are usually small in many countries. Households generally use a combination of energy sources for cooking that can be categorised as traditional (such as dung, agricultural residues and fuel wood), intermediate (such as charcoal and kerosene) or modern (such as LPG, biogas, ethanol gel, plant oils and electricity). Electricity use is mainly for lighting and small appliances, rather than for cooking and this represents a small share of total household consumption in energy terms (IEA, 2006).

There are abundant supplies of biomass in many developing countries, although local scarcity still exists (FAO, 2004). Biomass, indeed, is the only affordable energy source for some households. The commercial production and distribution of fuel wood and charcoal generates significant employment and income in rural areas of developing countries, though a switch to alternative fuels would also create employment and business opportunities (FAO, 2004).

In OECD countries and in most transition economies, there are available technologies to convert biomass to energy and they tend to be efficient and, usually, the resources are generally harvested in a sustainable way. But in developing countries, the technologies and practices are much less efficient and poor. Many people use the three-stone fires, cook without ventilation or harvest biomass at an unsustainable rate. Though, the dependence on biomass resources is important to many communities, it cannot be regarded as sustainable when is use impairs health and has negative economic and environmental impacts (OECD, 2006).

The number of people who rely on biomass as their primary fuel for cooking for each country in developing regions was compiled using survey and census data and direct correspondence with national administrations and it was estimated that over 2.5 billion people or 52% of the population in developing countries depends on biomass as their primary fuel for cooking. Over half of these people live in India, China and Indonesia. However, the proportion of the population who relies on biomass is highest in sub-Saharan Africa (WHO, 2006).

In many parts of Sub-Sahara Africa, more than 90% of the rural population rely on fuel wood and charcoal as a source of energy. The share is smaller in China, where a large proportion of its households use coal instead. Poor households in Asia and Latin America are also very dependent on fuel wood as a source of energy (FAO, 2004). The heavy dependence on biomass is concentrated in, but not limited to rural areas alone. Almost half a billion people in urban areas also rely on these resources. Although, a lower dependence of biomass is associated with urbanisation, the use of fuels such as LPG in towns and cities is not always evenly widespread (Jannuzzi and Sanga 2004). In sub-Saharan Africa, more than half of all urban households rely on fuel wood, charcoal or wood waste to meet their cooking needs. Over a third of urban households in some Asian countries also rely on these fuels (FAO, 2004).

Biomass share in household energy demand varies widely across countries and regions, thus primarily reflecting their resource endowments, but also showing their levels of economic development and urbanisation. In Thailand, for example, where per-capita income averages $2, 490, biomass accounts for 33% of household energy consumption, whereas in Tanzania, with per-capita income of only $320, the share is nearly 95% (World Bank, 2006). There are also important differences between rural and urban households. For example, fuel wood for cooking is three times more important in rural areas than in urban areas in both India and Botswana (Census of India, 2001 and Census of Botswana, 2001).

Households simply do not substitute one fuel for another, even as income increases, but rather add fuel in a process of fuel stacking. Modern forms of energy are usually applied economically at first and for particular services (such as electricity for radio, television and refrigeration, or LPG for making tea and coffee) rather than completely taking the place of an existing form of energy that already supplies a service adequately. The most common energy consuming activities in the household are often cooking and heating and are usually the last to switch. Normally, the use of multiple fuels provides a sense of energy security in the household, since the complete dependence on a single fuel or technology leaves households vulnerable to price variations and unreliable service (Jannuzzi and Sanga, 2004).

Some reluctance to discontinue cooking with fuel wood may also be a factor due to taste preferences and the familiarity of cooking with traditional technologies. In India and several other countries, for example, many wealthy households still retain a wood stove for baking traditional breads (Rwelamira, 1999). As incomes increase and fuel options widen, the fuel mix may change, but wood is rarely entirely excluded as a source of energy. However, over the long term and on a regional scale, households in countries that become richer will certainly shift away from cooking exclusively with biomass using inefficient technologies (Smith *et al.,* 2004).

2.3 Energy, Atmospheric Emissions and the Environment

Issues of energy and greenhouse gas emissions over the years in China have received little attention (Zhang *et al.,* 2009a). In the last three decades, the remarkable high speed development, continuous increase in total energy consumption and per capita energy consumption have led to increases in greenhouse gas emissions in rural China (Zhang *et al.,* 2009b). However, when compared with urban areas, rural households have suffered long term energy shortages, which causes rural populations to depend heavily on conventional biomass energy for cooking, heating and other domestic functions (Zhang *et al.,* 2009b).

Additionally, environmental problems from energy induced sources are posing threats to rural public health. Therefore, issues of rural energy have caught the attention of policy makers, and particularly in the current context of trying to address climate change and promoting low carbon development within rural energy settings. Residential energy is of paramount importance because it is the primary component of rural energy consumption and also directly relevant for the resident's quality of life. It is therefore crucial to first understand the general issues related to rural energy consumption and carbon emissions (Wenling *et al.,* 2012).

In recent decades, rural economy in China has undergone development rapidly, which is accompanied by a substantial and profound change of rural lifestyles and a gradual transition of residential energy use patterns. However, the persistence of poverty alongside energy shortages and environmental degradation in rural China is still obvious. Differently from urban residential energy use, commercial energy shortage and heavy dependence on conventional biomass use contribute to the persistent poverty in rural areas of China (Zhang *et al.,* 2009a).

Generally, there are some distinct features of residential rural energy utilisation, such that carbon emissions from traditional biomass combustion contribute to more than half of the total rural residential emissions. Aside from its contribution to global warming and deforestation, the current biomass combustion also contributes to hazardous substance emissions that pose threats to the rural environment and the health of the people (Wenling *et al.,* 2012).

The use of fuel wood and its implications for the global environment can be evaluated by estimating the associated greenhouse gas emissions (FAO, 2006). Greenhouse gases are known to be the major causes of global warming with Carbon dioxide (CO_2), accounting for 67% of the total emitted greenhouse gases, 18% Methane and 7% Nitrous oxide (NOx) (FAO, 2006). Carbon dioxide emission therefore is the most important cause of global warming. CO_2 is inevitably created by burning fuels like oil, natural gas, diesel, organic-diesel, petrol, organic-petrol, ethanol as well as biomass. The emissions of CO_2 have dramatically increased within the last 50 years and are still increasing by almost 3% each year (FAO, 2006).

Forests cover more than one-third of the total world's landmass and constitute the major terrestrial carbon pool (Roberntz and Sune, 1999). The sequestration of carbon dioxide from the atmosphere takes place in a growing forest and the fixing of CO_2 through photosynthesis is usually done with trees and other forest plants since all forest organisms release CO_2 through respiration (Musselman and Fox, 1991). Carbon locked up in the forests is greater currently than that held in the atmosphere in terms of total volume. The global terrestrial carbon held in the forest ecosystem of the world is as much as 77% (Stern, 2006). Forests are thus the sources and sinks of atmospheric CO_2. The improvement of forest management or decreased harvesting of the less fully developed trees has a potential option of enhancing sequestration of atmospheric CO_2 and can ameliorate global warming since it can increase the carbon content of the world existing forests (Musselman and Fox, 1991).

One of the consequences of deforestation is that the carbon originally held in forests is released to the atmosphere either immediately the trees are harvested, burned, or more slowly as unburned organic matter decays (Houghton, 2003). Most of the carbon is released to the atmosphere as carbon dioxide, but small amounts of methane and carbon monoxide may also be released by decomposition or burning (Houghton, 2003).

CO_2 in the atmosphere is stored as carbon as the trees absorb them in wood or soils. The burning of forest and forest conversion for farming as well as the harvest of timber and fuel wood, cause a net release and increase of CO_2 from the biota atmosphere (Boahene, 2008). These activities inject about six billion tons of carbon into the atmosphere every year (Silver and DeFries, 2000). CO_2 release coupled with the existence of other trace gases such as Methane (CH), Chlorofluorocarbons (CFCs), Nitrous Oxide (NO_x) and Tropospheric Ozone $(O_3)^2$ are expected to induce global warming through the greenhouse effect. Studies on global climate models have shown that the atmospheric CO_2 has doubled and that long-term temperature is expected to increase by 2-5^{0}C (Royer and Mahouf, 2002).

The contribution of fuel wood to greenhouse emissions arises from the combustion of the biomass and the unsustainable manner through which fuel wood is harvested (Hofsad, 2008). Fuel wood harvest from the forests and woodlands depends on whether or not supply is sustainable and determined between the harvest and growth rate. When the extraction rate is greater than the rate at which the biological system regenerates biomass, forest or woodland becomes degraded then deforestation takes place (Hofsad, 2008). Aggressively, fuel wood and charcoal producers often extract fuel wood faster than its regrowth, at much higher rates, particularly where the demand is high. Consequently, the density of woodland biomass becomes reduced, resulting in net CO_2 emission (Logan *et al.,* 2002).

The combustion of fuel wood gives rise to the emissions of greenhouse gases and there is about 50% carbon contained in a dry wood However, the carbon content in a growing tree is much lower because they contain a higher proportion of water than in dry wood. When one metric ton of dry wood burns or decays, 1.833 metric tons (1833kg) of CO_2 is emitted (Lamlom and Savidge, 2003).

Estimation indicates that biomass burning is the second largest sources of aerosols by humans after the production of sulphate from sulphur dioxide (Van Wilgen *et al.,* 1997). Over considerable distances, the in-depth diffusion and emissions of aerosol in the troposphere are the resultant of buoyant smoke plumes from fires which emits from the combustion of burnt biomass. Black carbon emissions from the combustion of biomass may exacerbate the effects of climate change in Asia (Venkataraman *et al.,* 2005). The strong atmospheric heating and large surface cooling that affects the South Asia climate and the greenhouse gases are a result of carbonaceous aerosols. Gustafsson *et al.,* 2009, found that the combustion of biomass produces two-thirds of the total bulk of the carbonaceous aerosols and more than half of the black carbon.

One of the most visible impacts in the atmosphere as a result of biomass burning is the brownish haze that usually pervades around rural areas of the tropics and the sub-tropics, which are a result of heavy biomass burning and in the long term, atmospheric transport transform this haze into a regional scale aerosol layer (Ramanathan *et al.,* 2001). In Southern Africa, it is estimated that smoke from biomass burning contributes about three quarters of the aerosol burden in the regional haze, while the remainder are contributions from other sources like fossil fuel burning (Kirchstetter *et al.,* 2003).

2.3.1 Global Warming

Emissions of greenhouse gases (GHGs) have been identified by the Intergovernmental panel on Climate Change as the primary cause of global climate change, and the changes are attributed to any change in climate over time which are owned to natural variability and human activities. Among the primary human induced (anthropogenic) greenhouse gases emitted, Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O) account for 92% of the total (World Bank, 2006).

Generally, CO_2 emissions in Africa are low in per capita terms, although, since 1950, the total emissions in Africa have increased twelve-fold, reaching 311 million metric tons of carbon in 2008 which is still far less than the emissions for some single countries such as Mainland China, the United States of America, India, Russia, and Japan. From all fuel sources, emissions have grown in all regions of Africa over time by approximately 35%, accounting from liquid and solid fuels and gas fuels accounting for 16.9% of the regional total (Boden *et al.,* 2011).

However, in Africa, a small number of nations are responsible largely for the emissions of fossil fuels; South Africa alone accounts for 38% of the continent's total, with the combination of Egypt, Algeria, Nigeria, Libya and Morocco accounting for 46%. These six countries on the continent have annual CO_2 emissions in excess of 10 million metric tons of carbon dioxide. Four African countries, however, have per capita CO_2 emissions, which are higher than the global average of 1.3 metric tons of carbon per year. They are Libya (2.53), South Africa (2.39), Seychelles (2.22), and Equatorial Guinea (1.99) and from the available data based on 2008 per capita emission rates, 28 out of the 55 Africa nations have emission rates per capita less than 0.1 metric tons of carbon per person per year (Boden *et al.,*2011).

2.3.2 Air Pollution

In most rural areas, cooking is done indoors, usually in a kitchen or outside a tent and the majority of the rural houses are without a chimney outlet to make the smoke escape. In South India, for example, the numbers of cooking hours range from 3.3 to 4.6 hours per household in a day (Venkataraman *et al.,* 2010). Females are therefore exposed to smoke from biomass combustion for a long period of time because they are the ones who cook most of the meals. When burnt, fuel wood emits pollutants such as repairable particulate matter, carbon monoxide, nitrogen oxides, organic compounds, methane and non-methane organic compounds (Venkataraman *et al.,* 2010).

Fuel wood that is not properly and completely burnt is diverted into products of incomplete combustion, which primarily produce carbon monoxide, but also benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and many other compounds which are posing threats and health hazards. The best single indicator of the health hazard of combustion smoke is thought to be small particles, which contain many chemicals (Smith *et al.,* 2004).

A risk assessment by WHO which combined the results of many published studies (Ezzati *et al.,* 2002), compared the burden of illness and premature death arising from fuel wood use with other major risk factors, including outdoor air pollution, tobacco smoking and hypertension. The results indicate that solid fuel use may be responsible for 800 000 to 2.4 million premature deaths each year (Smith *et al.,* 2004). The combustion of biomass fuel use has been found to be associated with diseases such as tuberculosis, cataracts, low birth weight in babies of exposed expectant mothers, and other health conditions in a number of other studies (Smith *et al.,* 2004).

The burning rate (kg of fuel burnt per hours) of biomass also affects the emission of smoke and pollutant as well as thermal efficiency. Females seem to adopt higher burning rates because it decreases the cooking duration and improves combustion with reduced smoke. Higher rates also lead to higher specific fuel consumption. Therefore, attempts to reduce pollution from smoke would have implications for total biomass used (Ezzati *et al.,*2002).

The burning of fuel wood is also a source of air pollution in high population density areas, the heavy use of fuel wood releases large amounts of fly ash into the air. Studies in Missoula show that 55% of the particles in the air during summer were a result of burnt fuel wood. In winter, wood was responsible for 75% of the particles. Households that mostly rely on traditional stoves use most wood fuel in Asia. These stoves have low efficacy and often burn wood incompletely, leading to the emission of pollutants (Enger and Smith, 1995).

2.4 Environmental Impact of Fuel Wood Harvesting

2.4.1 Deforestation

In Africa, 21% of its land area which is 635 million hectares is occupied by forest, which is equal to16 % of the global forested land area. In total, approximately 23 million hectares of this forest disappeared in the 1980s, while another 20 million hectares gave way for other land uses in the 1990s (FAO, 2006). Estimations have shown recently that another 4 million hectares of the forested land were deforested between 2000 and 2005, which is equivalent to one-third of the total deforested area. The deforestation rate is currently estimated at about 0.4 to 0.7% per year and is likely to continue at this level. Many uncertainties are attributed regarding these estimations and figures could easily be understated (FAO, 2009). Overall, the progress towards sustainable forest management in Africa appears to have been limited for the last fifteen years. However, there are few indications that the net loss of forest area has slowed down and that the areas of forest that are designated for the conservation of biological diversity has increased slightly. The fact remains that the permanent rapid loss of forest area occurring in Africa is represents the highest percentage of any region, particularly during the 1980s, 1990s and early 2000s (FAO, 2006).

The extraction of fuel wood plays a significant role in deforestation across Africa (Geist and Lambin, 2002). Extraction of wood for domestic fuel wood or charcoal production has remained a major issue in Africa, because most Africans, mostly in rural settings still use wood and charcoal for cooking, as other energy sources are not available or are expensive. Only 7.5% of the rural population currently have access to electricity in Africa (FAO, 2009). Africa has shown a steady increase in the removal of wood in recent years, reporting a rise from 49,900 hectares annually (1990) to 66,100 hectares (2005). The increase in the collection of fuel wood as a source of energy is also due to a decline in productivity and a subsequent decline in income, which means a greater dependence on off-farm employment, such as fuel wood collection and production of charcoal increase (FAO, 2009). It is estimated that the majority of the harvested wood is used as fuel wood. However, since most of the fuel wood collection activities are not usually recorded, the actual quantity of wood removals might be understated (FAO, 2006).

The region with the greatest use of wood fuels is Asia. However, unlike Africa, where most of the fuel wood production is on a small scale, much of the fuel wood production in Asia comes from plantations. There are roughly 8 million hectares of fuel wood plantation in the world, of which 6.7 million hectares, an area larger than the state of West Virginia in the United States are located in Asia (FAO, 2010). Most plantations are located in China and India, which are countries that have already depleted most of their natural forests. There is some empirical evidence that plantations help alleviate strains on natural forests (Kohlins and Parks, 2001). In most of the regions where fuel wood is harvested from plantations, they are used for preparing crops (e.g., tobacco and tea) and for the brick burning and ceramic industries. However, in India nearly two-thirds of plantations are non-industrial and the firewood is used for families and communities (Brown *et al.,* 1999). As in Africa, the majority of rural people in Asia relies on firewood as their primary source of fuel, but this is declining in most parts of the region (Arnold *et al.,* 2006). Charcoal is not heavily used in Asia when compared to fuel wood (Hofstad, 1997).

2.4.2 Hydrology

The global water cycle is also disrupted by deforestation because when part of the forest is removed the area affected cannot hold as much water as before, thereby creating a drier climate (Bruijnzeel, 2004). The water resources that are affected by deforestation include drinking water, fisheries and aquatic habitats, flood/drought control, waterways and dams affected by siltation, less appealing water related recreation, and damage to crops and irrigation systems from erosion and turbidity (Bruijnzeel, 2004).

Regarding the forest rainfall relationship, the major consideration is of a sudden upward movement of air over the forest which triggers the building of cumulus clouds and initiates rain. Furthermore, the forest is more effective than other vegetation types at trapping precipitation amongst which are fog, cloud and moisture. The decline in rainfall in many parts of Africa, including Eritrea, Tigray and Wallo provinces of Northern Ethiopia; Zambia, Zimbabwe, Mozambique and in the Sahel from Chad and Niger to Mauritania, are all due to deforestation (O'Connor, 1991).

Forests with high soil permeability enhance the moisture balance in their catchment area and reduce the catastrophic risk of floods and low flows. Rivers which are found in high forest areas with high rainfall, have a higher discharge in relation to the drainage area, when compared to rivers found in semi-arid or deforested areas (Lewis and Barry, 1998). In Africa, about 90% of the total river lengths are in small streams and these streams are highly affected by changes that occur in vegetation cover. The River Niger, the Rufji (in Tanzania) and Tana (in Kenya), which are large rivers, have been affected by weather conditions of the wet dry areas upon which they flow (Mortimore, 1999).

2.4.3 Biodiversity Loss

In the tropics, forests serve as a storehouse for biodiversity and the consequent deforestation leads to fragmentation and degradation, which destroys the biodiversity as a whole leading to species migration including the species that are endangered. Tropical forests support about two thirds of all known species and contain 65 per cent of the world's 10, 000 endangered species (Myers and Mittermeier, 2000).

According to the World Health Organization, about 80% of the world's population relies on forests for primary health care at least partially on traditional medicine. The biodiversity loss and associated large changes in forest cover could trigger abrupt, irreversible and harmful changes. These include regional climate change, including feedback effects that could theoretically shift rainforests to savannahs and the emergence of new pathogens as the growing trade in bush meat increases contact between humans and animals (Myers and Mittermeier, 2000).

2.4.4 Soil Erosion

The result of deforestation can also lead into watersheds, causing to cease to regulate and sustain water flows from streams and rivers. Once a forested area is deforested, too much water flow can result in downstream flooding, which can cause disasters in many parts of the world. This downstream flow causes soil erosion and the silting of water courses, lakes and dams. Flooding due to deforestation can increase for one of two reasons; firstly, with smaller tree fountain effects, the soils are more likely to be fully saturated with water. The sponges are quickly filled up in the wet season, causing additional precipitation to run off, thus increasing the flood risk. Secondly, deforestation often results in soil compaction, making it unable to absorb rain. Locally, this can cause a faster response of stream flows to rainfall and thus the potential of flash flooding (Chomitz *et al.,* 2007).

The proportions of other land use changes have increased due to deforestation of the basin, which subjects it to erosion and over the long run contributes to siltation. Heavy siltation has raised the river bed increasing the risk of flooding, especially in the Yangtze River basin in China, the major river basins of the humid tropics in East Asia and the Amazonian basin (Yin and Li, 2001)

2.5 Health Impacts of Energy Extraction

2.5.1 The Burden of Fuel Wood Collection

The dependence on biomass in developing countries is a burden for females and children who are responsible for fuel wood collection, a time-consuming and exhausting task. The average fuel wood load in sub-Saharan Africa is around 20 kg but loads of 38 kg have also been recorded (Rwelamira, 1999).

During the late 1980's the tribal females in Orissa in India were traditionally involved in fuel wood collection. The distances walked by these females in collecting fuel wood have become difficult since they go further and further away from villages to reach their receding tree line. Over a twenty-year period from the mid 1980's, the average distance that females have to walk to collect fuel wood increased from 1.7 to 7.0 kilometres. One obvious outcome of all this is that females have less time to care for themselves, even when they are ill because the larger part of the fuel wood collection lies on them (Parikh, 2007).

Physical damage from strenuous work without sufficient recuperation is suffered by females due to their long walks. This risk, as well as the risk of falling or assault increases further from home as females have to walk much longer distances (Parikh, 2007). For example, due to the land being converted for agricultural purposes in Tanzania, the average distance walked by rural females in the search for fuel wood collection is highest in the central region of Singida at over ten kilometres per day, followed by the western region near Lake Tanganyika where it is greater than five kilometres per day (FAO, 2006).

The collection time for fuel wood has a significant opportunity cost on females and children, it limits their opportunity to improve their education and engage in other income generating activities. Many children, especially girls, are withdrawn from school in order to attend to domestic chores which are related to biomass use, thereby reducing their literacy and restricting their economic opportunities. However, with modern energy services it can promote economic development by enhancing the productivity of labour and capital. The use of more efficient technologies can provide higher quality, energy services at lower costs and free up household time, especially that of females and children, for more productive purposes (Victor, 2005).

Importantly, there are more developmental benefits to be gained from expanding access to the use of modern energy services. The UN Millennium Project (2005) has emphasised that close links exist between energy and all eight of the Millennium Development Goals (MDGs). The use of modern energy services help reduce poverty (MDG 1) and can play a critical role in improving educational opportunities for children, empowering females and promoting gender equality (MDGs 2 and 3). The availability of adequate clean energy is important in reducing child mortality (MDG 4). Reducing the carrying of heavy loads of fuel wood improves maternal health (MDG 5). Inefficient combustion of fuel wood exacerbates respiratory illnesses and other diseases (MDG 6). Fuel substitution and improved stove efficacy would help alleviate the environmental damage of biomass use (MDG 7). Finally, widespread substitution of modern energy for traditional biomass can be a rallying point for global partnerships (MDG 8).

2.5.2 Health and Nutritional Cost

Due to the burden of fuel wood collection, it is easy to visualize a direct and indirect cost to this factor such that less food is cooked, there is a shift to meals that require less cooking time and increases in the workload and economic burden for female who are usually responsible for the purchase or collection of fuel wood. There are currently many references to literature that families eat one instead of two cooked meals a day due to the lack of fuel (FAO, 2004).

According to Casey (1981), there is a likelihood that fires may not be lit as often as they would have been if fuel supplies were adequate and that consequently the frequency of meals prepared may be reduced. For example, it asserted that in some cases, fuel wood shortages have reduced households to one cooked meal per day in South Africa.

The burden of fuel wood collection leads to the selection of foods with shorter cooking times instead of those with longer cooking times. It is asserted that the burden of fuel wood collection leads to the substitution of customary food with prolonged cooking hours. Two often cited examples of this, i.e. the substitution of greens for beans and rice for sorghum (Cecelski, 1984). Besides the burden of collecting fuel wood from longer distances which causes Severe backache and fatigue, the use of the fuel wood for cooking also has an impact on the health of the users. The smoke cause eye irritation, respiratory diseases as well as having negative effects on the skin due to extreme heat produced when the wood burns. Researches confirm that there is a cause effect between exposure to smoke and diseases such as chronic bronchitis and emphysema with females and children suffering the most (Smith *et al.,* 2004).

2.6 Socio-Economic Patterns of Energy Consumption

2.6.1 Energy Ladder Model

Household patterns of energy consumption normally represent the status and welfare as well as the stage of economic development. Generally, as the economy develops, more and cleaner energy is consumed. The household energy consumption pattern is expected to increase in the future in line with growth in the economy and a rise in per capita incomes. It is projected that increases in household energy consumption are expected to result from changes in lifestyles (Pachuri, 2004).

The total energy consumption in rural areas consists of biofuels majorly which are fuel wood, charcoal and agricultural waste, while in the urban areas kerosene, electricity and LPG are the major energy carriers. Fuels in rural households are collected from various sources such as from animal dung, forest land or the open land surrounding the villages, sometimes even from local retailers, while in many urban regions, these fuels have usually become traded goods. The energy carriers are used for multiple purposes such as for cooking, water heating, lighting, etc. Many households use fuel wood for both cooking and water heating while other households, which use kerosene and LPG for cooking, the water heating is done with either fuel wood or electricity (Schipper, 2000).

The household income influences the energy consumption pattern in many ways. Firstly, a rise in income levels impacts on energy consumption increases due to the increase of dishes prepared such that supplementary items like vegetables, milk, meat and other food items are added to the food grains and more energy is required to cook the additional food which will result in the increasing use of energy. Secondly, with increasing incomes, the price of the fuel is less of a constraint to the household (Laitner, 2000). With an increase in income, households will prefer to use a clean and convenient form of energy, such as Liquefied gas and electricity. Due to the use of efficient devices, the total consumption of energy will not increase significantly. With high income, households will opt for cleaner and more efficient “modern” energy carriers such as electricity or liquefied gas. However, many households use a mixture of modern and traditional fuels where by each are matched to a specific end use such as cooking with fuel wood and heating water with Liquefied gas (Schipper, 2000).

The form of substitution of one form of energy to the other is a clear cut pattern with an increase in income, solid fuels (charcoal and firewood) usually give way to a liquid fuel (kerosene), which in turn is displaced by gas (LPG) and electricity, which are the most desirable energy forms in any household with high income. With increasing disposable income and changes in lifestyles, households tend to move up the energy ladder (in terms of quality, convenience to use and cost) biomass to kerosene and then to LPG/Electricity. With technological advances associated with end-use devices also moving in the same direction, the efficiency of energy use tends to improve with the ladder climbing (Reddy, 2003).

Growths in per capita income and household demand for commercial fuels have a positive relationship between them. In most developing countries, commercial demand has risen more rapidly than per capita incomes since 1970. This is a reflection in the increasing desire for comfort and discretionary energy consumption. In general, there is a higher level of household energy consumption due to urbanization, although it is quite difficult to separate the effects of urbanization from the increases in income levels which generally complement each other. As urbanization and income increase sets in, there is also a shift from traditional to commercial fuels along the gradient of income levels. There are several factors that contribute to this trend which include a decline in access to biomass fuels in urban areas, transportation inconvenience and storage, and improvement in the availability of commercial fuels in urban areas (Laitner, 2000).

Nonetheless, the use of traditional fuels in many cities of the developing countries remains high in around the dwelling of low income groups. Another trend to this is a decline in the share of energy used for basic requirements such as cooking and lighting, as incomes increase, while energy consumption for space heating, water heating, refrigeration, audio/video appliances, air conditioning and other modern uses grows (Reddy, 2003). In relation to the occupation of the household heads, manual workers (labourers) have higher use of biofuels than that of non-manual (lower level employees) and when compared with manual and non-manual, the executives and middle-level employees generally use modern forms of fuels. Using the forms of occupation, there is an association between occupation and energy use, such that attaining higher employment status tend to have a shift to modern energy carriers or forms (Reddy and Reddy, 1994).

In urban areas, the annual per capita energy consumption of low income households does not differ significantly from those of the rural poor, as the main share of energy consumption in both urban and rural areas goes to cooking and lighting. However, with rising incomes, the energy consumption patterns of urban households will change significantly. This may be attributed to the increase in the number of dishes prepared and the use of various appliances such as televisions, microwaves, air conditioners, and ovens. The main determining factors for the selection of energy carriers include: prices of the fuels and the corresponding utilizing devices, disposable income of households; availability of fuels and cultural preferences ((Reddy and Reddy, 1994).

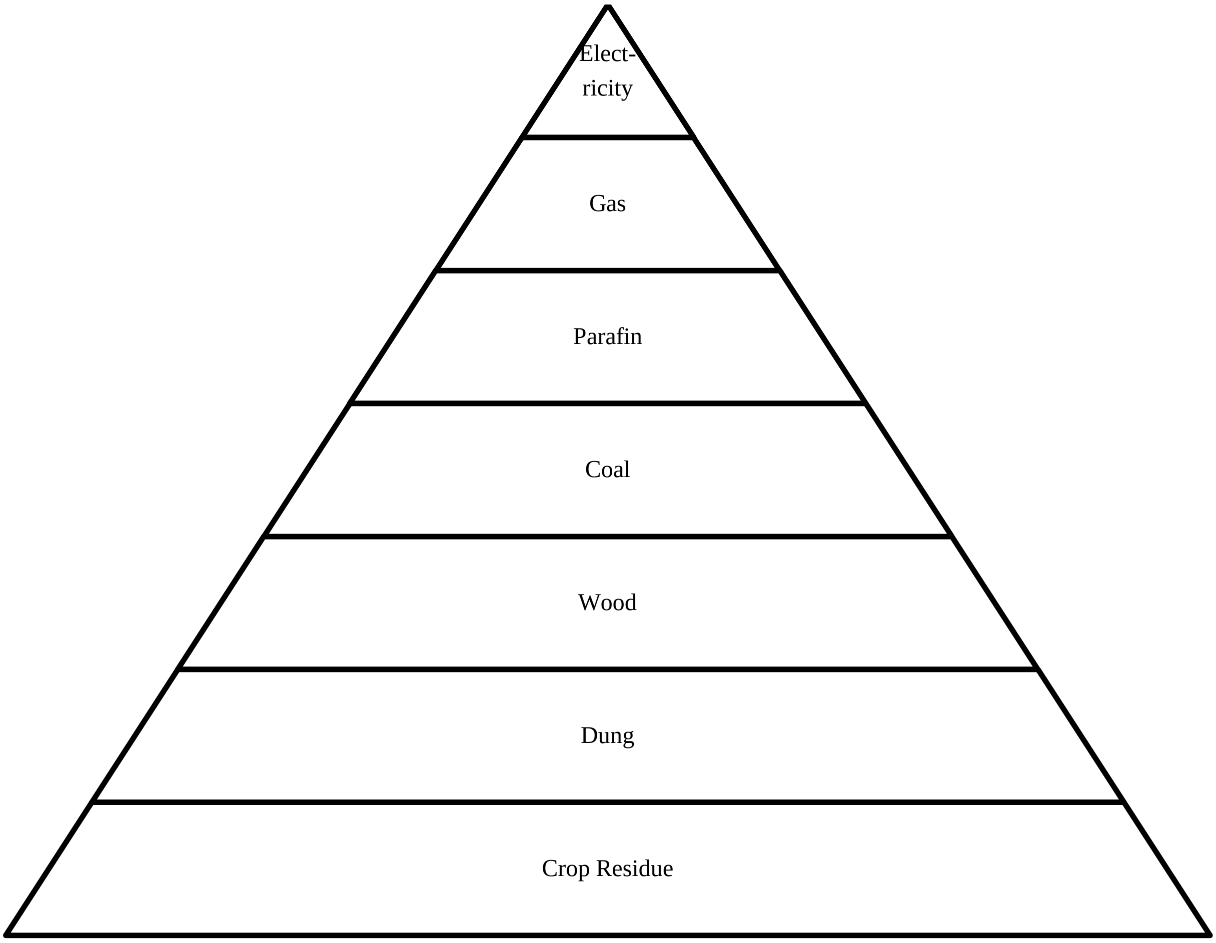


Fig 2.2: The Energy Pyramid (Pachuri, 2004).

2.6.2 Leap-Frogging

The leap-frog concept is also used to explain energy transit at household levels (Murphy, 2001). The concept of leapfrogging was used originally in the context of economic growth, as a metaphor to explain how Newly Industrialized Economies (NIEs) develop and transit from one form to the other. The catching up process in these countries does not actually follow the path of conventional technological development of the advanced countries, but instead skips some stages, or perhaps creates their own individual paths different from the forerunners. For example, countries which moved directly from not having telephones to having cellular phones, skipping the stage of copper wire telephones altogether.

In the energy sector, a similar leapfrogging concept can be used to denote the transition from traditional forms of energy (e.g. Fuel wood) to modern sources (e.g. Electricity) (Murphy, 2001) without necessarily passing through the conventional path of energy development (i.e. Crop residue to dung to fuel wood to coal to paraffin to gas to electricity). In such a transition, it is thought that modern energy resources can be brought to the users more quickly and making it more cost effective. The path of leapfrogging is seen as clean and sustainable while the conventional energy systems are thought to be dirty and wasteful (Murphy, 2001).

2.6.3 The Consumer Behaviour Model

The Consumer Behaviour Model states that over time, consumer's preference of a resource or product usage pattern changes. The consumer's behaviour for a product is influenced by three factors.These are how the consumer perceives the product, the belief on the product and the present situation of the consumer (Mmatloa, 2010). The Consumer Behavior Model points to real life situations; for example, reluctances by some people to discontinue cooking with fuel wood may also be a factor due to taste preferences and the familiarity of cooking with traditional technologies even with the availability of electricity because they believe that the food will not be well-cooked if the source of energy is electricity. In India and several other countries, for example, many wealthy households still retain a wood stove for baking traditional breads (Rwelamira, 1999).

2.7 Integration of GIS and Remote Sensing in Vegetation Change Detection

The techniques of GIS and remote sensing play an active role in solving many natural and human problems and there are several advantages in the use of these techniques of GIS and remote sensing that have led to the understanding of these issues, their causes and how to overcome them (Sadoun and Al Rawashdeh, 2009). Remote sensing is defined as the science of obtaining information from a distance without any actual contact with the object being observed (Mahmoodzadeh, 2007). Remote sensing is based on the fact that each object has its own spectral signature that facilitates its clear distinction from another object, while GIS has the ability to link different data that are spatial data and non-spatial data to support better decision-making. However, with the advancement in technology and the availability of data these two techniques are working closely as one integrated system for solving issues (Sadoun and Al Rawashdeh, 2009).

Often, change detection involves the comparison of satellite images or aerial photographs which are often taken at different times. The changes may involve the intensity or nature of the changes but it may also include spatial such as forest abatement at a village level and time aspects (Petit, 2001). In GIS and remote sensing application, change detection method is one of the techniques that can be applied. Change detection method can be applied severally such as in urban growth, vegetation change, land use change etc. Worldwide, there are several change detection method that have been developed that can be used to extract information from remote sensing images and such methods include, Post Classification using supervised classification or unsupervised classification, Normalized Difference Vegetation

Index (NDVI). Change Vector Analysis (CVA), Visual interpretation and manual digitizing and Differencing and Rationing image, Composite Analysis, Background Subtraction. These techniques are all useful tools that can help improve the decision processes in many applications which then can be utilised by planners, engineers, managers, environmentalist, government agencies etc. (Sadoun and Al Rawashdeh, 2009).

The application of NDVI in the study of vegetation change is one of the most successful methods of many attempts to simply and quickly identify vegetated areas and their associated conditions and it also remains the most well-known used index to detect live green plant canopies in a multispectral remote sensing data. Once the feasibility to detect vegetation had been demonstrated, users tended to also use the NDVI to quantify the photosynthetic capacity of plant canopies (Mahmoodzadeh, 2007).

The spectrum signature in vegetation is unique and different from other classes of land cover types. Vegetation reflection is highest in the green zone in the near infrared (NIR) because the reflection is much higher in the visible band due to the cellular structure of the leaves. The principle behind NDVI is that in the red reflectance light region of the electromagnetic spectrum, chlorophyll causes considerable absorption of incoming sunlight, whereas in the near infrared region of the spectrum, plant spongy mesophyll leaf structure creates considerable reflectance and vegetation that is healthy and vigorously growing and has a low red light reflectance but high in the near infrared which will reflect in high NDVI values (Almutairi and Warner, 2010).

NDVI is calculated as follows:

NDVI = (channel 2 – channel 1) / (channel 2 + channel 1)

Or the index is computed by dividing the difference of the near infra-red (NIR) bands by their sum as the equation given below.

NDVI = (NIR - R) / (NIR + R)
where NIR = Near Infrared reflectance value
and R = Red Reflectance Value

Estimated reports from surveys and field studies on deforestation rate are generally higher than those based on remote sensing (FAO, 2001), although, this is not always the case as Hansen and DeFries (2004) reported a higher rate with the use of satellite data compared to the field observation reported by FAO (2001) in five out of six countries monitored. It is quite difficult to determine the accuracy of the ground based estimates as the errors in the estimates of the FAO are unknown. The preliminary national communications from Zimbabwe and

Bolivia reported deforestation rates six times lower than that reported by FAO (Houghton and Ramakrishna, 1999).

Remote sensing estimates-based data are sensitive to various processes. Amongst these are the spatial variability of deforestation since the sample may consist generally of Landsat scenes and the variability among scenes may be so high that it requires >80% coverage of the region for an accurate estimate of deforestation (Tucker and Townshend, 2000). Achard *et al.,* (2004), in densely-populated areas, the clearing size is often too small for a change in tree cover to be recognized and the fact that some degradation of forest in some form is observed from space do suggest that the small patches may not be a problem but land use change studies have documented the distribution of these small patches. For instance, in several parts of Africa, the size of individual clearings may be the size of an individual tree crown which will not be readily observable from remotely sensed-images (Achard *et al.,* 2004).

2.8 Management Strategies in combating fuel wood harvesting and consumption

The production of renewable energy from sustainable natural sources will largely contribute to sustainable development. Most of the renewable energy sources are indigenous and naturally available and it guarantees energy supply that is afforded security and it is not subject to disruption by international crises or limited supplies.

2.8.1 Solar Energy

Solar energy by definition is quite simply the energy produced directly by the sun. The sun creates its energy through a process of thermonuclear, which converts about 650,000,0001 tons of hydrogen to helium every second. Through the process, it creates heat and electromagnetic radiation and the heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions (Borchers *et al.,* 2007).

With only a very small fraction of the total radiation produced reaching the earth is the indirect source of nearly all the type of energy that are used today with exceptions are geothermal energy, and nuclear fission and fusion energy. Fossil fuels, perceived as one of the major sources of energy, owe their origin to the sun; the remains were once living plants and animals whose lives were dependent upon the sun for support. Much of the energy required by the world can be directly supplied by solar power (FAO, 2000).

Energy is used by people for many purposes. However, most of the energy is generally consumed by a few tasks. These tasks include transportation, cooling, heating and the generation of electricity. The application of solar energy is very possible for all four of these tasks with different levels of success (Borchers *et al.,* 2007). The advantages of solar power over fossil fuels are, firstly in the fact that it is a renewable form of energy; it is never going to run out and secondly is its effect on the environment. While the burning of fossil fuels for energy generation is known to introduce many harmful pollutants into the atmosphere and eventually contributes to environmental problems such as global warming and acid rain, solar energy is completely non-polluting any harmful substances on the other hand (FAO, 2000).

Indeed, the incorporation of solar energy into every dwelling and business will result in no land being destroyed in the name of energy generation. The decentralization ability of solar energy is something that burning fossil fuel cannot match as the primary element in the construction of solar panels is silicon and is the second most common element on the planet and environmental disturbance caused by the creation of solar panels is very little (Borchers *et al.,* 2007).

In all of the energy sources available, the most promising is perhaps solar energy. Numerically, it has the capability of producing the raw required power to satisfy the energy needs of the entire planet and environmentally, it is considered as one of the least destructive of all the sources of energy available, practically, it has the capability to be adjusted to provide power generation to nearly everything except transportation and with very little adjustment, even transportation with some modest modifications to the current general system of travel solar energy can be used. It can be said clearly that, solar energy is a resource of the future (Gillenwater, 2008).

Globally, the level of solar radiation experiences in South Africa is amongst the highest. Averagely, the daily solar radiation in South Africa varies between 4.5 and 6.5 kWh/m2 (16 and 23MJ/m2) when compared to about 3.6 kWh/m2 for most parts of the United States and about 2.5 kWh/m2 for Europe and the United Kingdom. The direct and diffused solar radiation in South Africa, have revealed that considerable solar resource potential for solar water heating applications, solar photovoltaic and solar thermal power generation can be tapped from the Sun (DME, 2003).

2.8.2 Wind Energy

The use of wind energy is one of the most environmentally neutral and cleanest forms of energy sources available in the world today, compared to other conventional fossil fuel sources of energy, the generation of energy from the wind does not degrade the quality of our air and water and can make an important contribution as a reducing climate-change effects and meeting national energy security goals (Bossanyi, 2003).

The uses of windmills for generating energy have been used for many centuries for pumping water and milling grain in farms. The discovery of the internal combustion engine and the eventual development of electrical grids have caused many windmills to disappear in the early part of this century. However, there has been a revival of interest in recent years in energy produced by wind and there are several attempts over the world to introduce a cost effective energy sources from the conversion of wind systems which are renewable and environmentally friendly (Bossanyi, 2003).

In developing countries, the use of wind power can play a useful role in supplying water, irrigation purposes (wind pumps) and generation of electricity (wind generators). The conversion of energy to electricity from windmill is usually through the structure that is mounted on a high tower which consists of blades. An air-shaft then transmits the blades into the ration from approximately 40 pm to 180rpm power to drive a power generator. The powers that are generated are stored in batteries for future use (Bossanyi, 2003).

The use of wind for power generation is beginning to penetrate the market on a rather large scale because new turbine technology has reduced the cost and increased the reliability of wind generated electricity to the point that it can now compete with conventional sources even when environmental costs have not been internalized (Tietenberg, 2006).

Using wind as a source of energy to generate power has added advantages which include: wind as a resource is very sustainable, wind as a primary energy source is free, currently, technology is being developed such that in future it can allow energy to be stored for use when required since it can be stored at peak periods and sourcing energy from wind is clean because it is without emissions or waste products (Eskom, 2003).

The disadvantages of generating power from windmills are that it mainly affects the environment by being aesthetically unpleasant It is also capital-intensive (construction) and the cost of production per kWh, when compared to coal fired power stations, are higher. While it is a clean source of energy, environmental impacts can include noise, visual pollution as well as affecting birdlife and wind as a resource is erratic and can only be used at a certain speed (Eskom, 2003).

2.8.3 Nuclear Energy

The production of nuclear energy occurs when there is a split of an atom's nucleus into smaller nuclei by the process called fission. Large atom fissions such as that of Plutonium and Uranium produce a great deal of energy. The fission of 1 gram of Uranium in fact produces the same amount of energy when 3 tons of coal is combusted or burned. The fission of uranium or plutonium can produce harnessed energy that can be able to produce electricity, propel spacecraft, and to power weapons like the Atomic Bomb (Mudd and Diesendorf, 2007).

Unlike a traditional coal burning power plant, when the nuclear power plant uses the energy, or heat, it produces through the fission of Uranium, rather than the burning of coal, which is used to heat water into the steam that are required to turn the turbines that power electric generators. The main advantage of using Uranium over coal energy is that Uranium fission does not produce soot and potentially harmful gases such as Carbon dioxide, which are produced when coal is burned. However, just like coal, Uranium needs to be mined and then processed before it can be used as an energy source. Also, like coal, there are different mining and processing steps before the actual energy is produced, but unlike coal, however, Uranium produces a great deal of wastes which are radioactive and thus more difficult to handle (Sovacool, 2008).

Radioactive elements are elements that are very unstable, and which continuously decay by releasing radiation. High energy particles or rays that can penetrate and damage matter with which they come into contact with are found in radiation. For example, the sun also releases radiation, which, when in large doses, can damage our skin (Mudd and Diesendorf, 2007).

Controversially, the debate about the uses of nuclear power has been on for a long time, but the proponents of its use claim that nuclear power is a very clean form of energy since very little fuel is needed to generate a lot of energy, and also no air pollution is produced when compared to the burning of coal (Sovacool, 2008). However, because of accidents such as the one at Three Mile Island in the US, the one at Chernobyl in the former Soviet Union and more recently, the Fukushima accident in Japan made many people oppose Nuclear Power. Also, environmentalists are more concerned about the disposal of the radioactive waste that is generated by the mining, processing and use of nuclear fuel. Currently, there are no universally acceptable methods for the storage and disposal of these wastes and there is concern that buried wastes might leak into groundwater and eventually make it into surface waters or into drinking water supplies (Sovacool, 2008).

In South Africa there is one nuclear power station, which is located in Koeberg, about 30 km north of Cape Town on the west coast. It consists of two pressurised water reactor units, each with a capacity of generating 920 MWe, and is cooled by seawater. The first unit was commissioned in 1984 and it is the only large power station in South Africa that is not located in the north east of the country, and as such it assists grid stability in the southwest. The finished fuel for Koeberg is imported, which is more economical than manufacturing it locally (Eskom, 2003).

2.8.4 Biogas Energy

Biogas is methane rich, clean burning fuel gas that is produced through the process of anaerobic digestion (bacterial action in a tank without air) from suitable biomass feedstock. Energy from biogas can be generated from dung such as that of cattle and animal wastes, and substantially with more difficulty, from some crop residues. Although, feedstock is used frequently and directly as cooking fuel, but they are not preferred in most areas as fuels and are used only when wood is not available (Safley and Westerman, 1988).

The use of biogas systems offers multiple benefits which include, in the process of anaerobic digestion, the organic nitrogen in the manure is largely converted to ammonium. Ammonium is the primary constituent of commercial fertilizer, which is readily available and is utilized by plants. Biogas systems can reduce offensive odours from overloaded or improperly managed manure storage facilities because these offensive odours can impair air quality and can also cause nuisance to nearby communities and the use of biogas systems reduce these offensive odours through the volatile organic acid content, the odour causing compounds, are consumed by biogas producing bacteria (Hill and Bolte, 2000).

Biogas is a flexible energy carrier that is suitable for many different applications. One of such simplest applications of biogas is the direct use for cooking and lighting, it is simple and reasonably efficient to use the gas directly in conventional low-pressure gas burners (Hill and Bolte, 2000). However, nowadays in many countries biogas is used for combined heat and power generation (CHP) or it is upgraded and fed into natural gas grids, used as vehicle fuel or in fuel cells (Hill and Bolte, 2000).

A number of countries initiated programmes on the use of biogas which have been developed on a large scale. For example, In Asia alone, millions of small scale digesters are owned by families and are in operation in countries like China, India, Nepal and Vietnam, producing biogas for cooking and lighting (Qui *et al.,* 1996). Thousands of agricultural biogas plants are also in operation in North America and Europe, and their number is continuously increasing. In Germany alone, more than 3.700 agricultural biogas plants were in operation in 2007 (Rutz *et al.,* 2008). Results have been mixed, especially in the early stages of China's efforts which led to the construction of about 7 million household scale digesters from 1973–78 but lack of quality control and management problems resulted in a large number of failures.

Recently, coordinated efforts have been geared to regions that are thought to be most promising for the technology and service organisations and biogas services stations have been established in those regions and in 1994, 5 million domestic plants of biogas were operating satisfactorily. Slightly, the experience in India has been on a smaller scale, but the numbers are still impressive at the end of 1998, almost 2.8 million domestic plants were installed. India's Ministry of Non-Conventional Energy Sources have identified a potential for 12 million digesters (Rutz *et al.,* 2008).

The experience of biogas in Africa has been on a far smaller scale and has been disappointing generally at the household level. The capital cost, cost of maintenance, and management support required have been higher than expected. Moreover, under subsistence agriculture, access to cattle dung and water that must be mixed with slurry has been more of an obstacle than expected. Nevertheless, there are better possibilities where farming is done with more actively managed livestock and where dung supply is abundant such as rearing feedlot based livestock (Kammen, 1999).

The enthusiasm for initial biogas development in Africa has thus been somewhat dampened, by experience because of its requirement for relatively large amounts of animal dung and the niche for household biogas plants is likely to remain small. Poor families do not have access to enough dung, and the better off families with sufficient animals often prefer to purchase fuel and fertiliser rather than spend time gathering dung and managing the often-temperamental digesters. Regardless of this, in the right institutional and social context, and coupled with appropriate technical expertise, the potential for biogas remains significant (Kammen, 1999).

2.9 Mitigation Strategies in combating fuel wood harvesting and consumption

The mitigation strategies will greatly contribute to the reduction of emissions while providing incremental financial resources that will stimulate sustainable development (DME, 2003).

2.9.1 Cooking with Energy-Efficient Improved Stoves

Since the 1980, there have been several programmes around the world that have focussed on improving biomass cooking stoves in the villages and urban slums of the developing world with the aim to developing and disseminating them. Often, these programmes have ranged in size from the introduction of a few hundred stoves by local non-governmental organisations to huge national efforts such as in China and India, which have affected millions of households. The aims of these programmes are to seek and accelerate the natural trend of cleaner, more efficient devices and for people to move towards when they are available and affordable (Reddy, 1999).

Over the last 20 years, more than 90 percent of the worldwide installations of improved cooking stoves have occurred in China. From 1982–99 the Chinese National Improved Stoves Programme reported the installation of improved stoves in more than 175 million rural households and these were mainly biomass stoves that are used for cooking (Smith *et al.,* 1993). Another example that is commonly cited is the success in the introduction of a more efficient ceramic charcoal cooking stove, known as the Jiko, which was developed in Kenya. So far, at least 700,000 of such stoves are now in use in the country, in urban homes, more than 50% of it is being used why about 16 percent in rural homes. More than 13,000 stoves are produced each month by about 200 small scale businesses and artisans. Both the stove itself and the general programme for disseminating it have been adapted for use in a number of other African nations (Kammen, 2000). Also successful is the 2003 top down Basa Njengo Magogo piloted by the Department of Minerals and Energy in South Africa. The testing of the stove at Orange Farm reveals a total 76% of the households reporting less smoke in their homes (Le Roux *et al.,* 2009).

The simple design of the stoves makes it much easier and with its high energy efficiency for use with such low volatility, solid fuels relative to those that use the unprocessed biomass that is the main source of household energy in the world's villages. The stoves are also inherently less polluting than those burning unprocessed biomass, and thus do not incorporate chimneys (Kammen, 2000).

2.9.2 Harvest Control

Attempts have been made to control indigenous forests and woodland harvesting, such as controlling transport and the issuance of felling licences. For example, a sustainable charcoal production and licensing system was piloted in major charcoal producing areas in Uganda with success (Kalumiana and Kisakye, 2001).

In some major African cities, the uses of roadblocks to control charcoal transportation are common and these measures have also been implemented effectively in some Asia states but also most attempts have failed. Often at times, loggers may buy one licence, but use it repeatedly and others even operate without a licence as they know they are unlikely to get caught. Transporters usually find routes to town that are not controlled by roadblocks, or they drive at night why others bribe guards or forest officers to get their way. The placing of costly control measures to regulate the harvesting of low value products like charcoal and fuel wood are then not worthy of putting in place by the authorities (Hofstad, 2008).

A promising option may be to devolve trees and forests responsibility (Cooke *et al.,* 2008), for example, through some form of community forest management. If trees are owned by local communities or individual farmers, control harvest might then become profitable when stumpage fees are charged. The fees could be in the form of per unit output or a share in the final product. For households in many rural areas, fuel wood or charcoal is seen as a cash crop that can supplement the meagre income they earn. The transfer of property rights of trees to local communities, individuals or farmers would increase their income, although if the rights were communal, the elites of the community could capture some benefits rather than individual. Land grabbing by better-off people may threaten equity in the case of individual ownership. However, if fuel wood becomes more expensive as a raw material, certainly, some of the costs would be rolled over to urban consumers since the dependence of fuel wood is more of the poor households than the better-off households, fuel wood and charcoal would hit the poor harder if it becomes more expensive.

Quota systems, licensing and transporting of fuel wood harvesting open up possibilities for corruption. Therefore, corruption as a risk should be considered by policy makers when designing the system so that only the elite should not reap the benefits to regulate harvesting in woodlands and indigenous forests (Larson *et al.,* 2008). Furthermore, the personnel in forestry may also be excluded from the processes of issuing licences and collecting revenue, and be handled by finance departments. In these cases, there would be no monitoring of harvests and available stocks, as the finance departments do not carry out such assessments.

2.9.3 Afforestation and Plantations

The planting of fast growing species has been attempted in various locations. There were a number of established large scale plantations during the 1980s and 1990s to increase the supply of fuel wood (Evans and Turnbull, 2004). Some of the plantations resulted in the production of poles and wood for construction which were reasonably profitably, but hardly have they successfully supplied charcoal and fuel wood to urban consumers. As long as there is open access to woodland and forest which supply better and cheaper fuel wood, consumers are not likely to shift to wood grown from plantations.

For policies like this to work, there has to be a combination of measures that will make fuel wood from indigenous forest less accessible and more expensive, and this happens either when the resource base of the forest or woodland becomes exhausted or when there is effectively controlled harvest. However, plantations are becoming more important in some places as a source of fuel wood for commercial use. In Ethiopia, the study demonstrated that fuel wood, primarily for commercial or personal use, was the reason why 21% and 15% of respondents, respectively, planted trees (Arnold *et al.,* 2006). The success of fuel wood plantation is limited, however, there is an unexploited potential for fuel wood as by product mainly for the management of shrubs and trees used for other purposes.

A study from Orissa, India, shows that community plantations can decrease the pressure on open access to natural forests (Kohlins and Parks, 2001). For many wood industries, particularly those into logging, sawmills, veneer and panel factories which are in many parts of the tropics, waste huge volumes of wood that could provide raw material for bio-energy but if the prices of logs and fuel wood were made higher, the better use of raw material and waste products might follow.

2.9.4 Environmental Education

The use of education as a tool is essential in the management and acquiring support for environmental protection. The effectiveness of using education as a tool must be, among other things, tailored to the need of the communities concerned with highly trained and qualified people to work in the field. According to Boahene (2008), about 90 percent of 103 small scale farmers that were interviewed in the eastern region of Ghana, they consider soil erosion and drought serious environmental problems, while none of them viewed global warming as a problem. Future changes in the climatic patterns induced by global warming seems not to bother the rural poor when they find it difficult to cater for their daily survival and again to them, global warming is mostly seen in the context that because it a threat to the industrialized nations that is why there is so much campaign about it (Boahene, 2008).

Environmental education to the rural communities should be designed in a way that all local environmental problems associated with deforestation should be emphasised. Environmental education can include such topics about the depletion of the ozone layer, issues of global warming and environmental awareness. The dissemination of improved technologies to the rural communities could be achieved with the formation of efficient environmental extension centres, which at most times is virtually lacking or non-existent in most at local levels. The introduction of formal environmental subjects needs to be vigorously taught at elementary schools to raise environmental awareness at an early stage and a continuation at post-secondary to ensure it being sustained.

In South Africa, fuel wood and deforestation issues are published in publications such as Vukuzenzele, which is available to everyone free of charge. This informs people about the environmental concerns (DEA, 2009). Also, most forests have been converted into National Parks and Nature Reserves as part of conserving natural resources. This is guided by the Protected Areas Act (PAA), This Act hinders or prohibits people from extracting resources from these areas (DEA, 2009).

2.10 Conceptual Framework

Figure 2.3 illustrates the conceptual framework which guides this study. It focuses on the factors that determine the type of energy used, i.e. poverty and unemployment have a profound effect on the types of energy sources used. The impacts of fuel wood use on health and wellbeing, the harvesting impacts to the environment through deforestation and emissions of trace gases into the atmosphere are also discussed. Forest restoration can be done through implementing different management and mitigation strategies such as using alternative energy, like solar, wind, biogas and nuclear energies, environmental education, harvest control, afforestation and plantation.

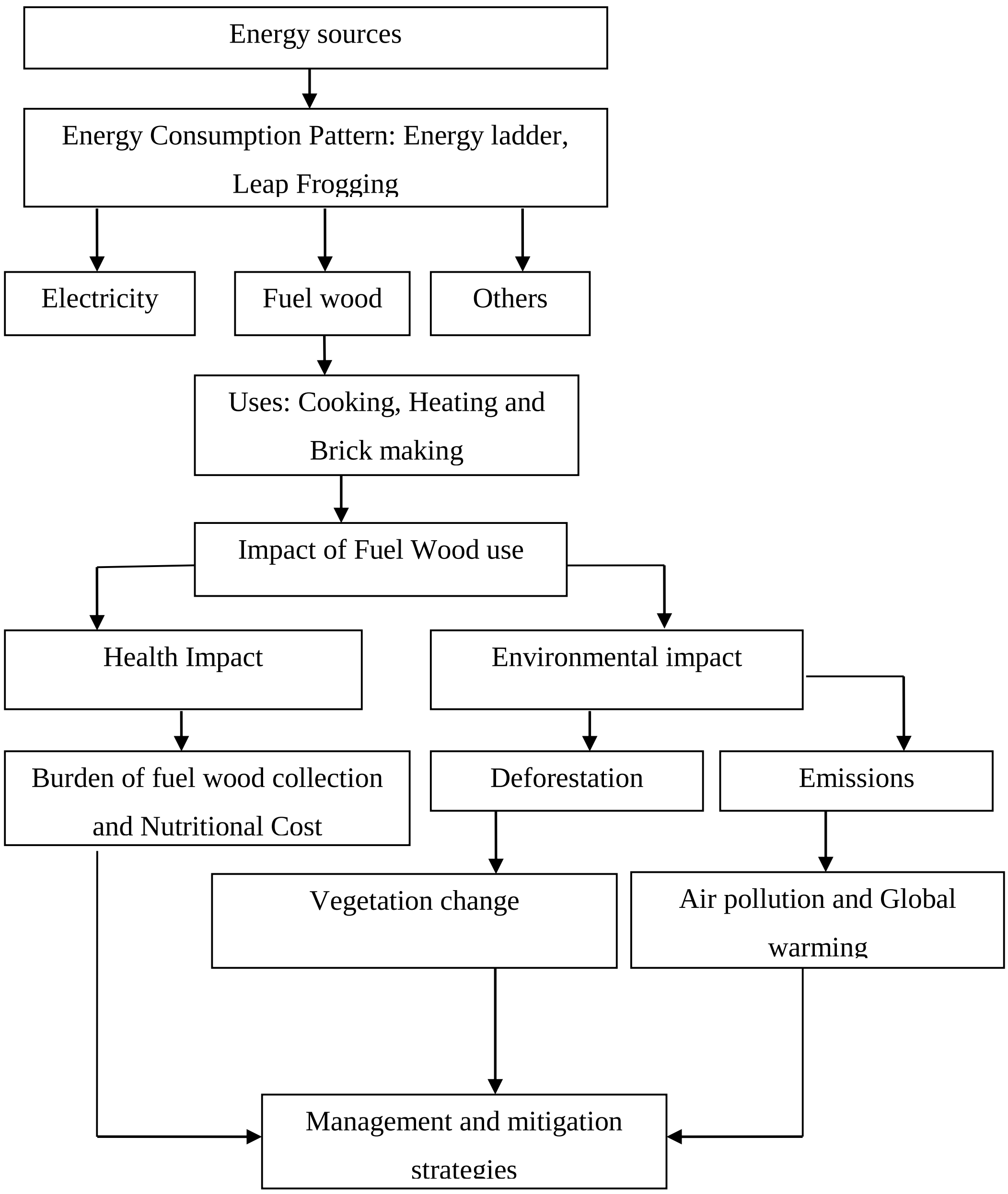


Figure 2.3: Conceptual Framework for the consumption of fuel wood as domestic energy.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methods that were used to collect and analyse data in the study areas. This section also covers the research design, methods of data collection and analysis that were used to achieve the objectives of the study.

3.2 Research Design

The research is designed to utilise both qualitative and quantitative methods of data collection and analysis and adopts a case study approach in assessing household energy use, emissions and deforestation in the Thulamela Local Municipality. It uses four villages as study areas.

3.2.1 Type of Design

This study takes a case study approach which is amenable to this study because it is designed to focus on the specific and interesting case of the study. The purpose of the study is to assess household energy use, the amount of carbon dioxide emitted from fuel wood used and the impact of deforestation from fuel wood harvesting, using four villages namely Altein, Botsoleni, Makovha and Thenzheni as study areas.

Questionnaires were designed to elicit quantitative data collection for each village and targets heads of households. Semi-structured interviews and focus group discussions elicit qualitative data. The questionnaires were administered with the aid of a local language translator. The interviews and focus group discussions were moderated by a local language translator, in order to facilitate a common understanding.

To examine the socio-economic profile of the respondents, Census data for 2011 from Statistics South Africa were consulted as well as the household questionnaires administered. To ascertain the extent of fuel wood use in relation to electricity, the administered questionnaires and Census data for 2011 were used. The questionnaires also had a section to record the weight and amount of fuel wood to be used by the households, and using the generic formula for CO_2 emissions, the amount of carbon dioxide emitted from the fuel wood was calculated from the weight recorded. Also from the recorded weight, using the Average Emission Factors, the amount of emitted Carbon monoxide, Nitrogen oxide and Methane were calculated.

To determine the extent of deforestation in the four villages, remotely sensed images were obtained and analysed using the remote sensing image interpretation technique of the Normalised Difference Vegetation Index (NDVI). To evaluate strategies to ensure sustainable energy provisions for the Thulamela Local Municipality from the case study villages, SWOT (Strength, Weakness, Opportunity and Threat) analysis was conducted on a focus group using semi-structured interviews and discussions involving Municipality Managers, Tribal Chiefs, Civil organization and Community members.

3.2.2 Sampling methods, Size and Unit of Analysis

This research followed the multi-stage sampling methods using stratified and systematic sampling. The use of the stratified sampling technique ensures that appropriate numbers of elements are drawn from homogenous subsets of the population (Huysamen, 2004). This method gives a representative sample of a population which clearly distinguishes the various subpopulations since the researcher can control the relative size of each stratum (Neuman, 2011).

The stratified sampling technique usually requires a smaller sample to ensure that the various subpopulations are included in the sample, and it is more representative of the population than a sample chosen using simple random sampling if the information in the stratum is accurate (Neuman, 2011). Systematic and cluster sampling can be used together with simple or stratified sampling or even in combination with each other. Although systematic sampling takes up less time and money, it still yields more accurate results (Huysamen, 2004).

The population size of the Thulamela Local Municipality is 618,462 people, spread across 228 villages and 156, 954 households. The sample sizes that comprise households and villages were divided into two strata as the unit of analysis, using the total number of households in the villages. The first stratum composes of villages of 1-500 households and the second stratum composes of villages with 500 and above households. Two villages with the highest number of households were selected from the first stratum and two villages with the lowest number of households were selected from the second stratum. This makes a total number of four villages, which are evenly-spread across the geographical location of the Thulamela Local Municipality. The unit of analysis is the households in the four villages.

Sampling frame

228 Villages and 156, 954 Households
in Thulamela Local Municipality

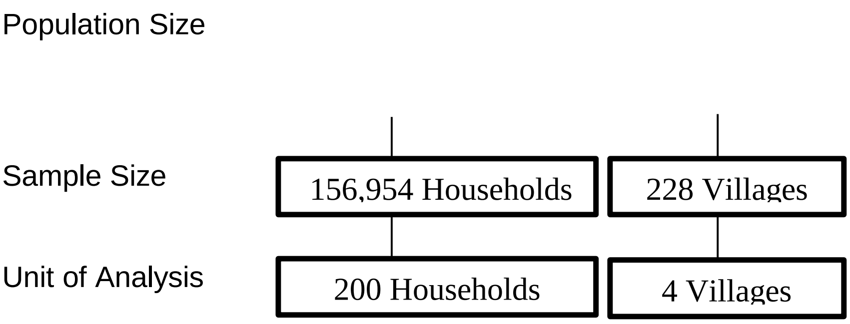


Figure 3.1: Sampling frame.

The study areas are spread across the geographical location of the municipality. In addition, the following criteria were used to justify the selection of the study areas: electrification, forest cover, and ecological environment under threat of fuel wood harvesting. Each criterion considered from the sample size is accurately represented in the unit of analysis. The villages and the total number of households are as follows: Altein (490), Thenzheni (500), Makovha (516) and Botsoleni (518) households (Statistics South Africa, 2011).

Proportionally, 50% of the total households, which is the unit of analysis in each village, were sampled systematically in numerical order of 1 in every 5th households which totals 203 households.

The sample sizes for the households were obtained as follows:

Altein = $\frac{\text{Total number of households}}{100} \times 50$

$= \frac{490}{100} \times 50$

$= 245 \text{ households}$

Systematic sample of every 1 in 5th of the 245 households = 49

Thenzheni = $\frac{\text{Total number of households}}{100} \times 50$

$= \frac{500}{100} \times 50$

$= 250 \text{ households}$

Systematic sample of every 1 in 5th of the 250 households = 50

Makovha = $\frac{\text{Total number of households}}{100} \times 50$

$= \frac{516}{100} \times 50$

$= 258 \text{ households}$

Systematic sample of every 1 in 5th of the 258 households = 52

Botsoleni = $\frac{\text{Total number of households}}{100} \times 50$

$= \frac{518}{100} \times 50$

$= 259$ households

Systematic sample of every 1 in 5th of the 388 households = 52

Total number of questionnaires administered = 49+50+52+52 = 203

3.2.3 Ethical Considerations

Ethical considerations were duly followed and permission obtained before visiting the field. Lupele (2002) emphasised the need to ask for permission from the traditional leadership or authorities before any research can be conducted in their rural set up. Permission was obtained from tribal leadership or authorities. The purpose of the study was explained to the leadership and authorities who publicise the study among the residents and to encourage them to give their full cooperation. Consent forms were also administered and fully explained to the participants. The participants were also free to withdraw from participation when they feel the need to do so.

3.3 Data Collection Procedures

The purpose of data collection is to obtain information that will aid in making decisions and achieving the objectives of the study. In this study, data collection process includes the gathering of primary and secondary data. The primary data collection was achieved through the use of questionnaires and interviews, while secondary data collection included remote sensing images and Census data (2011) from Statistics South Africa.

3.3.1 Questionnaire Survey

A total of 203 questionnaires with closed and open-ended questions were used to gather information from the respondents. The questionnaires were administered systematically to every 5th household in the four study areas of Altein, Thenzheni, Makovha and Botsoleni. The main targets were the household heads. Questions on demographic data, fuel wood use, harvesting and deforestation are contained in the questionnaire. The gathered information was used to achieve objective 1 and 2, which is to determine the socio-economic profile of the respondents and the extent of fuel wood use in relation to electricity, and also objective 3, which aims to determine the amount of carbon dioxide emissions from the fuel wood. The questionnaires have section to record the amount of fuel wood to be consumed. A few open-ended relevant questions were asked in the questionnaire.

3.3.2 Physical Measurement of Fuel Wood

To obtain the amount of fuel wood used, in order to calculate the amount of carbon dioxide, carbon monoxide, nitrogen oxide and methane emitted, households were asked to put aside the amount of fuel wood they are likely to use to prepare a meal. The fuel wood was weighed using a spring balance and the mass recorded on the questionnaire. The accuracy of this method in measuring the rates of fuel wood consumption has been assessed in Botswana and Rwanda by researchers of the African Energy Policy Research Network (AFREPREN) (Kgathi and Mlotshwa, 1994).

Fuel wood consumption rate by households can be determined using the normal per capita consumption where a simple household count is used. The daily per capita consumption of fuel wood per households can be measured.

3.3.3 Remote Sensing Imagery

Spot-5 satellite images at 20M resolutions and acquisition dates of 5 year intervals (2007 - 2012) were used to achieve objective 4, which is to determine the extent of deforestation from the impact of fuel harvesting on the study areas. The five year intervals were chosen because of the images availability. The Spot-5 images are of high resolution and also with much improvement designed primarily for vegetation monitoring. The satellite images were obtained from the South African National Space Agency (SANSA) in Pretoria.

3.3.4 Focus Group Discussions

The focus group discussion was led by a moderator and the target was drawn from Tribal Chiefs, Civil Organisations and community members in each of the four villages. The aim of the discussion is to understand their perceptions and views on alternative energy sources and uses. The outcome of the discussion is used to achieve objective 5, which is, to evaluate strategies to ensure sustainable energy provisions for the Thulamela Local Municipality using the four villages as case studies. The interviews and discussions were based on the SWOT Analysis (Strength, Weakness, Opportunity and Threat Analysis) framework.

The focus group discussions were done in a single meeting and the participants were from the Tribal Chiefs, Civil Organizations and community members. The discussion lasted for about 1-2 hours. The rationale behind the size of the group stems from the fact that focus groups should include enough participants, so that the result would yield diverse information, but at the same time should not include too many participants because large groups can create an environment where the participants will not feel comfortable sharing their beliefs, thoughts, experiences and opinions.

3.3.5 Field Observation

Field observation was used to identify some of the existing impacts such as the extent of de-vegetation on the forest. Field observation helps to glean information that could not be gathered from literature or through the administered questionnaire. During the field assessment, remote sensing images were complimented through 'Ground truth' where Global Positioning System (GPS) was used. The aim of 'ground truth' is to verify information extracted from remote sensing data. Also, during the field observation, a digital camera was used to capture moments of interest to support this study. Such pictures include areas where fuel wood is used for cooking. The pictures of fuel wood, harvesting hotspots and evidence of deforestation from fuel wood harvesting.

3.3.6 Document Analysis

The documentary analysis elicits the secondary data collections which are remotely sensed images obtained from the South African National Space Agency (SANSA) in Pretoria and Census data for 2011 obtained from Statistic South Africa.

3.4 Data Analysis

3.4.1 Questionnaire Analysis

In this study, the generated data from the administered questionnaires were analysed and simplified using Microsoft Excel (Excel 2010) and statistical procedures of Statistical package for Social Sciences (SPSS 21.0). The data were first coded, defined and labelled and fed in Microsoft Excel and were exported to SPSS program to generate descriptive and inferential statistics. The variables were summarised by determining the frequency of each code within the question and the analysis were undertaken for each sampled settlement. The data are presented in graph of cluster columns, pie charts and simple tables and contingency tables to clearly show the results. A non-parametric test (Chi-square test) was done to determine the nature of the relationship among the variables to ascertain the extent of electricity use in relation to fuel wood use in the sampled areas. The Cramer's V was used to test the association of the variables, the strength and the direction of the relationship.

3.4.2 Fuel Wood Consumption and Emissions Calculations

From the measured amount of fuel wood, the likely amount consumed by each household per meal in the four study villages was determined. Due to household sizes, there are variations in the number of people in each household in the case study villages which determine the quantity of fuel wood used in the preparation of meals per household.

Daily per capita consumption of fuel wood per households per meal was calculated using the expression: Consumption = C_w/P, where C_w is the total weight of fuel wood consumed daily by households per meal in kilogram (kg) and; P is the total sample population of the households. The per capita consumption rates are given as a means in kilograms (Kituyi *et al.,* 2001).

The accuracy in estimating the amount of emissions from fuel wood largely depend on the knowledge of quantities of wood consumed and the emission factors of the corresponding trace gas of interest that are needed (Bhattachayra *et al.,* 2000). According to Ludwig *et al.,* 2003, emission factor is defined as the mass of a compound that is released during the combustion per unit mass of dry fuel.

Two methods have been used for estimating trace gas emissions from fuel wood consumed. The first one requires the consumption rate of the fuel wood and the emission factors (Ludwig *et al.,* 2003; Bhattachayra *et al.,* 2000). The emission rates are estimated by multiplying fuel wood consumed by the emission factors (Ludwig *et al*., 2003). The second method is quite similar, except that the emission factor is based on an emission ratio using the carbon balance method. This requires knowledge of the carbon content of the fuel as well as moisture content and the non-carbon ash content (Yevich and Logan, 2003). The amount of carbon in fuel wood can vary from 35% by weight to 54%, but most research has assumed it to be about 50% (Lamlom and Savidge, 2003).

To determine the amount of carbon dioxide, the recorded mass of the fuel wood was used and the generic guideline used to calculate the carbon dioxide content of the fuel wood was followed. Dry wood is about 50% carbon and the equation for the conversion of carbon to carbon dioxide is: $C+CO_2\text{->}CO_2$. Carbon (C) has a molar mass of 12 grams and Carbon dioxide (CO_2) has a molar mass of 44 grams per mole (Lamlom and Savidge, 2003).

In this study the former method was used because as it only requires information on emission factors, which has already been determined for southern African fuels (table 3.1), and the amount of fuel wood to be consumed, which relatively, is easy to measure.

Table 3.1: Average emission factors calculated from the combustion of fuel wood based on on-line measurements conducted given as g C per kg of dry fuel (Ludwig, *et al.*, 2003).

Emission Factors

Type of fuel	**CO**	**NO**	**CH_4**
Fuel wood	**43**	**0.52**	**1.5**

The various gas emissions are calculated as: Emission estimate (g C per kg) = AC x EF

Where AC Average Consumption rate (kg of wood per household per meal) and EF is the Emission Factors (g C per kg of fuel wood burned).

3.4.3 Image Interpretation using Remote Sensing Technique

To analyse the extent of de-vegetation from the remotely sensed images, digital image-processing software ArcGIS 10.1 was used. The NDVI has been used for many years to measure and monitor plant growth and greenness (vigour), vegetation cover and biomass production from multispectral satellite data. NDVI is calculated as follows: NDVI = (channel 2 – channel 1) / (channel 2 + channel 1) or NDVI = (NIR - R) / (NIR + R) where NIR = Near Infrared reflectance value and R = Red Reflectance Value.

The analysed images were for the year 2007 and 2012 and this shows the vegetation pattern of the study areas. Satellite images of 2007 for the study areas were regarded as past vegetation cover and satellite images of 2012 were regarded as present vegetation cover. True colour composite of band combination of 4, 3, and 2 was carried out on the satellite images of the study areas. This was done to assist in identifying areas covered by vegetation within the study areas. The image analysis window in ArcGIS 10 software was used to calculate NDVI for each satellite image.

3.4.4 Focus Group Analysis

Using the SWOT analysis technique, the discussion and interview information was arranged in themes and issues. To analyse the views and perceptions from the focus group discussion and interviews, themes and issues were grouped in categories and discussed in simple descriptive narrative.

3.4.5 Field Observation

The collected data from the field observation were used in writing the report. The information was used mostly in the discussion of the results.

The methodologies employed to achieve the objectives and answer the research questions of this study are summarised in table 3.2.

Table 3.2: Summary of Research Questions, Methods and Procedures, Unit of Analysis and Data Analysis.

Research Questions	Methods and Procedures	Unit of Analysis	Data Analysis
What is the socio-economic profile of the respondents in the study areas?	Questionnaires and Census 2011 data	Household	Frequency distribution, Chi square and Cramer's V using SPSS
What is the extent of fuel wood use in relation to electricity use in the Thulamela Local Municipality from the four case study villages?	Questionnaires and Census 2011 data	Household	Frequency distribution, Chi square and Cramer's V using SPSS
What is the amount of greenhouse gases emitted from household fuel wood use?	Using the generic formula to calculate carbon dioxide emissions from fuel wood	Measured weight and amount of fuel wood	Calculate the total carbon dioxide emitted from fuel wood
What is the extent and rate of de-vegetation in the Municipality in the four case study villages?	Remotely sensed images (2007-2012)	Spot -5 Remotely sensed images (2007-2012)	Remote sensing technique using NDVI
What strategies may be recommended to ensure sustainable energy provision in the Thulamela Local Municipality?	Interviews and Focus Group discussions based on the SWOT Analysis framework	Focus Group	Analyse the views and perceptions of the respondents

CHAPTER 4: DATA PRESENTATION AND ANALYSIS OF RESULTS

4.1 Introduction

This chapter presents the analysed data that were acquired using administered questionnaires, field observations as well as satellite images. The data are presented using graphs, tables, chart and images. Themes dealt with in this chapter include demographic and socio-economic variables, which have a reflective effect that influences fuel wood harvesting.

4.2 Socio-Economic Characteristics of the Respondents

Socio-economic factors play an important role in determining the purchasing power of the respondents in respect to the kind of energy they used. From the administered questionnaires, the socio-economic profiles of the respondents were determined and presented as follows:

4.2.1 Gender of the Respondents

Gender describes the characteristics between men and female in a socially constructed society. It also refers to relationships which are a complex system of personal and social domination of power through which females and males gain access to power and material resources or how they are allocated status within society. The role of gender is crucial in this study as males and females plays different household duties. Men are mainly responsible with the supporting the family financially, while women are responsible with the management of the household. The gender of the respondents plays a role when dealing with the issue of fuel wood harvesting.

In African countries, particularly in rural settings, females and children (mostly girls) collect fuel wood because they are well acquainted to do house chores. The reason why there were more females respondents than males in the study is that females are the main collectors of fuel wood and the males also directed that the female's responds to the questions since they are more involved in domestic chores. It is rare to find a man carrying fuel wood on his head in the African culture and more so females know the type of trees to cut and how to tie them so that they can be able to carry them on their heads. This study found that females are the main collectors and users of fuel wood.

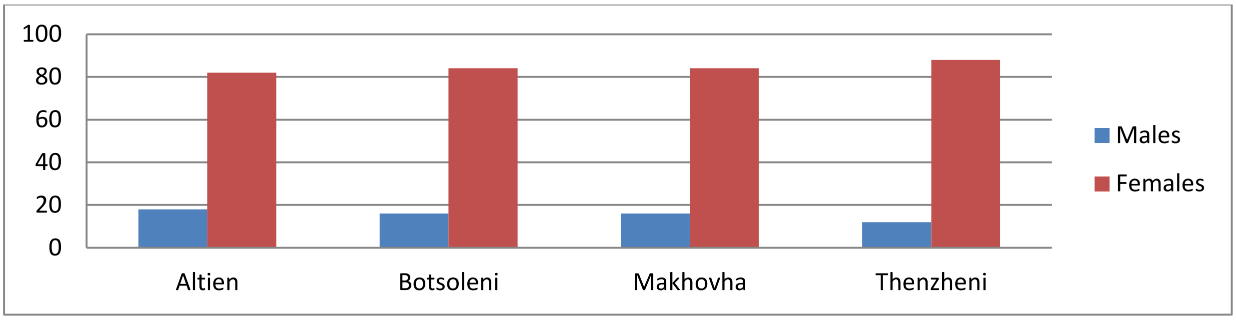


Fig 4.2.1: Gender of respondents in the four study villages

The survey revealed the respondent ratio in Altein to be 18% male and 82% female, Bostoleni 16% male and 84% female, Makovha 16% male and 84% female and Thenzheni 12% male and 88% female. The higher number of female respondents was due to the fact that female are more involved in domestic chores of the house, which include preparing meals for the family. This does not reflect that there are more female in the study areas than male, as most of the questionnaires were directed to the female by the male as they view it as more of a domesticated issue. The reason why there were male respondents is because the female were not available at the time of administering the questionnaires at the household.

4.2.2 Education Level of Respondents

Figure 4.2.2 shows that the educational level of respondents in the four case study villages to be generally low. Altein with 20% of the respondents having no formal education, 56% with primary, 18% with secondary and 6% with tertiary education, for Botsoleni, 14% were without a formal education, 55% with a primary, 22% with a secondary education and 9% with, tertiary education, Makovha reflects 22% without formal education, 61% had a primary education, 11% had a secondary and 6% had a tertiary education and Thenzheni shows 11% with formal education, 64% have a primary education, 17% secondary and 8% tertiary education respectively.

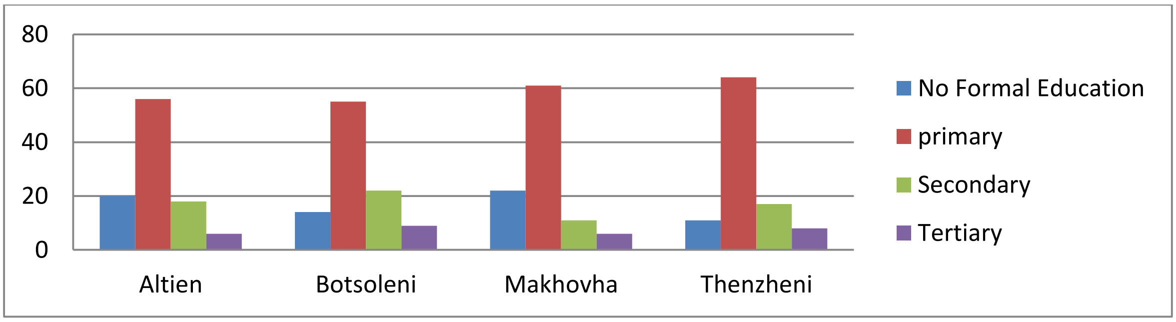


Fig 4.2.2: Percentage of respondent’s Educational level

The survey found that the respondents are likely to have a negative attitude towards the environment due to their low level of education, whereas those with a high level of education are likely to be associated with a positive attitude towards conserving the environment. However, even educated people in this study do purchase fuel wood to supplement electricity for domestic purposes.

4.2.3 Employment Status

The employment status of any given society plays a critical role in how the economy of the society is sustained and also a direct reflectance on how the environment is being preserved or degraded. If the level of unemployed people is more than that of the employed, there is a tendency of environmental deterioration in such a society since the communal forests are open for everyone to use, so people will able to harvest resources without hindrance. The employment status of the respondents is crucial as it shows how the households can access resources.

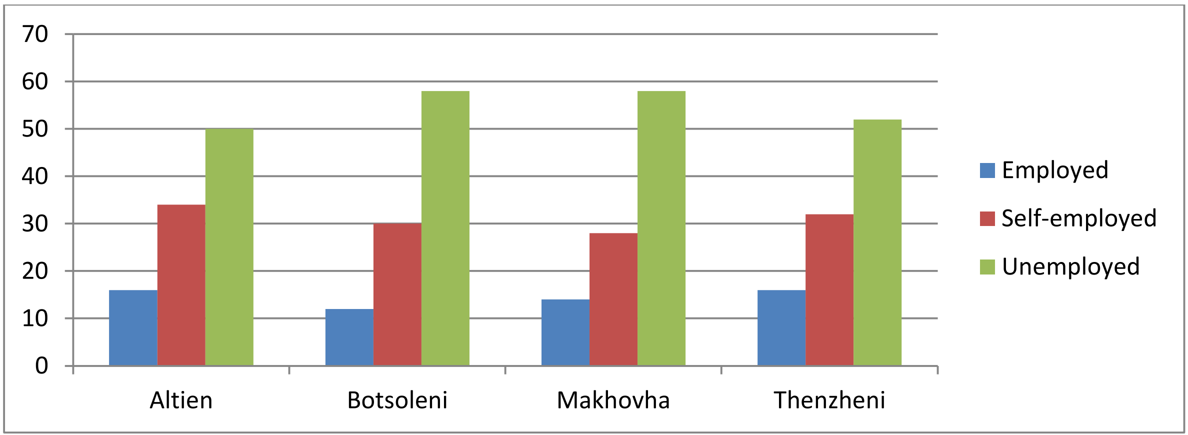


Fig 4.2.3: Percentage of respondent's Employment status

The field survey shows that for Altein, 16% of the respondents were employed, 34% self-employed and 50% representing half of the total survey as unemployed. For Botsoleni, 12% employed, 30% self-employed and 58% are unemployed. Makovha shows 14% as employed, 28% were self-employed, and 58% were unemployed while Thenzheni have 16% as employed, 32% self-employed and 52% unemployed.

Comparing the level of employment of the respondents in this study, the level of unemployment exceeds the levels of the self-employed and employed. This implies that a high rate of unemployment within the community is a threat to the environment. However, some of the employed respondents said they also harvest fuel wood. This study found that a high unemployment rate has a drastic effect on the environment as most of the unemployed spend most of their time harvesting fuel wood. The unemployed respondents depend on money/income from pension, government grants and remittance from family members working in urban centres. The self-employed women engage themselves by selling vegetables, fruits and other types of food in the village. The self-employed males are artisans who depend on their handiwork to earn income.

4.2.4 Household Income

Figure 4.2.4 indicates the variation in the monthly incomes earned by the household members in the study areas. It shows that in four study villages, the respondents earn far less than R3500 monthly with the majority in the bracket of R0-R1500.

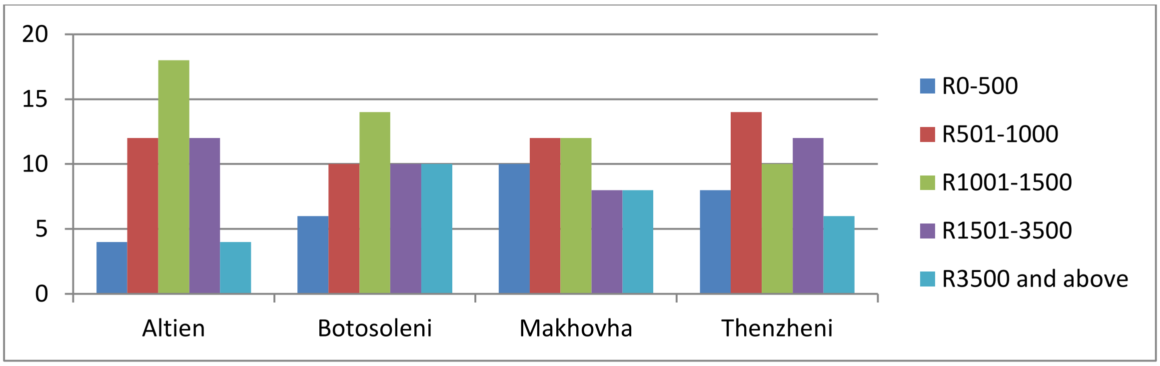


Fig 4.2.4: Households Income bracket

Altein has 4% of the respondents in the income bracket of R0-R500, 12% in R501-R1000, 18% on R1001-R1500, 12% in the bracket of R1501-R3500 and 4% earning above R3500. Botsoleni, has 6% of the respondents in the income bracket of R0-R500, 10% in R501-R1000, 14% on R1001-R1500, 10% in the bracket of R1501-R3500 and 10% earning above R3500. Makovha, has 10% of the respondents in the income bracket of R0-R500, 12% in R501-R1000, 12% on R1001-R1500, 8% in the bracket of R1501-R3500 and 8% earning above R3500. Thenzheni, has 8% of the respondents in the income bracket of R0-R500, 14% in R501-R1000, 10% on R1001-R1500, 12% in the bracket of R1501-R3500 and 6% earning above R3500.

From the survey, people with a low income spend most of their time harvesting fuel wood in order to meet their domestic energy demand. The sales of fuel wood were not found to be lucrative as a bundle of dried wood goes between R15 to R25. Low income earners will continually harvest fuel wood while reserving the little electricity they have for lighting.

4.3 Energy Mix of the Communities

This section reveals the available energy sources and its uses in the study communities of Altein, Botsoleni, Makovha and Thenzheni. The results show that all the respondents (100%) had access to electricity. However, fuel wood still played a major part of their energy mix, mainly for cooking and water heating purposes. Despite having access to electricity, the field survey in the villages points out that the respondents still used fuel wood as their main source of cooking.

4.3.1 Cooking

Extensively, cooking requires a lot of energy because it takes some time to get food prepared. The graph shows that in Altein 6% depend on electricity for cooking, 62%, on fuel wood and 32% do their cooking using both fuel wood and electricity to form their energy mix. The survey of Botsoleni respondents indicates 8% uses electricity for cooking, 66% depends on fuel wood and 26% forms their energy mix. Makovha has 4% of its respondents relying on electricity for cooking, 70%, fuel wood and 26% mix their energy for cooking. Thenzheni has only 4% of its respondents using electricity for cooking purpose, 74% heavily rely on fuel wood and only 22% mix their energy.

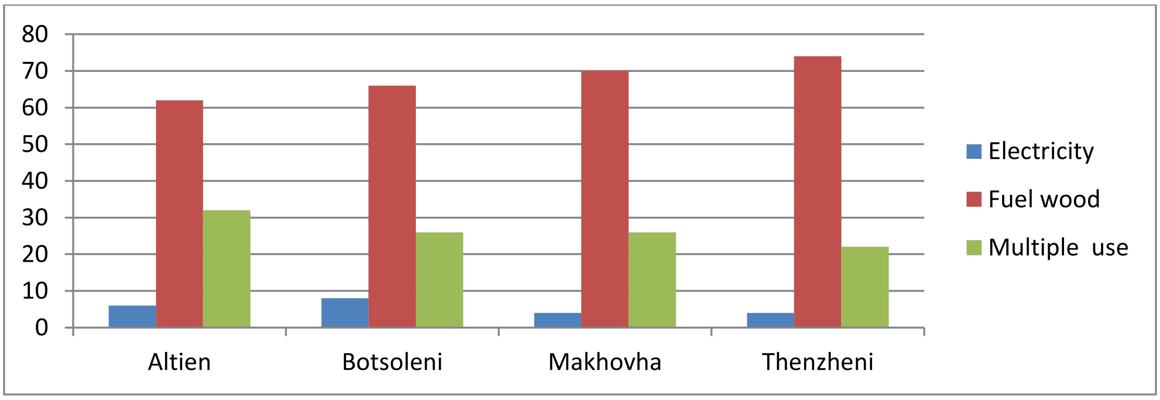


Fig 4.3.1: Percentage distribution of Energy used for cooking

4.3.2 Water Heating

Water heating also results in extensive use of energy. The graph shows how the four case study villages heat their water using electricity and fuel wood. Altein 10%, 58% and 32% indicates how electricity, fuel wood and the mix of both are used in heating water, Botsoleni 12% electricity, 52% fuel wood and 36% mixing the energy, Makovha indicated 6% electricity, 60% fuel wood and 34% using both electricity and fuel wood and lastly, Thenzheni has 8% of the respondents using electricity, 60% relies on fuel wood and 32% forms its multiple use.

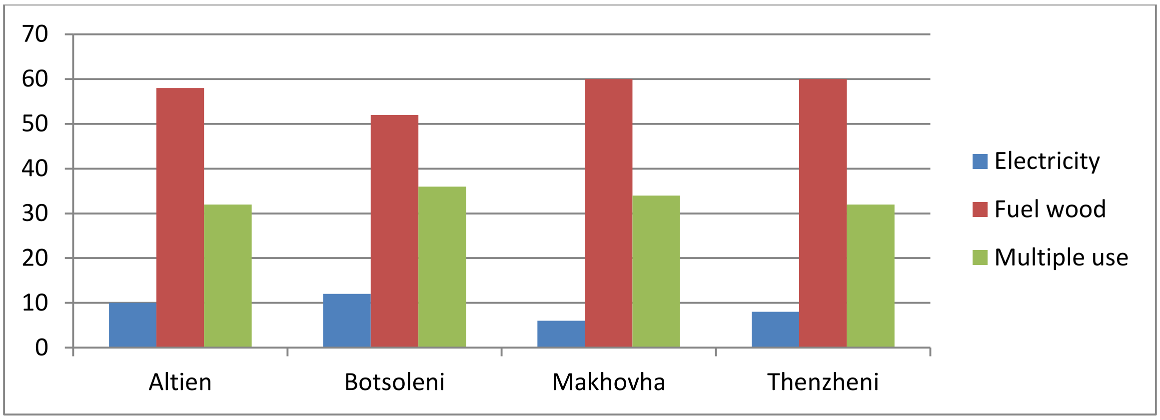


Fig 4.3.2: Percentage distribution of energy used for heating

4.3.3 Perceptions for Energy Usage

From the surveyed questionnaires, the perceptions of the respondents on why certain energy sources are preferred were also established. In Altein, 88% of the respondents ascertained that electricity is expensive, 58% are using fuel wood because of its abundance, 12% are using fuel wood because it is cheaper than other form of available energy and 42% believed meals prepared with fuel wood tastes better, 84% of Botosleni respondents indicate that electricity is expensive, 62% agree that fuel wood is abundant and 10% says fuel wood is a cheaper source of energy and 44% attribute it to taste. In Makovha, 90% say electricity is expensive; 60%, says there is abundance of fuel wood and 10%, says it is cheaper while 40% use it because of the taste and lastly, 84% of Thenzheni respondents indicated that electricity is expensive, 60%, says there is abundance of fuel wood and 18% agrees it is cheaper to use fuel wood as a source of domestic energy and 38% says food cooked on fuel wood tastes better.

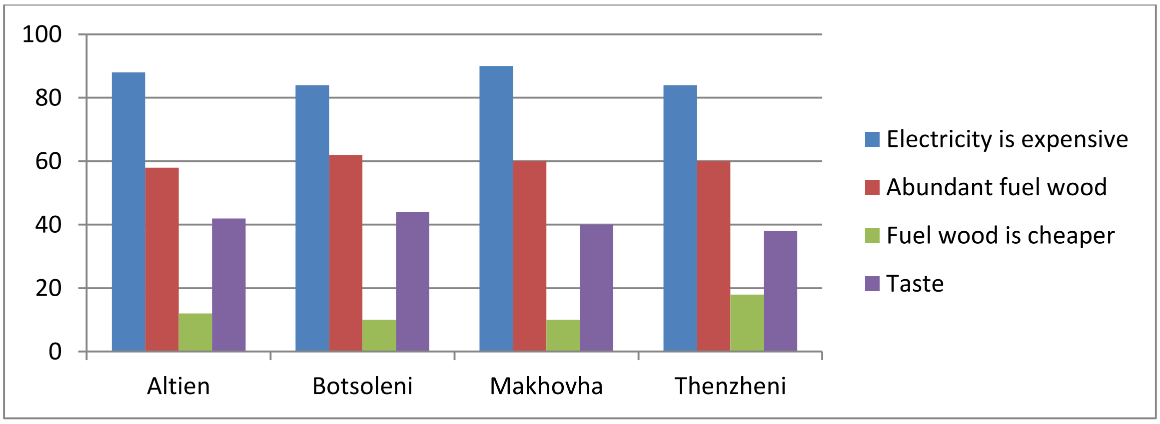


Fig 4.3.3: Percentage of respondents on why they use fuel wood

4.4 Fuel Wood Consumption and Emissions of Greenhouse gases

Using the daily per capita fuel wood consumption per meal per household in the four case study villages, the summed total of the 50 sampled households in each of the study areas are; Altein 98.2 kg, Botsoleni, 101.3 kg, Makovha, 105.2 and Thenzheni, 103.6 kg which total 611.3 Kg of fuel wood is consumed in the four villages in preparing a meal. Further, to determine the per capita consumption of fuel wood a preparing a meal in the four villages, the sum total is divide by the sampled households which is 50.

Altein, 98.2 / 50 = 1.96 kg.
Botsoleni, 101.3 / 50 = 2.02 kg
Makovha, 105.2 / 50 = 2.10 kg
Thenzheni, 103.6 / 50 = 2.07 kg
The trend in the summation indicates that Makovha consumed a little more fuel wood per meal than the other villages.

To determine the carbon dioxide emitted from the combustion of 1.96 kg per meal per household in Altein, the generic formula for the conversion of carbon to carbon dioxide was used, with the chemical equation of $C + O_2 \rightarrow CO_2$ = 1.96 X 0.5 = 0.98; 0.98 X (44/12) = 3.59 kg of CO_2 is emitted per household.

From the emission factors, the calculated amount of Carbon monoxide (CO), Nitrogen oxide (NO) and Methane (CH_4) are as follows:

Carbon monoxide (CO) = 1.96 x 43 = 0.84 g C or 0.00084 kg

Nitrogen oxide (NO) = 1.96 x 0.52 = 1.01 g C or 0.00101 kg

Methane (CH_4) = 1.96 x 1.5 = 2.94 g C or 0.00294 kg

In determining the carbon dioxide emitted from the combustion of 2.02 kg per meal per household in Botsoleni, the generic formula for the conversion of carbon to carbon dioxide was used, with the chemical equation of $C + O_2 \rightarrow CO_2$ = 2.02 X 0.5 = 1.01; 1.01 X (44/12) = 3.70 kg of CO_2 is emitted per household.

From the emission factors, the calculated amount of Carbon monoxide (CO), Nitrogen oxide (NO) and Methane (CH_4) are as follows:

Carbon monoxide (CO) = 2.02 x 43 = 0.86 g C or 0.00086 kg

Nitrogen oxide (NO) = 2.02 x 0.52 = 1.05 g C or 0.00105 kg

Methane (CH_4) = 2.02 x 1.5 = 3.03 g C or 0.00303 kg

To determine the carbon dioxide emitted from the combustion of 2.10 kg per meal per household in Makovha, the generic formula for the conversion of carbon to carbon dioxide was used, with the chemical equation of C + O_2 -> CO_2 = 2.10 X 0.5 = 1.05; 1.05 X (44/12) = 3.85 kg of CO_2 is emitted per household.

From the emission factors, the calculated amount of Carbon monoxide (CO), Nitrogen oxide (NO) and Methane (CH_4) are as follows:

Carbon monoxide (CO) = 2.10 x 43 = 0.90 g C or 0.00090 kg

Nitrogen oxide (NO) = 2.10 x 0.52 = 1.09 g C or 0.00109 kg

Methane (CH_4) = 2.10 x 1.5 = 3.15 g C or 0.00315 kg

To determine the carbon dioxide emitted from the combustion of 2.07 kg per meal per household in Thenzheni, the generic formula for the conversion of carbon to carbon dioxide was used, with the chemical equation of C + O_2 -> CO_2 = 2.07 X 0.5 = 1.03; 1.03 X (44/12) = 3.77 kg of CO_2 is emitted per household.

From the emission factors, the calculated amount of Carbon monoxide (CO), Nitrogen oxide (NO) and Methane (CH_4) are as follows:

Carbon monoxide (CO) = 2.07 x 43 = 0.89 g C or 0.00089 kg

Nitrogen oxide (NO) = 2.07 x 0.52 = 1.07 g C or 0.00107 kg

Methane (CH_4) = 2.07 x 1.5 = 3.10 g C or 0.00310 kg

4.5 Deforestation in the Studied Villages

The rate and extent of deforestation in the study villages are influenced by certain factors which include the following:

4.5.1 Access to Fuel Wood and Harvesting Preference

The communities have access to fuel wood in only two ways, which are, as harvesters and purchasers. The graph shows that the majority of the fuel wood consumers in the case study villages, harvest fuel wood, leaving very few respondents who purchase fuel wood. Respondents in Altein reveal that 78% harvests and 22% purchase fuel wood. In Botsoleni 80% are harvesters and 20% are purchasers. In Makovha 90% harvested the wood and 10% purchase it and Thenzheni shows 82% prefer harvesting and 18% prefer buying fuel wood. The reason why there are high percentages of fuel wood collectors is because most of the community members are unemployed and have access to the forest. The few that purchased fuel wood were those that were employed and at times, did not have time to go into the forests and harvest it.

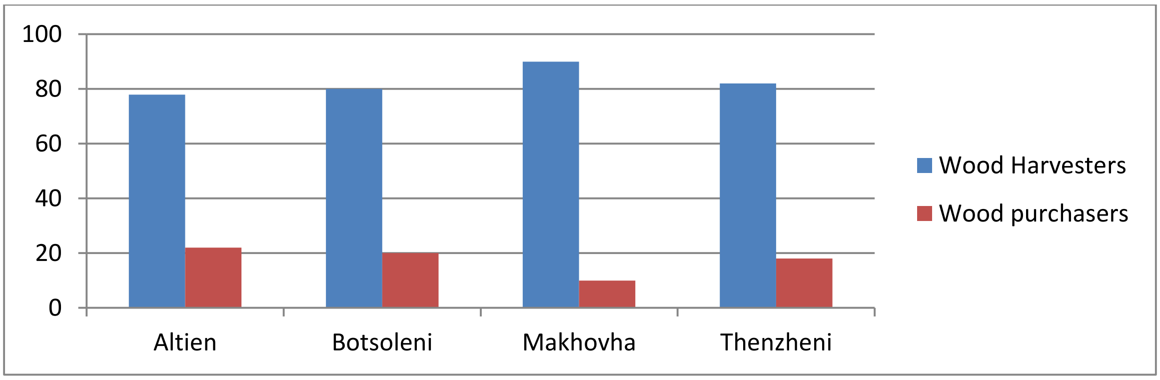


Fig 4.5.1: Wood accessibility

The questionnaires further reveal the preferences of fuel wood harvesting by the respondents. Fuel wood is harvested from different hotspots which are characterized by the dominant type of tree species. Certain species of trees are targeted due to their degree of flammability and availability. The respondents also said that they cut living trees as well as collect dead wood. Figure 4.5.2 shows fuel wood harvesting hotspots in the study areas.

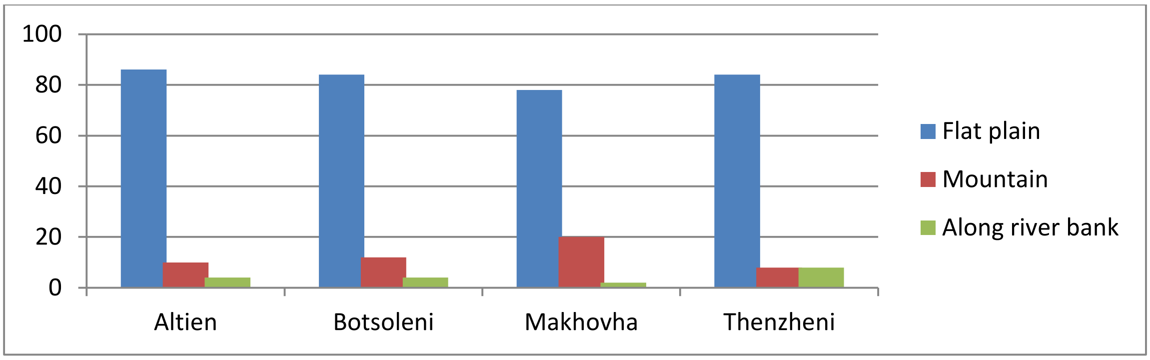


Fig 4.5.2: Percentage of fuel wood harvesting hotspot preference

Figure 4.5.2 shows that the most affected hotspots for fuel wood harvesting are the flat plains in the four villages, with Altein having 86% of fuel wood harvested from them, 10% from its mountain and 4% from its river bank For Botosleni, 84% of the respondents harvest wood from the flat plain; 12% from the mountainous areas and 4% from the bank of the river. Makovha has 78% harvest from the flat plain; 20% from the mountain and 2% from the river bank, while Thenzheni has 84% from the flat plain, 8% from the mountain and 8% prefer to harvest along the river. Tree species such as *Dichrostachys cineria* and *Combretum inbrebe* dominate the flat plains, *Barchemia zeyheri*is mostly available in mountainous areas while *Selerocarya birrea* is found mostly along the river. The figure above shows that the flat plain is mostly affected by the issue of deforestation as a result *Dichrostachys cineria* and *Combretum inbrebe* are under threat because they dominate the flat plains.

4.5.2 Rate and Extent of Deforestation from Satellite Imagery

The rate and extent of de-vegetation in the four study villages was determined by the remote sensing technique of the Normalized Difference Vegetation Index (NDVI).

Figure 4.5.3 shows the spot 5 non-panchromatic 4 band satellite images for Altein in 2007 and 2012 in Red, Green and Blue band.

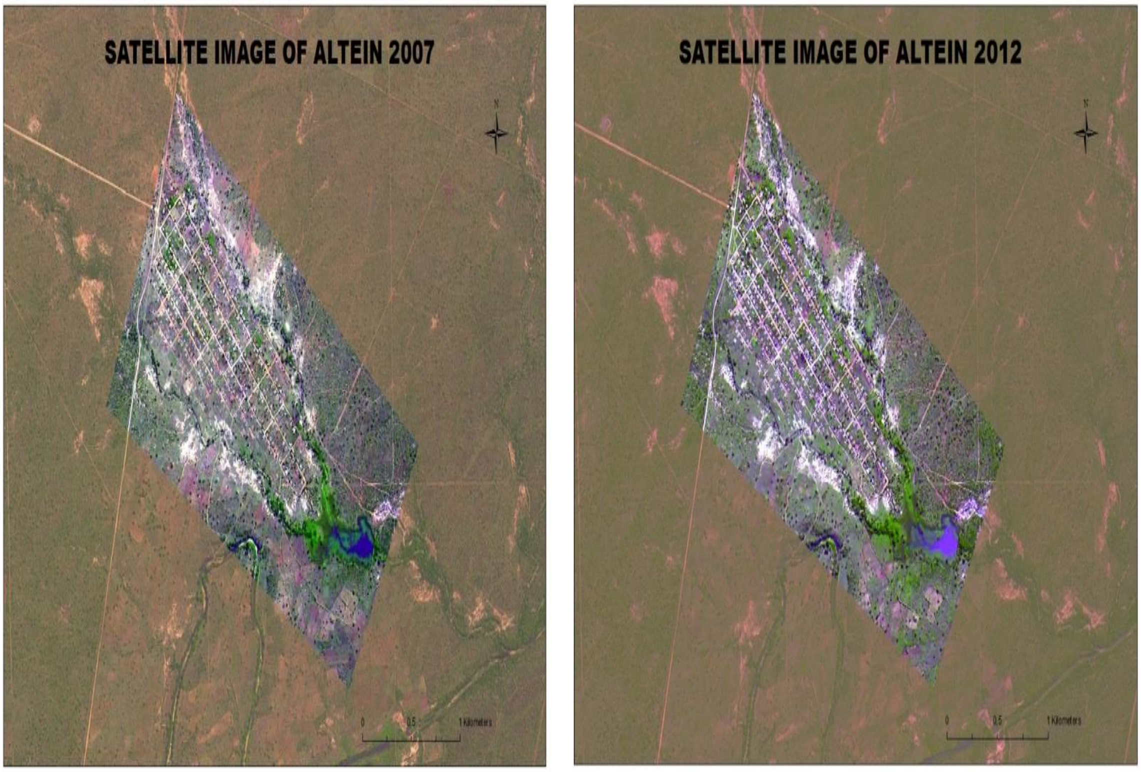


Fig 4.5.3: Satellite images of Altein 2007 and 2012.

Spot 5 non-panchromatic 4 band satellite images for Botsoleni and Makovha in 2007 and 2012 in Red, Green and Blue band showed in figures 4.5.4 and 4.5.5.

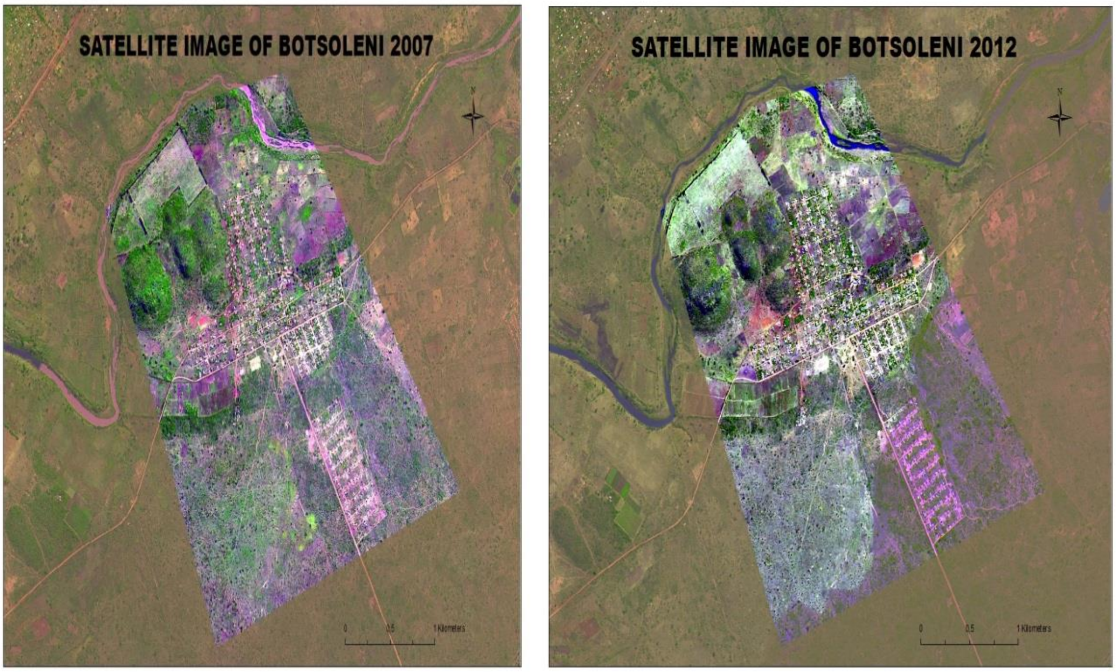


Fig 4.5.4: Satellite images of Botsoleni 2007 and 2012

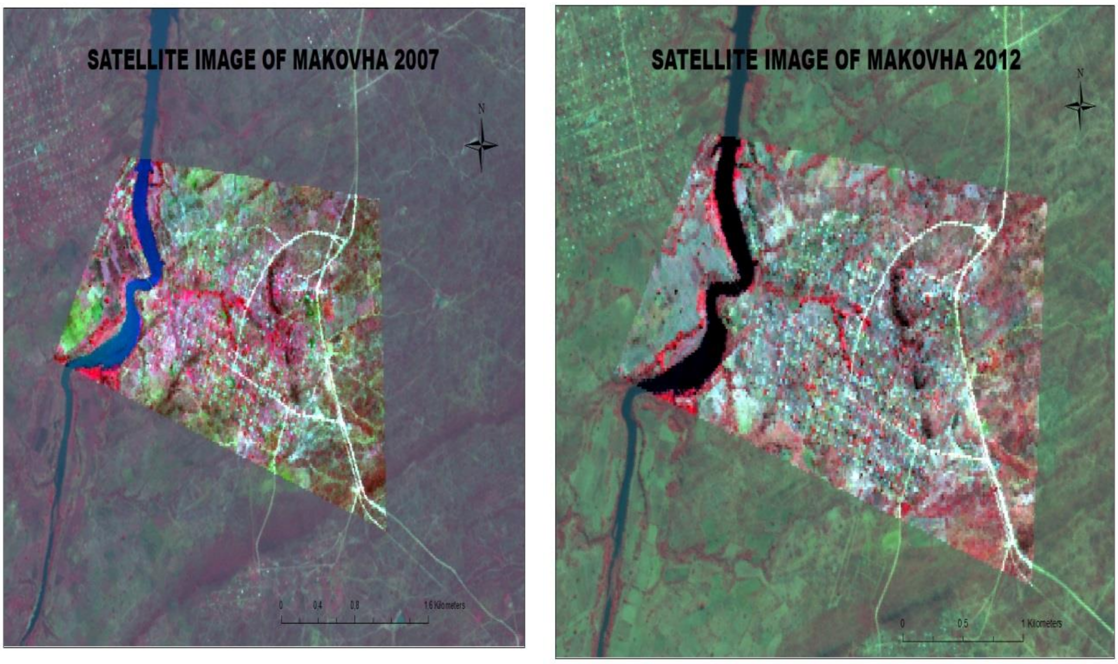


Fig 4.5.5: Satellite images of Makovha 2007 and 2012.

Figure 4.5.6 shows the spot 5 non-panchromatic 4 band satellite images for Thenzheni in 2007 and 2012 in Red, Green and Blue band.

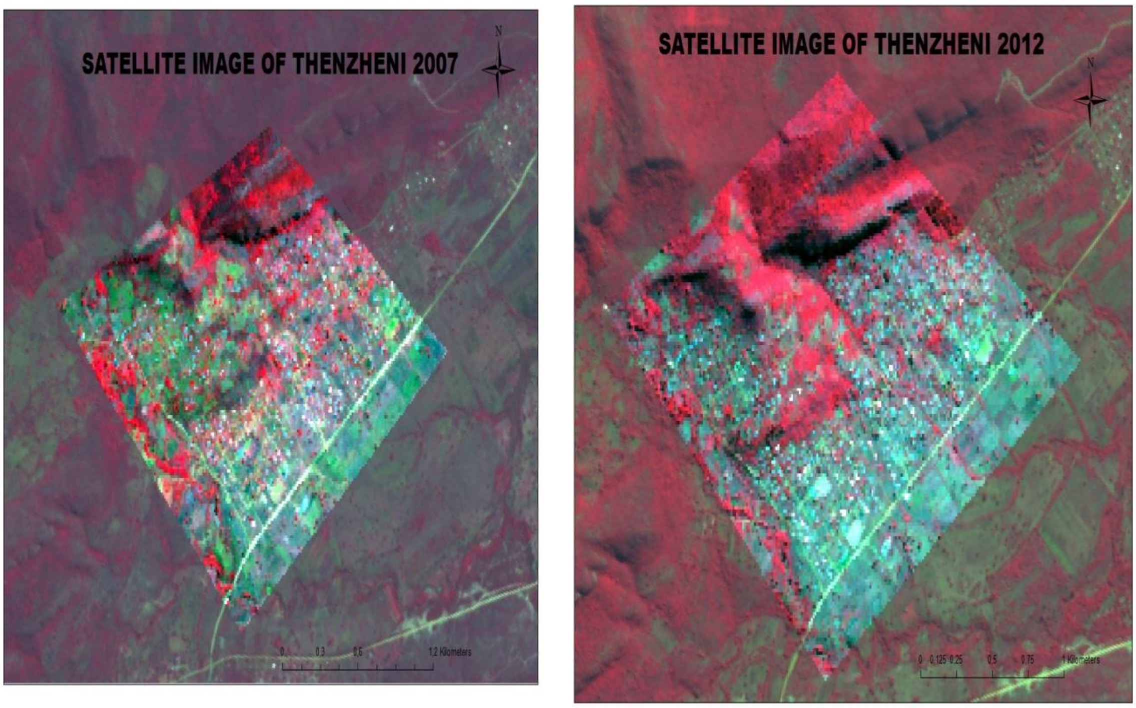
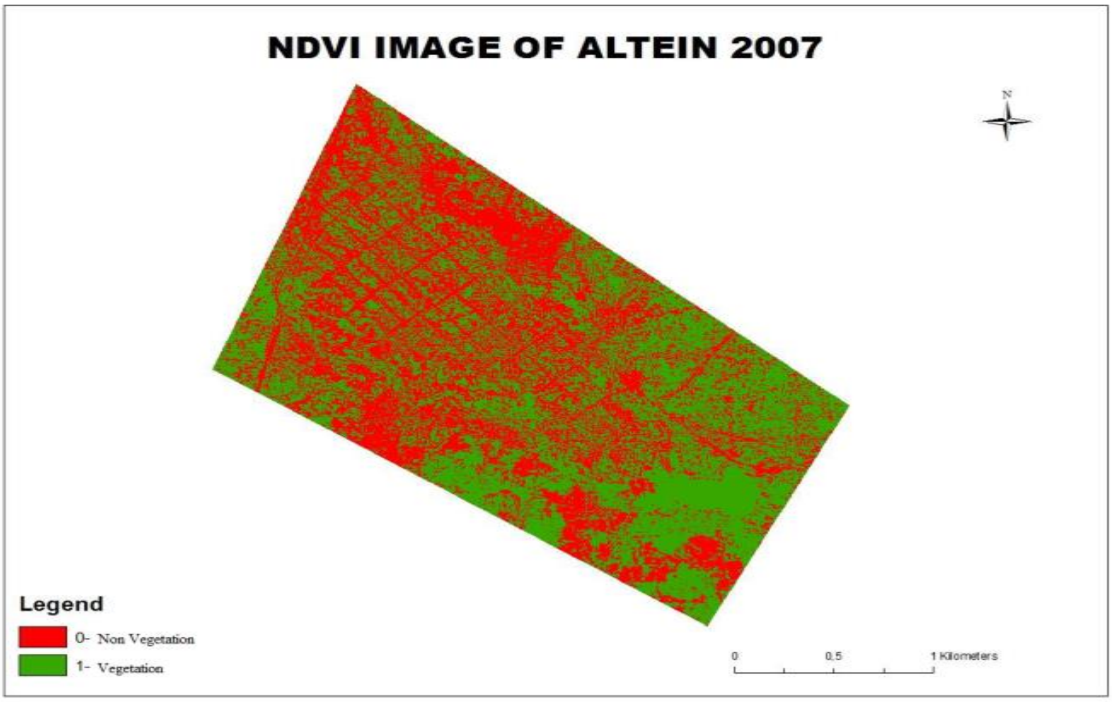


Fig 4.5.6: Satellite images of Thenzheni 2007 and 2012.

Figure 4.5.7 shows the processed satellite images with the technique of NDVI that determine the vegetated from non-vegetated areas of Altein for the year 2007 and 2012.



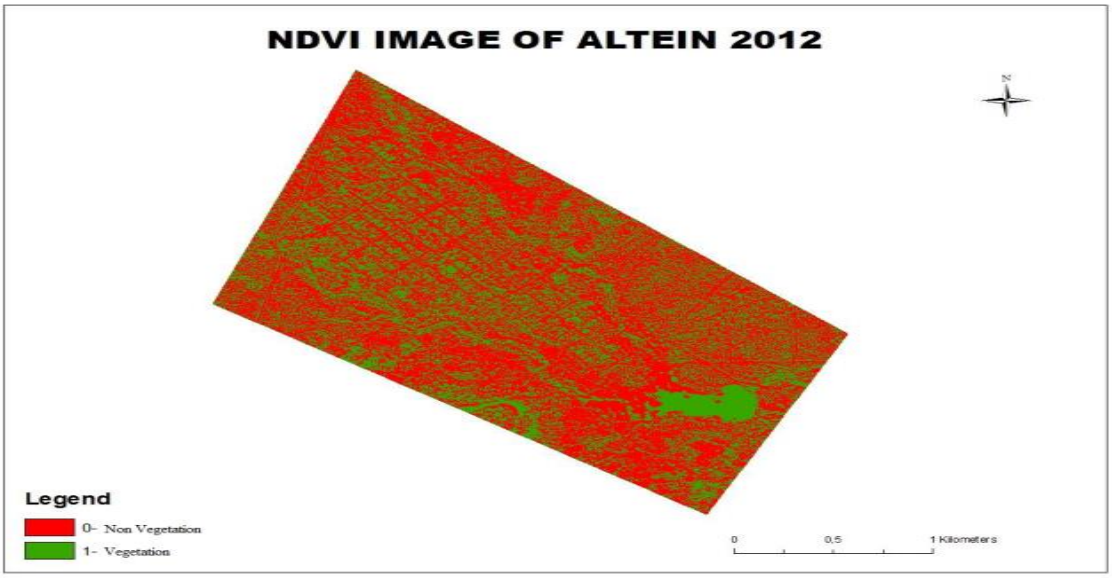
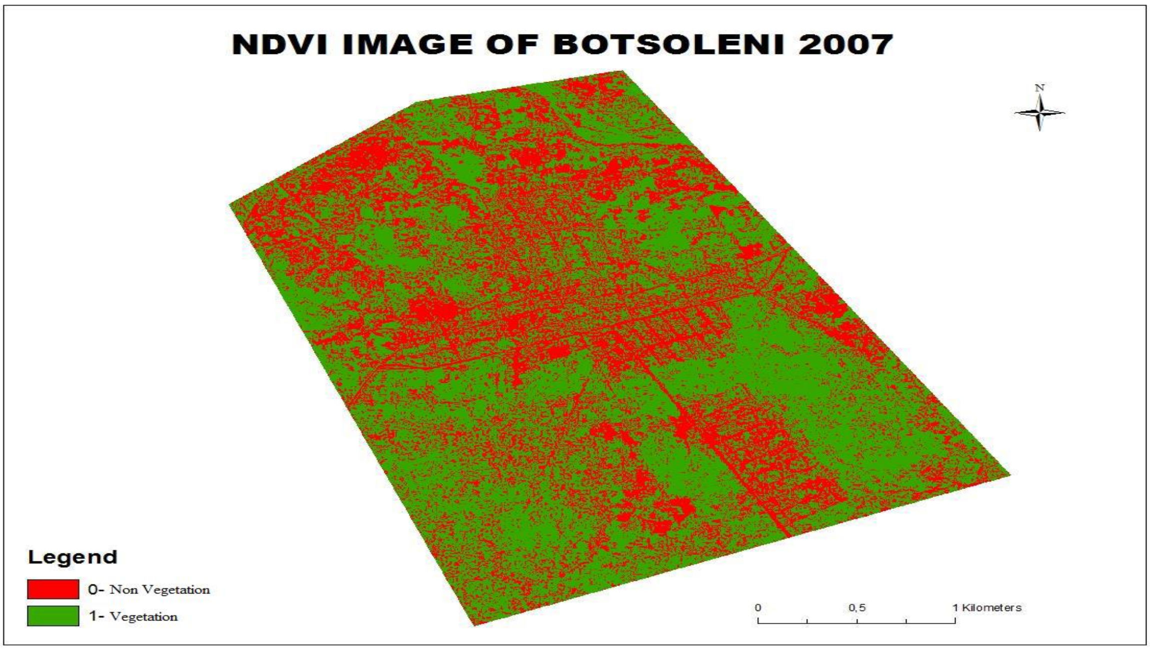


Fig 4.5.7: NDVI Images for Altein 2007 and 2012

Figure 4.5.8 shows the processed satellite images with the technique of NDVI that determine the vegetated from non-vegetated areas of Botsoleni for the year 2007 and 2012.



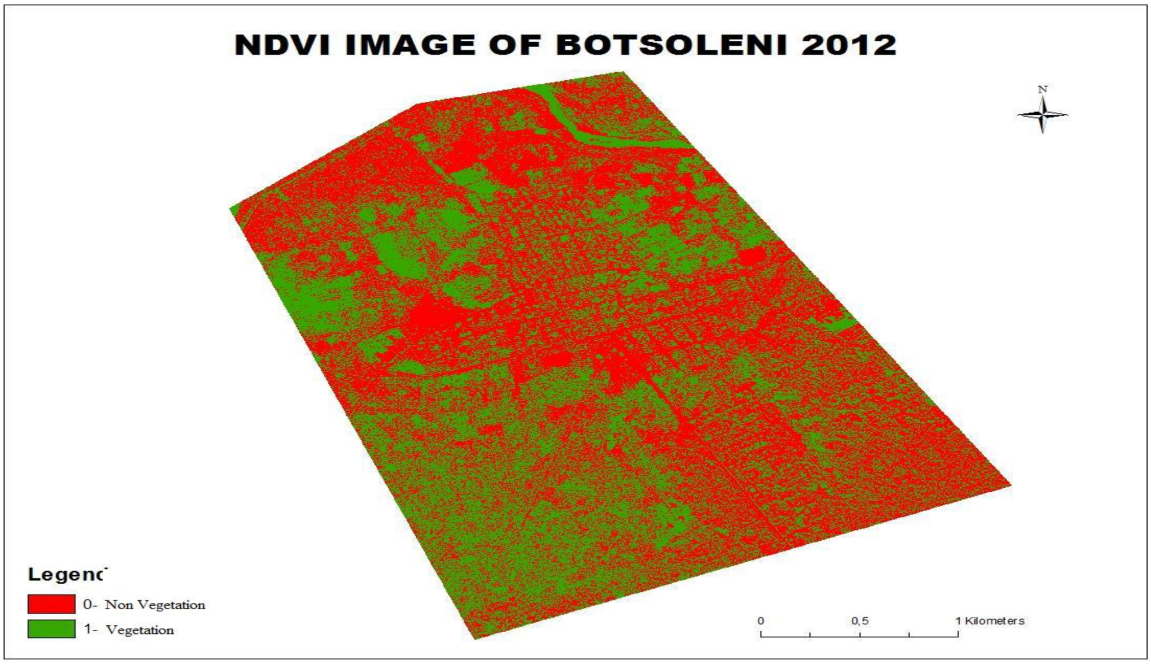
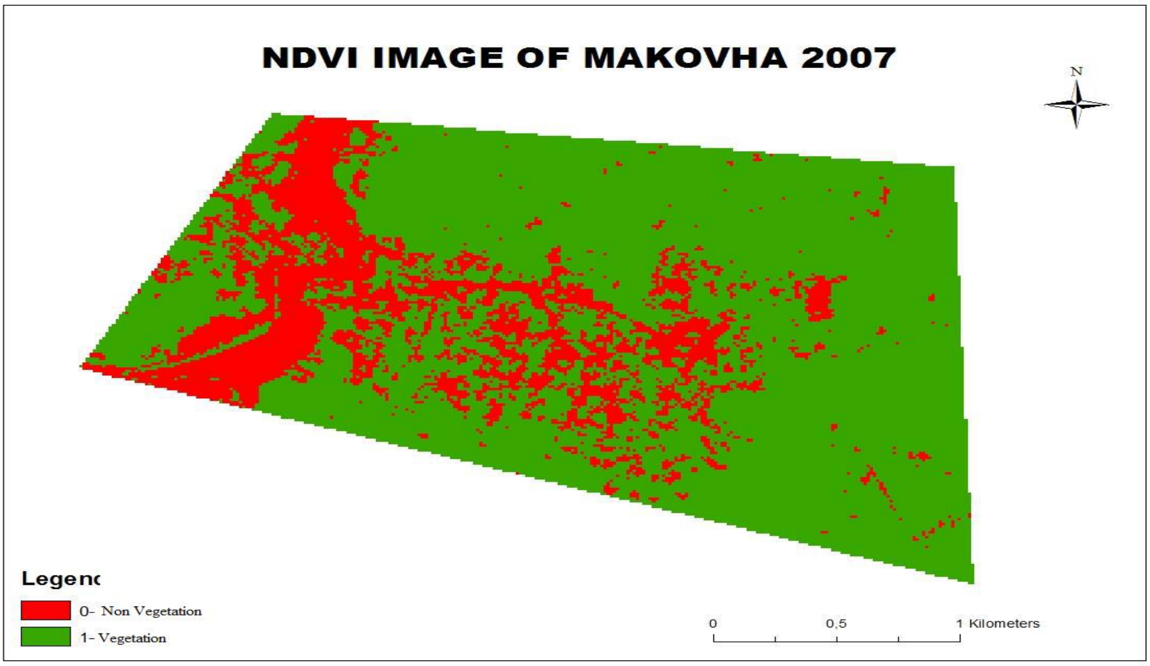


Fig 4.5.8: NDVI Images for Botsoleni 2007 and 2012

Figure 4.5.9 shows the processed satellite images with the technique of NDVI that determine the vegetated from non-vegetated areas of Makovha for the year 2007 and 2012.



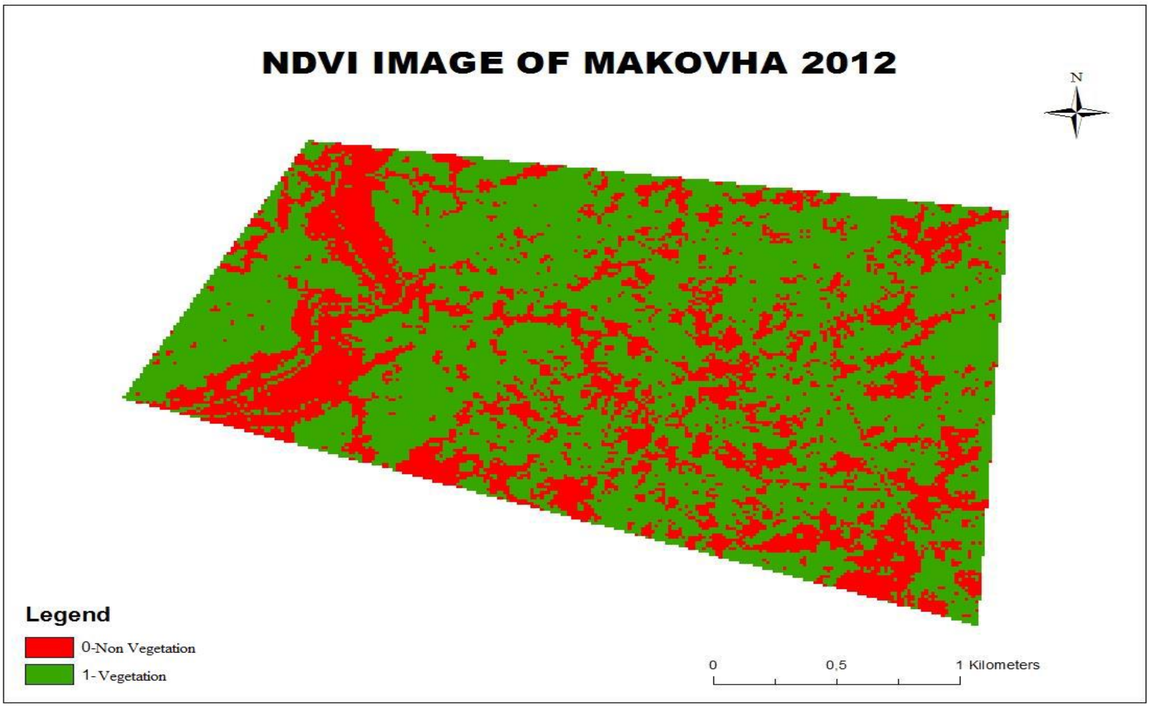


Fig 4.5.9: NDVI Images for Makovha 2007 and 2012.

Figure 4.5.10 shows the processed satellite images with the technique of NDVI that determine the vegetated from non-vegetated areas of Thezheni for the year 2007 and 2012.

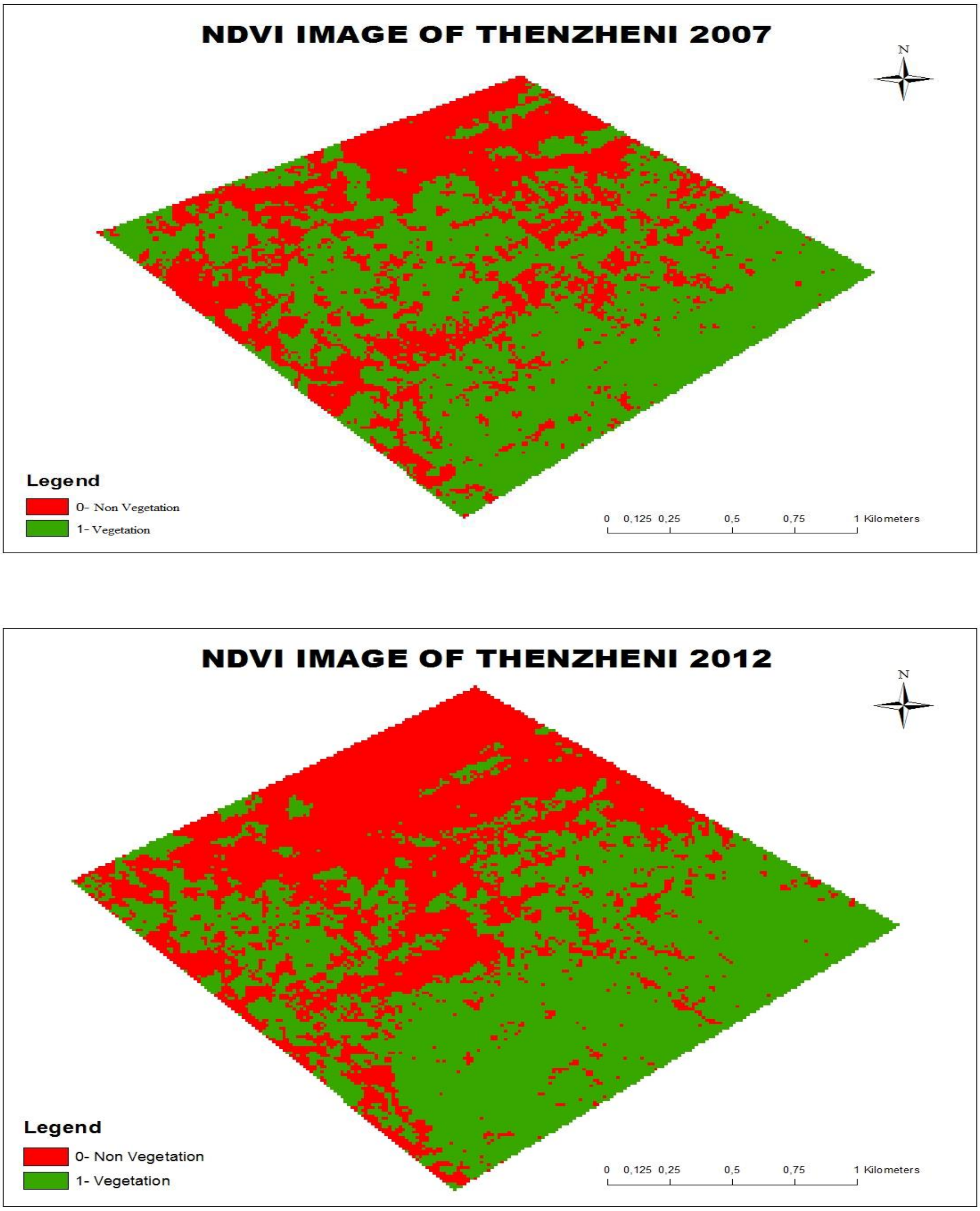


Fig 4.5.10: NDVI Images for Thenzheni 2007 and 2012

The results of the analysed satellite images for 2007 of the study areas reflects 53.42% of vegetation for Altein, 62.83% for Botsoleni, 77.65% for Makovha and 66.44% for Thenzheni. The 2007 images also show 46.58% of non-vegetation for Altein, 37.17% for Botsoleni, 22.35% for Makhova and 33.56% for Thenzheni. However, loss of vegetation cover was observed in 2012 with fuel wood usage by the communities as a major contributing factor. This resulted in vegetation loss of 13.86% in Altein, 16.59% in Botsoleni, 17.29% in Makovha and 8.49% in Thenzheni. The vegetated area in 2012 was reduced to 39.56% for Altein, 46.24% for Botsoleni, 60.36% for Makhova and 57.95% for Thenzheni resulting in increase of non-vegetative area in 2012 to 60.44% for Altein, 53.76% for Botsoleni, 39.64% for Makhova and 42.05% for Thenzheni.

The community with the highest vegetation loss was Makhova with 17.29%, followed closely by Botsoleni with 16.59%. The vegetation loss for Altein and Thenzheni was 13.86% and 8.49% respectively. The total land in hectares is, Altein 7542.48, Botsoleni 1260.97, Makovha 3335.80 and Thenzheni 2247.90.

The Normalized Difference Vegetation Index (NDVI) was a simple numerical indicator that was used in analyzing whether the surface area being observed contains greenness in vegetation or not. To calculate the vegetation change, the vegetation cover calculated from the images for the year 2007 was subtracted from the vegetation cover for the year 2012.

Table 4.5.1: Vegetation change for Altein, 2007 and 2012

Type	2007 (%)	2012 (%)	Diff. in Vegetation change (%)
Vegetation	53.42	39.56	- 13.86
Non- Vegetation	46.58	60.44	+13.86
Total	100	100	0

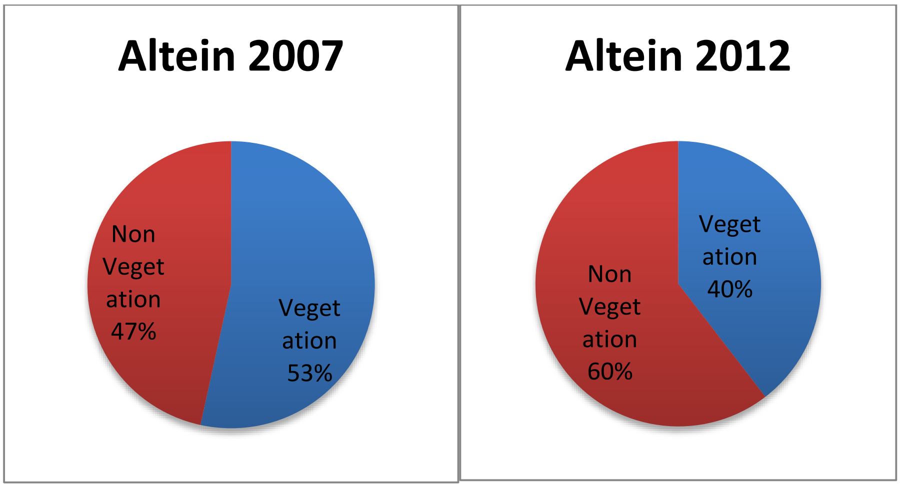


Fig 4.5.11: Vegetation change for Altein, 2007 and 2012

Table 4.5.2: Vegetation change for Botsoleni, 2007 and 2012

Type	2007 (%)	2012 (%)	Diff. in Vegetation change (%)
Vegetation	62.83	46.24	- 16.59
Non- Vegetation	37.17	53.76	+16.59
	100	100	0

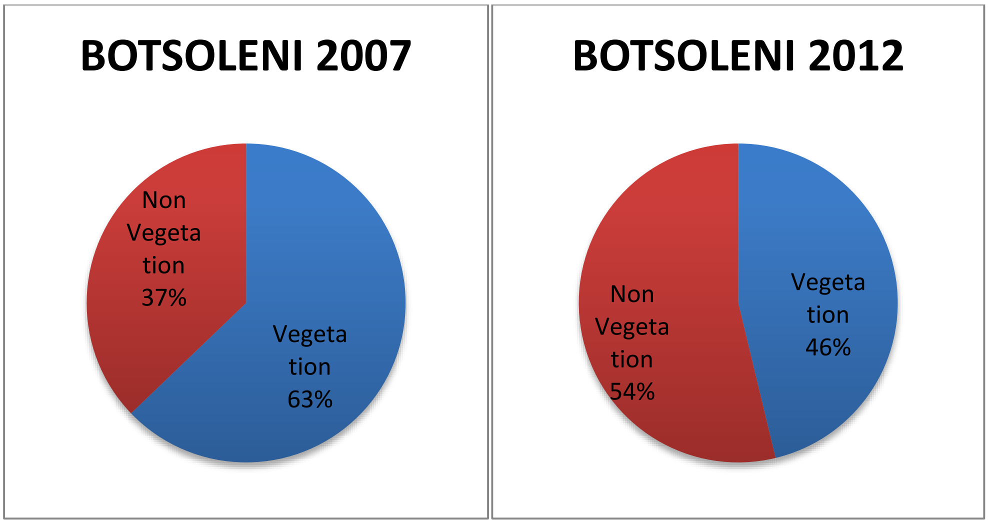


Fig 4.5.12: Vegetation change for Botsoleni, 2007 and 2012

Table 4.5.3: Vegetation change for Makovha, 2007 and 2012

Type	2007 (%)	2012 (%)	Diff. in Vegetation change (%)
Vegetation	77.65	60.36	- 17.29
	22.35	39.64	+17.29
Total	100	100	0

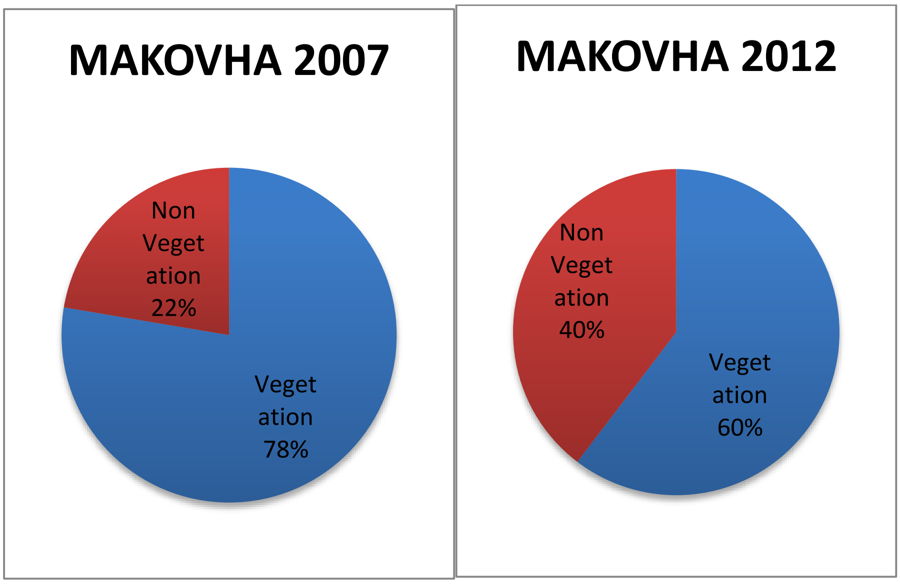


Fig 4.5.13: Vegetation change for Makovha, 2007 and 2012

Table 4.5.4: Vegetation change for Thezheni, 2007 and 2012

Type	2007 (%)	2012 (%)	Diff. in Vegetation change (%)
Vegetation	66.44	57.95	- 8.49
Non- Vegetation	33.56	42.05	+8.49
	100	100	0

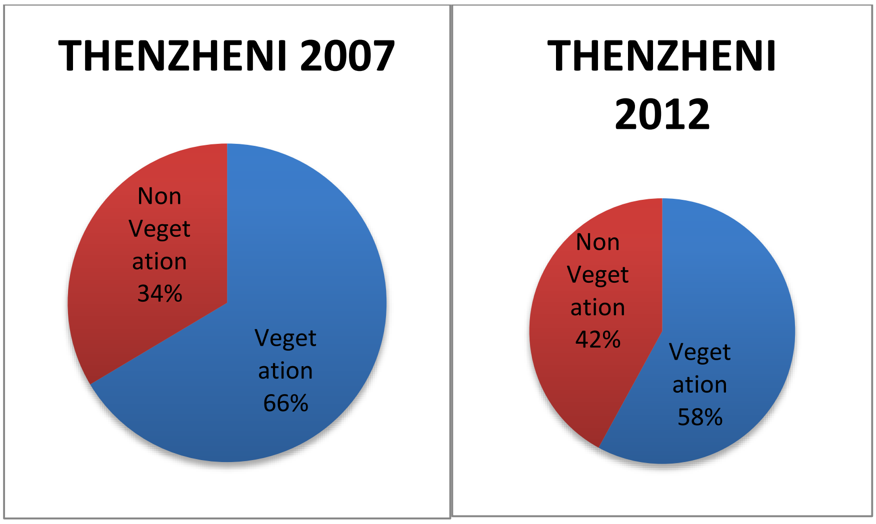


Fig 4.5.14: Vegetation change for Thenzheni, 2007 and 2012.

Table 4.5.5: Comparative Analysis of Vegetation Change between the study areas

COMMUNITY NAME	DIFF IN VEGETATION CHANGE (%)
Altein	13.86
Botsoleni	16.59
Makovha	17.29
Thenzheni	8.49

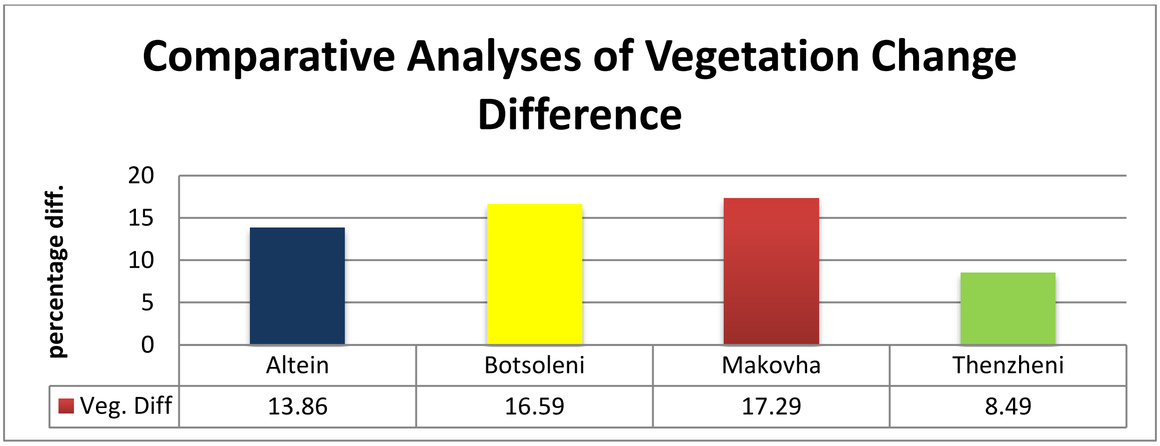


Fig 4.5.15: Comparative Analysis of Vegetation Change between the study areas

4.5.3 Environmental Impacts of Fuel Wood Extraction

From field observations, the photographs taken shows stumps of live stems and branches of wood that were cut down in order to obtain fuel wood. The figures gives an indication of the likely decrease in the vegetation cover from fuel wood harvesting as it reveals that the forest had less vegetation and the trees are more scattered due to the act.

Fig 4.5.16: Stump of cut trees. ***Source: Field survey (7th-9th May 2014).***

Fig 4.5.17: Cutting of trees. ***Source: Field survey (17th-21st May 2014)***

Fig 2.5.18: Bundle of harvested live woody stems. ***Source: Field survey (26th-30thMay 2014)***

4.6 An Evaluation of Sustainable Energy Provision Using SWOT Analysis

The summarized focus group discussion from the Municipal Director, tribal chiefs and community members in the four case study villages to ascertain what strategies may be recommended to ensure sustainable energy provision is indicated below:

The SWOT Analysis is a tool for strategic planning, usually as a framework in categorizing a wide range of inputs in a way that helps in facilitating decision making, providing a good outline for measuring and appraising the strategy, position and direction in evaluating the Strength, Weakness, Opportunity, and Threat involved in the venture. Using SWOT analysis, factors which are internal are usually classified as strength (S) or weakness (W), and those external are classified as opportunity (O) or threat (T).

Solar Energy

Strengths • Solar energy is readily available from the sun to meet up the required energy need for the households. • Good public acceptance of the use of solar energy. • The efficiency of solar energy shows that even at night, the energy stored can still be transmitted to provide energy for the households. • It is relatively harmless to the environment	Weaknesses • Absence of manufacturers around the case study villages. • Lack of technical know-how in the maintenance of the solar panels.
Opportunities • There is strong public support for the use of this technology through extensive programmes • Can create and open new market opportunities • Solar installations are being supported by the government. • The manufacturing of solar panels can increase growth in the relevant industries	Threats • Costs of purchasing the panels are high • High investment cost in the production of solar panels.

Wind Energy

Strengths	Weaknesses
• Energy sourced from windmills produces zero carbon • Generated energy can meet households need through the provision of electricity, which can be used for cooking	• Wind is limited to sites with high wind density • Construction of the windmill has relatively high initial investment costs. • Little awareness to the wider public about windmills and as a source of energy. • A windmill requires high wind density; thus it must be erected where there is sufficient wind
Opportunities	**Threats**
• The energy source is abundant and free • Can be a good alternative in the face of higher prices of conventional fuels	• The development of energy from wind requires a wind farm which can impact negatively on wildlife and the surrounding natural habitat. • Noise, danger for birds, change of landscape patterns.

Biogas

Strengths	Weaknesses
• Apart from being able to generate power, the manure acquired from biogas digestion is of greater nutritive value when compared to other manure obtained from the farmyard • Reduction in carbon footprint and the potentiality of global warming • Requires little technology, constructing biogas chamber • The methane can be produced from anaerobic decomposition of animal dung, agricultural residue and other organic matter • The construction of chamber for biogas in houses is simple and reliable	• Households that practice subsistence farming cannot obtain the much needed agriculture residue to meet the demand and most do not have cattle from which dung can be obtained • Not too compatible with ethical and cultural norms, especially the use of animal dung for cooking
Opportunities	**Threats**
• Can be a good alternative in the face of higher prices of conventional fuels • Can be used to solve the problem of organic waste deposal	• The improper collection of animal dung could lead to outbreaks of disease • There could a break in the supply chain

From the SWOT analysis, the energy provision strategy that best fits the need of the communities is the mixture of solar energy and biogas. The ready availability of the sun is a major advantage for the communities. Burgess is also a viable alternative because some of members of the Altein, Botsoleni, Makovha and Thenzheni communities' rear domestic animals in their households and the dung can be converted for energy production. The strengths of the alternatives can relive the forest from fuel wood harvesting.

A-not-so common alternative energy strategy that was evaluated was wind energy. The weakness and threats of wind energy were a limiting factor in the communities. From the focus group discussion, wind energy is not popular among the respondents and as such it is not suitable for the people.

CHAPTER 5: DISCUSSION OF THE FINDINGS

5.1 Introduction

This chapter discusses the findings of the results on the household energy sources, uses of energy, factors influencing the extent of specific energy usage, and focus group discussion using the Strengths, Weakness, Opportunities and Threats (SWOT) analysis.

5.2 Socio Economic Profile and Energy

The extent of fuel wood used in relation to electricity is mainly determined by the socio-economic status of the consumers. The more the consumers earn, the easier they can switch to cleaner energy. However other factors also play an important role and are highlighted as follows:

5.2.1 Income and Energy Sources

According to Pachuri (2004), household patterns of energy consumption normally represent the status and welfare as well as the stage of economic development. Generally, as the economy develops, more and cleaner energy is consumed. The household energy consumption pattern is expected to increase in the future in line with growth in the economy and a rise in per capita incomes. It is projected that increases in household energy consumption are expected to result from changes in lifestyles

Household income influences the energy consumption pattern in many ways. Firstly, a rise in income levels impacts on energy consumption increases due to an increase in dishes prepared such that supplementary items like vegetables, milk, meat and other food items are added to the food grains and more energy is required to cook the additional food. All these will result in an increase in the use of energy. Secondly, with increasing incomes, the price of the fuel will be less of a constraint to the households (Laitner, 2000).

A quote from one of the respondents is as follows: "*Electricity coupons are expensive for me. Presently, I am not working. I depend on a government grant. So, it is relatively better, cheaper and easier for me to cook my food and boil the water using firewood"*

Table 5.2.1: Income * Village Cross tabulation

			Village				Total
			Altein	Botsoleni	Makovha	Thenzheni	
Q7	<R500	Count	4	6	10	8	28
		% within Income	14.3%	21.4%	35.7%	28.6%	100.0%
		% within Village	8.0%	12.0%	20.0%	16.0%	14.0%
	R5001-R1000	Count	12	11	12	14	49
		% within Income	24.5%	22.4%	24.5%	28.6%	100.0%
		% within Village	24.0%	22.0%	24.0%	28.0%	24.5%
	R1001-R1500	Count	18	14	12	10	54
		% within Income	33.3%	25.9%	22.2%	18.5%	100.0%
		% within Village	36.0%	28.0%	24.0%	20.0%	27.0%
	R1501-R3500	Count	12	9	8	12	41
		% within Income	29.3%	22.0%	19.5%	29.3%	100.0%
		% within Village	24.0%	18.0%	16.0%	24.0%	20.5%
	>R3500	Count	4	10	8	6	28
		% within Income	14.3%	35.7%	28.6%	21.4%	100.0%
		% within Village	8.0%	20.0%	16.0%	12.0%	14.0%
Total		Count	50	50	50	50	200
		% within Income	25.0%	25.0%	25.0%	25.0%	100.0%
		% within Village	100.0%	100.0%	100.0%	100.0%	100.0%

Results show that in the four villages, the majority of the respondents earn between R5001-R1501. This is the reason why many of them prefer to use fuel wood instead of electricity for their domestic chores. The chi square value ($X^2 = 9.939$, *df* =12, *p*> 0.621), shows that income earned and villages are not significantly related, while the Cramer's V symmetrical measure (0.129, *p*> 0.621) indicates a weak association between income and the villages.

Employment and the level of monthly income, determine the type of energy source that a household prefers. The energy ladder model used in previous studies has indicated that as the income of the household increases, transition of energy use will occur and the energy required by households will change to more advanced energy sources ,such as electricity (Pachuri, 2004).

5.2.2: Occupation * monthly income Cross tabulation

			Monthly income					Total
			<R500	R5001-R1000	R1001-R1500	R1501-R3500	>R3500	
Occupation	Employed	Count	19	1	2	5	2	29
		% within occupation	65.5%	3.4%	6.9%	17.2%	6.9%	100.0%
		% within monthly income	67.9%	2.0%	3.7%	12.2%	7.1%	14.5%
	Self-employed	Count	2	20	6	22	12	62
		% within occupation	3.2%	32.3%	9.7%	35.5%	19.4%	100.0%
		% within monthly income	7.1%	40.8%	11.1%	53.7%	42.9%	31.0%
	Unemployed	Count	7	28	46	14	14	109
		% within occupation	6.4%	25.7%	42.2%	12.8%	12.8%	100.0%
		% within monthly income	25.0%	57.1%	85.2%	34.1%	50.0%	54.5%
Total		Count	28	49	54	41	28	200
		% within occupation	14.0%	24.5%	27.0%	20.5%	14.0%	100.0%
		% within monthly income	100.0%	100.0%	100.0 %	100.0%	100.0%	100.0%

The chi square value ($X^2 = 104.457$, *df* = 8, $p<0.000$), shows that there is a significant relationship between occupation and monthly income, while the Cramer's V symmetrical measure (0.511, $p<0.000$) indicates a moderate association between the variables.

This study, found that being unemployed, pushed the community members into using the easily accessible energy sources, which is fuel wood. Electricity is costly and it does not last long when used for cooking and water heating. The survey found that households that did not have a source of income or those earning a lower salary, harvest and use more fuel wood than those that had higher salaries, as the majority of the households depend on government grants, and remittances from family members who migrate to urban centres to work.

5.2.2 Household Size and Energy Sources

Household size is amongst the factors that influence household choice of energy. The findings showed that the average household size was five. The findings stipulate that the larger the household size, the more the energy that is required to meet their needs while lesser energy is required in smaller households. In large households, the predominant energy source for domestic purpose was fuel wood, as the households require more energy to meet their needs and fuel wood is readily available to them.

The following is a quote from a respondent *“My family is relatively large and with the prevailing economic situation, it is far cheaper for me to use firewood instead of electricity for my domestic energy needs. We are eight in the house and when we need to cook ortake a bath, a lot of energy is needed. So economically for us, the use of firewood is the cheapest and preferable because we don’t buy it. We harvest it from the forest and more so, food prepared with firewood tastes better than that cooked with electricity.”*

5.2.3 Accessibility and Energy Sources

Tropical Africa depends largely on fuel wood for about 90% of its total energy needs and it is still far cheaper than most alternative forms of fuel available, and even if the price of fuel wood was to increase, the demand would not drastically reduce due to the unavailability of substitutes (Boahene, 2008).

From the survey and Census data for 2011, there is 100% electrification in the four communities of Altein, Botsoleni, Makovha and Thenzheni. Households in these communities have access to electricity, which is provided by Eskom. When electricity coupons are purchased, there are free basic electricity units granted to them. Regardless of that, fuel wood is still one of their major energy sources. Respondents indicated that electricity is very expensive when used for cooking and water heating. Therefore, they resort to fuel wood because they have access to the forest to harvest fuel wood.

Although, the Chiefs that were interviewed in the four study villages indicated that they issue permission to their subjects before they can harvest fuel wood, as some trees are regarded endangered, many respondents do not consult the Chiefs before going into the forest as they consider the forest a natural resource for all. this, they believe, entittles the community members to harvest fuel wood at will, thus resorting to using fuel wood even if they had access to electricity.

5.2.4 Energy Preferences

There are different reasons why households to choose specific energy source. It can either be the efficacy of the sources for them in relation to time, taste, its availability/ accessibility, and their adaptations/behaviour towards a specific source. Some households choose a specific energy source because they are used to using that energy, and others just have their own perceptions of other energy sources. According to the Consumer Behavior Model, consumers have different preferences or beliefs on a product and that will determine whether they will purchase it or not (Mmatloa, 2010). The rural populace prefers cooking with fuel wood because of the belief that food prepared with fuel wood is tastier than food cooked using electricity. For this reason, fuel wood is their main energy source in most rural areas. Some households prefer fuel wood because they believe that it is fast, therefore less time is spent on cooking or heating water compared to using electricity. The majority claim that fuel wood is readily available. Therefore they do not have to buy it since they just have to go to the forests to harvest it, unlike electricity.

5.2.4: Village * Cooking energy source Cross tabulation

			Q24			
			Electricity	Fuel wood	Both	Total
Village * Q24	Altein	Count	3	31	16	50
		% within Village	6.0%	62.0%	32.0%	100.0%
		%within Cooking energy source	27.3%	22.8%	30.2%	25.0%
	Botsoleni	Count	4	33	13	50
		% within Village	8.0%	66.0%	26.0%	100.0%
		% within Cooking energy source	36.4%	24.3%	24.5%	25.0%
	Makovha	Count	2	35	13	50
		% within Village	4.0%	70.0%	26.0%	100.0%
		%within Cooking energy source	18.2%	25.7%	24.5%	25.0%
	Thenzheni	Count	2	37	11	50
		% within Village	4.0%	74.0%	22.0%	100.0%
		% within Cooking energy source	18.2%	27.2%	20.8%	25.0%
Total		Count	11	136	53	200
		% within Village	5.5%	68.0%	26.5%	100.0%
		% within Cooking energy source	100.0%	100.0%	100.0%	100.0%

The chi square value (X^2 = 2.550, *df* =6, *p*> 0.863), shows that villages and energy cooking source are not significantly related, while the Cramer's V symmetrical measure (0.113, *p*> 0.863) indicate a weak association between income and the villages.

Community members noted that, for them, electricity was slower than fuel wood when it came to cooking and heating water and the food cooked using fuel wood was tastier; that is why they preferred fuel wood over electricity. The way the community members perceived an energy source made them choose one over the other.

5.3 Greenhouse Gas Emissions from Fuel Wood Consumption

There are some distinct features of residential rural energy utilisation, such that carbon emissions from traditional biomass combustion contribute to more than half of the total rural residential emissions. Aside from its contribution to global warming and deforestation, biomass combustion also contributes to hazardous substance emissions that pose threats to the rural environment and the public health of the people (Wenling *et al.,* 2012).

The use of fuel wood and its implications for the global environment can be evaluated by estimating the associated greenhouse gas emissions (FAO, 2006). Greenhouse gases are known to be major causes of global warming with Carbon dioxide (CO_2), accounting for 67% of the total emitted greenhouse gases, 18% Methane and 7% Nitrous oxide (NOx) (FAO, 2006). Carbon dioxide emissions therefore are the most important cause of global warming, which are inevitably created by the burning of fossil fuels and biomass.

The calculated result of the study area shows the amount of gases emitted from the combustion of fuel wood used in a meal preparation per household collectively from the four case study villages of Altein, Makovha, Botsoleni and Thenzheni as, Carbon dioxide ($CO_{2)}$ (3.55++3.70+3.85+3.77) = 14.91 Kg, Carbon monoxide (CO) 0.000349 Kg, Nitrogen oxide (NO) 0.00548 Kg, Methane (CH_4) 0.01222 Kg. These gases are contributing in long term to the atmospheric budget of the area and together with other sources of emissions, which if not mitigated, contained or minimized may have the potentials to warm up the microclimate of the area in future.

5.4 Environmental Impacts of Fuel Wood Harvesting and Usage

Fuel wood harvesting has a greater impact on the status of the forests. The harvesting of trees for fuel wood consumption changes the natural canopies of the forest, ordinarily, the closed canopies become more open and it changes the superiority of the forest. The harvesting of trees in the villages of Altein, Botsoleni, Makovha and Thenzheni was greater because the forest was easily accessible, even though community members had to walk a long distance to collect fuel wood. Fuel wood harvesting has profound impacts on the forest in the following ways:

5.4.1 Deforestation

According to Geist and Lambin 2002, the extraction of fuel wood plays a significant role in deforestation across Africa. The extraction of wood for domestic fuel production has remained a major issue in Africa, because most Africans, particularly in rural settings, still use wood for cooking, as other energy sources are not available or are expensive. The field survey and analyses of satellite images from the study villages indicate that a large amount of forested land is being lost in the villages of Altein, Botsoleni, Makovha and Thenzheni due to un-restrained access to the forest. There is evidence of indiscriminate harvesting of wood for cooking in the four villages. From the survey, preference is given to picking dried wood from the forest floor (35%). However, in the absence of dry wood, the cutting of live trees is significant, as 65% of the respondents in the four villages practice this method.

However, the increase in the collection of fuel wood as a source of energy is also due to a decline in productivity and a subsequent decline in income, which means a greater dependence on off-farm employment, such as fuel wood collection increases (FAO, 2009). It is estimated that the most of the removed wood is used as fuel wood. However, since most of the fuel wood collection activities are not usually recorded, the actual quantity of wood removals might be understated.

5.4.2 Hydrology

The global water cycle is also disrupted by deforestation because when part of the forest is removed the area affected cannot hold as much water as before thereby creating a drier climate (Bruijnzeel, 2004). The water resources that are affected by deforestation include drinking water, fisheries and aquatic habitats, flood/drought control, waterways and dams affected by siltation, less appealing water related recreation, and damage to crops and irrigation systems from erosion and turbidity. A higher rate of fuel harvesting in the case study villages will pose a threat to the water cycle of the area, as this could lead to streams and rivers drying up. Significantly, the forest plays a role in the movement of air over which trigger the building of cumulus clouds. In addition, the forest is more effective than other vegetation types in trapping precipitation amongst which are fog, cloud and moisture, which initiate rain.

5.4.3 Biodiversity Loss

In the tropics, the forest serves as a storehouse for biodiversity and the consequent deforestation lead to fragmentation and degradation, which destroy the biodiversity as a whole, leading to species migration, including the species that are endangered. Tropical forests support about two thirds of all known species and contain 65% of the world's 10, 000 endangered species (Myers and Mittermeier, 2000).

A great threat to biodiversity is not the destruction of plants and animals, but rather the destruction of their habitat. Among the anthropogenic activities that have destroyed the environment is the harvesting of wood for domestic purposes. When large and small trees are harvested, it reduces the species population, which eventually affects the proper distribution of different tree sizes. The damage to biodiversity caused by humans in the four study villages is rapidly increasing as species are over-exploited, which could lead to their ecosystem being destroyed and ultimately extinction. The different hotspots that are targeted for fuel wood harvesting in the villages could also lead to habitat fragmentation whereby the forest becomes divided into small patches and the native vegetation is lessened thus creating a possible re-colonization by alien plant species. Fuel wood harvesting hotspots can also reduce the amount of habitat of fauna in that area leading to organism migration to new habitats that are foreign to them. The excessive cutting of trees may reduce the vegetation cover of the forest and may result in land degradation. As indicated in the study areas, the fuel wood harvesting preference, tree species such as *Dichrostachys cineria* and *Combretu minbrebe* dominate the flat plains, *Barchemia zeyheri*is mostly available on mountainous areas while *Selerocarya birrea* is found mostly along the river. This shows that the flat plain is mostly affected by the issue of biodiversity loss as a result *Dichrostachys cineria* and *Combretum inbrebe* which are under threat because they dominate the flat plains.

5.4.4 Soil Erosion

Once a forested area is deforested, too much water flow can result into downstream flooding, many of which have caused disasters in many parts of the world. This downstream flow causes soil erosion as well as the silting of water courses in lakes and dams. Flooding due to deforestation can increase for two reasons, firstly, with smaller trees fountain effects, the soils are more likely to be fully saturated with water. The sponges are quickly filled up earlier in the wet season, causing additional precipitation to run off and increasing flood risk. Secondly, deforestation often results in soil compaction, making it unable to absorb rain. Locally, this can cause a faster response of stream flows to rainfall and thus potential flash flooding (Chomitz *et al.,* 2007).

Without tree cover, forest soils experience nutrient deficiency exposing to flood vulnerability and erosion. Fuel wood harvesting in the villages has been one of the contributing factors to soil erosion vulnerability in the area. During rainy seasons, the lesser vegetation covers in the forest area of the villages create less infiltration rates, making the forests waterlogged leaving cracks in the soil when dry. The soil becomes degraded when the top soil is washed and transported either by wind or water, leaving the forest with infertile and less soil cover. Forest degradation is a direct consequence of the decrease in tree population, which can also leave the community with fuel wood scarcity.

5.4.5 Air Pollution

The administered questionnaires reveal that 90% of the respondents in Altein, Botsoleni, Makovha and Thenzheni prepare their meal using energy inefficient stoves in the form of open fire, thus creating incomplete combustion of the fuel wood, thereby emitting smoke and other pollutants into the atmosphere. The consequences of incomplete combustion of fuel wood result primarily in the production of carbon monoxide, particulate matter, nitrogen oxides, methane, benzene, butadiene, formaldehyde and many other organic compounds which pose threats and health hazards, mainly to female and children who spend more time in the kitchen.

According to Ezzati *et al.,* (2002), the risk assessment by World Health Organization (WHO), which combined the results of many published studies, compared the burden of illness and premature death arising from fuel wood use with other major risk factors, including outdoor air pollution, tobacco smoking and hypertension. The results indicated that solid fuel use may be responsible for 800 000 to 2.4 million premature deaths each year (Smith *et al.,* 2004). The combustion of biomass fuel use has been found to be associated with diseases such as tuberculosis, cataracts, low birth weight in babies of exposed expectant mothers, and other health conditions in a number of other studies (Smith, *et al.,* 2004).

5.4.6 Burden of Fuel Wood Collection

The dependence on biomass in developing countries is a burden for female and children who are responsible for fuel collection, a time-consuming and exhausting task. The average fuel wood load in sub-Saharan Africa is around 20 kg however, loads of 38 kg have also been recorded (Rwelamira, 1999).

Physical damage from strenuous work without sufficient recuperation is suffered by female due to their long walks. This risk, as well as the risk of falling or assault increases further from home as female have to walk much longer distances (Parikh, 2007). The collection time for fuel wood has a significant opportunity cost on female and children, it limits their opportunity to improve their education and engage in other income-generating activities. The field survey result reveals that in the four villages of Altein, Botsoleni, Makovha and Thenzheni, 70% of the respondents commute between 100km-200km when harvesting fuel wood with an average of 25kg head load of wood per trip, the majority of them being women and children. The study result shows that most of the fuel woos harvested is on the flat plains. However, they walk far from home to harvest as most the fuel wood close by has already been harvested.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The study assessed household energy use, emissions and de-vegetation in the Thulamela Local Municipality. The objectives of the study were to examine the socio-economic profile of the respondents in the case study villages, to examine the extent of household energy use in relation to electricity, calculate the amount of greenhouse gases emitted from the combustion of the fuel wood; determine the extent of de-vegetation in the study villages; and to evaluate strategies that will ensure a sustainable energy provision to the municipality using the four case study villages. From the findings of the study the following conclusions are made:

6.2 Conclusion

6.2.1 Energy Consumption and Households Income

Among the types of energy available to Altein, Botsoleni, Makovha and Thenzehni communities, electricity and fuel wood are the most paramount. These communities have access to electricity, but still prefer fuel wood as their main source of energy, meaning that electrification is not a solution to deforestation. The extent of fuel wood usage in relation to electricity is influenced by a number of socio-economic factors, including household income, access to forest, wood availability and cooking preferences. Community members that are employed or self-employed use electricity more often for in their households. However, most of them use fuel wood to supplement their energy mix. Unemployed community members are the main users of fuel wood. Larger households depend more on fuel wood as their main source of energy, and smaller households use electricity for cooking and water heating. A household’s preferences are based on the efficacy or the cost of the energy source. Community members indicated that, for them, fuel wood was faster than electricity, especially when a large meal needed to be prepared, and that it was freely available and accessible, unlike electricity that requires money to be purchased. However, this also has its own consequences such as air pollution and the burden of fuel wood collection.

6.2.2 Greenhouse Gas Emissions

The total amount of greenhouse gases emitted from the combustion of the fuel wood in the households is far less than the amount emitted in the conversion of coal to generate electricity. It has however contributed significantly to the atmospheric trace budget of the area. If it is not contained or minimized, it will have the potential to warm up the climate of the area in the long run. The emitted gases in the form of smoke during cooking can adversely pose a health risk to the community members, particularly female and children because they spend more time in the kitchen. Illnesses from exposure to smoke include are asthma, chest pain, emphysema, headaches, pneumonia, bronchitis, dizziness and heart diseases. At higher and prolonged concentrations it can impair vision, and visibility, causing confusion, nausea and speeding up the deterioration of man-made materials. The escaped gases cause air pollution, reacting with other gases in the atmosphere could cause acid rain and the gases also have the potential to warm the climate, which can lead to climate change.

6.2.3 Forest Depletion

From the satellite images and field observations, there is a high rate of tree cutting in the forests. This is resulting in deforestation. Deforestation is a major problem which can accelerate soil erosion, biodiversity loss and affect the hydrology of the area. The study villages are typical rural settings such that fuel wood harvesting is one of the leading factors causing deforestation. Although, the villages are witnessing developmental strides in terms of buildings (commercial and residential) and road expansions, but the fast depletion of the forest status can be said to be a result of fuel wood harvesting.

6.2.4 Alternative Energy

The most sustainable energy available to the municipality is solar energy, which is renewable and is a zero carbon energy producer, and biogas, which is gaining recognition in the villages. The municipality can also take advantage of the government awareness campaign on the use of sustainable energy of which renewable energy is a top priority. With the intense sun availability, provision of solar water heaters and photovoltaics that can generate electricity to meet the household demands of the populace will be a welcome idea. The cost of purchase and installation of the solar panels can be subsidised for the rural communities as a direct intervention effort to encourage its use, so as to relieve the stress on the forests. This will also reduce the burden of fuel wood collection that is mostly encountered by women and children while saving their time and cost that can be put into other productive activities such as education.

6.3 Recommendations

The recommendations are made based on the key findings of the research. This study recommends the following management and mitigation strategies that can be used to combat or prevent deforestation while improving the quality of the vegetation at the Altein, Botsoleni, Makovha and Thezheni Villages. These management strategies can also help limit the burden placed on the forests, so that it can regain its quality, while also reducing the amount of trace gases emitted to the atmosphere as a result of fuel wood combustion.

6.3.1 Environmental Education and Public Awareness

A low level of education as observed in the study is associated with a negative impact towards the environment. This is a contributing factor in fuel wood harvesting. The respondents consider forests to be a repository of fuel wood without considering the vital role that trees play in life and the consequences of their loss. Environmental education in the four case study villages is crucial in the sense that it will help change peoples' perceptions of the use of the environment from destructive to constructive. Environmental education can be carried out through implementing environmental awareness campaigns at national levels through the Department of Environmental Affairs (DEA) and at a provincial level through the Limpopo Department of Economic Development, Environment and Tourism (LEDET). Environmental education in rural communities should be designed in such a way that all local environmental problems associated with deforestation should be emphasized.

This study recommends a public awareness to be used as a strategy to reduce the clearing of trees for fuel wood and any other purposes. The government and NGO's at the local level can come together and make the public aware that cutting trees is putting the forest and the overall environment under a strenuous state. Public awareness campaign on fuel wood and deforestation issues can be conducted through radio jingle, television and in published articles The importance of trees should be highlighted and the potential impacts that may occur if more trees are cut, and how the trees are important for human existence should be stressed. Awareness and education will change the people's behavior, even though it may take some time to achieve the goal.

6.3.2 Afforestation, Plantation and Harvest Control

There is a need for the government at national and provincial levels to embark on afforestation to replace the harvested wood in the forest. Also, deliberate tree plantations should be encouraged and monitored by forest guards, and if need be, the local communities should harvest fuel wood in a controlled manner. The plantation can also serve as a source of carbon sink as forest can sink carbon and plantations can decrease the pressure on open access to natural forests. Forests are known to constitute the major terrestrial carbon pool and the sequestration of carbon dioxide from the atmosphere takes place in a growing forest and the fixing of CO_2 through photosynthesis is usually done by trees and other forest plants since all forests organisms release CO_2 through respiration.

As long as there is open access to woodland and forest which supply better and cheaper fuel wood, consumers are not likely to shift to wood grown from plantations and for such a policy to work, there has to be a combination of measures that will make fuel wood from indigenous forest less accessible and more expensive. This will happen either when the resource base of the forest or woodland becomes exhausted or when there is an effectively controlled harvest.

If trees are owned by local communities or individual farmers, control harvest might then become profitable when stumpage fees are charged. The fees could be in the form of per unit output or a share in the final product. For households in many rural areas, fuel wood or charcoal is seen as a cash crop that can supplement the meagre income they earn. The transfer of property rights of trees to local communities, individuals or farmers would increase their income, although if the rights were communal, the elites of the community could capture some benefits rather than individual. Land grabbing by better-off people may threaten equity in the case of individual ownership.

6.3.3 Provision of Cost Effective Energy

Although, there is a 100 percent electricity availability in the communities of Altein, Botsoleni, Makhova and Thenzehni there is a need to encourage community members to use alternative energy, mostly renewable energy such as solar energy because, it has zero carbon footprint. There are few households in the study villages that own animals like cattle, goats and sheep. Communities should be trained and encouraged to use the dung for energy production through biogas. However, solar energy remains the best option to the communities because it is readily available to all and the district under which the study villages fall is one of the hottest region in the country. Therefore, the advantage of using solar energy and biogas can be harnessed for cheaper and cleaner energy. However, due to the poverty level in the communities, the Government can help subsidise the cost of purchase, installation and maintenance of the solar panels. This can be achieved firstly by, creating employment to empower the people, then, a realistic subsidy option can be followed, which will not be more of a burden to the people. The use of renewable energy will change the livelihoods of the people, especially the female and children, as they will no longer walk long distances in search of fuel wood and carry heavy headload. This will save them time and costs which can be channelled into other productive activities, such as education.

6.3.4 Improved Cooking Stoves

From the study, it is impossible to rule out the continual use of fuel wood by the communities. Some attribute their reliance on fuel wood for cooking on cultural beliefs, taste of food, cost of purchase, income level and accessibility. Due to these factors, there is a need for the NGO's, the government at national and local level to introduce a more energy-efficient improved stove to the communities. These stoves can help reduce air pollution that is associated with fuel wood combustion when cooking. In the study areas, a most of the community members prepare their food using open stoves, where much of the smoke escapes to the atmosphere as pollution which is adversely affects their health. The successes of stoves like Jiko, developed in Kenya, and Basa Njengo Magogo, developed in South Africa, can be of immense help in reducing air pollution and health hazards associated with fuel wood combustion, if introduced to these rural communities.

6.3.5 Enforcement of Environmental Legislation

The forests of Altein, Botsoleni, Makhova and Thenzheni are easily accessible by everyone because there is no enforcement to restrict people from gaining access to forest. Forests are of immense importance to the environment because of the crucial roles they play. Therefore they are supposed to be conserved by the government using the law as tool. The enforcement of these environmental legislations when abided to, will prevent or limit the community members from gaining easy access to the forests. There are laid-down environmental legislations, which when adhered to will help in saving the remaining forests, such as the National Environmental Management Act 107 of 1998, the Environmental Conservation Act of 1989 and the Biodiversity Act 10 of 2004 with the preamble: "*To provide for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Management Act 1998; the protection of species and ecosystems that warrant national protection; the sustainable use of indigenous biological resources; the fair and equitable sharing of benefits arising from bio prospecting involving indigenous biological resources; the establishment and function of a South African National Biodiversity Institute; and for matters connected therewith*" (NEMBA, 2004). These legislations are meant to help in the protection and conservation of South Africa environmental resources.

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Appendices

Appendix A

Household Survey (Questionnaire)

The following household questionnaire will be distributed to the community of the Villages (Altein, Botsoleni, Makhova and Thenzheni) in Thulamela Local Municipality of Limpopo Province regarding fuel wood harvesting and deforestation.

Ethical consideration: The aim of this questionnaire is to collect data for academic purposes. Participation is voluntary and respondents can withdraw at any time. Respondents will not be exposed to any form of harm either physically or psychologically. Privacy and identity of the respondents will be safeguarded. This implies that the information will be kept confidential. NB: Please, Provide answers and cross(x) in the appropriate box next to the question.

Name of Village **Questionnaire ID** **Date………..**

SECTION A: Demographic information and socio-economic characteristics

1. Sex

Male	1	
Female	2	

2. Age

Under 20	1	
20-30	2	
31-40	3	
41-50	4	
50 and above	5	

3. Marital status

Single	1	
Married	2	
Divorced	3	
Widowed	4	

4. Are you the head of house?

Yes	1	
	2	

5. What is your level of education?

No formal education	1	
Primary	2	
Secondary	3	
Tertiary	4	

6. What are your occupation details?

Employed	1	
Self employed	2	
Unemployed	3	

7. What is your monthly income?

R0-500	1	
R501-1000	2	
R1001-1500	3	
R1501-3500	4	
R3500+	5	

8. How many dependants do you have?..................................

SECTION B: Fuel wood harvesting

9. Who is responsible for the management of the forest resources?

Chief	1	
Government Department	2	

10. If you harvest fuel wood, do you obtain permission?

Yes	1	
No	2	

A. If yes, from who..................................

B. If no, why?...

11. How often do you harvest fuel wood in your household?

Once a week	1	
Twice a week	2	
More than twice a week	3	

12. Who is responsible for fuel wood harvesting in your household?

Children	1	
Female	2	

Men	3	
Everyone	4	

13. Which technique do you use to harvest fuel wood?

Cut live trees	1	
Picking deadwood	2	

14. Which trees do you target the most when harvesting fuel wood?

Scientific name	**English name**	**Local name (Venda)**	**Local name (Tsonga)**		Mark
Parinaricuratefolia	Mobola plum	Muvhula	Mbulwa	1	
Brideliamicrantha	Mitzeeri	Munzere	Nxuva	2	
Acacia ataxantha	Flame thorn	Muluwa	Molele	3	
Combretummolle	Velvet bush willow	Mugwiti	Xinkhavi	4	
Dispyoslycioides	Transvaal blue bush	Muthala	Chugulu	5	
Eucleadivinorun	Magic guarri	Mutangula	Nhlangula	6	
Selerocaryabirrea	Murula	Mufula	Nkanyi	7	
Annona senegalensis	Wild custard apple	Muembe	Muyembe	8	
Acacia karro	Sweet thorn	Muugna	Munga	9	
Brachylaena discolour	Brown ivory	Mufhata	Nyiri	10	
Combretum mossambicensis	Knobby tree	Gopogopo	Xikayi	11	
Bauhinia galprini	Pride-de-kaap	Mitswiriri	Ntswiriri	12	
Dichrostachyscineria	Sickle bush	Murenzhe	Ndengha	13	
Barchemiazeyheri	Red ivory	Munie	Nyirani	14	
Combretuminbrebe	Leadwood	Muhiri	Mondzo	15	
Others (specify)				16	

15.Why do you target these trees?

Easily available	1	
Energy content	2	
	3	

16. How difficult is it to find these trees?

Easy to locate	Moderately difficult to locate	Very difficult to locate
1	2	3

17. How do you transport your fuel wood?

Head load	1	
Donkey cart	2	
Wheelbarrow	3	
Truck/Bakkie	4	

18. What are the units or bundles of fuel wood carried at once?

10-15kg	**1**	
15-20kg	**2**	
20-25kg	**3**	
25-30kg	**4**	
30-35kg	**5**	
35-40kg	**6**	
40kg and above	**7**	

19. What is the average distance from your household to where you harvest fuel wood?

<100M	1	
100-<200M	2	
200-<500M	3	
500-<1KM	4	
1KM-<2KM	5	
>2KM	6	

20. What are your preferred fuel wood harvesting hotspots?

Flat plain	1	
Mountain	2	
Along river banks	3	

21. Why do you prefer such place(s)?..

SECTION C: Fuel wood usage

22. Is your household electrified?

Yes	1		
No	2		

23. Why do you use fuel wood in your household?

Electricity is expensive	1	
Abundant fuel wood	**2**	
Fuel wood is cheaper	3	
Taste	4	

24. What energy sources do you use for cooking in your household?

Electricity	1	
Fuel wood	2	
Multiple (Electricity & Fuel wood)	3	

25. What energy do you use for lighting in your household?

Electricity	1	
Gas	2	
Paraffin	3	
Others (specify)	4	

26. What energy do you use heating in your household?

Electricity	1	
Fuel wood	2	
Multiple (Electricity & Fuel wood)	3	

27. How often do you use the fuel wood in your household?

Everyday meal	1	
Two meals a day	2	
One meal a day	3	
Others (specify)	4	

28. What is your opinion regarding using wood as energy fuel?
A. Problems/disadvantages………………………………………………………
…………………………………………………………………………………

B. Good things/advantages………………………………………………………

29 (A). Do you burn wood in stove?

Yes	1	
No	2	

29 (B). What type of stove do you use?

Improved stove	**1**	
Mud	**2**	
Clay	**3**	
Open fire	**4**	
Others	**5**	

30. Total amount of fuel wood used in Kilograms?

Per meal	**1**		
Per day	**2**		
Per week	**3**		
Per month	**4**		
Others	**5**		

SECTION D: Fuel wood purchase

31. Where do you purchase your wood fuel from?

Informal Market	**1**	
Supermarket/Retailer	**2**	

32. How far is the place of purchase from your residence?

<100M	1	
100-<200M	2	
200-<500M	3	
500-<1KM	4	
1KM-<2KM	5	
>2KM	6	

33. What is the fuel wood selling price against quantities? (E.g. Rand per kg or number of pieces/ load)
....

34. Any other additional information…………………………………………………....

SECTION E: Deforestation

35. Are you aware of deforestation?

Yes	1		
No	2		

36. How would you rate your knowledge about deforestation?

Poor	1	
Average	2	
Good	3	
Excellent	4	

37 (A).Are you aware that fuel wood harvesting contributes to deforestation?

Yes	1	
No	2	

B. If no, what do you think is the main cause of deforestation?..

38 (A). Would you like to stop using fuel wood?

Yes	1	
No	2	

B. Kindly indicate the reason for your option above
....
....

39. What in your view is the solution to deforestation?

Environmental education	1	
Afforestation and plantation	2	
Harvest control	3	
Nature reserve	4	
Others (specify)	5	

40. Any other additional information
....
....

INTERVIEW SCHEDULE

Study Site: [ ]

PREAMBLE: *Introduction, purpose and confidentiality statement read before any session.*

The interview questions to be directed to the tribal Chief or Head of the Village to obtain views pertaining to fuel wood harvesting and deforestation. The information obtained will be kept confidential and will only be used for academic purposes.

1. Do you issue people permit to harvest fuel wood?

2. Do you visit the forest when permits are issued?

3. How often do you visit the forest?

4. How was the state of the environment the last time you visited the forest?

5. Have you ever recognised the impact caused by fuel wood harvesting in the environment?

6. What do you think can happen if all trees are cleared?

7. Are you aware of deforestation?

8. What do you think are the main drivers of deforestation in this area?

9. Do you have effective legislation that is used to manage forests?

10. Any other additional information
....
....

FOCUS GROUP DISCUSSION CHECK LIST

Study Site:

The Focus Group discussions are to be directed to Tribal Chiefs, Civil Organisations and community members in each of the four villages. The information obtained will be kept confidential and will only be used for academic purposes.

MAIN ISSUE OF DISCUSSION: Evaluate strategies to ensure sustainable energy provisions for Thulamela Local Municipality (SWOT Analysis).

PREAMBLE:*Introduction, purpose and confidentiality statement read before any session.*

A. SWOT Analysis of Energy Sources

1. **Solar Energy**

Strength	Weakness	Opportunity	Threat
1	2	3	4

2. **Wind Energy**

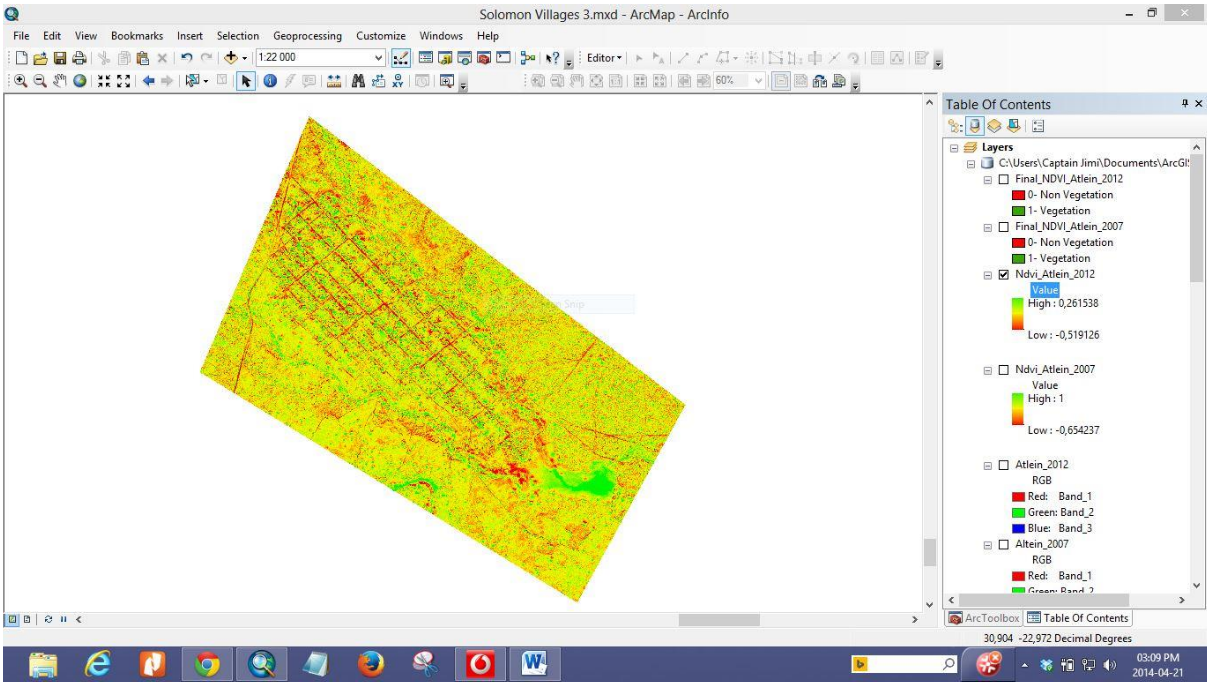
Strength	Weakness	Opportunity	Threat
1	2	3	4

3. Biogas

Strength	Weakness	Opportunity	Threat
1	2	3	4

Any other additional information
……
……

Appendix B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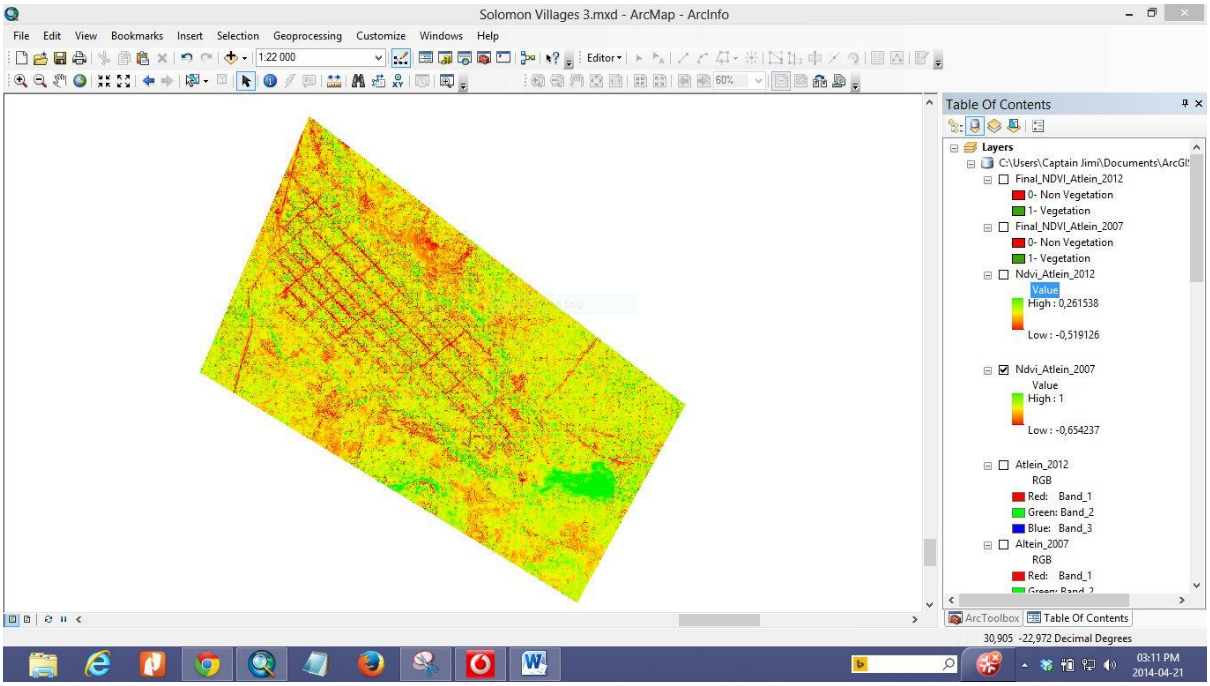
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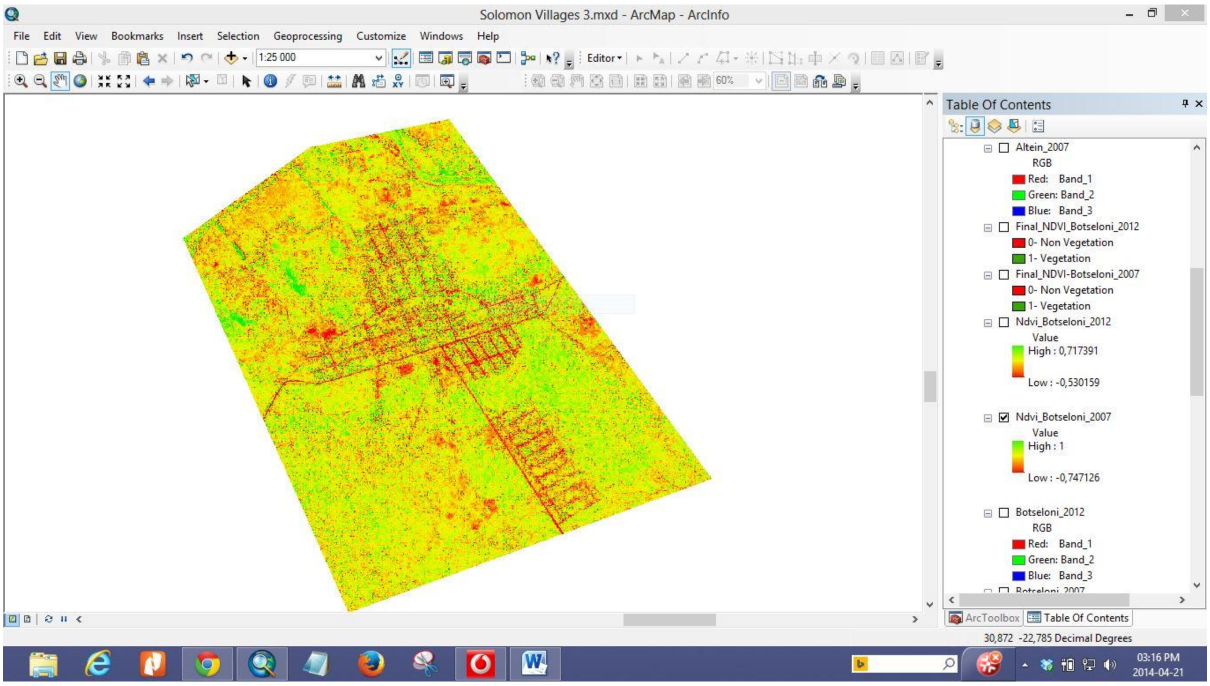
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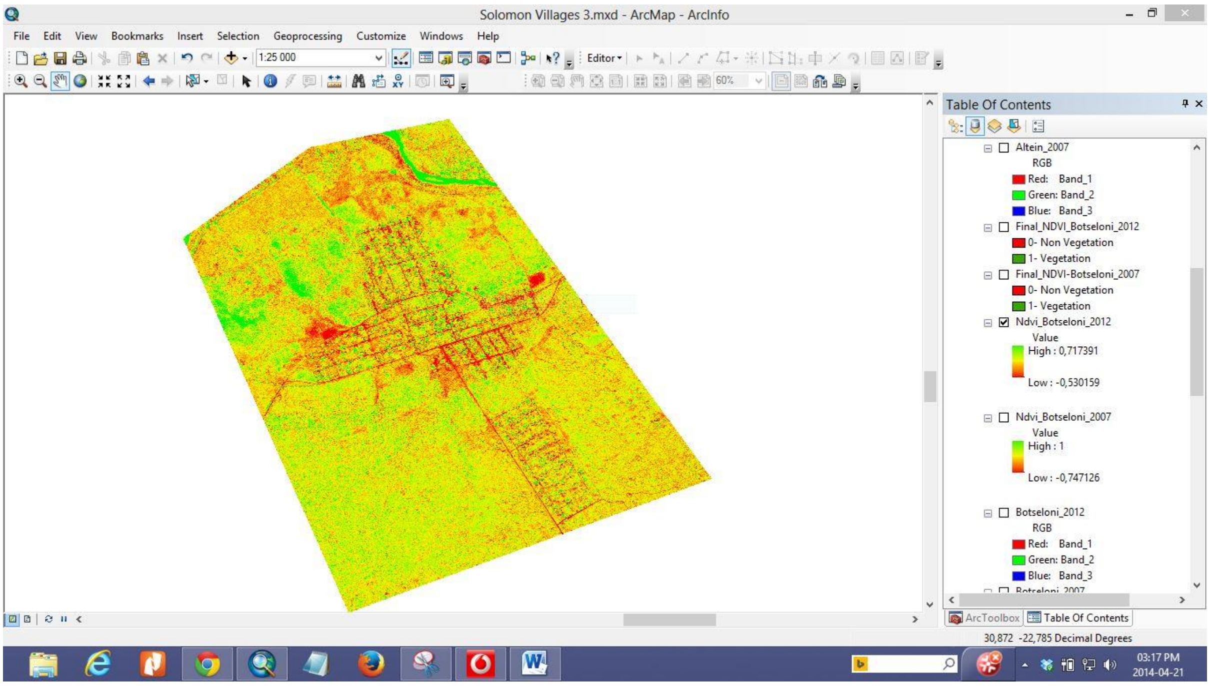
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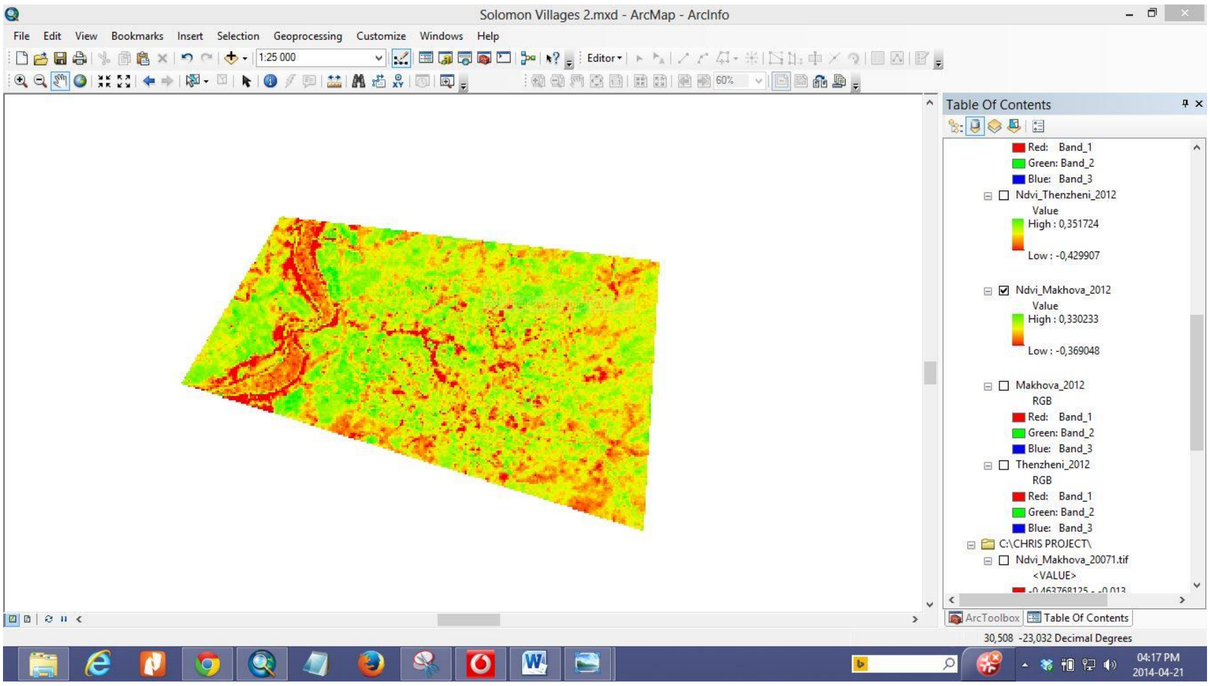
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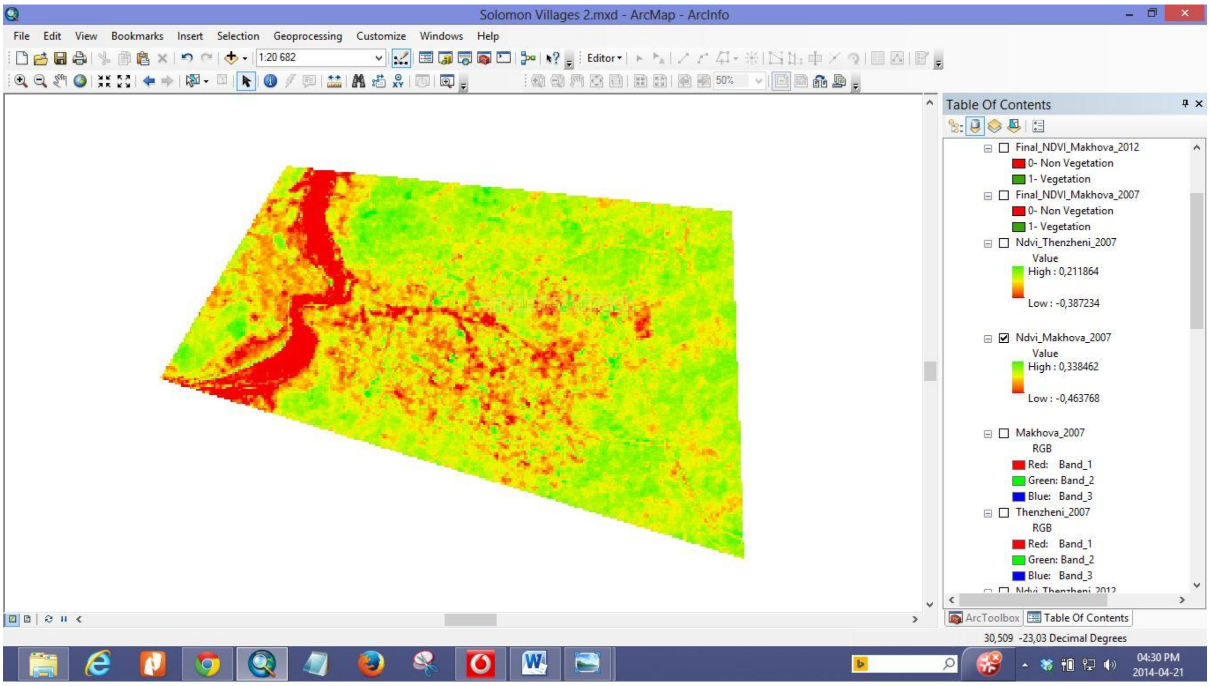
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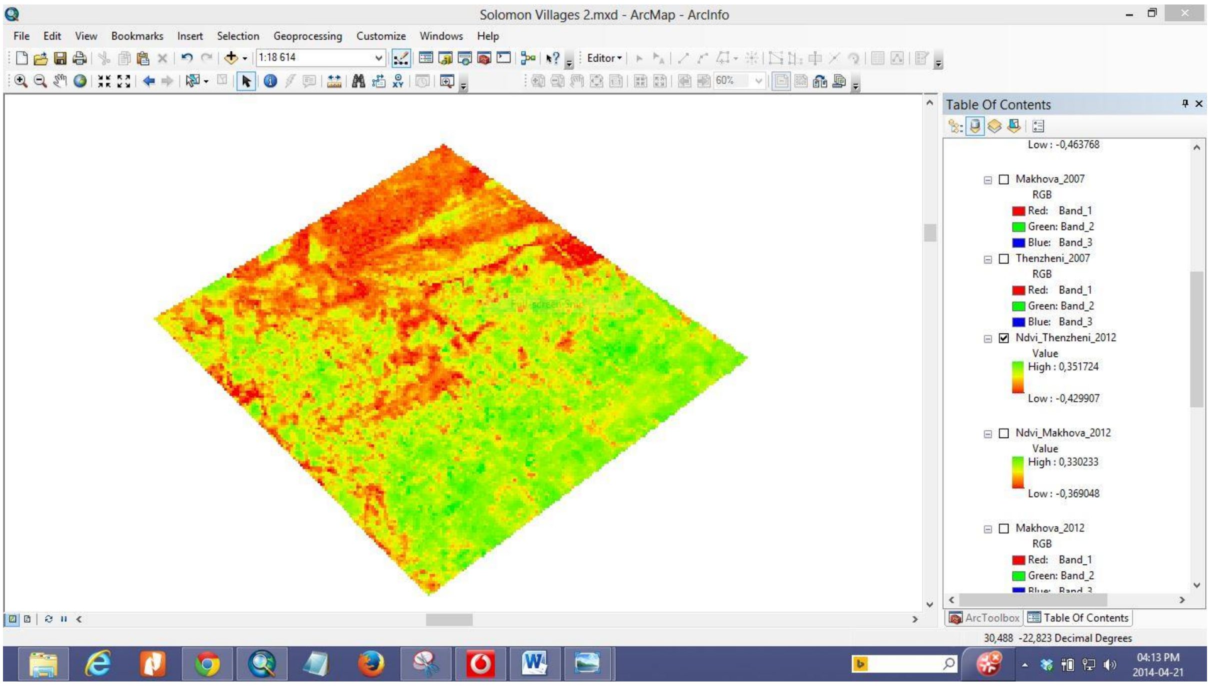
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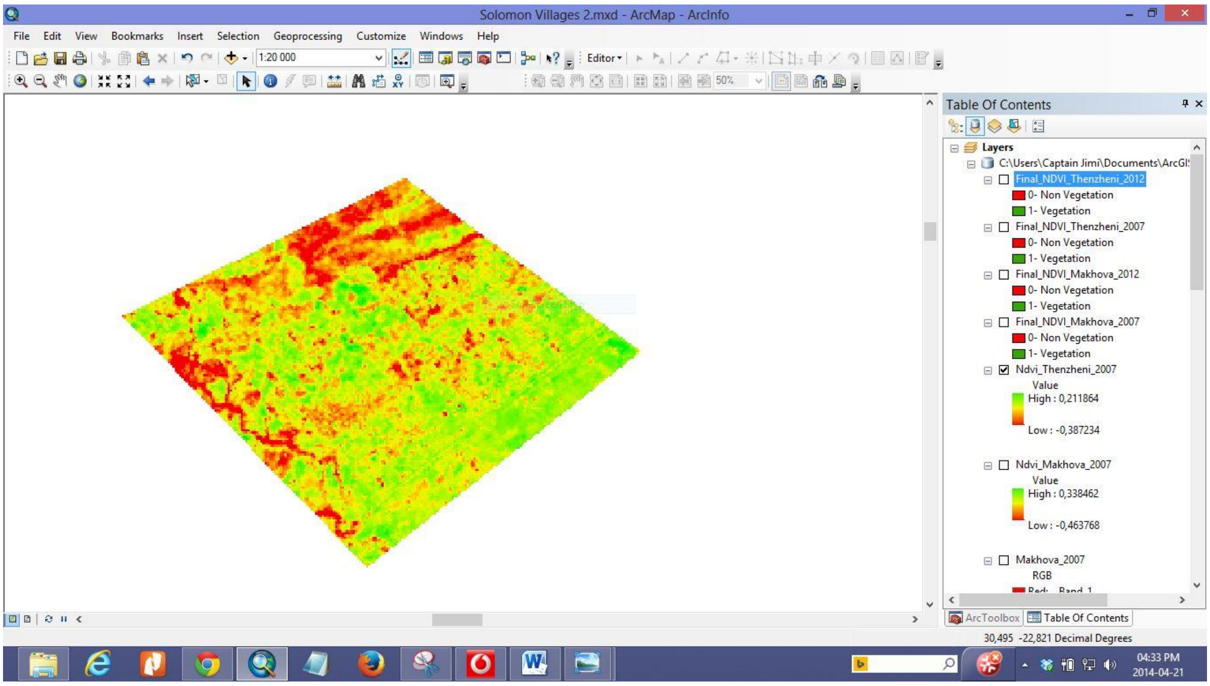
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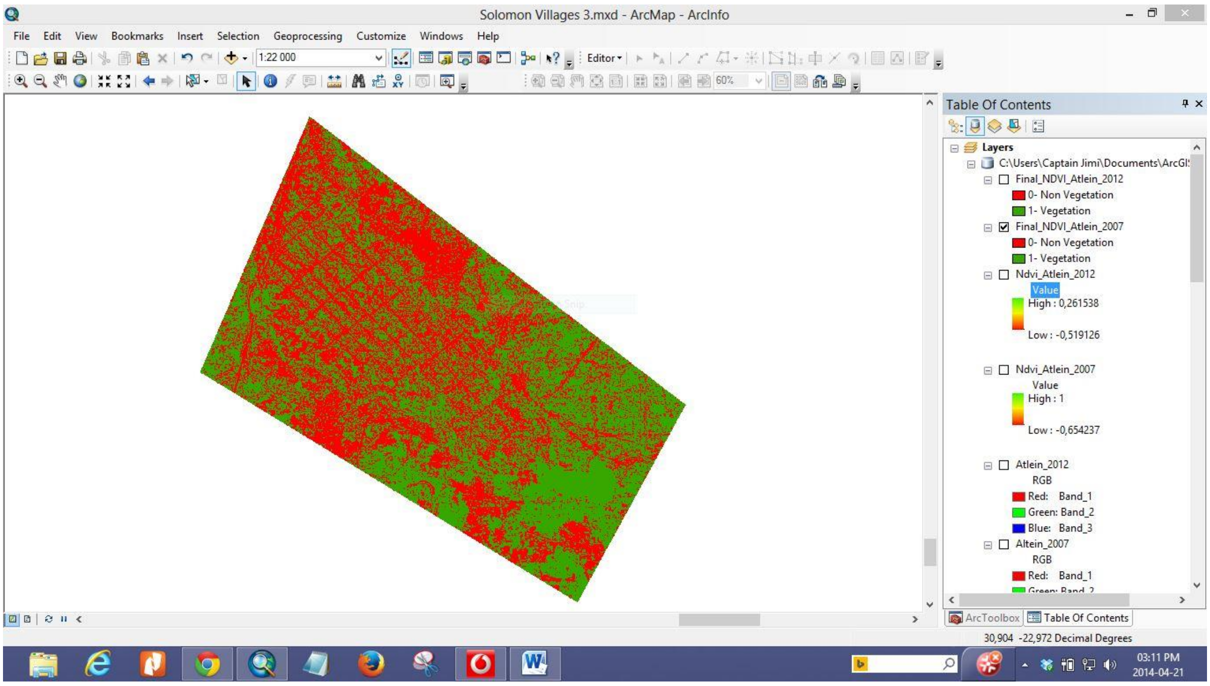
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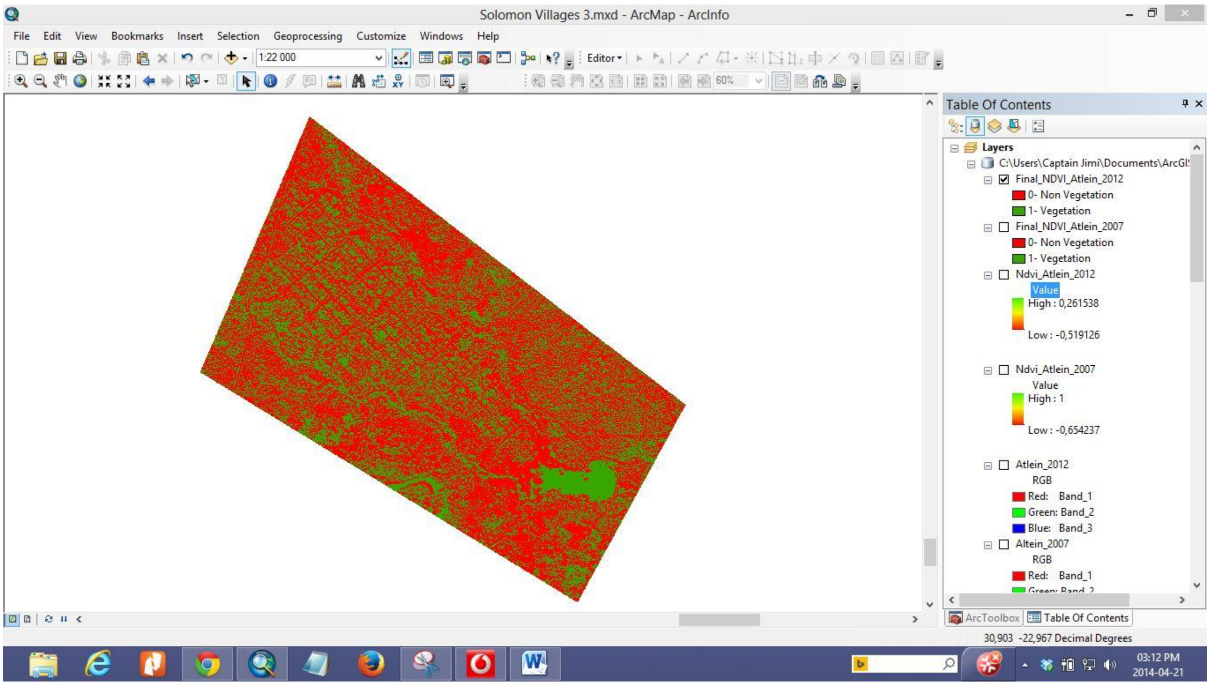
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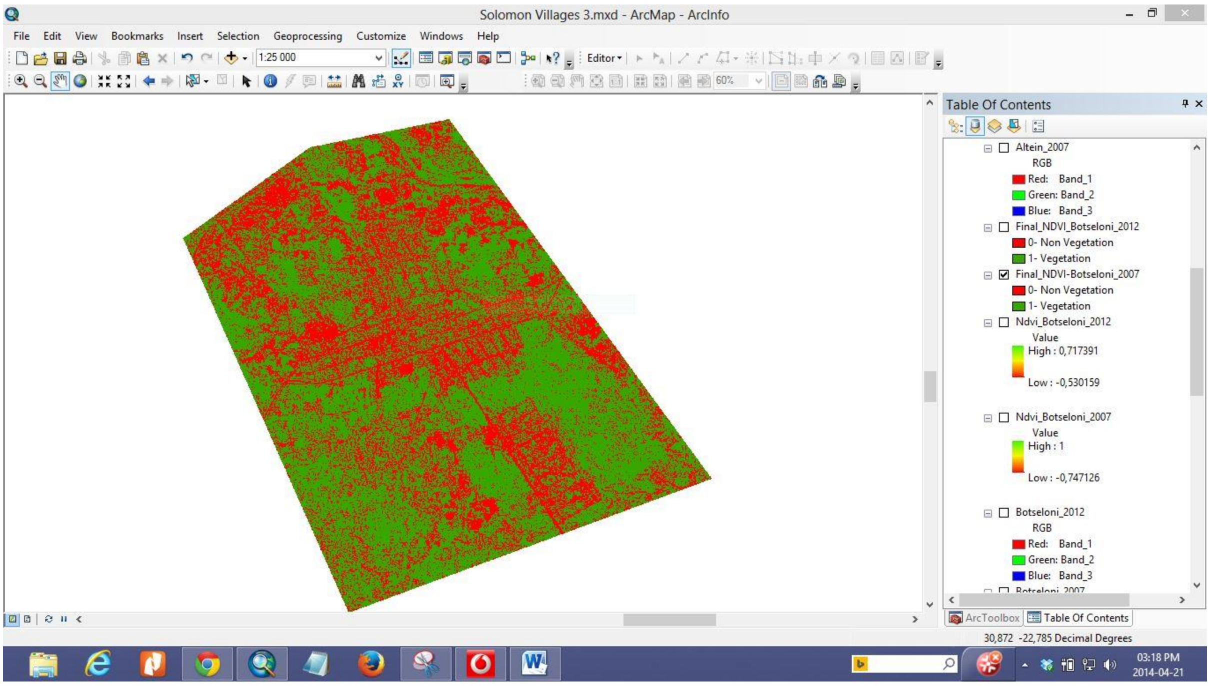
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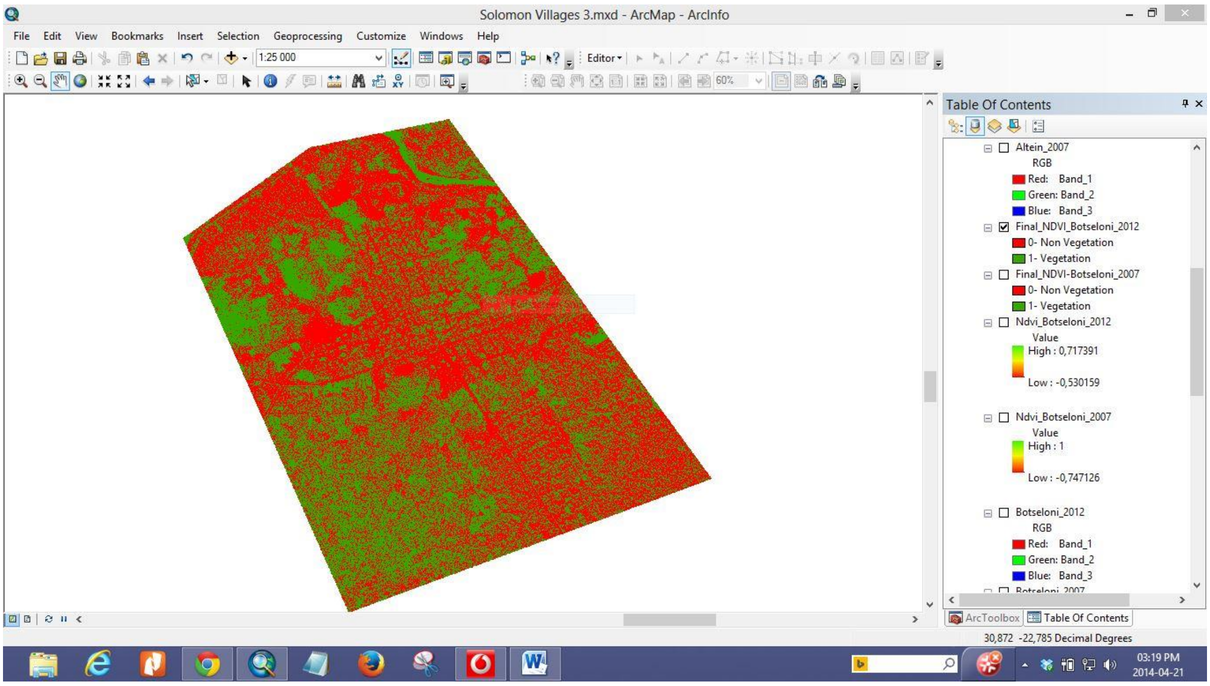
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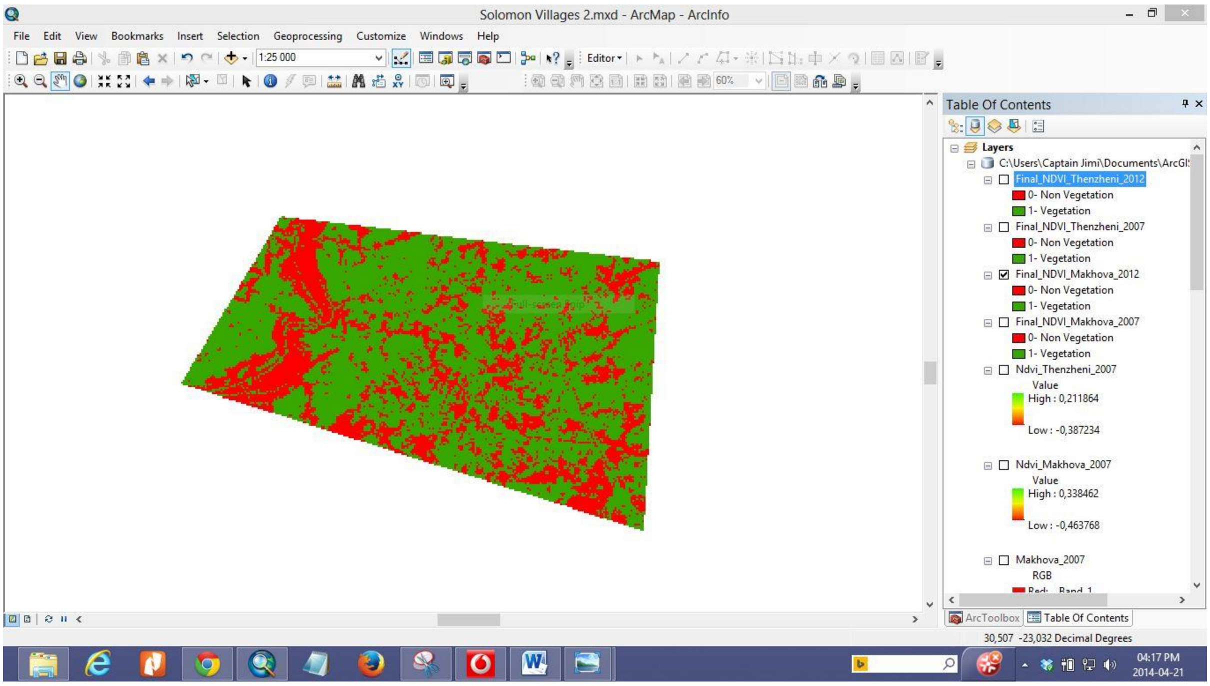
2014-04-21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1- Vegetation
Final_NDVI_Thenzheni_2007
0- Non Vegetation
1- Vegetation
Final_NDVI_Makhova_2012
0- Non Vegetation
1- Vegetation
Final_NDVI_Makhova_2007
0- Non Vegetation
1- Vegetation
Ndvi_Thenzheni_2007
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Low : -0,387234
Ndvi_Makhova_2007
Value
High : 0,338462
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Makhova_2007
RGB
ArcToolbox
Table Of Contents
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04:17 PM
2014-04-21

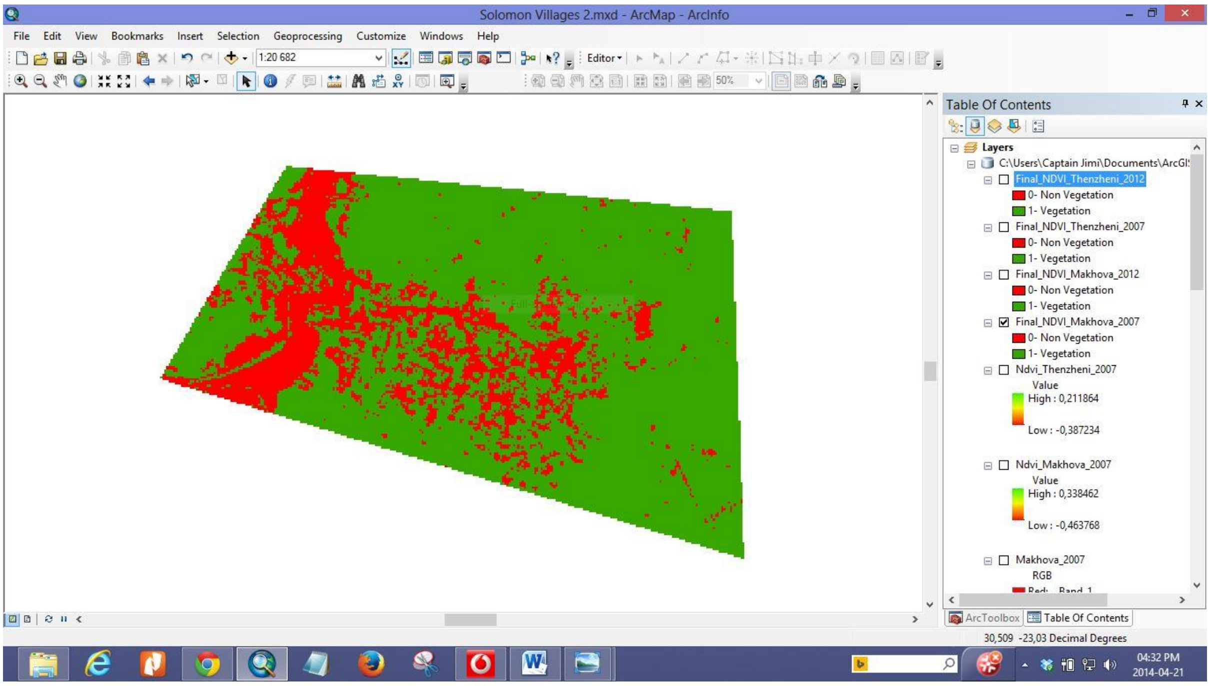
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Table Of Contents
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Low : -0,387234
Ndvi_Makhova_2007
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ArcToolbox
Table Of Contents
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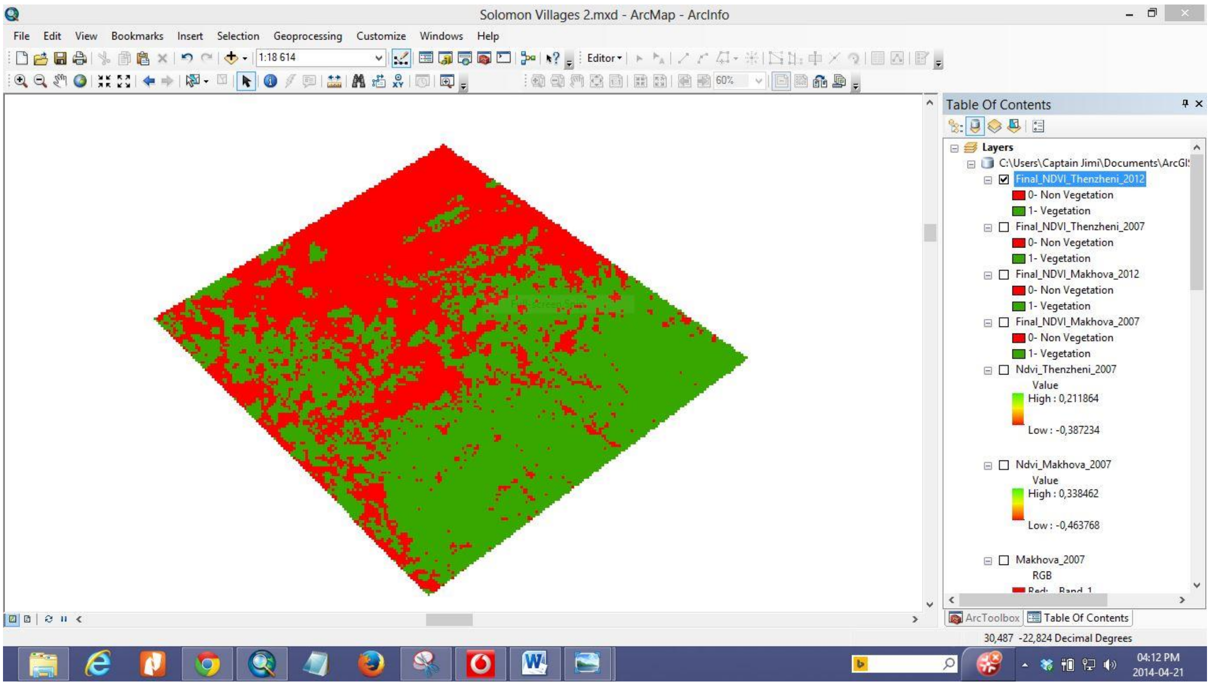
2014-04-21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File
Edit
View
Bookmarks
Insert
Selection
Geoprocessing
Customize
Windows
Help
1:18 614
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Table Of Contents
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1- Vegetation
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1- Vegetation
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Value
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Low : -0,387234
Ndvi_Makhova_2007
Value
High : 0,338462
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Makhova_2007
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Table Of Contents
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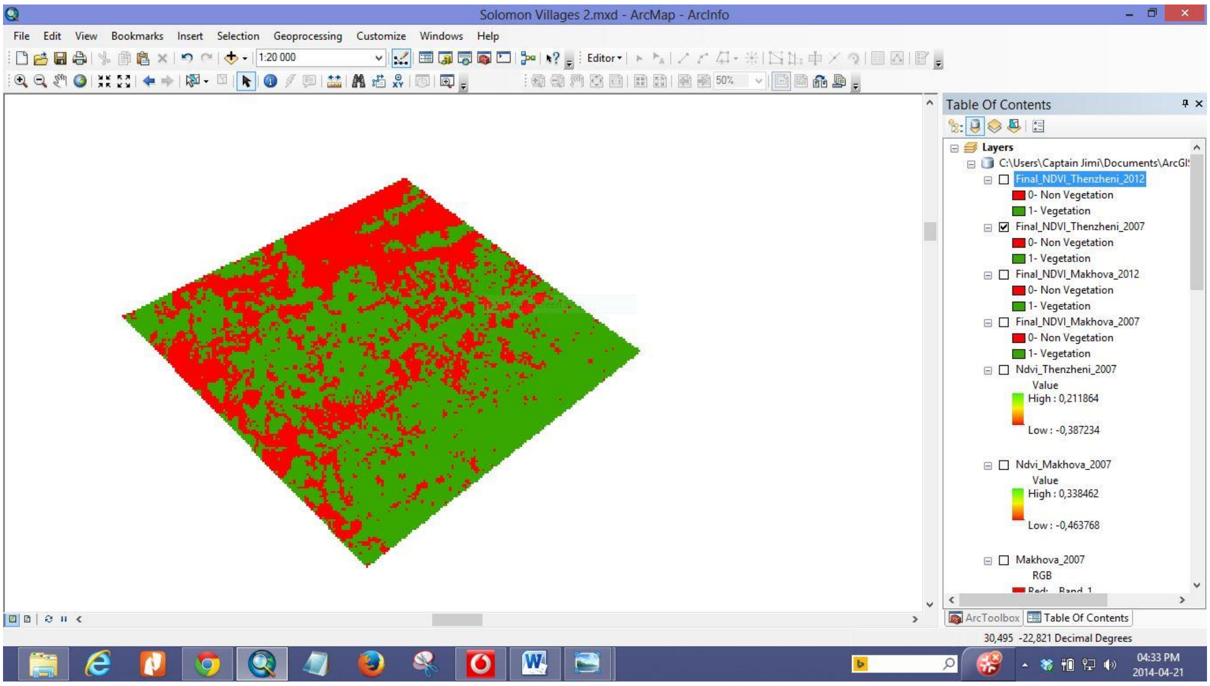
2014-04-21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File
Edit
View
Bookmarks
Insert
Selection
Geoprocessing
Customize
Windows
Help
1:20 000
Editor
Table Of Contents
Layers
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Value
High : 0,211864
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RGB
ArcToolbox
Table Of Contents
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