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Title:

Analyzing Signal Area Valleys Using Geuoeraphic Information Systems

Case Study Elwady Elseed Village River Nile State

تحليل الاشارة في مناطق الوديان باستخدام نظم المعلومات الجغرافية
دراسة حالة قرية الوادي السعيد ولاية نهر النيل

A thesis submitted in partial fulfillment of the requirement of M.Sc Degree in Computer science

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Confirmation Letter Master's Thesis Abubakr Yousif Babiker Saad, GIS Batch 2

Dear Dean of the College of Computer Science SUST,

Herewith I confirm, that the SUST student Abubakr Yousif Babiker Saad has finished his Dissertation/Master's Thesis Project, entitled as:
"Analyzing Signal Area Valleys using GIS"
under my supervision. He will submit the Thesis and is ready for defense. I will be available for the defense on Skype.

With best regards

Prof. Dr. Dieter Fritsch
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الآيـة

قال تعالى:

بسم الله الرحمن الرحيم

﴿وَيسالونك عن الروح قل الروح من امر ربي وما اوتيتم من العلم الاقليلا﴾

صدق الله العظيم

سورة الاسراء الآية(85)

Dedication

I dedicate this humble work to my father, who gave me anything

And to my mother, who gave me affection and love

I say to them: You and you gave me life and hope and the emergence of a passion for knowledge and knowledge

My brothers and all my family

To my colleagues and colleagues

To every martyr

And then to everyone who taught me a character that has become a shining light to illuminate the road in front of me

Abstract

The usage of telecom services is now creating a new vista in the societal applications. Increasing expectation of cell phone users and the usage of Information and Communication Technology (ICT) enabled services via cell phones in the entire world. These have driven demands to service providers to expand their network coverage to all the places including rural areas like Elwady Elseed Village River Nile State. The strategic location of telecom towers can ensure efficient provision of telecom services in a cost efficient manner.

The primary aim of this work is to demonstrate the effectiveness of advancement of geospatial technology for identifying optimized locations of new telecom towers strategically and analyze the nature of (height – low levels) to the test area. Furthermore we want to investigate the impact of highs and lows that might eventually disrupt signals and the distribution of towers in terms of coverage using GIS techniques. The outcome reported here is quite encouraging; the final results show a clear and direct strong relationship between signal strength and the valleys area under study. In order to overcome the weak signal strength or lack of signal, we found that it is necessary to add a new tower in the following geographical coordinates: longitude 32.839110°, latitude 16.472122°. This amendment will ensure that a signal is provided throughout the study area which was proven by a Viewshed Spatial Analysis and Signal Coverage Analysis - both have been integrated effectively.

المستخلص

إن استخدام خدمات الاتصالات يخلق الآن نسخة جديدة في التطبيقات المجتمعية، زيادة توقعات مستخدمي الهواتف المحمولة واستخدام خدمات تكنولوجيا المعلومات والاتصالات من خلال الهواتف المحمولة في جميع أنحاء العالم وقد دفعت هذه المطالب لمقدمي الخدمات لتوسيع نطاق تغطية الشبكة الخاصة بهم إلى جميع الأماكن بما في ذلك المناطق الريفية مثل قرية الوادي السعيد ولاية نهر النيل، يمكن أن يضمن الموقع الاستراتيجي لأبراج الاتصالات توفير خدمات الاتصالات بكفاءة وبطريقة فعالة من حيث التكلفة.

الهدف الأساسي من هذا العمل هو إظهار فعالية التقدم في التكنولوجيا الجغرافية المكانية لتحديد المواقع المحسنة لأبراج الاتصالات الجديدة بشكل استراتيجي وتحليل طبيعة (الارتفاع - المستويات المنخفضة) إلى منطقة الاختبار وللتحقق من تأثير الارتفاعات والانخفاضات التي قد تعطل الإشارات في نهاية المطاف ، وتوزيع الأبراج من حيث التغطية باستخدام تقنيات نظم المعلومات الجغرافية.

اظهرت النتائج النهائية علاقة قوية واضحة ومباشرة بين قوة الإشارة ومنطقة الوديان قيد الدراسة، من أجل التغلب على ضعف قوة الإشارة ، وجدنا أنه من الضروري إضافة برج جديد في الإحداثيات الجغرافية التالية [خط الطول 32.839110 ° ، خط العرض 16.472122°]، يضمن هذا التعديل توفير إشارة قوية في جميع أنحاء منطقة الدراسة التي أثبتت من خلال تحليل الرؤية (التحليل المكاني) وتحليل التغطية الإشارية - وقد تم دمج كلاهما بفعالية.

Acronyms

Acronym	Meaning
ICT	Information and Communication Technology
GIS	Geographical Information System
SDSS	Spatial Decision Support System
UTM	Universal Transverse Mercator
RF	Radio Frequency
BSTs	Base Transceiver Stations
3D	3 Dimensional
GSM	Global System for Mobile Communications
PSTN	Public Switched Telephone Network
DEM	Digital Elevation Model
SCBS	Sudan Central Bureau of Statistics
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
GDEM	Global Digital Elevation Model
SRTM	Shuttle Radar Topography Mission
NTCS	National Telecommunications Corporation Sudan
GSD	Ground Sampling Distance
WGS84	World Geodetic System 1984
EGM96	Earth Gravitational Model 1996

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CHAPTER ONE
Introduction

CHAPTER ONE

Introduction

1.1 search Background

Telecommunications (or telecoms) and information technology are set to overtake the automotive sector in the line-up of the world's biggest industries. In recent years, deregulation has opened up the telecommunications market to new companies, putting pressure on existing organizations to become more efficient or losing customers. New technologies, such as fiber optic cables, more efficient terrestrial broadcasting, and satellites are offering increased bandwidth and therefore better services. This has made possible the transmission and reception of data from computer networks, TV programs, interactive video, and conventional telephone and fax communications at reduced costs. These changes have forced companies to redesign their networks and rethink their operational procedures. Many now face the dilemma of whether to extend existing copper networks to incorporate fiber and radio technology, or to build new infrastructures from scratch.

Customer expectations have risen as new firms have introduced additional services to the marketplace. These demands have forced the pace of change in the telecommunications industry. Creating and maintaining up-to-date records on network infrastructures, engineering works, buildings, transport routes, and customer accounts and address details, have become vital for survival.

By any measure, telecommunications is a big business The huge amount of outside plants, the many and varied communication links, and the need to attract and keep customers in a changing world are all significant reasons to use GIS technologies. Surprisingly, however, it is only in recent years that GIS has become widely accepted. Telecommunications companies are increasingly becoming very large users of GIS technology.

Today GIS is extensively used to plan, build, and operate telecommunication networks and associated services. The applications of GIS include activities such as planning transmission capacities, locating cellular telephone transmitters, and recording customer complaints [1], to name only few. GIS is now a standard technology applied throughout the telecoms industry.

The expansion of services depends on many factors, for instance, choosing the appropriate location of the tower, which depends on other factors, including the distance between the towers and the number of participants, their expected incomes in the coverage area and so forth.

This research aims to apply GIS techniques in the field of telecommunications to become familiar with the different information related to this field, such as coverage of the network signal towers, and to know the impact of geographical factors such as high lands and low lands and valleys areas, and how it does effect the broadcast of telecommunication signals in the Case Study Elwady Elseed Village.

1.2 Problem

Areas with mountainous or low terrains and valleys areas are lacking signals and have weak access to them. This affects outgoing and incoming phone calls and internet services, which is the biggest problem for many people.

1.3 Research Scope

Research is carried out in this study, just to test signal zones in terms of several height classes, to be compared with neighboring areas determining the amount of signal decline, which affects the process of receiving the signal from the towers in the area and its surroundings. Afterwards it is tried, to draw possible solutions that will help to solve this problem.

1.4 Research Objectives

- Study and analysis of a testbed with different geographical nature.
- Performance analysis and distribution of existing towers of the surrounding area under study.
- The impact of natural factors (mountains, low-land areas, valleys areas) on weakness or blocking the signal.
- Find a solution, that solves the absence of services and provide proposals and solutions to hand-over to professionals.

1.4 Research Questions

- What is the impact of a valleys areas chain for blocking the signal for the testbed area?
- Is the current distribution of towers in the testbed area considered optimal?
- What are the possible solutions to resolve problems in these areas in general?

1.5 Research Motivation

To overall goal of this research is overcome a region of non-coverage or weak signal by a detailed simulation study. By experiences in daily life can say, that communication amongst people has got a new quality, as dealing with various communication forms and in particular using the Internet, making the world a small village. Being blocked from this communication isolates, and therefore this research will help to overcome natural factors.

1.6 Research Methodology

First of all a literature review is carried out and related work using Geographic Information Systems in the field of telecommunications is presented. The next chapter deals with an analysis of the topography of the region, in particular in terms of heights above mean sea level and the know-how about the dependence of signal coverage and terrain parameters of the study area. This is to be compared with areas with strong signals. After wards, a suitable location is chosen for placing a new tower in the testbed area, which represents the best solution to problem. As simulation tools will Use ArcGIS and Google Earth.

1.7 Expected Results

The expected results of this research are to learn about the distribution of towers in the testbed area, especially those which are located properly and those which are placed in wrong locations. In order to get the appropriate location, taking into account the geographical nature, the wrongly placed towers should be redistributed with respect to the total area of the region (high &low-lands areas) and the option of expansion.

1.8 Research Organization

Chapter (1) represents the introduction, highlighting a brief history of telecommunications and its evolution, the methods of Geographic Information Systems, and their entry into the field of telecommunications. The literatures review and related work appears in chapter (2). Chapter (3) presents new ideas to be applied, followed by the methodologies implemented. Chapter (4) is a narrative of the region under study in terms of natural terrain parameters. Chapter (5) inserts the data of towers and the region under study to analyze and produce final results with some discussions. Chapter (6) conclusions and outlook.

CHAPTER TWO
Literature Review and Related Work

Literature Review and Related Work

2.1 Literature Review

2.1.1 Introduction

GIS provides specialized processing power for the acquisition, access, and analysis of geographic and spatially referenced data. GIS is the core of knowledge for a location-based service solution because it manages and serves data relative to the surrounding environment such as addresses, streets, areas of interest, risks, and hazards. Position tracking is a critical element in location-based services shown in figure (2.1). In a mobile environment, there are essentially two forms of location tracking automatic and manual. Automatic location tracking is a systematic process of the mobile device and the wireless network using either GPS/GNSS or cellular tower triangulation. Position tracking also includes radio-frequency identification and telemetry technologies. Telemetry provides an ability to track position as well as package data from I/O sources such as vehicle computer buses to monitor critical sensors including emergency lights and security systems. With millions of dollars being spent on building wireless communication systems, there is a significant incentive to develop engineering tools that can be used in the accurate and efficient designing and planning of such systems. As the wireless system grows to meet the increasing and changing demands for service [2].

Definition of a Geographical Information System: A computer based system for the acquisition and update, storage and query, analyses and simulation as well as output and presentation of spatial data [3].

GIS software systems link features on a map to descriptive information known as attribute data. This allows GIS users to simultaneously leverage both the visual advantages of a map and the data storage and retrieval advantages of a relational database. The old adage that “a picture is worth a thousand words” is very relevant in this context, as many organizations have substantial amounts of data in tabular form that, when displayed on a map, become much easier to understand and analyze. GIS allows users to answer spatial questions of location, proximity, and geographic distribution. As shown in figure (2.1), GIS represents multiple attributes of geographic space as a set of overlapping layers. Layers may be turned on or off, and new relationships between layers can be discovered, both through simple observation and through the application of advanced spatial analysis techniques [4].

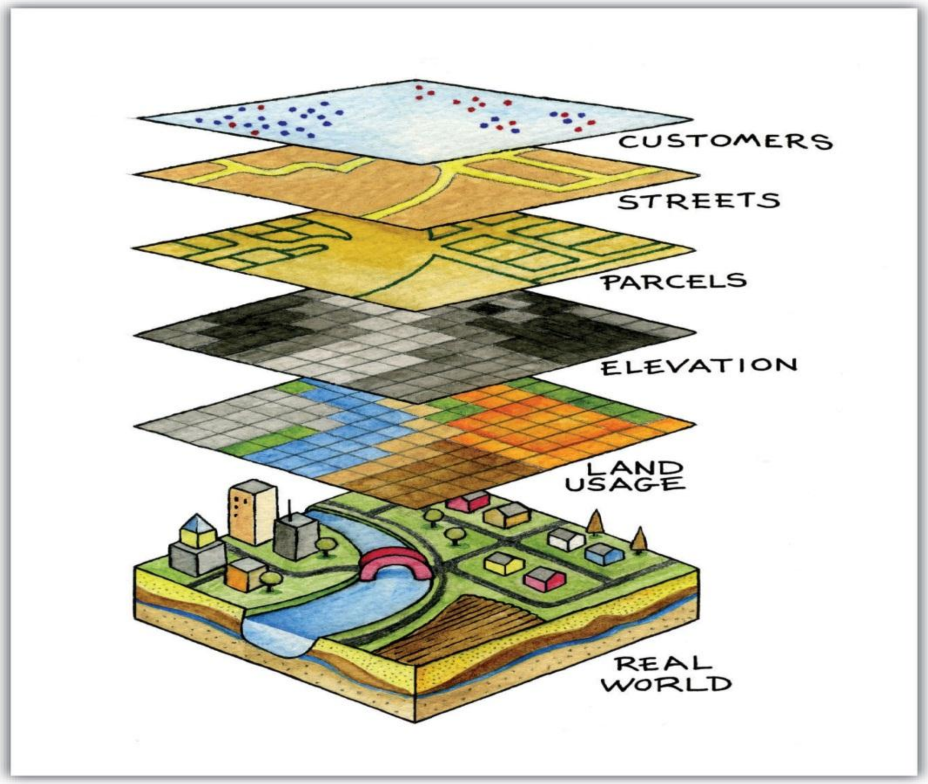


Figure 2.1: GIS Data Layers Example [13].

2.1.2 Role of Geographic Information System in Telecommunication

(GIS) as a tool will enable telecommunication professionals to integrate maps and information to make better decisions. There is a wide range of applications: from planning and maintaining network infrastructure to administering mobile telephone coverage, and managing existing customers. GIS users rely on location-based data to find the answers. GIS allows carriers to keep track of customer mobility and trends in the amazing bandwidth requirements driven by entertainment and internet services. Viewing information on a map makes it quicker and more intuitive than relying on spreadsheets and other tabular data shown in figure (2.2).

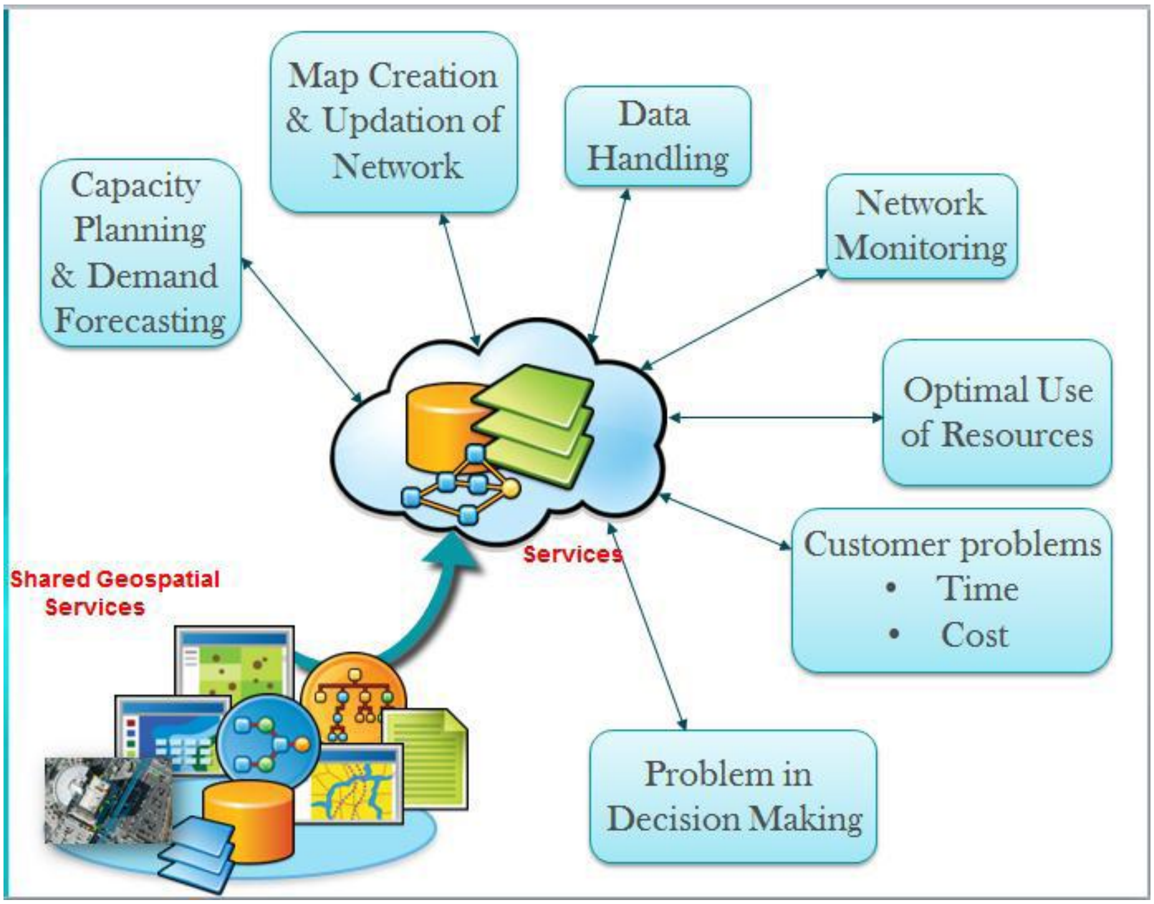


Figure 2.2: shared geospatial services [4].

Geographic Information Systems (GIS) have widespread application to many of the problems and activities of communities. And as this guide will demonstrate, GIS can serve as a powerful tool to inform policy decisions in this realm. This guide is intended to serve as a reference for those who are new to GIS, as well as those with some prior GIS experience that want to learn more about how to leverage it towards problems relating to community telecommunications. Community Telecommunications is a general term that refers to a wide range of activities that relate to the improvement of an area’s capacity for data transmission, such as [4]: Planning, Engineering and Management.

Solve many business problems of a telecommunications company requires a good understanding of where your network assets, facilities, and customers exist today and where they will be tomorrow. In an industry that changes so rapidly, the capability to find manage, and analyze data quickly and effectively makes a strategic difference.

Geographic Information System (GIS) is a technology that allows you to capture, manage, analyze, and display spatial data for use in solving complex problems.

GIS enables telecommunication professionals to integrate maps and information to make better decisions. From planning and maintaining network infrastructure to administering mobile telephone coverage, managing existing customers, and finding new ones, GIS users rely on location-based data to find the answers. GIS allows carriers to keep track of customer mobility and trends in the staggering bandwidth requirements driven by entertainment and Internet services. Viewing information on a map makes it quicker and more intuitive than relying on spreadsheets and other tabular data.

2.1.3 Base Transverse Station

A Base Transverse Station is a fixed station in a mobile radio system used for radio communication with mobile stations. Base stations are located at the center or on the edge of a coverage region and consist of radio channels and transmitter and receiver antennas mounted on a tower [5].

The Base Transverse Station (BTS) is one of the main units in the mobile communication system task. It represents the connection chain between the mobile station and the server, and it plays a major role for the completion of the process of communication between users. The towers locations (BTS) and its distributions have negative or positive effect on the active coverage power which affects the communication system [6]

2.1.4 Cellular Telephone Systems

A cellular telephone system provides a wireless connection to the Public Switched Telephone Network (PSTN) for any user location within the radio range of the system. Cellular systems accommodate a large number of users over a large geographic area, within a limited frequency spectrum. Cellular radio systems provide high quality service that is often comparable to that of the landline telephone systems. High capacity is achieved by limiting the coverage of each base station transmitter to a small geographic area called a cell so that the same radio channels may be reused by another base station located some distance away A sophisticated switching technique called "a handoff" enables a call to proceed uninterrupted when the user moves from one cell to another [6].

2.1.5 Geospatial technology for optimal site Selections

A number of studies have been reported for selection of optimal sites for development of infrastructure and other natural resources applications using geospatial techniques. Multicriteria spatial modeling enabled by spatial analysis is one of the most effective tools for the growth of a spatial decision support system (SDSS). It not only improves the management, analysis and presentation of any SDSS, but also supports spatial [7].

2.1.6 Signal Coverage Optimization

In telecommunications, the coverage of a radio station is the geographic area where the station can communicate. Broadcasters and telecommunications companies frequently produce coverage maps to indicate to users the station's intended service area. Coverage depends on several factors, such as orography (i.e. mountains) and buildings, technology, radio frequency and perhaps most importantly for two-way telecommunications the sensitivity and transmit efficiency of the consumer equipment. Some frequencies provide better regional coverage, while other frequencies penetrate better through obstacles, such as buildings in cities.

The algorithms currently employed in network optimization are extremely complex and computationally intensive. To achieve the study objectives in a fast and effective way, the problem was considered as a spatial analysis problem and the best locations for BTSs were determined in a two stage process, namely selecting the potential sites and determining the best locations using optimization [8].

2.2 Related Works

(**Haitham, et al., 2015 [2]):** The authors of this paper the real locations for 22 towers had been taken and these towers were distributed in 6 regions in the southern west side of Sulaimany city in Iraq, The process of studying the distribution of mobile communication tower with the help of GIS was the target of this paper, where the real locations of the towers belonging to the communication company were added to the GIS software. The re-distribution of the towers was accomplished by eliminating some towers and as further results the weak area and the Interference Region had been reduced in order to ensure maximum access of the active coverage area.

The software used is ArcGIS (Version 9.3)

The process of distribution, such as the optimization in the number of towers has several targets, in more detail:

Reduce the cost for the Communication Company; reduce environmental pollution and electromagnetic radiation, improving urban aesthetic of the City, minimizing the interference region between the towers, and improving the communication system tools by reducing the distances between the towers and the server.

(**Victor, et al., 2016 [7]):** The authors of this paper the technique of geospatial analysis and fuchsite analysis was used for the identification of undefended villages. Selections of suitable locations for communication towers have been presented. Finally an optimization of the number of new communication towers 78, 95, 115 and 121have been proposed.

The software used is ArcGIS (Version 10.1) with analysis tools: Viewshed.

(**Rakesh, et al., 2014 [8]):** The author of this paper is dealing with improving the coverage of the signal is dealing with improving the placed towers strategically to minimize the costs. The research aims to find a simple implementable algorithm which effectively determines the strategic positions of the cell towers. Given a satellite image and population density, and obtaining topographical information from GIS (Geographic Information Systems), potential tower locations can be determined. Applying the proposed three-stage algorithm, out of many potential tower locations only the indispensible and optimal locations can be chosen. In addition, this algorithm helps to find out the optimal height of the tower at a chosen potential tower location. Hence, the proposal will provide a cost-effective way for tower placement specifying their optimal position and height to cover area and population.

(Mohammed, 2016 [9]): Discussed in his research lack and weakness signals in the Kasingar Area in the Northern State as a solution to provide better services. After analyzing the nature of the ground and distribution of towers using GIS techniques, he got the relationship between the height and location of towers and added a new tower to coordinate [31 ° 54 ' 45.0828 "E-18 ° 35 ' N ' 48.7422] [31 ° 54 ' 45.0828" E-18 ° 35 ' N ' 48.7422] in order to provide a good signal in all regions.
The software used is ArcGIS Desktop 10.1 and Google Earth Pro v.4.2.0205.5730

(**Munene, et al., 2014 [10]):** The authors of this paper is dealing with improving the coverage of the signal and bearing in mind public buildings and facilities in terms of altitude and locations to suit the signal or the mobile network technology users protruding the third dimension (3D), and measuring the signal strength for the selection of suitable sites for the development of broadcast service devices.
The researchers found out, that wireless network planning is a complicated task for network engineers. The most important consideration, particularly at the beginning of the wireless network design process, is optimizing the radio signals' spatial coverage of the target area.

Dense urban environments characterized by high-rise buildings are particularly challenging to the network engineer owing to the numerous factors, which affect the signals and which must be modeled as accurately as possible. As demonstrated in this study, the 3D ray-tracing model, when used with 3D geodatabases of the target area, is the most accurate method of modeling signal coverage.

The location of BTSs plays a crucial role in ensuring optimal signal coverage. Thus in wireless network design the determination of the best BTS sites that offer optimal signal coverage is a very important consideration, which must be handled with utmost seriousness. This is particularly important due to the fact that setting up of a single BTS requires colossal amounts of money and thus elimination of any redundant BTS(s) would result in significant savings for the network operator.

Potential tower locations can be identified using a graphical representation of the surface. Using Geographic Information Systems (GIS) the satellite image/contour plots of the given area is converted into a Surface plot. A curve of the form $z = f(x,y)$ is obtained after this simulation, in which we can see that most of the population in this region is covered by the chosen towers. Here arbitrary values have been used, just to simulate the algorithm to illustrate its implementation

Chapter Three
Methodologies

Chapter Three
Methodologies

3.1 Overview

The main objective of this research is to study and analyze different geographical nature testing, performance analysis and distribution towers located in the surrounding area under study, the influence of natural factors (mountains and lowlands and valleys land areas) on weak or prevention of signals. We want to find a solution that solves the lack of services and submitting proposals and solutions for delivery to professionals.

We did use a set of programs and applications of GIS in the collection, sampling and processing, not only for considering the heights of the tested, but also to carry out an analysis of spatial and non-spatial data to come up with recommendations and results. This will help with the interpretation of lacking communication signals and the strong relationship between the force of reference and natural obstacles.

To achieve the research objectives there are several factors that must be considered

- First the distance - while we try to increase the signal strength or improving it, the communication networks in areas of abnormal terrain are first to be discussed using GIS techniques. e.g. the length between the transmitting and receiving station, has a direct correlation to setup requirements such as signal power and frequency.
- In addition to terrain parameters, this is a most crucial factor in our research and has a great influence in the outcome of our research, as this is a key variable and can be assessed with the help of GIS. Terrain also plays a major role, as it is the reference surface for existing installations and buildings. In particular, the following parameters have to be studied: roughness, slope, and aspect.

3.2 Procedures for Data Acquisition

- First, a user assessment study had been carried out to identify the user information needs. This was primarily concerned with telecommunication companies, their desire to effectively and efficiently provide communication services, and the citizens in the regions of weak signal coverage.

- Second, a data identification is involved determining the various datasets to be used in the analysis like boundary data, satellite imagery, elevation data etc.

- Third, data were collected from companies, relevant ministries, and other sources like the National Telecommunications Corporation Sudan (NTCS) [11].

- Forth, data collection and processing validating the information collected and then incorporating all available data in software, for map data processing and images analysis.

- Fifth, the analysis was carried out using mainly ArcGIS software and other software.

- Sixth, tabulation and display of results.

3.3 Research Methodology

Using a set of programs and applications of GIS, not only for considering the heights of the testbed, but also to carry out an analysis of spatial and non-spatial data to finally come up with recommendations and results. This will help with the interpretation of lacking communication signals and the strong relationship between the force of reference and natural obstacles.

Therefore we start with digital elevation models (DTMs) and contour maps as 2.5D references for the towers and the surrounding regions, to determine the extent of signal declines.

3.4 Methods Flow Diagram

The methodology used for carrying out the GIS research work is shown in figure (3.1).

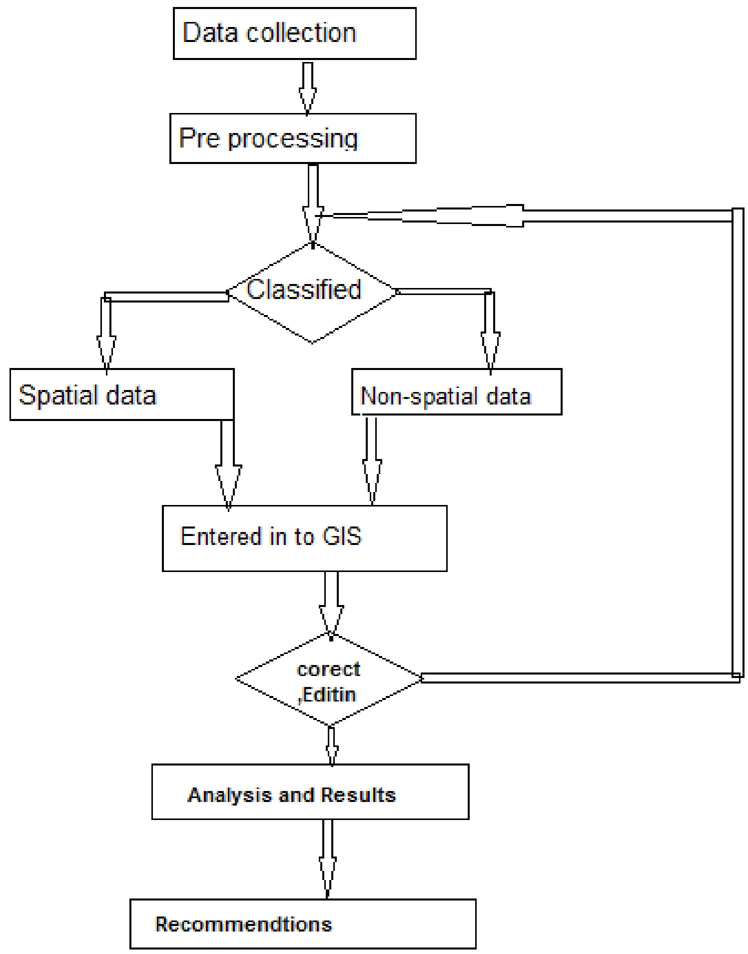


Figure 3.1: Methods Flow Diagram

3.5 Application and Tools

3.5.1 ArcGIS for Desktop

For this thesis, we are using ArcGIS Desktop 10.2, although ArcGIS Desktop 10.4 is the latest version of the popular GIS software produced by Esri [14]. ArcGIS Desktop allows for analyzing any kind of spatial and non-spatial data and to author geographic knowledge to examine relationships, test predictions, and ultimately make better decisions.

With ArcGIS extensions, you can do the following:

- Analyze data in a realistic perspective.
- Conduct advanced spatial analysis to get specific answers from data.
- Use advanced statistical tools to investigate the data.
- Perform complex routing, closest facility, and service area analysis.
- Reveal and analyze time-based patterns and trends.
- Represent and understand any network.

3.5.2 Google Earth

For this thesis, we are also using Google Earth Pro v. 7.1.2.2019 [15]. Google Earth displays satellite images of varying resolution in an more or less accurate manner of about 2-5m of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle (see also bird's eye view). The degree of resolution available is based somewhat on the points of interest and popularity, but most land (except for some islands) is covered in at least 15m resolution (GSD, Ground Sampling Distance). Google Earth allows users to search for addresses for some countries, enter coordinates, or simply use the mouse to browse to a location.

3.5.3 Viewshed (Spatial Analyst)

A Viewshed identifies the cells in an input raster that can be seen from one or more observation locations. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of 1. All cells that cannot see the observer point are given a value of 0. The observer points feature class can contain points or lines. The nodes and vertices of lines will be used as observation points [16].

Chapter Four
The Study Area Elwady Elseed

Chapter Four

The Study Area Elwady Elseed

4.1 Study Area

The Elwady Elseed village is one of the most important villages in the River Nile State in Sudan, located on the East Bank of the Nile off Wad Hamed and away from Khartoum city about 110 kilometers. The average elevation is about 374 feet above mean sea level (MSN).

Its coordinates are 16.468703°N 32.8426409° E (in decimal degrees). Its X 483300.93452834996 Y 1820639.7285369362 UTM position on the 36 N grid.

Agriculture is a source of income for the residents of Elwady Elseed village where farmers are cultivating beans of all kinds, chickpeas, lentils and potatoes in addition to vegetables such as onions and tomatoes etc. Moreover there is also a cultivated population of clover and other forage for sale in Khartoum market. 60% of the population is farmers besides other crafts and other trade and business. Many people migrated into the capital and outside Sudan, being doctors, engineers, university professors and others. The soil consists of the fragmented rock hard, where all processes of nature and chemicals as interspersed with seasonal valleys see figure (4.1).

The study area has a population of about 1603 persons, and the neighboring EMeria area has a population of about 1298 persons, using the projection of 2015, predicted from the last population survey in 2010, accomplished by the Population Bureau of Statistics (SCBS) [12] see Figure (4.2).

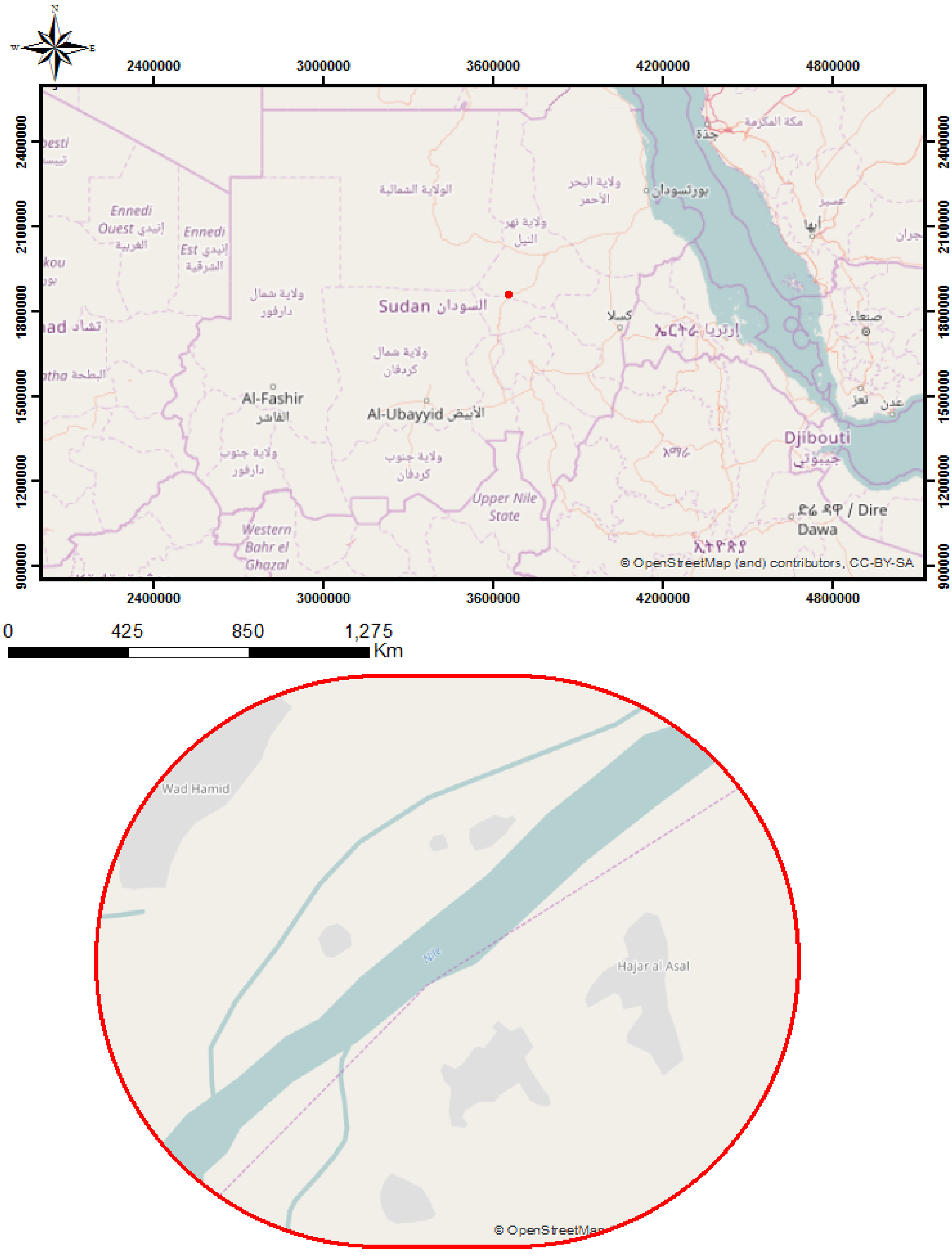


Figure 4.1: Study area

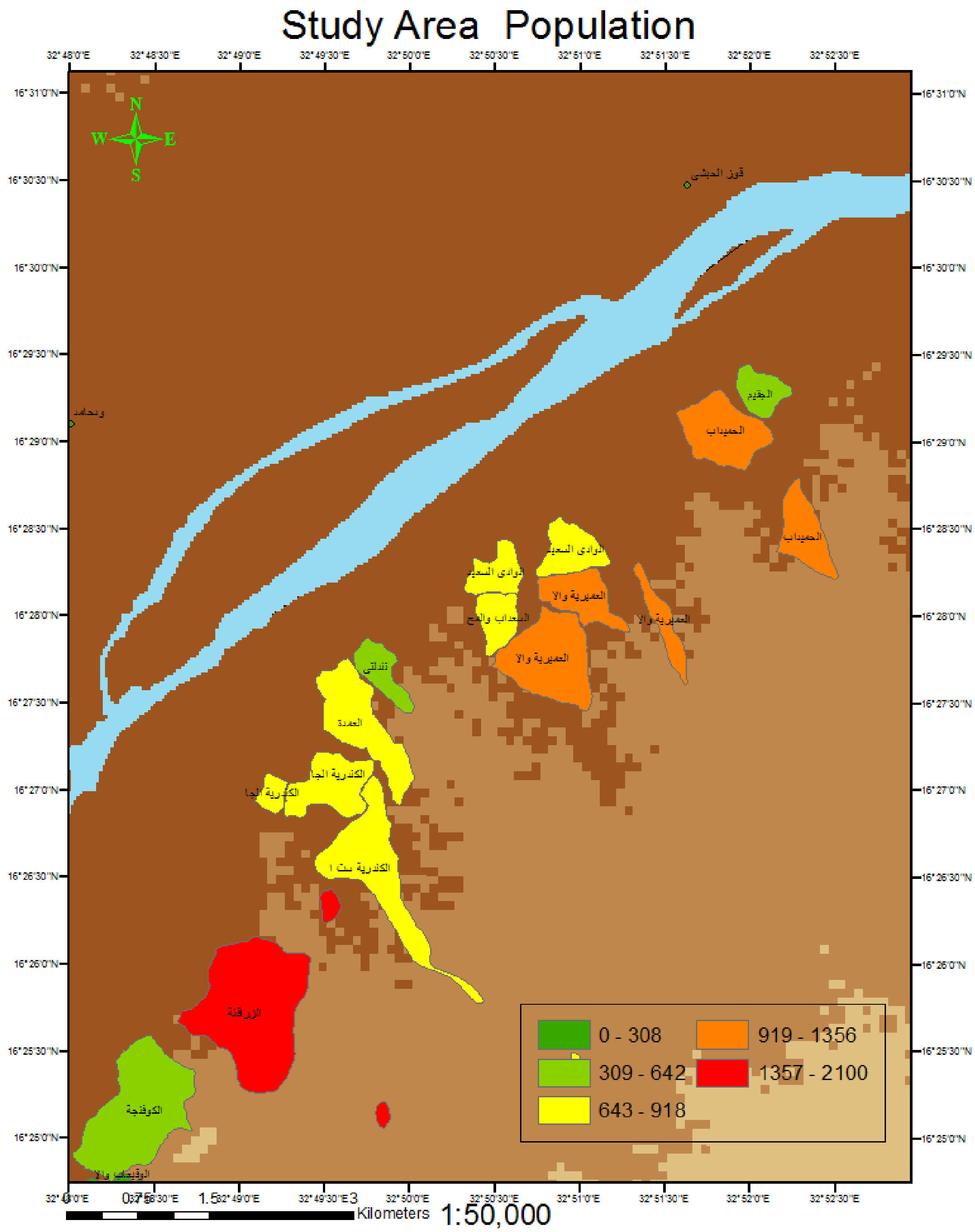


Figure 4.2: Study area Population

4.2 Data Collection:

The Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model ASTER GDEM covers land surfaces between 83N and 83S and is comprised of 22,702 1 x 1 tiles. Tiles that contain at least 0.01% land area are included. The ASTER GDEM is distributed as Georeferenced Tagged Image File Format (GeoTIFF) files, and in geographic coordinates (latitude, longitude). The data are posted on a 1 arc-second (approximately 30-m at the equator) grid and referenced to the 1984 World Geodetic System (WGS84)/1996 Earth Gravitational Model (EGM96) geoid[17] see figure (4.3).

Figure 4.3: Height class coded STRM satellite image

Chapter Five
Simulation and Analysis

Chapter Five
Simulation and Analysis

5.1 Overview

Using the ArcGIS software an interpretation of the DEM could be made. The DEM of the Nile State shows, that the study area is considered one of the villages – an area located at the minimum altitude, where the blue color indicates the boundaries of the testbed, see figure (5.1).

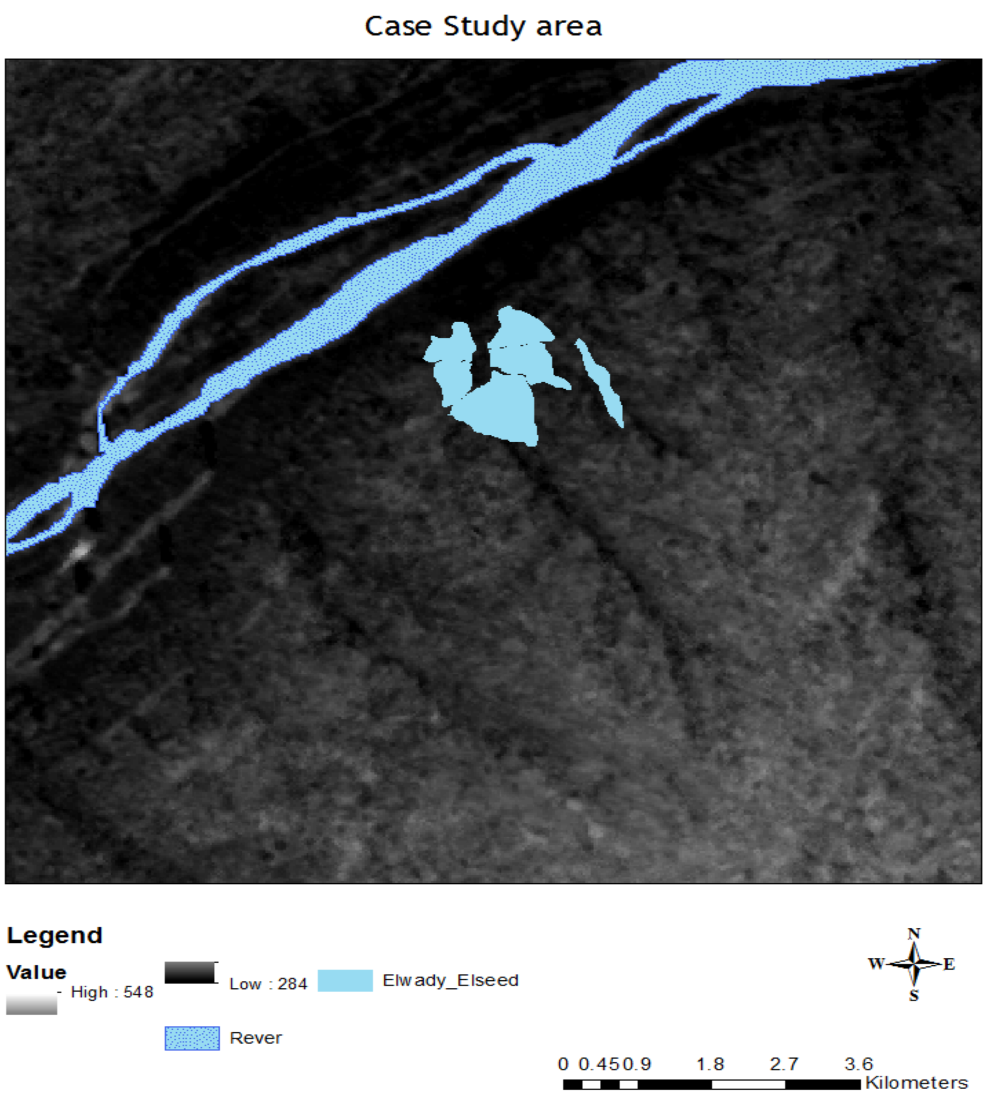


Figure 5.1: DEM of the study area

5.2 Analysis and Results

5.2.1 Towers Distribution

The numbers of towers that are found near the study area vary in terms of ownership or subordination to the companies working in the field of communications. In Sudan this is limited to the three companies Zain, MTN, and Sudani. In order to not mentioning names we used the aliases to symbolize each company and each tower, as shown in table [5.1].

Company	LATITUDE	LONGITUDE	Technology	Power
S	16.503419	32.917873	GSM	49
M	16.403059	32.79462	GSM	49
Z	16.496948	32.810188	GSM	49

Table 5.1: Summary of Telecommunication Towers

There are a number of communication towers in the area that have been excluded, the towers that do not cover the area, and the routed connection towers along the Tahadi road as shown in table [5.2].

SiteID	Power	Technology	Sector_Hei	Longitude	Latitude
1970	49	GSM	75	32.79462	16.40306
2089	49	GSM	75	32.81019	16.49695
2089	49	GSM	75	32.81019	16.49695
2124	49	GSM	75	32.91787	16.50342
72748	49	3G	75	32.91989	16.45103
41103	49	3G	75	32.93089	16.46811
26192	49	3G	75	32.95301	16.47391
26171	49	3G	75	32.79639	16.41034

Table 5.2: All Telecommunication Towers

5.2.2 Towers Coverage Analysis

We are using Google Earth in order to calculate many processes, such as the distance between each tower and the study area (Elwady Elseed), to calculate the height of towers above sea level, compared with the study area as follows, and ArcMap.

5.2.3 Distance between the Towers and the Study Area

Distance is a very influential factor in the strength of the signal, so that the more we move away from the tower, the more the existence of other natural barriers, which represent essential factors in the non-arrival of the signal or decline, can be identified. Thus the distance between the study area and each tower in an accuracy of about 2-5m had calculated using Google Earth following [15] and as shown in table [5.3] and figure (5.2).

Company	LATITUDE	LONGITUDE	Technology	Distance
S	16.503419	32.917873	GSM	8.84km
M	16.403059	32.79462	GSM	8.90km
Z	16.496948	32.810188	GSM	4.80km

Table 5.3 Distance between the towers and the study area

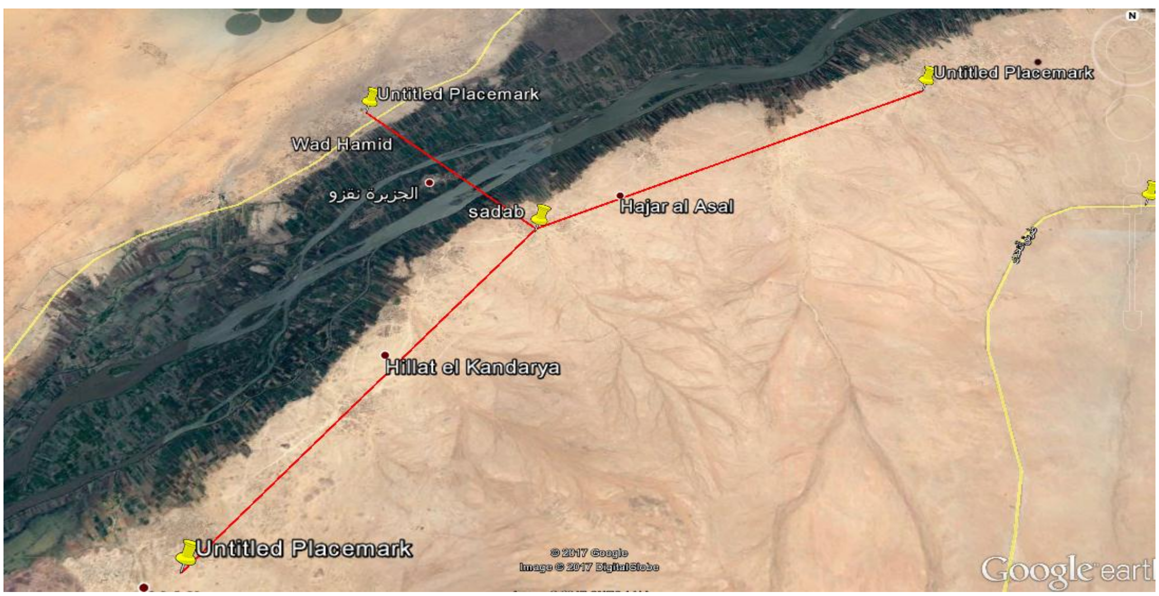


Figure 5.2: Map of the study area using Google Earth

5.2.4 GSM Signal Levels

When a signal is transmitted, we know from experience that this signal is meeting many obstacles affecting the speed and strength. These factors can be man-made infrastructures and natural phenomenas decreasing the signal strength, the more we move away from the tower. For this reason we introduce a classification for the signal level, as shown in table [5.4] and outlined in figure (5.3).

Level	Quality	Coverage
1	Strong	>=6Km
2	Good	>=8Km
3	Week	< 12Km

Table 5.4:GSM Signal coverage levels (standard)

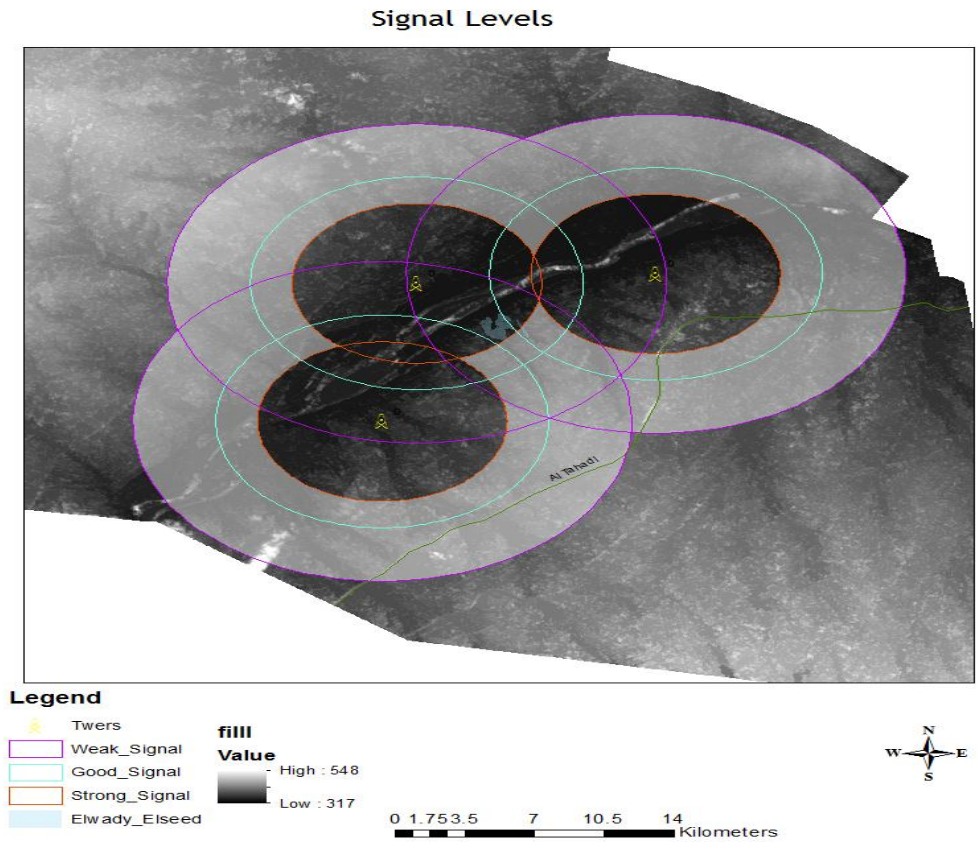


Figure 5.3: Distribution of Towers & Coverage by Level

5.3 Viewshed Tool

Viewshed identifies the cells in an input raster that can be seen from one or more observation locations. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of 1. All cells that cannot see the observer point are given a value of 0. The observer points feature class can contain points or lines. The nodes and vertices of lines will be used as observation points.

The Viewshed tool creates a raster, recording the number of times each area can be seen from the input point or polyline observer feature locations. This value is recorded in the VALUE item in the table of the output raster. All cell locations assigned NoData on the input raster are assigned NoData on the output raster.

5.3.1 Controlling the Visibility Analysis

It is possible to limit the region of the raster inspected by specifying various items in the feature attribute dataset, such as observation point elevation values, vertical offsets, horizontal and vertical scanning angles, and scanning distances. There are nine items in total: SPOT, OFFSETA, OFFSETB, AZIMUTH1, AZIMUTH2, VERT1, VERT2, RADIUS1, and RADIUS2, see figure (5.4).

The image below graphically depicts how a visibility analysis is controlled. The observation point is on the mountain top to the left (at OF1 in the image). The direction of the viewshed is within the cone looking to the right. You can control how much to offset the observation point (for example, the height of the tower), the direction to look, and how high and low to look from the horizon [18].

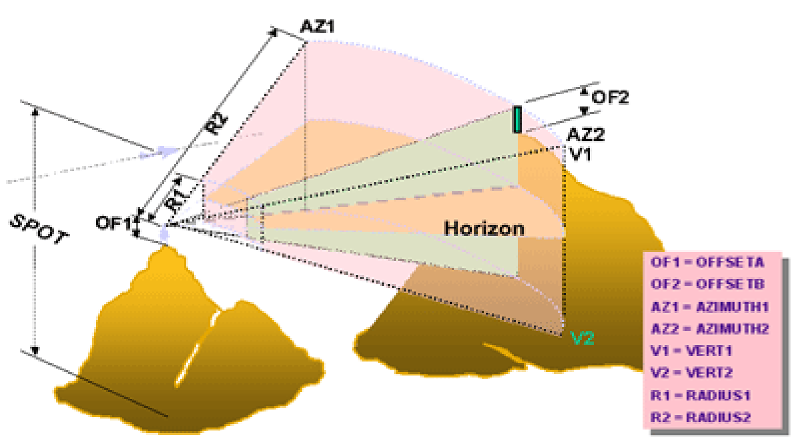


Figure 5.4: Parameters for controlling the Viewshed Analysis [18].

When the observer features dataset is a point feature class, each observation point can have a unique set of observation constraints in the attribute table. When it is a polyline feature class, every vertex along an input polyline uses the same observation constraints contained in the polyline's record in the attribute table.

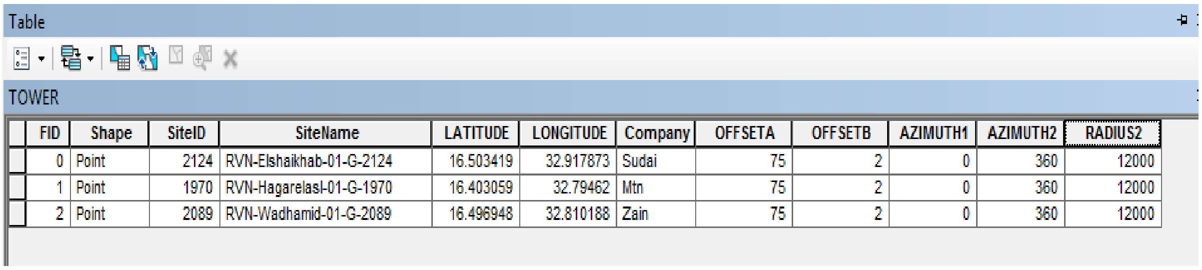
The definitions for these items can vary as long as they are numeric. Whenever an item does not exist, the default values are applied.

5.3.2 Default settings

The following table shows the default settings for the options that control the visibility analysis:

Option	Default setting
SPOT	Estimated using bilinear interpolation
OFFSETA	1
OFFSETB	0
AZIMUTH1	0
AZIMUTH2	360
VERT1	90
VERT2	-90
RADIUS1	0
RADIUS2	Infinity

Adding fields such as OFFSETA and OFFSETB allows you to customize the transmitter antenna/tower height and receiver antenna/tower height, respectively. The azimuth of the antenna can be changed by adding two new fields, AZIMUTH1 and AZIMUTH2, and formulate them to represent the starting and ending angles, respectively. These fields are added directly to the observer point feature class before the Viewshed algorithm is run [18]. An ArcGIS Table with the Viewshed parameters is given in figure (5.5).



Table

TOWER

FID	Shape	SiteID	SiteName	LATITUDE	LONGITUDE	Company	OFFSETA	OFFSETB	AZIMUTH1	AZIMUTH2	RADIUS2
0	Point	2124	RVN-Elshaikhab-01-G-2124	16.503419	32.917873	Sudai	75	2	0	360	12000
1	Point	1970	RVN-Hagarelasl-01-G-1970	16.403059	32.79462	Mtn	75	2	0	360	12000
2	Point	2089	RVN-Wadhamid-01-G-2089	16.496948	32.810188	Zain	75	2	0	360	12000

Figure 5.5: Attribute Viewshed Tool [18].

5.3.3 Tower M Coverage Analysis

The study area of Tower M is located in the weak signal range at 8.90 km. After the modification of parameters for controlling the viewshed analysis and applied, we find that a large number of regions are not reached by the signal sent from the transmitter, see figure (5.6).

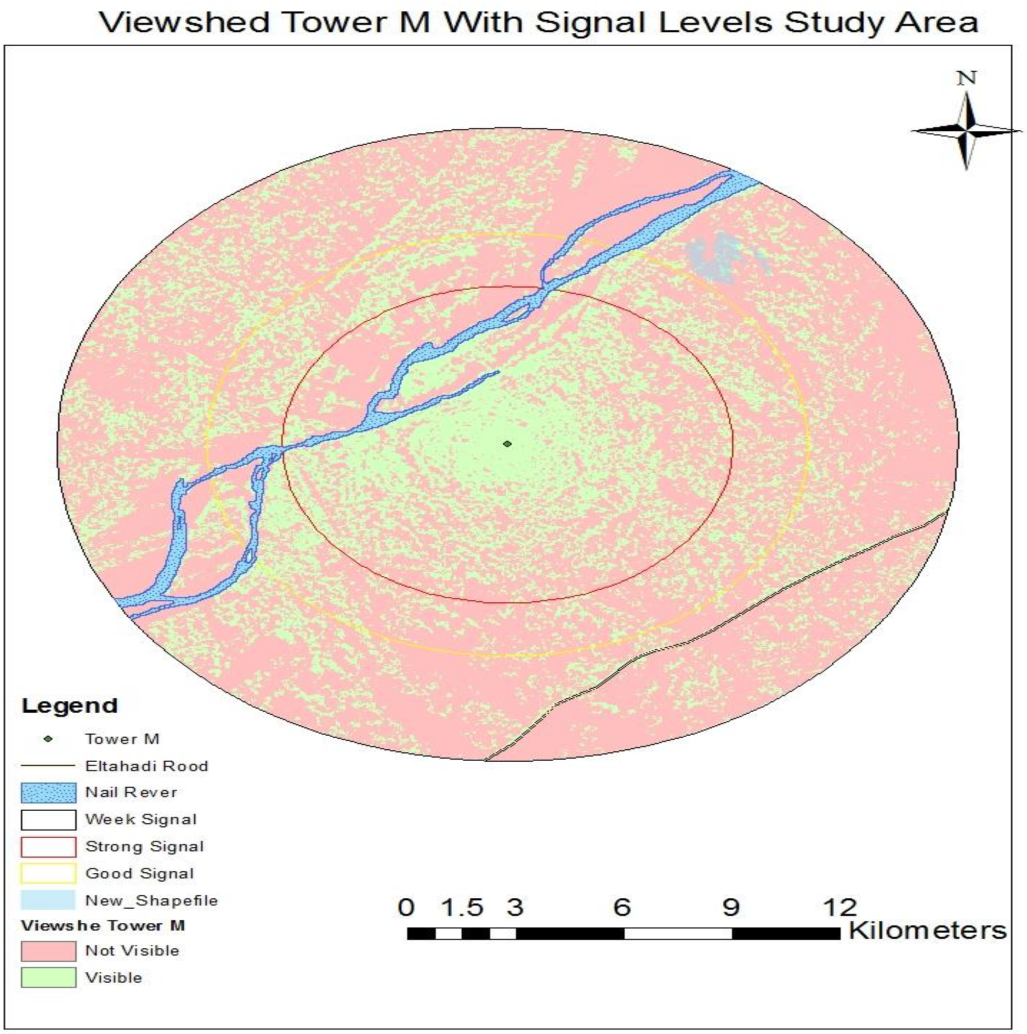


Figure 5.6: Tower M Coverage with Viewshed Analysis

5.3.4 Tower S coverage analysis

The study area of Tower S is located in the weak signal range at 8.84 km. After the modification of parameters for controlling the viewshed analysis and applied, we find that a large number of regions are not reached by the signal sent from the transmitter, see figure (5.7).

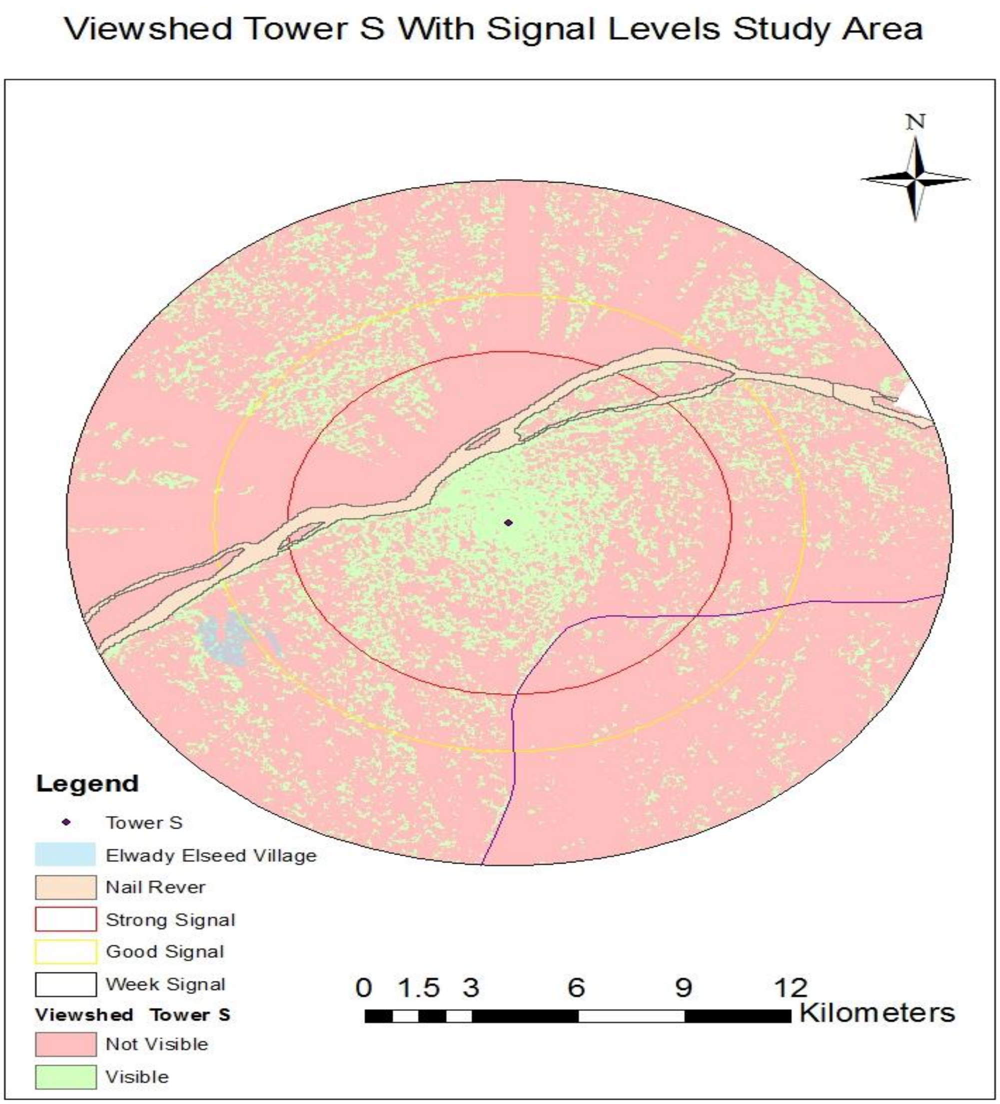


Figure 5.7: Tower S Coverage with Viewshed Analysis

5.3.5 Tower Z Coverage Analysis

The study area of Tower Z is located in the strong signal range at 4.80 KM, Although the location of the tower after the Nile in the north-west and the area of study is within the scope of the strong signal, it seems that the river is a barrier to the signal and reflected on the surface of the water. After the modification of parameters for controlling the viewshed analysis and applied, we find that a large number of regions are not reached by the signal from the transmitter see Figure 5.8. The Viewshed to all towers can be seen in figure (5.9).

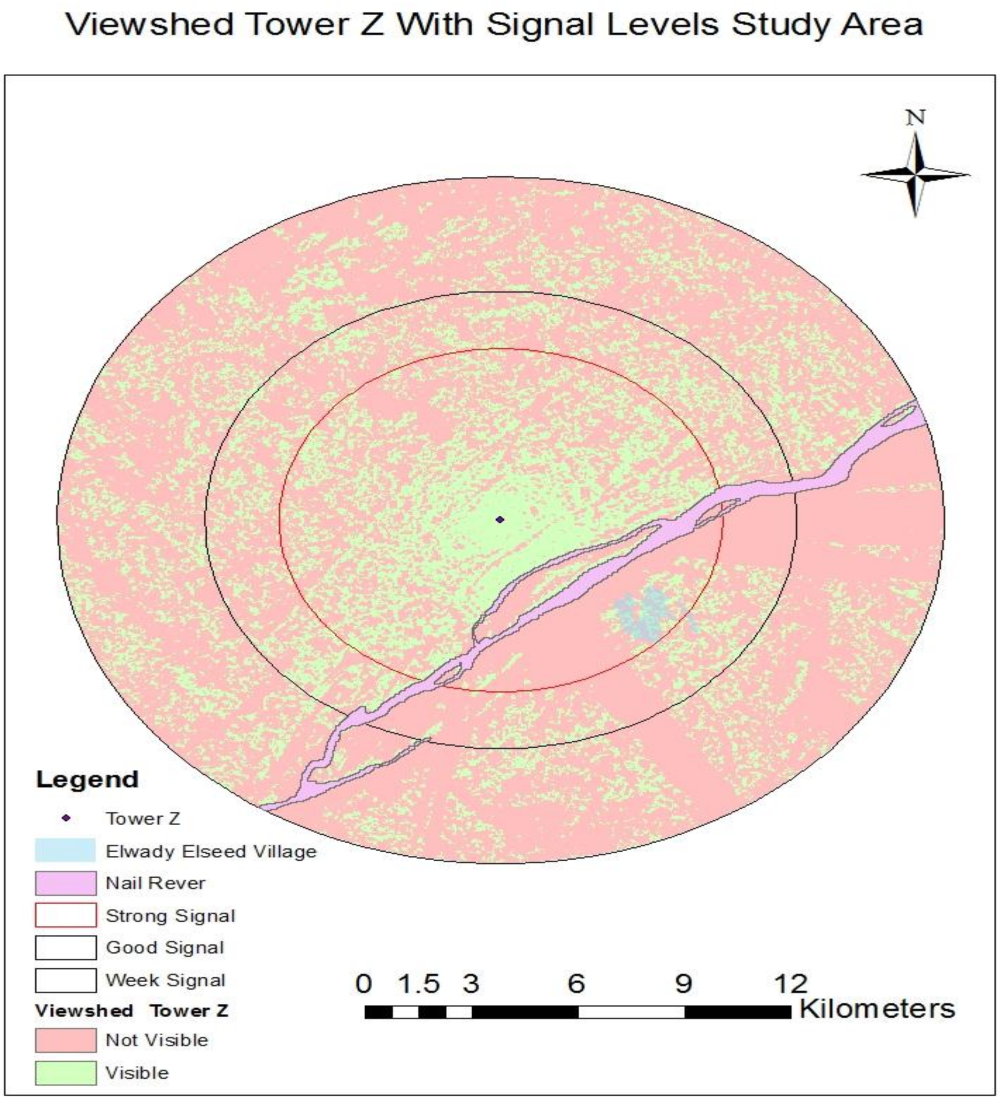


Figure 5.8: Tower Z coverage with Viewshed analysis

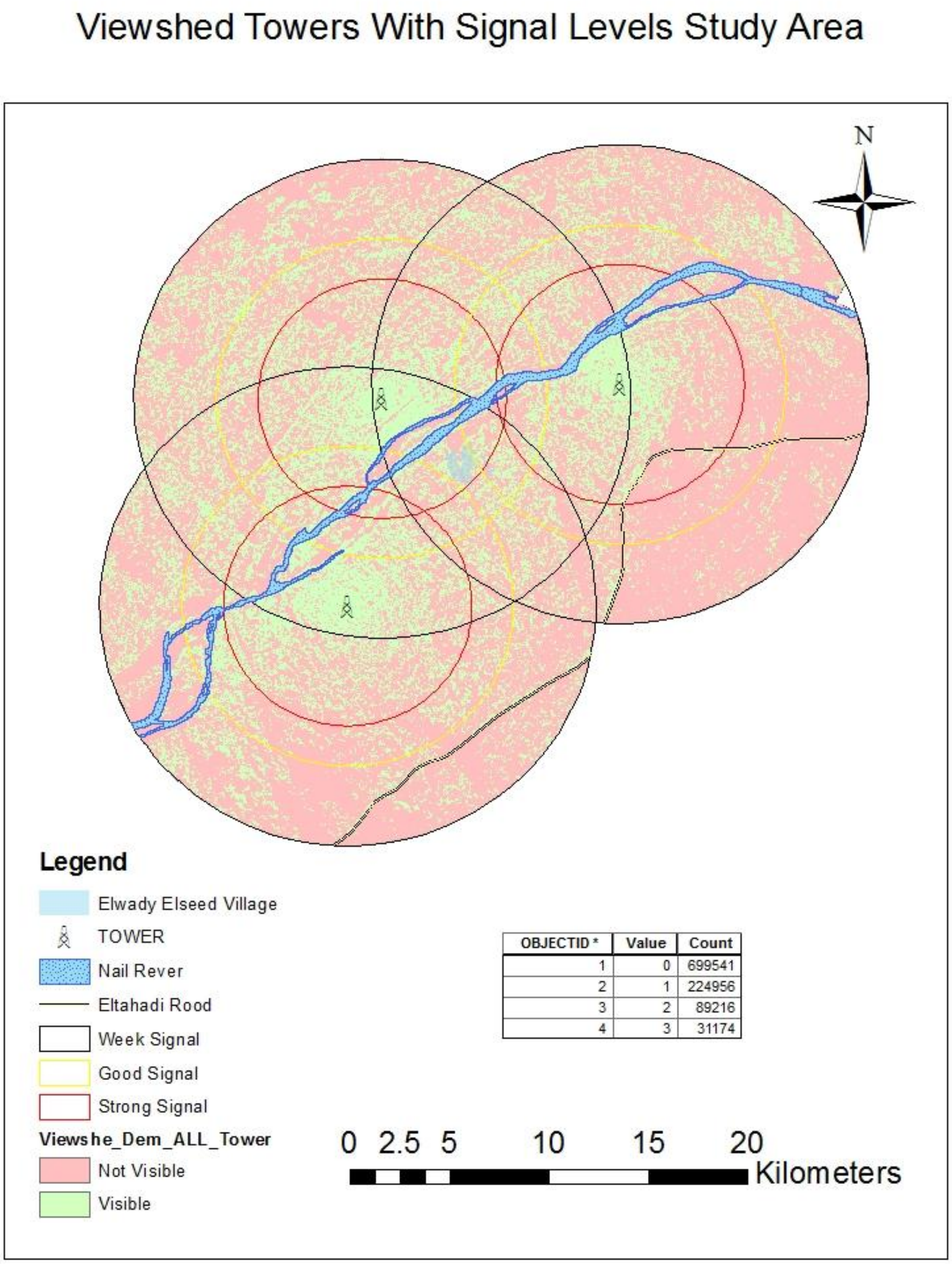


Figure 5.9: Towers coverage with Viewshed analysis

5.4 Discussion of Results

We have introduced an analysis method to get key terrain parameters of the region. Moreover, we measured the elevations and rate of decline in the region, with respect to the height of towers and distance to determine the impact onto communication signals.

We found, that the number of towers surrounding the area is 8. Calculating the distance between each tower and the study area and the height of each tower in addition to its length, it seems to exclude those towers which are most-distant in terms of the distance ratio. Obviously the land north of Sudan is non-flat and there are natural phenomena, such as rocks, valleys and slopes.

In addition to the exclusion of towers we have found in the other part (the other side), that the signal is reflected multi-path, when it collides water surfaces. This refers to the inability of the signal to cross the water with reference to the nearest tower for the region, in our case tower Z with minimum distance of 4.80km.

We have excluded the towers along the ELtahadi road because they are on the road to serve the marchers on the road

5.5 Proposed Tower

We propose to choose a suitable location to place a new tower such, that it covers the affected area fully with a strong signal and bridges the gap, that exists between the existing towers.

Therefore we propose that a new tower is to be built at coordinates [longitude 32.839110°, latitude 16.472122°]. A simulation using the newly proposed tower and exploring the coverage is shown in figure (5.10).

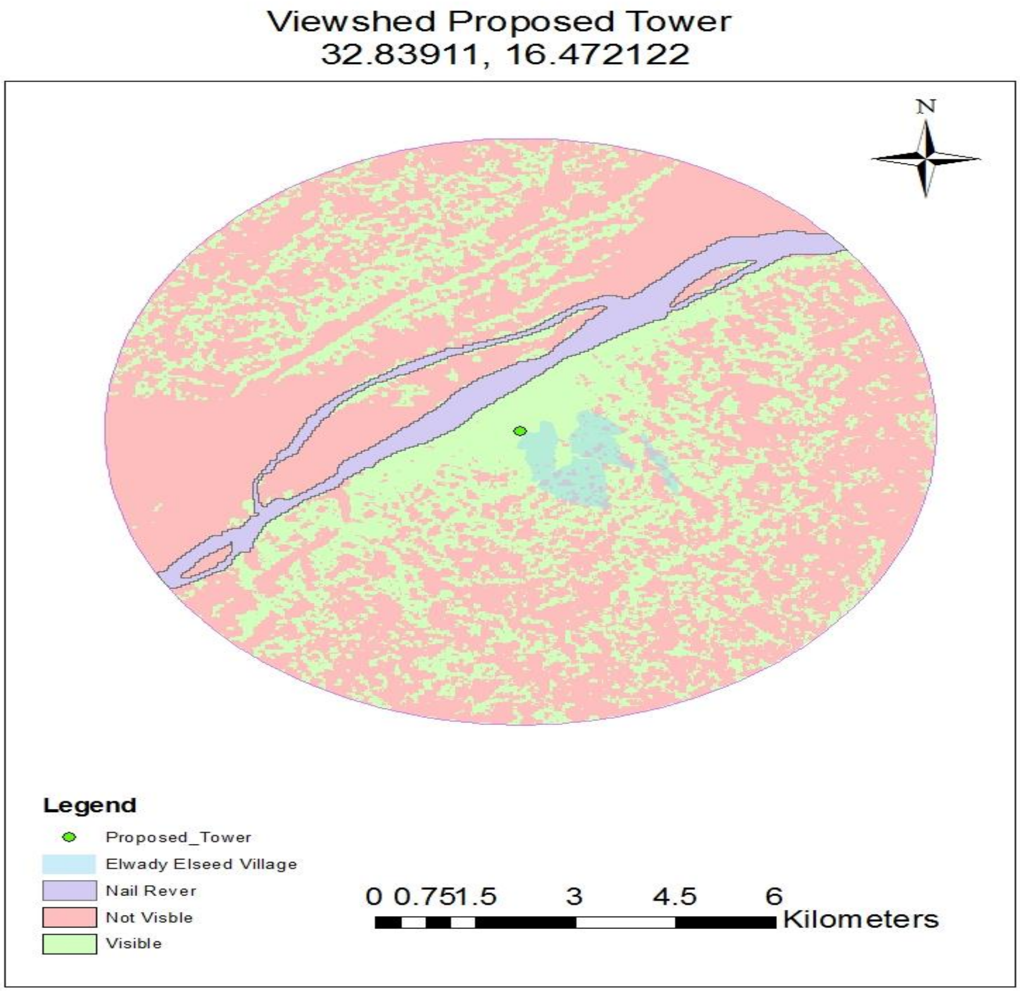


Figure 5.10: Proposed Tower Coverage with Viewshed

Chapter Six
Conclusions and Outlook

Chapter Six
Conclusions and Outlook

6.1 Conclusions

In chapter one we introduced a brief description of our research background, motivation, research questions and objectives.

In chapter two we gave an overview of selected literature dealing with our problem. We learned about the scientific background of the methodology which was specified in the first chapter. Some studies have been discussed in this chapter.

Chapter three presented details of the methodology which was introduced in chapter one. Here we described how the experiments to be performed will deliver the results we were looking for.

In the fourth chapter we studied the study area, its nature and population.

In chapter five we described the results obtained after the analyses of terrain parameters. Also we gave a brief discussion about how our research and GIS can support actual issues providing better telecommunication services.

In this work, we provide a quasi-optimal solution for the problem of quality of the telecommunication signal, in particular to offer the maximum coverage to a terrain represented by a DEM. The algorithmic solution is a total Viewshed analysis.

We can say now, after having discussed the analysis and the results, that there is a very strong inverse relationship between distances firstly and secondly a decline in influencing the quality of the signal. Furthermore we found that there is a positive relationship between the quality of the signal and the rise and fall in the region. We paid attention to this phenomenon and made the decision to propose the construction of a new tower bearing in mind the special nature of the area under study.

6.2 Recommendations

This research has shown how Geographical Information Systems (GIS) can provide and help in testing natural phenomena and their impact on public services and can offer several ways to solve these problems.

A very big economic factor in terms of profitability is the rate of the population density in the region under study, which ensures an increase in corporate profits. In order to take advantage of the communication services by more people we recommend the establishment of the new proposed tower site. This in itself is a competition between companies in the process of customer acquisition.

6.3 Future Works

As mentioned before in chapter one, the motivation for this research was to provide better communication services, in particular to deliver stronger signals necessary for general purpose applications. Thus, this work can be understood as a basic study to enable telecommunications service providers expanding the scope of services by placing the towers in the right location, at low cost in terms of time and efforts.

Future work can be briefly identified and some recommendations are given:

1. Expand the scope of this study to include all states of Sudan in terms of low-lying areas or highlands and its impact on the strength of the communication signals.
2. A calculation of the financial costs of the towers in the next study.
3. Coverage of signal for the whole region under study for various telecommunications companies - so that the customer can choose the appropriate network.

References

References

[1] Fry, C. "GIS in Telecommunications." Geographical Information Systems 2 (1999), pp. 819-826.

[2] Haitham, K. Ali, Hussien D. Mohammed, and Jihan S. Abdaljabar. "Geographic Information Ssystems (GIS) Spatial Analyst Techniques - A Reference For Determining the Position of Cellular Systems." European Scientific Journal 11.18 (2015).

[3] Fritsch, D. Signal Processing Lecture Notes (2015). GEOENGINE, Univ Stuttgart, www.ifp.uni-Stuttgart.de/GEOENGINE.

[4] Peery, S. "GIS Applications in Community Telecommunications." Virginia Tech eCorridors (2004), pp. 08-30.

[5] Abualgassim, J. A., and H. E. Idris. "Electromagnetic Radiation Evaluations of Some Cellular Base Stations in Kasala" Journal of (IOSR-JECE), (Jan. - Feb .2016), PP 61-63.

[6] Rappaport, T. S. "Wireless communications: principles and practice". Vol. 2. New Jersey: Prentice Hall PTR, 1996.

[7] Saikhom, V., Chutia, D., Sing, P., Raju, P., & Sudhakar, S. (2016). A novel geospatial approach for identifying optimal sites for setting-up of mobile telecom towers strategically. Journal of Geomatics, 10(2).

[8] Kashyap, R., Bhuvan, M. S., Chamarti, S., Bhat, P., Jothish, M., & Annappa, K. (2014, January). Algorithmic Approach for Strategic Cell Tower Placement. In Intelligent Systems, Modelling and Simulation (ISMS), 2014 5th International Conference on (pp. 619-624). IEEE..

[9] Mohammed Elfatih "Signal Coverage of Low-land Areas Using Geographic Information Systems, Case Study: Kassingar Area, Sudan", Master's Thesis Sudan University of Science and Technology (2016).

[10] Munene, E. N., and J. B. K. Kiema. "Optimizing the Location of Base Transceiver Stations in Mobile Communication Network Planning: Case study of the Nairobi Central Business District, Kenya." (2014).

[11] National Telecommunications Corporation Sudan.

[12] Sudan Central Bureau of Statistics.

REFERENCES FROM WEBSITES:

[13]https://saylordotorg.github.io/text_essentials-of-geographic-information-systems/section_11/ca6ce94cdd2e09a1da8aa6ec22336835.jpg, 23/3/2016 at 3:44pm.

[14] http://www.esri.com/software/arcgis/explorer-desktop, 3/2/2017 at 4:40pm.

[15] http://googleearthcommunity.proboards.com/, 20/2/2017 at 3:20pm.

[16] http://desktop.arcgis.com/en/arcmap/10.2/tools/spatial-analysttoolbox/

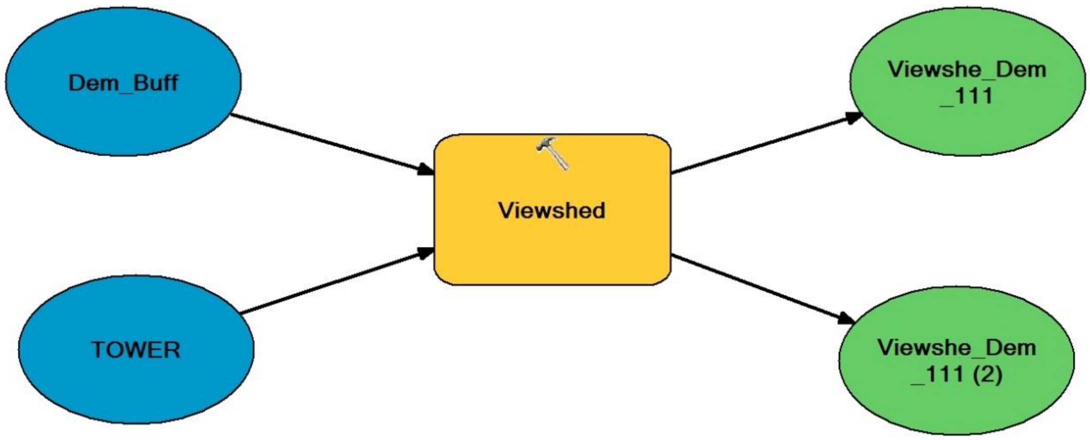
viewshed.htm, 22/2/2017 at 5:00pm.

[17]https://earthexplorer.usgs.gov, 22/2/2016 at 7:10pm.

[18] ESRI. “Using Viewshed and Observer Points for Visibility Analysis”. Web2012,http://resources.arcgis.com/en/help/main/10.1/index.html#/Performing_visibility_analysis_with_Viewshed_and_Observer_Points/009z000000v8000000. , 3/3/2017 at 2:30pm.

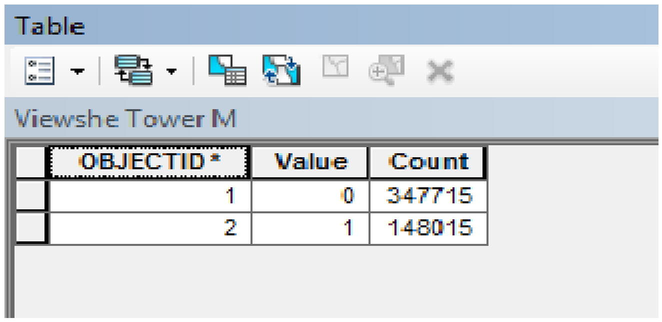
Appendix

Appendix A



This figure shows the viewshed raster is created from a DEM and a point shape file.

Appendix B



Table

Viewshe Tower M

OBJECTID *	Value	Count
1	0	347715
2	1	148015

This figure shows the number of cells that can be seen from the tower using viewshed, number of cells can be seen 148015 and not be seen 347715.