EVALUATION OF THE OPTIMUM CELLULAR NETWORK SITE USING GEOSPATIAL TECHNOLOGIES: A CASE OF MUNESA WEREDA, ARSI, ETHIOPIA.

Ahmed Tola Tibesso

A Thesis Submitted to The department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's

In Geo-Informatics

Office of Graduate Studies

Adama Science and Technology University

July, 2021

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Co-advisor: Anteneh Lemi (Msc)

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APPROVAL SHEET

We, the advisors of the thesis entitled "Evaluation of the optimum cellular site using Geospatial Technologies; A case of Munesa wereda Arsi, Ethiopia" and developed by Ahmed Tola, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Tilahun Erduno (Dr.Ir)	____________________	________________
Major Advisor	Signature	Date
Anteneh Lemi (MSc)	____________________	________________
Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Ahmed Tola have read and evaluated the thesis entitled "Evaluation of the optimum cellular site using Geospatial Technologies; A case of Munesa wereda Arsi, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-Informatics.

Chairperson	Signature	Date
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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

DECLARATION

I hereby declare that this Master Thesis entitled “Evaluation of the Optimum cellular site Using Geospatial Technologies; A case of Munesa wereda Arsi, Ethiopia” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Ahmed Tola	____________________	____________________
Name of the student	Signature	Date

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "Evaluation of the optimum cellular site using Geospatial Technologies; A case of Munesa wereda Arsi, Ethiopia" Prepared under our guidance by Ahmed Tola submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tilahun Erduno (Dr.Ir)	____________________	________________
Major Advisor	Signature	Date
Anteneh Lemi (MSc)	____________________	________________
Co-advisor	Signature	Date

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LIST OF ACRONYMS AND ABBREVIATIONS

AHP	Analytical Hierarchal Process
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
BTS	Base Transceiver Station
CR	Consistency ratio
CSA	Central Statistical Agency
CDMA	Code Division Multiple Access
DEM	Digital Elevation Model
DBMS	Database management system
EIR	Equipment Identity Register
ETC	Ethiopian Telecommunication Corporation
FDMA	Frequency Division Multiple Access
GIS	Geographical Information System
GPS	Global Positioning System
GSM	Global System for Mobile
IDW	Inverse distance weight
ICT	Information Communication Technology
ITU	International Telecommunication Union
LAN	Local Area Network
LULC	Land Use/Land Cover
MHz	Mega Hertz
MS	Mobile Station
MS	Mobile Switching Center
RBS	Radio Base Station
RF	Radio Frequency
RS	Remote Sensing
TDMA	Time and Frequency Division Multiple Access
TIN	Triangulated irregular network
UMTS	Universal Mobile Telecommunication Systems
USGS	United State of Geological Survey
SIM	Subscriber identity module
TIFF	Tagged Image File Format
TIRS	Thermal Infrared Sensor

ABSTRACT

This Thesis presents a Geospatial technologies tools as a helpful tool in optimum site selection for cellular networks and modeling. It shows how GIS can reveal features through its visualization capabilities. Cell phone subscribers is increasing use of cell phones in both urban and rural areas. Accurately locating base stations is vital to the quality of the cellular service communication system and to satisfying the demand of clients, which different in areas. The cellular network tower (bts) placement is key factor that causes disappearing of cellular service from areas. In munesa wereda also there are several external factors affect the quality and strength of a signal, including slope, altitude, obstruction and distance to a cell tower. Identifying the optimum locations for a new cellular sites of base stations capacity, required signal quality, and satisfactory demand coverage, is a challenge, especially in rural areas. Many important factors must be considered when determining the optimum location of new cell phone towers. Towers must be placed in such a way that they reach the most people, while trying to avoid unnecessary overlap with already well covered areas. This study aims to evaluate the optimum location of the cellular network sites in addition to analyze vulnerability due to electromagnetic radiation from base station according to ITU guide lines. GIS is a useful tool to visualize as well as analyze many of the factors that go into deciding the best areas to build a new cellular tower. A model was created in ArcGIS Model builder and converted to python script tool programming for Applications to automatically area coverage of existing cellular sites and display it spatially on map. The study identified that total area covered with existing sites and succession of suitability analyses show that within distance around 3km more than 80% of the cellular network service population are accessible to services currently in Munesa wereda. The results shows how the excellent visualization and spatial handling capabilities of GIS gives it an extra advantage as a site selection modeling tool. Thus, the integration of GIS into existing cellular sites and path loss analysis applications is recommended for fast, accurate and the ability to visualize the terrain and other great features. Finally this study recommends that, the prepared maps and models for cellular network optimum site selection in this study may assist the Telecom Tower planner in the detailed planning phase of the future network in this wereda.

Keywords: Geospatial analysis, cellular networks, optimum location, Munesa wereda

CHAPTER ONE: INTRODUCTION

1.1 Background of study

The increasing use of mobile Network technologies wherever people are impacts directly on the design of mobile radio networks. All users must share a limited amount of spectrum allocated to a given operator and would interfere with each other unless an appropriate design was put into operation.

Cellular network designers must carefully plan the deployment and configurations of radio base stations in order to support traffic at a level of quality expected by customers. Telecommunication service providers must achieve the radio coverage of a given area under time and required quality constraints and usually many other practical aspects, including the physical location of radio equipment, availability of fixed core network connections, expected traffic, and growth projections. Telecommunication defined as a technology concerned with communicating from a distance. It includes mechanical communication and electrical communication because telecommunications has evolved from a mechanical to an electrical form using increasingly more refined electrical systems (Tarmo & Omogunloye, 2013)

There are three important stations in operationalization of Mobile Communications. Mobile Services Switching Center (MSC), Base Station Controller (BSC) and Base Transceiver Station (BTS). Both MSC and BSC are intelligent units and communicate each other through microwave frequency. These two stations can be stationed anywhere inside the rooms or buildings, whereas the BTS have to be kept in high elevated place like high rise building top or mountain top or tower of height over 27 to 35 m.

The installation of BTS is a critical component in the operationalization of Mobile communications (NOKIA, 1999). Establishment of Ethio-telecom as a continuation of the 2005/06–2009/10 after concentrating its efforts on education, health and agriculture, the Ethiopian government has decided to focus on the improvement of telecommunication services, considering them as a key lever in the development of Ethiopia. The Ethiopian government has decided to transform the telecommunication infrastructure and services to world class standard, considering them as a key lever in the development of Ethiopia. Thus, Ethio telecom is born from this ambition to bring about a paradigm shift in the development of the telecom sector to support the steady growth of our country. Brief historical review of telecom sector in Ethiopia, (May, 2019).

Ethio-telecom (ETC) is a government owned company. It is a sole service provider in the telecom technology. One of its services is providing with reliable mobile connection throughout the country. With the increasing number of subscribers and advancement of telecom technology the implementation of ICT, which integrate geographic information system (GIS), is a useful solution to all location base services. So, information technology that integrates spatial data will enable ETC to go in line with its objective (Tadesse, 2017). Use Currently Ethio telecom, has undergone several telecom expansion projects to meet the ever increasing service demand from the public at large. Currently, it became one of the operators in Africa that joined the upgrading path towards the latest 5G cellular network technology by deploying LTE Advanced 4G in its capital Addis Ababa (Mamo, 2016). The 4G LTE cellular networks released early for South regions Area towns, Like Dukem, Bishoftu, Adama and other towns North West region, south west region and East region. Early Ethio telecom start tele birr in country. This can be considered as one of the remarkable achievement in the history of telecom service in the country. However, considering LTE as the latest technology, the radio network planning used for the implementation of LTE network in the country was basically vendor dependent.

(Ethio-telecom official website www.ethiotelecom.et, 2021).

Many telecommunication services providers are using GIS to establish and work on a competitive base. With GIS, providers can integrate their workflow based on the location of their assets, customers, sales territories, and coverage areas. As telecommunication networks grow more complex, complementing GIS applications to their system becomes very important.

Telecommunications companies are increasingly becoming very large users of GIS technology. Which is widely used to planning, operate telecommunication networks and related services. The Geospatial technology applications such as GPS for location information determination, Remote Sensing and GIS include activities such as Satellite imagery for ground truth, planning transmission sizes, locating cellular telephone transmitters (BTS), predicting pass loss coverage area, recording data from users, and using geodemographic information to find new optimum area for cellular Network sites (BTS).

According to (Akin and Margaret, 2014) studied location suitability of Telecommunication Masts and residents livability. The radiations coming from Telecom masts according to radiologist are electromagnetic waves, RF radiation and infrared. These radiations are capable to cause: epilepsy, leukemia and different types of cancer. This implies that residents living very near these masts are at risk.

To provide the best quality of network service for customers, Telecom needs to build the main infrastructure and its distribution which is base transceiver stations (BTS). The Base Transverse Station is one of the main units in the mobile communication system task which represents the connection chain between the mobile station and the server. 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. (Haitham K.Ali, Hussien D. Mohammed,Jihan S. Abdaljabar,et.al, 2015)

In the study area with existing towers there's good service area around towns also interference regions and weak regions, which are areas with a weak signal or hidden or unserved; thus both can cause some types of disappearing of service from study area. The weakness of the signal at these areas appears because of the irregular distribution of the towers.in another way the selected area locations for the telecom towers are visited by another group of peoples and do not have a good coordination between Telecom professionals and them. Therefore, to select suitable locations for Cellular network, it is necessary for avoiding damages to public and properties due to the towers. The existing file is not integrated with map information, and it is not updated frequently to know about the signal coverage area of each Base Transceiver Station.

Geographic information system (GIS), remote sensing (RS), and Global Positioning system GPS tools are together will enable telecom professionals and users to integrate maps and information to make better decisions from planning and maintaining network infrastructure to administering mobile telephone coverage, managing existing BTS towers, and finding new unserved area which is not covered by BTS, GIS users rely on location-based data to find the answers.

Cellular Network services are available frequently but the utilizing of network survives cannot serve whole area with existing Base Trans receiver station BTS.

As a result show with existing cellular network sites the area town and surrounding are covered with good connection, while the area in suburban and rural are weak network connection to no network convergence respectively. In the munesa wereda where there's no coverage area is no scheduled approach of distributions in the demanding situation of the community so that Cellular networks are highly concentrated at infrastructure like electricity road and utility where as rare amount of cellular networks with less signal are seen in other areas of population. This situation intern caused some parts of the population remain unreachable while the others are bounded by high potential of coverage and accessibility.

Additional cellular network facilities are required in the more parts of wereda are mostly the recommended. Area that around the new candidate site locally known as shune, lakicha, wollu dikale, and gujicha area is partially populated and needs developments of infrastructures, utilities and social services such as health center, waters, and electric facility are highly requirements.

The current sites of cellular network infrastructure consist of 8 sites from which three sites covered the urban area, one sites suburban and the rest four sites cover the area of rural to provide service for a subscribers. Based on the analysis 4 sites can cover the urban with the optimization of more number of customer which reduce the number of infrastructure and cost by improving the quality of network. Generally, based on analysis, the munesa wereda can be covered by 17 sites (3, 3 and 11 sites for urban, suburban and rural area respectively) which sites to cover the same area with better signal strength.

1.2 Statement of the problem

Ethio-Telecom (ETC), is a telecommunication company serving as the major internet and telephone service provider. Telecom is the largest company in Ethiopia which provides network communication between organizations and individuals person.

Ethio telecom network, there will always be an expansion projects to satisfy an ever increasing user demand for various kind of services and mobile applications.

However, most of the time due to the professional gap, network sites selections for telecom towers, preparation and design works are done by vendors (Mitikie, 2016, pp. 1-116).

So, the main motivation behind this research is to verify if already implemented number of Existing BTS cellular networks can satisfy the required input coverage, capacity and signal strength value set by Ethio-telecom. So using Munesa wereda as a case study and at the same time to understand cellular Network coverage signal strength and capacity planning design principle and methodologies to be used in and also to determine where to place new cellular base stations with reduced vulnerability. The areas of study for this research is included all kebeles in munesa wereda specially focus on three districts. The first one is shune, which include one small town and three rural area. Second is waji which include one small town and three rural kebeles, the third area is Heban which includes one town which currently upgraded from villages to town and three villages and four rural kebeles.

The reason behind choosing this area was three major. First, these area is almost uncovered area with cellular network while some area are poorly served. Secondly the area is mostly mountainous and flat land with no incredibly large geological barriers that could skew the data for a large number of telecom tower locations. Thirdly, this area needed the most obtainable data and has a problem with weak signal of network connection from this area. However there are few of number of cell towers across the munesa wereda. Some of which would not access network service and cellular data for entire of study area. In munesa wereda the expansion of basic development like cellular networks, roads, and electricity are expand almost in some parts of wereda. These new selection transmitting BTS locations will expand the systems, and increase quality of network services and capacity in study area.

1.3 Research Objectives

1.3.1 General

The general objective of this study is to evaluate the optimum location for cellular network sites and examine areas at vulnerable to electromagnetic radiation associated with the existing of base Transreceiver station using geospatial technology in the entire of study area.

1.3.2 Specific

The specific objectives to be undertaken to reach at the general objectives are to;

1) Create database for features mapped that perform spatial analysis information.
2) Analyze existing BTS towers data and its relationship to nearby Settlement and roads.
3) Identify possible areas at vulnerable to electromagnetic radiation from BTS.
4) Prepare map out for the selected new optimum positions which providing the better coverage of signals in study area.

1.4 Research Questions

To address the above objectives, the following research questions are designed as follows.

1) How many additional Telecom BTS are needed for study area?
2) Which area is not covered by the existing Base Transceiver Station?
3) Which area is suitable to install new Base Transceiver Station (BTS)?
4) How are the existing BTS distributed in terms of distances from one another, to existing residential after suitability evaluation?

1.5 Significance of study

The result of this research is deeply helps both the government and society in location and use of Network service in the study area. The significance of this study can be generalized in three ways which is first for Consultants or network planners, secondly contribution for society and thirdly for government.

1.5.1 Consultants or network planners:

The Way it can be used by network planners and consultants even by operators to be used as a design document like database to quick access and advice for future network maintaining, expansion projects and even for optimization activities of the existing network and For the new one.

1.5.2. Value contribute for Society:

The services accessed via mobile devices have fundamentally changed how we stay in touch, make purchases and participate in wider networks, and are increasingly critical to business, creating an ever more connected society. The integration of information technology and communication technology is bringing great changes to our social life. Mobile technology and the Internet have become the main driving forces for the development of information and communication technologies. Through the use of high-coverage mobile communication networks, high-speed wireless networks, and various types of mobile information terminals, the use of mobile technologies has opened up a vast space for mobile interaction. And has become a popular and popular way of living and working.

1.5.3. Value contribute for government

The operations of a modern community are highly dependent on telecommunications. We can hardly imagine our working environment without telecommunications services. The local area network (LAN) for instance, to which our computer is connected is interconnected with the LANs of other sites throughout our Company. This is mandatory so that the various departments can work together efficiently. We communicate daily with people in other organizations with the help of electronic mail (internet), telephones, facsimile, and mobile telephones. Governmental organizations that provide public services are as dependent on telecommunications services as are private organizations, (Godin, et.al, 2001). Everyday life is dependent on telecommunications. Each of us uses telecommunications services and facilities that rely on telecommunications daily. In the telecom world, a GIS is ideally suited for network planning and development. The ability to layer information onto the earth's surface, complete with attribute data, allows engineer the unique ability to model and assess a network from the office. This saves valuable time and reduces the number of trips, if any that the engineer must make to the field. Furthermore, the powerful automation capabilities offered by a GIS increase the speed and accuracy of the network design process and can help reduce, and even eliminate, the downstream impacts of design-phase errors on cost and schedule during the network deployment phase. Rule based features found in a GIS can also offer network designers the ability to produce better products, optimized for cost, shortest routing distances, or other user-defined metrics.

1.6 Scope of the Study

The scope of this study involves mainly on issues that are within the wereda of Munesa. Which covered an area of 1071.59 km^2 more over the study is also confined to network problem in study area. This research encompasses the population density, plots and improved land use land cover details were used. The slopes and transport network was included to demonstrate accessibility of the study area. To model and analysis of the telecom towers (BTSs) capacity with respective potential customer and number of customer supported, the research is bounded only on one wereda, in Arsi Zone Munesa. In the suitability analysis part the Factors considered are limited. Only seven factors are considered as potential customers of cellular phone in a given location. As a factors the whole population in wereda, LULC, Buildings in Towns, main Rivers across the study area, Roads networks, Slopes and distance from existing sites are taken.

1.7 Limitation of the Study

The researcher has been met different obstructing problems that faced when collecting data and visiting sites. Few area which cellular network connection are unserved is not visited due to Major road connected wereda under construction and where there is no access road for the vehicle. The another limitation of this thesis is that the study area have no Updated digital map during the formulation of this thesis, network planning data and tools are mostly available with vendors. But, Vendor's document, materials, and their planning tools are not easily accessible for academic research. When regulating interview some telecom experts are not tell fully information due to privacy of company.

1.8 Organizations of the Thesis

The paper generally comprises of five chapters beginning from introduction (explaining backgrounds of the problem, setting purpose and objectives) and ends at analysis, results and discussion. Reviews literature terminologies and technical problem solving methods from the literatures. Both theoretical and empirical concepts of optimum location analysis are explained in detail. Primary cellular networks location selection related literatures that describe efforts on cellular network at a global, continental, country and local contexts and participatory organizations. In Chapter Three, Historical, Physical and backgrounds of the study area is explained in detail. Brief description of data and datasets used as inputs of analyses is also specified in the same chapter. Chapter four analyses and discusses the practical solutions of the problem towards the achievement of the designed purpose and objectives set in chapter one. The thesis is finalized by Summarization, Conclusions and Recommendations of the author in Chapter five.

CHAPTER TWO: LITERATURE REVIEW

The study is primarily focused on Evaluation of the Optimum site selection for cellular network and how Existing cellular network distributed in the telecom sector. The aim of this literature review is to present previous studies on the subject matter to form the basis of Arguments and assertions in the study. This presents the related literature and studies after a thorough and in deepness search done by the researchers. Various viewpoints expressed by previous researchers on the subject matter are presented and discussed. In this chapter also presents as the theoretical and conceptual framework was developed based on objectives and statement of problem discussed in chapter one.

2.1. Theoretical framework

Different scholars have forwarded different definitions and problem for cellular network. Among different study (Danraka, 2010) examined the distribution of Zain base stations in Kano metropolis using GIS technique. The pattern was related to the concept of central place theory. His result shows that, the impact of Zain base station is perceived with high response of people using the network and more business own phone rather than private users. 70 percent of the respondent indicates a regular network provide by Zain and only 30 percent experience a network failure and actions were taken from the network providers for proper and stable network. The study recommended the use of cellular radio communication system due to high cost associated to construction of base stations.

The other study on telecom towers placement and its problem on society are many.

(Aderoju, olaide et.al, 2013) study that the assessment of the level of noise from base transceivers station using geospatial techniques as he stated the concentration of environmental Pollution is significantly increasing and causing serious threat to the quality of the environment. Recent studies have illustrated a link between human exposure to noise and negative effects on their health. Noise pollution in large urban areas is regarded as a growing problem of communities (Ronni W, & Danny, 2019). Present studies shown that more than 20 % of the world population lives under unacceptable noise levels and nearly 60% of the European population is exposed to high noise levels during the day (Silvia, 2003). (Plog et.al, 2002) defined noise as a word often used to mean unpleasant sound that the listener does not want to hear. They further stated that although there are no physical characteristics distinguishing noise from wanted sound. Noise pollution is not unique or peculiar to developing countries alone; it is a common occurrence and of highest magnitude in most of the advanced countries (Eldhose N.V, 2017). Hence there is need to monitor and manage the level of noise in our environment for health reasons and also for our environmental sustainability.

2.1.1 Cell tower

Telecommunication towers are the building blocks on which telecommunication thrives. Their cost forms a high part of the property, Plant and Equipment cost of telecom companies. A cell site is a term used primarily for a site where antennas and electronic communications equipment are placed to create a cell in a mobile phone network (cellular network). A cell site is composed of a tower or other elevated structure regular and backup electrical power sources, and sheltering (Cranfield, et.al, 2003).

A synonym for "cell site" is "cell tower". However, In GSM networks, the technically correct term is Base Transceiver Station (BTS), and in conversational British English it is termed "base station". The term "base station site" might better reflect the increasing co-location of multiple mobile operators, and therefore multiple base stations, at a single site (Repacholi, et. al, 1997). Depending on an operator's technology, even a site hosting just a single mobile operator may house multiple base stations, each to serve a different air interface technology (CDMA or GSM, as example).

2.1.2 Cell Tower site selections

Cellular tower locations are the result of an engineering field called Radio Frequency Engineering or RF, for short. RF engineers work closely with the marketing departments to determine areas where the placement of a new tower will accomplish one (or more) of three goals (Akdag et al., 1999).

a. Expansion: The tower site provides coverage over areas that do not currently have Coverage and where networks are not exist areas such as rural area.

b. Capacity: The tower site provides additional capacity for the carrier to handle more Calls in areas where existing towers are overloaded. The usage of Cellular phones is high in urban and suburban areas. Peoples in these areas are motivated to do more calls because non business of the network due to increased capacity of the network.

C. Quality: The tower fills in a hole or an area where customer calls are frequently dropped or call service is poor. (Al.hashem and soukaena .et.al, 2011)

According to Vertical Consultant (2012), Cell tower locations are the result of a cell phone carrier working with their internal engineering staff to satisfy specific needs that a company has in certain locations throughout the country. The engineering aspect is classified as Radio Frequency Engineering or RF Engineering for short. RF engineers must act in concert with their company‘s site development and construction staff to optimize any cell tower site development and related construction projects they may have scheduled.

The following are some of the ways by which a customer is enriched:

(i) Signal Strength/Coverage

Cell towers are built to eliminate those locations were that cell phone company‘s services are lacking, also known as the hated "Dead Spot". RF Engineers determine where there are high rates of service interruptions due to either interference or cell phone signal issues and a new cell tower will be selected and developed to eliminate these dead areas (Anupma & Dhamija, 2017)

(ii) Data Usage Capacity

Cell phones are being used for an increasing amount of purposes, i.e. phone calls, text messaging, data transfer, internet research etc. and other devices like laptops, tablets and even televisions are now using wireless signals (Andarge, 2018). These are the main reasons that new cell tower locations are being constructed to meet these growing data usage needs and requirements.

(iii) Call Clarity & Network Speed

The telecom industry is a complex industry but like most industries it relies upon getting new customers and satisfying the needs of its existing customers. If a cell phone carrier‘s customers can‘t make calls or retrieve data, it will not be in business very long. So cell towers must be constructed to make sure the customer needs are met (Jiang, et.al, 2018).

Cellular tower locations are the result of an engineering field called Radio Frequency. The Tower must serve a specific purpose. The majority of the times, the purpose is to increase the number of minutes that people talk or receive/send data on their phones. The industry refers to this as "Minutes of Use" or MOUs. The main way of increasing MOUs is by placing cell towers or sites in locations that have high daytime working populations. Most carriers have wireless plans that provide cheap or free "off time" rates, so the emphasis is daytime calling minutes which are typically the most expensive (Kumar, Girish, 2010)

To provide coverage for people traveling between particular urban/suburban areas, highways, state roads, and higher traffic zones, local roads are covered by towers as well. Placement of towers at strategic intersections of major roads is often preferred.

Generally To meet the RF engineering requirements, size of the Search Ring is depend upon the topography (hilliness or flatness), the demographics (where and what type of customer base) and urban, suburban or rural in nature. Nowadays the entire thing related to search ring is done by using digital software's. Then the site acquisition agent's use hand held GPS to navigation of predicted areas where suitable for towers. Further site the search finds the suitable land that meets below minimum criteria.

a) The parcel must have easy and cheap access from a public road.
b) The parcel must suitable for zoning of that area. Some jurisdictions allow in tower site in commercial and industrial zoned parcels or agricultural areas not allow in residential zoned sites.
c) Site must not have conditions that would construct a tower unduly expensive. Such as wetland, poor or rocky soil conditions, significant distance to the tower site from the main road, lot of trees and possible hazardous waste on the property.
d) Parcel land owner must be willing to lease the site at rates that acceptable to the wireless company. (Tower Site Selection, 2014)

2.1.3 Location of cell site

The following factors are items that are taken into consideration by a site acquisition agent/cell tower company:

1. Construction Limitations

A site acquisition agent will conclude if a site has suitable access and space necessary for construction of a tower. An optimal site will have level terrain with minimal or no ground or airwave obstructions (i.e. tree cover); as the more obstacles the more expensive it is for a tower company to construct on a site (Malmel, 2010). A tower company/carrier will sometimes be willing to pay higher rent for a more suitable site in order to avoid more expensive construction costs on a similar site.

2. Zoning/Permitting Restrictions

The Priority to a cell phone carrier/tower company getting approval to build on a site they must first get a conditional use permit or special use permit to construct their facilities. Most local governments have permitting requirements that will establish parameters on where a tower may be constructed; therefore one property may be able to skate through the approval process while other very similar properties in the same immediate area may not.

3. Access to Power and Telephone Service

All tower locations need utility and telephone service. As a result, the farther the distance to telephone service and power, the higher the price tag to the cell tower developer. In our country Ethio telecom use some rural area and small town which have no Power they use solar charger and Gas as a power on BTS in rural area.

4. Ground Elevation.

Elevation is important, but not the most important factor by far as cost will always outweigh elevation. If you have the highest point in the city or region that is not a guarantee you will be chosen. The cell phone carrier/tower company always has the option to build a taller cell tower at a lower evaluation as it may be extremely expensive at the end of the day.

5. Cell Tower Site Alternatives

All cell phone carriers build tower sites to fit inside their network. Cell towers are very similar to pieces of a puzzle that, at the end of the day, have to fit together. The cell towers are set up to transfer traffic from one cell tower to the other. The cell phone carriers have an exact search ring that they use when constructing a cell tower, so that it will be able to easily transfer phone traffic. These search ring areas can be as small as 0.25 mile to as large as 5 miles. A site should be large enough for a cell tower normally (but not always) this is a parcel double the size of the height of the tower. So if a tower is 100 ft tall, the parcel must be 200' x 200'. Sites must have easy and cheap access from a public road. The site must be suitable from a zoning perspective. In many jurisdictions, towers are only allowed on commercially or industrially zoned parcels. Some areas allow towers on agriculturally zoned sites, and most do not allow towers on residential or forest land and restricted areas.

Sites must not have conditions that would make constructing a tower unduly expensive. These conditions can include wetlands, poor or rocky soil conditions, significant distance to the cell tower site from the main road, lots of trees, and possible hazardous waste on the property and high voltage power lines (Laurence et al., 2000; AGNIR, 2001). Land owners must be willing to lease the site at rates acceptable to the wireless carrier. One thing to note is that, contrary to public belief, the ground elevation is not the most important factor. Just because you live on the tallest or second tallest hill in the area or county does not mean that your location is preferred from a wireless perspective, unless the location is in a "Search Ring." Generally, in areas where there are enough cell sites to cover a wide area, the range of each one will be set to):

- Ensure there is enough overlap for "handover" to/from other sites (moving the signal for a mobile device from one cell site to another, for those technologies that can handle it - e.g. making a GSM phone call while traveling in a car or train).
- Ensure that the overlap area is not too large, to minimize interference problems with other sites.

(Smash, 2012) state that in practice, cell sites are grouped in areas of high population density, with the most potential users. Cell phone traffic through a single cell mast is limited by the mast's capacity; there are a finite number of calls that a mast can handle at once. This limitation is another factor affecting the spacing of cell mast sites. In suburban areas, masts are commonly spaced 1.5km-3 km) apart and in dense urban areas, masts may be as close as (400–800 m) apart. Cell masts always reserve part of their available bandwidth for emergency calls.

(Cranfield et al., 2001; Di Carlo, et. al, 2002) The maximum range of a mast (where it is not limited by interference with other masts nearby) depends on the same circumstances. Some technologies, such as GSM, have a fixed maximum range of 40km, which is imposed by technical limitation. As a rough guide, based on a tall mast and flat terrain, it is possible to get between 50 km to 70 km. When the terrain is hilly, the maximum distance can vary from as little as 5 km to 8 km. The concept of "maximum" range is misleading, however, in a cellular network. Cellular networks are designed to create a mass communication solution from a limited amount of channels (slices of radio frequency spectrum necessary to make one conversation) that are licensed to an operator of a cellular service (Zunia, 2012).

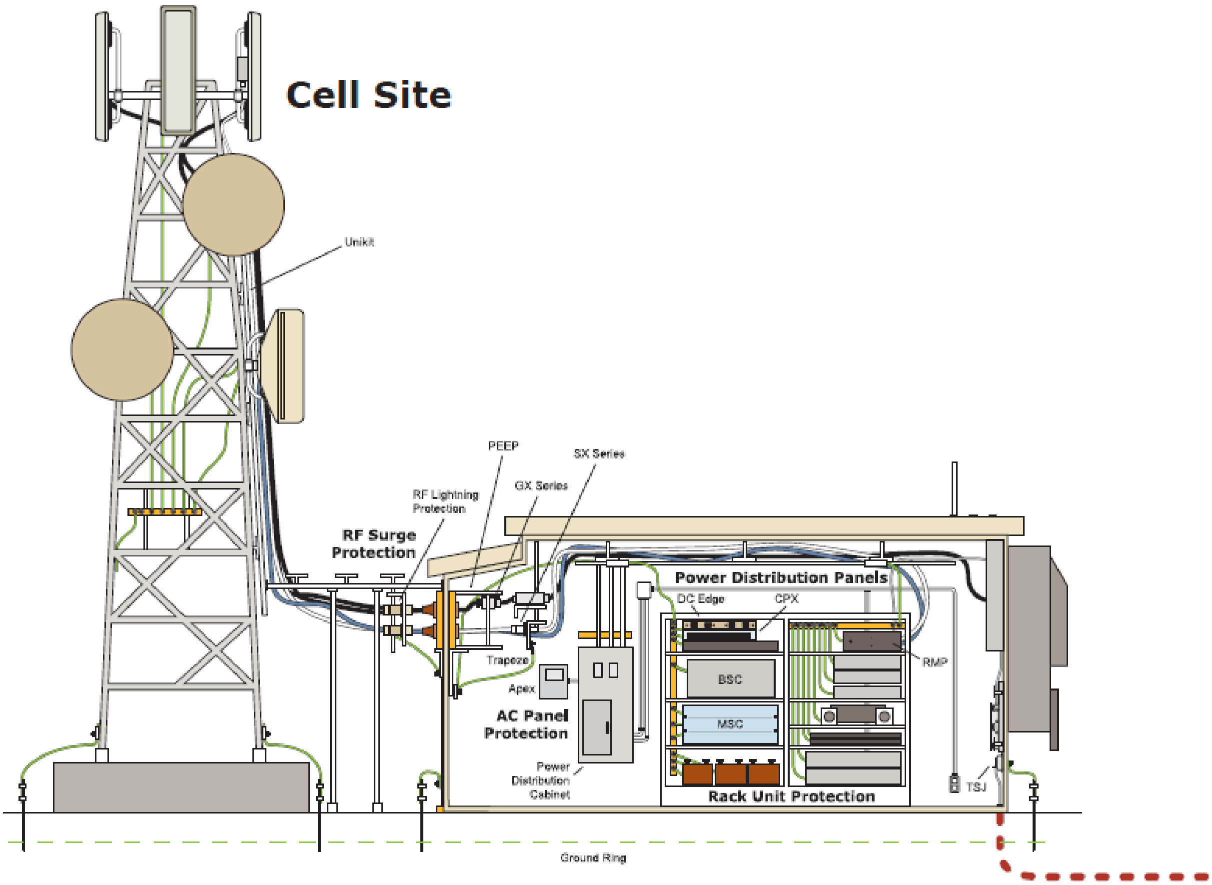


Figure 2.1 Typical cell site that has a RF flow protection and a Power distribution panel (Adopted from www.idirect.net, 2018)

2.2. Generation of mobile network

A key part of any mobile phone specification is its operating frequency bands. The supported frequency bands determine whether a certain handset is compatible with a certain network carrier.

a) First generation (1G) of mobile communication

Introduced in 1979 in Japan Analog circuit-switched technology is used for this system with FDMA and worked mainly in the 800 – 900 MHz frequency bands had only voice transmission. (Tayal, 2017) Examples are; Analog Mobile Phone Systems (AMPS) Used in North America, Total Access Communication Systems (TACS) Used in Europe. The limitation of 1G are they Supports only speech, Low traffic capacity, Unreliable handoff, Long call setup time and frequent call drops, Inefficient use of bandwidth and poor battery life, Analog signals were prone to interferences. So poor voice quality. Large phone size and Allows users to make voice calls within one country only.

b) Second Generation (2G) of mobile communication

Introduced in early 1990s and it was digital Technology Were Digital, encrypted and more efficient on the spectrum enabling far greater wireless penetration levels. 2G introduced data services for mobile such as text messages, picture Messages, and multimedia messages.2G can be divided into two standards TDMA, and CDMA.

The frequency bands used by GSM are 935–960 MHz is used for the downlink communications. The advantages of 2G are Voice quality was improved as well, with the introduction of newer voice coding algorithms 2G technology supports speech, digital data services such as FAX, SMS etc.

Lower power emissions have helped in dealing with health concerns. Improved sound quality (digital error checking to reducing the noise in transmission system. They are most secure and reliable than 1G. The limitation of 2G are they it Provides lower data rates ranging from 9.6 Kbps to 28.8 Kbps.Circuits switched network, where the end systems are dedicated for the entire call session. This causes reduction in usage of bandwidth and resources. In rural areas, the weaker digital signal may not be enough to reach a mobile cell tower. But this is a very rare problem as 2G is deployed on very high frequency and low power.

c) Third Generation (3G) of mobile communication

3G networks succeed 2G ones, offering faster data transfer rates and are the first to enable video calls. This makes them especially suitable for use in modern smartphones, which require constant high-speed internet connection for many of their applications.

It operates in the frequency band of 1710 - 2170 MHz and provides high transmission rates from 348 Kbps for a moving vehicle to 2 Mbps for stationary or walking users. It Support for global roaming. Examples of 3G system are Universal Mobile Telecommunication Systems (UMTS) and International Mobile Telecommunications at 2000MHz (IMT-2000). The 3G systems should work in all radio environments such as urban areas, suburban areas, hilly and mountainous regions, and indoor environments.

d) Fourth Generation (4G) of mobile communication

4G **is** the fourth generation of mobile phone communications standards. It is a successor of the 3G and provides ultra-broadband internet access for mobile devices. The high data transfer rates make 4G networks suitable for use in USB wireless modems for laptops and even home internet access. 4G networks have transmission rates up to 20 Mbps higher than that of 3G. It provide very smooth global roaming universally with lower cost. Theoretically, 4G is set to deliver 100Mbps to a roaming mobile device globally, and up to 1Gbps to a stationary device. The main objective of 4G is seamless communication with broad range connection with internet at anytime and anywhere with support of data, pictures and videos on internet. The expected features of 4G are video conferencing, streaming picture perfect video (i.e. Tele-medicine, Tele-geo processing application etc).

Long Term Evolution (LTE) Long LTE term evolution is the world's leading 4G cellular network technology.it provide high data rates and low latency enable applications such as streaming HD video, High definition voice over LTE (VoLTE),broadcasting, and public safety emergency response. Their band widths ranging from 1.4MHZ to 20 MHz.this makes LTE a natural upgrade path for carriers with both GSM/UMTS and CDMA2000 networks. Generally bands currently in use range from 450 MHz to 2700 MHz, with bands as high as 3.5GHz.

e) Fifth Generation (5G) of mobile communication

5G **is** the fifth generation of mobile phone communications standards. It is a successor to 4G and promises to be faster than previous generations while opening up new uses cases for mobile data. The 5G benefits range from faster speeds (up to 10x faster), much lower latency (up to 50x lower) and greater capacity allowing many more devices to be connected at the same time. Their Speed: 10 to 100 times speedier than your typical cellular connection, and even faster than anything you can get with a physical fiber-optic cable Ultra low latency: In 5G, that latency gets reduced to as little as 1 millisecond. 5G initially used super high-frequency spectrum, which has shorter range but higher capacity, to deliver a massive pipe for online access.5G technology is expected to officially launch across the world by 2020, with testbeds in the US and UK already live. Many companies are busy making sure their networks and devices are '5G ready' in time for 2021, meaning some networks may launch before then.

2.3. Cellular Networks and Its Architecture

2.3.1. Base Transceiver Station /cell Tower

A base transceiver station (BTS) is a piece of equipment that facilitates wireless communication between user equipment and a network. UEs are devices like mobile phones (handsets) and computers with wireless internet connectivity. (Zakaria & suliman, et.al, 2018). The network can be that of any of the wireless communication technologies like GSM, CDMA, wireless local loop, Wi-Fi, or other wide area network technology. A BTS comprises all radio equipment, i.e., antennas, signal processing, amplifiers necessary for radio transmission. A BTS is connected to MS via the Um interface, and to the BSC via the Abis interface. The Um interface contains all the mechanisms necessary for wireless transmission (TDMA, FDMA etc.) The Abis interface consists of 16 or 64 kbit/s connections. A GSM cell can measure between some 100 m and 35 km depending on the environment (buildings, open space, mountains etc.)

For planning cellular network coverage the most important element in the network as it provide the physical connection to the mobile station through the air interface.

2.3.2 Mobile Station (MS)

Mobile station is made up of two parts, the handset and the subscriber identity module (SIM).the SIM is the personalized and is unique to the subscriber. The hand set or the terminal equipment should have qualities similar to those of fixed phones in terms of quality, apart from being user friendly. The equipment has functionalities like modulation and demodulation up to channel coding or decoding. The MS comprises all user equipment and Software needed for communication with a GSM network. An MS consists of user independent hard and Software and of the subscriber identity module (SIM), which stores all user-specific data that is relevant to GSM. While a MS can be identified via the international mobile equipment identity (IMEI), a user can personalize any MS using his or her SIM, i.e., user specific mechanisms like charging and authentication are based on the SIM, not on the device itself.

2.3.3 Mobile switching center (MSC)

The control entire system resides in the MSC, which maintains all mobile related information and controls each mobile hand-off. Also it perform all of the network management functions, such as call handling and processing, billing, and fraud detection within the market. The MSC is interconnected with the public switched telephone network (PSTN) via land line trunked lines (trunks) and a tandem switch. They set up connections to other MSCs and to the BSCs via the A interface, and form the fixed backbone network of a GSM system. Typically, an MSC manages several BSCs in a geographical region.

2.3.4 Public switched telephone network (PSTN)

PSTN is separate network from the signaling system network.in the modern cellular telephone system, long distance voice traffic is carried on the PSTN, but the signaling information used to provide cell set-up and to information used to provide cell set-up and inform MSCs about a particular user systems to automatically accommodate subscribers who roam into their coverage region.

2.3.5 Home Location register (HLR)

The HLR is the most important database in a GSM system as it stores all user-relevant information. This comprises static information, such as Mobile subscriber ISDN number (MSISDN), Subscribed services (e.g., call forwarding, roaming restrictions, GPRS), and International mobile subscriber identity (IMSI). Dynamic information is also needed, e.g., the current location area (LA) of the MS, The mobile subscriber roaming number (MSRN), with each MSC, there is associated a visitors location register. The visitor's location register can be associated with one or several MSCs. The VLR stores data about all customers who are roaming within the location area of MSC. This data is updated with the location update procedure initiated from the MS through the MSC, or directly from the subscriber home location register (HLR). As soon as an MS leaves its current LA, the information in the HLR is updated. This information is necessary to localize a user in the worldwide GSM network.

2.3.6 Equipment identity register (EIR)

The equipment identity register (EIR) is an optional register. Its purpose is to register of mobile stations in use.by implementing the EIR the network provider can blacklist multifunctioning MSS or even receive reports to the operations center when stolen mobile stations are used to make calls.

2.4 Global system for mobile communication (GSM)

The GSM network uses the frequencies 900 MHZ (GSM 900) and 180 MHZ (GSM 1800). (Nasir Faruk, 2017) The GSM network which was established in the middle of the nineties is using the frequency 1900 MHz a technical trick, the so called time slot method increases the number of simultaneous cellular phone users. Since radio spectrum is a limited resource shared among all users, GSM introduced the method for splitting the bandwidth among as many users as possible. The method is a combination of time and frequency division multiple access (TDMA/FDMA). The FDMA part involves the division by frequency of the maximum 25 MHz bandwidth into 124 carrier frequencies spaced 200 KHZ apart and one carry frequency is use for guard band.

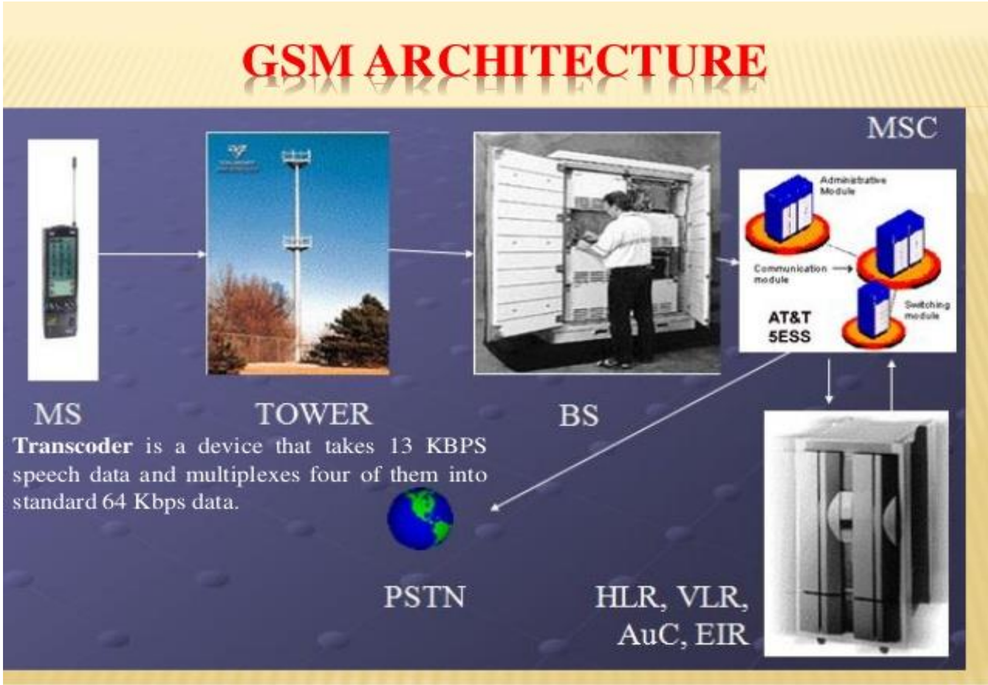


Figure 2.2. GSM architecture (*Sources Mr.Nimay Chandra Giri, 2019*)

2.5 General Concept of cellular Networks

The cellular concept is a system level idea in which a single, large cell is replaced with many small cells. The area serviced by a transmitter is called a cell. Each small also called a base station provides coverage to only a small portion of the service area. Base stations close to one another are assigned to relatively small number of neighboring base stations. Neighboring base stations are assigned different groups of channels so that the interference between base stations is minimized (Chaurasia, 2016).

2.5.1 Shape of the Cell

A cell is a basic geographic unit of cellular system. It comprises of a small logical area which has a low power antenna installed in the form of a unit called the base station. In mobile network we talk in terms of cells; Environment, Microcellular (Jambuwant Shrawankar, 2016).The base stations can have many cells. In general, a cell can be defined as the area covered by base station. The hexagonal shape is selected for cell shape size coverage of more area. This shape is that closet to being circular, which represents the ideal coverage of the power transmitted by the base station antenna. The location of the base station can be at the center of the cell Center excited cells and uses Omni directional antenna. At the border of the cell Edge excited cells uses Directional antenna.

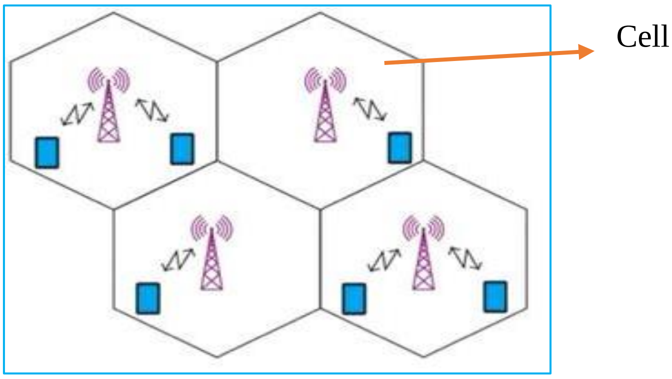
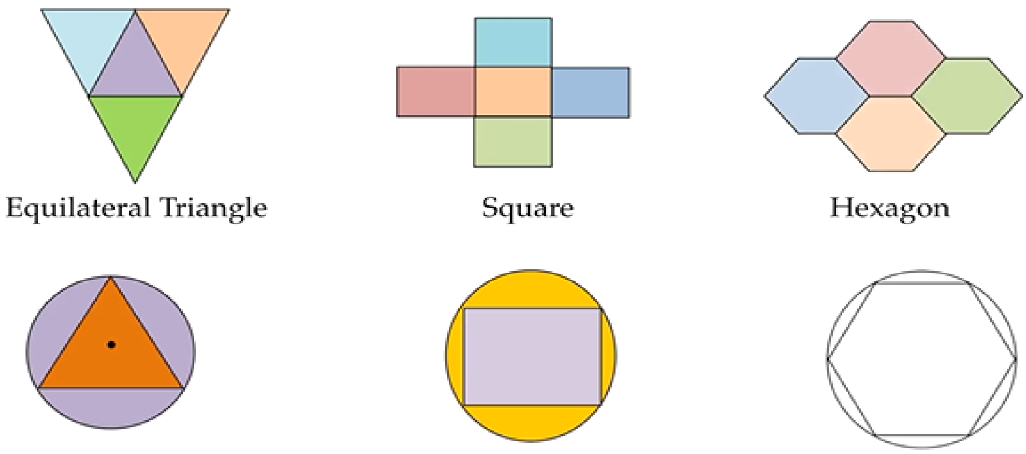


Figure 2.3 Cell shape (*Adopted from sources; Vijay Kumar, 2016)*

The power of the antenna will be only up to a particular distance to avoid co channel interference. For the transmission of the base station to be identified it must be within a particular thresholds value. This area is called Footprint or coverage area of the cell.

Deciding shape of the cell

In Cell shapes for cellular system Expected shape is circular but there is a problem with shape (overlap and gap) Gaps will result in loss of the coverage also Overlapping will lead to the interference of the signals. In hexagon the distance between the center and the farthest point in the cell is maximum. Other eligible cell shapes that might solve these problems are shown in below (fig.2.4).In practice nether the cells are equal in size, nor hexagonal in shape, nor non-over lapping. Actually all cells overlap but for mathematical or designing purpose, the shape of the cells is considered to be hexagon.



Equilateral triangle 17.77% area of circle

Square.63.7% area of circle

Hexagon: 83% of area circles covered

Figure 2.4 different cell shapes shows more coverage area.

2.5.2 Frequency Reuse

In frequency reuse what should be the appropriate cluster size? Small size vs larger size? If the number of cells in the cluster is C, the frequency reuse factor is 1/C. Distance between co-channels cells (with same frequency) is called reuse distance. The base station antennas are designed to achieve the desired coverage within the particular cell.by limiting the coverage area to within the boundaries of a cell the same group of channels may be used to cover different cells that are separated from one another by distances large enough to keep interference levels within tolerable limits. The design process of selecting and allocating channel group for all the cellular base stations within a system is called frequency reuse or frequency planning. When designing cell site (RBS) network mainly focus on coverage of the area. For easiness large area divided into clusters and cluster further are divided to cells especially for large urban areas, a cell is splitter to small sub cells (Sharma, 2018).

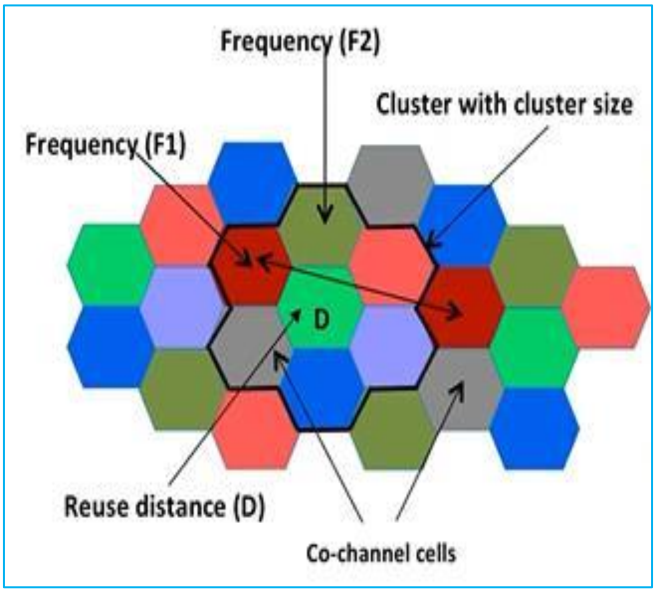


Figure 2.5 Frequency reuse. *(Sources; Sharma, 2018*)

The size of cells

The size of cells depends on (a) the tele density of a particular area or population which indicate the number of subscribers. (b)The topography of the particular area.

For example the size of cell is different based on area coverages; Size of cells in rural areas or plan surface are; Big size, More powerful and Small in numbers. The Size of cells in urban areas or not plan surfaces are; small in size, Low power and huge in numbers.

2.5.3 Handoff

The term handoff used in U.S. cellular standards documents. ITU documents use the term handover. The meanings are the same. Handoff is the procedure for changing the assignment of a mobile unit from one BS to another as the mobile unit moves from one cell to another.

However, a handover should not cause a cut-off, also called call drop. Handoff may be Network initiated, in which the decision is made solely by the network measurements of received signals from the mobile unit. The principal parameter used to make the handoff decision is measured signal strength from the mobile unit at the BS. The handoff operation involves identifying a new base station, assigning a free channel in the new cell to the mobile to change the frequency and transfer the voice circuit to the new base station.

2.6 Coverage planning and definition of morphology classification

Definition of classification in telecommunication can be defining the clutter types available in that area. This is depend upon types of buildings, isolated houses; tress open area in that region (Chaurasia, 2016). In telecommunication area can be categorized in four classes as follows.

Urban area: - as defined urban areas as localities with 2000 or more inhabitants. Urban areas also include all administrative capitals of regions, zones, and wereda, as well as localities with at least 1000 people who are primarily engaged in non-agricultural activities, and / or areas where the administrative official declares the locality to be urban. Central Statistical Authority. (CSA, 2014)

Suburban: - Suburban areas are lower density areas that separate residential and commercial areas from one another. They are either part of a city or urban area, or exist as a separate residential community within commuting distance of a city. As cars became the dominant way for people to get to work, suburbs grew.

Rural area: - The areas located outside of cities and towns are termed "rural". Rural areas have low population density. Rural areas often have a lot of undeveloped land, farmland or forest. Along major roads/highways where there are isolated houses or open ground town/village areas within the city limits.

2.7 Image Preprocessing

Generally, a remote sensing images is not used directly in raw from due to the presence of certain geometric errors in it. These errors occur due to the movements of the satellite platforms that carry sensors. The image therefore may have to be geometrically rectified (registered) to exact useful information. For planning of cell towers establishment topo sheets and satellite images plays a role for identify the name and the location of area class use as reference data. These are registered in geographical projection system in erdas imagine software.

2.7.1 Mosaicking

Mosaicking is the process of image made up of two or smaller images by the mosaic, we can create a long strip of images it is an integrated spatial optimization framework for exploring future land use and management options at regional and landscape scales. Mosaic provides the capability of identifying the social, environmental and economic trade-offs of changing the way land is managed in particular landscape contexts. A mosaic is a combination or merge of two or more images. In ArcGIS, we can create a single raster dataset from multiple raster datasets by mosaicking them together.

2.7.2 Digitization

Digitization is the process of converting information into a digital (i.e. computer-readable) format, in which the information is organized into bits. The result is the representation of an object, images, document or signal. It is usually done by features for points feature, the digitization process builds up a database of the points of their coordinates. For the lines it builds up a database, the starting and end nodes for the line and its length.in addition the GIS also create a database of the topology that is the spatial relationships between the lines.

2.7.3 Overlay

Overlay is an operation in which the spatial locations of features from two or more layers and their attributes are joined to derive new data relationships in the output layer. Overlaying layers is like overlaying map sheets, but with additional when analysis. We can get an output layer that combines data from all layers.in this research we use weighted overlay after Analytical hierarchy process is applied for comparing factors to be weight.

2.7.4 Buffer Analysis

Buffer analysis creating a zones of proximity around one or more geographic features, then using the zone for display and other spatial queries. A buffer polygon feature or simple graphic around some geographic feature or set of features (points, lines, polygons). A buffer operation is one of the most common spatial analysis tools. Buffer operation creates a new polygon data set, where a specified distance is drawn around specific features within a layer.

2.7.5 Thiessen polygon

Thiessen polygons define individual area of influence around each of set of points. Thiessen polygons whose boundaries define the area that is close to each points relative to all other points. Thiessen polygon are generated from a set of points that they are mathematically defined by the perpendicular bisectors of the lines between all points. A TIN structure is used to create Thiessen polygons converts input coverage points to coverage of thiessen proximal polygons. Thiessen polygons have the unique property that each polygon contains only one input point, and only location within a polygon is closer to its associated point than to the point of any other polygon.

2.8 Conceptual frameworks

As stated under theoretical frame work different scholars, researchers, reports, books, journals used different methods and different results to solve the problems for cellular network site selection and in telecom industry. Under this conceptual framework this researches brief explain how the gap that the study identified and solved, which materials and methods are used. The conceptual framework developed from the literature was shown in below figure 2.7

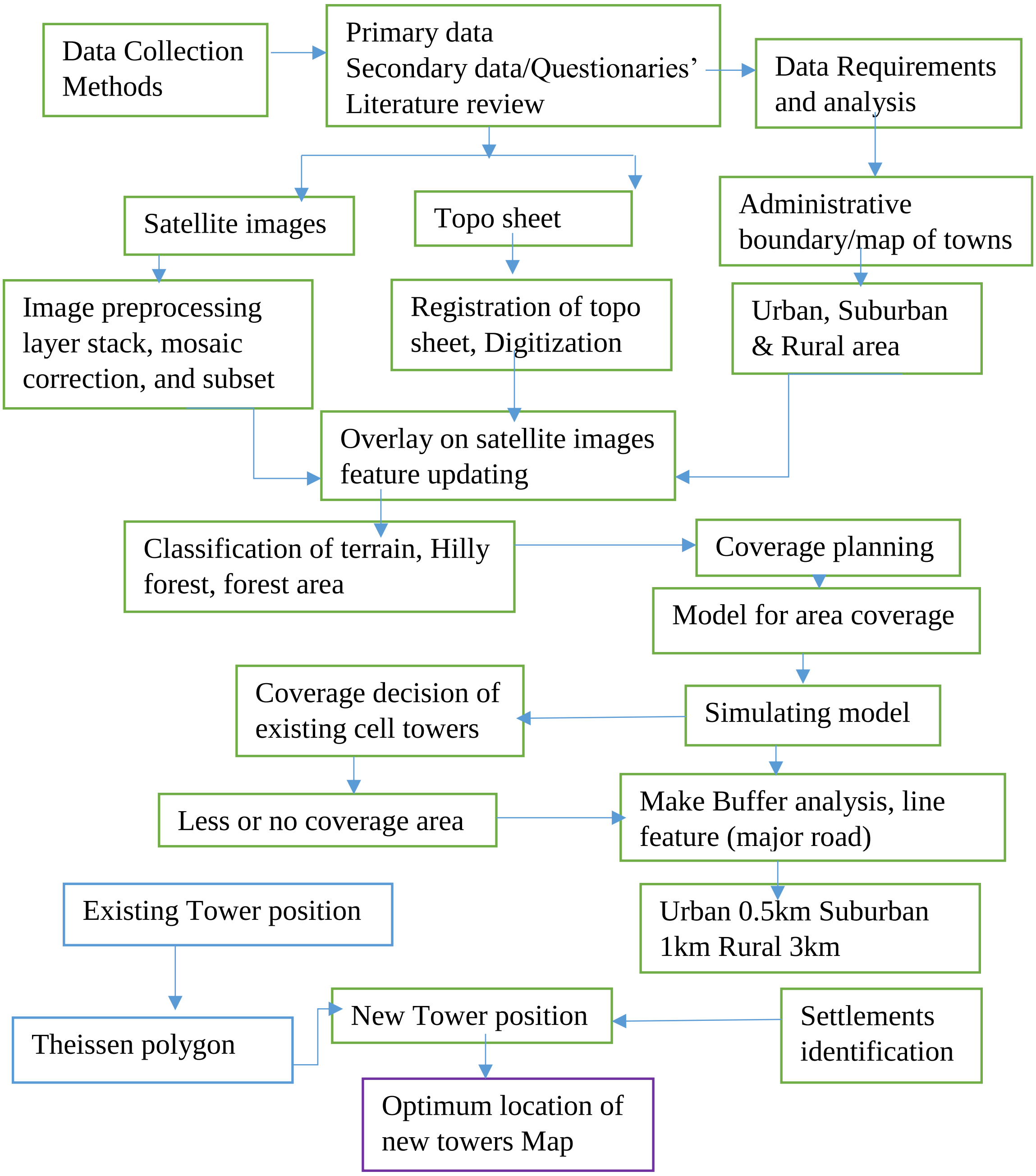


Figure 2.6 Conceptual framework Diagram From literature and by the Author

The methodology of working for the establishment of new cell towers, it need more decision during the work on the basis of coverage, Buffering Analysis, theissen polygons rules. The new optimum location of cell tower can be suggested with the help of coverage, buffer around the major road in urban, suburban and, rural area as well as existing cell tower which help us to identify which area are not covered with those cell towers, theissen intersection points, lines and settlements.

We should establish the new cell tower which should be comes under these buffers and intersection of the thiessen polygons or very near to intersection where is the large settlements can be visualize. Generally the study used geospatial analysis tool like GIS that used to organize the data for usage in Optimum cellular site selection store in geodatabase and analysis. Primary data and secondary data was collected from the field and organized in geodatabase.

2.9 Propagation Prediction model for cellular networks

The predictions are required for a propagation characteristics for any primarily building or installation, the determination of path effects as well for interface and cell radius calculation which are the basic for the finding new optimum location for cellular network in geospatial analysis, fatherly it's mandatory to know area coverages for the existing one. Because we don't have find optimum location for new cell tower while identifying the existing cell towers and coverages. (Mekonen, 2019) In global system for mobile the high level network planning process include, frequency assignment, and the determination of base station subsystems parameter set. The environments where these systems are intended to be installed are stretching from in house areas up to large rural areas.

The Factors which influence radio wave propagation can generally be described by four basic mechanism refraction, penetration, diffraction and scattering. For the practical prediction of propagation in a real environment these mechanisms must be described by approximations. The other modelling step includes the definition of mathematical approximations for the physical propagation mechanisms, which are applicable to all cell types. The mobile radio environment causes some special difficulties to the investigation of propagation phenomena;

a. The distance between a base station and mobile range from some to several kilometers distance.
b. Man-made structures and natural features have size ranging from smaller to much larger than a wave length and effect the propagation of radio waves.
c. The description of the environment is usually not at our disposal in very much detail

d. These are simulated model based on specular, reflection, diffraction, multiple diffraction, scattering, penetration and absorption, guided wave, atmospheric effects etc.

(Hoomod, 2018) Evenly numerous paired approaches can be identified to deal with this difficulties: Propagation models are main tools, which are daily in Use for designing. Planning and analyzing wireless communication networks. Propagation models can be divided into three main groups. Deterministic, statistical and empiric models. Empirical models are based on extensive measurements and mainly give prediction of path loss. They are more often used in practice than statistical and deterministic propagation models, because of low cost and model simplicity with acceptable accuracy (N.S Nkordeh, 2014).

Commonly use Empirical models are;

1. Okumura-Hata Model
2. Cost-231-Hata Model
3. Lee's Model
4. Free space model
5. Ericsson model

Okumura-Hata Model

The Okumura - Hata-Model, incorporates the graphical information from the Okumura Model (Okumura et al. 1968). The Hata Model for Urban Areas (also known as the Okumura-Hata model), is a widely used propagation model for predicting path loss in urban areas. The Cost 231-Hata models developed by COST European Cooperative for Science and Technology Collected measurement data developed a Hata-like model. It is usable in the frequency range from 500 MHz to 2000 MHz Hence, Most researchers can use Cost231 Hata model for pass loss prediction. (Fesseha, 2018) As ethio telecom GSM network was designed by Okumura-Hata model. The formula for the median path loss is described by:

$L_P = 46.3+33.9*\log(f) - 13.82 \log(h_b) - \propto(h_m) + (44.9-6.55*\log(h_b))*1og(d) + C$…….(2.1)

Where Lp is pass loss

fc frequency from 150 MHz to 1500 MHz

d distance (d) from transmitter to receiver antenna (0 up to 20km)

h_b transmitter antenna height is (considered 30 m to 200 m)and

h_r receiver antenna height (1m to 10m).

$\propto(h_r)$ is the correction factor for effective mobile antenna height which is function of the size of the coverage area for small to medium sized city.

The mobile antenna correction factor is described by:

$\propto(h_r) = (1.1\log f - 0.7)\, h_r - (1.56 \log f - 0.8)$ dB ....(2.1(a))

For large town it is given by

$\propto(h_r) = 8.29(\log 1.54 h_r)^2 - 1.1$dB for $fc \leq 300\ MHz$ ....2.1(b))

$\propto(h_r) = 3.2(\log 11.75 h_r)^2 - 4.97$dB for $f \geq 300$ MHz ....(2.1(c))

C = 0dB for medium sized cities and suburban scattered with trees and house with some obstacles near the mobile but not very congested.

The path loss for a suburban area from the Hata model is given by the following equation:

$$Lp(dB) = Lp(urban) - 2\{log10\left(\frac{fc}{28}\right)\}^2 - 5.4 \qquad (2.2)$$

The path loss for the open rural areas is obtained from the following equation:

$$L_p\,(dB) = L_p\,(urban) - 4.78\,(\log_{10} f_c)^2 + 18.33\log_{10} f_c - 40.94 \qquad (2.3)$$

Formula (2.1) can be written as (2.4) where A is the fixed attenuation in okumura-hata model. Depending on value for A the formula (2.4) gives different path loss for different frequencies stated in below table 2.1

$$L_p = A - 13.82\log h_b - \propto(h_r) + (44.9 - 6.55 \log h_b) * \log d \qquad (2.4)$$

Table 2.1 fixed attenuation A in okumura-hata propagation model

Environment	Frequency (MHz)							
	700	850	900	1700	1800	1900	2100	2600
Urban	144.3	146.2	146.8	153.2	153.8	154.3	155.1	157.5
Suburban	133.5	136.1	136.9	145.4	146.2	146.9	147.9	151.1
Rural	125.1	127	127.5	133.6	134.1	134.6	135.3	137.6

Sources; (Mesfin, 2017)

Resolving formula (2.4) according, *d* gives the radius of the coverage area:

$$D = 10^{\frac{Lp - A + 13.82\log(hb) + \propto(hr)}{44.9 - 6.55 \log hb}} \qquad (2.5)$$

The coverage area can be calculated as following:

$$\text{Coverage Area} = \frac{9 * \sqrt{3} * d2}{8} \qquad (2.6)$$

The Hata model predicts the mean signal path loss for transmitter receiver separation of more than 1km. Therefore, it is very much suited for large cell mobile communications, but not for personal communication systems radius < 1km.

CHAPTER THREE: MATERIALS AND METHODS

The chapter discusses the way the research is conducted from how literatures are reviewed to the final data discussion stage. The four main points provided detail in this chapter are the Research design, data, and description of study area and research methodology. Brief image of the research design is presented through which the structural flow of the research can be understood. Data types used in the research and their sources, methods through which they are collected are clearly described. Finally the geospatial analysis methodology and techniques that is Optimum location analysis supplemented with service area analysis and spatial analysis on how to evaluate existing sites and find the optimum cellular network sites with reduced vulnerability are presented.

3.1. Description of Study area

3.1.1. Location Description

Geographically Munesa Wereda is located in Arsi, Oromia, Ethiopia, its geographical coordinates are lies between 7° 21' 0'' to 7° 48' 0'' North and 38° 54' 0'' to 39° 12' 0''East.

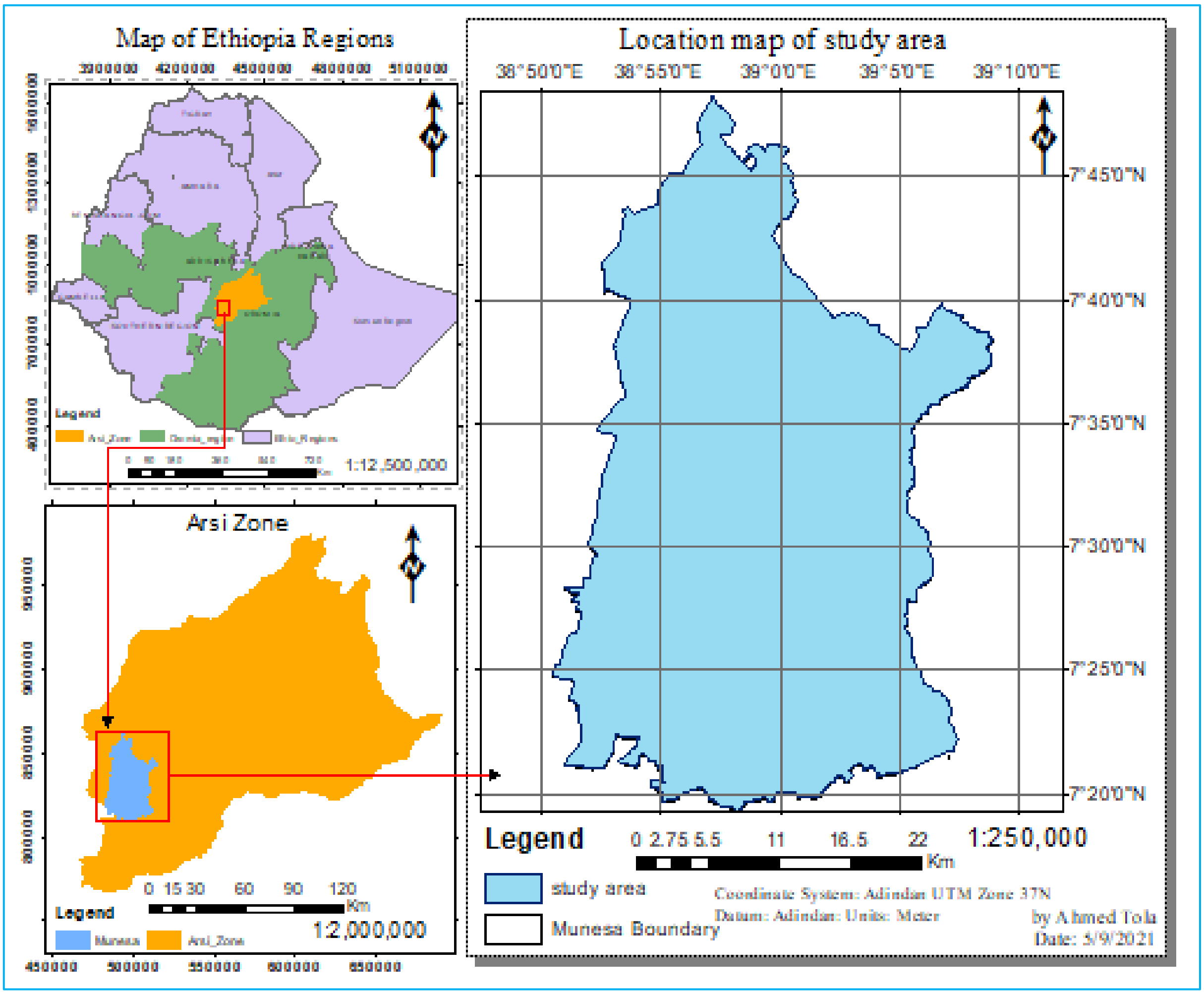


Figure 3.1 Location map of Study area.

Munesa is one of the wereda in the Oromia Region Part of the Arsi Zone located in the Great Rift Valley. It's bordered on the south and west by the West Arsi Zone and Lake Langano, on the northwest by Ziway Dugda, on the north by Tiyo, on the northeast by Digeluna Tijo, and on the east by lemuna bilbilo. The administrative center of the woreda is Kersa town; other towns are Ego, shune, asharge, kanchere and lakicha. The altitude of this wereda ranges from 1500 over 4100m above sea level. The highest point in this wereda is Mountain Chiqe 4193m. Rivers include Kersa, Teji, and Guracho which their lengths are; 45, 50,60km respectively. All of these flow into the Rift valley. A survey of the land in this wereda shows that 37.1% is arable/cultivable, 24.1% pasture, 34.6% forest, and the remaining 4.2% is considered swampy, mountainous or unusable. Sources (en.m.Wikipedia.org, 2021)

3.1.4. Climate

The climate condition of the wereda administration which falls in to two climatic zones namely the highland and temperate. The highland are temperate and cold climate (are locally called Dega or Baddaa ranges from 2300-3200), midland (warm or locally called Woinadega or Badadaree ranges from 1600 to 2300msl), each comprising 45.5% and 39.6% of the land area respectively.

3.1.5. Population

The population of Munesa Wereda as year of 2007 national census reported a total population for this wereda of 166,539, of whom 82,559 were men and 83,980 were women; 15,171 or 9.11% of its population were urban occupants.With an estimated area of 1,454.85 square kilometers, Munesa has an estimated population density of 142.6 people per square kilometer, which is greater than the Zone average of 132.2. (CSA, 2016)

The 1994 national census reported a total population for this wereda of 148,030, of whom 73,208 were men and 74,822 women; 9,756 or 6.59% of its population were urban dwellers at the time. Based on this statistics report population of wereda is growing yearly.

Table 3.1 population of Munesa Wereda

Year	1994	2007	2012
Population	148,030	166,539	228,592
Parentage increase	---	+12.50	+37.26

[Source :(https://en.wikipedia.org, 2021)] And CSA reports July 2020

3.1.2. Geographical and administrative division of Munesa

Munesa is one of the wereda in East Arsi zone Ethiopia. At present, the Munesa Wereda is divided into 32 rural kebeles, one wereda town and 6 small towns in different villages.

Topographically, Munesa wereda can be taken as flat with slope rarely exceeding moderate particularly along river paths. The average elevation of the town is about 2800m above (msl).

Research Design

The conceptual structure or the design of the research project that the researcher followed to conduct the research became important issue to be clearly defined to visualize the whole image of the work. Preparing research design highly contributes by showing over all highlights of methods towards result findings. Therefore, before beginning of the research techniques it is decided to prepare tracks of the research by assembling all the requirements for the problem solving objective. The transformation of information about the geographic environment to geospatial data, and in turn to maps can be achieved through information modelling.

Using map in cellular network Evaluation can be provide a dramatic improvement over traditional optimization methods that allowing experts to see a precise picture and location of the entire network sites and quickly identify the trouble area. To find the optimum locations for the towers of the cellular network sites, it is important to identify the overall details of the Existing towers.

The methodology followed in this research is illustrated on (page.30) from initial, processing and final stage. (Fig. 3.2)

3.2 Material and software Used for the study

3.2.1. Software used

ArcGIS software used for primary data storage analysis and digitizing features. According to Environmental Systems Research Institute (ESRI, 1990), a geographic information system (GIS) is “an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.” From the perspective of application, GIS is consisted of five key parts: hardware, software, data, methods and people. The data and information in GIS is geographically referenced (geo-coded). For the GIS methods, as (Lakhoua, 2011) concluded that “A GIS has considerable capabilities for data analysis and scientific modeling, in addition to the usual data input, storage, retrieval, and output functions”. The second software used in this study was Erdas Imagine version 2015, which is used for image processing, registration (checking ground truth of images), correction and finally classification of images and check accuracy assessment as well as kappa coefficient for classified images.

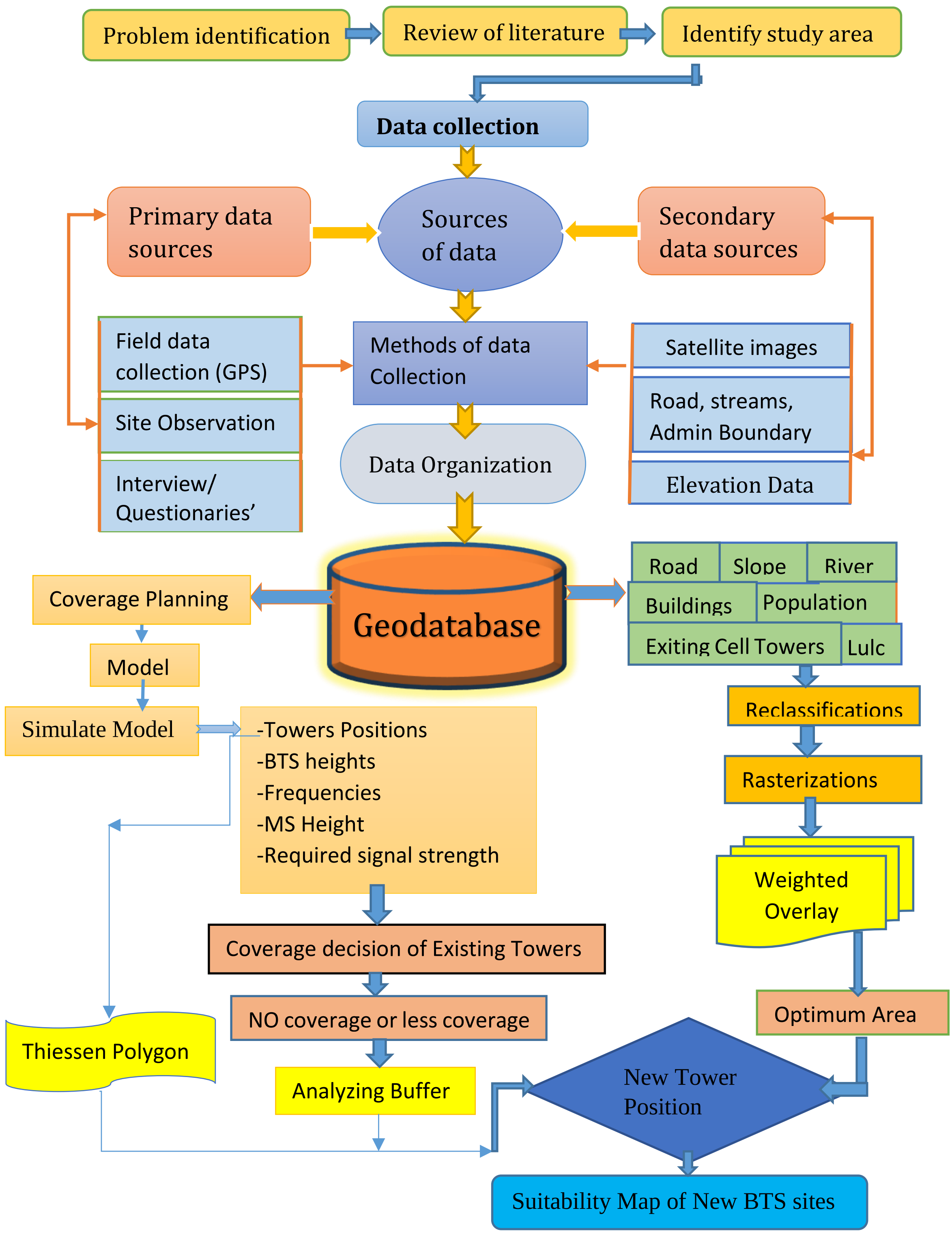


Figure 3.2. Technological scheme of the work

Idrisi Selva, version 17 is free open software an integrated raster-based GIS and Image Processing software for the analysis and display of digital spatial information for basic and advanced spatial analysis surface and statistical analysis, decision support, and change and time series analysis mainly for weighted overlay analysis by AHP (analytical hierarchal process) methods. AHP, which was proposed by (Saaty, 1980) is a structured technique for decision making based on a hierarchical framework constructed through mathematical pairwise comparisons. The weights for the decision making criteria are derived from the pairwise comparisons of the relative importance between each two criteria the sum of the weights equals to 1. (Saaty & Vargas, 1991) portrayed a scare for the pairwise comparisons, where the judgments are represented by a degree of importance. The reciprocals of the numbers are adopted to represent the inverse relationship (Mohammad et al., 2009).Table below shows that the software used description and its purposes.

Table 3.2 Software used in the research

S/N	Software name	Version/sources	Purposes
1	ArcGIS	10.8//ESRI	Data store, process and Map preparation
2	Erdas Imagine	v2015/	Image Processing
3	Global Mapper	v20.1	Processing DEM(generating contour)
4	Google Earth	v7.3	Verification of timely updates image and generate coordinate points for the images
5	Python 2.7	2.7/open sources	Calculate coverage range of Cell
6	Idrisi Selva	V17.02/open sources	AHP weighted rank/compute pair wise comparison
7	Ms-Office	2016	Writing paper and reporting results

The above table show all software's used in the research and its sources as well as show its purposes for what process we used.

3.2.2. Equipment and tools used for study

Laptop computer is the main equipment that is most commonly used for data processing and the final output preparation. The handheld type of GPS is used for collecting X, Y coordinates of existing BTS cell towers in the study area. It is more comfortable, portable and accessible for use and thus is preferred to be used by the researcher.

3.3. Data requirement and sources of data

3.3.1. Data Requirement

a) Administrative Boundary: Boundary of study area which limit area from another area by polygon feature this include boundary for all kebeles in munesa wereda and show boundary of Whole munesa wereda in Arsi zone, it taken from wereda administration office.

b) Road Networks: Road data is most importance data in processing for this research. Road Network include all road in wereda and identified by road types. It's digitized from topo sheet with scale of 1:50,000 which taken from Ethiopian Geospatial information Institute and the updated roads are verified in google earth map and structure plan of kersa and ego towns.

c) Existing Cellular Network Towers

To evaluate the existing cellular network in study area it’s highly importance to know the performance of the existing cellular towers in study area. The existing cellular sites locations are collected from field using handheld GPS for study area. Also detailed explanation of this data is asked telecom professionals.

d) Digital elevation model (DEM)

A (DEM) is a digital representation of ground surface topography or terrain. It is a 3D computer graphics representation of elevation data to represent terrain, commonly of a planet (e.g. Earth), moon, or asteroid. A "global DEM" refers to a discrete global grid. DEMs are used often in geographic information systems, and are the most common basis for digitally produced relief maps. The quality of a DEM is a measure of how accurate elevation is at each pixel (absolute accuracy) and how accurately is the morphology presented (relative accuracy). Several factors play an important role for quality of DEM-derived products: Terrain roughness, sampling density, grid resolution or pixel size, interpolation algorithm, vertical resolution and terrain analysis algorithm. It’s acquired from United States Geological survey (USGS) and with spatial resolution of 20m.It is processed in global mapper 2021 software.

e) Satellite Image:

Satellite images are images of Earth collected by imaging satellites operated by governments and businesses around the world. These images reassure forecasters to the behavior of the atmosphere as they give a clear, concise, and accurate representation of how events are unfolding. Sources of These images are form USGS Earth Explorer which provide Satellite images, aerial photos, maps, and much more Now includes on-demand ASTER products and Landsat Surface Reflectance. There are three types of satellite images.

Visible Imagery: Visible satellite pictures can only be viewed during the day, since clouds reflect the light from the sun. On these images, clouds show up as white, the ground is normally grey, and water is dark.

Infrared Imagery: Infrared satellite pictures show clouds in both day and night. Instead of using sunlight to reflect off of clouds, the clouds are identified by satellite sensors that measure heat radiating off of them.

Water Vapor Imagery: Water vapor satellite pictures indicate how much moisture is present in the upper atmosphere. Satellite images used in this study is downloaded from

USGS sentinel 2A 2021 and select February month because in this season there's no cloud cover image is clearly shown.

f) Topo Sheet

Topo sheet are obtained from Ethiopian Mapping Agency (EMA) currently known as Ethiopian geospatial Information institute a topo sheet published by the Ethiopian governments ministry of lands and Settlement (Surveying, Mapping and Geography Institute Sheet name kersa, Sheet No 0738 B4 and R.F scale of 1:50,000 for study area. in general Topography describes the physical features of an area of land. These features typically include natural formations such as mountains, rivers, lakes, and valleys. Manmade features such as roads, dams, and cities may also be included.

g) Population data

Population data is taken from Ethiopia central statistical agency which checked by year of 2012 E.C.its one of the factors used to predict optimum site for unserved area based on populated area are need cellular service.

3.3.2. Data Sources

Data sources for this research is collected from different sources by organized them into both primary and secondary data listed with their sources and types in bellow table.

Table 3.3 Data sources and formats

S/N	Data required for research	Types of data	Scale/ cell size	Sources of data	Software process
1	Administrative boundary/building	Shapefile/cad	__	Municipality of (kersa,Ego and Shune)	ArcGIS
2	Road and rivers	Shape file	__	Diva-GIS	ArcGIS
3	Existing Towers (BTS) information	Written document/xyz		ETC & field	ArcGIS
4	DEM	GRID	30m	ASTER DEM	Global Mapper 2020
5	Satellite images 2021	Tiff	10m	Sentinel-2 (USGS)	Erdas Imagine v2015
6	Topo sheet	Tiff	1:50,000	(EMA/EGII)	ArcGIS
7	Population data	Text	__	CSA	Excel &ArcGIS
	Materials		Accuracy		
8	GPS (Garmin)	Coordinate (XYZ)	2m	Collected from field	Excel &ArcGIS

3.4 Methods of Data Collection

Methods of data collection involves primary data collection and secondary data collection. Data gathering procedure includes different techniques that are applied formally and informally in order to achieve all documents for the study. The data collection methods used are two major primary and secondary data collection.

3.4.1 Primary data collection

Field data obtained by conducting direct surveys to the field such as the tower coordinate point collecting, this can be done with the use of handheld (Garmin GPS) with accuracy of 2m to obtain the coordinates of Base Transceivers Stations (BTS) in the study area.

3.4.2 Secondary data Collection

One of the most noticeable advantages of using secondary data analysis is its cost effectiveness. Because someone else has already collected the data, the researcher does not need to invest any money, time, or effort into the data collection stages of his or her study. But need to check correctness of data and its legal sources. data obtained from other sources such as legal basis, Topo sheet/digital map usage, population data, Spatial Plan, existing tower zone, new tower zone in munesa wereda, and Ethio telecom standard/policy in country. The ancillary data will be used in this study are Administration boundary, road data, satellite imagery Sentinel-2 of 10m resolution. Another method of data collection used in this study was Interview with Organizations: The interview method was used to collect secondary data. Simple questionnaire comprising of both close and open ended questions was prepared to contact and make conversations with relevant workers in organizations to identify and collect valuable data and materials as shown in the above (table 3.2).

3.4.3 Land Use Classes of Munesa Wereda

A land use classification is a classification providing information on land cover, and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on, and potential or alternative uses of, land. There are several land use types are recognized in irregularly mixed appearance with one another through the whole study area. Before optimum location of Cellular network facility distribution is made, it is important to identify each and every parts of the area under study and for what purpose it is used because it helps to separate where the demand (request) for the Cellular network and where there is no coverage of networks, where the demand is high and where it is low etc. According to information from wereda Administrative, there are about many class number of land use types identified in Munesa wereda which include both in urban and rural area. Generally they are described as follows.

a) Farm land

This types of land in study area is large area coverage than others land types. Agricultural land is typically land devoted to agriculture, the systematic and controlled use of other forms of life particularly the rearing of livestock and production of crops to produce food for humans. It is generally synonymous with both farmland or cropland, as well as pasture or rangeland. Agricultural lands consist of three main types: (a) arable land (including cropland and fallows), (b) land under permanent crops, and (c) hayfields and grazing land.

Munesa wereda partially covers the rural part of the wereda and thus includes land use for farming purposes.

b) Shrub land

Shrub land are mostly lands next to forest area where some are used for cultivated and another are occupied by small tree, scrubland, scrub, bush is a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs. Shrub land may either occur naturally or be the result of human activity. A large plant with a rounded shape formed from many small branches growing either directly from the ground or from a hard stem, grown in gardens also included in shrub lands.

c) Hilly forest

This types of land in study area is very important to identified them because the cellular tower stablished near or around hilly forest are no transmit balanced services and also there's no villages or population live in this area. Hilly forests are composed of tropical evergreen and semi-evergreen vegetation's. This is one of the main forest types in Munesa wereda. These types of forests are to be found in mountain cike, shune area to Kaka Mountain and kubsa covering an area of approximately cover area of 63.84 Sqkm.

d) Forest land

Land that is legally designated as a forest is defined as a forest even if no trees are growing on it. In study area it's difficult to classify such land without forest but assigned area for forests. It is used primarily for production of wooden. Also is a part of land with many trees Forest lands are those ecosystems that have a tree or more and are stocked with trees capable of producing timber or other wood products.

e) Riverine

Riverine Land cover types available in study area mostly in rivers edge around kebele of shune, Golba, and koma ocha. Riverine is stream which drain or not drain to river and resembles (is related to) river but not always flown by water. They are found along the edges of rivers, streams and creeks and include rivers, valleys.

f) Administration area:

Wereda administration that serves as the center for wereda administration and responsible for the Main town government whereas the second one is prepared for each kebele in the wereda that closely governs the issues of population under it and responsible for the wereda administration.

g) Infrastructures and Utilities

The most important to identify land use occupied by Infrastructures are institutes such as water supply services that provide services for the population living in the wereda at a large scale while utilities are small storehouses and sites such as ground water reservoirs, cell towers for telecommunications, etc. that give services around the neighborhood.

h) Residential

This type of land use includes settlements works for only residential use. Almost in urban area most parts of the wereda is occupied by the population houses. Residential takes the highest of all other and uses area cover. It is where demand of mobile user's population for cellular phone service facilities is believed to grow. It is also the place in which most of existing Cellular towers are hosted. Residential areas are also assumed to be clues around which services are available.

i) River

A river area is important to classify because the candidate cell tower cannot possible to build in a river area. A river is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river. In some cases a river flows into the ground and becomes dry at the end of its course without reaching another body of water. In munesa remarkable amount of area is also covered by rivers and their tributaries that flow from the Northern mountainous parts down the southern borders of the wereda. Instead the rivers in the area are polluted by different kinds of dry and liquid wastes from the residential area. Industrial and commercial areas.

j) Mixed Forest

An area covered by mixed forests of Acacia, Juniper, Eucalyptus, Cupressaceous (Yeferenj Tid), Cordia Africana (Wanza), and White Thorn acacia etc. Such kinds of mixed forests are seen mostly on areas where only some artificial plantation activities are applied and naturally Occurring plants are protected, beside religious centers, along river basins and where knowingly varieties of flora are planted (Bahirzaf) etc. the area 8726.95 ha of land is covered by mixed forest.

k) Grass land

Grass land area in which the vegetation is dominated by nearly continuous cover of grasses. Grasslands occur in environments conductive to the growth of this plant cover but not to that of taller plants, particularly trees and shrubs.in study area grass lands cover area of free space in towns such football fields school gardens and stadium.

3.4.4 Image Classification

Image classification is important to convert image data to thematic data. According to Author (Kiefer, et.al.2000), the overall objective of image classification procedures is to automatically categorize all pixels in an image into land-use/land-cover classes.

Below (fig.3.4) show land use land types of munesa wereda and its corresponding area coverage described in Table 3.6 on (page.39)

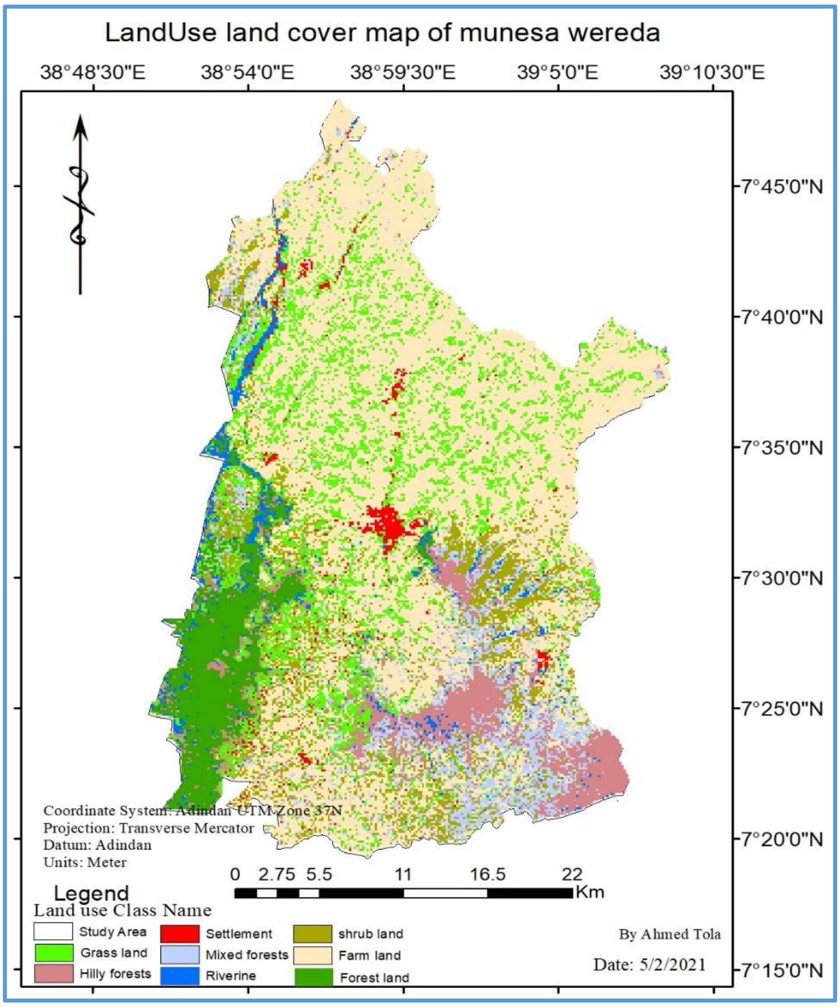


Figure 3.3 Land use Map of munesa wereda.

As shown above figure the maximum area of munesa wereda is covered with farm lands

And exceeding by grass land while the low area of land cover is settlements.

Table 3.4. The land use land cover types and their respective area coverage

S/N	Land use types	Area(Hectares)	Coverage area (%)
1	Farm Land	53284.9	49.72
2	forest Land	7103.43	6.63
3	Grass Land	16000.2	14.93
4	Hilly forests	8052.36	7.51
5	Mixed forests	8726.95	8.14
6	Riverine	2710.46	2.53
7	Settlements	1709.98	1.60
8	shrub land	9571.03	8.93
Total Area		107159.31	100.00

The above table show the classified total area of land use coverage area and its Percentages year of 2021.

The image data was preprocessed in ERDAS imagine 2015 and standard image processing techniques such as image extraction, rectification, atmospheric correction, radiometric correction and classification was used for analysis of satellite imageries. Image classification was performed by the maximum likelihood algorithm methodology for the extraction of land-use/land-covers of the study area. Finally, major land use land-cover types was identified by using the satellite images of sentinel 2 in specified year. In ERDAS Imagine software, the signature editor also created for defining classes.

Accuracy assessment of land use land cover classification

Accuracy assessment is the final step in the analysis of remote sensing data which help us to verify how accurate our results are. It is carried out once the interpretation/classification has been completed. The confusion matrix/error matrix has numbers as the quantity of sample.

Any particular quantity arranged in rows and columns i.e. square matrix, where columns represent the referencing data while row represents the classification data.

The overall accuracy for the LULC image are defined as the total correct pixels (major diagonal's sum) divided by the total number of pixels in the provided matrix which is 91.91% (Table 3.4). In addition, the overall kappa coefficient for the image was 0.8321 i.e. 83.21% better agreement than by chance alone respectively.

Kappa values are characterized as < 0 as indicative of no agreements and 0 to 0.2 as slight, 0.2 to 0.41 as fair, 0.41to 0.60 as moderate, 0.60 to 0.80 as substantial and 0.81–1.0 as almost perfect agreement. Therefore, the overall classification accuracy of the image yielded a Kappa statistic of 83.21% (Table 3.5) for the 2021 image. This implies that the image classification accuracy was almost perfect agreement.

Table 3.5 Accuracy Assessment and Error Confusion matrix of lulc map 2021

Classified Data	Reference Data								Row Total	producers Accuracy
	forest Land	Riverine	Farm Land	shrub Land	Grass Land	Settlement	Hilly forest	Mixed forest		
forest Land	99.93	0.58	0	0	0	0	10	0	110.51	90%
Riverine	0.01	97.84	0	0.19	0	0	0.73	0	98.77	99%
Farm Land	12	0	96.81	0.5	14.22	1.38	3	2.4	130.31	74%
shrub Land	0	0.43	0.81	96.83	0	0	0	2.75	100.82	96%
Grass Land	0	0	1.96	0.27	85.78	1.77	0.32	0.24	90.34	95%
Settlement	0	0	0.39	0.15	1	96.84	0	0	98.38	98%
Hilly forest	0.07	0.29	0	0.18	0	0	97.9	7.31	105.74	93%
Mixed forest	0	0.86	0.04	1.88	0	0	1.06	87.31	91.15	96%
Column Total	112	100	100	100	101	99.99	113	100.0	826.02	
Reliability(users Accuracy)	89%	98%	97%	97%	85%	97%	87%	87%		

Generally from the above table we calculate the Overall Accuracy of classification =91.91 %, the Average Accuracy =93 % and the Average Reliability/users accuracy = 92 %.

Table 3.6 Conditional Kappa for each Category

Class Name	Hilly forests	Grass Land	forest	Settlements	Shrub Land	Farm Land	Mixed forests	Riverine
Kappa	1	0.90	0.65	0	0.77	0.78	1	0

The above table show conditional kappa for each classes and kappa value 0 show as indicative of no agreements between two classes.

Existing Road Network: In selecting optimum location for cellular site one of most important land use type to be studied in research work is the road network existing in the study area. Road is a transportation route that determines the degree of importance of another land use type by increasing the accessibility of that area. There are four major categories of roads connected to one another in the study area namely asphalt road, gravel road (status uncertain), earthen roads and Cobblestone.

Table 3.7 Existing Road Type and length in munesa wereda

Road Types	Road class	Area(hectares)	Length(km)	Percentage (%)
Gravel Road	1	351.23	175.66	81.94
Earthen Road	2	67.70	33.98	15.79
Asphalt Road	3	8.38	3.47	1.96
Cobblestone	4	1.34	0.80	0.31
Total		428.65	213.92	100.00

Above table show an area of 428.65 hectares are covered with road network while other areas are by different land use (Table.3.4). In general, it can be easily identified that which area are related to population from which request for cellular network service facilities arise and which are cover the facilities (services) answer the needs of the population live without network access.

3.5 Methods of Data Analysis

3.5.1 Munesa wereda cellular coverage

The resulting lack of service coverage has so far ensured basic telephony services are Unavailable to a significant number of people in some of the more rural areas, where the Common challenges of life would favors a wireless telecommunications solution the most. In addition to the rural areas, basic telephony services are still considered to be inaccessible for large numbers of people living in cities, or around them, either due to a lack of fixed telephone lines, because significant expansions of the existing wireline infrastructure are laborious and time-taking, or because they are not able to afford subscribing to telephone services.

Mobile phone, one of the modern technologies for developing countries, that is used for accessing different rural innovation services. It has the potential to allow rural households to get marketing services, agricultural extension services, health services and other mobile services timely. The internet users in Ethiopia and other countries are presented as the percent of people who have access to the internet either at home, at work, or in public spaces. The Internet can be used via a computer, mobile phone. According to the latest researcher data provided from 1990 to 2019 the average value for Ethiopia during that period was 3.48 percent with a minimum of 0 percent in 1990 and a maximum of 18.62 percent in 2017.

Ethiopia was one of the last countries in Africa to allow its national telco a monopoly on all telecom services including fixed, mobile, internet and data communications. For many years Ethio Telecom's monopolistic control stifled innovation, restricted network expansion and limited the scope of services on offer. However, in June 2019 the government approved legislation which will open the market to competition and provide much needed foreign investment. (Etc, 2021)

At the same time the government aims to part-privatize Ethio Telecom, with a 45% stake in the company to be made available. During the coming year the telecoms sector to various degrees is likely to experience a downturn in mobile device production, while it may also be difficult for network operators to manage workflows when maintaining and upgrading existing infrastructure. Overall progress towards 5G may be postponed or slowed down in some countries.

On the consumer side, spending on telecoms services and devices is under pressure from the financial effect of large-scale job losses and the consequent restriction on disposable incomes. However, the crucial nature of telecom services, both for general communication as well as a tool for home-working, will offset such pressures. In many markets the net effect should be a steady though reduced increased in subscriber growth.

Although it is challenging to predict and interpret the long-term impacts of the crisis as it develops, these have been acknowledged in the industry forecasts contained in this report. The report also covers the responses of the telecom operators as well as government agencies and regulators as they react to the crisis to ensure that citizens can continue to make optimum use of telecom services. This can be reflected in subsidy schemes and the promotion of tele-health and tele-education, among other solutions. (Sources: Ethio telecom reports, 2021)

3.5.1 Optimum location of cellar network

Data analysis is the process of cleaning, analyzing, interpreting, and visualizing data to discover valuable insights that drive smarter and more effective result decisions. Data analysis tools are used to extract useful information from collected data, and help make the data analysis process easier. The analysis of existing data is a cost-efficient way to make full use of data that are already collected to address potentially important new research questions or to provide a more detail assessment of the primary results from the original study.in this study we use bellows data sets evaluate and analysis to achieve the objectives mentioned in chapter one.

A) Existing cellular networks

Existing cellular sites are identified using directly collecting data from field using handheld gps.this is done by methods of the Euclidean distance from existing cell towers as factors.

B) Land use/land cover

Land use can be one of most important factors in site selection of Telecom towers.it can be defined as a series of activities undertaken to produce one or more goods or services definition of land use in this way provide a basis for identifying possible land suitability for telecom towers with precise and quantitative economic evaluation.

C) Elevation data

Elevation data is most of the time stored in raster format. Elevation data for this research was used Aster Dem free open source from USGS with resolution of 20m. This data is stored as raster format. The advantage of raster format for elevation data is that a preprocessed height value is easily detectable for every point of planning area. The exact height can be detected by the next neighboring pixel or bilinear interpolated by the four neighboring pixel. Elevation data in vector format would require a detection of all neighboring elevation contours needed to interpolate the exact height at that position. It represents the height of the surface of the earth above sea level.

D) Slope

Slope is the most importance factor which used to find optimum area for new site of cellular networks (BTS).Slope is one of the topographic parameters that can determine the affectance of land use planning. It’s also calculated from digital elevation model.

E) Existing road networks

Existing road networks are digitized in ArcMap and categorized as major road, intermediate road. We use the major road for data analysis because when the connection of cellular network is occurred during traveling so to evaluate this the data was calculated as road in urban, sub urban and rural area.

F) Rivers

Stream data like rivers are digitized from Topo sheet and verified on current google earth map updated. It’s mandatory to identify the stream data before finding suitable area as one factors. Because we do not built the tower on river as well as drainages,

G) Population Distribution layer

Population distribution raster obtain by applying IDW tool for previously created Munesa Keeble’s population distribution center point feature class. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process (ESRI, 2008).

3.5.2 Creating Geodatabase and its structure

A geodatabase is more than a collection of datasets; the term geodatabase has multiple meanings in ArcGIS. The geodatabase is the native data structure for ArcGIS and is the primary data format used for editing and data management. While ArcGIS works with geographic information in numerous geographic information system (GIS) file formats, it is designed to work with and leverage the capabilities of the geodatabase. It is the physical store of geographic information, primarily using a database management system (DBMS) or file system. You can access and work with this physical instance of your collection of datasets either through ArcGIS or through a database management system using SQL. Geodatabases have a comprehensive information model for representing and managing geographic information. This comprehensive information model is implemented as a series of tables holding feature classes, raster datasets, and attributes.

In addition, advanced GIS data objects add GIS behavior; rules for managing spatial integrity; and tools for working with numerous spatial relationships of the core features, raster’s, and attributes.

File geodatabases: a collection of various types of GIS datasets held in a file system folder. (This is the recommended native data format for ArcGIS stored and managed in a file system folder.) Its Stored as folders in a file system. Each dataset is held as a file that can scale up to 1TB in size. The file geodatabase is recommended over personal geodatabases.in file geodatabase storage format each dataset is a separate file on disk. A file geodatabase is a file folder that holds its dataset files.

Personal geodatabases: Original data format for ArcGIS geodatabases stored and managed in Microsoft Access data files. This is limited in size and tied to the Windows operating system. All datasets are stored within a Microsoft Access data file, which is limited in size to 2 GB. In personal geodatabase all the contents in each personal geodatabase are held in a single Microsoft Access file (.mdb).

Enterprise geodatabases: a collection of various types of GIS datasets held as tables in a relational database (This is the recommended native data format for ArcGIS stored and managed in a relational database.)Also known as multiuser geodatabases, they can be unlimited in size and numbers of users. Stored in a relational database using Oracle, Microsoft SQL Server, IBM DB2, IBM Informix, or PostgreSQL.

Elements of Geodatabase:- Geodatabase elements includes; Objects & Object classes, Features & Feature classes, Feature datasets, Spatial references, Domains, Subtypes, Relationships & Relationship classes, Geometric networks, Labels and Annotation

Building a Geodatabase: Building GDB have the following process (fig 3.4)

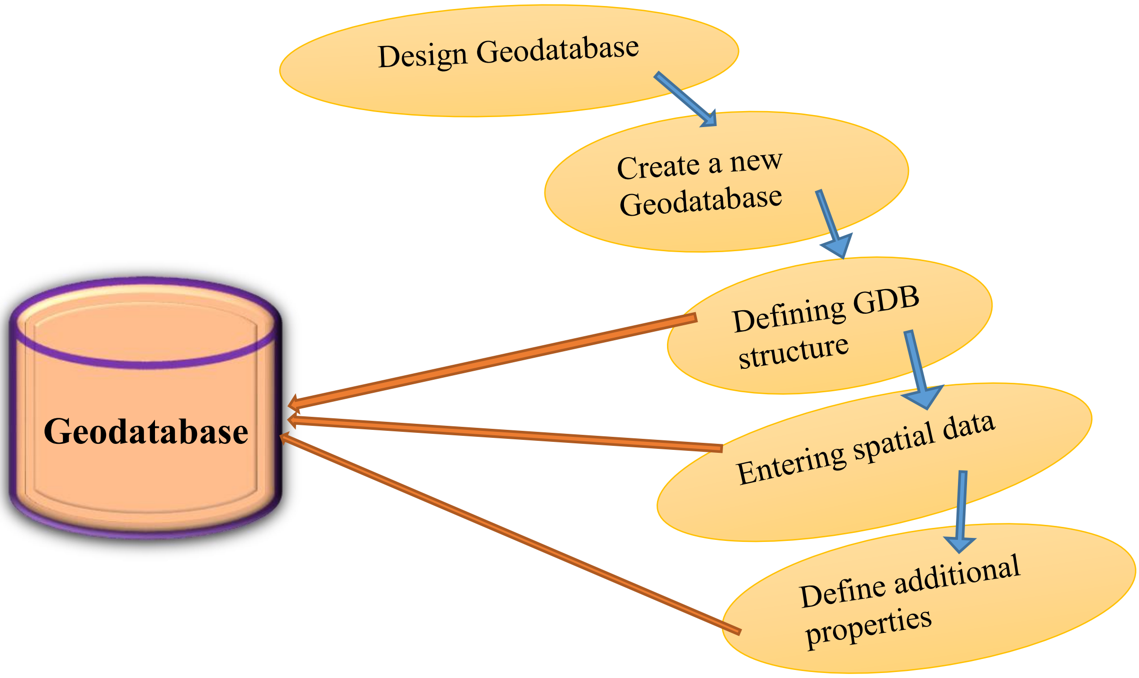


Figure 3.4 Geodatabase building process.

Above figure show how GDB building processed and Designing the geodatabase tell us to think before we create, Creating a new geodatabase indicate Name and location only, Defining the geodatabase structure have Schema and data, Entering spatial data Loading or automation, Define additional properties Validation, relationships, and networks.

A geodatabase has three primary components: feature classes, feature datasets, and non-spatial tables. All three components are created and managed in Arc Catalog. A feature dataset is a collection of feature classes. All the feature classes in a feature dataset must have the same spatial reference. A feature class is a collection of features that share the same geometry type (point, line, or polygon) and spatial reference. A non-spatial table contains attribute data that can be associated with feature classes.

Geodatabase and workflow procedure

3.5.3 Georeferencing Scanned map

Georeferencing is a process of establishing a mathematical relationship between the image coordinate system and the real world spatial coordinate system. This mathematical relationship can be assigned by any one of the transformation settings. Polynomial order 1, 2 or 3, Linear, Projective and Thin Plate Spline etc. Polynomial order 2 is the most widely used transformation in Georeferencing. The base map for the other maps used in this thesis is the munesa Wereda topo sheet map of the kersa obtained in softcopy file. With the help of ground control points located on the map, four sharp point from four corner of the city are used as a sample ground controlling points to georeferenced the base map. These coordinate points are carefully read from the scanned map, registered and used as a Control points to georeferenced it on ArcGIS. This was done by adding these data in to Arc Map and checking the georefencing tool from the Arc Tool box then magnifying and adding the ground controlling points of the four corners of the map's layout in to georeferencing table. After the points were carefully inserted, it was necessary to rectify (save as new georeferenced map) or apply these few points to the whole areas on a map. Therefore, rectify option have been chosen from the georeferencing tool and saved in the created database.

3.5.4 Projection and Transformation

For this thesis we use different data; some data such as Global Positioning System readings taken from Existing cell towers and sample unserved (area with no coverage) areas on the field were in a projected coordinate system i.e. In UTM WGS_1984 ZONE 37 N. All the data are converted in to shape files and they are projected to the coordinate system similar to the spatial reference system of base map, which is Projected Coordinate System. Therefore, the data taken plan in AutoCAD file) and collected with handheld GPS from the field, which was in projected coordinate system is projected and transformed to a Adindan_UTM_Zone_37N. This can be done in projection and transformation from spatial analyst tool in ArcGIS.

3.5.5 Analysis of model for coverage planning.

It's mandatory to know about coverage planning of pass loss with existing BTS in study area. Coverage and capacity are important issues in the planning process for cellular of GSM and in Third Generation (3G) mobile networks. The planning process aims to allow the maximum number of users sending and receiving satisfactory signal strength in a cell. So it's possible to calculate a radius of each cell towers (BTS) in study area.

Thiessen Polygon: Thiessen polygon is a tool available in ArcGIS Arc Toolbox it is used to divide the area covered by the input point features into Thiessen or proximal zones. These zones represent full areas where any location within the zone is closer to its associated input point than to any other input point. Thiessen proximal polygons are constructed as follows: All points are triangulated into a triangulated irregular network (TIN) that meets the Delaunay criterion.

3.5.6 Creating Python Script tools for coverage area calculation

A Python script is a collection of commands in a file designed to be executed like a program. The file can of course contain functions and import various modules, but the idea is that it will be run or executed from the command line or from within a Python interactive shell to perform a specific task. Python script is One of the methods of data analysis is to calculate the existing wireless tower area coverage ranges in written python program. Python was an open-source object-oriented programming language and it was offered two to tenfold programmer productivity increases over languages like C. C++, Java, C#, and Visual Basic (V B). Python programming language was consisted with many advantages.

Easy to Read, Learn and Write. Python is a high-level programming language that has English-like syntax. This makes it easier to read and understand the code. The other Advantages were such as Object-oriented, simple, stable and wealth of third party packages. The reason why we chose python programming is that it was the only supported programming language for ArcGIS beyond released of ArcGIS 10.x software's. Other language such as VB programming language further was not supporting by ArcGIS it was integrated with python. ArcPy was a site package which builds on the successful ArcGIS scripting module. ArcPy was provided to access geoprocessing tools as well as additional functions, classes, and modules that allow researchers to create simple or complex workflows. (ESRI. 2012)

Python Script was able to deal with spatial geoprocessing by adding ArcPy site package. It was helped to create Python Script which was directly gave results researches defined rules Such as complex algorithms, arguments, spatial geoprocessing.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This chapter tried to deal with the data in order to answer the research questions expressed Previous starting from estimated assumptions up to the most reliable solutions that even Stakeholders can apply to action. Relevant data analyses using the predefined methodology and Consecutive techniques of location allocation and spatial analysis are engaged. Descriptions of the discussed results in the form of information are briefly arranged. Discussions are provided to meet the purpose of study and objectives set briefly at the beginning of the study. Finally the intentioned and refined greatest output of the research that is the most Optimum cellular network sites are distinguished as a candidate sites. These are candidate sites for cellular network service that in arrangement with the existing cell towers which are accessing cellular network in study area can progressively support the Essential Communities.

4.1 Geodatabase Creation

As explained in chapter 3 database is the most importance for storing data in ArcGIS environment. The key element in GIS work is the design of the database. Among the databases used in Esri's ArcGIS program, file Geodatabase have been chosen as an appropriate geodatabase for this particular research work. Geodatabase is a container, similar to folder, which is used to input, store, manage feature datasets, and feature classes.

The database is designed to consist of detailed information includes data related to road network, GPS evaluations of sample positions, stream data (river) data, and both vector and raster data used in this research, boundary map, map of wereda, land use map as well as data in raster formats such as Digital Elevation Model (DEM) Slope data used during the analysis process DEM. When optimum location for cellular network suitability is assessed in a raster GIS environment, each land unit in the database is valued according to its priority in land for cellular network site selection and each thematic layer represents its unique in the evaluation process. Following the File Geodatabase creation, feature dataset is also created to hold the feature classes like land use map, road map, slope map and others with the same steps followed in feature dataset creation. Having finished feature class creation, domain and topology are adjusted by clicking the right mouse on feature classes and pointing to topology and domain respectively. (Figure 4.1) below show sample created geodatabase, feature dataset and feature class including non-spatial (attribute table).

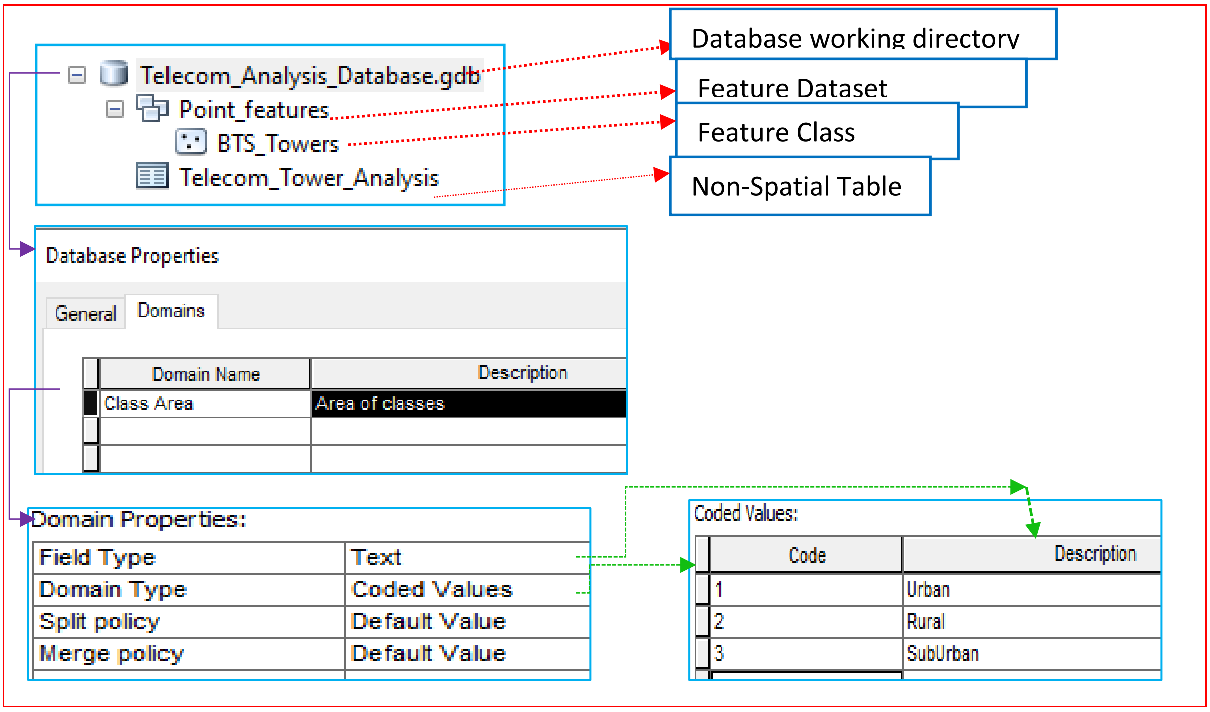


Figure 4.1 geodatabase and its structures.

Geographic information system database with corresponding feature types,datatypes are listed in below Table 4.1 and detaied field of Tower location is described (Table 4.2)

Table 4.1 Layers of GIS database and featureType

S/N	Layer Name	Feature Type
1	Munesa Boundary	Polygon
2	Tower Location	Point
3	Roads	Line
4	Stream	Line
5	Buildings	Polygon
6	Topo Sheet map	raster
7	DEM	Grid

Table 4.2 Tower Location Attribute and DataTypes

S/N	Field	Data Type	Length
1	Point ID	Text	20
2	Site Name	Text	20
3	Address	Text	20
4	Area types	Text	20
5	Elevation	float	
6	Easting(X)	float	
7	Northing(Y)	float	
8	BS Height	float	

4.1.1. Importing Vector and raster data into Geodatabase

One of the main data analysis is to create Geodatabase and import features, tables, asters/images all data we use in this thesis and analyze these data from created database. We can use the Feature class to Geodatabase tool in Arc Catalog and Arc Toolbox to import feature classes from one geodatabase to another or to import features from one feature class into a new feature class in the same geodatabase. This tool creates simple feature classes only and does not preserve object identity. Simply we can also Export file to geodatabase under Arc Catalog tree.

4.1.2. Availability and Coverage of Cellular network in Study area

The magnitude to which the existing Cellular Network towers BTS in the area are serving the surrounding community is important issue to know before further analysis. It is also significant to identify location of each existing Cellular Network towers BTS in terms of utility Electric power infrastructures i.e. roads and population. Below (fig.4.2 – 4.3) shows the distribution of existing cell tower in terms of roads and entire population of Keeble's in munesa wereda respectively.

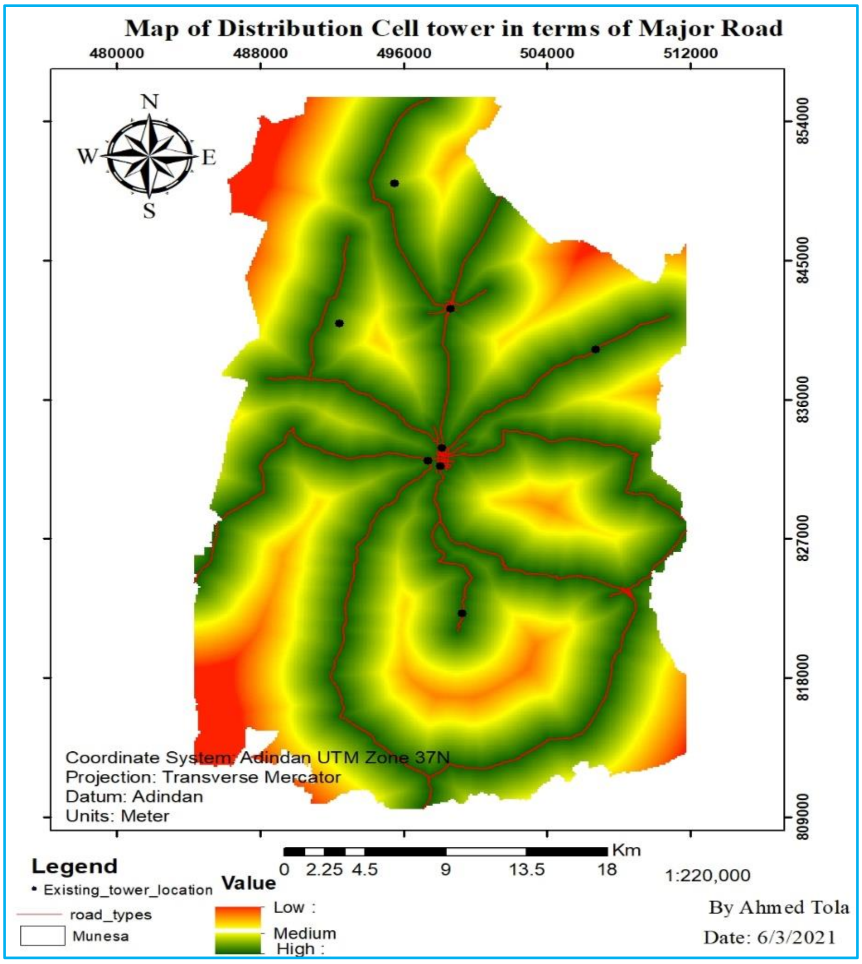


Figure 4.2 Distribution Pattern Map of cell tower location in Terms of major Road

The (fig 4.2) shows the distribution of existing cell towers in terms of major road in study area. A green colored area show very high to access while red to yellow color show medium to low. Computation of access Indicators is done to give a rough approximation for the cellular networks at the area. These are discussed using the evidences from the spatial and non-spatial evidences collected from different sources in combination with the researcher's works. Currently the existing cellular sites are consist of eight sites from which two sites covered the urban area, two sites suburban and the rest four sites cover some part area of rural to provide service for a subscribers.

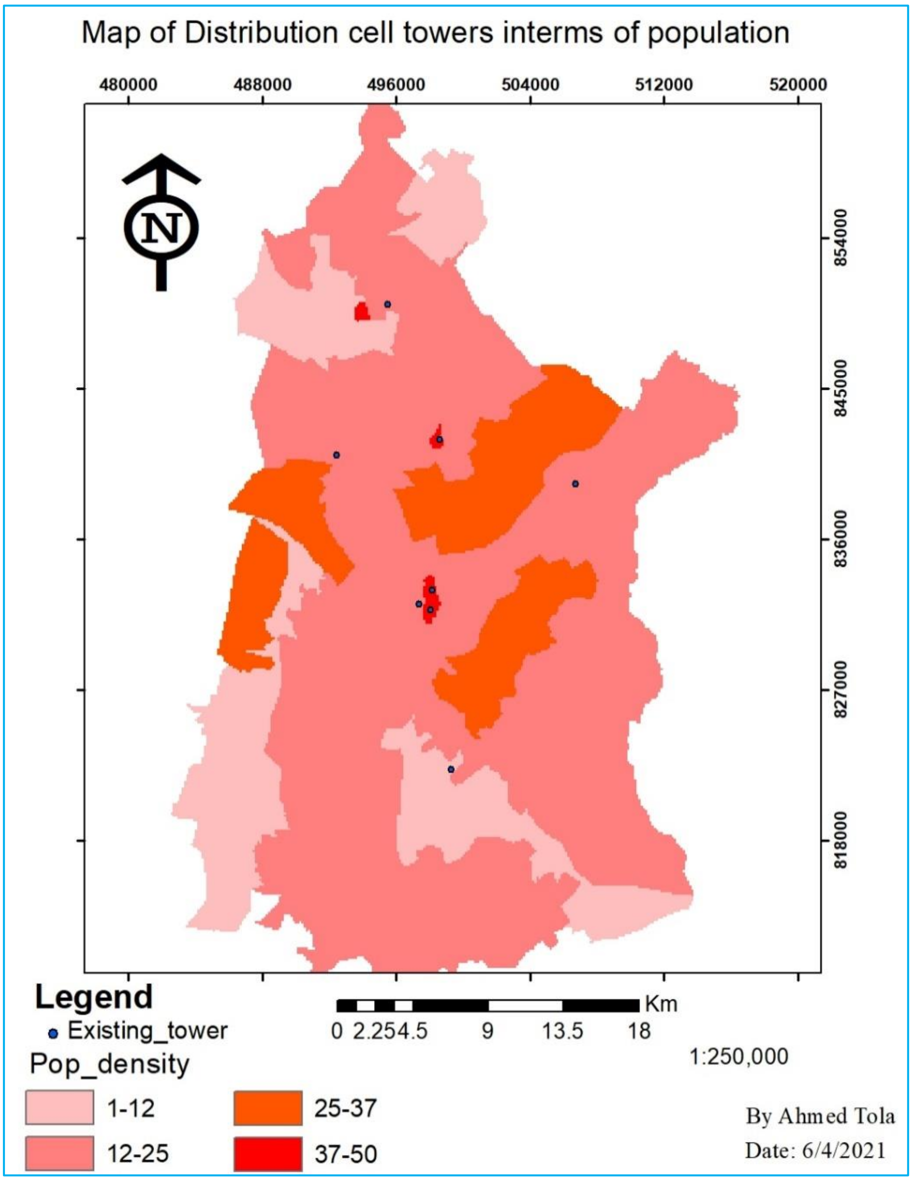


Figure 4.3 Distribution Pattern Map of BTS location in Terms of Population.
(Sources: CSA, 2012)

Above figure show the population density of wereda classified into four groups (population density up to [12, 25, 37, and 50] less than 12 area are very low and greater than 37 are highly required area.

4.2 Data Analysis and Results

Data analysis in combination with the results are consequently and clearly provided in this section. The predefined methodologies which explained in (Fig.3.3 are followed for location analysis and finding optimum cell tower sites in spatial analysis respectively to solve location problems of cell tower in munesa wereda.

4.2.1. Optimizing cellular network BTS Sites Using Spatial Analysis

In order to achieve our objectives we need to convert each data to be file format that can be used for next process like image classification. Every GIS analysis has two basic components: data and analysis tools. In the early days of GIS, most spatial data had to be captured (i.e. encoded in digital form) manually. This was time consuming, difficult, and error-prone. Fortunately, there are now many spatial datasets that are already in digital form. Our tasks as GIS analysts are to find these data sets and assess their suitability for our needs. Optimizing cellular networks sites using geospatial analysis we have conclude in two stages. The Spatial analysis methods of decision making requires the input data to be changed in a valid format to come to the desired result. Therefore rasterizing is the process from which participating data are converted from either vector or from raster to a raster form that is required. So the raw elevation data is changed to slope data. Data collected from filed Existing cell tower Location, population and suggested sites for new Cell towers are point data that are originally in the vector format. Euclidean distance toolset from the spatial analyst tools changes these into raster format. It is distance because it calculates the proximity for each pixel in the output raster from the existing source data within an extent of munesa wereda boundary in this case.

Slope Analysis: The Ethio Dem data was used for generation of contour map that covering of Munesa wereda. The slope in percentages were categorized and maps were prepared to understand and identify the heighted sites in study area. In the wereda contour value lie between 1925 to 3766 meter. Terrain analysis data which include dem, contour data which are analyzed from surface analysis toolset in ArcGIS. Surface slope is divided mostly into four common ranges based on the steepness of the surface which are flat 0^0-5^0 , Rolling or gentle (5^0-25^0), mountainous (25^0-50^0) and escarpment (>=50^0). As shown in Figure 4.3 we classified slope data into constant intervals of five 1 (0^0 -5^0), 2 (5^0-8^0), 3 (8^0 -16^0), 4 (16^0 -32^0), and 5 (32-58^0). Intervals that are at high degree values show mountainous or escarpment areas and are Moderately Comfortable to build cell tower. On the other hand areas from zero to gentle slope will suitable. This implies suitability increment is the reverse of slope increment. Straight line distance between the listed input datasets are already prepared. Reclassification is made by giving similar intervals (scale values) of slope for each (Figure.4.3).

Existing cell towers existing are places that negatively influence the course of finding the suitable areas for new cell tower in other ward cell nearest to another have no negative side it helps signal strength for coverage range increase, but due to high cost it does not advice to stablish nearest towers.

Suggested sites and existing population sites on the other hand positively influence the search Work for suitable Cellular network areas. This is because proposed sites and population attracts need network services to be serve them therefore, the reclassed scale values and old values of their respective distances will be opposite to each other the scale values are reversed in the way it is done for slope.

4.2.2 Constraint and Factor Maps

4.2.2.1. Constraint Maps

‘‘Constraints, which are non-compensatory criteria that determine which areas should be excluded from or included in the suitability analysis. The excluded areas will get a nil (0) performance value in the composite index map, whereas the remaining areas will obtain a value between 0 and 1.Constraints are thus expressed in the form of a Boolean (logical) map’’ (Valentina, 2011:239). Accordingly, constraint maps, as it is explained above, are areas that have some kind of constraint and are unsuitable due to environmental concerns. Therefore, these maps are identified as constraint maps based on accepted and defined criteria. In this thesis: road networks, Slope, stream maps, all have certain buffer distances set to identify areas that have certain constraint. Similarly, land use has its own constraint for cell tower site selection and analysis. As show in figure 4.3 – 4.6 below, constraint maps created based on accepted distance to a proposed new cell tower site in the wereda of munesa. The buffer distances for each criteria maps is made based on reviewing different local and international research project works and Consultation of experts in the Adama town (because ETC experts for South region control and manage in this town) and kersa town.

i) Slope Constraint Map for Cellular Network site

Landscape has plays a great role in determining the choice of cell tower Cellular Network site. As it is lying on relatively flat 0^0-5^0, Rolling or gentle (5^0-25^0), mountainous (25^0-50^0) and escarpment (>=50^0). Much of the wereda topography lies on a slope steepness not greater than eight degree. Though this has been seen as a minor constraint, still slope has been well considered as a constraint in locating a suitable Cellular Network site. The following slope constraint map have been obtained based on a define steepness level (fig.4.4)

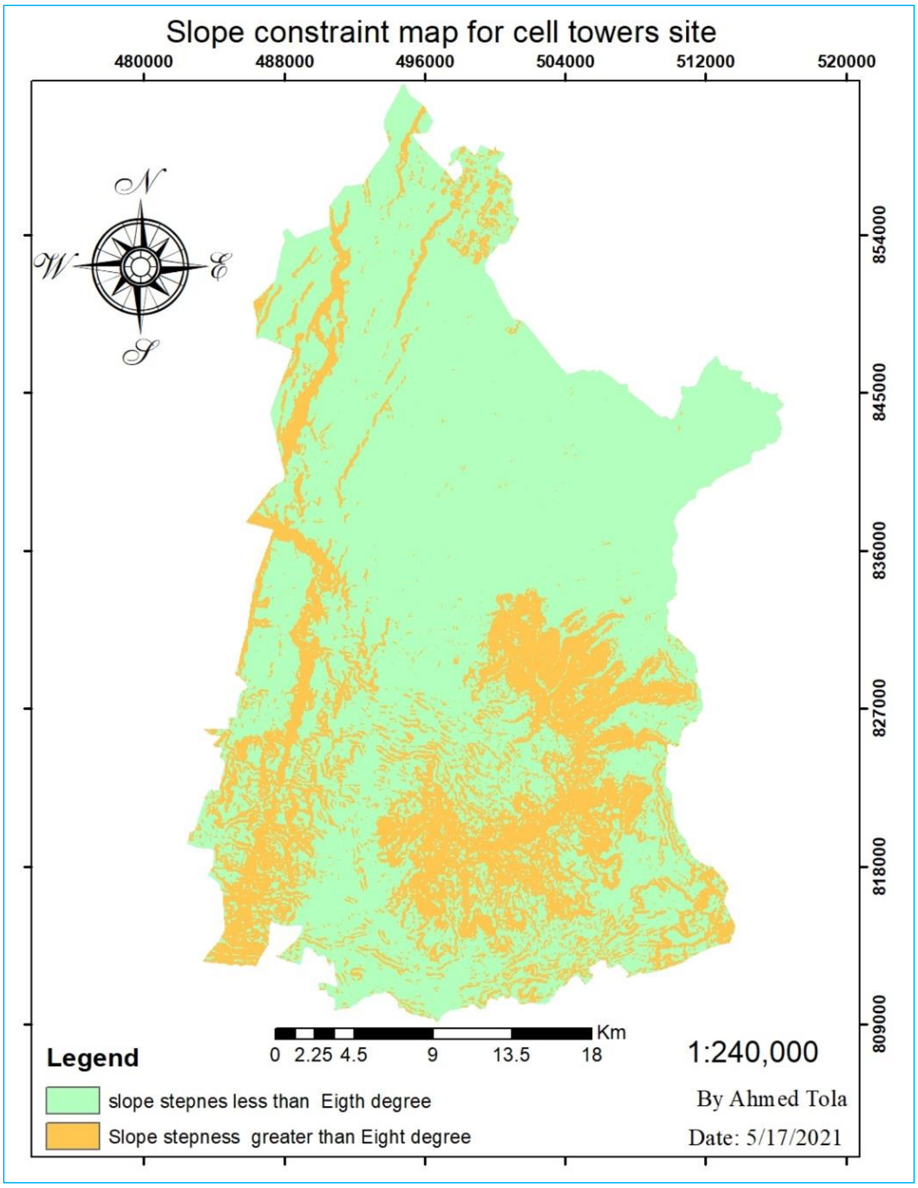


Figure 4.4 Slope constraint Map

The resulting slope constraint map above indicates that the areas with steep slope are shaded with jade color while relatively gentle slope areas are shaded with light mango color. The Maximum steepness for cell tower site suitability analysis on this thesis is preferred eight degree and areas with performance value of greater than eight degree are less suitable and considered as costly for construction, development and management of a cell tower while those lying on steepness less than eight degree are preferred for consideration.

ii) Road Constraint Map for Cellular Network site

Road accessibility is the major factor affecting the choice of suitable site for an optimum location of cell tower. A road constraint map (Fig4.5) has been created in consistent with the local consideration.

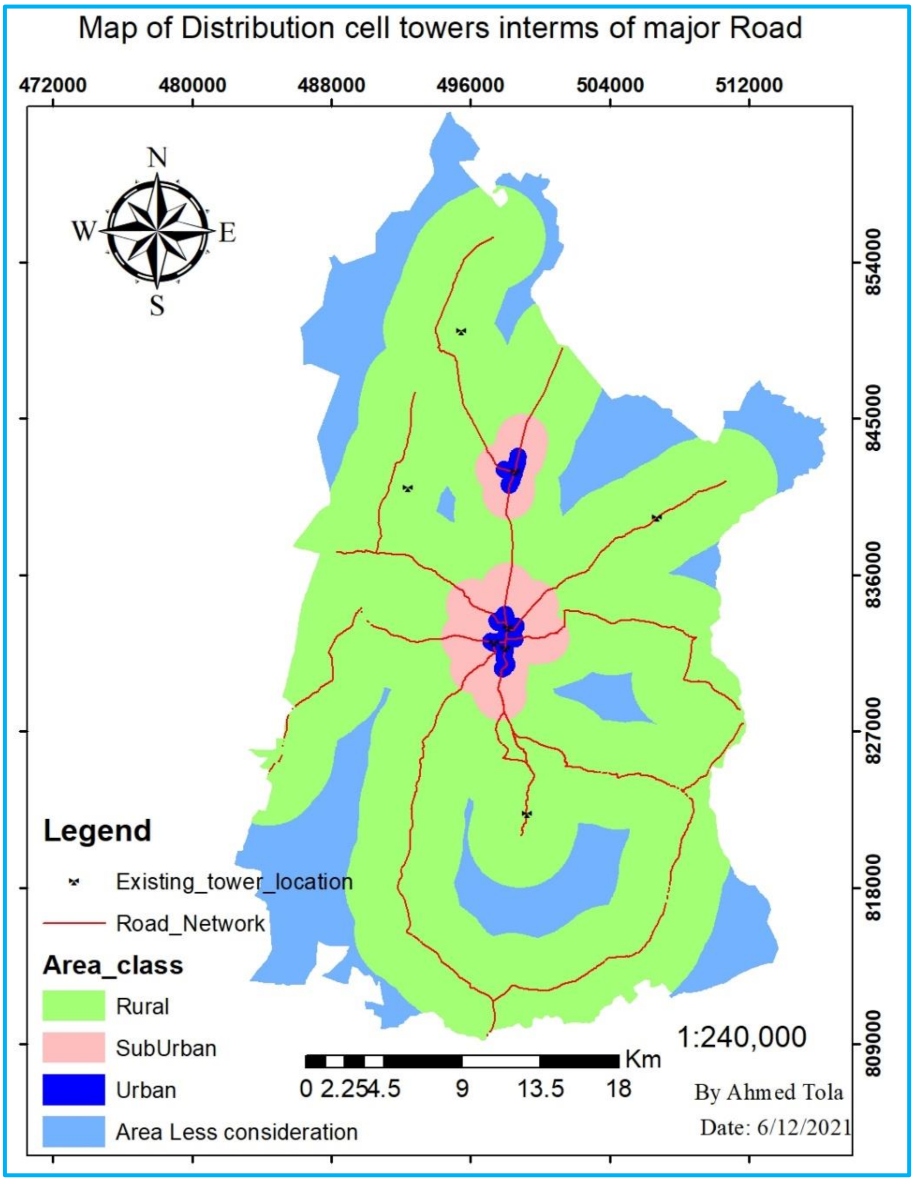


Figure 4.5 Roads networks distribution in terms of existing cellular tower in munesa wereda.

(L.C. nanayakkara, 2014) According to research made Locations for Telecom tower, areas located within a buffer distance 500m,1500m,3000m road in urban, suburban and rural remaining respectively from roads are considered to be less suitable due to construction cost and services cost and less service based on populated area mainly depending on distance from the road. Therefore, as road network has not been a serious barrier due to the existence of alternatives roads, an area within a buffer distance of 500m, 1500m, and 3000m (urban, suburban and rural remaining Fig 4.5) respectively has been considered as constraint for locating a Cell tower. The Major roads with red color are buffered in one distances i.e. areas located within 3000 m from the main roads and areas covering greater than 3000 m from the main road to any parts of the wereda boundary. The buffer distance applied here is based on consideration of the topography and infrastructural development status also based on area classification such Urban, suburban and rural. Therefore, the more nearest away from the main road, is the lesser the suitable for locating of a cell tower site in the wereda. As a result, areas with in the first 3000m buffer distance are rejected from consideration due to the availability of cellular network services around area while the rest areas are considered for the analysis process to locate new cell tower.

iii) Land use Constraint Map for a Cellular Network site

LULC maps of an area provide information to help users to understand the current landscape. Land cover data documents how much of an area is covered by forests, hilly forest, shrub lands, grass, wetlands, farm land, and other lands types (fig 4.5)

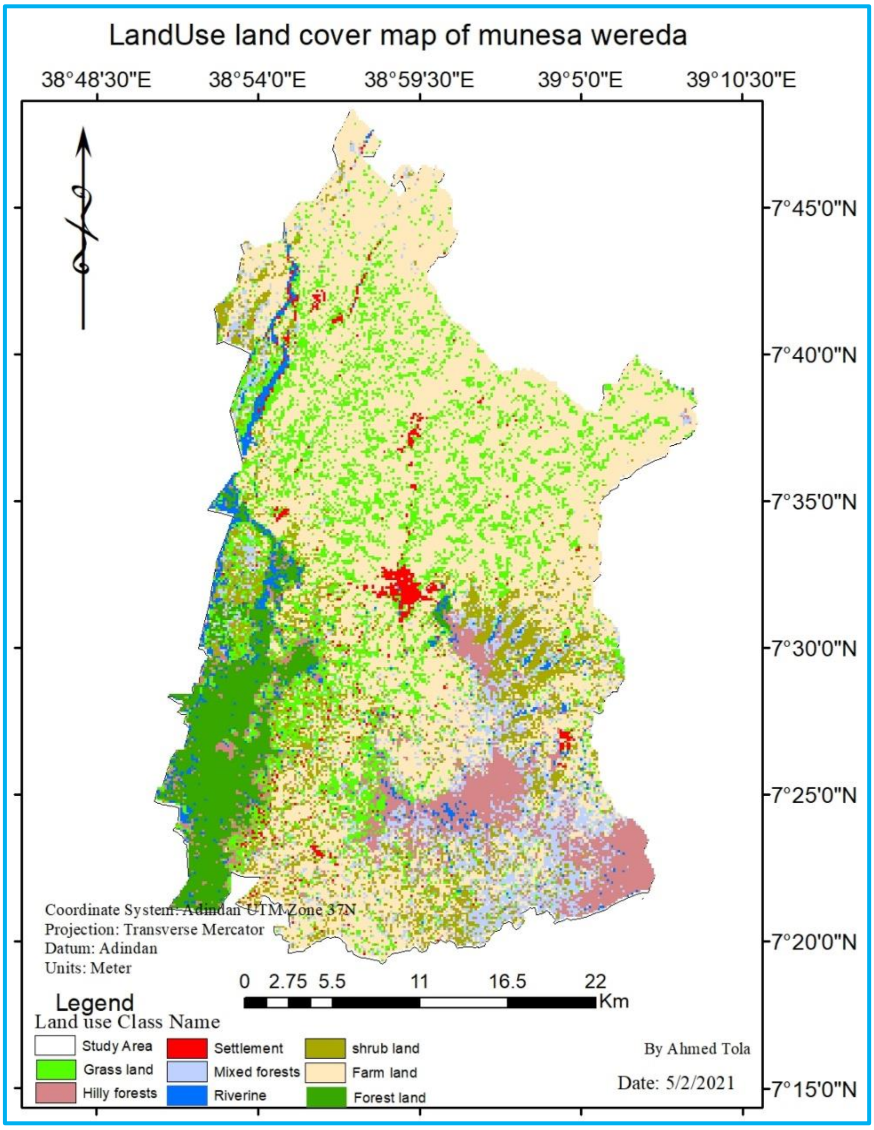


Figure 4.6 land use constraint map of munesa wereda

As shown above figure land use type shaded with different color on a Land use map (fig.4.6) consists of hilly forest, dense forest, riverine areas, are rejected from analysis while others area are considered as suitable for further analysis.

Unlike others criteria, whose suitability is determined based on some commonly accepted area for cellular site, here the natural value of a land plays an important role in determining an optimum site. This criteria seems a bit subjective than the others. In generating a constraint map shown above, issues related to environment, population lives arounds, and cost of construction and management are some of the priority criteria to classify a given land use type as a constraint. As a result, suitability of sites for a cellular network in the wereda have been considered and rejected based on issues mentioned above as criteria. Therefore suitable land use should be located away from hilly forest, dense forests in the low-density population areas, and near stream areas.

iv) Stream/river Constraint Map for a Cellular Network site

Rivers and Water pollution is the major causes of cell tower in many developing countries. Surface water, rivers, streams and lakes is among the most vulnerable area to locate the cell tower. Therefore, a cell tower should be located at least 30m away from water bodies.

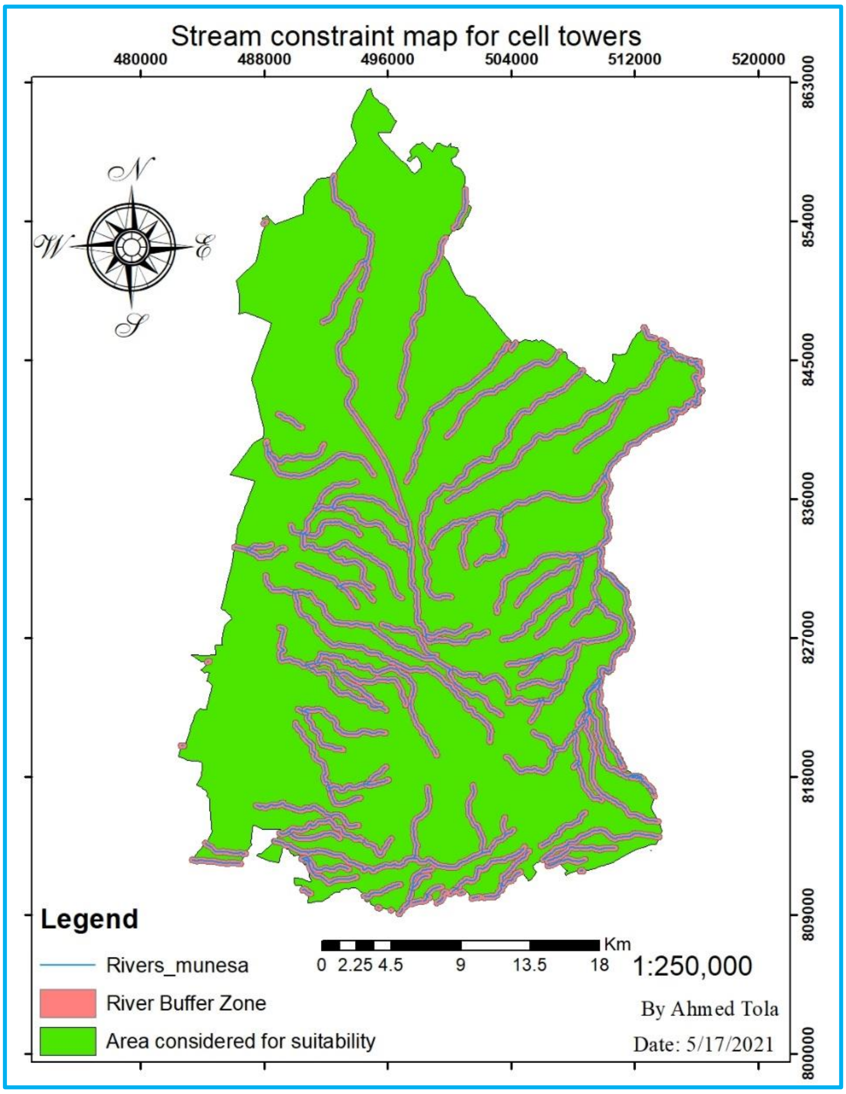


Figure 4.7 Stream Constraint Map for Cellular Network site in munesa wereda

Those areas located within this buffer distance are unsuitable as their under underground water level is high and higher discharge and greater downstream influence.

As a result, the stream constraint map for this thesis is made on the basis of this buffer distance as it complies with the local environmental situation similar with the study area.

4.2.2.2 Factors (Suitability) Maps

Suitability maps also known as factor maps are output maps showing the degree of suitability of a given factor in different suitability scales ranging from higher , medium to lower suitability of a given factor map in a given area. Factors which are compensatory criteria that contribute to a certain degree to the output suitability. There are two types of factors, benefit criteria and cost criteria. A benefit criterion Contributes positively to the output (the higher are the values, the better it is), whereas a cost criterion contributes negatively to the output (the lower are the values, the better it is)’’ (Valentina 2011:239)

4.2.3. Euclidean Distance Analysis

Euclidean distances uses an addition to single buffering, a multiple ring buffer operations have been used for the same criteria maps to generate more than two option suitability classes. Suitability maps here are Expressed in more than two suitability classes range between extremely unsuitable, marginally unsuitable, suitable, marginally suitable and extremely suitable.

Euclidean Distance Analysis is a tool Used to create multiple ring buffers for some of the layers. Distance buffers were created for suitability maps showing the class range between extremely unsuitable, marginally unsuitable, suitable, marginally suitable and extremely suitable areas for cell tower locations. The suitability of main roads, rivers, land use, distance from building, and slopes are measured according to their nearness to any part of the study area taking these data as a point of origin. Unlike the constraint maps, which are created with single ring buffering where two results are obtain only suitable and unsuitable) ,suitability maps are created using Euclidean distance analysis to show the whole area of the study area divided in to multiple classes based on given scale value by user. Therefore, multiple ring buffer i.e. the Euclidean distance buffer operation have been used from Distance toolset under spatial analysis tool in Arc Toolbox.

4.2.3.1 Distance to Main Roads

In a specified location is said to be suitable for locating a cellular network tower if it has an access to road transportation and is located at optimal distance from road networks. Transport network plays a vital role for communication and mobility. Because of good road network, peoples, goods and products can move from one area to the other easily and visit site. Road layer is represented as line feature. It should be converted to raster format. In raster Layer roads are represented as string sequence of cells. It is associated with the Distance from Road main criteria. Hence the Euclidean distance for raster should be created. Therefore, the road network data, which is obtained from the very latest google earth map of the wereda, is digitized and buffered using the Euclidean Distance tool in spatial analysis.

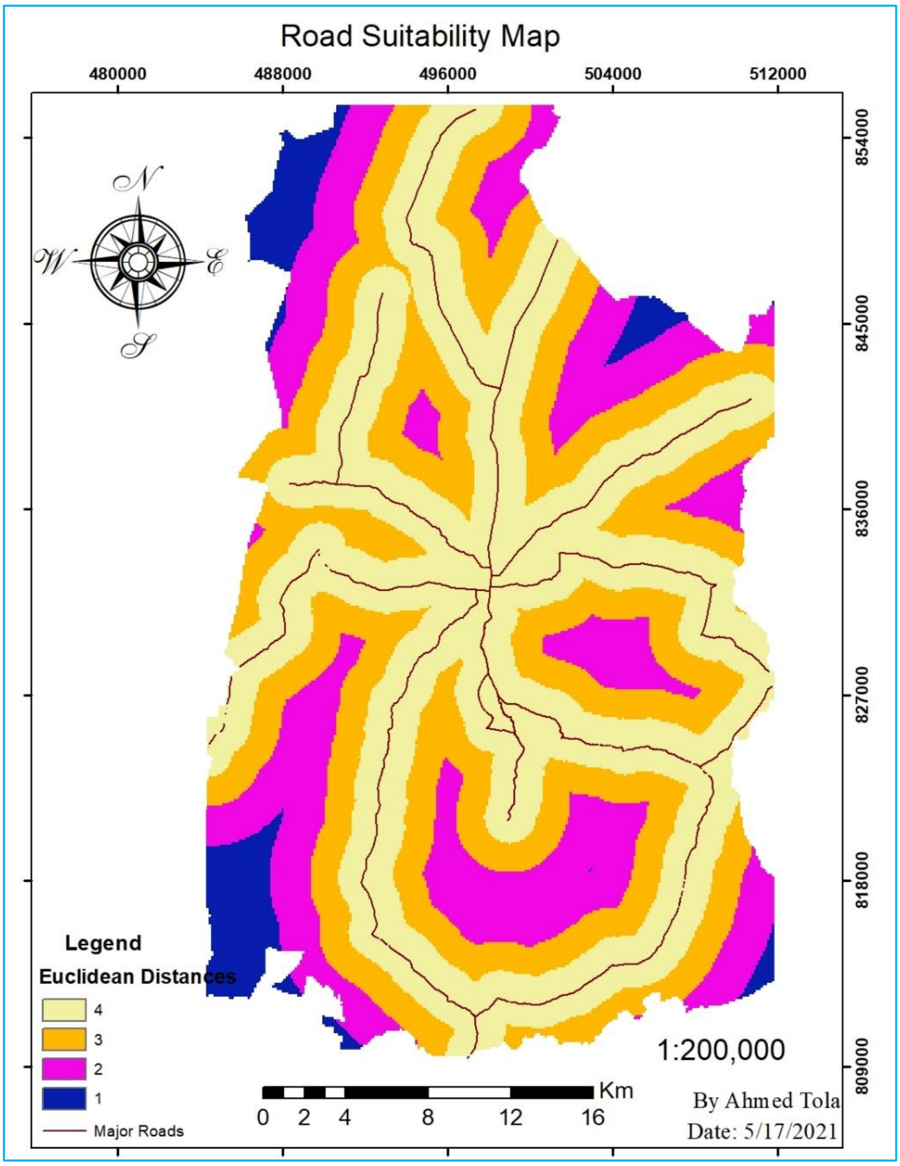


Figure 4.8 Distance from Main Roads in meter of munesa wereda

As seen from figure 4.8 above, areas shaded with blue black color (1) are extremely far from and the areas shaded with light mango color (4) are very near to the main roads. Accordingly, areas within the buffer distance of 0 m-500m, 500-1000m and 1000 m – 2000m are ordered as highly suitable, moderate suitable, suitable, and while the rest are less suitable. Areas within 3 Consecutive buffer zone of 2000m are suitable for a cell tower site selection.

Euclidean distance raster is reclassify according to questionnaire data by distance from major road. Final suitability map for each of the factors is shown on Reclassification parts of this thesis.

4.2.3.2 Distance to Stream / Rivers

The suitability of a cell tower site selection and its distance from rivers and streams are inversely related as rivers make up an important agents for washing and transportation of wastes from one place to the other. With exception of a buffer distance specified on constraint map part of this thesis, rivers have huge role in balancing environment, movement, and transportation.

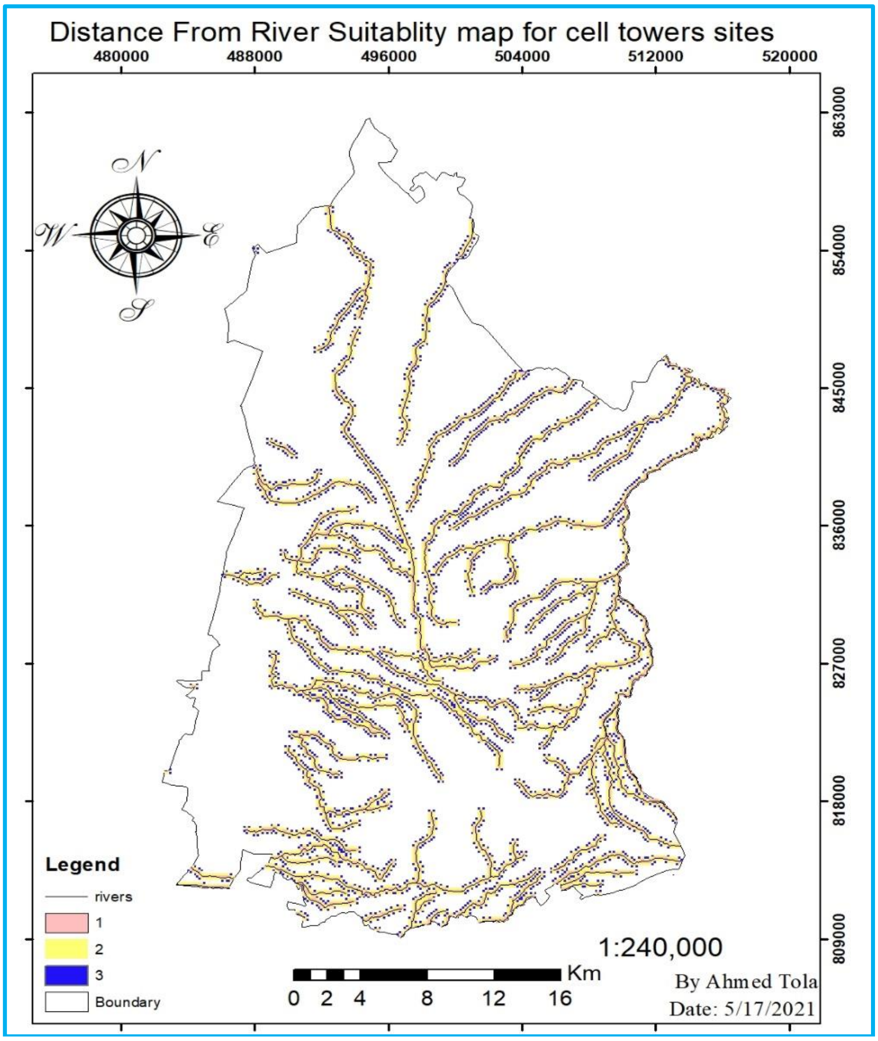


Figure 4.9 Euclidean distance from river to any part of study area.

So to build cell tower near river does not advice because its step by step land slide is occur when heavy rain and hazards in area of rivers. Figure 4.9 above shows rivers in wereda of munesa are buffered and have three classes, where the more the beige (1) shaded areas, the more their extremely not suitability scales are given. While light yellow (2) areas (except for the first 30m) are fewer suitable for locating a cell tower site, the blue (3) areas are smallest suitable for a cell tower selection.

4.2.3.3 Slope Suitability Analysis

The existence of terrains, ups and downs affect the preference of an area for cellular network coverage site, particularly for a cell tower. Cellular networks in more parts of the wereda of munesa are not properly discovered even in terms of topography, hilly region creating huge challenges on cellular network of the wereda. As a result, areas of flat and gentled slope are favorable for selecting a cell tower site than the steeper's one. Even though there is no as such big variation in the study area, the slope map has been prepared from DEM data.

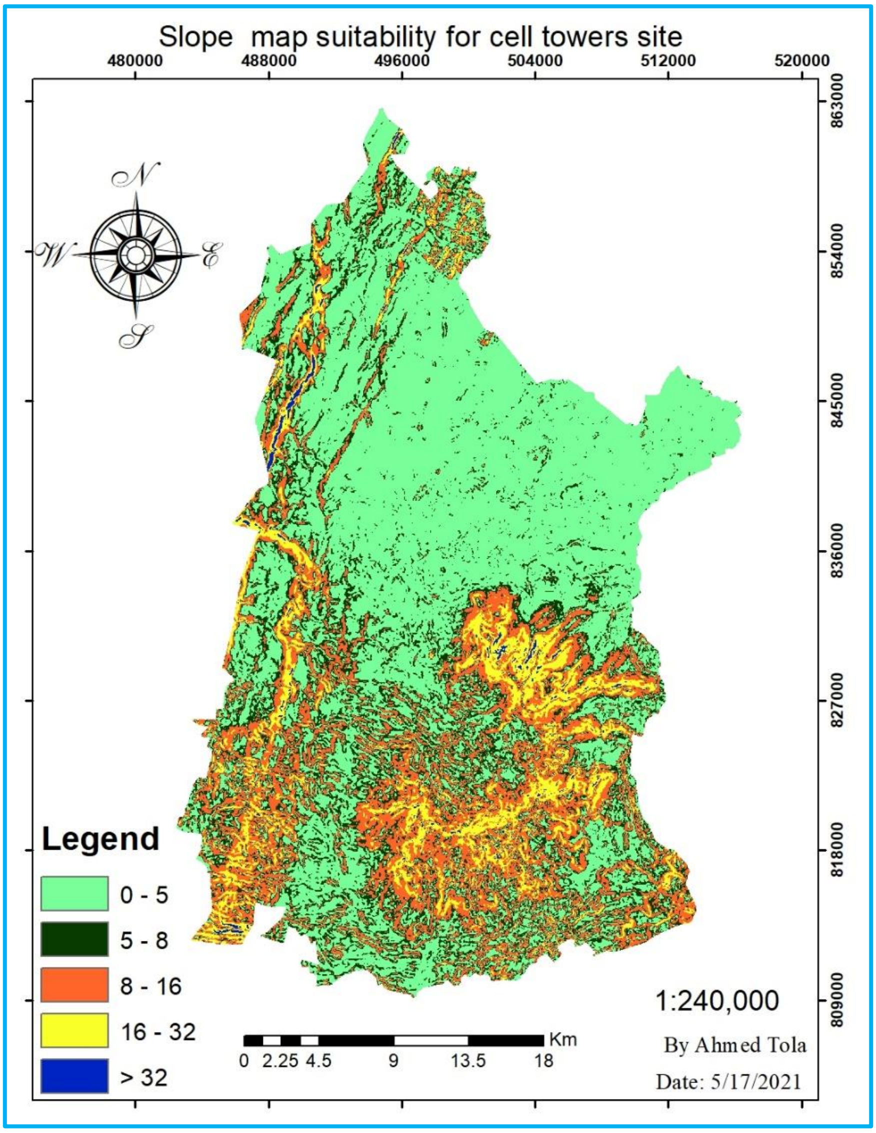


Figure 4.10 Reclassified Slope in Terms of Suitability

As it is shown on a map under figure 4.10 above, the maximum steepness of the slope of the wereda is 57 degree. Areas greater than eight degree are less suitable and considered as costly for construction, this area are usually not suitable for expansion of a cell tower are

less suitable further suitability analysis (see under slope constraint map page.53). Therefore, slope map, which is generated from DEM using slope toolset under surface tool spatial Analyst tool bar, is classified into five equal interval classes according to their steepness.
In general, as it is described under definition of criteria subtopic areas with slope less than 8 degree are suitable for the location of a cell tower sites.

4.2.4. Reclassification of Factor Maps

Reclassification is a process of converting the floating, continuous datasets into discrete and integer values. In other words, to reclassify a data means replacing the input cell value with new output cell value according to their importance. Once datasets such as slope, distance to main road, distance to rivers, and the land use /land cover map are derived from the input maps, the next step was reclassifying the datasets in to common number of classes. From the above definition therefore, it is fair to understand reclassification of the factor map as a task of giving suitability scales to each class values in that particular factor map. There are different suitability scales have been on practice today.

Table 4.3 FAO’s Land use suitablity classification

land use suitability orders	Land Suitability classes
suitable	Highly Suitable
	Moderately Suitable
	Marginally Suitable
not suitable	Currently Not Suitable N1
	Permanently Not suitable(N2)

(Sources FAO, 1993)

The most common suitability scales are either three (ranging from highly suitable, moderately suitable and not suitable) to five suitability classes, which are most commonly used suitability scale in land use classification. For this particular thesis however, the United Nations Food and Agricultural Organization‘s (FAO’s) standard scale of suitability classification is applied.

4.2.4.1 Reclassifying Distance to Main Roads Data

The road map which was Obtained from through on screen digitization from google earth of the wereda, was then measured distance from the roads to all parts of the wereda boundary using the Euclidean distance extension of the spatial analysis tool. The resulted map however, was not ready for overlaying with the other parameters. Therefore, to make it ready for overlaying, the buffered road data had to get reclassified so that it would match and have equal number of suitability class with other maps for overlaying process. Fig 4.11 show Reclassified road map.

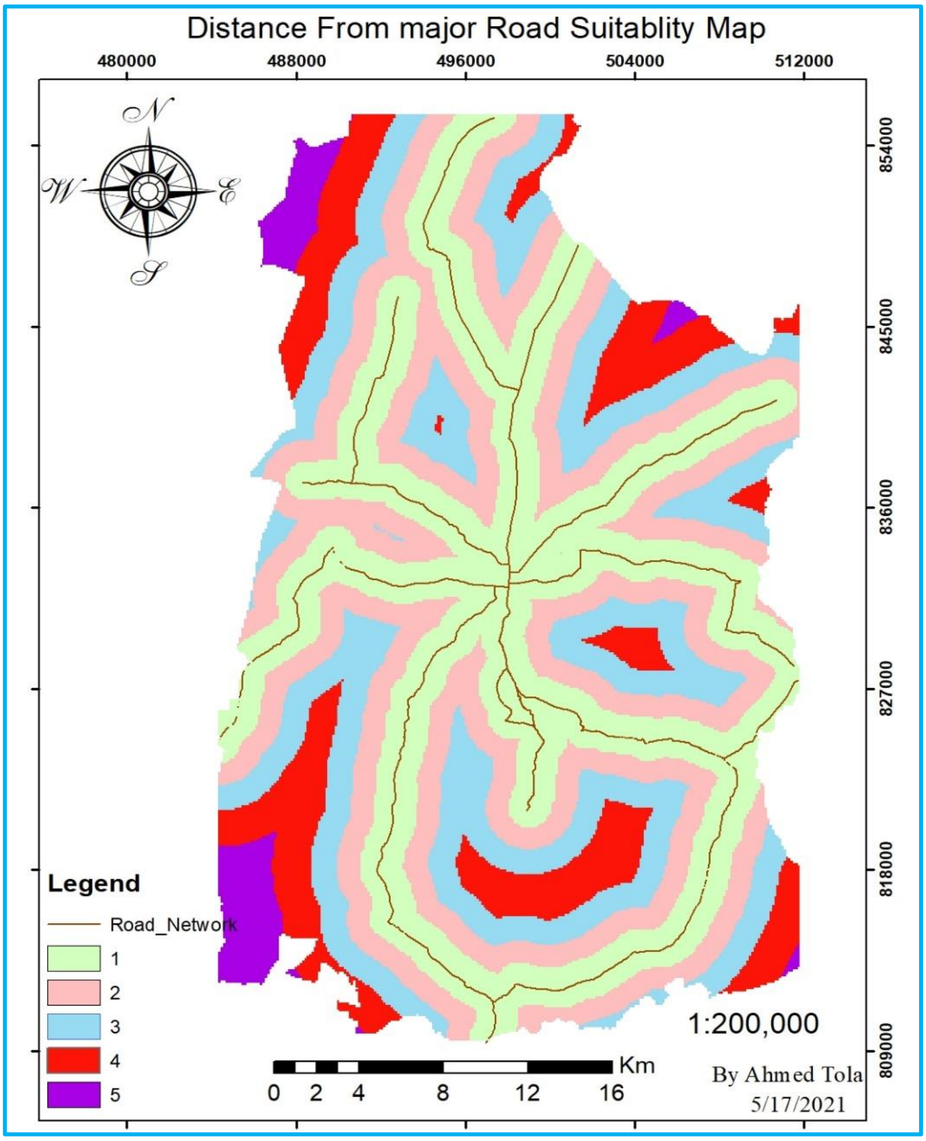


Figure 4.11 Reclassified road suitability map.

Finally reclassify tool have been used to create a road constraint and suitability map for a cell tower site. Figure 4.11 as shown above indicates legends numbered with 1,2,3,4,5 road distance 0-0.5km, 0.5-1km,1-2km,2-3km and >3km respectively.

4.2.4.2 Reclassifying Population Distribution

Population data are acquired from Ethiopian statistical agency and munesa wereda year of 2020 current data. The Population distribution could not get as spatial data but only as tabular format. As we describe in chapter three Munesa kebele population Concentration centers point vector layer is created using Polygon center to point. Showing below (Fig 4.12)

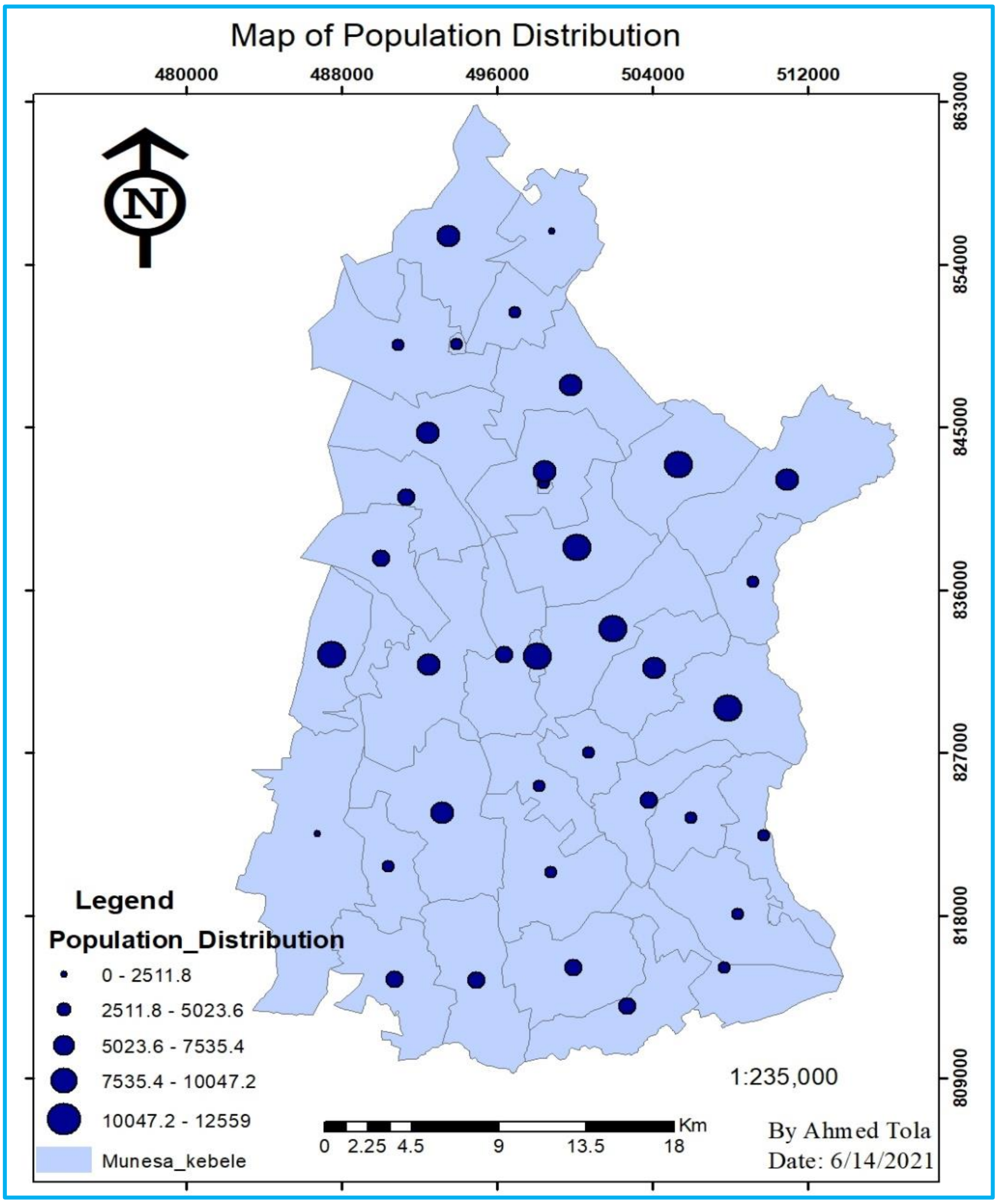


Figure 4.12 Distribution of Population In munesa wereda by kebeles. (*Source CSA, 2021*)

The Interpolation tools create a continuous (or prediction) surface from sampled point values. Distribution surface was created by IDW tool. In here population distribution are calculated by interpolation of cell values set of munesa kebele's population Concentrations centers points. The weight is a function of inverse distance. Result rater was reclassified according population range from population distribution 2841 to 12559 into five class range (0-3000),(3000-5500),(5500-7500),(7500-9500) and (>9500). The scale value assigned are (0, 1, 2, 3, 4) respectively. (Shown in fig.4.13)

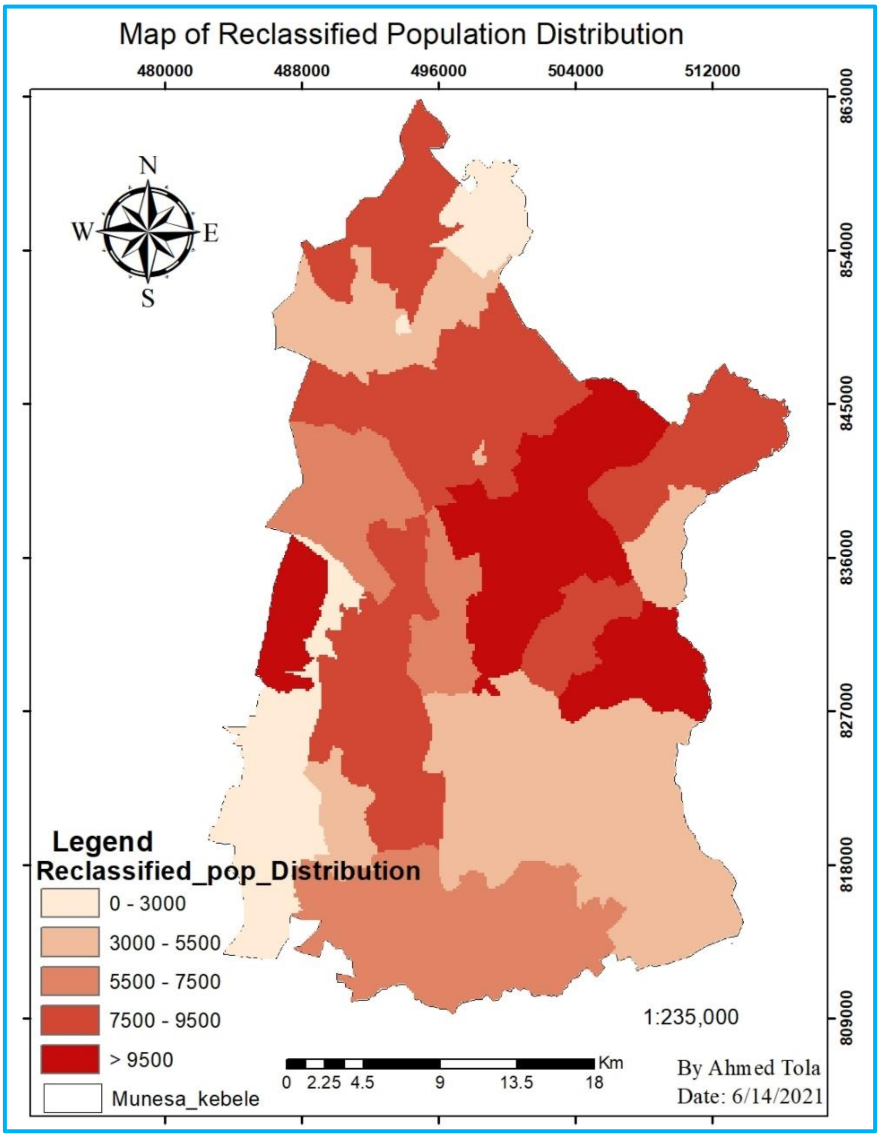


Figure 4.13 Reclassified Population Distribution Raster of Munesa wereda

4.2.4.3 Reclassifying distance from Rivers Map

The river data which have been obtained from the (Ethiopia river lines, source (diva-gis) and digitized from topo sheet of munesa wereda has been used as a factor affecting the location of cell tower site in the wereda. Because the model or any other site selection for cell tower are approximately put point in radius of 100 m in center; so to find optimum cell tower site we must identify factors that affecting cell tower placement. So as to overlay the stream with other factor maps and investigate its contribution to site suitability analysis, the buffered stream data have been reclassified in to five suitability class. Keeping the rejected values constraint, as in the analysis process, four suitability classes have been identified depending on how far each class values apart from the proposed cell tower site for future. This stream data have then been reclassified as those having constraints and those rivers with suitability for a cell tower site development as shown below (fig 4.14).

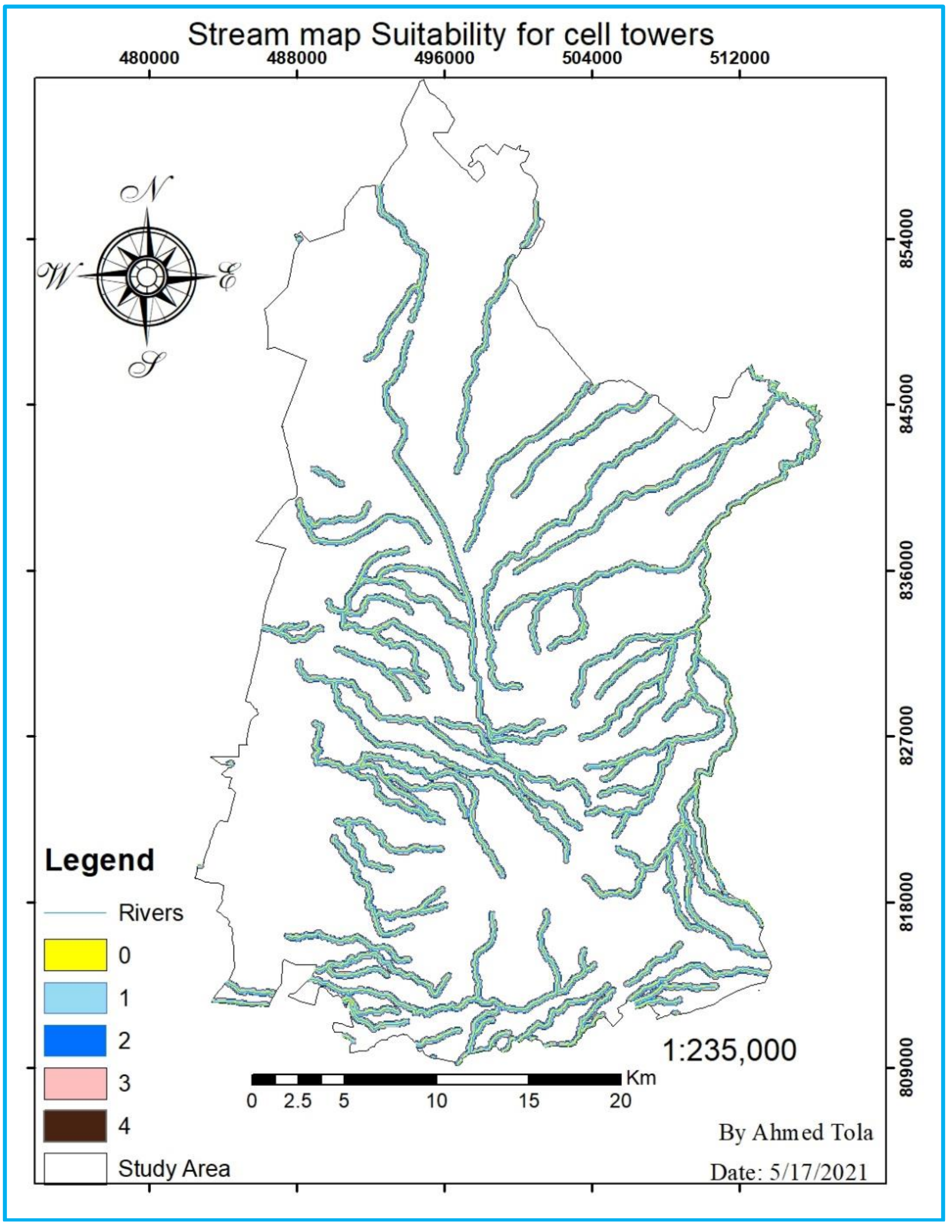


Figure 4.14 stream/rivers Suitability Map in munesa wereda.

As shown above figure road can be classified into five classes. Class with yellow color (0) and 1 as not suitable which distance 0-10m, 10-20m and 20-30m, 30-100m,and >100m low to suitable area. Finally suitability scaling gives for all class are (0, 1, 2, 3, 4, 5) raking as Not suitable, less, Marginal, moderate and suitable respectively.

4.2.4.4 Reclassification of Slope Map

The slope map of the study area was by default classified in to five class values with an interval of approximately three degrees. This had to be reclassified in to 5 discrete class values for the sake of maintaining a common measure scales with the rest datasets. As shown in Figure 4.15 we classified slope data into constant intervals of five classes 1 (0^0 -5^0), 2 (5^0-8^0), 3 (8^0 -16^0), 4 (16^0 -32^0), and 5 (32-58^0).

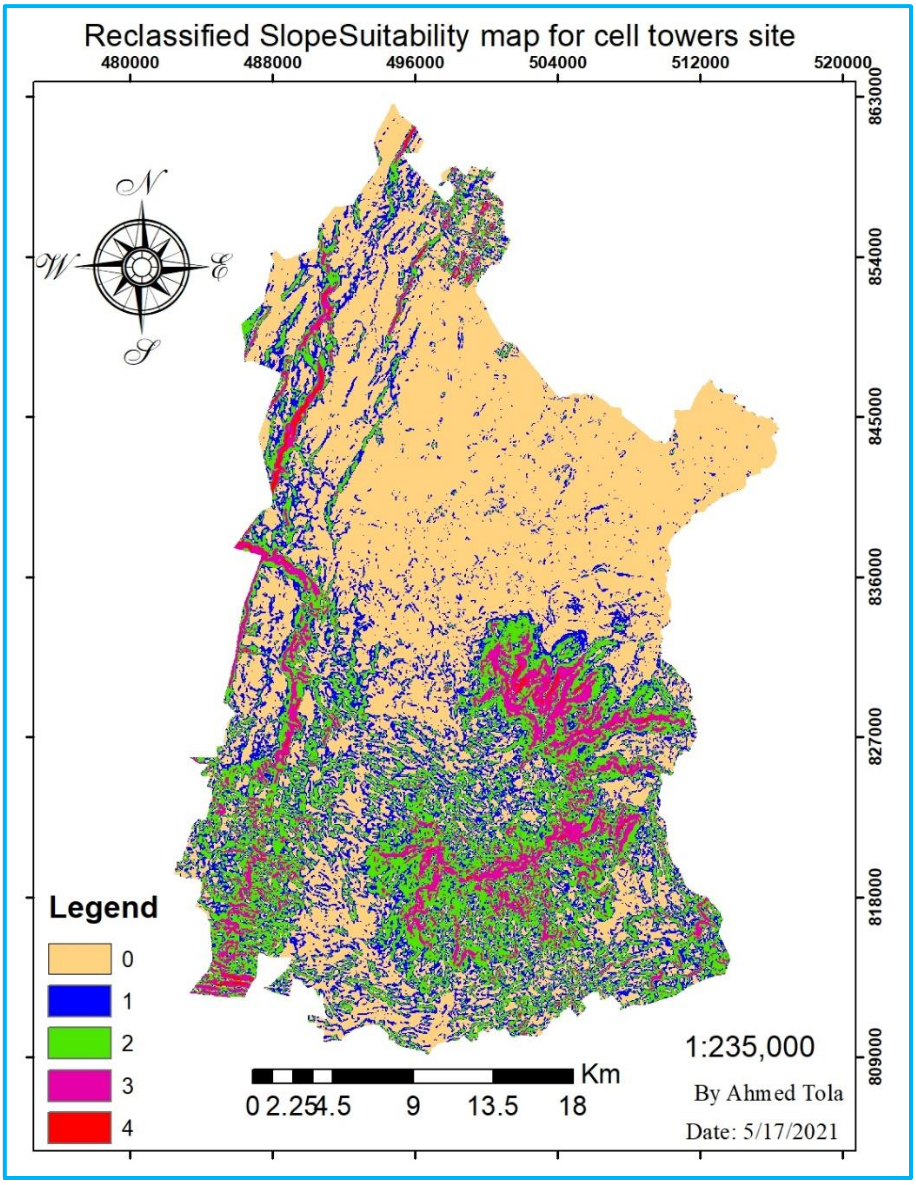


Figure 4.15 slope suitability map.

As a result, the slope is reclassified in to 5 class values with an interval depending on their steepness. The slope data have then been reclassified in further to create constraint map (having suitable and unsuitable) and suitability classes (having more than two a suitability classes). The suitability scale is given higher for higher class values and vice versa. Unsuitable areas that have some sort of constraint have been ignored from analysis and shaded with red color on a map. In general, slope steepness between 0-5 degree are given the highest suitability value i.e. four and three respectively while those areas lying on a slope steepness between 5-8 degree are accepted as medium and those having steepness of higher than 8 degree are categorized as least suitable for selection of optimal cell tower site. Therefore, areas in a relatively flat topography, having a gentle slope are given higher suitability scale values while the rest are given lower.

4.2.4.5 Reclassification of Land Use/Land Cover Map

In this study the land use land cover of the wereda is classified in to eight classes. This data had to be converted in to numeric suitability scales. Therefore, the land use /land cover map is reclassified in to five classes based on similarity in use for suitability. So as to overlaying a land use data with other factor maps, the land use map which was in feature data have been converted in to a rates using a convert feature to raster tool from spatial analysis tools in Arc tool box. The resulting raster data have then been reclassified (divided in to suitability classes) to identify a land use type that are suitable and have some constraint for location of a cell tower site. Details of the ranking steps is shown below figure 4.16.

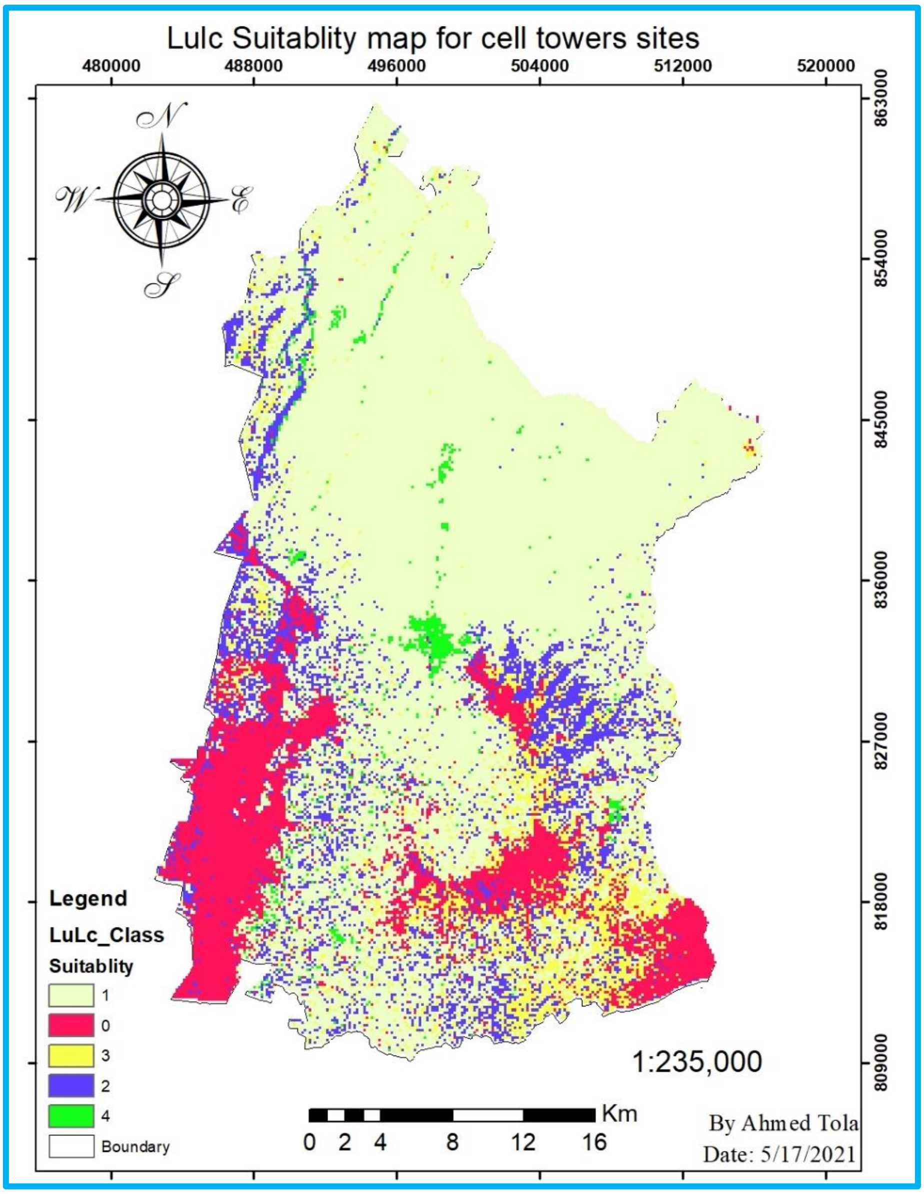


Figure 4.16 Land use /Land cover Suitability Map in munesa wereda

Accordingly, about eight land use/ land cover classes are obtained through satellite images by supervised Classification with maximum likelihood algorithm method namely, agricultural land, grass land, Shrub land, Forest land, Hilly/mountainous area, mixed forests, settlements areas, and Riverine land areas. Based on their similarities and suitability scales all these land use/land cover types would be grouped and merged together in to five suitability classes in this thesis. While hilly forests and dense forest land are ignored from further analysis due to their major constraint in optimum location for cell tower construction and they are a place where population are less or no populated area. Mixed forest area, shrub land, agricultural and grass land area have got a higher suitability scale of 4, 3 and 2 respectively. The higher the suitability scale, the higher the suitability value they have for optimum cell tower location.

4.2.5. Ranking, scaling and Weighting Factor Maps

The suitability model in this thesis included three steps: identify site selection constraint and suitability factors, rating and ranking the suitability factors, and weighing the factors selected and finally implementing the suitability model. (Appendix 2) scaling, ranking and weighting are the remaining procedures discussed below.

Ranking

After Euclidean distance calculation, reclassification of the raster layers has been carried out. Reclassification is indirectly refers to putting the suitable values (ranks) in their suitability order. This was done simultaneously during the reclassification process. Ordering entities and their attributes is not arbitrary made. Ranking and specifying the suitability class values have been made based on document analysis and experts comment and suggestions during the field work. The ranking of suitability classes are grouped in to five suitability classes namely high suitable, moderately suitable, marginally suitable, and currently not suitable and not suitable areas. Accordingly, permanently not suitable areas, area that are rejected from consideration are ordered with suitability rank of zero while suitability class 4 , 3,2 and 1 are ranked as high suitable, moderate suitable , marginally suitable and not suitable respectively.

Scaling Value

After the suitability classes are ranked in order, the next step was to numerically value a given factor based on extent of strengthen or weakness of influencing a given variable in comparison with the others. Rating is refers to an evaluation, usually expressed in numerical terms, of how suitable a site is supporting a specific land use. Numeric scores to a total of five (one as least and five as most suitable) are assigned to each factor attribute class. Comparisons between classes were based on their level of suitability with respect to the choice of optimal location selection for a cellular network tower. Since environmental factors for each specific study areas are different with others, there is no uniform standard for rating factors. For this thesis however, factors are rated based on the situation of study area, review of literatures and suggestion from experts. For example, a site having a slope over 35 degree is assigned a rating of zero (rejected area) while area with slope steepness less than 5 degree is rated one (highly suitable) for the location of a cell tower sites. This is related to cost of construction, transport and accessibility issues.

4.2.6. Weighted Overlay

Weighted Overlay is defined as a technique use to integrate and combine different factor maps with common measurement scale values to produce one final integrated output. The Weighted overlay Process allows us to set weights for as many different factors as we want to analyze. The weight establishes the relative importance of the factor under consideration. The sum of the weights must equal to 100 percent. Using the Weighted Overlay tool found under spatial analysis tools, the values of each dataset can be weighted and combined at one time (Giap et.al, 2003).

When considering main criteria's, each can be categorized to several classes according to values and assign Scale value for classes which may influence to desire outcome of Weighted Overlay results. For an example population distribution raster can be categorized to several classes based on population and assign weight for each class. It will give less important to population low areas and more for population high areas. It can be achieve by assigning low scale value for class value low and high value for class value high classes. Scale values are helped to bring all the different main criteria's value unit to single value unit. Overlay of several raster inputs using a common measurement scale and weights of each according to its percentage influence is prepared (Table 4.6). The reclassed results obtained above are all compare by pair-wise comparison to get percentages of each layers and combined through the weighted overlay toolset from spatial analyst tools.

Weight and Scale values for Main Criteria's and Sub Criteria's

Weights are defined Main criteria's by using Analytic Hierarchy Process (AHP) technique and sub criteria by averaging the questionnaire data which given to Ethio telecom service providers (professionals) and according to international telecommunication union (ITU) based on country policy.

Analytic Hierarchy Process (AHP) technique.

The AHP is used to calculate weights for the criteria map.it is a structured methods for analyzing complex decisions by breaking them into pair-wise alternatives of two at a time (saaty 1988, 2008). Using pair-wise comparison matrix AHP calculates comparative weights for individual criteria layer. The results also produce consistency ratio (CR) that serves as a measure of logical inconsistency of expert or user judgments during pair-wise criteria comparisons measured. The CR measurement facilitate identification of potential errors and thus judgment improvements depends on this value.

According to (saaty 1988) if the CR value is much in excess of 0.1 the judgment during pair-wise comparison are untrustworthy because they are too close for randomness. The consistency level of the comparison matrix can be computed considering its maximum eigenvalue, namely λmax. Since λmax is substituted for the order of the matrix (n), its difference from n is used to compute the Consistency Index (CI) and the closer to the more consistent the judgments.

$$CI = \frac{\lambda\text{max}-\text{n.}}{n-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

The principal eigenvalue of the matrix is divided by the average of the principal eigenvalue of a certain number of matrices filled in a random way (RI). If the result is smaller than 0.1, the comparisons are confirmed (perfect comparisons lead to (CR = 0)

$$\text{CR} = \frac{CI}{Ri} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.2)$$

Where CI: represent consistency index, and RI: Random Index.

In AHP method Using the data which have collected by the questionnaires from different organization (Appendix 5) and Analytic Hierarchy Process (AHP) technique, weight matrix was formed for Population Distribution, Land Use, Distance from Building, Distance from Road, Distance from rivers and Elevation data as Main criteria's. In AHP technique each every criterion's are compared with every other criterion's with user define scale values.

Table 4.4 AHP Technique Based Comparison Value Scale of Main Criteria's

Degree of importance	Description of pair wise comparison decision
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	The important is between the two degrees

In this research we have taken questionnaires were given for Ethio telecom and TSP Experts in southern region (Adama). Each Main criterion's pair wise comparison data of questionnaires are averaged and results are used to create single Pair-wise Matrix by AHP technique. (Table 4.5) is representing Pair-wise Matrix of main criteria's. Description factors to be compare for Pair-wise Matrix in Idirisi Selva software (AHP technique).

DS_Distance from stream PD_Population Distribution LU_Land Use

DR_Distance from Road EL_Elevation DB_Distance from Building

DExt _Distance from Existing Cell tower

Table 4.5 Pair-wise comparison matrix for main criteria

	DExt	DR	DB	PD	LU	EL	DS
DExt	1						
DR	0.5	1					
DB	1.5	0.5	1				
PD	0.5	1.2	0.6	1			
LU	1.2	1.5	0.4	2	1		
EL	0.5	1.5	0.5	1.5	0.6	1	
DS	1.2	0.5	0.6	0.5	0.4	0.5	1

In this case the normalized relative weight matrix is generated by using dividing pair-wise matrix element by sum of each factor column. Here we have to enter values for rows based on a questionnaires results. Priority vector was produced by averaging sum of each factor rows. And multiplying priority Vector elements of each factor by 100 could use to find influence of each factor (weights).

Table 4.6 Priority weighted matrix for main criteria's

Factors	Weighted factors	weighted percentages
Dext	0.166	17 %
DR	0.142	14 %
DB	0.200	20 %
PD	0.108	11 %
LU	0.171	17 %
EL	0.126	12 %
DRv	0.087	9 %
Total	1.00	100

Table above show weighed factors calculated in idirisi selva software based on a given data we entered in rows and column Consistency ratio = 0.08 Consistency is acceptable.

4.2.6.3. Sub -Criteria's Scale Value for each factors

Scale value which we describe as rating value in main criteria here for Sub- criteria's are defined value from 0 to 4. It is equal value with main criteria values. According questionnaires on appendix 5 question number 2 suitability data for Sub - criteria's was generated. Averaging all semi-structural questionnaires data which are obtained by the experts create single values for each sub criteria's. We use this criteria directly for weighed raster overlaying purpose.

Table 4.7 Details summarized of raster dataset weighted overlay

S/N	Raster data set	Weight (%)	Reclass scale	Overlay scale	suitable ranking	remarks
1	Distance from Main road	14	1	4	High suitable	
			2	3	moderate suitable	
			3	2	suitable	
			4	1	less suitable	
			5	0	Not suitable	
2	population Distribution	11	1	4	High suitable	
			2	3	suitable	
			3	2	moderate suitable	
			4	1	marginally suitable	
			5	0	less suitable	
3	Distance to Existing sites	17	1	4	High suitable	
			2	3	suitable	
			3	2	moderate suitable	
			4	1	less suitable	
			5	0	Not suitable	
4	slopes	12	0	4	High suitable	
			1	3	suitable	
			2	2	moderate suitable	
			3	1	marginally suitable	
			4	0	less suitable	
5	Distance from Building	20	5	0	Not suitable	
			10	1	less suitable	
			12	2	moderate suitable	
			20	3	suitable	
			>20	4	High suitable	
6	Distance from stream	9	0	0	Not suitable	
			1	1	less suitable	
			2	2	marginally suitable	
			3	3	moderate suitable	
			4	4	suitable	
7	LULC	17	0	0	Not suitable	
			1	1	less suitable	
			2	2	marginally suitable	
			3	3	moderate suitable	
			4	4	suitable	

The Above (Table 4.7) show Sub criteria's scale values are assigned as 0 - Not Suitable 1- Less Suitable 2 - Suitable 3 -Moderate Suitable 4 - High Suitable.

4.2.6.4 Optimum Area site Selection

Choosing the correct site concept provides significant site-level savings.

One of main goal is to selecting Suitable areas for Tower (BTS) construction.

A new base station site of marginal profitability could turn into a good investment, if a more economical site solution was found.

Lack or quality of electricity as a challenge especially in rural area they use solar charger this can be damaged due to almost people around that area has charge their mobile phone on solar charger. A restricting factor in many cases that increases the radio access site cost is the unavailability or poor quality of electricity at base station sites. The traditional mobile network approach has been to overcome this by installing generators and battery backup systems. However, in regions with no previous telephony services, the operator's income stream may not allow for such costly implementations. The high power drain of sites, combined with the difficulty of providing a proper supply of electricity, may contribute to the decision not to extend the service to the region at all, or to put the expansion on hold for an undetermined period of time.

While the base station equipment is the main cause for energy consumption on a base station site, the second important drain on supply is the systems to support the base station, primarily the air conditioning system. As air conditioning systems are also a major maintenance problem, and target for theft, it makes sense to try and avoid their use whenever possible. (ITU Telecom Network Planning January, 2007)

Vector data used as factors area all seven Main criteria's are converted meaningful raster format layers in previous sub chapter.

Seven Main criteria's weights and sub criteria's scale values were defined. Hence effective and efficient results could be getting by weighted overlaying seven Main criteria's raster together in weighted overlay tools from spatial analyst tool. Suitable areas are found by using "weighted overlay" tool and weights of the layers of stream reclassified, Land Use, Population Distribution reclassified, elevation reclassified, distance from existing sites reclassified, Road reclassified and Building reclassified raster.

Fig 4.16 bellows show weighted overlay map of all main criteria and their suitability with different color rates as [Not suitable, less suitable, Suitable, Moderate Suitable, High Suitable].

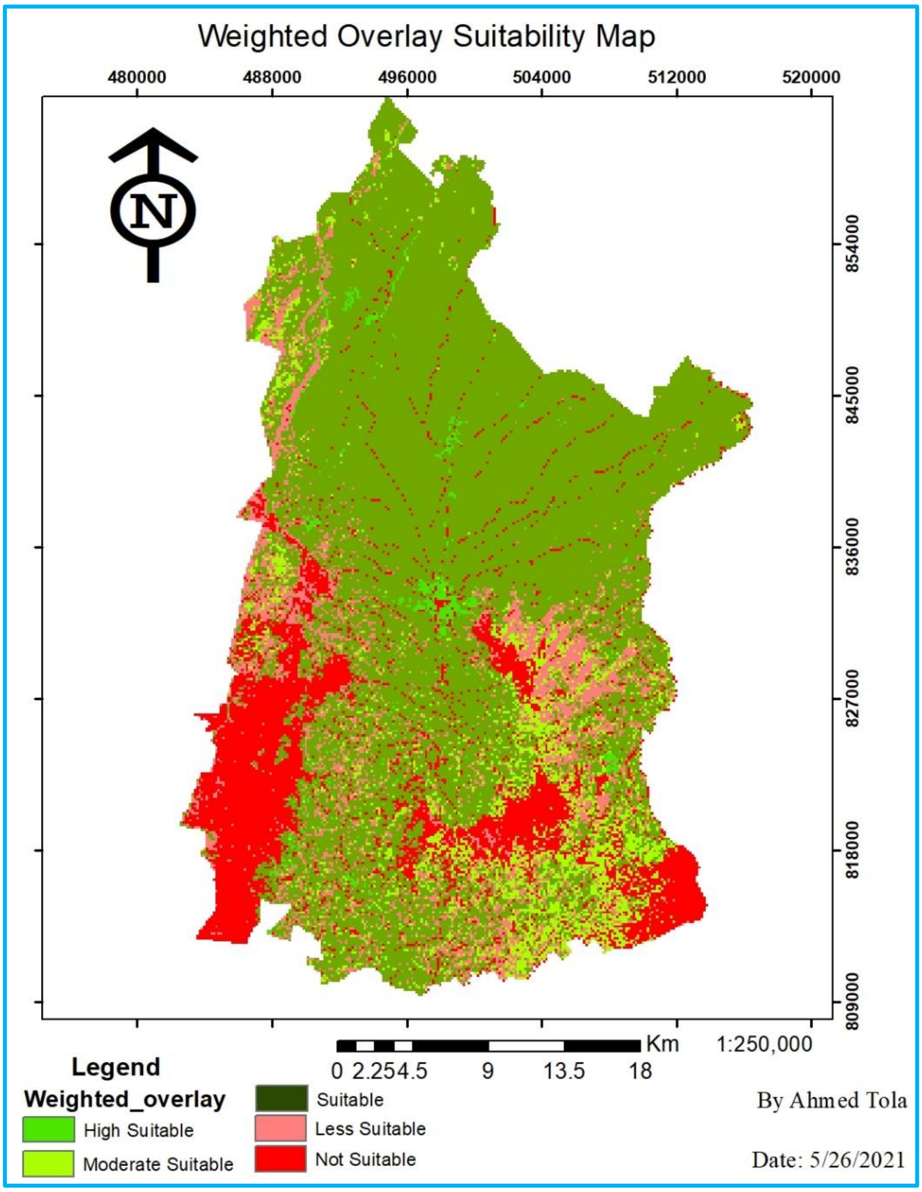


Figure 4.17 Weighted overlay suitability map of cellular networks

In Weighted raster data Suitable raster is converted to polygon layer to identify and export not suitable from suitable area .this can done by using raster to polygon tool in arc Toolbox conversion tool. After converted we have to select Using select tool only less - high Suitable areas (1-4) and copy/export as new feature on model builder to create a new suitability polygon feature class. Not suitable or rejected areas are removed and the rest area are considered as farther analysis for Optimum sites selection.

4.2.7. Cellular Coverage area Calculation

After we calculate for each BTS sites of coverage area we can convert all procedure to Python script code and check on python win 2.7.2 which is integrated with ArcGIS 10.8 software. Workflow of spatial analysis is modeled using model builder shown (fig.4.18)

4.2.8. Buffering around the existing positions of cell towers.

After calculating the coverage for all cell towers in urban, suburban and rural by given model we can make the buffer around the existing tower position by buffer analysis in ArcGIS. Because we can't built new towers in covered area with existing sites. So if coverage is decided then less coverage or no coverage area can be identified shown (fig.4.18)

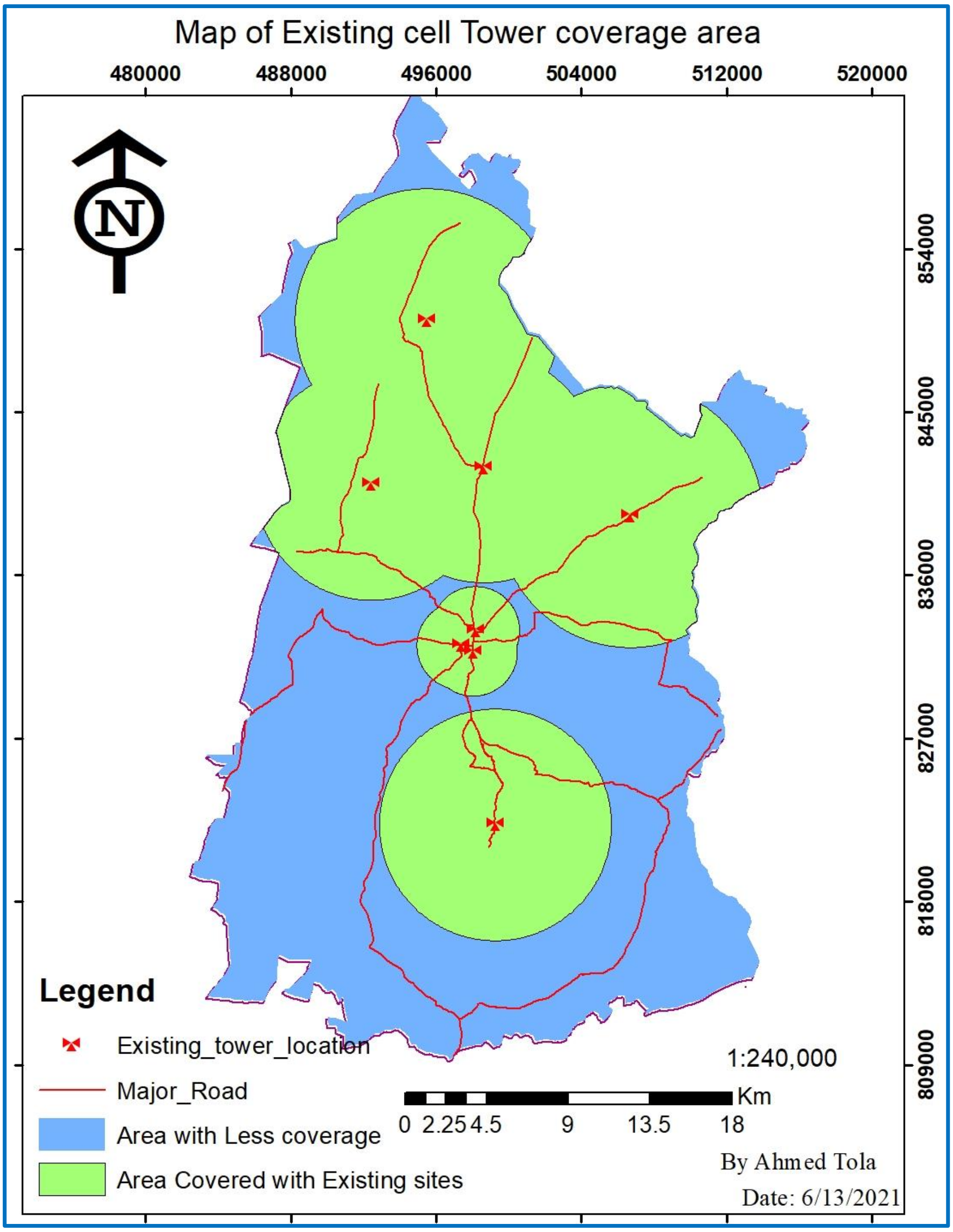


Figure 4.18 coverage area of Existing cell sites buffered in Munesa wereda.

Above figure show Buffered area based on two principle the 1st one is area classes divided into Urban, Rural and Suburban area.2nd depending on existing cell tower radius calculated in given formula stated in literature for all sites using python code scripts. A Model builder work flow of all steps show the spatial analysis of the Research (fig.4.19 p.76) Factors Map and Land use Land Cover are Main criteria's which compared with each other criterion's with user define scale values And Weighted by AHP technique before weighted.

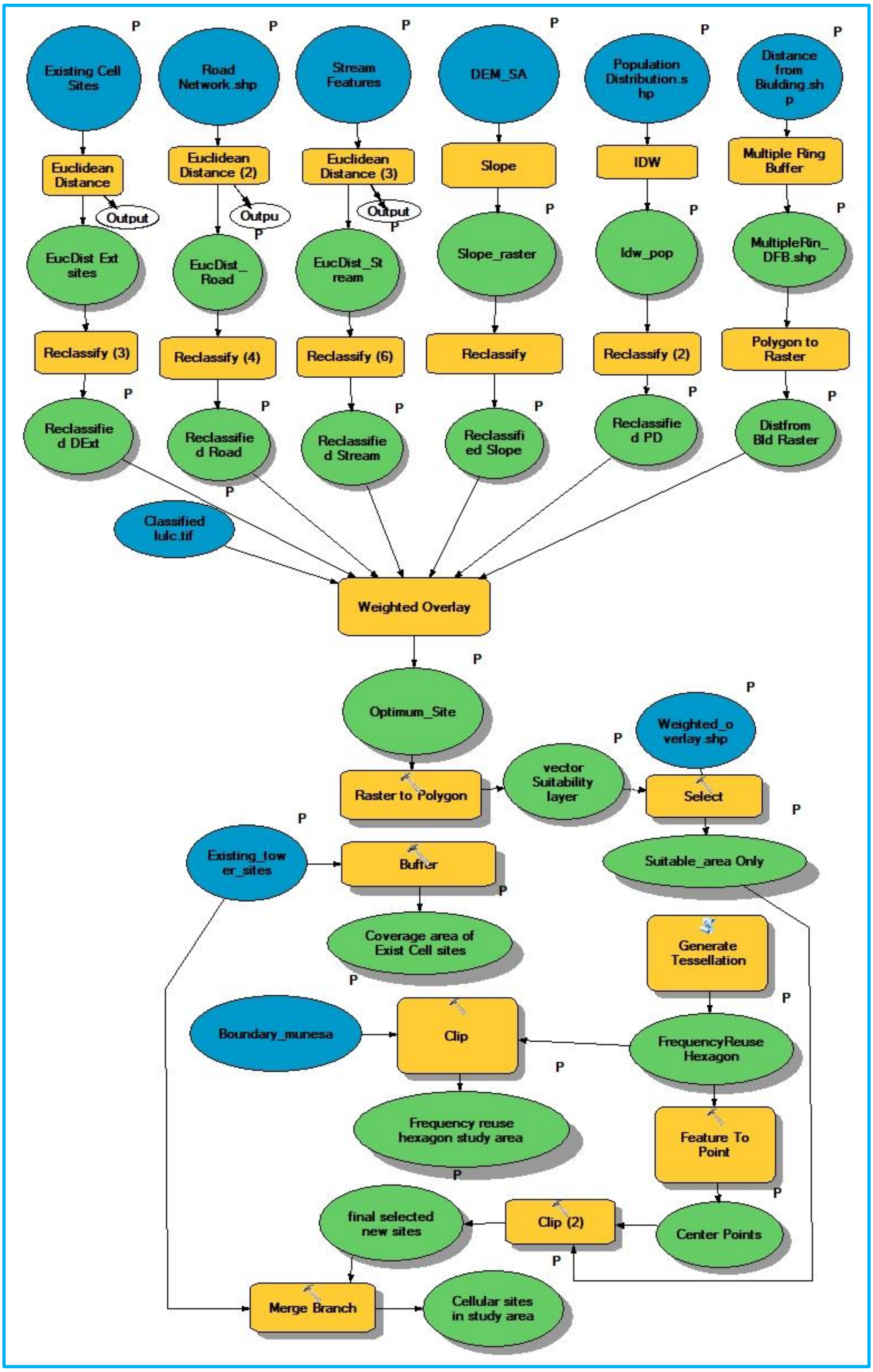


Figure 4.19. Model builder work flow of the spatial analysis.

Create Frequency Reusing Hexagon Network

Hexagon feature created using Generate Tessellation which generates a polygon feature class of a tessellated grid of regular polygons which will entirely cover a given extent. The tessellation can be of triangles, squares, or hexagons. (Hexagon network also created reference to the Base Tower location hexagon). It is graphically representing coverage of Munesa Wereda area considering that each center of Hexagon having a Tower.

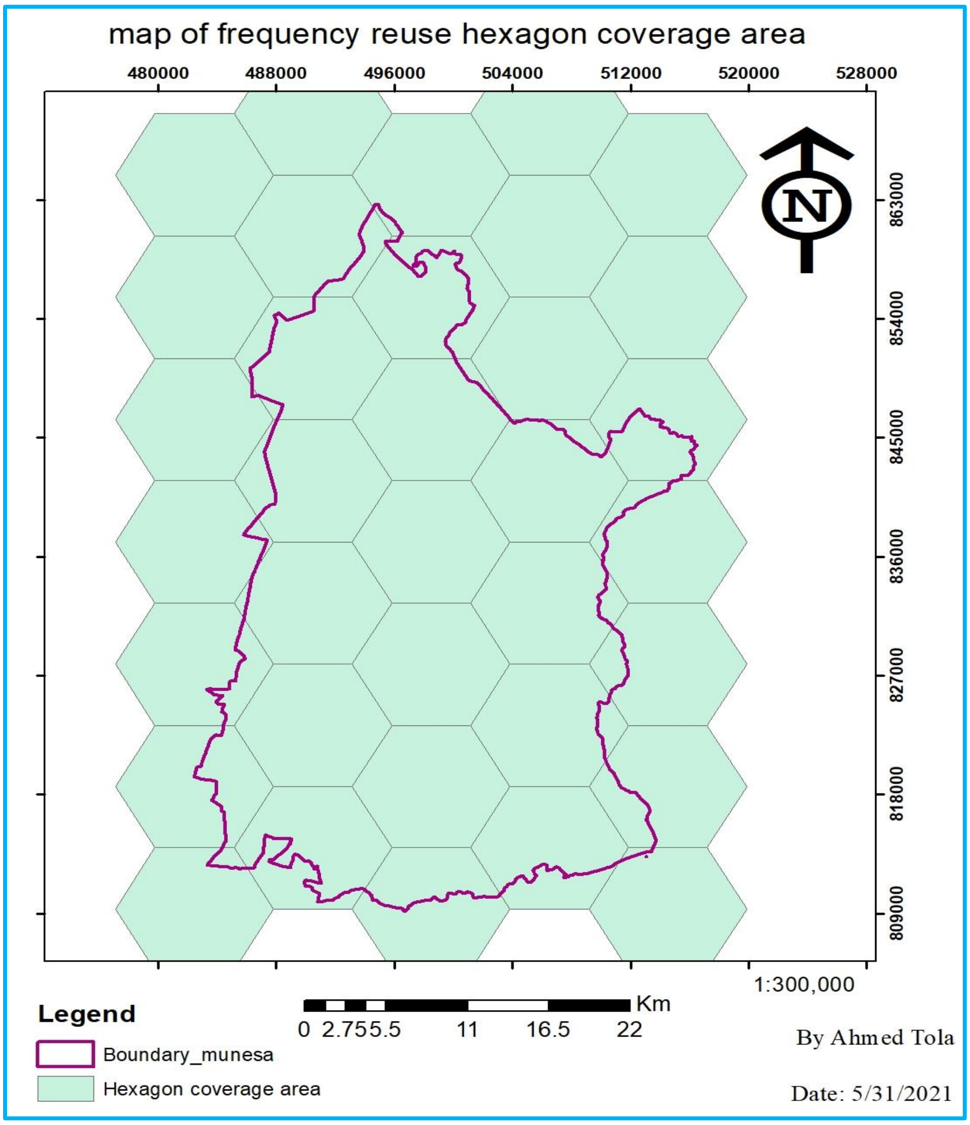


Figure 4.20 frequency reuse hexagon coverages of Cell towers

Above figure show a hexagon of frequency reuse the result can be a regular six-sided polygon with equal side lengths. This enable us to divided area with any gap.

4.2.9. Location of new cell Towers in study area.

Thiessen polygon

After frequency reuse map procced we select only suitable area polygon as clip feature clips the Thiessen Inputs point layer. The Result is a Thiessen Inputs (figure 4.21) only having inside suitable area of Study area. Other unnecessary and not suitable area coincide Thiessen inputs points are not consider.

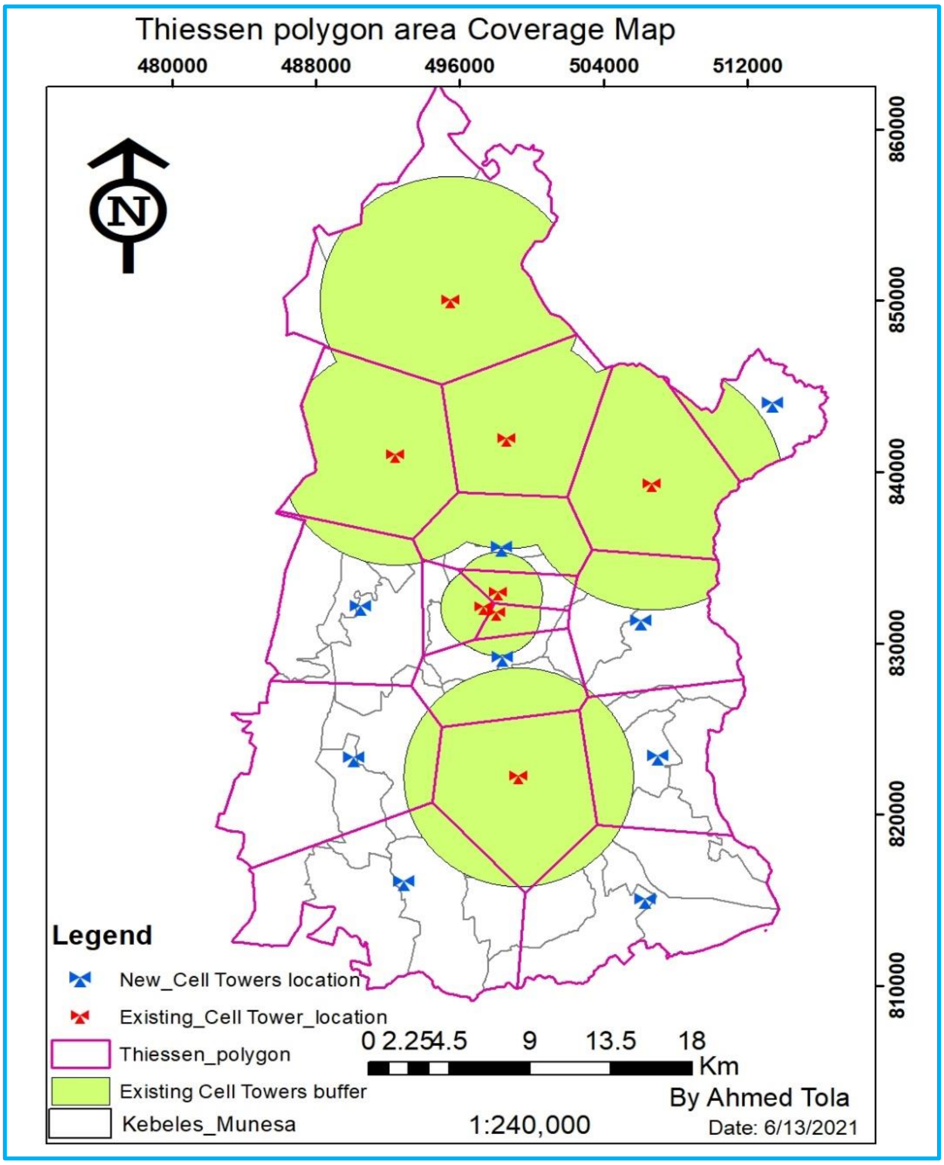


Figure 4.21 Thiessen polygon Analysis area coverages of Cellular network

Figure above show thiessen polygon having center points of one station inside which show the coverage area of 1 station in polygon. Also points near boundary less than one km are removed because networks from neighbors are available surrounding. This layer can be considering as rough location of new cell towers locations. Based on this points location of new cell tower locations are created.

View shed of spatial Analyst of Existing and proposed cellular sites.

In spatial analysis this tool supports two visibility analysis types, frequency and observers, which is controlled by the analysis type tool parameter. For the first type, the tool determines which raster surface locations are visible to a set of observers. For the other, it identifies which observers are visible from each raster surface location. In this case we take as an observer existing cell sites points shown in red color (fig 4.22). View shed of Exiting Cellular Network sites are shown below figure 4.22.

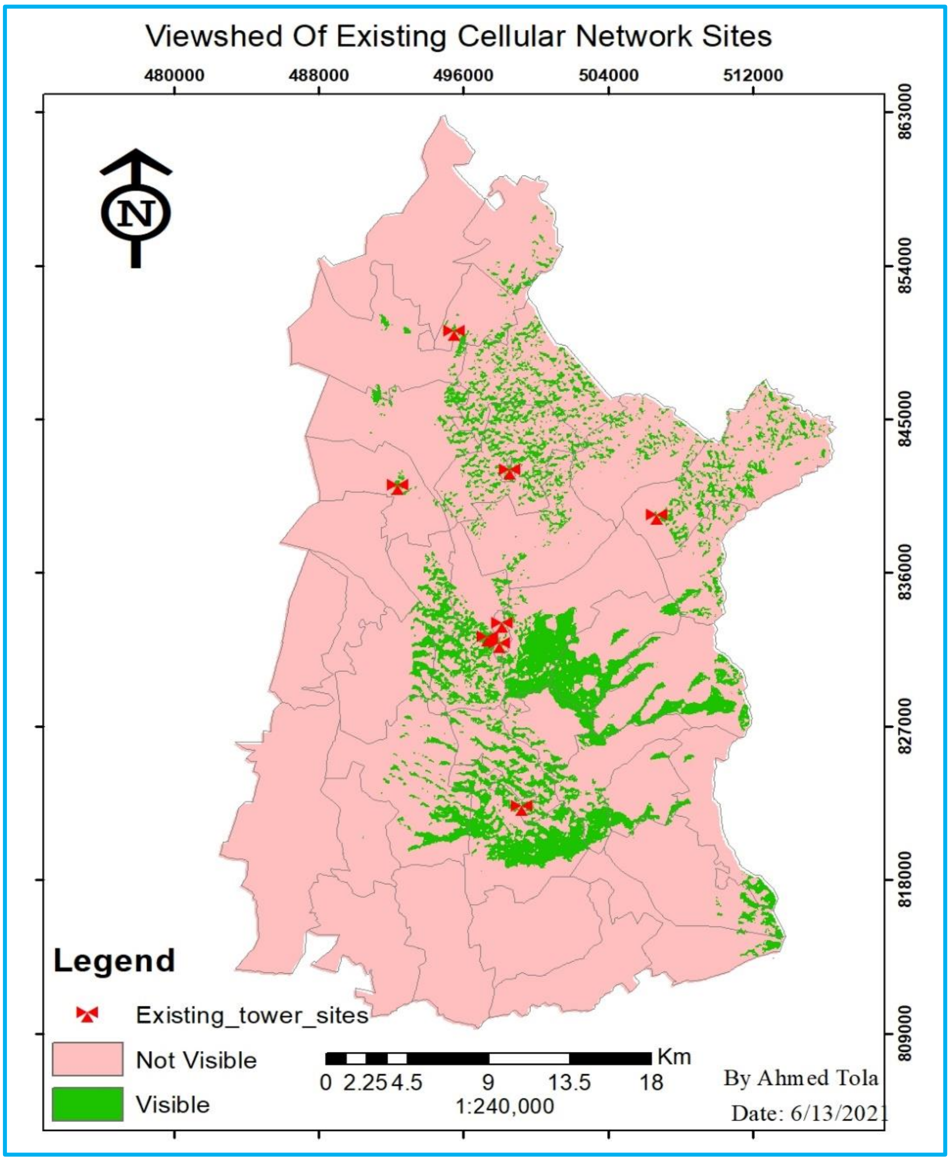


Figure 4.22 View shed of Existing Cellular Network sites.

The visibility of each cell center is determined by comparing the altitude angle to the cell center with the altitude angle to the local horizon. The local horizon is computed by considering the intervening terrain between the point of observation and the current cell center (Munesa DEM.tif). If the point lies above the local horizon, it is considered visible.viewshed of existing cell sites location description shown below (table 4.8).

Table 4.8 Existing Cellular network site attribute table

FID	Shape *	Name of sites	Site No	Northing(X)	Easting(Y)	Elevation (Z)	Area class
0	Point	Kersa Ano	211518	497364	832061	2738.02	suburban
1	Point	Kersa Tele	211517	498041	831710	2751.43	Urban
2	Point	Kersa 2nd.S	211520	498161	832889	2717.902	Urban
3	Point	Dirbu	211521	506707	839227	2558.18	Rural
4	Point	Doge Jirma	211522	492415	840949	2595.067	Rural
5	Point	Koma Ocha	211561	499268	822170	3049.82	Rural
6	Point	Tuwiso	211523	495498	849981	2503.93	Rural
7	Point	Ego_town	211519	498614	841868	2592.01	Urban

Above table shows the location of existing cell sites and their perspective area classes urban, suburban and rural area. After the buffered analysis applied for all cell sites and area coverage calculated for each cell tower the Results indicate that area covered with existing sites are around 561.78 sqkm.

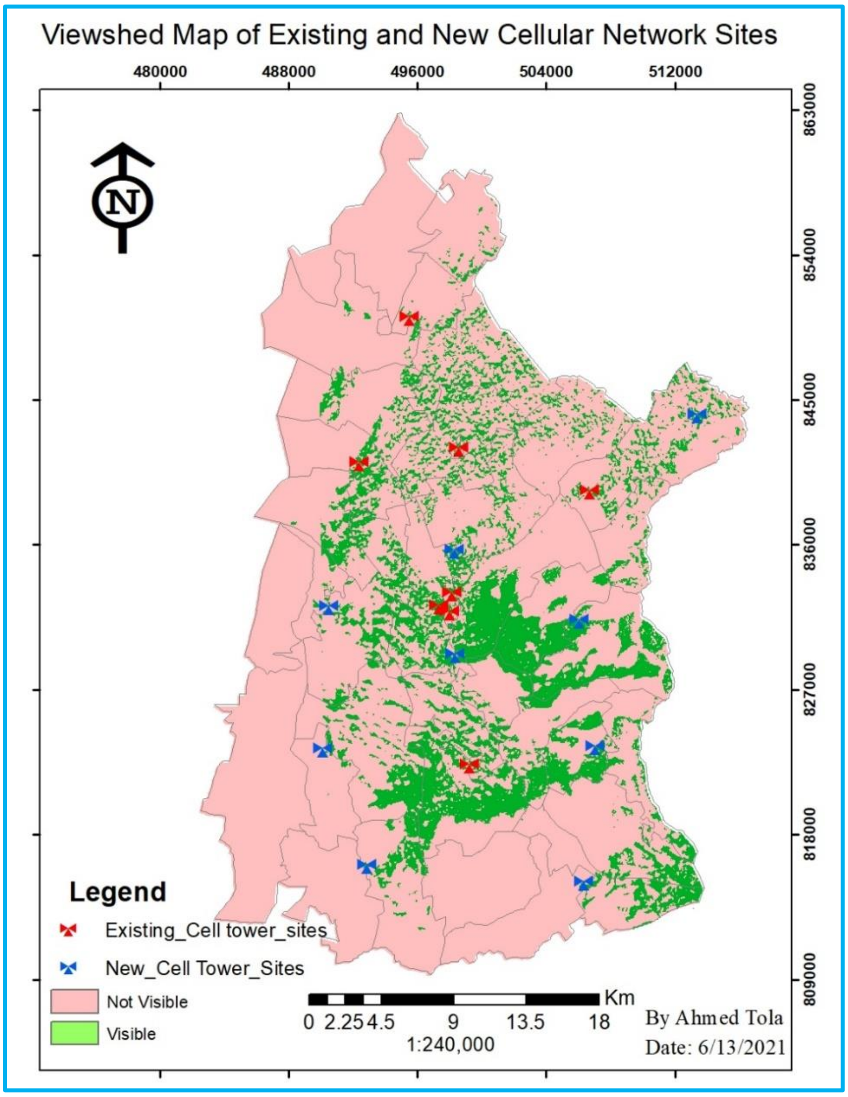


Figure 4.23. View shed of proposed cellular Network sites

After evaluation done with existing sites the whole area of study cannot cover so it's important to find and identify the new sites at the same time. The area types and locations of candidate's sites are shown below table (T.4.9)

Table 4.9 Proposed cellular Network location attribute table

FID	Shape *	X_coord	Y_Coord	Site_kebele	Area Class
0	Point	506349	815004	Waji	Rural
1	Point	490131	823271	Lakicha_Town	SubUrban
2	Point	497942	816044	Sh_keransa	Rural
3	Point	507032	823384	Shune Town	SubUrban
4	Point	490488	832111	Choba	Rural
5	Point	498368	829140	Kersa_Ano	Rural
6	Point	506085	831269	Gunguma	Rural
7	Point	498320	835585	Kersa_Ano	Rural
8	Point	513397	844018	Koji	Rural

In the above table a proposed sites are categorized by area class (urban, suburban, rural) and its location with in which kebele it locates. Based on results shown table (4.9) the new Proposed with existing sites are covered area of 1071.55 sqkm.

4.3. Discussion

4.3.1. The Optimum Location of Cellular networks spatial Analyses

The main objective of conducting the research is to find results on how to evaluate distribution of the cellular networks coverage and how to locate area for the new cell network sites services near to the customer (population) environment. Numerous factors are examined in order to achieve the planned goals and objectives set for this study.

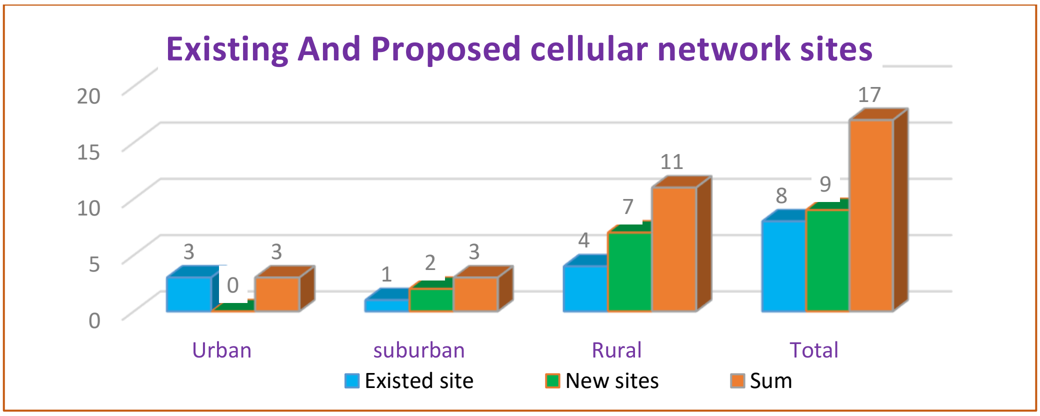


Figure 4.23 Evaluation of the suggested number of Sites with existing proposed (2021)

Above graph shows number of existing site in study area which divided into class area of [Urban, Suburban, and Rural/open area] and a proposed (required) sites for year 2021 to cover all area of munesa wereda.

4.3.2. The Spatial Analysis

Even though some solution sites are more Stable (Fig. 4.16 p.67) than others, the results show that almost some locations can be shown to be "optimal" for the cell tower location. The optimality of a set of sites obtained from weighted overlay analysis only pertains to a general set of area are well suitable in case of location in area where suitable are need only one points in central area to cover surrounding.

4.3.3. The Final Selected Suitable Locations

These are areas that are free from the limiting factors listed above (i.e. slope is safe for constructing houses, land use type is the most preferable for cell tower, distance from road, distance from existing sites, and distance from population is the most suitable).

4.3.4. Vulnerability of the Existing and Final Selected Sites

High levels of RF waves can cause a warming of body tissues, but the energy levels on the ground near a cell phone tower are far below the levels needed to cause this effect. So far, there is no evidence in published scientific reports that cell phone towers cause any other health problems. The consensus of the international scientific community is that the power from these mobile phone base station antennas is far too low to produce health risks as long as people are kept away from direct contact with the antennas. It is the antennas that you need to keep your distance from and not the towers that hold the antennas. You also need to be aware of the many different designs of mobile phone base stations that vary widely in their power and characteristics, as well as their potential for exposing people to RF radiation.

Radiation affected area calculation can perform on buildings polygon were extracted from Cad files or master plan data, updated google earth images after classification technique done for urban and sub urban where population and high buildings are densed.

According to ITU a buildings near cell towers to 100m distances are highly affected and Building distance 100m to 200m are affected building where their intersected area are identified with intersection tool from ArcGIS geoprocessing Tools. As results show an area affected with radiation zone are in total 91 buildings from which 53, Ego and 38 are from kersa town. (Eldhose N.V, 2017) In order to establish more coverage, most of the towers are mounted near populated areas. People living nearer to the towers receive much more signal level than required for most of the times. In Ethiopia, many of people live in the high radiation zones. But most of the people are not concerned about the effects of radiations on health and possible safety measures to overcome the hazards. This demands the need for continuous studies on the effects of radiation on public health.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Conclusion part discusses the results presented in previous chapters, General concepts and procedures for a comprehensive location analysis context, and states the contributions of this study. It also suggests future research that may extend the concept and implementation of the integrated location analysis framework. The results we obtained from spatial analysis and additional analysis to reach at the goals and objectives of the research based on which the following conclusions and recommendations are developed.

As result indicated in table 4.8 area coverages And total area of covered with existing sites figure 4.17 , and succession of suitability analyses show that within distance around (three) 3km more than 80% of the cellular network service population are accessible to services currently existing in Munesa wereda.

In the context of Ethiopia, the state owned telecom operator, Ethio telecom, has undergone several telecom expansion projects to meet the ever increasing service demand from the public at large. Currently, it became one of the operators in Africa that joined the upgrading path towards the latest 5G cellular network technology by deploying LTE in its capital, Addis Ababa and 4G LTE cellular networks released early for South regions Area towns, Like Dukem, Bishoftu, Adama, and other towns North west region, south west region and East region also Early Ethio telecom start tele birr in country.

This can be considered as one of the remarkable achievement in the history of telecom service in the country. However, considering LTE as the latest technology, the radio network planning used for the implementation of LTE network in the country was basically vendor dependent(Mamo, 2016). In the munesa wereda where there's no coverage area is no scheduled approach of distributions in the demanding situation of the community so that Cellular networks are highly concentrated at infrastructure like electricity road and utility where as rare amount of cellular networks with less signal are seen in other areas of population. This situation intern caused some parts of the population remain unreachable while the others are bounded by high potential of coverage and accessibility.

Additional cellular network facilities are required in the more parts of wereda are mostly the recommended. Area that around the new candidate site locally known as shune, lakicha, wollu dikale, and gujicha area is partially populated and needs developments of infrastructures, utilities and social services such as health center, waters, and electric facility are highly requirements.

The current positioned infrastructure consist of 8 sites from which 3 sites covered the urban area, 1 sites suburban and the rest four sites cover the area of rural to provide service for a subscribers. Based on the analysis 4 sites can cover the urban with the optimization of more number of customer which reduce the number of infrastructure and cost by improving the quality of network. Generally, based on analysis, the munesa wereda can be covered by 17 sites (3, 3 and 11 sites for urban, suburban and rural area respectively) which sites to cover the same area with better signal strength.

5.2. Recommendations

The evaluation and implementing of Optimum cellular sites has to be done primary by performing detailed assessment of the existing cellular network. After that, new expansion of the cell network sites has to be done with proper optimization of the current topology and the expected quality using the standard and scientific parameters. It has to be planned to efficiently minimize both the initial asset cost and as well as operational cost to the placement of the optimized location of cellular network, but this needs to conduct study on cost analysis to compare the planned cell network sites with existing cellular networks.

In the study cellular network sites Coverage (cell towers) is created and represented as vector format. Vector data are excellent for capturing and storing spatial details while raster data are well suited for capturing, storing and analyzing data such as elevation data, temperature, soil, aerial photo and satellite imagery etc. That vary continuously from location to location. Raster format for cellular network Coverage is better than vector model which is more suited to mathematical modeling and analysis.

When consider practically for radio frequency propagation may influence by varies factors. Telecom Service Providers are using special kind of license software for designing tower locations by radio frequency propagation. If any of these software could integrated with this research model (ArcGlS), better results can be achieve.

Wireless Network towers exclusively does not bringing customer satisfaction. It needs to provide the service with reasonable price based on the network traffic analysis and dynamic tariff. So study on this and other value added services is recommended to manage the available resource and generate extra money and service in addition to fully customer satisfaction. The prepared maps and models for cellular network optimum site selection in this study may assist the Telecom Tower planner in the detailed planning phase of the future network in this wereda. The methodology introduced and the result obtained in this study can be used as a quick reference material while planning cellular network for other towns or area.

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APPENDICES

Appendix 1: Citation and Reference Information

Referencing style used: APA (American psychological Association)

Reference source: published materials listed in Bibliography

Table 1: shortened and contrasted words used in both text and reference list in APA style

Reference Symbol	Full words	Description
P.	Page	Specify page number in text and reference list
n.d	No date	Used where year of publication is not specified

Appendix 2. Data collection procedure using handheld Gps

STEP 1: Setup

- System configuration → satellite system → GPS+GLONASS
- Position format →UTM
- map datum → Adindan
- Map spheroid→ Clarke 1880

Unit: Distance and Speed /Metric Elevation: m/sec

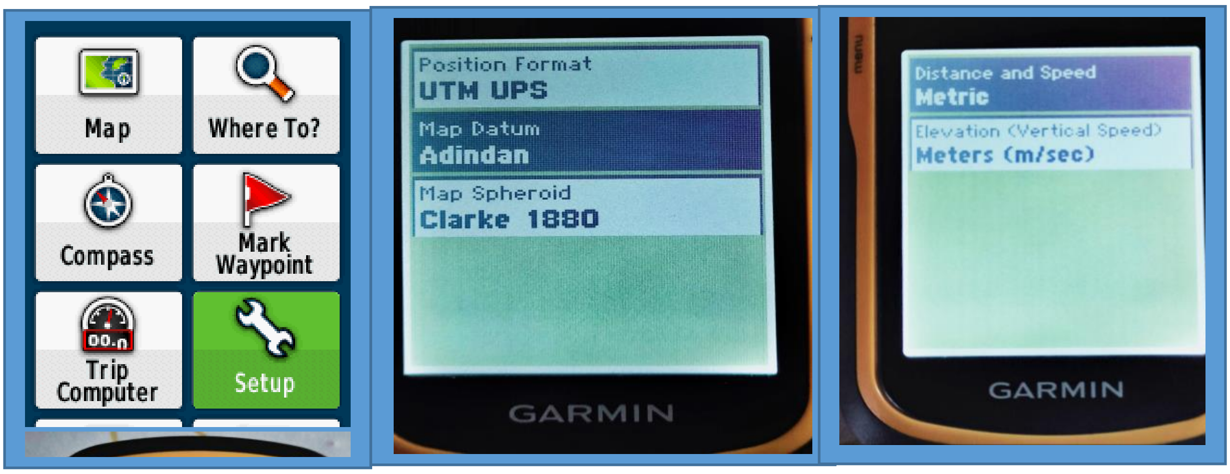


Figure 1 GPS interface showing setting up during data collection

- **Getting started and tracking satellites**

Important information to remember before data collection from field.

- ✓ The GPS requires a clear sky view (clouds don't matter) to work well.
- ✓ Stay clear of tall buildings, trees or similar that might block your (and therefore the GPS's) view of the sky.
- ✓ For a GPS to locate itself, it is required to 'see' to at least four (4) satellites.

STEP 2: Marking a waypoint

Using the waypoint manager we collect and store data.

A waypoint is a location that can be recorded and stored onto the GPS.

- ☞ On the main functions menu page, select the 'Mark Waypoint' icon.
- ☞ A screen will be displayed (as displayed below in the figure) indicates that location of the GPS in Eastings and Northings, and an elevation above sea level.
- ☞ A name and note can also be attached to each waypoint. This can be edited by navigating to each of the sections using the THUMBSTICK and clicking in with the THUMBSTICK.

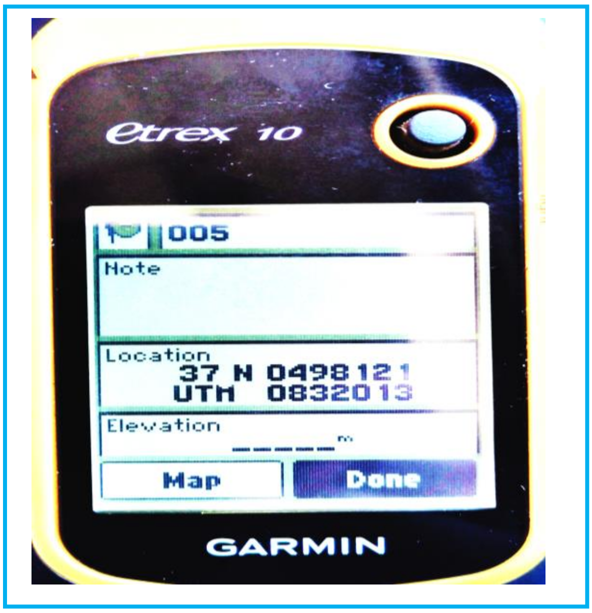


Figure 3 showing saving/marking location during collecting data.

STEP 3 Transferring data between a computer and the GPS
Easy GPS software connected with pc through cable.

Opening Easy Gps on pc

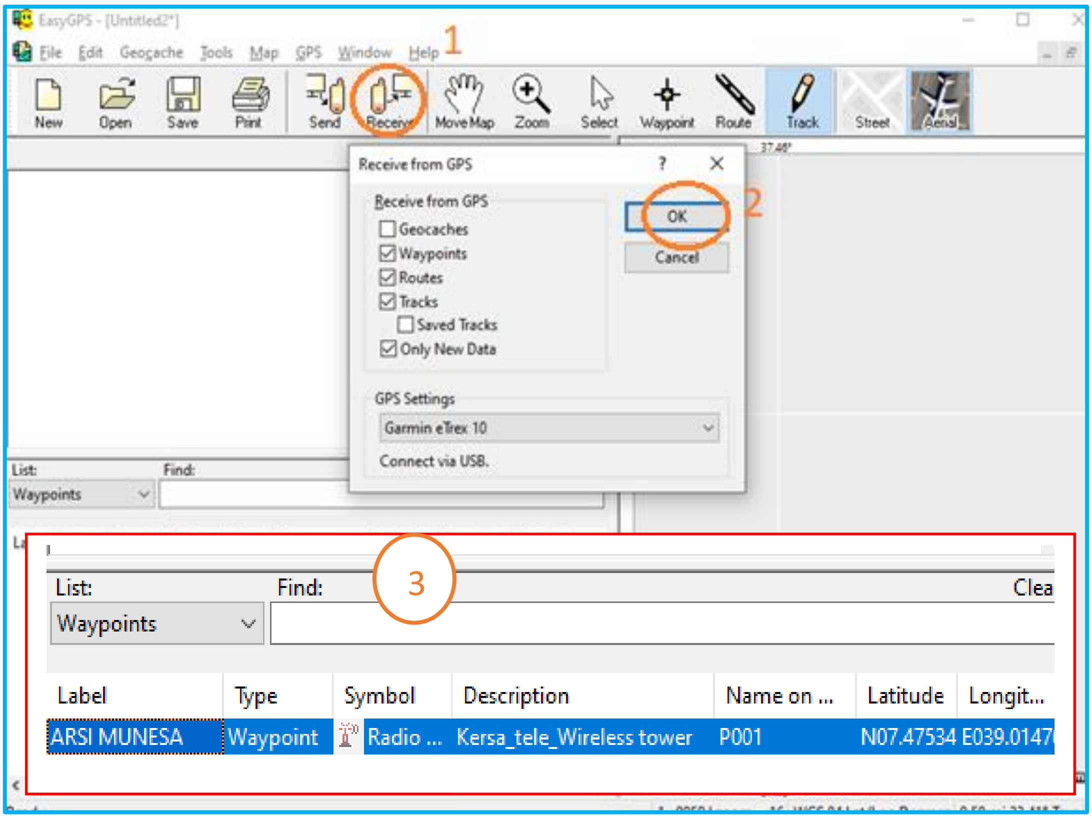
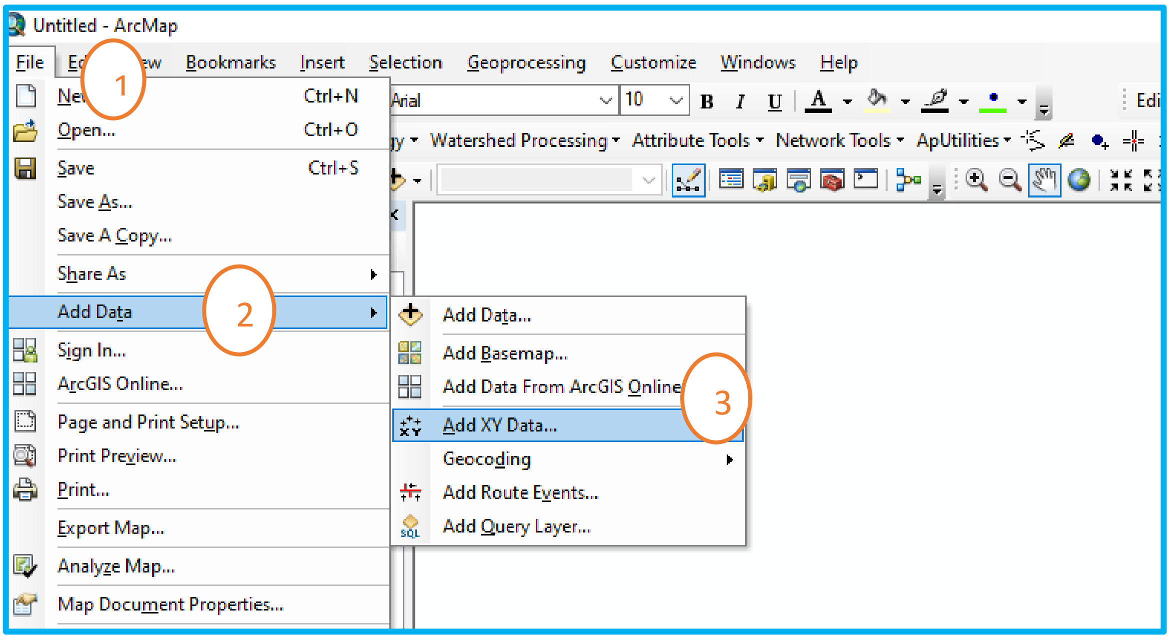


Figure 4: showing EasyGPS software interface transferring data from GPS to PC procedure

Appendix 3: Adding and Displaying Downloaded Data in ArcMap



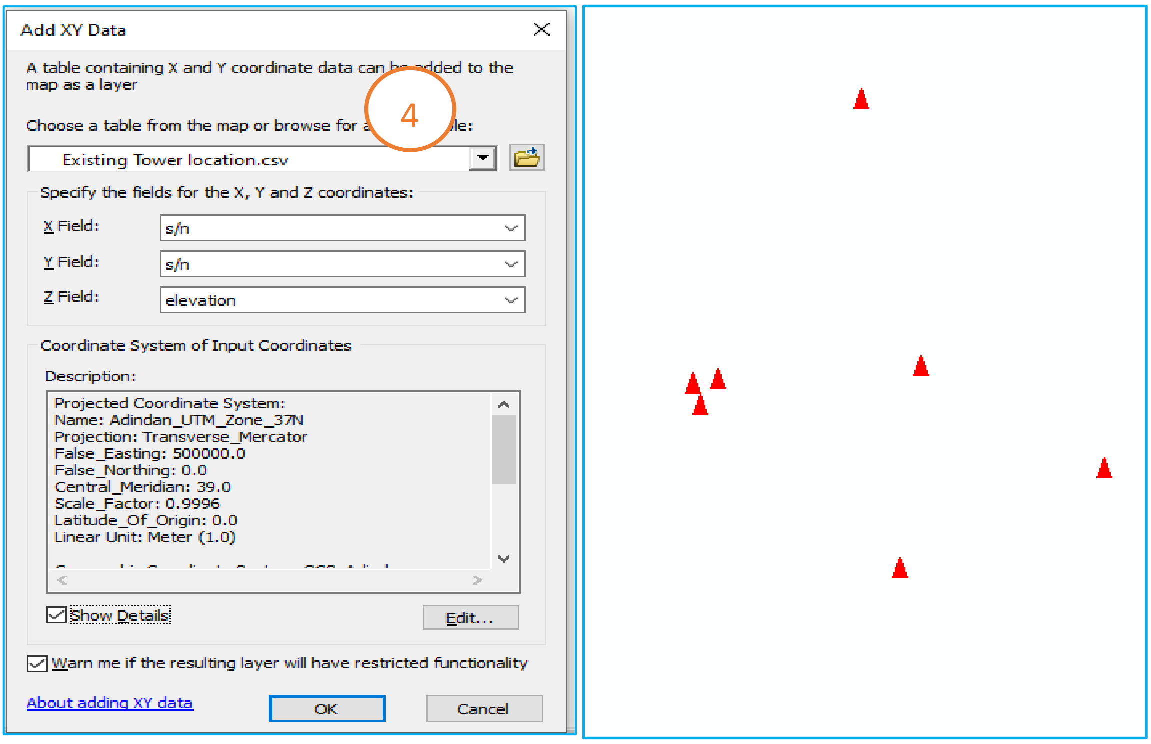


Figure 5: Showing adding and displaying data in ArcMap

Appendix 4: Field book data collection format

Table 2. Data collection format

Manual Data Collection Gps Field Book						
Point No	Name Of Site	Site No	Northing	Easting	Elevation	Remark

Manually collecting data when device cannot store data/when memory full. In another way is to save data in different format and store, data during collecting from field use also hardcopy materials are recommended.

Appendix 5 Questionaries' given to Ethio Telecom professionals Adama district.

1. Answer the question 1 to 2 according to the given instruction.

Criteria that effect the selecting optimum site for Telecom Tower Construction.

To selecting a suitable location. A, B, C, D, E and F are main criteria.

A- Population	B- Land use	C- Distance from road(DR)
D- Elevation (Elev)	E- Distance from building (DB)	F- Distance from stream

Example: - if you consider the criteria A is extremely important than B. then shade box the suitability degree of the below table based on description information given here.

Population(A)	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B

If you consider the criteria B is extremely important than A, then mark/shade box the suitability degree of the table as follows:

Population(A)	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B

Table 1 description of degree of importance

Degree of important	Description of pair wise comparison judgment
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	The important is between the two degrees

Table 2 Degree of important for suitability comparing

Population(A)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
Land use (B)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
DR(C)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
DR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
DR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
Elev(D)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Elev(D)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
DB(E)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F

Table 3 Degree of important for suitability comparing

Population(A)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Population	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
Land use (B)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Land use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
DR(C)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	D
DR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
DR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
Elev(D)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	E
Elev(D)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F
DB(E)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	F

2. Indicate the suitability level of following attribute of sub criteria based on the given standard, in selecting a safe distance from road, building and land use types.

NB this information based on Ethio-telecom standard or ITU Guidelines

Table 4 suitability rank description

Suitability Rank	**Suitability Rate**
0	Not Suitable
1	Less suitable
2	Suitable
3	Moderate Suitable
4	High suitable

Table 5 sub criteria suitability rate

Sub criteria	Attribute value of criteria	Suitability rate
Access to Major/ Minor Roads	0-0.5km	4
	0.5-1km	2
	1-2km	3
	>2km	1
Distance from nearby houses	0-5m	0
	5m - 10m	1
	10m-20m	2
	>20m	3

Land use land cover

Land Use Type	Shrub land	1
	Hilly forest	0
	Dense Forest	0
	Mixed forest	1
	farm land	2
	Riverine	1
	Rock	3
	Water hole	0
	Grass land	3
	Settlements	1

Appendix 6: Interview questions and Answer.

Interview question involved face to face communication between the interviewer and the interviewee. Face-to-face or personal interviews are very labour intensive, but can be the best way of achieving high quality data. It's preferable when the subject matter is very sensitive, but not personal, if the questions to be coded are very complex or if the interview is likely to be lengthy.

The main purpose of this interview was to know and conclude the current systematic ways they use to identify and Find area where there's no network coverage and plan for new optimum location of cellular network service of Ethio-telecom Adama District.

Interview question and answer responses summarization

Question number 1: would you introduce yourself, your position and Experience in Telecom Sector?

Response of first Respondent.

Name: xxxxxxxxxxxx

Position: Wireless communication and towers site manager

Experience: above 14 years

Response of Second Respondent:

Name: xxxxxxxxxxxx

Position: Power controller and communication Engineers

Experience: above 12 years

Interview Date and time: March 24, 2021 start from 09:00-10:30am
Location: ETC south region main office Adama.

Response of third respondent
Name: xxxxxxxxxxxxxx
Position: wireless network towers Guard manager.
Experience: above 7 years

Interview Date and time: March 13 2021 from 2:30pm-4:00pm
Location: Arsi Zone Munesa wereda, kersa Town.

Questions number	Interview question and answer responses summarization
Question number 2	Would you tell me how telecom services infrastructure deliver to community? How to check network coverage service of unserved area? **Response of first respondent**. According to his Explanation in Etc., there are different offices have technician, data collectors that check infrastructure and inform even if maintenance problem are available. This can be by site supervision. **Respond Of second respondent** According to his explanation in ETC there's Telecom services providers department which deliver facility for community based on government ordering.
Question number 3	Would you tell me how many staff that organize telecom facility and maintenance and how do telecom install/build new tele tower for area unserved respectively? **Response of first respondent**. In ethio-telecom there are different sectors or department such as the office that evaluates the current condition of cell tower and area coverage. They use different software and working on study before decision to install new sites. **Respond Of second respondent** According to his explanation there are many office which have different job position, such power controlling engineering, lightning effect,

	structures of BTS towers and checking antenna direction to populated area. Telecom sector use its own criteria to install new BTS towers, sometimes it's based on question from community, for all area including urban and rural areas. For example if new highest building is built in area near BTS few areas have not network service in this case Ethio telecom have prepare research study for such problem before Installing any Wi-Fi antenna or devices, for such problem they fix antenna on top of Building.
Question number **4**	What problem are occur in rural BTS telecom sites and How does Ethio telecom fix problem, hazards and other related things respectively? **Respond of third respondent** According to his explanation a BTS towers in rural areas stop services in few sites, specially which using their power as solar and generator when this equipment are not work properly, this takes one to 3 weeks.