University of Nairobi

School of Engineering

Using GIS to Map a Wi-Fi WAN Network in Murang'a County

Case Study: Murata Sacco

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Abstract

Many studies have been conducted on the best method for setting up wireless links in remote and rural areas, most having opted either to research on factors affecting electromagnetic dispersion or the effect of vegetation on transmission power. In this study, the effect of terrain in a Geographic Information System (GIS) setting and how it influences wireless network transmission over a mountainous terrain was considered. This aimed at exploring factors that have previously hindered effective establishment of wireless Wide Area Network (WAN) in Murang'a County that can effectively be utilized by various stake holders to establish a reliable wireless communication network.

A lot of progress has been made in Geospatial technology, enabling easy creation of three dimension (3 D) perspective image maps using remote sensing data and Global Positioning System (GPS). This has enabled the creation of complex optimum wireless paths for communication.

This paper investigates the best way to set up an optimum wireless optimum path over a proposed mountainous terrain of Murang'a to solve existing communication problems experienced by the Murata Sacco. Considered were the effects of terrain and vegetation, their interaction in a geospatial model and resulted in a wireless pilot link between Murata headquarter in Murang'a Town and Gatugi branch in Gatugi location . The resultant finding can then be replicated to enhance communication requirement throughout other Murata Sacco branches and at the village level in Murang'a County and in other similar Sacco and investments elsewhere.

It was established that without a proper geo-location map and geospatial analysis of terrain among the many other factors affecting transmission, a wireless pilot link cannot be successfully established.

Declaration

I, Ndung'u Joseph Matheri, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

Ndung'u Joseph Matheri....................

Name of student Date ....

This project has been submitted for examination with our approval as university supervisor(s).

D. K. Macoco. ……………………… Date ....

Name of supervisor

Dedication

I dedicate this work to my family for the support and encouragement they have given me during the course of my study.

Acknowledgement

I wish to start by thanking my supervisor, Mr. D. K. Macoco for his encouragement and guidance throughout the duration of this study.

I would also like to thank the staff of Murata Sacco for the necessary assistance, accessibility and for availing the required information during my field work.

I am grateful for to the large number of people who cannot all be named here, who assisted in one way or another leading to the successful completion of this study.

Lastly I would like to thank my lecturers and staff in the Department of Geospatial and Space Technology , University of Nairobi, for the patience and dedication they tirelessly offered me during the course of my study.

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Chapter 1 Introduction

1.1 Background

1.1.1 Murata Sacco

Murata Sacco is a rural based saving and Credit cooperative registered under the cooperative society act C.S No 8056 on 20th February 1997, is owned and managed by coffee farmers of Murang'a County who form bulk of the members. It is run and governed by it members who elect a board that govern the day to day running of the Sacco. Murata Sacco offers Savings and loans facilities. It aims at providing small term assistance to farmers to enable them run their agricultural activities by providing farm inputs, farmer education, marketing of their products while at the same time handling their income and disbursement of the same.

1.1.2 Sacco's in Kenya, Africa and elsewhere

Sacco is a credit union which is member based institution managed through by laws of this institutions. In Kenya Sacco's are regulated by ministry of cooperative through Sacco societies Regulatory Authority (SASRA). Sacco is managed by committees whose membership are drawn from the members and are elected democratically.

1.1.3 Why Sacco's were started

Sacco are mainly started to cater for the welfare, needs and aspiration of its poor members and are instrumental in poverty alleviation. They offer microfinance services, encourage savings and provide loans to members. They also invest member's funds in authorised instruments such as shares, Treasury bill and bonds while providing high returns to members than offered by banking institutions.

1.2 Geographic Information System (GIS)

This is a term applied to computerised information storage, processing and retrieval systems that use software and hardware designed to cope with geographical referenced spatial data such as maps, field survey, satellite pictures and corresponding attribute data (Karanja, F.N)

1.2.1 Reason for Implementing GIS

GIS has been used successful to replace in part or completely many complex operations resulting to saving and reduction of cost.

It also assist in cost avoidance by analysing best possible ways in locating facilities or best possible delivery routes avoiding natural/man man hazards .

This will result in increase of revenue through attracting new customers or getting of wholly new products and services, which could not be previously realised.

This results to non tangible benefits to the community, due to better decision making, providing betters services and use of consistent information across the organisation. (Siriba, D.N)

Awareness and Use of GIS has lagged behind in Kenya. As a result many factors affecting use and distribution of spatial data are not fully exploited.

1.3 Situation in which the Project Exists:

This research proposes considerations for installation of a wireless communication network to serve the whole of Murata Sacco. There is a need to interconnect Murata Sacco branches which require centralizing data and voice network to run their core banking system. This will facilitate inter-branch communication. This will facilitate the use of centralized Banking systems in a server /client model and enable data sharing and Backup. The growth of Sacco by enabling faster processing and handling of transactions for its clientele will be enhanced thereby enabling the capture of bigger share in this financial market.

The already installed Global System for Mobile communications (GSM) network provides third generation telecommunication signaling (3G) Data but works intermittently to the effect that it cannot be relied to provide reliable data connection. Murata Sacco had to revert to their old system of sending data backup on external hard drives by motor bike between the branches and the head office.

This method of physically sending information is slow, time consuming and expensive and security of the data is not guaranteed. Data is only sent to the head office for update and backup after the day's transactions have been captured. This practice exposes the Sacco to poor service delivery and might also lead to fraudulent malpractice and insecurity.

A test pilot Wi-Fi link interconnecting Murata Sacco head office and one of the branches Gatugi located within the Murang'a County is to enable us investigate the possibility and viability of setting up a wireless wide area network .

A communication link will enable instant business transaction updates between the head office and branch enabling Murata Sacco reduce time taken to transact their business. Provide instant electronic mail communication for effective running of day to day business.

1.4 Study Area

This research project focuses on Murang'a region which is one among several counties in Kenya

Murang'a lies between -0.969' and -0.564 latitudes, 36.706°and 37°27' Longitudes.

Bordering Nyandarua county to the west, Kirinyaga county to the east, Kiambu county to the south, Nyeri county to the north and both Embu and Machakos county south east.

This sub county covers 1798 km square, with five administrative locations namely Kangema, Gatanga, Kahuro, Mathioya and Murang'a south sub county.

Murang'a County has a population of 942,581 as per year 2009 census. Murang'a county is a predominantly an agricultural economy, the main economic being agriculture and most farmers are small scale holding, there main agricultural crops grow here are Coffee, tea, milk, maize and beans.

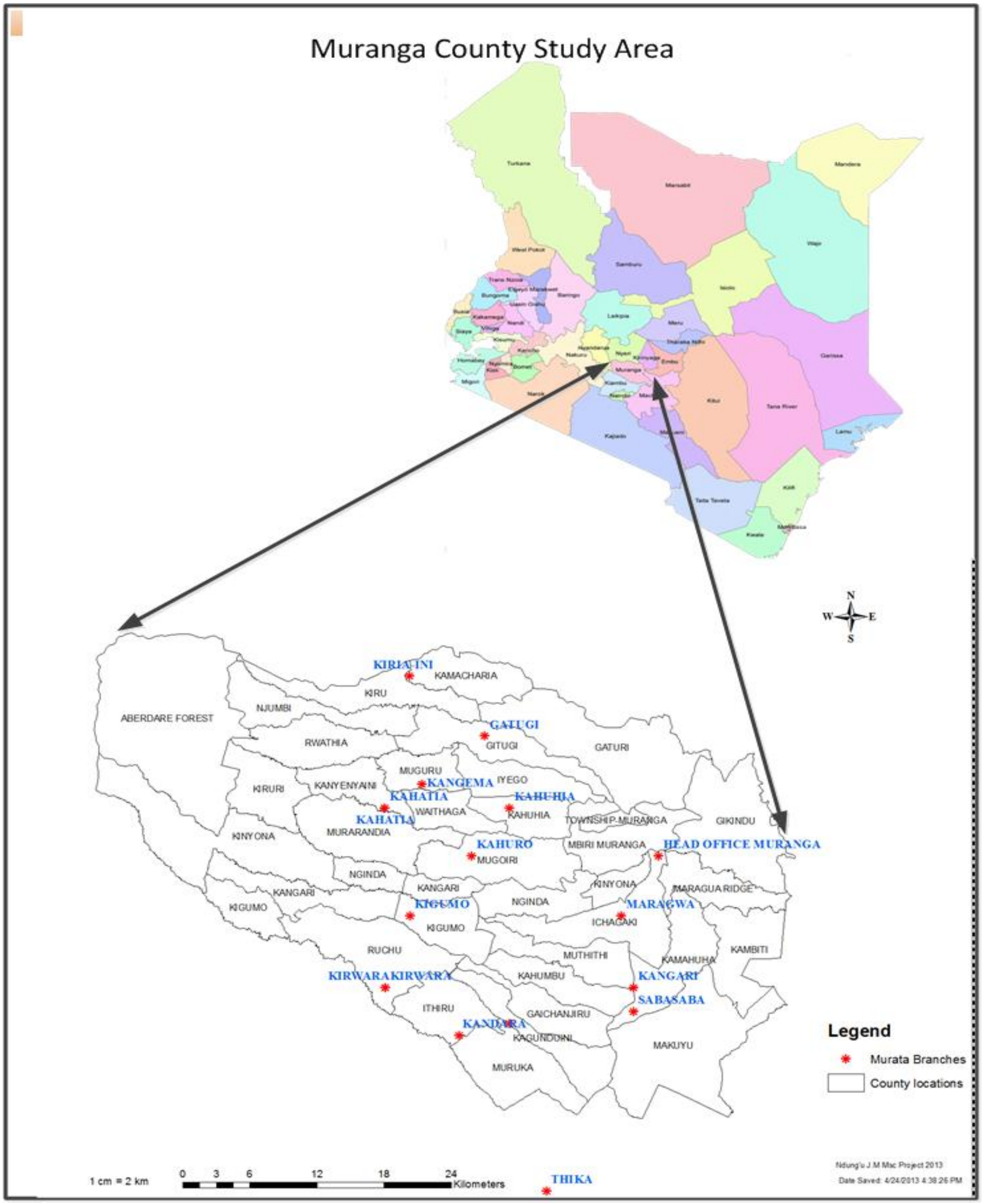

Figure 1.1 Murang'a County Study Regions

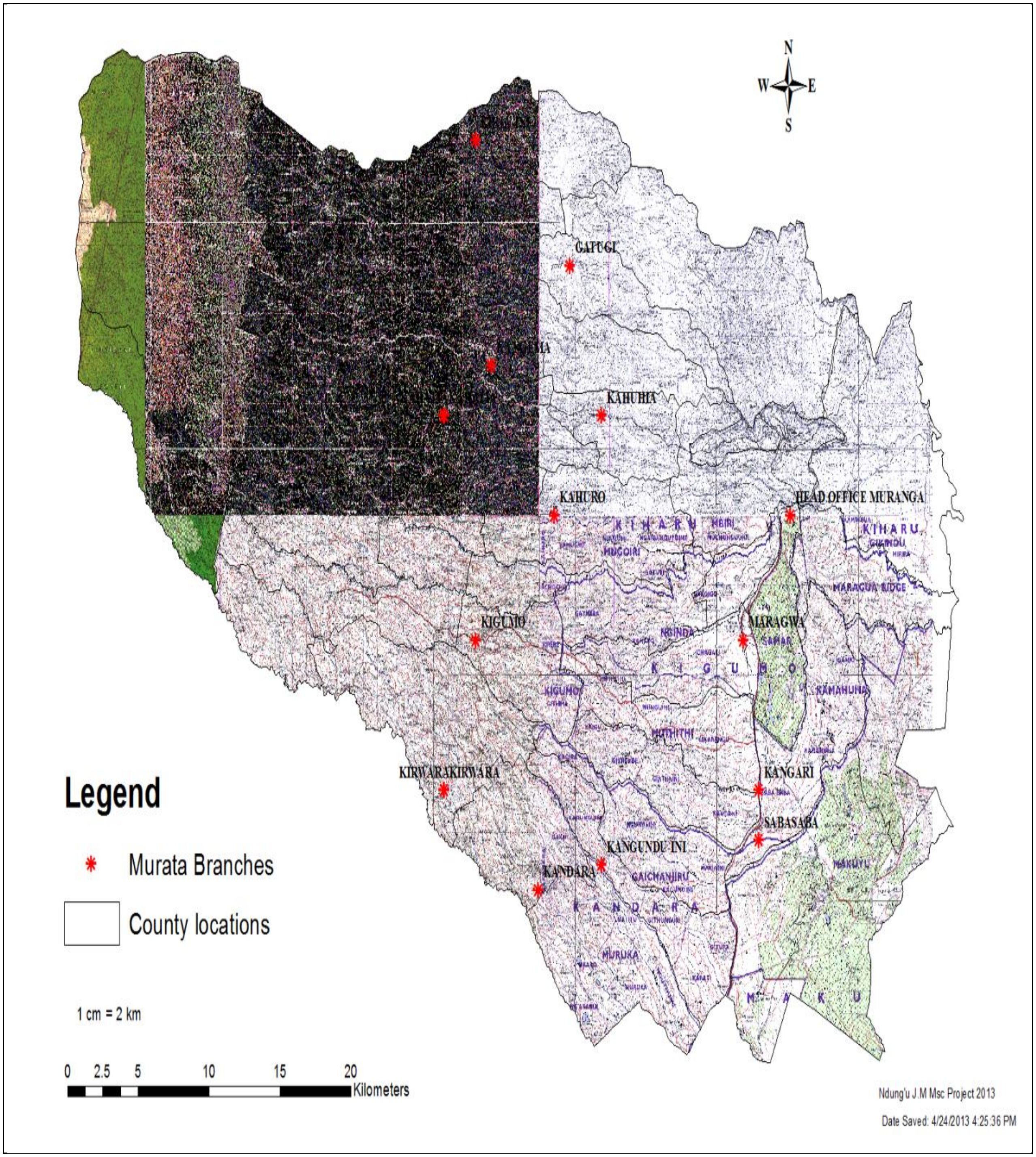

Figure 1.2, Murang'a County Map

The topography of this region is significantly mountainous with the terrain rises from an altitude of 914m in the east to as high as 3,353 along the Aberdare range slopes in the west, which are heavily trenched.

95% of the land is generally mountainous with several rivers transverse the landscape and draining eastwards joining River Tana.

There's a big variation of rainfall, temperature, soil type and geology of both volcanic and basement rock culminating in different environment between the highlands and low lands.

Figure 1.3, Murang'a County Vegetation

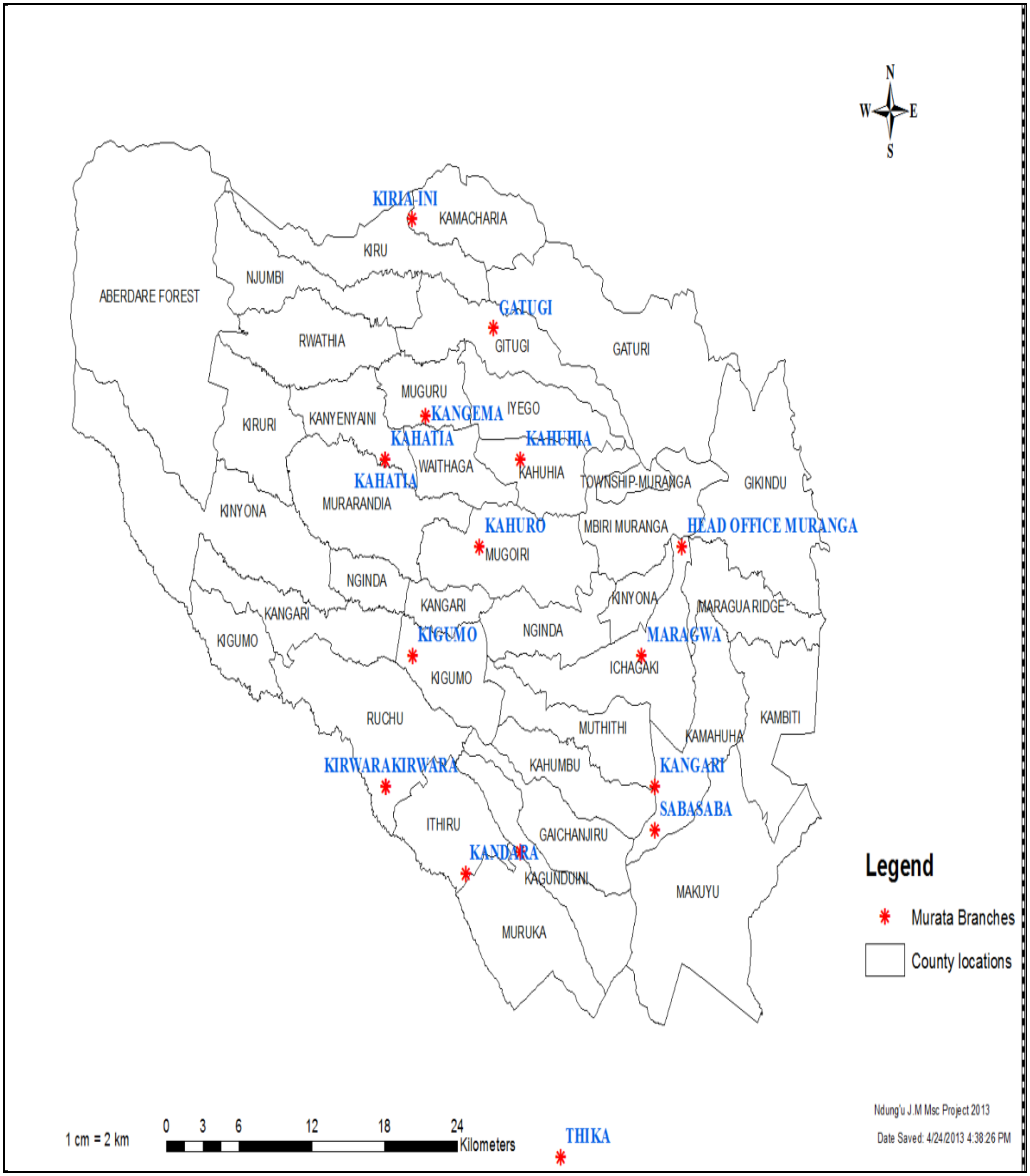

Figure 1.4. Murang'a County locations

1.5 Problem Statement

Murata Sacco has been growing exponentially, and has recently been authorized to trade as a micro finance institution offering banking services. Having fifteen branches distributed over Murang'a County there is a requirement of inter-branch communication to facilitate day to day trade.

Murang'a county being a mountainous region and the branches being scattered over a radius of more than thirty five kilometers poses a challenge of how to connect the branch network , This is complicated by the difficult encountered by the ruggedness of the terrain , distance in between and remoteness of this rural setting . The quest to set up of any mode of network, wired or wireless, or the use of existing cellular services for inter-connectivity has time and again been meant with low success rate.

The current connectivity services offered by various service providers namely Safaricom and Kenya Data network (KDN) are not achieving network coverage adequate to provide required level of connectivity for banking services.

Safaricom GSM network achieves only partial coverage and some areas do not have network resulting to black spots, while in other areas the network is very weak and can only be used for voice only.

The KDN Wi-Fi network that was installed performed intermittently over the various seasons in the year. It works poorly in the dry season and fails completely during the rainy season.

This led to the conclusion that the previous attempts to interconnect murata branches could not be relied upon to provide 99.9% data connection as required by banking services.

The distance between the branches is too large to effectively install a fiber network. The size of the branches and the economic activities in this centers where the branches are located cannot afford the high cost of installing a fiber network.

This proposal aims at getting most effective way of setting up a last mile wireless network for Murata Sacco thus enabling a wider coverage of data and voice in the most appropriate and cost effective method .

1.6 Objectives

1. The Main objective of this study is to Produces a Geospatial Model Wireless Wide Area Network pilot Link between Murata head office and Gatugi branch by use of Digital Elevation Model (DEM) of Murang'a County using existing Topo Maps and available satellite imagery.
2. The Specific objectives are as follows
    - 2.1.1. Using GPS (global positioning system) coordinates for our murata Sacco branch geographic positions to tabulated 3 D surface, set the locations for wireless base station that will ensure optimum wireless transmission between the branches.
    - 2.1.2. Providing wireless Line of site between the created base stations to ensure 99% connectivity at all conditions and times.
    - 2.1.3. Design a Wi-Fi WAN to achieve several specific business/operational objectives:
    - 2.1.4. Secure Service: The purpose of this network is to provide secure administrative computing service to the Murata Sacco covering all its branches. It is designed to be functionally and physically isolated from access by people not employed by the Murata Sacco, minimizing the risk of Data loss during normal inter branch transfer.

This will ensure the following

- 2.1.5. Versatile Information Processing: The network will enable users to retrieve, process, and store information in real Time from any connected computer.
- 2.1.6. Collaboration: The network will combine the power and capabilities of diverse equipment across the branches and especially the Head office to provide a collaborative medium that help users provide Bank facilities regardless of their physical location resulting to efficiently and productive services.

2.1.7. Scalability: The design is scalable so that more Branches can be easily added as they become necessary without having to redo the WAN network.

2.1.8. Resources re-distribution: Free up various personnel engage in inter branch commuting to provide services i.e. IT

1.7 Justification for the Study

Setting up a reliable communication network is paramount to the operations and growth of murata Sacco as a financial institution. The stake holder among them the coffee farmer will not only received prompt financial services but also gain economically with the growth of their Sacco.

A connected institution will be on the fore front of Serving this farming community, not only in providing financial services, but also opening up this society in a digital age connecting it to the global village. This will go a long way in facilitating the government initiative of fulfillment of its economical agenda in the vision 2030.

Overcoming the communication challenges experienced due to mountainous and rugged nature of Murang'a is paramount to achieving a viable and amicable solution once and for all.

Failure of previous communication network service providers to adequately provide a connectivity solution between the branches has cost murata Sacco in lost revenues and slowed its growth in its quest to become a micro finance.

Investigation of new methods to achieve , network interconnection that has previously not been exploited, such as use of Geographic Information system (GIS) in the design of wireless network is the key to a successful implementation..

The design of a success full wireless pilot link will guarantee expansion of this project to other centers within the Murang’a County covering all the other branches. This same system will then be utilized by the community to setup village communication centers (e-Kijiji) to be used for education, health and social services.

1.8 Scope of work

Setting up wireless network involves propagation prediction and measurement. Reflection, refraction, diffraction and scattering of radio waves influence on propagating paths of electromagnetic wave's transmission.

Many of the factors influencing radio wave propagation and effect of vegetation on transmission have been well researched as such this research focuses on the effect of proper terrain analysis in propagation design using GIS methods

This will include analyzing effect of terrain on line of site by use of GIS software to create 3D surface and consider other various factors influencing RF propagation.

QGIS, ARGIS, 3Dem software will be used to simulate 3D surface which is then used to predict and appreciate the radio transmission path.

Setup a pilot link by use of line of site. Predict positioning of mast in the terrain in order to provide the strongest possible signal and minimal interference.

The acquire GPS location of murata centers together with satellite image and Topo maps are used in this analysis.

1.9 Organization of Report

1.9.1 Abstract

This report starts with an abstract giving a short description of the summary of this report, why it is being done and hints on what it aims to achieve.

1.9.2 Introduction

The Introduction chapter looks at the study region and subject, introducing problem statement as defined by the stake holders and its justification outlining benefits, defining the scope. This also sets out clearly the objectives and goal achieved at the end.

1.9.3 Literature review

Looks at the various study previously done on the subject of wireless, their focus and indication on what the report set out to achieve , It introduces previous works on the study areas of terrain analysis and effect of vegetation on wireless transmission .

1.9.4 Methodology and methods,

This chapter defines methods, tools as used, how the study was done and the various outcomes obtained. It also defines the data set used and analysis of the same to achieve the set objectives.

1.9.5 Results and discussion,

This chapter looks at the obtained result from the analysis done under the methodology, it analyses and helps make conclusion of obtained outcome.

1.9.6 Conclusion

Comes lastly in the arrangement of this report and it makes a conclusion, which is a deduction from results and comes up with a finale on the best method as defined from the study, it concludes whether the objectives have been met or not and best way forward.

Chapter 2 Literature Review

2.1 Introduction

Poverty in many under developed regions of the world, high costs of communication and social constraints continue to stifle socio-economic advancement. Information Communication Technology (ICT) access is crucial in bridging the digital divide as a key foundation of development, for rural development in particular. Creating local capability, motivating inventiveness and originality and boosting human skills and performance are important factors in linking rural communities to the information and communication network. (ICTARD 2006)

The world is experiencing a revolution in which industrial societies are transforming themselves into information-based societies. Unlike the industrial or agricultural revolutions, where large amounts of physical and financial capital were necessary to stimulate growth, this information revolution has the prospect of unlocking the potential of human capital everywhere. Still, this promise cannot begin to be realised without first providing the vast numbers of humanity excluded from international networks with access to the Internet and other information and communication technologies (ICTs). Wireless Fidelity, or Wi-Fi, may be the key to unlocking that promise in remote, poor areas. (Munyua, 2000)

Digital divide. The information revolution has been quick to take off in developed countries, but much of the rest of the world lags behind, the most serious case being Africa. The resulting inequalities are referred to collectively as the ‘digital divide.’ The international community is convinced that ICTs can play a vital role in facilitating economic and social development, so the ‘divide’ is cause for great concern. Fortunately, there is the emerging promise of proven and inexpensive technologies to bridge the connectivity gap that is at the root of the divide. Cumulatively, global connectivity has been on the rise. (InfoDev et al., 2003)

In 2001, 95 per cent of the world's countries were connected to the Internet. However, in Kenya, access remains limited to a privilege few. The 'information gap' (measured by the number of Internet hosts per 10,000) between high-income economies and the low, lower-middle and upper-middle economies has widened substantially. In many countries, for varying economic, geographic, social and technical reasons, there are no wired alternatives available by which to surf the web or speak on the telephone.

National and international connectivity is in short supply, especially in Kenya, where satellite links are limited and expensive, optical fibre has only been sparsely installed and internal telecommunication infrastructures are concentrated in the few main cities and hardly exist in rural areas.

Technical barriers together with weak market economies and limited political support for telecom policies, has deterred investment and supported high data prices, thereby hindering the penetration of communication services among the poor counties.

Digital opportunity through any kind of connectivity – better roads, flight connections or telephone lines can economically empowered people.

Development is not resource transfer from rich countries to poor ones, but engagement of citizens in economically meaningful ways. Access to information has become such a hot topic among the international development community that a number of international organisations argue that it is directly linked to poverty reduction.

Connectivity and the information access unleash human capital and increases productivity and knowledge sharing in underserved areas where it has been most constrained. In the developing world, the promise of wireless Internet technologies presents an unprecedented opportunity for people who have been excluded from the global economy and its communication networks. More than just linking huge numbers of new users to the Internet, Wi-Fi presents attractive opportunities for developing countries to leapfrog several generations of telecommunications infrastructure, including wire-line and wireless local loop telephony, to the forefront of broadband communications technology.

Wi-Fi can become a critical factor in shrinking the digital divide by providing high-speed Internet access to whole new segments of underserved populations throughout the world at a fraction of the cost of wired technologies. Today's wireless economics are already compelling: wireless local loops are about one third the cost of copper or fibre land-line service, while packet-based broadband computer networks cost one ninth of land-line service.

Ease of set-up, use and maintenance are affordable for both users and providers. Tests in rural settings show that a $20 wireless PC card can provide good connectivity up to a half-kilometre radius with line-of-sight and up to 50 kilometres with antennas and repeaters. Moreover, Wi-Fi access points can be purchased for less than $50. (InfoDev et al., 2003)

Wireless systems are easy to deploy and expand and they are more reliable, safer and easier to maintain than landlines. E-mail, voice and video mail are the most popular uses of wireless broadband networks in the developing world. Nevertheless, the more quickly the Internet can be mobilised to provide solutions and products for e- banking, e-governance, e-health, e-education and e-commerce, the sooner the significant effects of ICTs on development will be felt. Field experiments suggest that wireless Internet can be sustainably – and in some cases profitably – deployed in support of economic and social development objectives.

For a continent like Africa, where the poor or absent infrastructure has been an obstacle for traditional Internet connection, the possibility of a low cost connectivity in the form of wireless Internet would have tremendous effects. With these new kinds of solutions the digital divide could more easily be narrowed and African nations could more quickly benefit from e-society. Through better connectivity, brought about by Wi-Fi, e-government, e-education, e-health, e-business and e-agriculture would suddenly be within the reach of even the poorest.

Leading by example, When affordable and relevant, ICTs – including wireless technology – have been adopted at a fast pace within developing countries, leapfrogging traditional infrastructure. There has been considerable evidence of innovation and creativity in the deployment of wireless Internet among early adopters in developing countries. Demonstrating the practicality of the technology for rural connectivity, researchers from the Indian Institute of Technology at Kanpur, working with Media Lab Asia, have ‘unwired’ a 100-sq-km area of the Gangetic Plain in central India. This project provides broadband connectivity to the homes of almost one million people at under $40 per home. (InfoDev et al., 2003) Thanks to wireless infrastructure, Internet access has helped rural agricultural clients, for example, gets access to commodity pricing to maximise their returns. Because of the poor state of the telephone network, e-mail is now the primary medium for doing business with both national and international clients. Some businesses have begun to increase their exports worldwide because of their ability to take online orders.

In Senegal and Kenya the deployment of wireless technology has been critical to provide distance education. Overseas, for instance, Over the past couple of years, the John McCormack Graduate School of Policy Studies at the University of Massachusetts in Boston has partnered with universities to build community resource centres. The universities' Internet links have enabled the institute to wirelessly connect the centres and realising their vision.

The wealth of opportunities presented by wireless internet technologies has been recognized by the United Nations Secretary-General, who expressed a bold vision in this November 5th, 2002 declaration: "We need to think of ways to bring wireless fidelity applications to the developing world, so as to make use of unlicensed radio spectrum to deliver cheap and fast Internet access." (InfoDev et al., 2003) Kofi Annan set up the United Nations ICT Task Force in 2001 as multi-stakeholder group aimed at forging linkages and exploring ways to use information and communication technologies to reach the Millennium Development Goals and bridge the digital divide. The Task Force works to bring the benefits of the digital revolution to the developing world, focusing on vital areas such as poverty reduction, education, health care, the environment and gender equality. It provides a global forum in which to discuss and share best practices on integrating information and communication technologies into development programmes and a platform to promote partnerships between public, private, non-profit, civil society and multilateral stakeholders in order to address the issues of the digital divide and digital opportunity more comprehensively. This culminated to the June 26, 2003, UN ICT Task Force held a conference at the UN headquarters in New York, ‘The Wi-Fi Opportunity for Developing Nations.’

Wireless fidelity was also on the agenda at the first phase of the World Summit on the Information Society (WSIS) in Geneva on 10-12 December 2003 and will be addressed during the second phase, which will take place in Tunis in November 2005. The objective of the Summit is to develop and foster a clear statement of political will and take concrete steps to establish the foundations for an Information Society for all. An essential foundation for the Information Society is the information and communication infrastructure, which is to enable the universal, sustainable, ubiquitous and affordable access to ICTs even in the remotest and poorest of areas. In order to achieve this goal the Summit encourages the use of unused wireless capacity, including satellite and the further implementation of low-cost connectivity in developing countries. (WSIS, 2005)

The potential of Wi-Fi to contribute to the infrastructure and access-building was brought up in several WSIS background papers and roundtable discussions. A critical mass of support is building up behind the spread of wireless technologies thanks to these and other fora and the engagement of enthusiastic and influential stakeholders from all sectors of society. Barriers remain Wi-Fi alone is not a panacea for the world's development problems. To start, it isn't yet a perfect technology. Compared to wired infrastructure, for instance, wireless provides lower levels of performance. However, technologies are under development to address the known weaknesses of wireless systems and improvements in effectiveness and efficiency can be expected. Wi-Fi is relatively inexpensive to propagate, but necessary interconnection equipment and service to a backbone remain a major expense for countries or private actors. In remote areas, absent or erratic power supply remains a challenge to further implementation. Rigid spectrum policies, protective regulatory environments and lack of sustainable business models remain critical obstacles to faster and broader deployment of wireless Internet technologies, though they will vary with every market. One step of many Wireless Internet may be a very effective and inexpensive connectivity tool, but it does not carry any magic in itself. It can only be successfully deployed for development as demand for connectivity and bandwidth emerges in support of relevant applications for the populations served. These include e-government, e-education, e-health, e-business or e-agriculture applications. These, though, are not easily implemented in the developing world. Consequently, the demand for wireless Internet connectivity, which aggregates according to applications, needs to be explored and documented to support wireless infrastructure investment needs. Even after content that is relevant to users is on place, there will be the need to inform and train users to capitalise on the benefits of ICTs. Wireless broadband technologies offer the potential to shift the goal of the Information Society from the oft-quoted telephone in every village to broadband connectivity everywhere. It is now within reach.

2.2 Wireless Communication System

Wireless network is the use of radio frequency for communication over an area without physically connecting the communicating devices by use of wire. Wireless uses both wireless transmitter and receiver at both ends to enable the sending of electromagnetic waves from the sender to the receiver. This is in contrast to a wired network where computers are connecting to the internet or to each other using cables. Receiver and transmitter in a wired network are specialized in sending electrical signal over a cable medium. (Nwawelu N. et al, 2012)

2.2.1 Wireless standard

Guided by the IEEE Standards documents which are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board.

This includes Standards for Local and Metropolitan Area Networks:

2.2.2 Overview and Architecture,

Provides an overview to the family of IEEE 802 Standards. It defines compliance with the family of IEEE 802 Standards; it describes the relationship of the IEEE 802 Standards to the Open Systems Interconnection Basic Reference Model [ISO/IEC 7498-1:1994] and explains the relationship of these standards to the higher layer protocols; it provides a standard for the structure of LAN MAC addresses; and it provides a standard for identification of public, private, and standard protocols.

Keywords: IEEE 802 standards compliance, Local Area Networks (LANs), LA N/WAN architecture, The standards defining the technologies noted above include among others the following: • IEEE Std 802® :1 Overview and Architecture . This standard provides an Overview to the family of IEEE 802®Standards.

IEEE Scope of work. IEEE STD 802.1B® LAN/MAN Management. Defines an Open Systems and 802.1K® Interconnection (OSI) management-compatible architecture,[ISO/IEC 15802-2]: and services and protocol elements for use in a LAN/WAN environment for performing remote management. IEEE Std 802.11®: Wireless LAN Medium Access Control (MAC) Sublayer and [ISO/IEC 8802-11] Physical Layer Specifications.

2.3 Wide Area Networks (WAN).

A WAN is optimized for a larger geographical area than is a LAN, ranging from several blocks of buildings to entire cities. As with local networks, WANs can also depend on communications channels of moderate-to-high data rates. A WAN might be owned and operated by a single organization, but it usually will be used by many individuals and organizations. WANs might also be owned and operated as public utilities. They will often provide means for internetworking of local networks.

Size and extend of Wan as defined by the IEEE Std 802 can be designed to support over 200 stations and can span an extend of very large area (IEEE 802, 2001)

2.4 Wireless networking Benefits

Convenience of access, one is able to access communication from any location within the wireless coverage area including areas of un favorable condition and terrain

Cost of connecting over long distance and over rough terrain is very minimal as compared to installation of fiber or Ethernet cable. Eliminating cost of wiring reduces the cost of maintaining a wireless network

Logistics of setup, it is easier to setup wireless network and takes a shorter time as compared to other methods. It is also easier to extend and expand the network at minimal cost.

Security, with advancement of wireless security, it is possible to provide robust protection from interference and unauthorized access of information.

2.5 Factors Affecting Wireless Signals Transmission

Because wireless signals travel through the atmosphere, they are susceptible to different types of interference than standard wired networks. Interference weakens wireless signals and therefore is an important consideration when working with wireless networking.

Wireless communication over long distance depends on a number of factors; this includes distance of the communicating nodes, method of communication, bandwidth and frequency in use. Line of site, characteristics of electromagnetic waves in use, transmitting equipment and there power, effect of external factors such as, vegetation, weather condition, interference from other transmissions.

The medium located between transmitting and receiving antennas has a major influence on the transmitted signal; this is because radio wave propagation is very sensitive to properties and effects of medium located in between. When radio wave encounters an obstruction some of energy is either absorbed by the medium, refracted, scattered and diffracted. The interaction of the radio wave with the obstruction reduces its signal strength and may degrade the overall strength to appoint that communication may be dropped or lost. (Nwawelu et al, 2012.)

These are some of effect experience by previous service providers in their quest to connect murata Sacco.

All this factors are in one way or another associated with geographical location of communicating nodes, the terrain characteristics such as hills, vegetation and soils.

By mapping out and factoring the various geographical parameters we can be able design GIS knowledge based wireless network that will guarantee required transmission characteristics most of the time.

2.6 Radio Propagation models for a radio channel;

Reflection, refraction, diffraction and scattering of radio waves influence propagating paths of radio waves (electromagnetic waves) transmission .Path traveled can cause multipath fading phenomenon.

Transmitted signal from direct and indirect propagation path can either combine constructively or destructively causing variation of received signal strength at the receiving station.

(Parthornratt et al, 2006)

The maximum distance between wireless nodes depends on the gain of the antennas, output power of the transmitter and attenuation, either in free-space or due to obstacles. Normally propagation models are used to evaluate the values of attenuation. However the traditional propagation models might not be the most adequate for wireless sensors applications. (Mestre P et al. 2011)

2.7 Wireless Interference

Wireless interference is an important consideration when you're planning a wireless network. Interference is unfortunately inevitable, but the trick is to minimize the levels of interference. Wireless LAN communications typically are based on radio frequency signals that require a clear and unobstructed transmission path.

The following are some factors that cause interference:

2.7.1 **Physical objects**: masonry, buildings, and other physical structures are some of the most common sources of interference. The density of the materials used in a building's construction determines the number of walls the RF signal can pass through and still maintain adequate coverage. Concrete and steel walls are particularly difficult for a signal to pass through. These structures will weaken or at times completely prevent wireless signals.

2.7.3 **Vegetation** : Different vegetation have distinct specific attenuation values , it is therefore very important to consider distribution and type of vegetation along the wireless propagation path in order to consider the direct effect on transmitted wireless radio wave. (Mestre P)

2.7.4 **Radio frequency interference**: Wireless technologies such as 802.11b/g use an RF range of 2.4GHz and so do many other devices, such as cordless phones, microwaves, and so on. Devices that share the channel can cause noise and weaken the signals.

2.7.5 **Electrical interference**: Electrical interference comes from devices such as computers, refrigerators, fans, lighting fixtures, or any other motorized devices. The impact that electrical interference has on the signal depends on the proximity of the electrical device to the wireless access point. Advances in wireless technologies and in electrical devices have reduced the impact that these types of devices have on wireless transmissions.

2.7.6 **Environmental factors**: Weather conditions can have a huge impact on wireless signal integrity. Lightning, for example, can cause electrical interference, and fog can weaken signals as they pass through. (Harwood, 2007)

2.8 Terrain Analysis

This is a set of analysis techniques done to analysis surface of the earth, this identify slope angle or aspect. This is carried on Digital elevation model (DEM) a raster data layer denoting position and height in respect to one another.

Indivisibility analysis can be carried out analyzing for visibility in a straight line between two points. This is used in communication planning in relation to line of site between transmitter and receiver. (MacFarlane, 2005)

2.9 Measuring Vegetation ,Normalized Difference Vegetation Index (NDVI)

Vegetation cover affects transmission of Radio wave negatively, it is therefore important to consider these effects and also a way that we can use to determine the density of vegetation in vast region and therefore take necessary measures that will alleviate these effects.

To determine the density of vegetation, the amount of color reflected by the visible and near infra red wavelength.

As sunlight strikes the green leaves, certain wavelength are absorbed while others are reflected. The chlorophyll strongly absorbs visible light from 0.4 to 0.7 µm to use in photosynthesis while strongly reflecting near infrared from 0.7 to 1.1 μm, by noting the amount of absorption of visible light and reflection of infrared wavelength we can be able to determine amount of leaves in a plant. Vegetated areas will appear darker in visible light while areas with less vegetation appear light; at infrared light the inverse is true.

The NDVI is calculated from ratio of visible and near –infrared light reflected by vegetation to help determine the level of density of vegetation cover.

NDVI is represented mathematically as

NDVI = (NIR — VIS)/ (NIR + VIS)

This calculation for a given pixel always has a result of range of minus one (-1) to Plus one (+1)

A answer closer to closer to zero means no vegetation as no green leaves gives a value close to zero while on the other end an answer closer to +1 (0.8 to 0.9) indicate very dense vegetation.

2.10 Wi-Fi Positioning by Using Geographical Information System (GIS)

Wi-Fi positioning system with knowledge of GIS can achieve higher accuracy in terms of distance error computing in comparison with a traditional placement method where GIS was not factored in. By Using Positioning algorithm we expectedly gets rid of unlikely crossing area in the study region by use of geographical information as a major key contribution factor

Proper placement of access points in service area is another issue of concern. It yields the same consequence as optimal coordinate fitting.

Wi-Fi positioning system with knowledge of Geographical Information is conducted to improve accuracy of positioning system. Reliability and accuracy of the system mainly depends on numbers of learning points, optimization of crossing point finding algorithm and sufficient signal strength samples to represent each point with least error. (Parthornratt, et al, 2006) Positioning techniques can be divided into two broad types (Jan et al, 2003), these are locations fingerprinting and propagation based computation.

For a location fingerprinting, site survey is required to collect signal strength samples at every single equally divided area of that building to build up a signal strength database.

After learning and surveying process is done, real-time signal strength is captured and mapping process is started. This type of positioning technique can be visualized as a scene analysis.

For propagation-based computation technique, no signal strength database is required before. Positioning computation is done according to different propagation models with different techniques of triangulation (Hightower et al, 2001).

2.11 Wireless Long-Distance 802.11 Links

The use of 802.11 long distance links is cost effective means of providing wireless connectivity in rural areas. IEEE802.11 (Wi-Fi) has been proposed as a cost-effective option to provide wireless broadband in rural areas. In the developing and developed world alike, 802.11 links are being used in long-distance (up to several tens of kilometers) settings. Some examples are: (a) the Ashwini project in Andhra Pradesh India, This shows that long distance links can be planned well for predictable performance , However interference from within and without can drastically reduce performance, as a result it is important to develop a GIS /RF knowledge –base for deployment plan

2.12 Long-Distance Links Used

Along-distance link consists of two Wi-Fi radios communicating with one another between two sites. We use towers or tall buildings for line-of-sight, which is essential for long-distance Wi-Fi links. Directional antennae mounted a top tall buildings/towers are used at one or both ends to achieve the necessary transmit/receive gains for link setup. (Chebrolu et al,2012)

2.13 The Least Cost Path (LCP)

The Least Cost Path (LCP) procedure for routing linear features was one of the earliest advanced applications of GIS technology.

While the technical approach has changed little from its earliest use, procedures for calibrating and weighting model criteria have radically changed. Of the three basic steps in LCP analysis (discrete cost, accumulated cost, and steepest path) the development of a robust discrete cost surface is the most critical.

It is imperative that this summary map appropriately reflect relative preference for various conditions within each map layer (calibration) and appropriately balance the relative influence among the map layers (weighting).

Technical considerations involving a consistent data range, map value normalization and treatment of exclusion areas are important; however the calibration and weighting of model criteria are the dominant factors. They also are the most difficult to establish in a manner that fully engages domain expert and stakeholder perspectives. (Berry, Joseph K.)

2.14 Land Use and land cover

According to (Harry Anderson et al) Clutter (land use/groundcover) data can have many uses in wireless system design. . Land use/land cover (LULC) data can play a significant of role in designing wireless communication systems. It can be used to improve predictions of signal attenuation and other radio propagation effects and to assist in finding the optimal location of network base stations and other wireless system transmitters .

Significant in design of wireless system is the use of, terrain elevation data (DTEM) digital terrain elevation models which have profound effect on propagation of radio frequency, others include environment (trees and structures)

The most significant applications are in refining signal level predictions to take into account local clutter attenuation effects, and in projecting demands for wireless service. The latter is becoming increasingly important as new types of mobile and nomadic broadband wireless services such as WiMAX and LTE are built out, taking their place alongside existing mobile cellular/3G services. With an increasing trend toward high capacity data wireless services, groundcover/land use data used in conjunction with building height and location data can provide the wireless system designer with a valuable understanding of where service will be required and at what capacity. In this regard, land use data which is as up-to -date as possible is important.

2.15 Shutter Radar Topography Mission (STRM)

This constituted an international research effort to obtained digital elevation model (DEM) , and provides a recent snapshot of the Earth's surface, This is a collection of elevation data over 80% of the earth's land , representing best freely available Digital elevation model (DEM).

SRTM mission consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. This was coordinated by National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).

2.16 SRTM Publication

The STRM geo Tiff image that can be obtained is STRM 1" STRM 3" and STRM 4" data. The available image for regions outside the United States is sampled at 3 arc-seconds, which is 1/1200th of a degree of latitude and longitude, or about 90 meters (295 feet).

SRTM data obtained are in ARC GRID, ARC ASCII and Geotiff format, in decimal degrees and datum WGS84. They are derived from the USGS/NASA SRTM data.

CIAT has processed this data to provide seamless continuous topography surfaces. Areas with regions of no data in the original SRTM data have been filled using interpolation methods described by (Jarvis et al., 2008).

2.17 Dimension Visualization for GIS

Many GIS problems can only be solved using 3D. Seeing your data in 3D can very quickly highlight spatial relationships between GIS features, and analytical tools can quantify these relationships into patterns.

Thematic layers and images ie aerial photographs and satellite can be draped on top of 3D visualization producing realistic experience

3 D visualization is being successfully implemented by Environmentalists, forestry departments. Civil engineers use 3D Analyst to understand and sculpt terrain to allow for design and construction of Dams, roads and bridges.

2.17.1 Use 3D Visualization Propagation of Radio Frequency

By leveraging 3DEM Analyst we can ask complex 3D questions about man-made structures, and landscape especially in regard to both current and proposed lines of sight within an urban area.

Viewing data in three dimensions gives us new perspectives. Three-dimensional viewing can provide insights that would not be readily apparent from a planimetric map of the same data. For example, instead of inferring the presence of a valley from the conFigureuration of contour lines, you can actually see the valley and perceive the difference in height between the valley floor and a ridge.

Figure 2.1 3DEM Surface (Horne, 2011)

2.17.2 3 Dimension Surface

You can create and modify functional surfaces with 3DEM analyst. 3D surface tools allow you to create surfaces, convert surfaces to 3D features or other surface types, extract surface information, and conduct advanced surface analysis such as slope, aspect, and contouring. Examples of 3D surface analysis are elevation analysis for residential development, groundwater modeling, disaster management, or floodplain mapping.

You can conduct visibility analysis in your 3D GIS environment. A suite of visibility tools exist to conduct visibility analysis. For example, you can use the line-of-sight analysis on a landscape to optimize the location of telecommunication towers, or analyze the effects of a new proposed building on the city skyline.

2.18 Use of GIS

Geographic Information system is used for capturing, storing, checking and displaying spatial information.

With GIS information various parameters can be compared to enable us to easily understand there relation to one another.

Using to topographical maps of our study area, aided by various tools such as Global positioning system (GPS), satellite pictures (land stat tm), GIS software, we will be able to locate most cost effective Wi-Fi nodes placement to effectively design a wireless network that will not only be used by murata Sacco, but by other institution in the region for communication providing effective coverage.

This will include the following

- **2.18.1.** Education institutions, connection of schools in the area, help provide quality education
- **2.18.2.** Healthcare, create an interactive infrastructure to be used by hospital, clinics
- **2.18.3.** Economical Development, to be used by Microfinance institution and community networks
- **2.18.4.** Humanitarian Use; Use by rapid response team for communication, response, this area known for landslides, can be effective be used, to coordinate disaster mobile centers

Chapter 3 Methodology and Materials

3.1 Methodology

3.1.1 Introduction

Having examined previous works on establishment of Wi-Fi links from the various literature works we appreciate the role that various factors affecting Wi-Fi transmission will have in establishing a wireless link between Murata head quarters and our pilot branch Gatugi.

Wireless communication over long distance will be influenced by the following factors

Distance , this is length between the transmitting and receiving stations and has direct correlation to setup requirements such as transmitting power and radio frequency to use .

Distance is a constant factor that we do not expect to change and is decided by already existing murata Sacco branch locations.

Terrain, this is the most critical factor in our research and has greatest influence in the outcome of research, it is a non variable, and bring in the aspect of GIS. This is one factor that has been least considered in most of the existing studies and will be our main focus.

Terrain also plays a major role, when we consider terrain we are going to consider ruggedness, slope aspect and existing installations and buildings

Vegetation, Variations and type of vegetation over the terrain, has adverse effect on the absorption and transmission of the electromagnetic waves

3.2 Methods Flow Diagram

The methodology opted for in carrying the GIS research work was as shown as in Figureure b

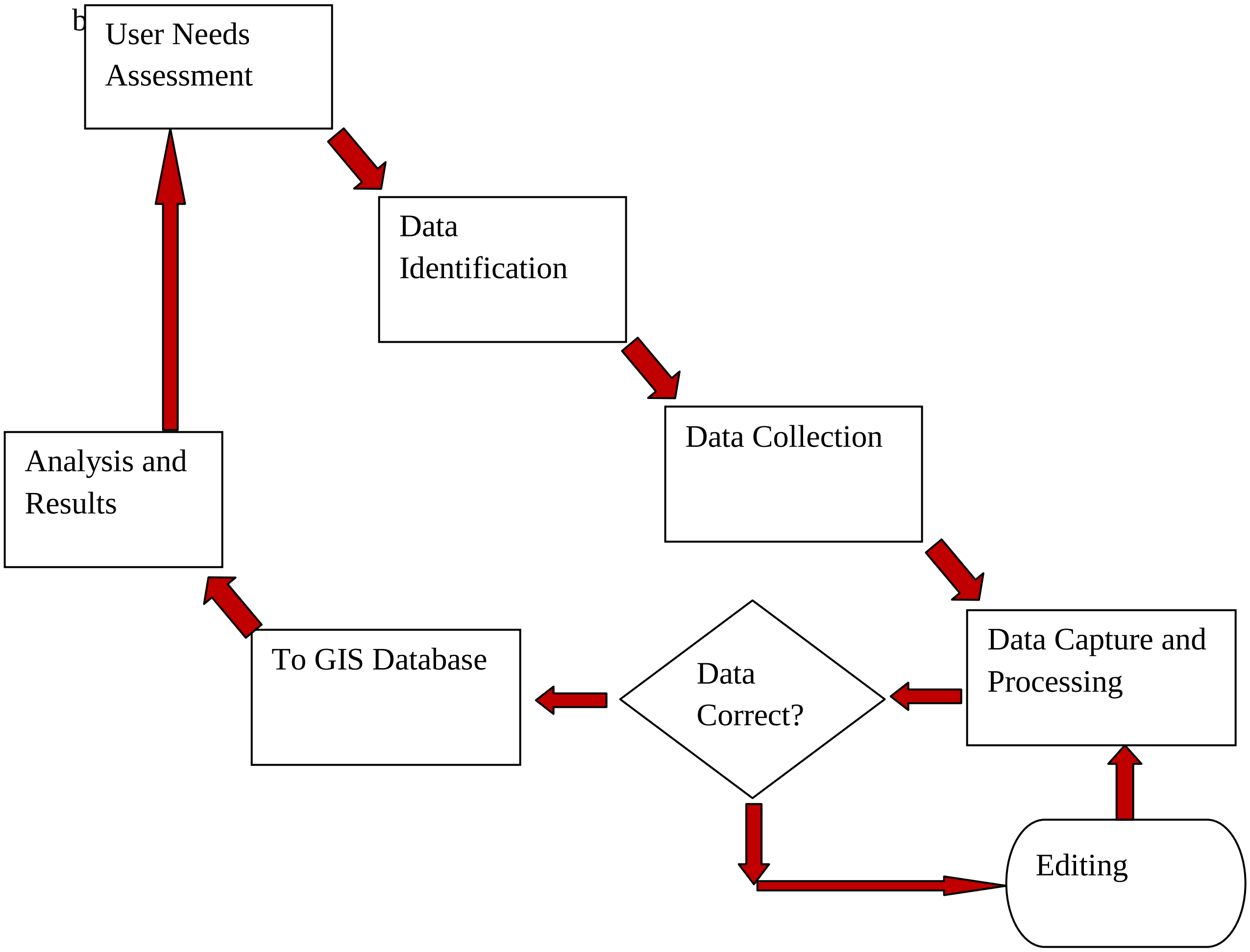

Figure 3.1, Procedural Methods

3.3 Procedures for Data Acquisition

3.3.1. A user assessment study was carried out to identify user information needs. This was primarily concerned with Murata Sacco and her desire to effectively and efficiently communicate with her satellite centers

3.3.2. Data identification involved determining the various datasets to be used in the analysis like boundary data, satellite imagery, elevation data etc.

3.3.3. Data collection was from relevant ministries and other sources like Survey of Kenya headquarters. This involved spatial data, attribute data. Secondary data was collected using structured questionnaires.

3.3.4. Digitizing and editing was done using Arc-GIS and QGIS software.

3.3.5. The database was equally created using Arc-GIS and QGIS software.

3.3.6. Analysis was carried out using Arc-GIS software and 3DEM software.

3.3.7. Analysis of 3 D surface by use of profile generated by 3DEM, examining elevation and line of site.

3.3.8. Simulation using radio module software. To confirm communication via established line of site.

3.3.9. Tabulation of results

3.4 Equipment

3.4.1 Hard Ware

Garmin Etrex Hcx (GPS), Used to collect location data, longitude, latitude and altitude

Computer, processing all the GIS information and presenting this in a palatable format

Digital Camera, Panasonic Lx2 for acquiring photo graphic evidence

3.5 Software

3.5.1 Quantum GIS

Quantum GIS (QGIS) is open source Geographic Information System (GIS) software running under GNU public License, this is being run by Open Source Geospatial Foundation (OSGeo) and run on both windows and Linux platform.

This is used to visualize, manage, edit, analyze geospatial data and compose maps.

3.5.2 ArcGIS

This is a suite of commercial products for designing and managing solution based on geographical information. It is designed and maintained by Esri (esri)

3.5.3 3DEM

3 DEM is a freeware visualization software created by Horne Richard capable of producing three dimension terrain scene and fly by animations from a wide variety of data source including USGS Digital Elevation Model (ASCII DEM), STRM file from NASA shuttle radar Topographical Model, Lidar point cloud (LAS) files among other format. (Horne, R.) It consists of conversion and editing utility for digital elevation model (DEM) of terrain in the real world.

We have utilized it to analysis the physical terrain and create profile of the landscape along the pilot link path. This also provides elevation and visibility data in our line of site analysis.

3.5.4 Radio Mobile Deluxe

Radio Mobile is free radio propagation simulation software operating between the frequency of

20MHZ and 20GHZ based on ITS (Longley-Rice) propagation model.

Using SRTM data, the program enables use of elevation to generate route radio coverage data analyzing performance of radio coverage along the path of proposed pilot link. (Brown, I.D)

3.6 Fieldwork and Data Collection Procedure

3.6.1 Data Sources

The main datasets used in the analysis came from various sources and in different formats as shown in Table below

Table 3.1: Data Sources

Dataset	Characteristics	Data source
Boundary	Shape file	Survey of Kenya
Road network	Scanned topographic map	Survey of Kenya
Distribution network	Discrete Coordinates	GPS hand picked
SRTM	Raster at 60m resolution	GLOVIS geo-portal
Landsat	Geo tiff Image	U.S geological Survey (USGS)
Major Towns	Shape files	Survey of Kenya
Photo Graphic	Tiff	Field work
Murata Branch Location	GPS data Latitude, longitude and Altitude	Field Work

SRTM……Shuttle Radar Topographic Mission

3.7 Data Collection

The fieldwork to collect data that was necessary to execute the objectives of this research was carried out in the district between January 2013 and April 2013.

Satellite images to create a three dimension (3D) perspective image map were downloaded on 10/4/2013. Equally important were satellite landsat images of the study area which were used to show the general trend in vegetation cover which equally affects transmission trends. The SRTM (USGS website http://www.usgs.gov/pubprod/aerial.html#aerial)having a course resolution of 60 m was improved to 20m resolution by the elevation data provided by Survey of Kenya.

This combination was then subjected to 3D surface modeling from which a DEM and 3D scene of the study area was created. Analyzing and processing the obtained satellite images was done using Erdas Imagine, whereas creation of digital elevation model (DEM) and digital terrain model of Murang'a county was achieved using Arc-GIS and QGIS software.

Collection of GPS points of existing coverage of Murata Sacco branches was done using Garmin Eterx consumer unit. Since the GPS point positioning requires clear unobstructed view to the sky, the study was able to collect the branches with +_ 3 meter accuracy, this is adequate for our analysis. Additionally, the name of the branch and their respective altitudes were picked.

All the datasets were geo-referenced and overlaid on digital elevation model map to assist in location of or Wi-Fi optimum path.

3.8 Vegetation Requirements

To enrich the research, the type of existing vegetation along the chosen location was highlighted to enable us factor in the effect of vegetation as classified from satellite images. This has a strong bearing when interfererence on radio frequency transmission is considered. We obtained NVDI of the vegetation coverage for the whole region. This was also coupled with photographic evidence from the site.

3.9 Satellite Image Acquisition

In order to create 3 D surface for our analysis

3.9.1. Satellite images (SRTM) to create a three dimension (3D) perspective image map.

The STRM data is divided into tiles of 1° x 1° of latitude and longitude.

The STRM data is a download from CSI.CGIAR.ORG website http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp

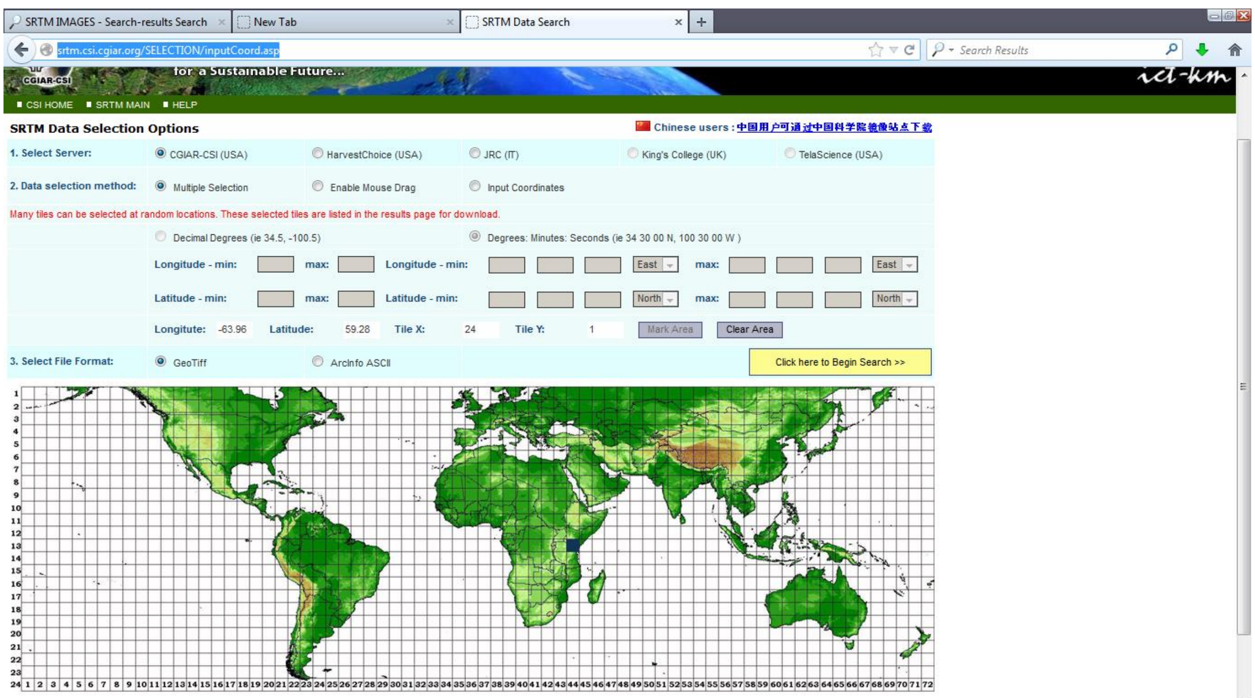

Figure 3.2: STRM data selection

Longitude 36.22 latitude -1.09

Tile x: 44 Tile y: 13

Selection server is CGIAR-CSI (USA)

The downloaded image is GEO TIFF

Data obtained here is in ARC GRID, ARC ASCII and Geotiff format, in decimal degrees and datum WGS84. They are derived from the USGS/NASA SRTM data. CIAT have processed this data to provide seamless continuous topography surfaces. (Jarvis A. et al)

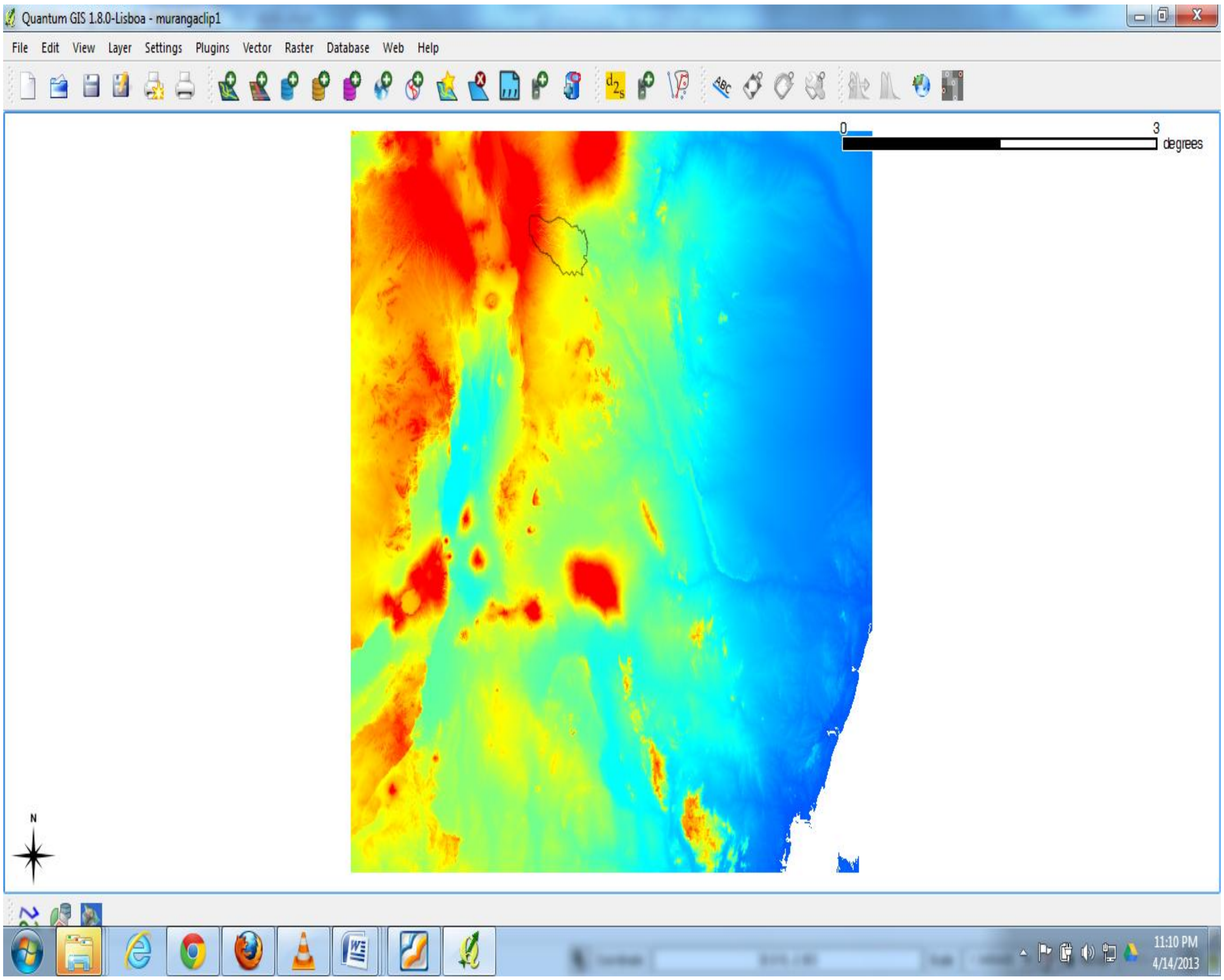

Figure 3.3, STRM Satellite picture

NB: note size Murang'a County at the top center of image marked by a boundary

3.9.1.1. Obtaining Satellite Data, Land sat 5 Tm, for the prescribe Murang'a county, this was obtained from USGS website http://www.usgs.gov/pubprod/aerial.html#aerial .This were obtained in two tiles, they were then merged ready for clipping of study area.

3.9.2. Obtained Branch location data from Murata Sacco.

After a visit to each Sacco branch, the following data is obtained

Information Gathered at Murata Branches

3.9.2.1. Branch Name

3.9.2.2. GPS location coordinates , Longitude and latitude

3.9.2.3. Branch altitude

3.9.2.4. Accuracy of the GPS coordinates

3.9.2.5. Ownership details to enable easy set up of Mast

3.9.2.6. Status of IT infrastructure, existence of local area net work

3.9.2.7. No of computers and operating systems

This is recorded in an excel worksheet for later transferred to a csv file for easy export to GIS database

3.10 Field Work Data

Table 3.2 Murata Sacco Branch Data

MURATA SACCO LOCATION AND NETWORK INFRASTRUCTURE DETAILS					
BRANCH NAME	HEAD OFFICE				
BUILDING OWNERSHIP	MURATA				
LOCATION					
LATITUDE	00°43´15.8"S				
LONGITUDE	37°09´26.7"E				
ALTITUDE	1344m				
ACCURCY	4m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	USES TOGETHER WITH MURANGA BRANCH		1	21	GOOD AND AVAILABLE
BRANCH NAME	KIRWARA				
BUILDING OWNERSHIP	MURATA				
LOCATION					
LATITUDE	00°55´41.7"S				
LONGITUDE	036°56´32.5"E				
ALTITUDE	1732m				
ACCURCY	2.1m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	7	GOOD AND AVAILABLE
BRANCH NAME	SABA SABA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°52´41.5"S				
LONGITUDE	037°08´18.1"E				
ALTITUDE	1424m				
ACCURCY	3.4m				

NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	NONE	4	GOOD AND AVAILABLE
BRANCH NAME	KANGARI				
BUILDING OWNERSHIP	MURATA				
LOCATION					
LATITUDE	00°52´41.5"S				
LONGITUDE	037°08´18.1"E				
ALTITUDE	2082m				
ACCURCY	9m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	NONE	8	NOT GOOD
BRANCH NAME	KIGUMO				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°48´0.84"S				
LONGITUDE	036°57´45.2"E				
ALTITUDE	1805m				
ACCURCY	9m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	8	GOOD AND AVAILABLE
BRANCH NAME	MARAGWA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°47´49.0"S				
LONGITUDE	037°07´47.3"E				
ALTITUDE	1367m				
ACCURCY	4m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK

CAT 5e	6U	SARIAN 4110	1	7	GOOD AND AVAILABLE
BRANCH NAME	MURANGA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°43´15.8"S				
LONGITUDE	037°09´26.7"E				
ALTITUDE	1344m				
ACCURCY	4m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	11	GOOD AND AVAILABLE
BRANCH NAME	KAHURO				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°44´54.4"S				
LONGITUDE	037°00´27.5"E				
ALTITUDE	1671m				
ACCURCY	3m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	4	NOT GOOD
BRANCH NAME	KAGUNDU-INI				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°53´28.0"S				
LONGITUDE	037°02´28.2"E				
ALTITUDE	1586m				
ACCURCY	9m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	NONE	5	NOT GOOD
BRANCH NAME	KANDARA				
BUILDING OWNERSHIP	RENTED				

LOCATION					
LATITUDE	00°53´49.1"S				
LONGITUDE	037°00´10.0"E				
ALTITUDE	1679m				
ACCURCY	5m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	9	GOOD AND AVAILABLE
BRANCH NAME	KAHATIA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°43´57.9"S				
LONGITUDE	036°56´39.3"E				
ALTITUDE	1880				
ACCURCY	5m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	NONE	5	GOOD AND AVAILABLE
BRANCH NAME	KAHUHIA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°42´46.2"S				
LONGITUDE	037°02´11.2"E				
ALTITUDE	1624m				
ACCURCY	8m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	4	NOT GOOD
BRANCH NAME	KANGEMA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°41´12.2"S				
LONGITUDE	036°58´18.5"E				
ALTITUDE	1791m				
ACCURCY	12m				

NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	6	GOOD AND AVAILABLE
BRANCH NAME	GITUGI				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	00°39´07.2"S				
LONGITUDE	037°01´17.2"E				
ALTITUDE	1715m				
ACCURCY	5m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	NONE	3	GOOD AND AVAILABLE
BRANCH NAME	KIRIA-INI				
BUILDING OWNERSHIP	MURATA				
LOCATION					
LATITUDE	00°36´08.4"S				
LONGITUDE	036°57´24.9"E				
ALTITUDE	1885m				
ACCURCY	2m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	8	GOOD AND AVAILABLE
BRANCH NAME	THIKA				
BUILDING OWNERSHIP	RENTED				
LOCATION					
LATITUDE	01°02´03.1"S				
LONGITUDE	037°04´29.6"E				
ALTITUDE	1510m				
ACCURCY	2.5m				
NETWORK TYPE	CABINET SIZE	ROUTER	SERVER	No. OF DESKTOPS AND LAPTOPS	LOCAL AREA NETWORK
CAT 5e	6U	SARIAN 4110	1	7	GOOD AND AVAILABLE

3.11 DEM Preparation

Analyzing and processing the obtained satellite images, create digital elevation model (DEM) of Murang'a County using QGIS.

Using the boundary shape file obtained from survey of Kenya, we were able to clip the DEM to our study region which is Murang'a County

We then added the GPS data we had already obtained from the field survey.

We then took various Topo maps sheets that had been obtained from survey of Kenya and merged those using Arc GIs and clipped to obtain our study region.

We then extracted contours and used them to create DEM; this was then overlaid on top of earlier DEM created using STRM for comparison. The locations of centers from top map and our GPS location were compared after overlaying on top of the other to verify the accuracy.

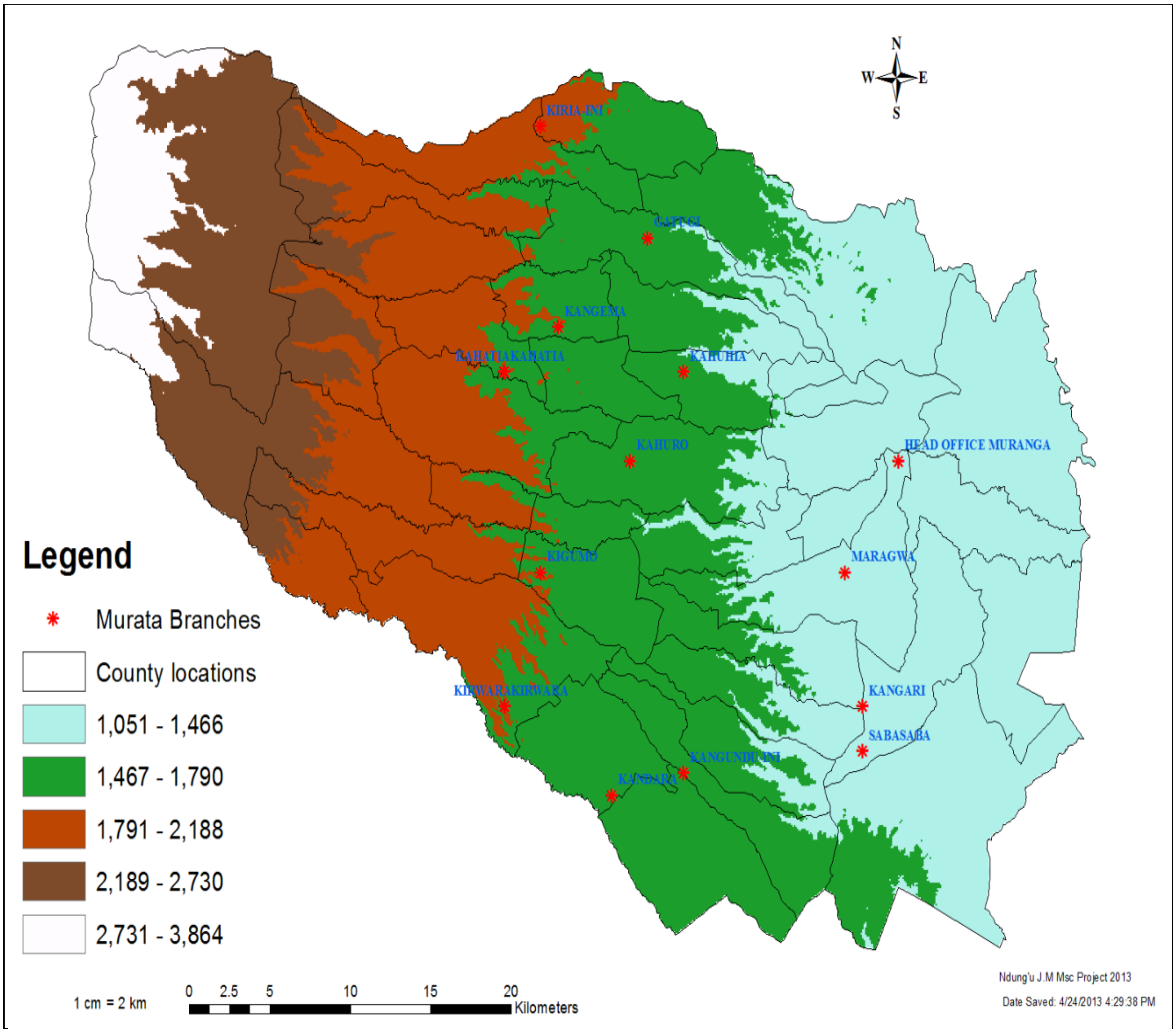

Figure 3.4 DEM Murang'a counties

All the centers are located between elevations of 1051m and 2188m above mean sea level. The head office is located at approximately 1210m above mean sea level while the closest center to the head office i.e. Maragua is approximately 1344m above mean sea level. The furthest center from the head office i.e. kiria-ini is approximately 1750m above mean sea level.

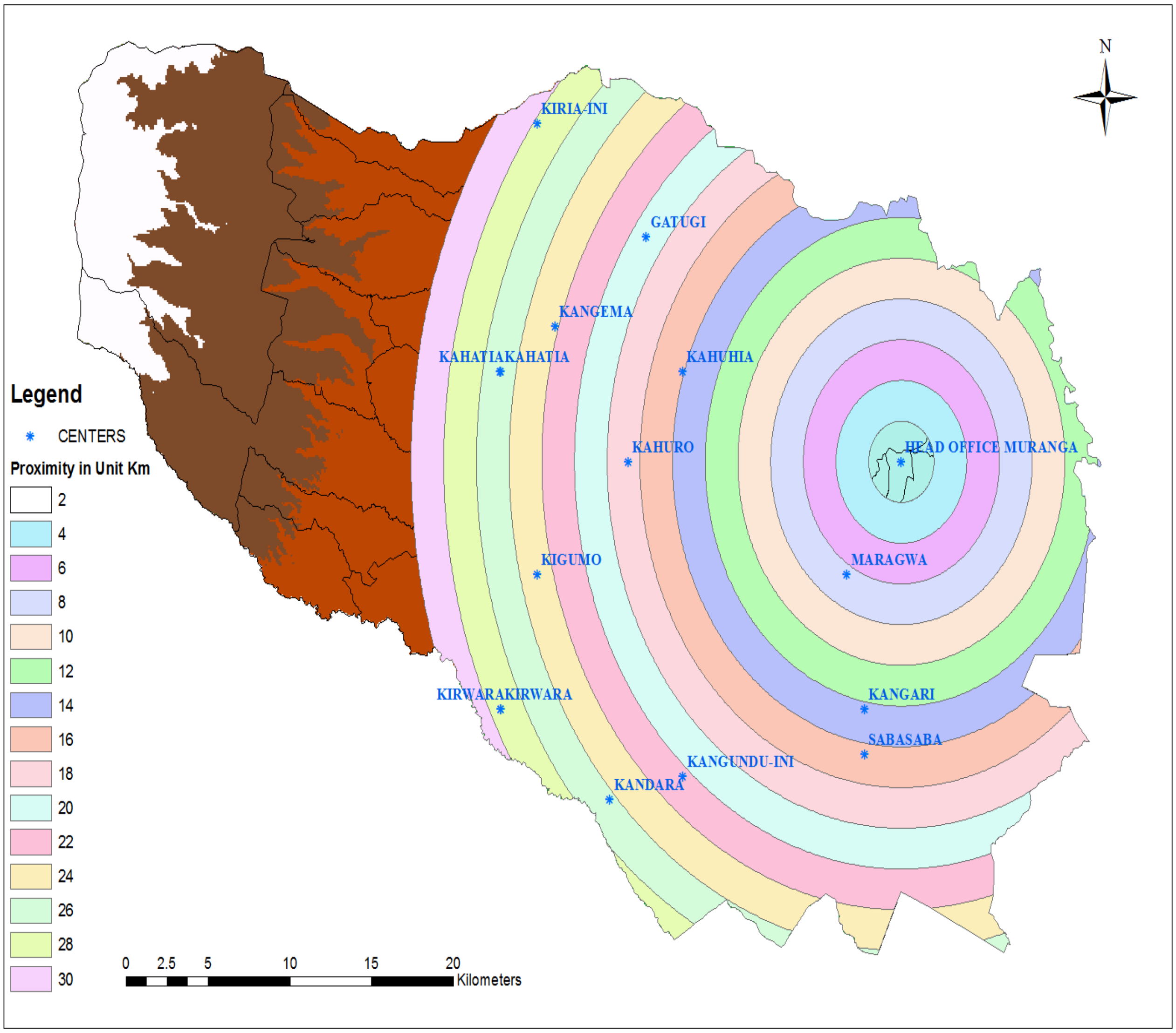

Figure 3.5: Proximity of Murata Branches

Using Arc-Gis we determined proximity of various branches to the head office, this assisted through visual analysis and distance apart, estimation of required wireless equipment and their transmission power capacity and antennae type required.

Chapter 4 : Results and Discussions

4.1 Terrain Analysis

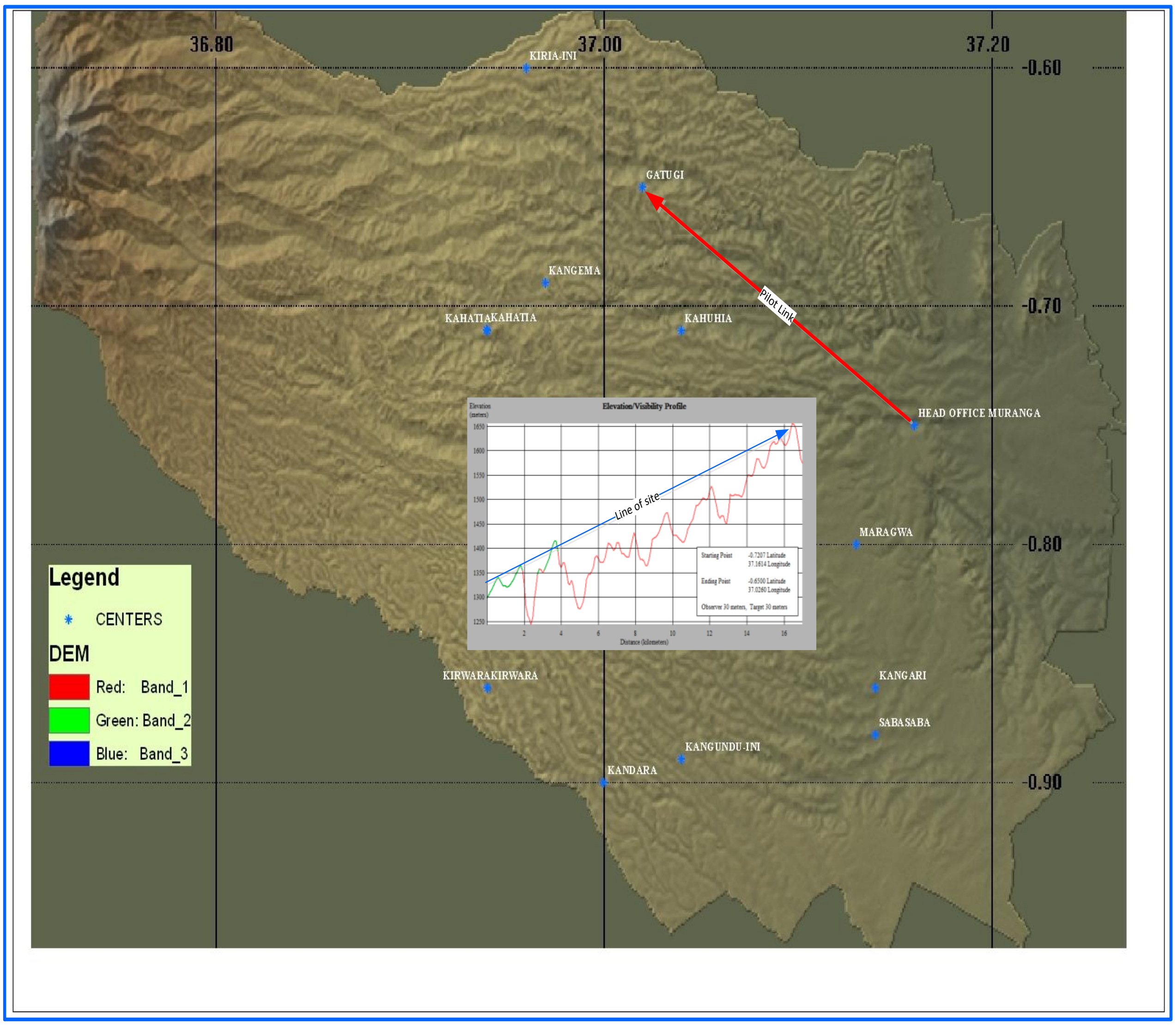

Figure 4.1 : 3Pilot Link

Proposed pilot link between murata Head office and Gatugi branch showing the orientation to one another, location on the map and profile of the elevation together with visibility using 3Dem software.

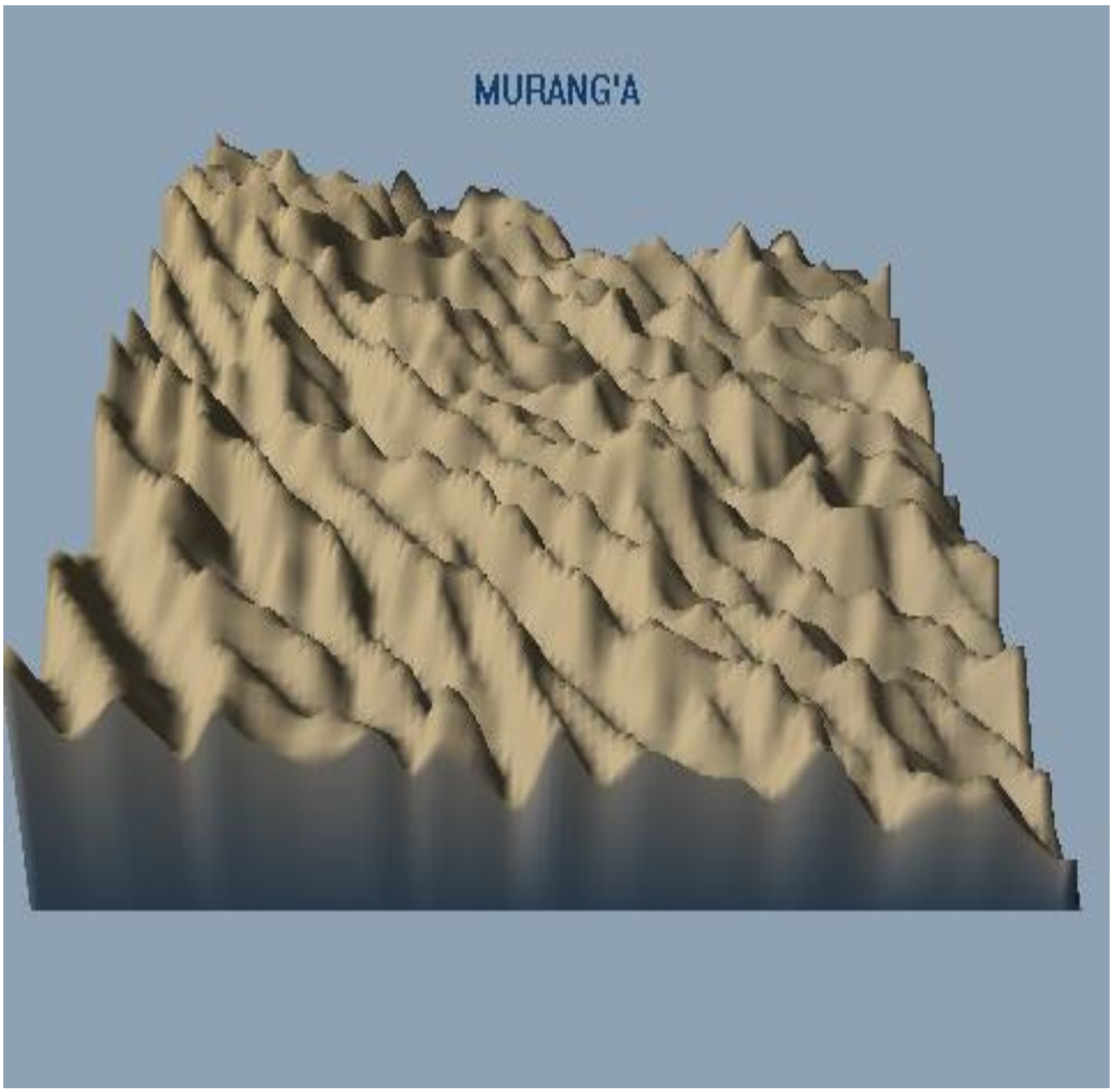

Figure 4.2: 3D terrain simulation

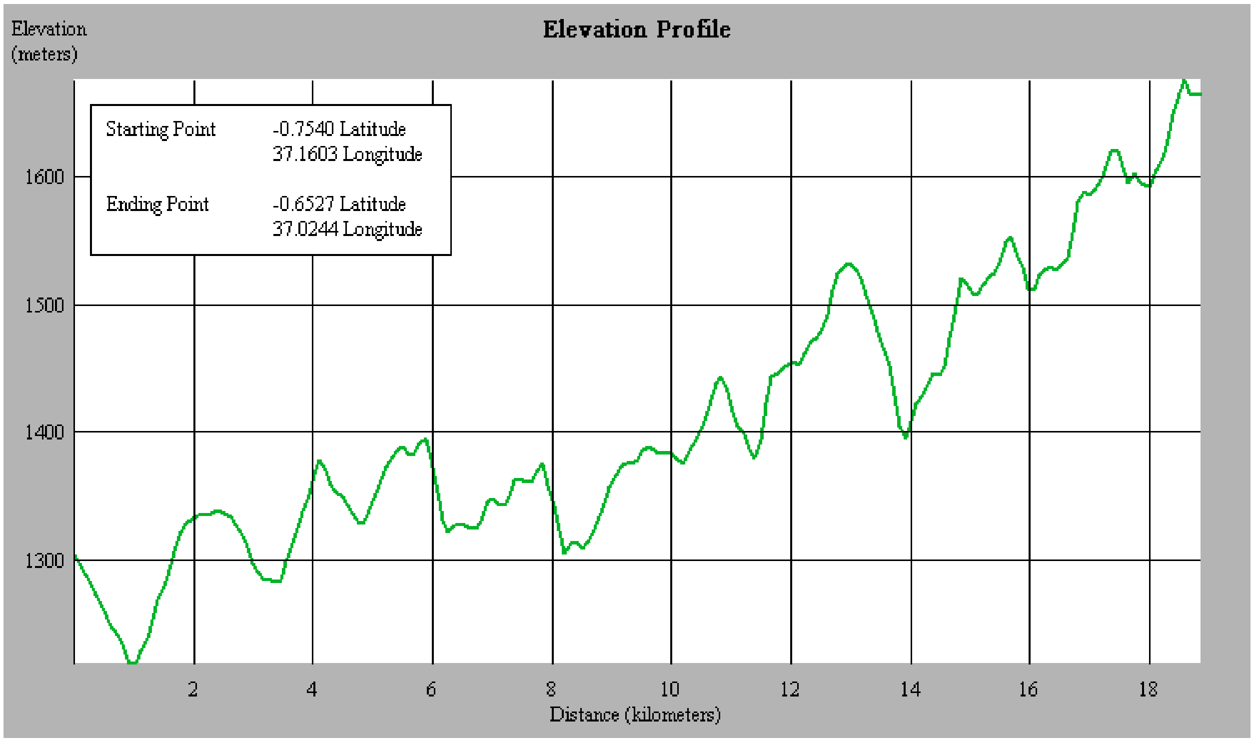

Figure 4.2: Elevation profile of Murata head office and Gatugi branch

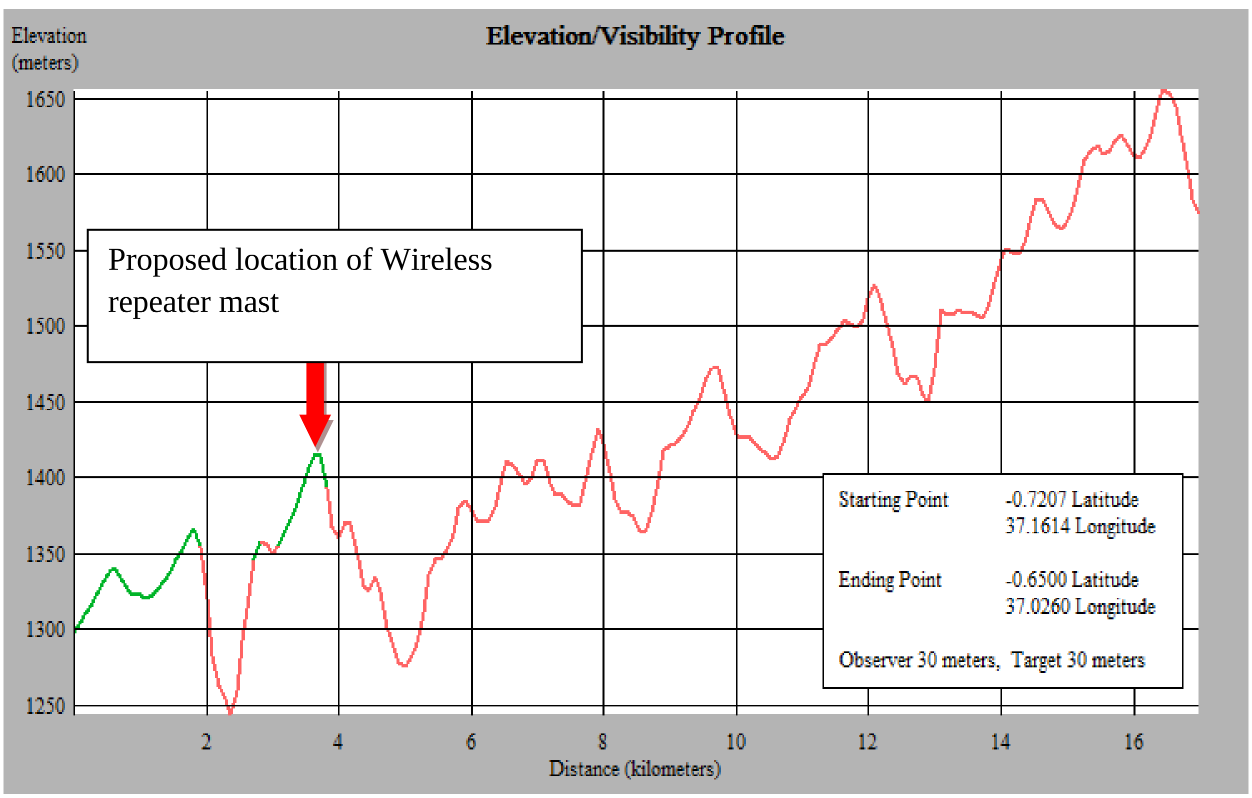

Figure 4.3: Repeater Mast location and Visibility profile

4.2 Visibility Analysis

There is no visibility between the two stations, the red shading colour on the terrain profile indicate where there is lack of visibility from the starting location – 0.7207 latitude and 37.1614 longitude to end point .

The green shading colour indicates area that will be covered by wireless signal.

From the initial elevation profile we are able to note distance where the signal coverage disappears, this is a proximately 3.7 km from Murang'a town, murata head office.

From this information and using our scaled map we are able to deduce that point and get the location coordinates. This will be the spot where we should put our mast 2. The Mast 1 is at the beginning which is murata head office.

We note the location the longitude and latitude of this point which is 3.7km on a straight line between murata head office and Gatugi using our map. This location is -0.7303 latitude and 37.1330 longitude

From this point Mast 2, we again repeat the procedure and try to obtain line of site profile together with elevation and visibility the 3DEM software between this point and Gatugi

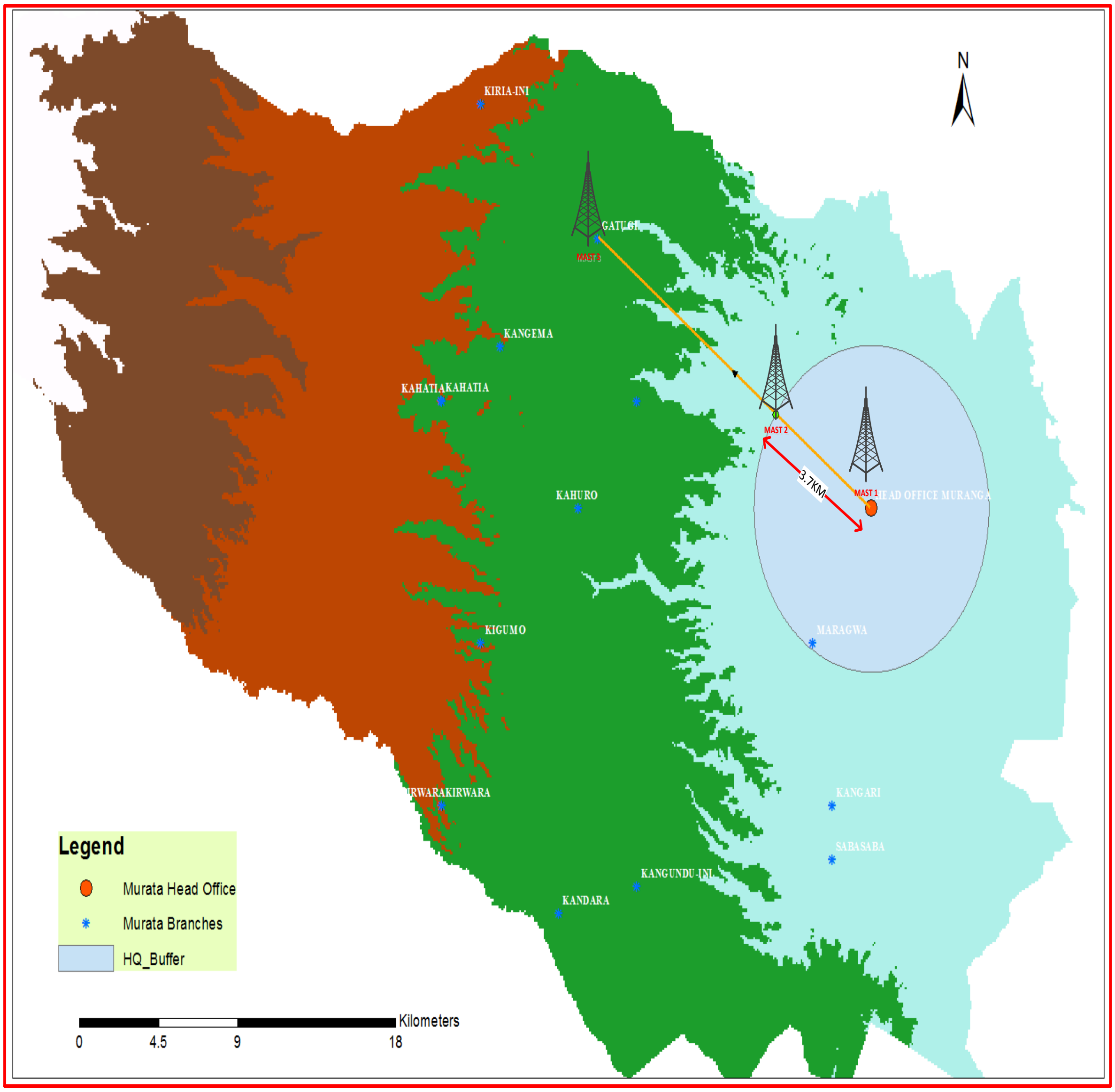

Figure 4.4: Location of Mast 2

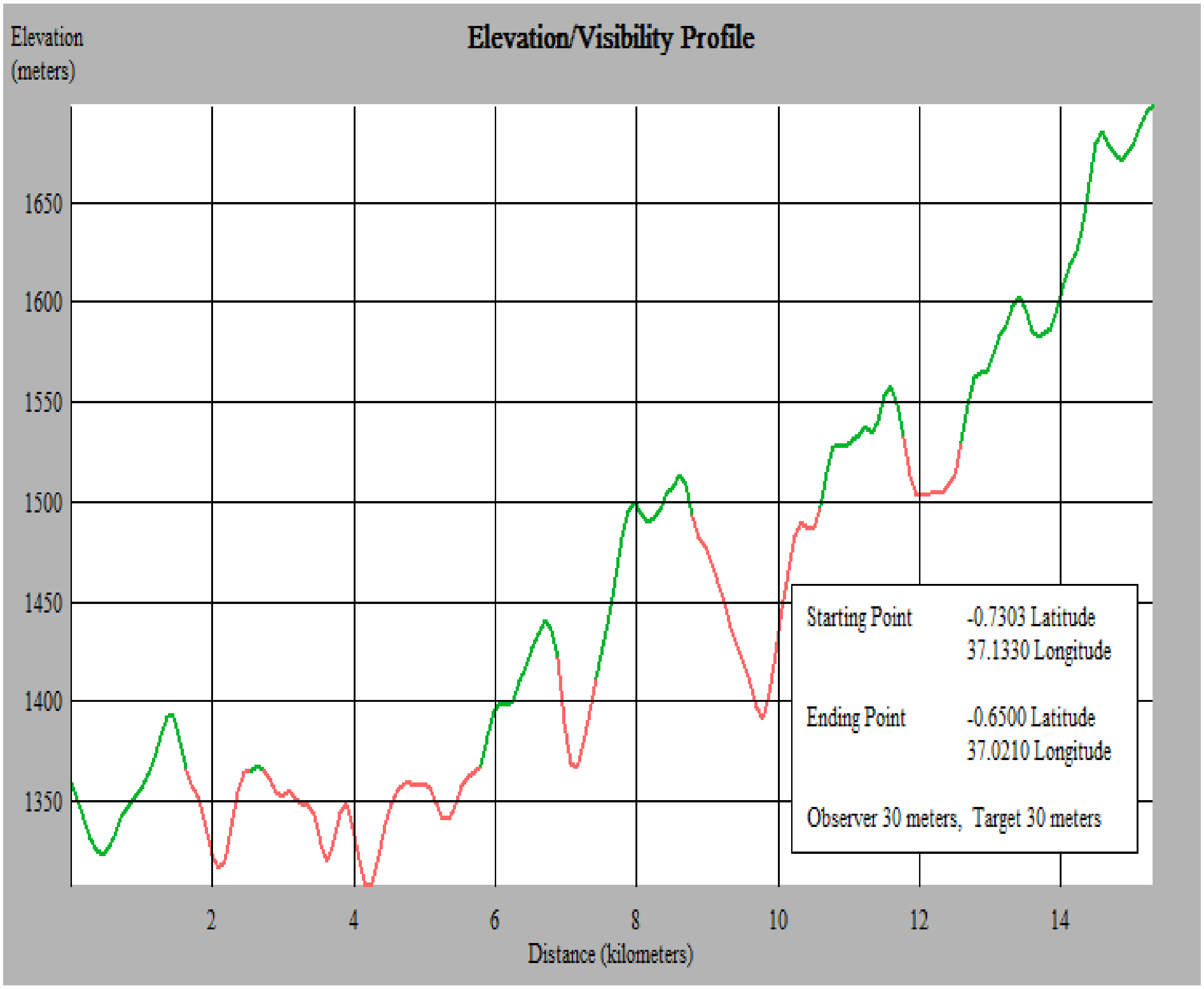

Figure 4.5 Mast2 to Gatugi visibility profile

4.3 Mast Location

Once a mast2 is set at location -0.7303 latitude and 37.1330 longitudes we are able to comfortably simulate straight line visibility to Gatugi using the 3DEM software and get a clear line of site.

From the simulated elevation/visibility profile we are able to see that there is clear visibility to the highest end point Gatugi location -0.6500 latitude and 37.0210 longitude. This is indicated by the green shading. We interpret this as a clear line of site from vantage point of mast 2 to Gatugi.

With this we conclude there is no need of any other mast in between for a repeater station.

This was then repeated to other branches surrounding Gatugi to determine suitability of this mast location, and confirm this was best overall position and route.

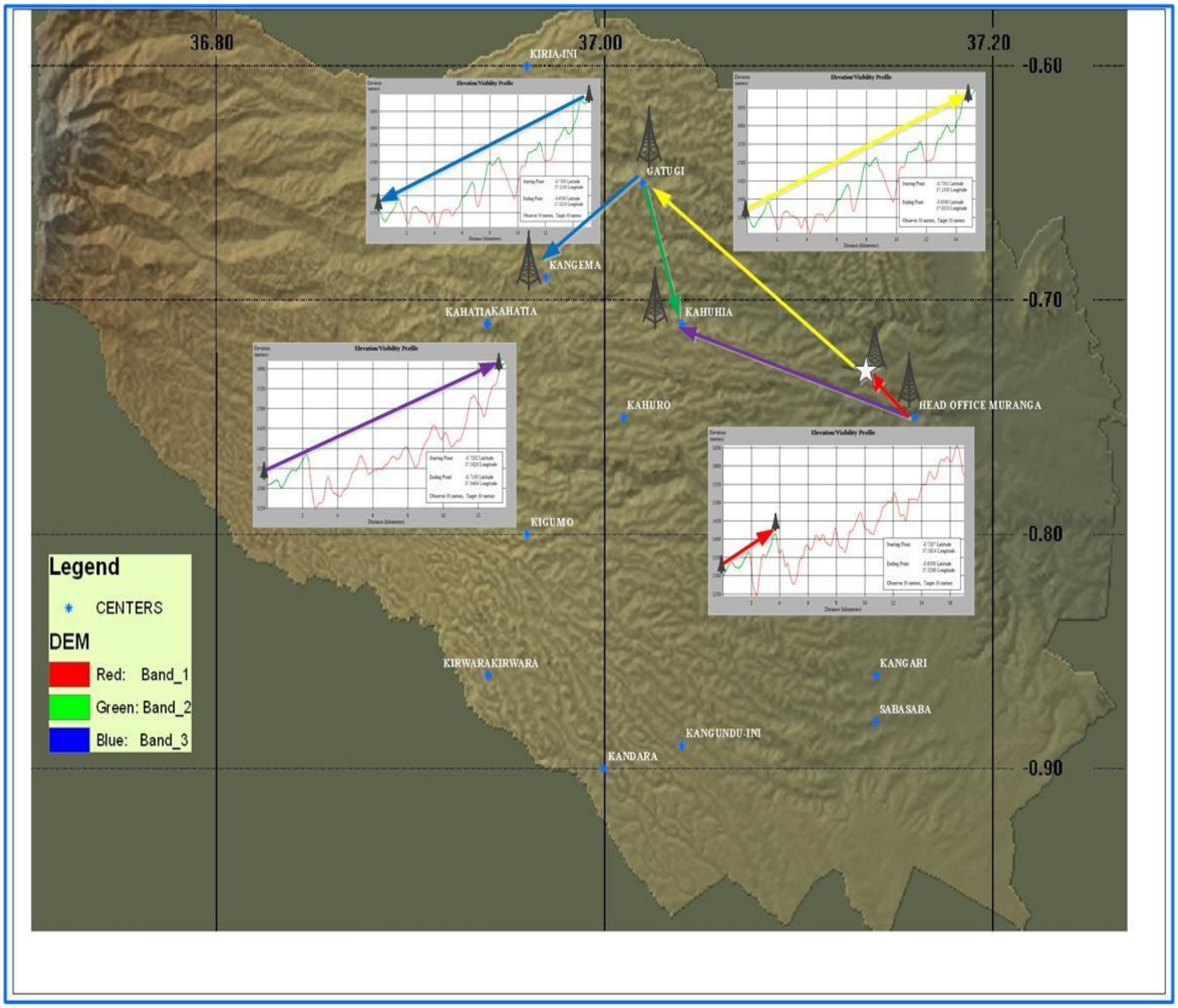

Figure 4.6: Summary line of Site profiles

4.4 Elevation/visibility profile of different links

Using 3Dem elevation and visibility analysis we are able to also quickly compare other sites surrounding Gatugi and Head office.

From graphical representation we conclude that it is advisable to establish a link to Gatugi then distribute the signal to kagema and kahuhia branches.

The profile of Head office to kahuhia shows that transmission along path though shorter might be problematic.

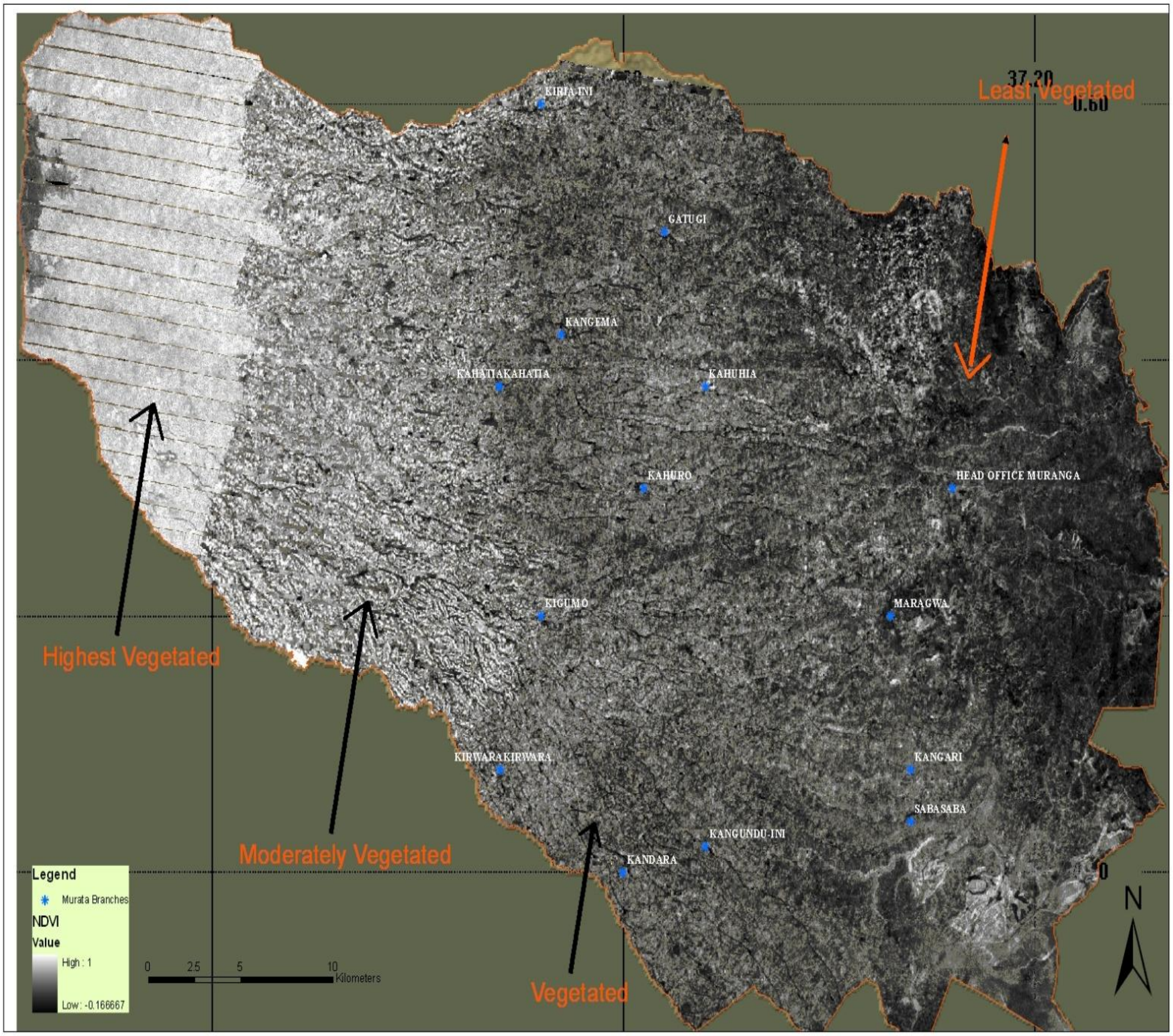

Figure 4.7 NDVI Analysis Murang'a County

4.5 Vegetation Cover Analysis

4.5.1 Normalized Difference Vegetation Index

The darker the area, the least the vegetation cover.

All the centers are located in vegetated and least vegetated zones forming of Murang'a County.

Vegetation may thus not be a very disturbing area to communication.

From the map the path to Gatugi from head office is in a region where the vegetation index is approaching zero, very dark coloration as indicated by the legend scale. This could imply very little effect from vegetation in the dry season however we must still consider effect of the available vegetation and especially in the wet season.

Figure 4.8: Vegetation in rainy season

From the photographic evidence most of vegetation in our study pilot link path is patches of plantation trees and crops forming a uniform blanket over the terrain with the highest trees being on average 15m height.

The effect of the vegetation plays a very important role in Radio frequency transmission, once the layout of terrain has been obtain we add the vegetation and building layer .depending on the resulting height of this layer we are able to recommend the height that the transmission and receiving mast should be.

To reduce the effect of vegetation on our link the transmitting mast and the receiving mast has to be set at a minimum of 30 meters above the ground.

Figure 4.9: Height of trees and vegetation

The effect of Building both for Murata Head office and Gatugi is negligible as the antenna mast will be located on top of this building. The surrounding buildings also do not have an effect as they are placed away from the line of transmission; however the height of proposed mast still takes into consideration buildings that might interfere or block line of site.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

Having set up to design and map up a wireless pilot link between murata Sacco head office in Murang'a town and Gatugi branch in Gatugi centre. The resultant finding indicate the process of using GIS is fairly simple and straight forward and produces better and realistic results .

However the main challenges is having expertise to use the GIS software to manipulate the various inputs such as satellite images creating DEM and in the interpretation of the obtained result.

The success of the wireless link connectivity is dependent on the accuracy of the deduced mast location which is in turn dependent on accuracy of the GPS coordinates that have been obtained during the site survey together with the accuracy of the tabulated digital elevation model. The 3DEM software will produce result depending on the input.

The line of site analysis using the digital elevation model that dominated our study is the main variable in setting up the wireless link, once this is established the other factors such as obstruction from vegetation and building, the distance apart and performance of radio equipment come into play.

The cost of this initial network design is more due to use of GIS but success rate is guaranteed and does not result to any repeat due to design flaws.

5.2 Recommendations

It has been observed that failure of the previous service providers was , the network design did not cater for a Geospatial modeled solution as such did not cater for challenges resulting from the mountainous terrain , sparse location , vegetation coverage , Electromagnetic transmission and dispersion during various seasons.

Design of Wide Area Network in Mountainous region like Murang'a should be done in two phases. Phase one should cater for the terrain and vegetation. The second phase caters for transmission of effect of radio waves catering for distance and transmission equipment. Available radio design software does not seem to work well in instances of extreme rugged terrain. However once the line of sight has been effectively established by use of GIS methods, then success of transmission is but guaranteed.

The success of establishment of mast catering for line of site in Murata head office to Gatugi pilot links enables to use same network to easily establish connectivity to the surrounding murata branches using same methods and principle.

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