# OPTIMIZATION OF MOBILE ANTENNA LOCATION USING GEOGRAPHICAL INFORMATION SYSTEMS TECHNIQUES IN NANDI COUNTY, KENYA

**BY**

**ABIGAIL RUTH MUTAMBU**

**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN ENVIRONMENTAL INFORMATION SYSTEMS**

**IN THE DEPARTMENT OF MONITORING, PLANNING AND MANAGEMENT,**

**SCHOOL OF ENVIRONMENTAL STUDIES,**

**UNIVERSITY OF ELDORET, KENYA.**

**2014**

# DECLARATION

## DECLARATION BY THE CANDIDATE

This thesis is my original work and has not been submitted for a degree award in any other university. No part of this thesis may be reproduced without prior permission of the author and/or University of Eldoret.

Signature……………………………. Date………………….

**ABIGAIL RUTH MUTAMBU**

SES/PGI/04/08

## DECLARATION BY SUPERVISORS

This thesis has been submitted for examination with our approval as University Supervisors.

Signature…………………………….. Date…………………..

**Prof. B. D. O. ODHIAMBO**

Signature…………………………… Date……………………

**Dr. BEN MWASI**

## DEDICATION

This work is dedicated to my parents Mr. Joshua Mutambu and Mrs. Angelinah Mutambu, my sister Prisca and brothers Abel and Steven for their financial and moral support during my entire masters’ programme. May God abundantly bless you all.

## ABSTRACT

This study was conducted to optimize the location of mobile antennas to improve the strength of signal in Nandi County. Nandi County has been covered with dead zones in most areas for a long time despite the fact that the area has seven Base Transceiver Stations (BTS) located in various places. Poor network communication has been a challenge to many people in the area. Factors considered in optimizing BTS in the areas were; high altitude, visibility and high population. The study was conducted through ground truthing. The datasets that were involved are; development of a (Digital Elevation Model) DEM, land cover patterns, determination of dead zones using GPS in field survey and GIS analysis, examination of the characteristics of dead zones and optimisation of BTS location. The data was collected between the months of November 2009 – January 2010. To solve the problem, the study used GIS and GPS techniques. The data collected from the field was analysed using GIS techniques to give final products which were interpreted. The important variable controlled throughout the study was intervisibility in making visibility maps. The study came up with nineteen suitable locations at several areas mostly in the south east part of the study area where mobile antennas could be placed in any of the locations or a few of them to reduce the dead zones and improve mobile signal transceiver for efficient communication.

The results of this study are the basis for other studies that can be done and used by service providers in making use of GIS techniques to come up with the most suitable areas for placement of BTS. This study will lead to improved infrastructure, communication and technology and meet millennium development goals by year 2015 in

ensuring that all areas with dead zones have been solved using this project as a guideline for other researches.

## TABLE OF CONTENTS

## LIST OF FIGURES

**LIST OF TABLES**

## ACRONYMS

BTS---------------------------------------- Base Transceiver Station

CID -------------------------------------- Complete Intervisibility Database

DEM-------------------------------------- Digital Elevation Model

ICT--------------------------------------- Information, Communication and Technology

JPEG------------------------------------- Joint Photographic Expert Group

LOSA------------------------------------ Line of sight analysis

LOS-----------------------------------------Line of Sight

GIS--------------------------------------- Geographic Information System

GoK------------------------------------- Government of Kenya

GPS-------------------------------------- Global Positioning System

GSM-------------------------------------- Global System for Mobile communication

KCAA---------------------------------- Kenya Civil Aviation Authority

$Km^2$-------------------------------------- Kilometre squared

m----------------------------------------- Meter

MAP------------------------------------- Masked Area Plot

MHz------------------------------------- Mega Hertz

Mm-------------------------------------- Millimetre

$O^0C$------------------------------------- Degrees Centigrade

RGB------------------------------------- Red, Green, Blue

RMSE------------------------------------ Root Mean Square Error

TIN-------------------------------------- Triangulated Irregular Network

UTM------------------------------------- Universal Transverse Mercator

WGS 84--------------------------------- World Geodetic System 1984

**DEFINITION OF TERMS**

***Dead zones:* -** Dead zones are the areas where cell phone service is not available because the signal between the handset and the cell site antenna is blocked (e.g by hilly terrain). These are areas without mobile network coverage.

***Line of Sight (LOS):* -** LOS is defined as an uninterrupted signal transceiver from the BTS to the receiver (mobile phone)

***Live zones:* -** These are the areas where there are signals with the already existing antennas.

***Strength of signals*: -** This is the absence or presence of signals in the area.

***Viewshed analysis:* -** It is the study of visibility between points on a terrain surface. Its therefore the visibility between the existing BTS.

***Viewshed:*** - is an area that is visible from a specific location based on elevation values of a DEM.

***Visibility:*** **-** It is defined as the detection of the portion of the terrain that is visible from the viewpoint (existing BTS)

***Visibility surfaces*****: -** Visibility surfaces provide insights into intervisibility characteristics of the terrain that are not available from line-of-sight or masked area plots.

## ACKNOWLEDGEMENT

I want to take this chance to show my sincere appreciation to my university supervisors, Professor Beneah D. O. Odhiambo (Department of Geography Moi University) and Dr. Benjamin Mwasi (School of Environmental Studies, Department of Environmental Planning, Monitoring and Management, University of Eldoret) for taking their time to guide, correct and assist me from the inception of the project, data analysis and during thesis write up. I'm grateful for the hospitality offered to me by the residents at Nandi Hills throughout my study. Thanks to Bitok for your company and direction you gave me during the study. I'm grateful to Mr. Esipila for the time you allocated for me during the analysis period. To my family and Paul who have supported me endlessly throughout my studies and making all this happen, God bless you all. Finally, special thanks go to Moi University, Department of Planning, Management and Monitoring for allowing me carry out my studies under the guidance of the staff.

To Almighty God, for the gift of life and good health during my entire masters programme.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Globally, mobile phone communication networks play the same role that fixed-line phone networks did in facilitating growth in Europe and North America in the $20^{th}$ century. Mobile phone communication industry has experienced exponential growth in a relatively short time (GSMA, 2007). It was projected in 2010, 90% of the world will be covered by mobile networks and mobile communication will deliver data, internet and voice services to more than 5 billion people by 2015 (GMSA 2007).

Mobile communication has given us the ability to access the Internet with mobiles phones which are web enabled and in an area with signal coverage have offered us access to internet at any time (Kumar, 2004). Mobile communication allows people to stay in touch with each other at any time. It is an industry which has grown rapidly worldwide in the past decade and is a key influence in the world economy in this century (Kumar, 2004).

In developing countries, mobile telephony services and its increasing importance as a means of communication has played a role in sustainable rural poverty reduction (GSMA, 2007). Mobile communication has become the primary form of Telecommunication in both developed and developing countries (GSMA, 2007). Mobile phones have emerged as the most widespread ICT in the developing world (ITU, 2008).

Mobile telecommunication has a positive impact on the economic welfare in the developing countries by generating gross domestic product (GDP); creation of job;

productivity increases; and increase in taxation revenue by mobile operators. Vodafone (2005) reported that, in a typically developing country, an increase of 10 mobile phones per 100 people boosts gross domestic product (GDP) growth by 6% (Bhavnani et. al, 2008). According to report by Deloitte 2008 which studied 6 countries namely; Bangladesh, Malaysia, Pakistan, Serbia, Thailand and Ukraine showed that mobile phones had a significant impact on GDP when analyzed. Communication is at the core of intelligent life and business thrives on communication because it keeps track of consumers' trends, consumers and retailers are aware of different options available and where they can be found at a particular time (Bhavnani et. al, 2008).

In a recent study of fishermen in the Kerala state in India, Jensen has shown that the use of mobile phones by fishermen in Kerala to arbitrate over price information from potential buyers and coordinate sales has helped them to increase incomes and reduce wastage (Jensen, 2007). Mobile phones, the Internet and Telecommunication centres play a vital role in supporting the livelihoods of the poor and spurs growth in developing countries. Mobile phones are the main form of digital progress that helps the poor and bridges the connectivity divide (Jensen, 2007)

Mobile telephony has also given intangible benefits in the developing and developed countries by aiding in disaster relief and enabling dissemination of locally generated information (Bhavnani et. al, 2008). Goodman (2005) found that there were links between mobile usage, rural communities and social capital in his study of communities in South Africa and Tanzania.

As it is in the rest of the world, the use of mobile telephones is spreading rapidly in Kenya. Kenya has shown impressive growth rates with significant opportunity, (McHenry, 2009). By the end of 2008, Kenya had more than 15.0 million mobile subscribers, with a mobile penetration rate of 39 percent. The subscriber base is expected to rise to 29.28 million, or 66.7 percent penetration, by year-end 2013 (Worldwide Telecommunication, 2009). Kenya has emerged as one of the leaders in ICT technology development in Africa. Since the liberalization of the Kenyan Telecommunication sector in July 1999 and the formation of the country's Telecommunication regulatory body Communication Commission of Kenya (CCK), the country has witnessed a surge in the investments made in Telecommunication infrastructure and has ensured competitiveness in the country's Telecommunication sector (McHenry, 2010). Total revenue of Kenya's Telecommunication market is forecast to grow by 42 percent from $1.39 billion in 2008 to $1.98 billion by 2013, with 78 percent of the total revenue to be generated by the mobile sector (McHenry, 2010). Presence of mobile signals in the country has improved means of communication unlike in the early 1990's when the most means of communication was through post office and actually took long time. People are more informed in areas where there are steady mobile signal transceivers.

To support signal transceiver, mobile antennas have to be erected at identified locations. The location with an increase of number of mobile BTS will improve the line of signal transceiver and hence the quality of the service will improve. Antenna heights in Kenya depend on Kenya Civil Aviation Authority (KCAA) standards ranging from 35 to 70 metres to avoid aircraft obstruction in taking off and landing.

When several antennas are mounted on concrete bases and many tall steel structures erected they become unappealing to the environment and could also be a hazard to movement of birds and low flying aircrafts. Therefore to minimise these effects, a few number of BTS should be erected in the area. This could be achieved by ensuring that all mobile service providers will share a BTS among them to mount their masks. In incorporating GIS analysis in this study ensures that there is limited interference of the environment because of the limited BTS's. This study ensured that most suitable areas are determined which can be used by all the service providers in conjunction with CCK in selecting the most preferred site.

A Geographic Information System (GIS) viewshed is the result of function that determines, using a terrain model, areas on a map that can be seen from a given point(s), line of sight or area. In the communications industry, viewshed has been used to model radio wave coverage and to site transceiver towers for cellular phones (Dodd, 2001). Some of the factors involved in tower sitting are the number of customers in a potential area, the terrain of the area, and tower to tower connectivity. GIS can aid in dealing with all of these factors (Dodd, 2001).

There are areas in Kenya which have dead zone and this study focus on the Nandi County where despite the fact that there are seven BTS in the area there are still areas not covered by the network due to the topography. The study area is $625km^2$ with seven BTS available, three were for Orange network and four for Safaricom and one for Zain which was mounted on the Safaricom mask. The signal quality in large part of the area was still very poor with all those antennas.

**1.2 Statement of the Problem**

The important factor that is driving the growth in the country's Telecommunication sector is the increase in the number of Telecommunication operators, which has made the country's Telecommunication sector more competitive. The increased competition has led to price war among operators in a bid to increase their respective mobile subscriber base. Therefore to ensure efficient growth of Telecommunication in Kenya, in this area of study there is need to allocate suitable areas for new BTS location to optimize the signal transceiver in the area.

For many Telecommunication companies, GIS is used as a facilities management system to handle network maintenance and construction, and to incorporate customer service and billing information into their network geography (Owen, 1998). However, increased competition has also caused Telecommunication companies to seek customers actively. As a result of the Telecommunications Act of 1996 and the National Infrastructure initiative, they must also provide sufficient access to rural communities (MapInfo, 1997). GIS can help in both cases by using its data analysis capabilities in conjunction with its facilities management features. To find new customers, GIS can locate areas with a high density of persons who meet a particular marketing profile. To serve rural communities, Telecommunications can use GIS to find the areas with the highest population densities, to map their current facility locations in relation to the potential service area, and to plan the network extension. They can then use the results to estimate the cost of covering new territory. Overall, GIS can benefit Telecommunications companies by placing their data in a spatial context and analyzing that data to discover new information on relationships between different data types and by integrating data from different company departments to present a more comprehensive business outlook (Owen, 1998).

Visibility analysis has traditionally been restricted to point-to-point line- of -sight profiling. This constrained view of visibility necessarily limits our ability to understand the visibility surface characteristics of the terrain. A viewshed analysis has improved the determination of intervisible areas. Use of visibility analysis of the GIS allows a greater scope in determining the best placement of base transceiver stations

## 1.3 Objectives of the study

This study shows how GIS technology can be used in Telecommunication by optimizing locations for new mobile BTS and thereby reduces dead zones in Nandi County.

### 1.3.1 Specific Objectives

1. To determine dead zones with the current existing antennas.
2. To examine the characteristics of dead zones for all network mobile signals.
3. To identify optimal locations for new antennas that would reduce dead zones and improve network of mobile signals in the study area.

## 1.4 Research Questions

1. Which areas of the study area have weak or no signals?
2. Which part of the study area is most visible from the existing BTS?
3. What are the characteristics of dead zones in the area?
4. What parts of the study area has the most suitable sites?
5. What is the optimal number for new antennas to be placed in the area?

## 1.5 Rationale of the study

Despite the fact that there has been four different mobile communication service providers in Kenya for quite a long time with (Kencell leading in the market - it is now known as Airtel followed by Safaricom, then Orange and finally YU, this particular area of study continuously experiences signal problems due to the obstruction by the topography of the area. Mobile signal obstruction has also affected the people travelling along the road and it could cause major communication barriers. The County is not well served by telephone services (Nandi County development plan, 1997-2001). People in the area have to move to strategic areas where mobile signals are available in order to use their mobile phones.

Nandi County is located along the tea production belt in Rift Valley province and for the farmers to be in a position to serve their customers adequately and efficiently there is need of improving the communication by optimizing new BTS that will serve the area adequately with signals thus Kenya will achieve its target of improving Information, Communication and Technology (ICT) infrastructure in the country. ICT is the World's fastest growing economic activity; the sector has turned the globe into an increasingly interconnected network of individuals, firms, schools and governments communicating and interacting with each other through a variety of channels and providing economic opportunities transcending borders, languages and cultures (EPZA, 2005). ICT has opened new channels for service delivery in areas such as e-government, education, and e-health and information dissemination. Rapid development of ICT accompanied by the convergence of Telecommunications, broadcasting and computer technologies is creating new products and services (EPZA, 2005). Kenya is an active member of the International Telecommunications Union (ITU) and is also a participant and a signatory to a number of international conventions and standards relating to ICT (EPZA, 2005). This therefore requires diversifying its mobile phone signals to almost all parts of the country.

This study applies GIS and Global Positioning System (GPS) to determine potential areas for placing new antennas so as to provide efficient services to serve many people in the region.

## 1.6 Assumptions

1. Weather conditions do not significantly affect the strength of the signals.

2. The model of mobile phones used in the area does not significantly determine the reception of signals.

3. Land use Land cover patterns do not significantly affect the placement of mobile signals.

## 1.7 Study area

The study area covers an area of 625 square kilometers and falls in parts of Nandi and Kisumu County. These are Nandi Hills, Kapsabet and North Tinderet in Nandi County and Muhoroni division in Kisumu Districts which since become Counties.

### 1.7.1 Administrative Boundaries

Nandi District is situated in the western part of Rift valley Province. It borders Kakamega District to the north-west, Uasin Gishu District to the north-east, Kericho District to the south-east, Kisumu District to the South-east and Vihiga District to the West. The District lies within latitudes $0^0$ and $0^0$ 3 4” north and longitudes $34^0$ 44” and $35^0$ and $35^0$ 25” east. It is divided into nine divisions. Kapsabet is one of the divisions and it marks the upper end of the study area.

Muhoroni division is in kisumu District and covers an area of 329km$^2$ (District Commissioner's Office Kisumu, 1996).

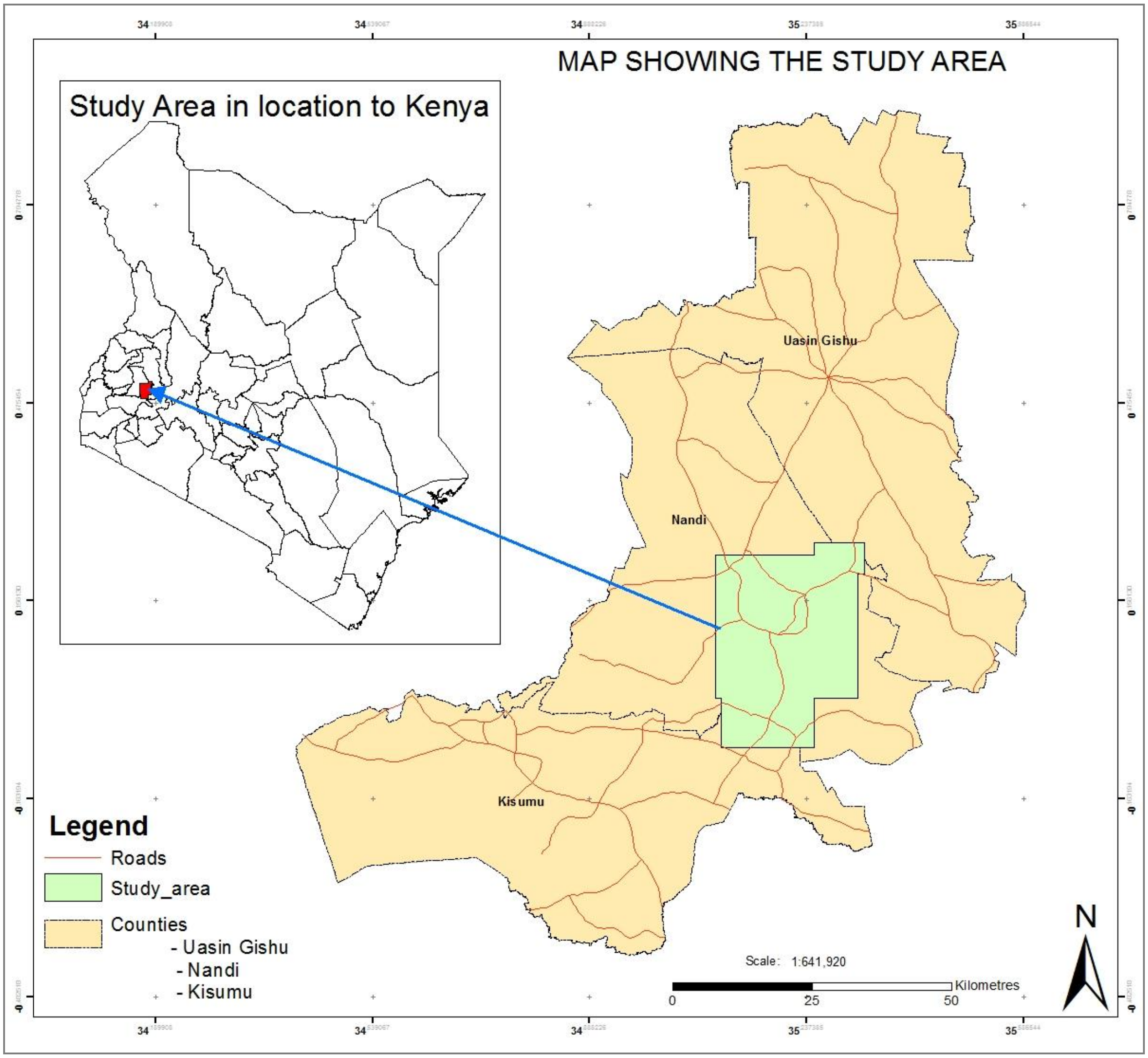



**Fig 1.1** Map showing the study area. (Source: Author, 2010)

### 1.7.2 Geology and Physiography of Study area

Nandi District can be subdivided into five distinct geologic regions namely; a) the rolling hills to the west which is composed of more or less granitized gneisses of the Basement System and its drainage is of arbores cent pattern, b) the Uasin Gishu phonolite plateau in the north-east of Kapsabet is an extensive lava plain rising steadily to the east and its monotony is broken only where the upper of the two major flows that are present forms a distinct scarp feature rising above the lower, c) highlands and foot hills of Tinderet in the south east formed by volcanic lavas alternating with agglomerates and tuffs and its rivers forming the north-west quadrant of a radial drainage pattern, d) Kingwal wetland which lies at a height of above 6,400feet (Jennings, 1964) and (e) the dissected Nyando escarpment at the southern border.

The altitude ranges from 1,300 m to 2,500 m. It is hilly and is underlain by banded gneisses rock outcrops of the Basement system as shown in the Geological map (Jennings, 1957). Other rocks present are the agglomerate phonolitic, patches of limestone, tuffs and ashes, dolerites and highly metamorphosed intrusive rocks. The topography is favourable for the growth of the natural forests which serve as watersheds for the major rivers.

### 1.7.3 Climate

The average rainfall received is between 1,200 mm to 2,000mm per annum and is high because of its high altitude. The distribution of rainfall is governed by the topographical influence of the south-westerly winds from Lake Victoria. The southern and central parts which receive a minimum of 1,500 mm per annum form the tea production belt. Nandi Hills has a cool and wet climate with two rain seasons during the year. Temperatures vary between $18^0$C and $24^0$C.In Muhoroni, a mean annual rainfall of 1,525mm is received and rainfall varies with altitude and proximity to the highlands along Nandi Escarpment and Tinderet.

### 1.7.4 Soil

Nandi County is endowed with good soils suitable for cultivation of diverse crops. Seven major soil types have been identified. Soils found on the mountains and major scarps have developed from basement system especially granite, they are shallow and excessively drained, and range from red friable clay loams to sandy clay loams. In some areas they appear as rock outcrops e.g. Songhor.

### 1.7.5 Population

The 1989 national population census established the Nandi population to be 433,613 with an annual growth of 3.71%. The County's population was projected to be 583,446, 628,384, and 676,784 in the years 1997, 1999 and 2001 respectively (County planning unit, Nandi, 1996.) Nandi county has a total population of 752,965 (2009, Census).

Muhoroni division had a population of 110,338 in 1989 national census and projected population for years 1997, 1999 and 2001 were 144,238, 154,230 and 164,913 respectively (County planning unit, Kisumu, 1996). Muhoroni hosts a town council. It has an urban population of 13,664 and a total population of 31,148 (1999 census). Songhor is an area in Muhoroni where Safaricom antenna is located.

### 1.7.6 Economic activities

Tinderet Highlands is best for tea production given its mean annual rainfall of 1,600mm and cool temperatures ranging from $18^0$ to $20^0$C. Predominant cash crops in the study area include; tea, coffee, wheat, sugarcane, pyrethrum and horticultural crops. Maize growing is widespread and is used both as staple food and cash crop. Dairy farming is also practised in the area and most farmers keep pure breeds and high grade crosses.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

In this section, various issues in mobile communication and methods of locating areas for placement of antennas have been discussed. Mobile communication was first discussed and then dead zones. So that an area can have dead zones, there are observation points which do not meet the areas network and due to that base transceiver station (BTS) were discussed. Digital Elevation Model (DEM) will be discussed since it formed the basis of the analysis of the data in selecting suitable sites. Other factors considered are: intervisibility mapping; viewshed analysis; Geographic Information System (GIS) applications in Telecommunication and signal transceiver respectively.

## 2.2 Mobile communication

As the explosive growth of mobile communications continues, it is very valuable to have the capability of determining optimum base-station locations, obtaining suitable data rates, and estimating their coverage, without conducting a series of propagation measurements, which are very expensive and time consuming (Sarkar et. al, 2003).

To ensure adequate communication, mobile systems have to assure a high capability of communication to its customers (Barrile et. al. 2009). Current projections suggest that the world will continue to add mobile lines faster than fixed lines; indeed, the next billion new phone users will use primarily mobiles (ITU 2003; Lanvin 2005). Network coverage will also increase the number of customers it caters for.

A mobile is an incredibly powerful tool for exchanging ideas at a distance, and for managing daily life (Donner, 2005). The clearest examples of impact studies come from the Information, Communication and technology and Development (ICTD) perspective, where researchers are interested in whether mobiles promote or enable economic growth or broader well-being (Sridhar and Sridhar 2006). Effective mobile communication will be achieved through optimizing mobile antenna locations.

## 2.3 Dead zones

Dead zones occur when a telephone is in the extreme limit of the area of cover of a Base Transceiver Station (Barrile et. al. 2009). A number of factors can create dead zones which may exist even in locations in which a wireless carrier offers coverage, due to limitations in the locations of antenna, limited network density, interference with other cell sites, and topography (Anynomous, 2009). Since cell phones rely on radio waves, and radio waves travel through the air and are easily attenuated, cell phones may be unreliable at times. Like other radio transceivers, cell phone calls can be interrupted by large buildings, terrain, trees, or other objects between the phone and the nearest base station antennas (Anynomous, 2009). Dead ground initially were determined by drawing a series of radiating lines from the view point and examine the points at which the lines of view are obviously interrupted and estimate the heights. By comparison with the height of the point of observation, it can be seen at what rate the line of view declines in altitude. Thus height of ray can be calculated at any point along it, and where the ground level is shown by the contours is below the height of ray, there is the dead zone (Monkhouse, 1991)

## 2.4 Base transceiver stations (BTS)

In recent years the technological development in general and the spread on the territory of antennas for mobile phones urged a state of widespread public concern of social alarm. There is a need for a greater territorial coverage of mobile telephone service, due to the continuous request of users and to the presence of more operators in the market, lead to an intensification of the installations that not only make to a progressive decrease the power radiated from individual installations, it also requires that they be placed closer to homes with consequent concern of the population for their own health (Barrile et. al. 2009). The information of BTS makes use of Global System for Mobile communication (GSM) to 900 and 1800 MHz in rural areas. In order to maintain the signal that reaches mobile phones and the BTS within the reception threshold, it would be necessary setting the BTS at the maximum height level.

Data deemed necessary to define a site are: Provider; Location; Elevation and Coordinates and so it is possible to georeference sources and to visualize therefore the impact on the land and the surrounding buildings (Barrile et. al. 2009).

In areas where there are enough cell sites to cover a wide area, the range of each one will be set to ensure there is enough overlap for "handover" to/from other sites and that the overlap area is not too large, to minimize interference problems with other sites. The maximum range of a mast (where it is not limited by interference with other masts nearby) depends on the population density. Based on a tall mast and flat terrain, it is possible to get signals in an area of 50 to 70 km (30-45 miles). When the terrain is hilly, the maximum distance can vary from as little as 5 kilometres (3.1 miles) to 8 kilometres

(5.0 miles) due to encroachment of intermediate objects into the wide centre (Anonymous, 2009).

## 2.5 Signal transmission

The Mobile phone signal (or reception) is the strength of the connection the mobile phone has to its network. Depending on factors, such as proximity to a tower and intervisibility, the signal may vary. Most mobile devices use a set of bars of varying heights to display the strength of the signal being received by the device wherever it is located. In telecommunications, particularly in radio and mobile transceiver, signal strength refers to the magnitude of the electric field at a reference point that is a significant distance from the transmitting antenna. It may also be referred to as received signal level or field strength. Typically, it is expressed in voltage per length or signal power received by a reference antenna (Anonymous 2009).

Digital signal is discretely variable over time. That is, ideally, the signal is either a pulse, or not a pulse, at any given instant of time. There are no in-between states for this digital signal. This signal is not continuously variable as is an analog signal. If this digital signal is sent over a telephone line, it suffers the same distortion, attenuation and degradation like the analog signal (Poland and Revision, undated). Digital signal is one which consists of a sequence of symbols taken a finite set. The simplest digital signal transmitted is the binary signals which use only two symbols denoted by 1 or 0. During transceiver, digital signals have the most important features whereby the effects of noise and interference can be virtually eliminated (Bissell and Chapman, 1997). A large variety of transceiver media are used for digital links. Digital signals as they leave an encoder or a data terminal are typically in the form of a polar bit stream in which each bit takes either a high level or a low level according to its binary value (Inose, 1981).As the distance between the transmitting and receiving antennas increases, the energy concentration for a given area decreases. Therefore, the distance from the transmitting antenna also determines how much energy an antenna intercepts. This loss of signal strength due to increased distance is known as path attenuation. Antenna height establishes the maximum possible range (Inose, 1981).

Global System for Mobile communication (GSM) provides three various functionalities that leads to succeed in the attempt to contain as less as possible the power of transceiver signal, system. These include: the static control of the transceiver power, the dynamic control of the transceiver power and the transceiver batch processing line (Barrile & et. al. 2009). The considerably faster dial-up poses an advantage over the connections with the receivers in the analog fixed line network. The bit rate adjustment is important for digital transceiver. The power of signal transceiver necessary for catching up customers, who are near limits of the cell, even if masked from buildings or other structures, is very smaller. So the maximum power of the signal transceiver is set up within lower limits.

## 2.6 Digital Elevation Model

Digital Elevation Models (DEMs) have become a widely used tool and product in the last 20 years that provide a snap shot of the landscape and landscape features while also providing elevation values. DEM allows better visualization of topographic features. The higher the resolution of DEMs will present more accurate real representation of landscape (Fisher, 1993).

Digital Elevation Models are data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the "Bare Earth". The intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems.

DEMs are computer-generated images of the earth's surfaces, which can be produced by raster grids and/or TIN models. Aerial photography can also assist in producing DEMs (Mannin, 2001).

## 2.7 Intervisibility Mapping

Intervisibility is the term used to describe the effects of terrain on visibility. It is a key factor in military terrain analysis and impacts a soldier's field-of-view, viewing distance, and engagement ranges (Caldwell et.al. *2002*).

A number of different intervisibility products are available. Point-to-point intervisibility results in a line-of-sight profile. Single point to multiple point intervisibility produces a masked area plots (MAP). Intervisibility products have been largely limited to line-of-sight profiles and MAPs because of the amount of time required generating individual products (Dowers and Mineter, 2004). **Line of Site** is the concept of Intervisibility applied to two points. Line of site (LOS) is a 3D graphic drawn from an observation point to a target point. LOS not only tells whether the target is visible, it shows which parts of the terrain along its length lie within the observer's field of view (Ormsby and Alvi, 1999). Intervisibility calculations made between two points on the ground using a given digital terrain database can provide approximations of how much of a given unit located at one point is exposed to visual contact by an opposing unit at another point (Barr, & et.al 2008). From a Digital Elevation Model (DEM), intervisibility allows 3D visualization and Visibility calculations. For each DEM pixel, the spaces that the researchers can visually accesses can be determined (Barr, & et.al 2008).

Intervisibility analysis in GIS requires at least two data sources: a digital elevation model (DEM) representing the terrain in the study area, and the coordinates of each signalling location in question. Intervisibility describes the effects of terrain on visibility and can therefore be used as a measure of visual exposure of locations in a region, practically as a data layer in a geographical information system (GIS). Using spatial statistics, pairing an intervisibility map with a wind resource map, the effectiveness of intervisibility mapping as a planning tool was analyzed as a guide in the researchers' analysis (Möller, 2007). Intervisibility can be quantified in a raster-based GIS as the number of landscape cells, which are visible by (Line of Sight Analysis) LOSA from each landscape cell. The visibility count is influenced by the topography of a locale. Intervisibility could therefore be used as a measure of visual exposure of locations in a region, practically as a data layer to be used for further analysis in a GIS (Moller, 2008). The purpose of visibility analysis is to explore the visual organization of features across a landscape, where the concept of visibility has both cognitive and perceptual implications (Wheatley, 2000).
According to Monkhouse (1991), intervisibility can be determined by use of contour maps which he explained using three different methods. The most accurate method of determining intervisibility employs the principle of similar triangles which estimates the altitude above ordnance Datum of the two points, using the nearest contour or spot

height, and by subtracting to find the difference in height hence draw a line parallel to the line of view. Then each end of the line of sight is joined to the opposite end of the parallel lines and the lines will cross at a point.

The term intervisibility is used to describe the reciprocity between two points, and is often represented as a binary: 1 = visible; 0 = not visible. If intervisibility is established, then sanctioned signals of Telecommunication and wireless internet are able to reach the transceiver tower and the tower relay is able to reach that visible surface (Mannin, 2001).

There are various techniques that are used to create visibility surfaces to guide the Telecommunication industry and the wireless internet companies for placement of valuable and vital equipment that will allow cellular and other wireless signals for optimal reception for their customers. Viewshed analysis and 3-d modelling are among the most used techniques. Digital elevation models (DEMs) generally form the basis of a viewshed map.

## 2.8 Geographical Information System

According to Huxhold and Levinsohn (1995), a geographic information system (GIS) is a collection of information technology, data, and procedures for collecting, storing, manipulating, analyzing and presenting maps and descriptive information about features that can be represented on maps. The technology required to construct a GIS is not just a single piece of software purchased from a vendor. It is a combination of information technologies including GIS, computer aided design, database management systems, remote sensing and image analysis, GPS, multimedia and computer hardware. GIS has the added capability to analyze spatial data through attribute and location analysis or spatial modeling. Adding a relational database further enhances the capability of a GIS to solve complicated spatial problems (Lukas, 2007). A GIS provides a convenient way of testing intervisibility as well as its significance.

GIS software has been utilized in map making for analyzing the collected data from the field and even data generated from images. Useful analysis such as area and distance measurements, coincidence tabulations between layers, and extensive spatial statistical functions and modeling of various layers can be conducted routinely. Data can also be entered directly from GPS receivers in the field. GIS data can be used to create DEM by manually or onscreen digitizing contours from topographic maps. These contours are interpolated into a raster array (Madry and Rakos, 1996).

In GIS, Viewshed analysis identifies the areas on a surface that are visible from one or more observation points. It answers the question: What can I see from these locations? (Kay, 2001). One of the more interesting results from the GIS analysis is the line-of-site analysis and viewshed analysis among other functions (Madry and Rakos, 1996). This GIS technique allows one to determine the parts of the landscape that are visible from any given location. Madry and Rakos (1996) run the line-of-site analysis from four locations on each of the known Celtic hillforts in their research area.

The fundamental strength of a Geographical Information System upon which this study draws, is its ability to acquire, visualize and generate spatially referenced data. Although the function of visibility analysis has a long pedigree before the widespread adoption of GIS, this form of spatial analysis not only has a valuable contribution to landscape studies but also towards the application of how data is managed within an environment (Kay and Sly 2001).

Adoption of GISs by the Telecommunications industry as a whole is still incomplete. We are realizing the benefits of geospatial data analysis, but integration could be progressing faster (Lukas, 2007). When a GIS is used only as the design tool, the initial network design time is reduced by two-thirds.

### 2.9 GIS Applications in Telecommunications

In the Telecommunications industry, deregulation and increased competition have made GIS a business necessity (Owen, 1998). For many Telecommunication companies, GIS is used only as a facilities management system to handle network maintenance and construction, and to incorporate customer service and billing information into their network geography (Owen, 1998). In the Telecommunications world, a GIS is ideally suited for network planning and development (Lukas, 2007). The ability to layer information onto the earth’s surface, complete with attribute data, allows engineers the unique ability to model and assess a network from the office. This saves valuable time and reduces the number of trips, if any, that the engineer must make to the field. Furthermore, the powerful automation capabilities offered by a GIS increase the speed and accuracy of the network design process and can help reduce, and even eliminate, the downstream impacts of design-phase errors on cost and schedule during the network deployment phase. Rule-based features found in a GIS can also offer network designers the ability to produce better products, optimized for cost, shortest routing distances, or other user-defined metrics (Lukas, 2007).

To serve rural communities, telecommunication can use GIS to find the areas with the highest population densities, to map their current facility locations in relation to the potential service area, and to plan the network extension. They can then use the results to estimate the cost of covering new territory. Overall, GIS can benefit Telecommunications companies by placing their data in a spatial context and analyzing that data to discover new information on relationships between different data types and by integrating data from different company departments to present a more comprehensive business outlook (Dodd, 2001). GIS is able to calculate the electromagnetic field produced by the antennas (Barrile et. al. 2009) for health purposes to the surrounding area.

Beyond the many uses of a GIS in Telecommunications applications, the greatest power of a GIS lies in its ability to spatialize and integrate databases. The capabilities for structured query language (SQL) queries, compounded with geospatial functions, allow users to generate complex relational database solutions to geospatial questions (Lukas, 2007).

While GISs have been used to great success in the wireless industry, their full potential has not yet been reached in the Telecommunications industry as a whole. The major GIS vendors are touting Telecommunications applications and plug-ins for wireless and outside plant design and maintenance. At the same time, major Telecommunications service providers with custom-built legacy databases are being locked into dealing with specific contractors that are familiar with the software (Lukas, 2007).

Use of spatial analysis and 3D analysis of the GIS allows a greater scope in determining the best placement of wireless equipment. Surface visibility which can be determined by

LOS is instrumental in the placement of antennas, transmitters, relayers and other vital equipment in the wireless industry.

## 2.10 Viewshed analysis

A viewshed map outlines areas that cannot be seen from a particular point and is used for multiple purposes. In turn, this technique creates possible visibility surfaces that can be “seen” from that same point.  Viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. The determination of the area visible from a location or locations in the landscape is a process which landscape architects have dealt with for many years (Smardon et al., 1986).

Visibility analysis is a basic terrain analysis capability used in a wide variety of applications, from resource management and urban planning to crime mapping and military operations analysis. It has been used in communication networks. Line-of-sight profiles and masked area plots are limited in their ability to represent the overall visibility surface characteristics of the terrain. Line-of-sight profiles model point-to-point visibility, while viewsheds, model point-to-area visibility. Neither line-of-sight profiles nor viewsheds provide information on the overall visibility characteristics of the terrain surface (Cadwell et.al 2003).

Visibility surfaces were introduced in the mid- 1990s by Ray and Richbourg (Ray, 1994a; Ray, 1994b; Richbourg et. al., 1995a). The focus of their innovative research was on the generation and exploitation of visibility surfaces, but their individual viewshed used to calculate the surfaces were not maintained.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Introduction

The main objective of this study is to determine new suitable sites to optimize placement of base transceiver stations (BTS) using GIS and GPS technologies. This chapter highlights the data used and its sources in developing the set of information in accomplishing the objectives of the study. To achieve this main objective, the following data was used; the first set consists of a digital elevation model (DEM). The second set consists of land cover patterns while the third set consists of two data types namely location of BTS and areas of no signal reception (dead zones). The final set shows the characteristics of the dead zones.

## 3.2 Data used and its sources

### 3.2.1 Topographic maps

Three topographic maps that is Kapsabet Sheet 103/3, North Tinderet Sheet 103/4 and Muhoroni Sheet 117/1 at a scale 1:50,000 were used in the study. These topographic maps were obtained from Survey of Kenya, Nairobi. Area of study was extracted from these maps which were digitized to create the digital database from the topographical maps. The digital database extracted was; contours, roads and the settlements in the area.

### 3.2.2 Remotely Sensed Data

LandSat TM images (Path 170 and 169) and (Row 60 and 60) were used. These images were obtained from Regional Centre for Mapping of Resources for Development in Nairobi (RCMRD).

### 3.2.3 GIS Software used

Several GIS and Remote Sensing softwares were used to accomplish this entire project. These included; ArcGIS 9.3, ArcGIS 10 and ArcView 3.2 were used for GIS analysis and map composition while IDRISI Andes and ERDAS Imagine 9.3 were used for image processing and interpretation.

## 3.3 Data Acquisition

### 3.3.1 Development of a DEM

A DEM was developed from the contours that were extracted from the georeferenced digital 1:50,000 scale topographic map sheets of Kapsabet, Muhoroni and North Tinderet. The elevation of the contours varied from 1340m to 2180m above sea level in Kapsabet map, 1220m to 1740m in Muhoroni map and 1540m to 2520 in North Tinderet map. The contour interval was 20m above sea level (a.s.l.) and Muhoroni area had the lowest points in the study area. DEM development was achieved through several procedures namely; scanning, georeferencing, clipping study area, on-screen digitization of contours and converting digitized contours to grid respectively. Scanning the analogue topographical maps was the first step done so as to convert the data from analogue (hard copy) to digital form that can be used as the base of all other processes involved. The scanned maps were georefenced using existing coordinates for the area. After georeferencing, it was important to ensure that the error involved in georeferencing is minimized. The roots mean square error was 0.00029.  This showed that the process was accurate because the standard error of accuracy is 0.001. The three separate maps were mosaicked to a single map.  Area of interest was clipped out from the mosaicked map using the shapefile of the study area. Figure 3.1 shows the georeferenced and clipped study area from the topographic maps.

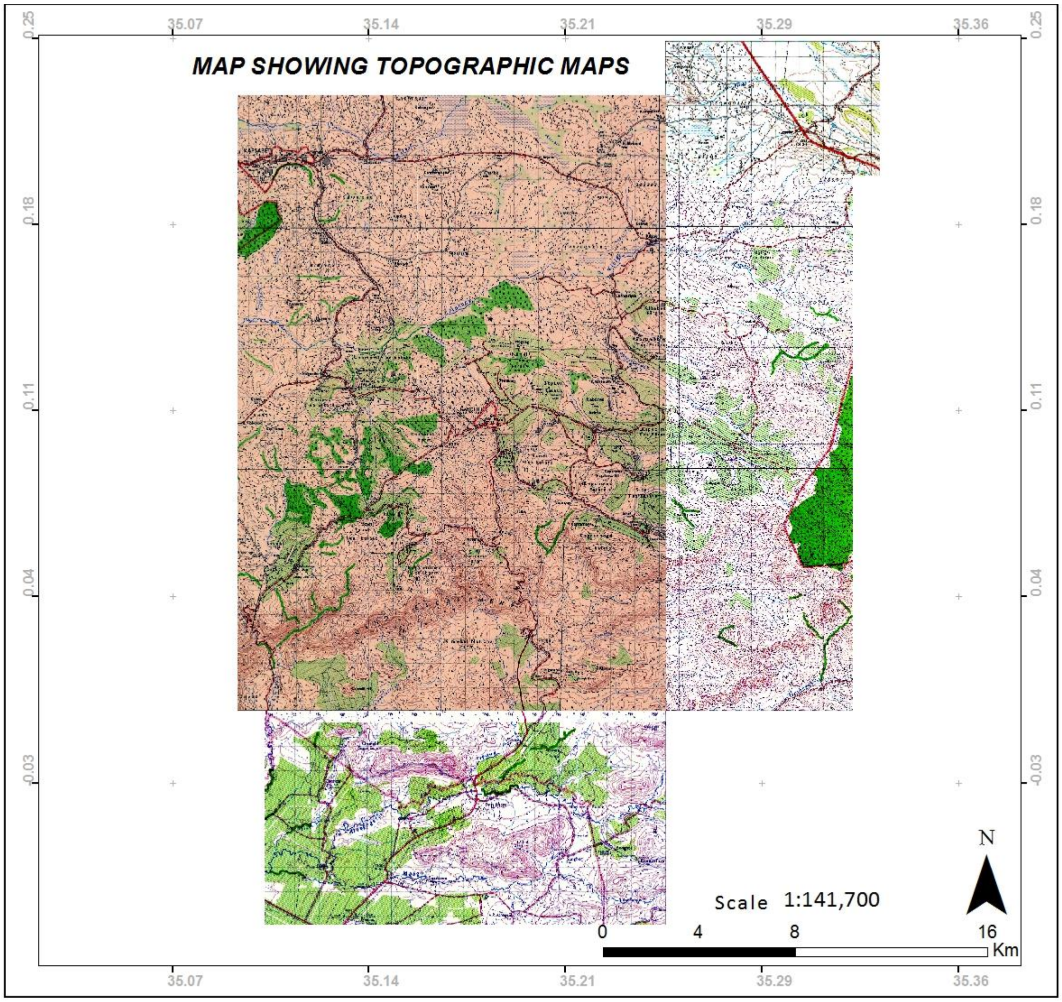



**Fig.3.1** Map showing topographic maps of the study area. (Source: Author, 2010 )

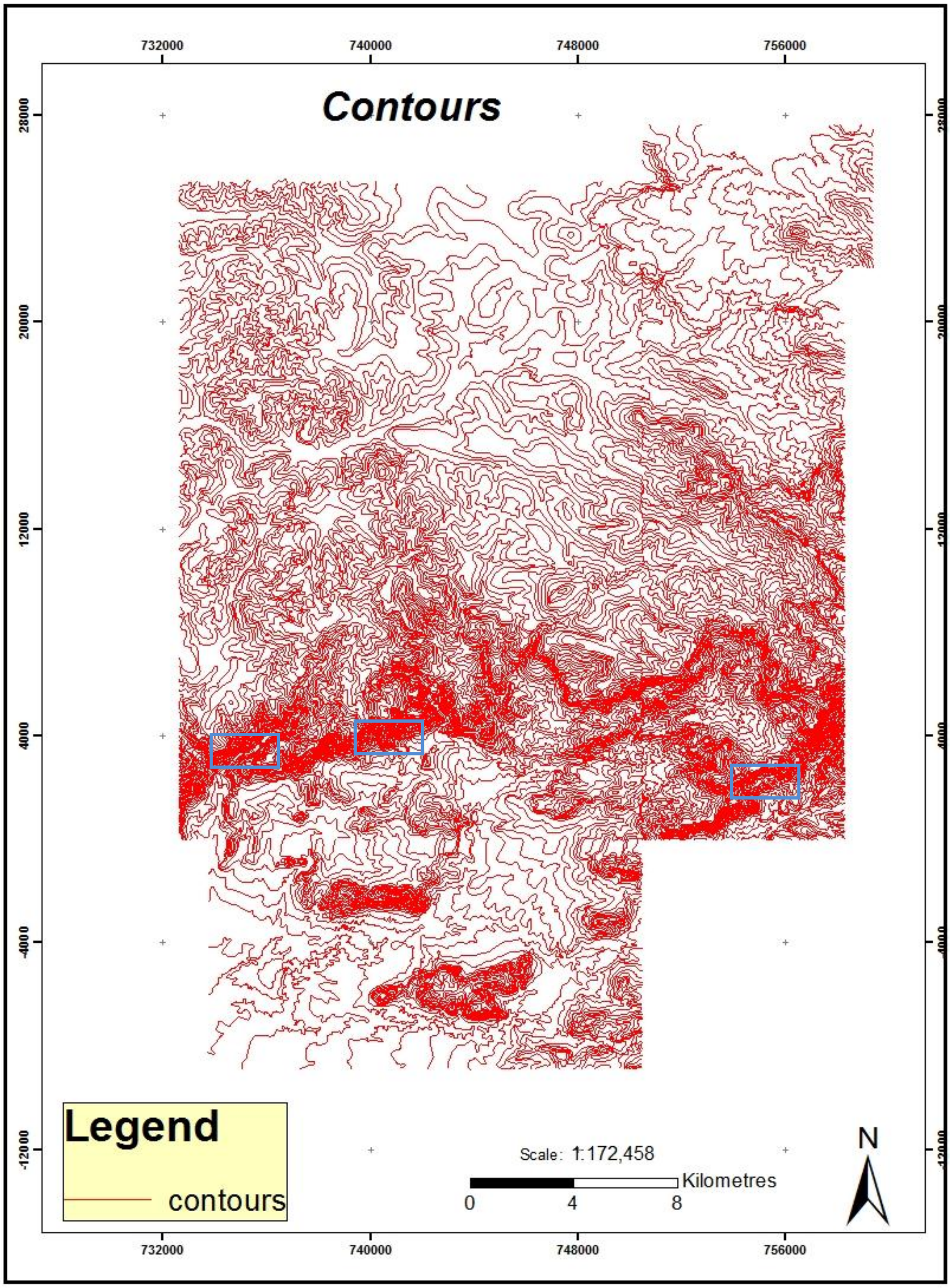



**Fig.3.2** Digitized contours. (Source: Author, 2010 )

The digitized data from the contours and the study area boundary was required in order to obtain a digital elevation model. The digitized contours were projected to GCS_WGS_1984_ UTM_Zone_36N so as to overlay with the other maps which were overlaid with it. Digital Elevation Model was generated from the digitized contours. The area on the map with deep red falls in Nandi escarpment.

### 3.3.2 Land cover patterns

LandSat TM imagery (P 170 and 169) and (R 60 and 60) were classified using supervised classification since the study area lies in those two images. The images obtained from RCMRD were processed to correct for geometric errors. The images were in single bands and the band combination that was used was false color (4, 3, 2) to create a layerstack. It was preffered combination because forests will be depicted clearly. The layerstack images were mosaicked to create a continuous surface of features. The mosaicked images were stretched to enhancement visualization of the features. Training areas were created and the study required two classes for forested and non forested area. All other land uses in the area were given non forest codes while forested areas were given forest code and supervised classification was performed. Several classes of non forest were generated in the first round of supervised classification. The classes were merged to form one class of non forested area. The map is shown in Fig. 4.6.

### 3.3.3 Dead Zones and Base Transceiver Station (BTS)

Points of existing mobile antennas (BTS) were picked using a hand held Global Positioning System (GPS) in a ground survey conducted in the area. These points were located in Nandi Hills, Kapsabet town, Lessos and Songhor. In the analysis the points were used as the observation points. The BTS points were saved as text delimited in

Microsoft excel and added to ArcView 3.2 as a table. The events of the table wee added from the view menu icon.

Developed DEM was used to create Triangulated Irregular Network (TIN) from theme menu in ArcView 3.2. The degree of accuracy was specified with the Z- tolerance value. Existing BTS points were overlaid with the generated TIN to create visibility maps that would show the dead zones as well as the zones with mobile network coverage.

A visibility map was created by selecting viewsheds calculations from the surface menu. Viewshed calculation takes some time, depending on the number of observation points, the spatial extent of the surface elevation theme and the cell size of the output grid. By default the visibility grids were symbolized by red (non visible) and green (visible areas). Non visible in the visibility map showed the dead zones while the visible showed the live areas with the existing antennas. The table for the visibility map was opened by activating the view and then opening the theme table icon. The visibility map generated was also displayed in 3D scene for visualization.

Through a ground survey in the area, dead zone coordinates were picked using a GPS and were also converted to shapefiles and overlaid to the generated maps.

### 3.3.4 Slope

The contours were exported to ArcGIS 9.2 and analysed to create a DEM. This DEM was used in creating the slope map of the area in degrees. 3D Analyst in ArcGIS was activated and surface Analysis tool selected. From surface analysis, slope was selected. Slopes in degrees were then formed using the slope module.

DEM developed was also used in creating cross section of the area using the observation of the existing antennas. Interpolation line was used in drawing lines through the observation points in sets of three to develop three different profile graphs by clicking on create profile graphs.

### 3.3.5 GIS modeling

This is a tool which was used in generating the suitable areas for BTS location in the area. The layers (products) developed earlier were used in spatial analysis to calculate suitable area. These layers are; forest, visibility maps, Roads, BTS and settlements. The study required two classes for Dead or live zones. Therefore all these layers were reclassified to 1 (suitable) and 0 (not suitable) areas. After reclassifying the parameters separately, the reclassified data was used to calculate the suitable sites using raster calculator where by a mathematical formular was used (reclassified forest * reclassified visibility map * reclassified BTS * reclassified roads * reclassified settlements) to calculate the suitable sites. A final product of the suitable area was generated with 1 being the suitable sites where all the parameters had value 1. It was in polygon form and out of the polygon, centroids were extracted as point shapefiles and X, Y coordinates were added to the points to give them geographic coordinates using ArcMap 10.

### 3.3.6 Map Composition

Maps were generated from the outputs throughout the analysis process. ArcMap 9.3 was used to prepare the map output. North arrow, scale, legend, title, grid and scale bar were added to the maps. After map composition, the map was exported as a JPEG because of its good resolution when used in a word document.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter presents results of the GIS analysis and their discussions.

## 4.2 Digital Elevation Model (DEM) and Triangulated Irregular Network (TIN)

DEM was developed from contours as discussed in chapter three. This DEM was used as the base for all other analysis. The highest value in the DEM was 2417 m shown in the pink colour on the north east part and partly northern side generally. North Tinderet side of the study area lies in the highest parts in altitude and some part of the Kapsabet areas. Figure 4.1 and figure 4.2 show the DEM and Triangulated Irregular Network respectively. Southern part is in Muhoroni were the altitude was lowest.

Fig. 4.1 depicts that the elevation is decreasing towards south-west part of the area. The lowest area is towards the equator and has a value of 1220m a.s.l in the lower part of the DEM with an higher point of 2520m a.s.l. of the contours used to generate the DEM in the eastern part of the DEM. The Nandi escarpment lie in the dark green colour between 1654m to 1797m a.

Figure 4.2 shows a TIN layer. It presents the area in 3D. It was generated from the grid because it allows it to be zoomed in the 3-D scenes and can be edited easily. The degree of accuracy specified in generating this TIN in the Z- tolerance was 30m. The cells maximum difference seen in the TIN was defined by the 30m Z- tolerence which were calculated by the 3D Analyst in ArcView 3.2.

TINs show good capabilities to adapt to terrain features since they can deal with irregularly distributed data sets and may include surface- specific points and lines (Floriani and Magillo, 1994). The TIN was overlaid with the existing base transceiver station points (BTS) collected from the field.

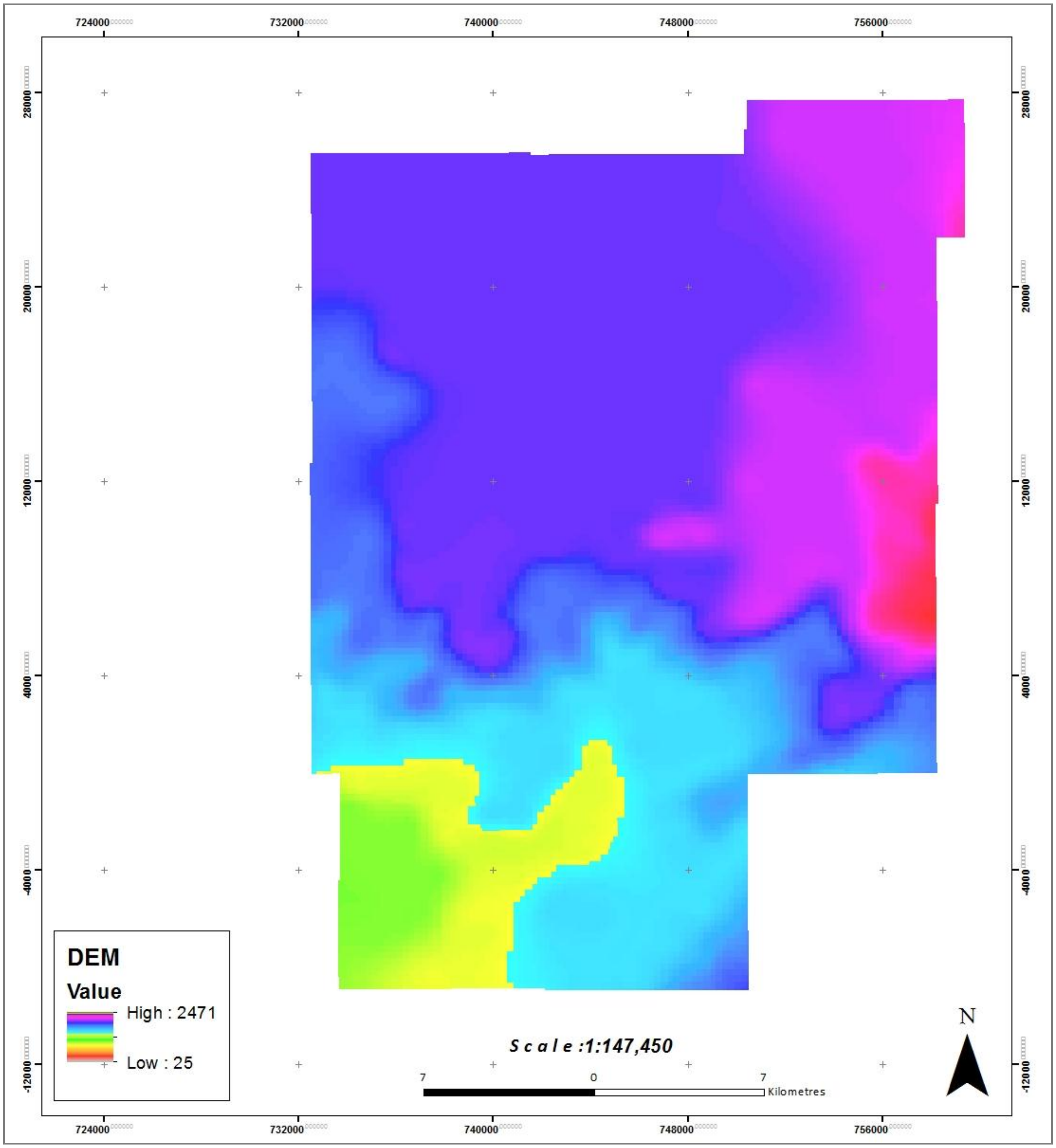



**Fig.4.1 Digital Elevation Model of the study area.** (Source: Author, 2010 )

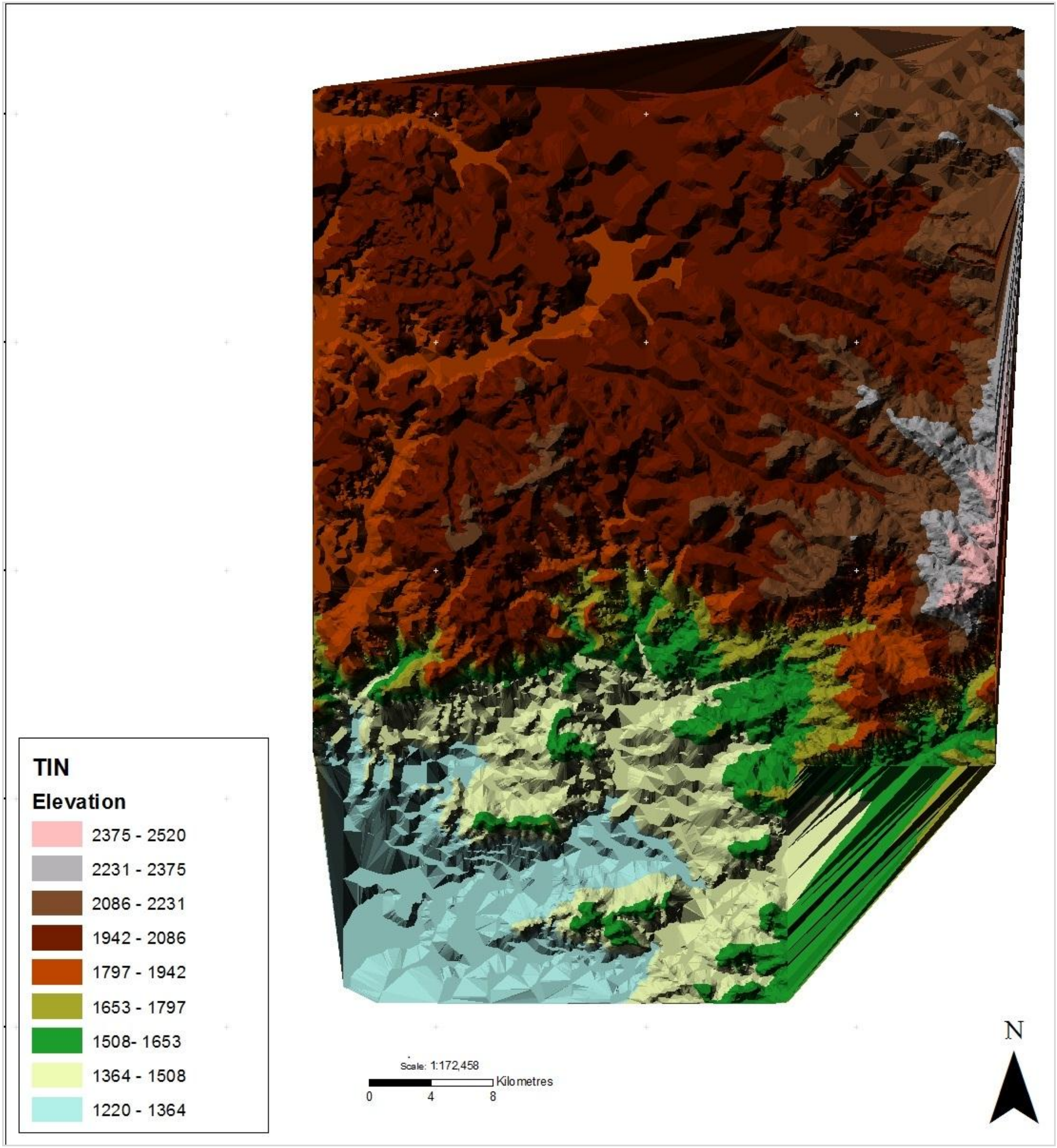



**Fig.4.2 Triangulated Irrengular Network.** (Source: Author, 2010 )

Fig 4.2 was overlaid with the existing Base Transceiver Stations (BTS) to generate visibility maps.

### 4.2 Visibility maps

The figures 4-3, 4-4 and 4-5 below show the visibility maps that were developed from the TIN. From the observation points collected for Safaricom and Orange, a visibility map was generated from each and finally the points were combined to develop a joined visibility map from the observation points for comparison. From figure 4-3 below, Orange Company had placed its Base Transceiver Stations in Kapsabet and North Tinderet upper part of area. This therefore supplied network signals for mobile in the northern part of the study area.

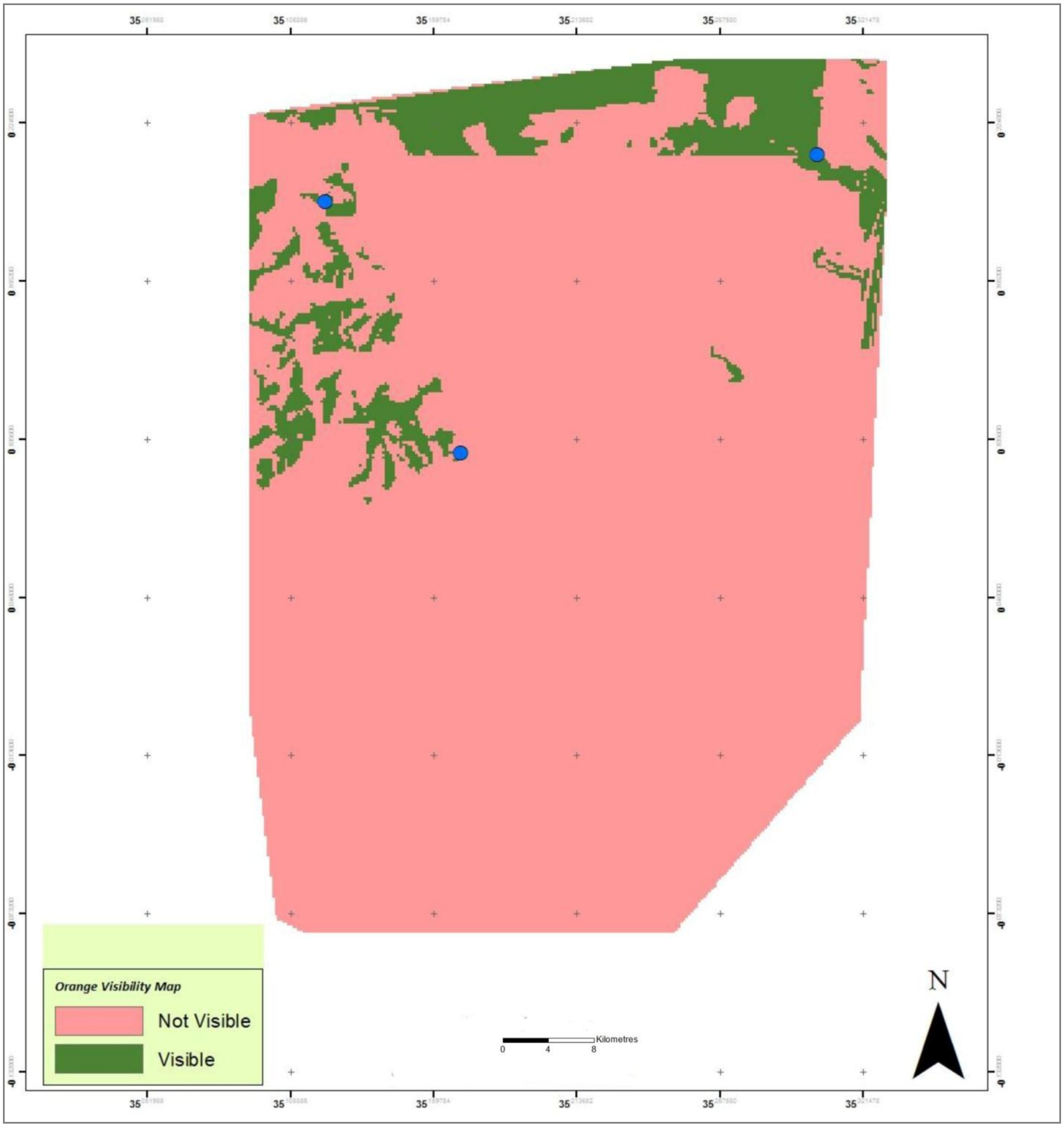



**Fig.4.3 Visibility map of orange antennas.** (Source: Author 2012 )

This fig. 4.3 shows that most of the area is a dead zone because its covered by the red colour which shows that the areas are not visible from the antennas. The dead zones have been caused by lack of intervisibility among the antennas due to the topography of the area. From the map, the southward part of the part which includes the equator and the major

road to Kisumu city is covered by dead zones. The points used as the obervation points area for orange visibility were 3, 4 for Safaricom and 7 for all the antenna visibility.

0 shows the cell which can not be seen from any of the three observation points while 1and2 shows cells which can be seen by either 1 or 2 observation point. 3 shows that only few cells can seen from all the three observation points. This table 4-1 shows that the number of cells visible from the three antennas is 673 as the value decreases with increase in number of antennas. This leaves area which are served by non of the antennas with the highest value.

**Table 4.1 shows the visibility for Safaricom antennas from ArcView attribute table**

| **No. of antennas** | **cells not visible** |
|---|---|
| 0 | 22296 |
| 1 | 9195 |
| 2 | 2128 |
| 3 | 673 |
| 4 | 100 |

This table 4.1 was extracted from the Safaricom visibility map. There were four existing antennas which also revealed a tendancy of alot of dead zones in the area. This is shown in figure 4.4 below.

**Table 4.2 Visibility attribute table for all antennas**

| No. of antennas | cells not visible |
|---|---|
| 0 | 20791 |
| 1 | 5458 |
| 2 | 2365 |
| 3 | 3788 |
| 4 | 915 |
| 5 | 532 |
| 6 | 426 |
| 7 | 18 |

With the all the observation points only 18 cells were visible from all of the points and still with so many dead zones. Fig. 4.4 shows the visibility map developed from the Safaricom antennas. Most of the areas from the map had dead zones concentrating on the southern part of the study area. North-east part of the area was visible which showed that the people received mobile signals for their communication purposes. Comparing it with the first visibility map of the Orange Company, Safaricom serves a larger area. This is because of the number of antennas available.

Some areas had dead zones despite the fact that there was an BTS in the vicinity. This was attributed by the topography of the area showing that are factors which were not considered prior to placement of the BTS.

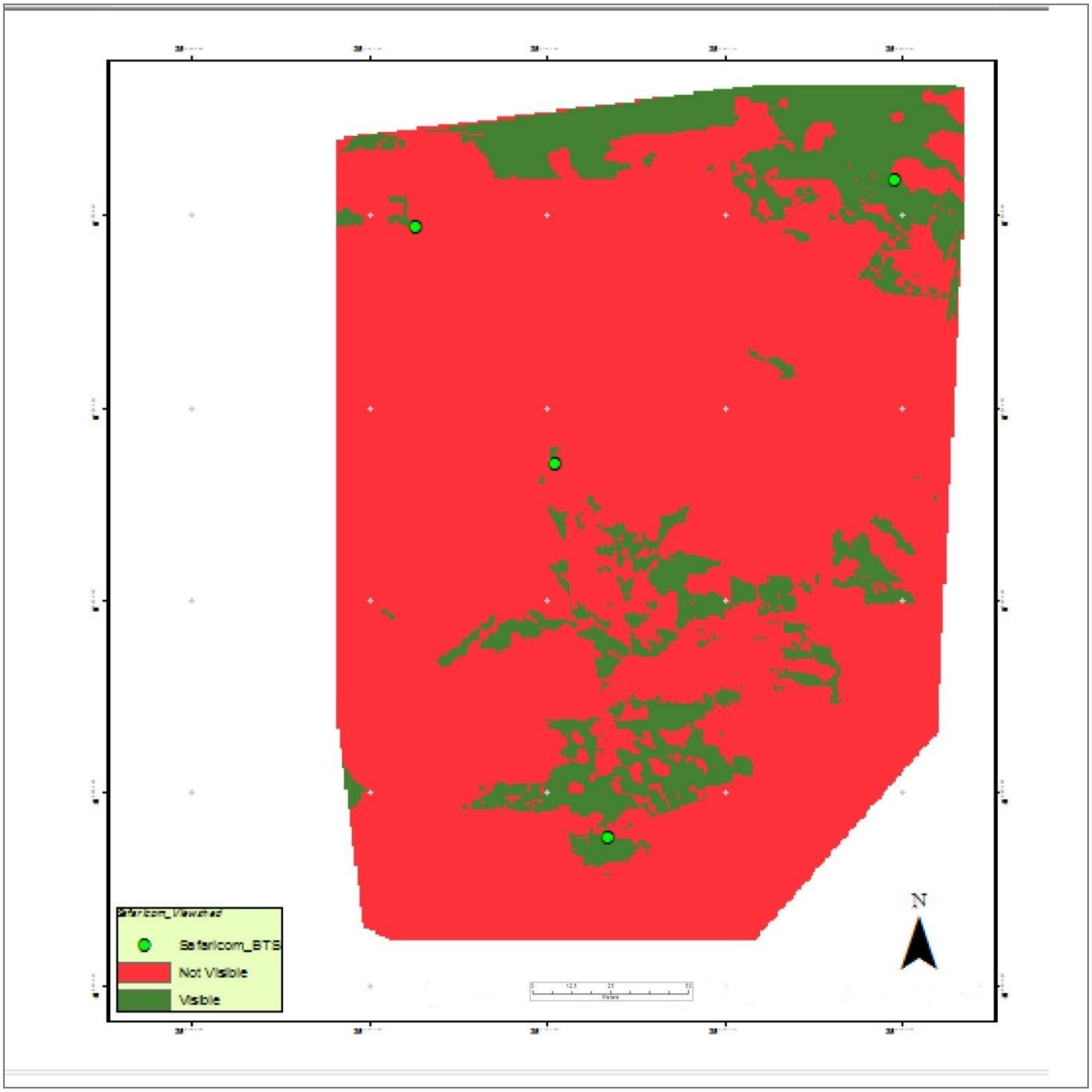



**Fig. 4.4 Visibility map of Safaricom antennas.** (Source: Author, 2012 )


**Fig. 4.5 Visibility map for all antennas.** (Source: Author, 2012 )

A combined visibility map was prepared from all the antennas present in the area. Figure 4-5 was generated which shows at least reduced dead zones in the north-east part of the map. Most dead zones are shown in the north, south-east and partly in the south -west. This indicates that topography of an area influences greatly the transceiver of mobile telephone signals. GIS and GPS techniques proved the suitable option for determining intervisibility in the study.

## 4-3 Image analysis

The images acquired were processed and from them the study area was subset. These images were then classified into forest and non forest areas since this was required to see how the forest height affects the intervisibility of objects.

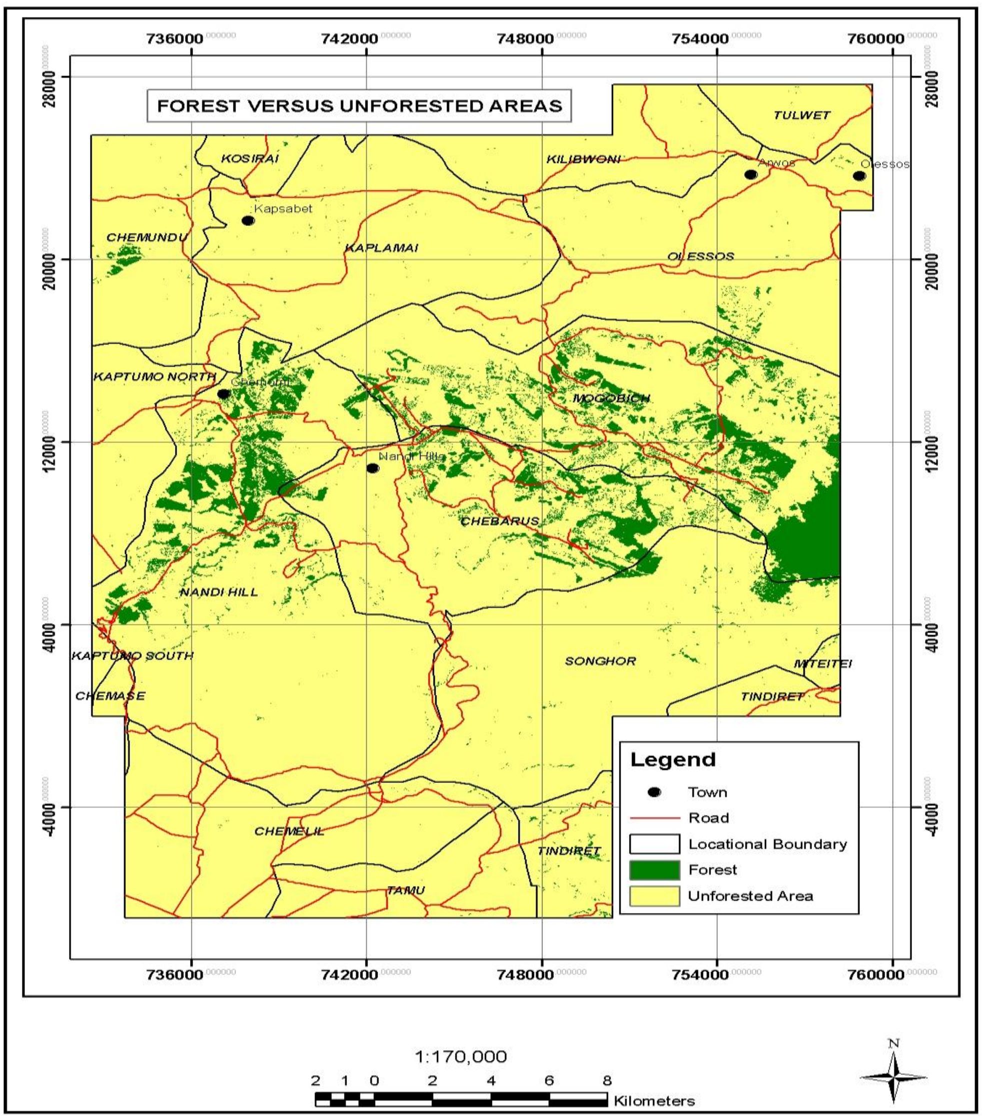



**Fig. 4.6 Classified image into forest and unforested area.** (Source: Author, 2012 )

This figure was generated from supervised classification of the images in Idrisi Andes. From the image, forested area is represented by green and it lies in the middle of the study area along  Nandi hills and North Tinderet forest while the unforested area is represented by the sun colour and occupies most of the area. Forested area was 56.945 $km^2$ while for unforested area was 765.73 $km^2$. The height of the trees in the area was in the range of 15-20 metres. Road network in the area was both bound and loose weather roads which adequately serve the people in the area and even passages along the Kisumu highway.

## 4-4 Slope map

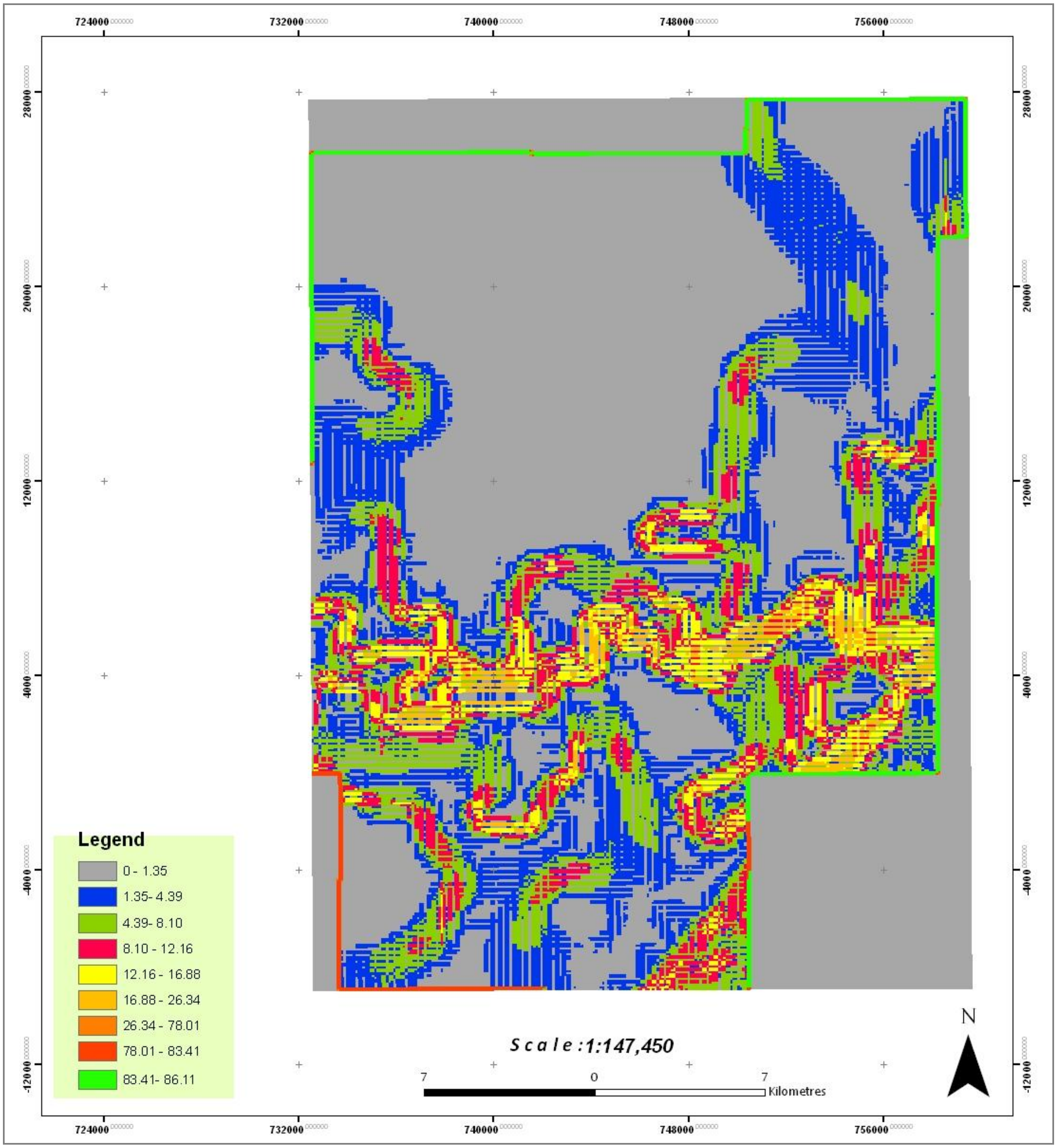


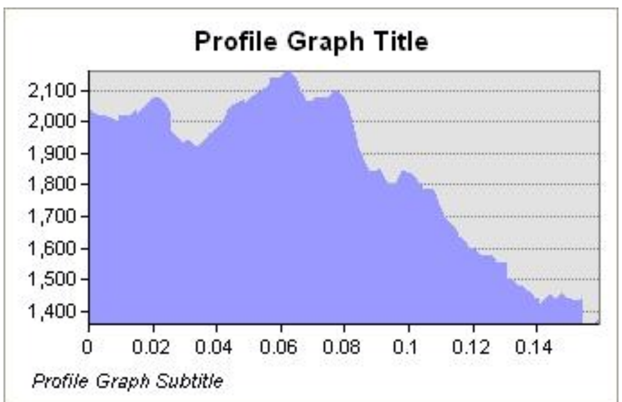

**Fig.4.7 Slope in degrees of the study area.** (Source: Author, 2011 )

Most of the area has a slope between 0-86.11 degrees and was the cause of obstruction of the transceiver of mobile signals in the area. There were 9 classes generated and the dominating class was the range of 0-1.35$^0$ which shows that most area is in the lowest part whereby, the existing BTS will not supply signals those areas because of various obstructions from the higher grounds. As the degrees increased, there was decrease in the slope. Slope is a major characteristic in optimizing antenna location in area and was incorporated in determining the best sites for new antennas.

**a)** Cross- section using antennas at Kapsabet, b)Cross- section using antennas at Kapsabet,

Nandi hills and Songhor

Nandi Hills and Lessos



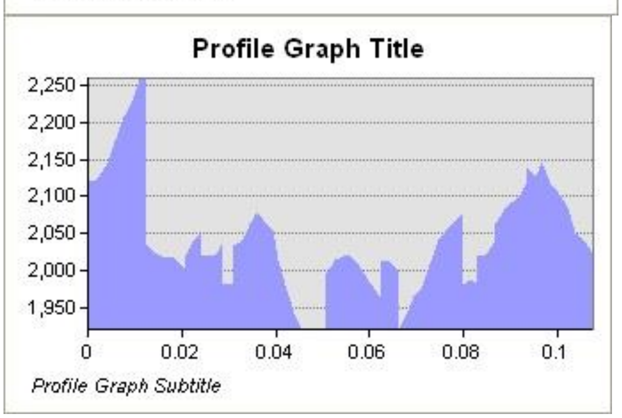



**Fig. 4.8 and 4.9; Cross- section using antennas at Kapsabet, Nandi Hills and Lessos and at Kapsabet, Nandi Hills and Songhor respectively.** (Source: Author, 2011 )

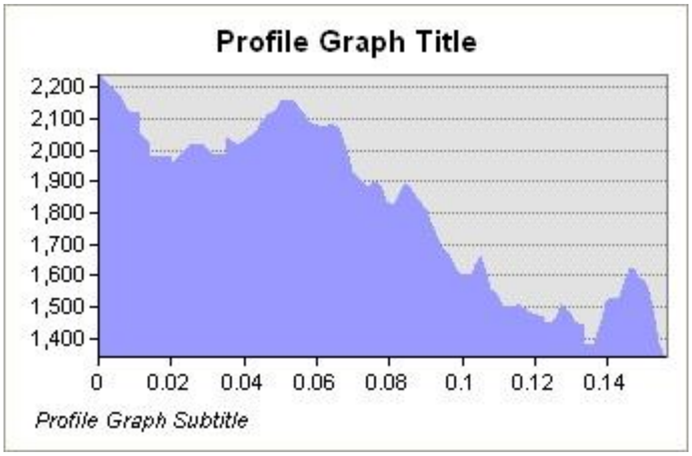



**Fig. 4.10 Cross- section using antennas at Nandi Hills, Songhor and Lessos.** (Source: Author, 2011 )

In all the graph, fig 4.8, Y axis is the altitude in meters while the X axis is the interval in developing the cross- section. The area lies in a visible area and its where most the area is covered by network due to the Line of Site (LOS) involved. The heighest point was 2100m while the lowest was 1400m.

In fig. 4.9 there were intervisible areas in the cross section. These were the areas that were experiencing network problems (dead zones). Though there was a heighest point where the observation point could be placed to allow visibility and lowest point to cover the escarpment the current observation points lacked this information.

In the extreme right and mid- right of the graph in fig 4.10 are areas in the south- east part of the study area which was also experiencing high network problems. The area was intervisible from the observation points of the above antenna location and therefore depicted more dead zones.

## 4.5 Reclassified antennas, viewshed and population densities

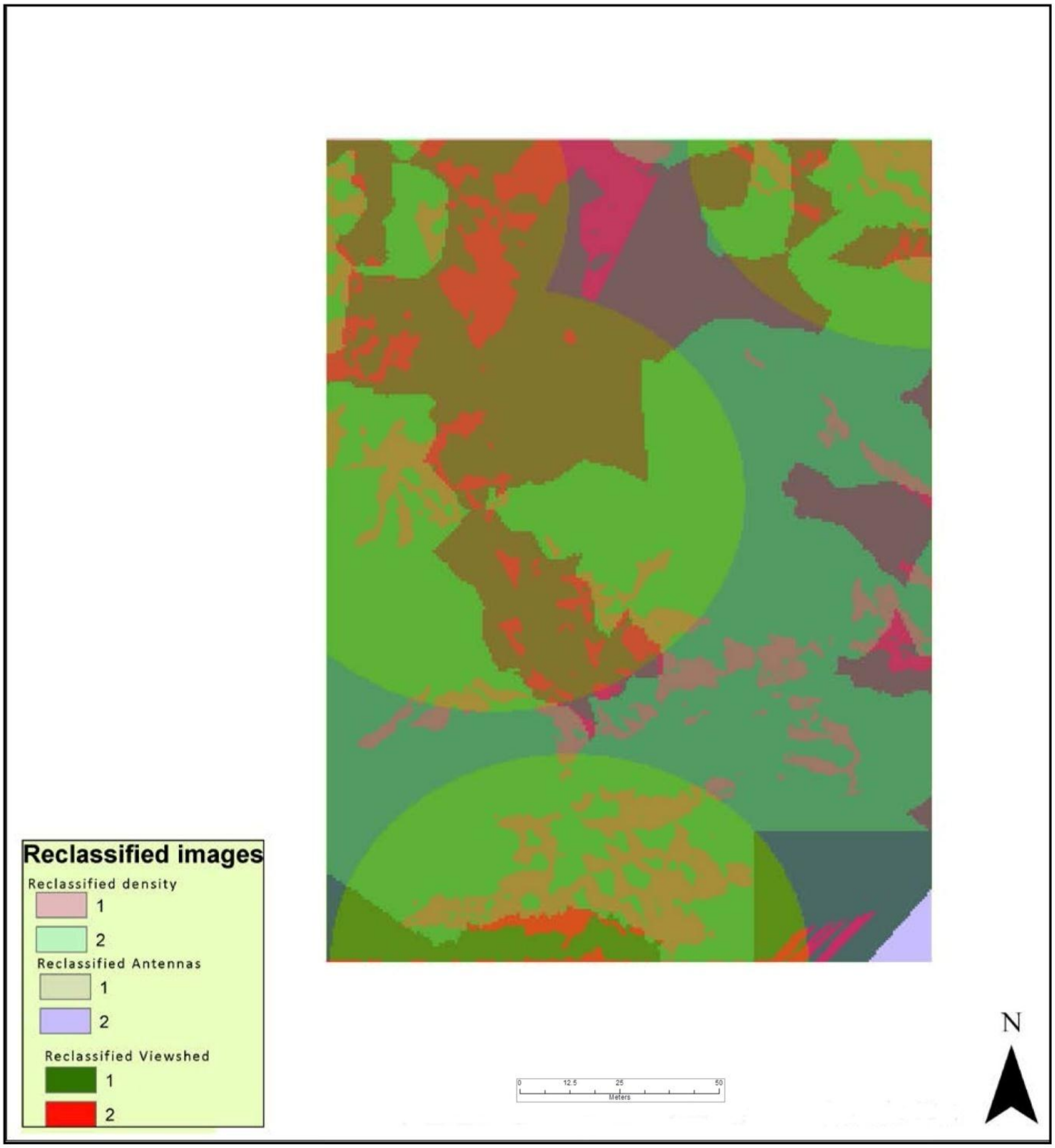



**Fig. 4.11 Reclassified antennas, viewshed and population densities.** (Source: Author, 2012 )

This fig. 4-7 shows the reclassified maps of antennas, viewshed and population densities. Antennas were classified from the generated straight line map shown in Appendix 5. This was done to give the maps the same classification which was generated from the viewshed. Reclassification was done because the available maps had not similar classes and the interpreter wanted maps which are similar because will aid in determining the suitable sites for BTS location. Therefore antenna, viewshed and population density suitability layer was calculated using reclass in spatial analysis. The ranges necessary for the reclassification were 1 and 2. Therefore all the other data used was reclassified so as to give meaningful analysis. 1 show the favored areas in all the three reclassifications and therefore the areas where the three had 1 was most suitable and considered during the raster calculation which was performed using this map.

**4-6 Suitable site maps**

**a) Raster calculation map for suitable sites**

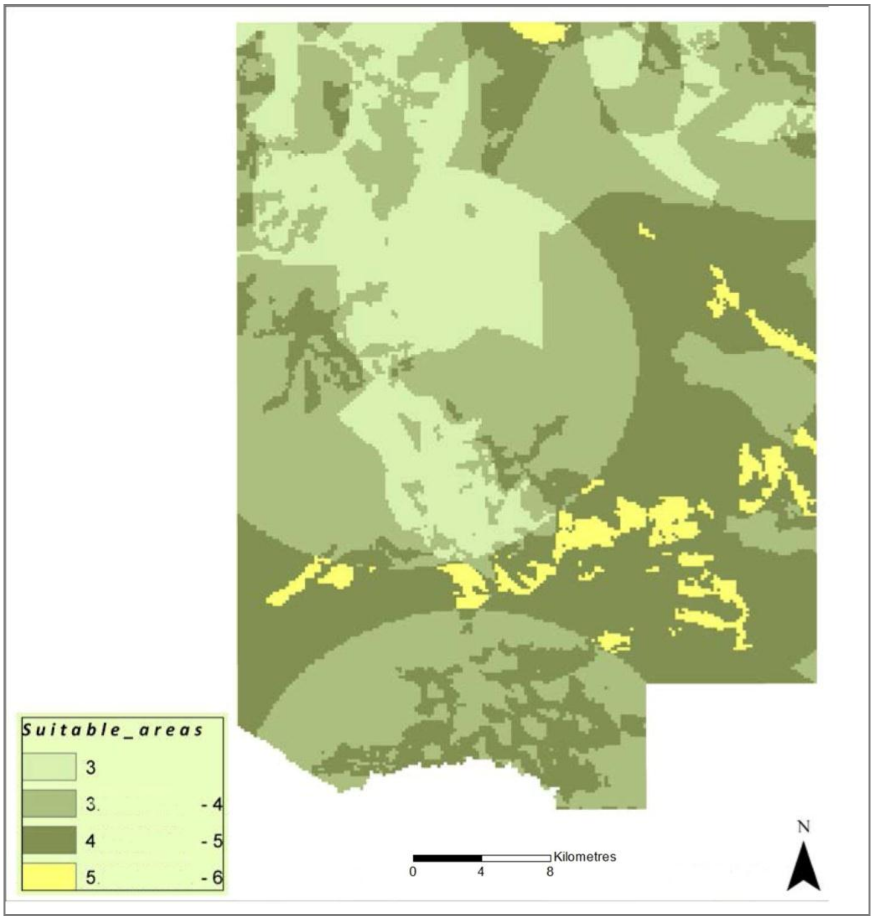



**Fig. 4.12 Raster calculation map for suitable sites.** (Source: Author, 2012 )

**b) Suitable areas for antenna location**

**Table 4.3 Suitable sites for antenna location**

| FID_ | **Proposed Point** | **Longitude** | **Latitude** |
|---|---|---|---|
| 1 | point 1 | 35.215551 | 0.210646 |
| 2 | point 2 | 35.25011 | 0.145302 |
| 3 | point 3 | 35.293168 | 0.110311 |
| 4 | point 4 | 35.301344 | 0.078153 |
| 5 | point 5 | 35.291206 | 0.071286 |
| 6 | point 6 | 35.269187 | 0.056461 |
| 7 | point 7 | 35.265371 | 0.039456 |
| 8 | point 8 | 35.281178 | 0.016019 |

| | | | |
|---|---|---|---|
| 9 | point 9 | 35.258831 | 0.016346 |
| 10 | point 10 | 35.23812 | 0.014275 |
| 11 | point 11 | 35.231252 | 0.034005 |
| 12 | point 12 | 35.233214 | 0.064527 |
| 13 | point 13 | 35.228745 | 0.048503 |
| 14 | point 14 | 35.192663 | 0.030844 |
| 15 | point 15 | 35.137581 | 0.032697 |
| 16 | point 16 | 35.237067 | 0.178696 |
| 17 | point 17 | 35.25451 | -0.022213 |
| 18 | point 18 | 35.124661 | 0.102467 |
| 19 | point 19 | 35.135643 | 0.187094 |

This table 4-3 was generated from the above suitable sites through digitizing the points in the area with the sun colour in the map. A point was placed at the center of the area and eventually their coordinates were added to give the data geographical meaning. The suitable sites are many from which the service providers can decide on which point with the terms of the accessibility to the points. These points fall in different areas as shown below in fig.4-13 below shown in TIN background. These points will reduce dead zones in the area.

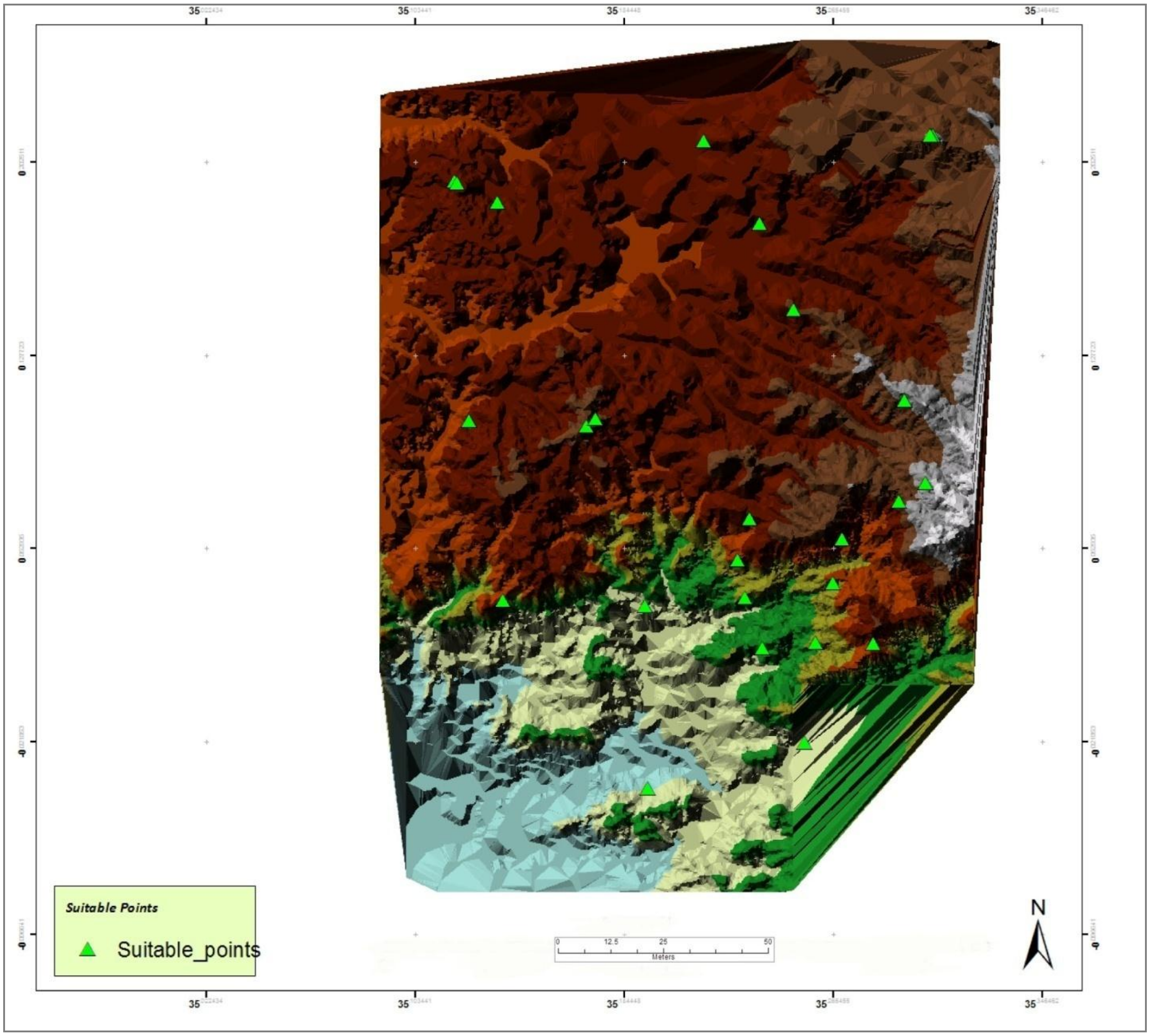



**Fig. 4.13 Suitable points for consideration in locating antennas.** (Source: Author, 2013 )

**c) Reclassified interpolated suitable sites**

The suitable points shown in fig 4.13 were reclassified to show the similarity of the points in the area. From fig 4.14, 1 shows the lowest area in the map while 10 showed the highest point. At least a number of BTS can be selected in the area with 1 being in the lowest and requires to be served with mobile signals.

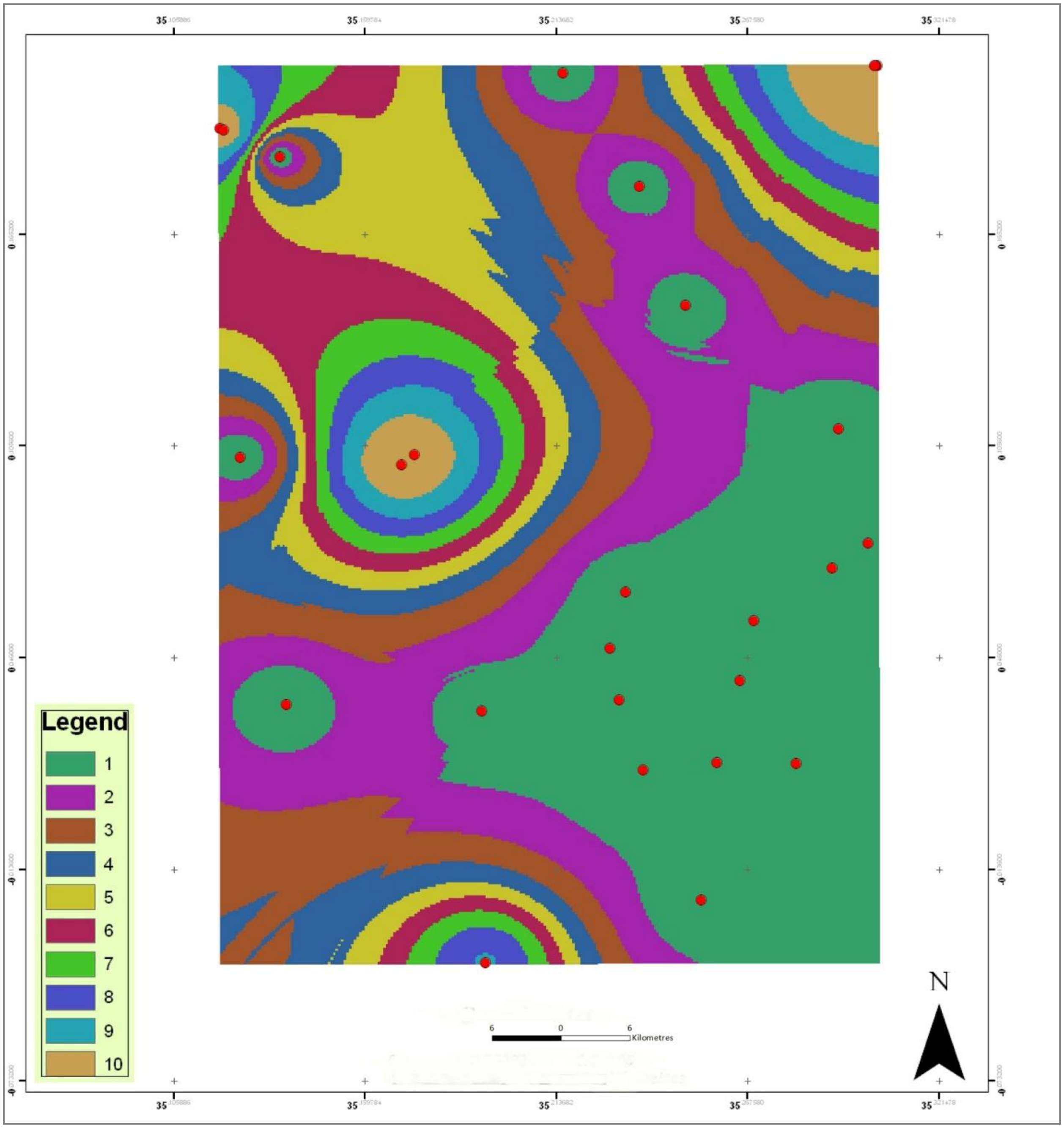



**Fig. 4.14 Reclassified interpolated suitable sites.** (Source: Author, 2013 )

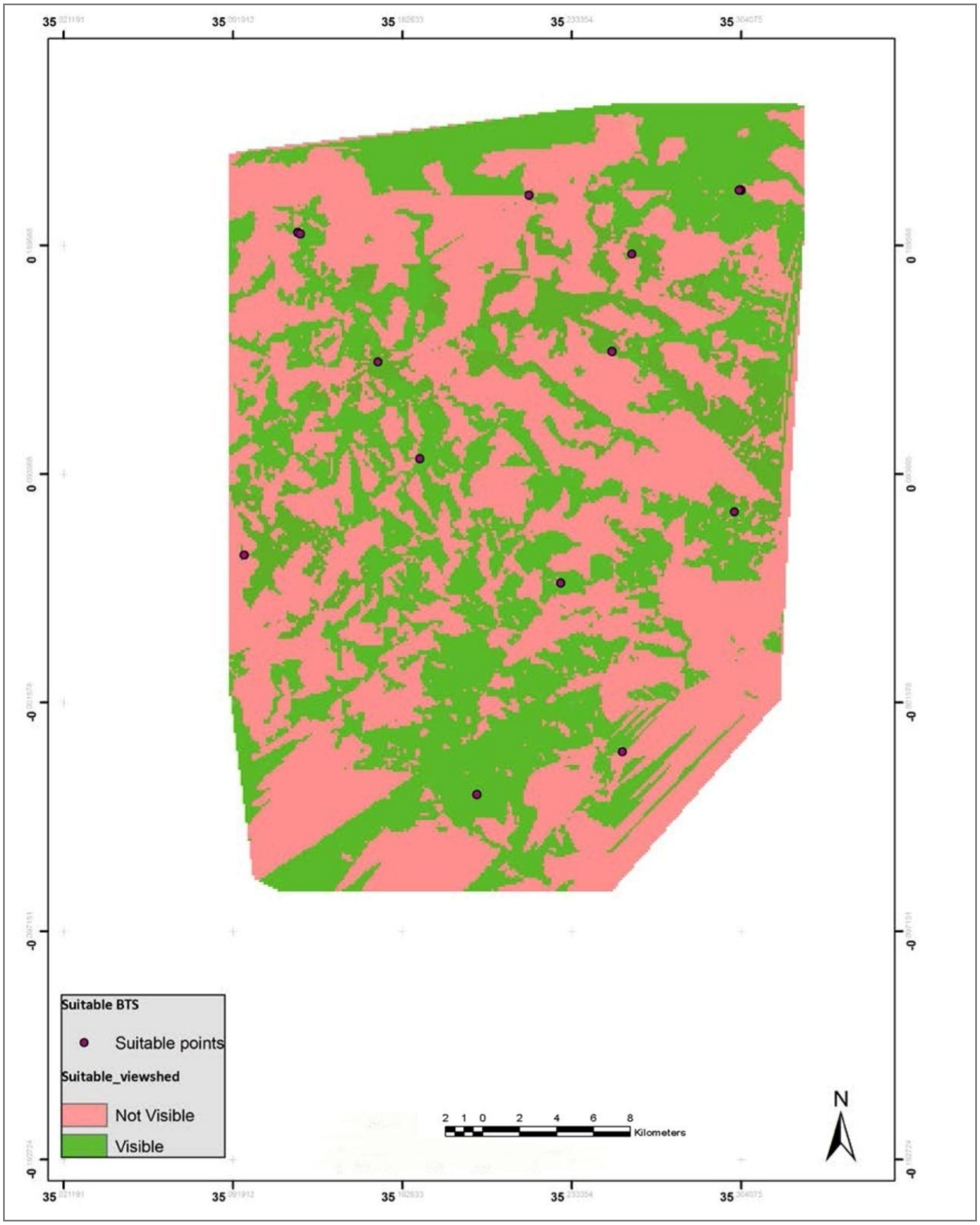



**Fig. 4.15 Visibility map of the selected and most suitable BTS.** (Source: Author, 2013
)

Fig. 4.15 shows a visibility map that was generated from twelve BTS which from various analysis carried out, the combination of these points provided better mobile signals to curb the dead zones in the area and hence can be used. This map shows that mobile signals transceiver was even distributed in all the areas making the area which initially didnt have signals fully or partially covered. The areas in green on the map are places covered with mobile signals.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

GIS and GPS techniques were appropriate means of optimizing new base transceiver stations in this study. The procedure was less time consuming and the results were accurate considering the prior methods used in determining intervisibility of an area. Using a GIS 3-d model or a communication viewshed (commshed), Telecommunications companies are able to test many different viewpoints to find the optimal tower location without actually going in the field. This provides an advantage from a transmitting and customer base standpoint. GIS plays a major role in Telecommunication in order for Kenya to achieve millennium development goals in the year 2015 in diversifying area for network coverage should adopt this method.

Visibility surfaces provided insights into intervisibility characteristics of the terrain that are not available from line-of-sight or masked area plots. This study therefore was an adequate example to show the importance of GIS and GPS in determining suitable areas for placing new antennas.

Nineteen different areas were identified in the study area which could be considered in placing new antennas in any selected area to optimize antenna location for efficient mobile signal transceiver. Out of these points, seven were preferable and visibility map was generated. These areas had the highest population and were in visible points within the distance of antenna location.

With the areas suitable for new antenna placement sited, this study can be utilized by all the service providers in Kenya to deal away with dead zones in the areas. This can be in collaboration with Communication Commission of Kenya. The network providers can be incorporated in placing new and few antennas by intersecting in the same base transceiver station (BTS) all the networks available. This will reduce the number of BTS hence environment will not be compromised. With diversified network coverage, there will be more subscribers and in turn more profit generated from scratch cards and all other services provided by mobile providers e.g. money transfer. Due to high competition, subscribers will be able to enjoy lower rates of calling and still profit attained by the mobile providers.

## 5.2 Recommendations

From the study, recommendations given below have been suggested which can apply in Nandi East County as well as other parts of the country with dead zones.

1. New suitable areas for placing BTS can be determined using GIS to reduce dead zones in the area and other parts of Kenya.
2. GIS can be used in diversifying the network coverage by placing more antennas in different areas of the country so as to become ICT experts and improve on dissemination

of public information. This paper can be used as a base for dealing with dead zones in the Country.

3. All mobile service providers should work in harmony in determining new areas for BTS so as to cater for all factors that are considered in selecting suitable sites.

4. Visibility analysis is recommended in future to determine suitable sites for placement of new BTS in Kenya. It is easy to select suitable areas using the GIS software.

## REFERENCES

Barr, D. R., Mansager, B., Fox, W.P. and Riddle, T. (2008) *Topological Terrain Map Resolution: Intervisibility, Crest, and Military Crest.*

bbs.100math.com accessed 11 July 2009

Bissell, C.C. and Chapman, D.A. (1997) *Digital signal transceiver*; Cambridge University Press: United Kingdom

Barrile V., Armocida G. and Bilotta, G. (2009): *GIS supporting the Plan of BTS (Base Transceiver Stations) for mobile network in urban context:* ITALY

Cadwell D.R., Miniter M.J., Dowers S., and Gittings B.M. 2003. Analysis and visualization of visibility surfaces; proceedings of the 7th international conference on Geocomputation accessed 21 July 2009

Dowers S. and Mineter, M., 2004. *Enhancing Intervisibility Analyses using Multi-Computing Techniques;* Scotland

Duan, B.Y., Wang, C. S. And Zhang, F.S. 2004. *On Multidisciplinary Optimization of Antenna Structures.* Albany: New York

Fisher, P. (1993). Algorithm and Implementation Uncertainty in Viewshed Analysis: *International Journal of Information Science*, vol. 7, no. 4, 331-347.

Floriani L.D. and Magillo P., 1994. Visibility algorithms on triangulated digital terrain models.

*International Journal **of** GIS,* 8(1):13-41.

Huxhold, W.E. and Levinson A.G., 1995. *Managing Geographic Information system projects*. Oxford university press: Newyork.

Inose H. 1981. *An Introduction to Digital Intergrated Communication System*: University of Tokyo Press; Japan.

ITU (2008b). Asia-Pacific Telecommunication/ICT Indicators 2008. Geneva, ITU.

Jennings, D. J. 1957. *Geological Map of the Kapsabet- Plateau Area.* Rept No. 63. Scale: 1: 125,000.

Jennings, D.J.1964. *Geology of the Kapsabet- Plateau Area.* Rept 63, Geol. Surv. Kenya. Nairobi.

Kay S. and Sly T. 2001. *An application of cumulative viewshed analysis to a medieval archaeological study*: the beacon system of the Isle of Wight; University of Southampton: United kingdom. http://soi.cnr.it/archcalc/indice/PDF12/09Kay.pdf. Accessed 04 Sept 2009

Madry S.andRakos L., 1996. *GIS Geographic Information Systems* http://www.informatics.org/france/gis.html accessed 11 June 2009

Mannin D. H. (2001) *The Validity of Using a Geographic Information System's Viewshed Function as a Predictor for the Reception of Line-of- Sight Radio Waves.* http://scholar.lib.vt.edu/theses/available/etd-09202001-155212/unrestricted/1etd_dodd_0911.pdf 2001

Möller, B. (2007) *could landscape intervisibility be a suitable criterion for location of wind turbines?* 10th AGILE International Conference on Geographic Information Science Aalborg University: Denmark accessed 11 June 2009

Moller, B. 2008. *Local wind energy as new commons- evidence by quantitative geographical analysis*.iasc2008.glos.ac.uk.accessed 05 Sept 2009

Monkhouse F. J. and Wilkinson H. R. (1991) Maps and diagrams: Their compilation and construction, 3rd Ed.: Methuen: United Kingdom

Ormsby, T. and Alvi, J. (1999) *Extending ArcView GIS*. ESRI Press. USA.

Podobnikar, T. ( ). *Suitable Digital Elevation Model*.

http://www.gisdevelopment.net accessed 28 Sept 2009

Poland, K. L. and Revision, F. ( ), *Digital Signal Transceiver: Advantages and Problems*

Web.ccsu.edu/technology accessed 28 Sept 2009

Sklar, B. (1988) *Digital communications: Fundamental and application.* Prentice-Hall International Editions: USA.

Smardon, R.C., J.F. Palmer, and J.P. Felleman (editors), 1986. *Foundations for Visual Project Analysis*, Wiley and Sons, New York.

Stiles, P.N. 2007. *Intervisibility determination*.

www.freepatentonline.com accessed 28 Sept 2009

Wheatley D., Gillings M. 2000, *Vision, perception and GIS: Developing enriched approaches to the study of archaeological visibility*, in G. LOCK (ed.), *Beyond the Map: Archaeology and Spatial Technologies*, Amsterdam, IOS Press, 1-27.

bestuniversities.info/wheatley-oxford accessed 04 Sept 2009

Li, Zhilin. *Advances in photogrammetry, remote sensing and spatial information sciences: 2008 ISPRS Congress Book*. Boca Raton [etc.: CRC Press, 2008. Print.

# APPENDICES

## Appendix I

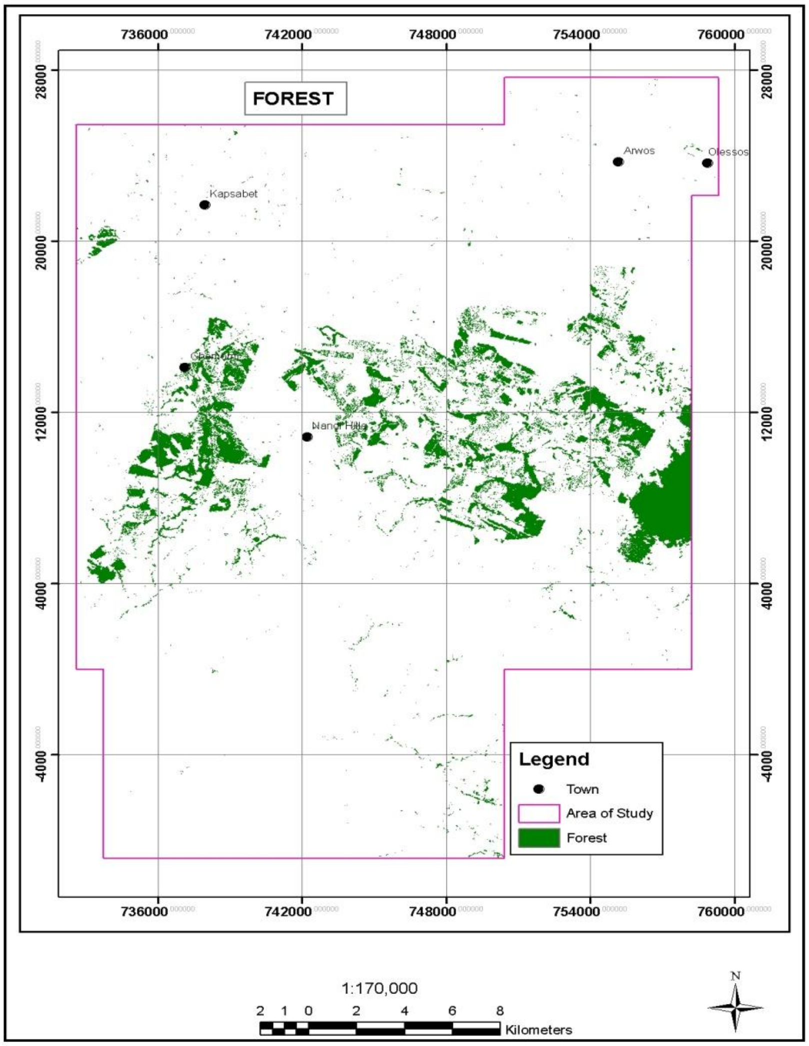



**Fig.i Classified forest area.** (Source: Author, 2010 )

This figure shows the map of the areas which were classified as forest during the classification process and they covered an area of 56.95 km$^2$ and was used in raster calculation to determine if the height of the forest in the area hindered transceiver of mobile signals.

**Appendix II**

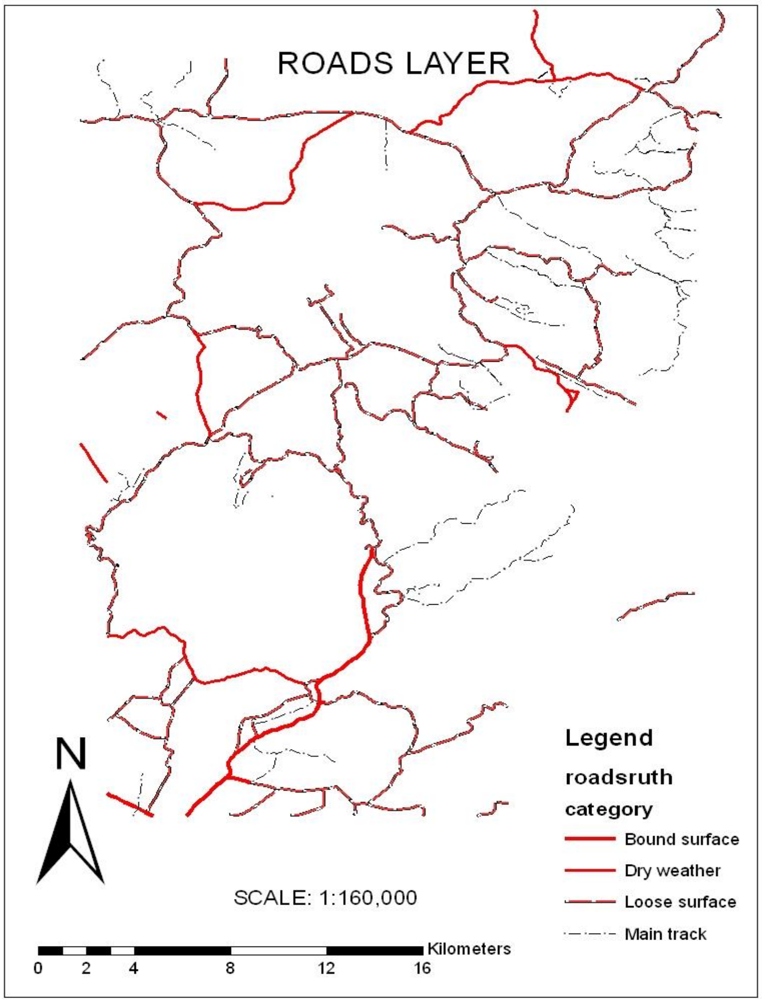



**Fig.ii Roads layer.** (Source: Author, 2010 )

This is a map which was generated by digitizing the roads in categories. This was incorporated with the final map of the best areas for placement of base transceiver and also guided during verification and validation process of the areas generated as visible

Most stationsand not visible in the visibility maps genarated. of the area was covered by loose surface and clearly show that the transport network was efficient in the north-eastern part.

**Appendix III**

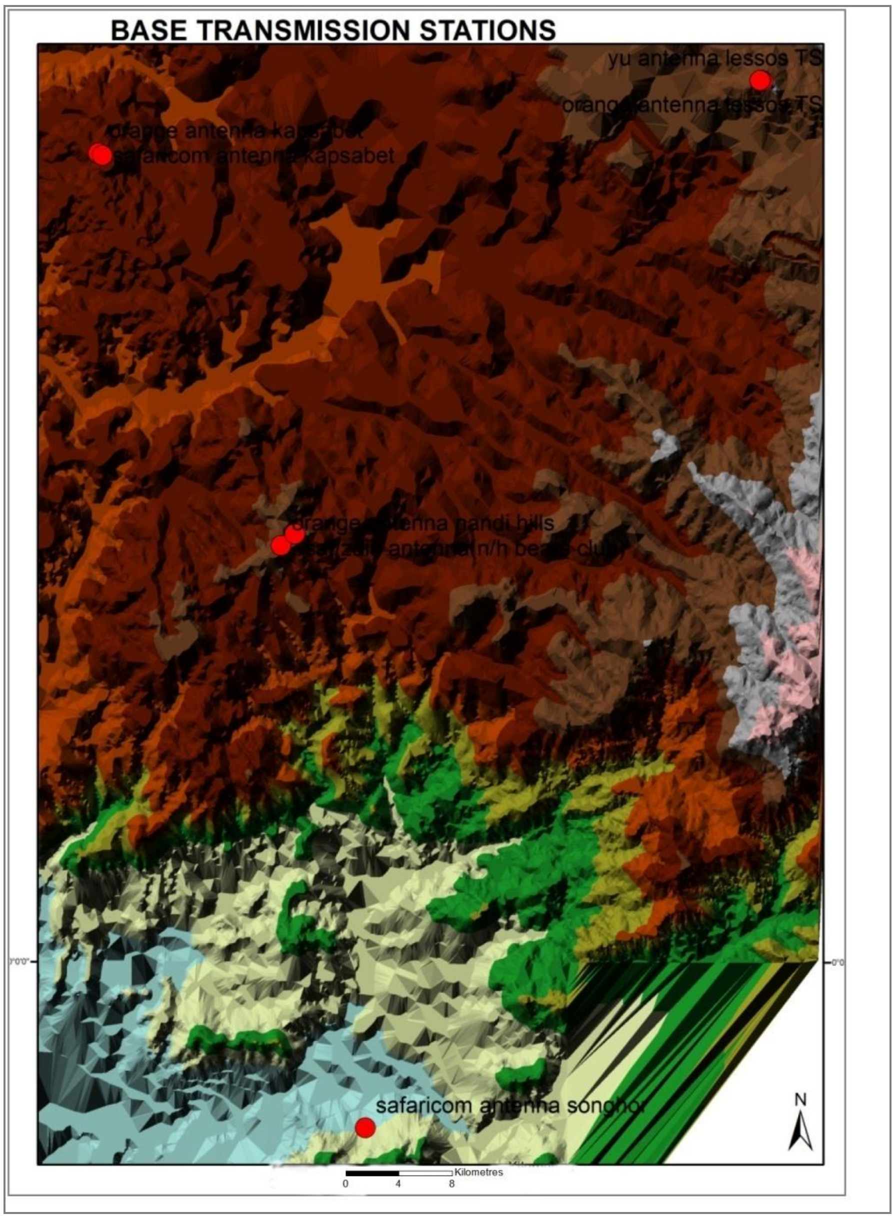


**Fig.iii Base Transmission Stations.** (Source: Author, 2013 )

The fig. shows the base transmission stations existing that were mapped using GPS by ground truthing. 7 BTSs were mapped in Nandi Hills, Kapsabet and Songhor as shown in Appendix 3 above

**Appendix IV**

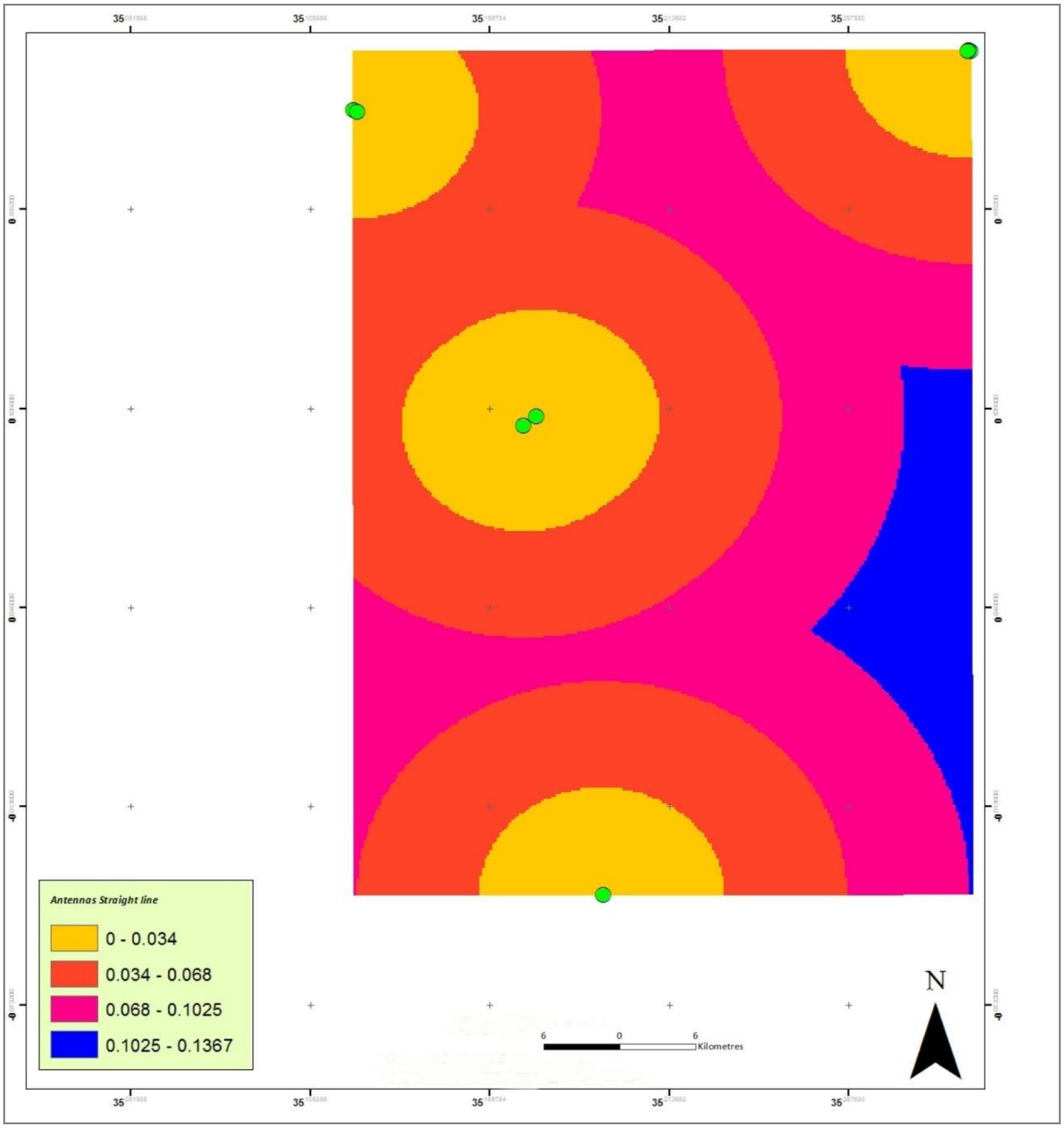



**Fig. iv Reclassified Base Transmission Stations.** (Source: Author, 2012 )

This map shows that the existing mobile antennas were limited in visibility to one another. The inner circle included the area most covered with signals in the straight lines.