# ANALYSIS OF PHYSICAL ACCESSIBILITY TO HEALTH FACILITY: A CASE STUDY OF NORTH SHEWA ZONE, AMHARA REGIONAL STATE OF ETHIOPIA

**YETNAYET FANTAYE**

**A Thesis Submitted to**

**The Department of Earth Sciences**

**Presented in partial fulfillment of the requirements for the Degree of masters of Sciences (Remote sensing and Geographic Information System (GIS))**

**Addis Ababa University**

**Addis Ababa, Ethiopia**

**May 2014**

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**Under the guidance of**
**Dr. Getachew Berhan and**

**Ato Degelo Sendabo**

**Addis Ababa University**
**Addis Ababa, Ethiopia**
**May 2014**

**ADDIS ABABA UNIVERSITY**

**SCHOOL OF GRADUATE STUDIES**

This is to certify that the thesis prepared by Yetnayet Fantaye,
entitled: *Analysis of Physical Accessibility to Health Facility: A Case Study of North Shewa Zone*, *Amhara Regional State of Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of MASTERS OF SCIENCE in Remote Sensing and Geographic Information System (GIS) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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# D E C L A R A T I O N

I here by declare that the dissertation entitled "ANALYSIS OF PHYSICAL ACCESSIBILITY TO HEALTH FACILITY: A CASE STUDY OF NORTH SHEWA ZONE, AMHARA REGIONAL STATE OF ETHIOPIA." has been carried out by me under the supervision of Dr. Getachew Berhan and Degelo Sendabo, School of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2013-2014 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

**YETNAYET FANTAYE**

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Place: Addis Ababa University

Addis Ababa

Date: May, 2014

# C E R T I F I C A T E

This is certified that the dissertation entitled "ANALYSIS OF PHYSICAL ACCESSIBILITY TO HEALTH FACILITY: A CASE STUDY OF NORTH SHEWA ZONE, AMHARA REGIONAL STATE OF ETHIOPIA" is a bonafied work carried out by Yetnayet Fantaye under our guidance and supervision. This is the actual work done by Yetnayet Fantaye for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University, Addis Ababa.

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# ABSTRACT

ANALYSIS OF PHYSICAL ACCESSIBILITY TO HEALTH FACILITY: A CASE STUDY OF NORTH SHEWA ZONE, AMHARA REGIONAL STATE OF ETHIOPIA.

Yetnayet Fantaye

Addis Ababa University, 2014

Population of Ethiopia is still facing higher rate of morbidity and mortality. Majority of population lives in rural areas where healthcare service is very poor. Physical accessibility to healthcare measures interms of travel time, and distance to the nearest health facilities from people’s residential areas. From these measurement options, this study used traveling time to reach health facilities from patients home. The central aim of the study is to assess physical accessibility to health facility within an hour travel time both by walking and vehicles in North Shewa Zone. To achieve this objective the study depends on AccessMod 4.0 model and incorporates population, land use, road network, digital terrain model, location of health care facilities and travelling time scenarios. Population distribution data is prepared by interpolating population at kebele level. Land cover data for the study area is prepared from Landsat enhanced thematic mapper plus satellite images and classified into five land cover types by using supervised method of image classification. Classified land cover types are assigned traveling speed per hour in the traveling scenario table. Results obtained from the model provide hospitals serving about 72937(4%) and health centers 240,473(13%) out of the whole population in an hour travel time both by walking and vehicles, and covers 4,167 $km^2$ and 704.91 $km^2$ area, respectively. Hence, priority must be given to areas with higher health facility population ratio and areas where there are access limitations to these facilities within the defined scenario.

**Keywords:** Accessibility, GIS, Health Facility, Travelling scenario

**ACKNOWLEDGMENT**

I would like to sincerely thank my advisor, Getachew Berhan (PhD) and Co-advisor, Degelo Sendabo for whose guidance and comments to the success of this work.

In addition, I am also grateful to my classmates for their sharing of ideas and technical skills with them plays a great role in the successfulness of this paper.

I want express my gratitude to my best friend Awelachew Dejen for his all rounded help and support from the very beginning of the research process to the end of the study.

I am Very happy to convey my special thanks to my beloved family who teach me love and courtesy as well as for their moral support to accomplish the paper.

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## ACRONYMS

| | |
|---|---|
| CSA | Central Statistical Agency |
| DEM | Digital Elevation Model |
| ERDAS | Earth Resource Data Analysis System |
| ESRI | Environmental System Research Institute |
| ETM | Enhanced Thematic Mapper |
| GIS | Geographic Information System |
| HEP | Health Extension Package |
| HSDP | Human Sector Development Program |
| LCEF | Leadership Conference Education Fund |
| LULC | Landuse Land Cover |
| MoH | Ministry of Health |
| NGO | Non-Governmental Organization |
| PHCU | Primary Health Care Unit |
| SRTM | Shuttle Radar Topographic Mission |
| UNECA | United Nation Economic Commission for Africa |
| USGS | United States Geological Survey |
| WHO | World Health Organization |

# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Background of the study and Justification

Accessibility to public services is important issue in health system, and it is directly related to disease control as well as emergency services. It is major problem for many third world countries.

Accessibility is defined as the degree at which something is nearer (Lue and Wang, 2003). Some places are inaccessible as a result of physical and social dimensions of accessibility. Physical accessibility refers to the ability to command transportation network facilities needed for reaching health facilities locations at suitable times while social accessibility focuses on the individuals who must fulfill certain requirements interms of age or ability to pay or overcome barrier to reach the destination (Moseley, 1979 cited in Tuan et al., 2007).

According to Oliver and Mossialos (2004), accessibility to healthcare is concerned with the ability of population to obtain specified set of health care services with the concept “specific” having potential to vary depending on policy focus or impact of disease.

Access to health services means the timely use of personal health services to achieve the best health outcomes. It results gaining entry into the healthcare system, accessing healthcare where needed, and finding health care provider with whom patient can communicate and trust.

Geographic Information Systems (GIS) and remote sensing data are necessary in order to keep the surveillance and control of infectious diseases, determination of geographical distribution of diseases, analyzing spatial and temporal trends of diseases, mapping populations at risk, stratifying risk factors, assessing resource allocation, planning and targeting interventions over time (WHO, 2010).

The first application of spatial epidemiology dates back to 1854 when John Snow succeeded in locating the origin of cholera in London at the local scale. In developed countries, further development of spatial information technologies in public health took place. These research developments have resulted wide range of tools, and methodological approaches including mathematical models of epidemic disease spread, integration of epidemic spread models in GIS, spatial and temporal epidemic analysis modeling and preventive what-if scenarios (Abdulkader, 2011).

Weak infrastructure development and limited distribution system in least developed countries worsen access to healthcare services especially in rural areas (Nada, 2007). Ethiopia is developing country with an improving healthcare system and infrastructural development. Most aspects of health are generally poor with significant regional disparities in relation to health service accessibility and outcomes.

Ethiopia's population still face high rate of morbidity and mortality, and health status remains relatively poor. Figures on vital health indicator show life expectancy of 54 years (53.4 for male and 55.4 for female), infant mortality rate of 77 per 1000, and under five mortality rate is about 101 per 1000 population in 2010 (WHO, 2010). These poor demographic situations in one way or another way are related to low level of availability and accessibility of healthcare.

GIS technology has been employed in order to assess healthcare needs, analyze access to healthcare services to understand disparities in access among different groups, evaluate healthcare service and to provide spatial decision making support for healthcare delivery (Huerta and Kallestal, 2012).

## 1.2 Statement of the Problem

Disparities in access to health services affect individuals and society. Limited access to health care impacts people's ability to reach their full potential, negatively affecting their quality of life. Lack of health service with specified distance and poor infrastructure are barriers to health services. These barriers to accessing health services lead to unmeet health needs, delays in receiving appropriate care and inability to get preventive services and hospitalization (Black et al., 2004).

Public provision of healthcare services is among the biggest problems in developing countries, and accessibility of healthcare institutions is one of the most important factors in constituting healthy communities. The degree of accessibility to health care institutions is one most significant indicator for measuring the efficiency of healthcare system. Access to healthcare institution seriously restricted by distance. Longer distances affect elderly and physically-impaired people. In general, the longer distance to healthcare facilities, the higher risk of fatalities will be.

Recent advancement of Geographic Information Systems (GIS) has provides an important tool for healthcare planning particularly in measuring access to health services. Major progress was made in industrialized countries where detailed data inputs are available. However, application of such methods in developing countries is characterized by lack of data inputs. In developing countries, roads are unpaved and adopted by convenience for travelling on foot or by vehicle. There is no well-established and functioning public transport system in many areas in developing countries. Instead measuring access to health services in developing countries remains imprecise and relies mostly on asking patients about the time and distance they travelled (Perry and Gesler, 2000).

Healthcare delivery system in Africa particularly in sub-Saharan countries suffers from weak infrastructure, lack of trained human resource and poor supply chain management system. In these countries, access to healthcare facilities is particularly low where majority of population resides. In addition, there is also uneven distribution of health workers, which results little availability and poor quality of health service in rural areas (Nejmudin et al., 2010).

Healthcare situation in Ethiopia is improving from time to time but most aspects of health in Ethiopia are generally poor with significant regional disparities in access to services and health outcomes (Tasew Demese, 2003). Improving physical infrastructure and strengthening health systems are keys to improve healthcare, and requires investment and much time. Ethiopian government is striving to achieve the millennium development goal in the health sector. Assurance of healthcare accessibility for the whole segment of population is major component of health policy of Federal Democratic Republic of Ethiopia. Ethiopia is a large country characterized by diverse type of climate, terrain, ethnicity and environment. To provide equitable distribution of healthcare services for all segments of population consideration of diversity in climate, landuse land cover, topography and slope are important.

Diversity in socioeconomic environment, climate and terrains in North Shewa Zone greatly influence health condition. This will affect travel time to reach health facility. Poor health coverage is particular concern in rural area where access to any type of modern health institutions is limited. Development of health system and transport sector influence accessibility of healthcare especially, during rainy season (Nada, 2007). This situation also supports to analyze travel time that peoples expected to go towards health facilities in the study area.

As far as the researcher reviewed there were no works done regarding GIS and remote sensing based healthcare accessibility in the study area in particular and Ethiopia in general. However, Central Statistical Agency (CSA) and Ministry of Health (MoH) express healthcare accessibility and coverage interms of population to health professional ratio. Such type of measurement options does not consider factors which can potentially affect health care accessibility and coverage. Such reports are used as an input in decision making regarding healthcare planning but this does not show the real picture of accessibility due to exclusion of different factors that affect travel time and distance as well as mode of transportation to reach health facility.

So as to get real picture of healthcare accessibility all factors affecting healthcare accessibility has to be included in the measurement of healthcare accessibility. This is supported with various literatures. According to World Health Organization (2012), access to health facilities depends on nature of landuse that determines speeds per hour, population, elevation, mode of transportation. Accordingly, WHO recommended using

AccessMod 4.0 model to measure spatial access to healthcare which incorporates different variables.

## 1.3 Objective of the Study

### 1.3.1. General Objective

The general objective of the study is analysis of physical accessibility to health facility using Geographic Information System and remote sensing techniques in North Shewa Zone, Ethiopia.

### 1.3.2. Specific Objectives

In line with the broad objective, the study has the following specific objectives:

- Identifying and integrating major factors for physical accessibility to healthcare using AccessMod 4.0.
- Creating Travel time distribution grid for a given health facilities.
- To analyze spatial coverage of healthcare in relation to major factors.

## 1.4 Scope of the Study

The study has conducted in North Shewa Zone Amhara Regional State of Ethiopia. It relay on AccessMod 4.0 model. Therefore, the paper shows physical accessibility of health services in relation with population, elevation, LU/LC, road and river by delineate catchment for specific healthcare services. In addition, hospitals and health centers are main target of the study. Therefore, physical access to hospitals and health centers with an hour travel time both walking and vehicles have been analyzed.

## 1.5 Limitation of the Study

The present analysis assumes that accessibility is uniform through gender; in context this may not be the case. Gender-based inequalities in education, asset ownership, income, and employment as well as women's lack of decision-making power limit their ability to access and obtain health care they need. A second assumption is that, patients will always travel to the nearest health facility. However, patients might be inclined to use more distance to health care facilities thought to provide higher quality services.

Health care accessibility analysis needs detail information on mode of transportation used to reach health facilities from patient’s location. Detail data on road network is not available for the area. Therefore, healthcare accessibility analysis was conducted by considering Asphalt road only. Interpolation is used to prepare population distribution at Keble level for the study area but, availability of household location would have improved interpolation result.

Different literature regarding healthcare accessibility analysis has been included in this research but its absence in Ethiopia context prevents researcher from incorporating national works conducted by different individuals.

## 1.6 Organization of the Thesis

This thesis is comprised of six chapters. The first chapter provides an introduction to the study. The general background information about this study had been presented in this chapter. Statement of the Problem, objective, scope, and limitation of the study are presented in this preliminary chapter.

The second section of this thesis is review of related literature. Several issues about access to health care accessibility discussed. Overviews of Ethiopian health development and health care accessibility have been presented.

Chapter three is about data sources, materials and methods of the study. Profile of the study area presented and methods employed to achieve each specific objective.

In chapter four, data processing and analysis has been presented according to the objectives.

The fifth chapter is all about result and discussion, and events are elaborated via maps, graphs and tables.

Last chapter is about conclusion and recommendation. In this section, findings and results summarized and concluded. Finally, some recommendations are forwarded by the researcher.

# CHAPTER TWO

## 2. LITERATURE REVIEW

### 2.1 Introduction

The purpose of this chapter is to review the literature in order to establish what other relevant researches have been done to date. The following sections attempt to clarify the key terms access, accessibility and spatial accessibility within the context of the work that is presented in this study. It has been integrated this concept to health care. Factors that affect access to health care facilities, role of GIS in healthcare accessibility and model used to measure access to healthcare are discussed. Then, brief overview of health sectors and their development in Ethiopian context.

### 2.2 Access

Access can be described as the degree of fit between users and a service. The degree of fit might be influenced by the availability, accessibility, accommodation, affordability and acceptability of service (Penchansky and Thomas, 1981).

Furthermore, access is linked with the demographic, socio-economic and cultural characteristics of the population, locations of the health care facilities and of the transportation network. In other words, access is patterned both spatially and socially (Field, 2004). Spatially, the more resources that are provided into an area for use the greater the likelihood that people will use those resources and live in that surroundings. Access to an existing resource or facility (e.g. a hospital or a road network) is generally understood as the capacity of an individual to obtain a service when it is needed (Samat and Shattar, 2014). The meaning of access, however, can vary among researchers, policy makers, politicians and publics due to differences in their education, history, workplace condition and cultural context.

Over the last four decades, scholars focusing on access issue generally agree that access is not a well-defined term (Aday and Andersen, 1974). The literature also suggests that the term access cannot be understood by its own rather, it must be differentiated from other closely related terms, which are often used interchangeably like accessibility, availability, affordably, barrier, right of entry, right to use, mobility, and level of permission (Bagheri et al., 2005). Penchansky and Thomas (1981) distinguished spatial and socio-economic aspects of access and described spatial aspect of access in terms of availability, accessibility and accommodation and socio-economic aspect of access in terms of affordability and acceptability.

Bagheri et al. (2005) and Guagliardo et al. (2004), only consider the first two dimensions as the spatial components for spatial accessibility. Khan (1992) described access interms of both spatial (geographic) and non-spatial qualities. In the literature, other terms such as resource allocation, equity and social justice are also frequently used by social scientists and planners. These terms help the planners and policy makers to decide for whom the benefits are to be distributed (Talen and Anselin, 1998). To add the complexity of the concept, access and accessibility are often used indiscriminately and poorly measured (Geurs and Wee, 2004).

Access is quite complex term to define and it becomes more complex because the measure of access does not simply indicate the presence of a health care facility. The presence of service does not ensure the utilization of these facilities in relation to need and health care service users and service provider professionals. Penchansky and Thomas (1981) observed that access most frequently viewed as a concept that somehow relates to the consumers' ability or willingness to use health care services and should consider the personal, financial and organizational barriers to health care service utilization. In contrast, Murad (2004) argued that access is a question of supply whereas, utilization is a function of both supply and demand. Equity of access is purely a supply side consideration in the sense that equal services are made available to patients who have equal health concern (Goddard and Smith, 2001).

## 2.3 Accessibility

According to Vickerman (1974), accessibility is a combination of two elements: locations of a surface relative to suitable destinations and the characteristics of transportation networks linking points on that surface. Accessibility definition is similar to the notion of access, as it has a number of spatial and temporal properties that constraint an individual’s ability capacity or preference to access specific destinations (Witten, 2003). Accessibility can be defined in terms of mobility, which includes a number of spatial and non-spatial attributes as well as temporal constraints, of individuals or groups.

Accessibility can be measured by either Euclidean and Manhattan distance or travel (driving or walking) time or travel cost. Accessibility can be described as travel impedance (travel distance or travel time) between patient location and health care service points (Guagliardo, 2004). Accessibility and availability are not similar terms and accessibility may depend on availability of services. In urban areas, where multiple service locations are commonly available, accessibility and availability should be considered simultaneously (Guagliardo, 2004). With regards to health care service utilization, accessibility is influenced by spatial structures of health care service supply and demand, neither of which is distributed uniformly in space (Wang, 2011).

## 2.4 Spatial Accessibility

The term access refers to an entrance into, the right of entry to or the use of facilities and the term spatial accessibility refers to physical accessibility in which one possesses to a preferred location or the ease at which individuals in one location can reach another location (Kwan and Weber, 2003). Spatial accessibility refers to the relationship between the locations of the supply of and the locations of demand for specific services, taking into account existing transportation infrastructure and travel impedance. In the literature, spatial accessibility (Hewko, 2001; Guagliardo, 2004), and geographical accessibility (Brabyn and Skelly, 2002; Apparicio et al., 2008) are often used in an interchangeable manner, in the sense that both concepts are location based, and spatially constrained. Khan (1992) noted that spatial accessibility is specifically conditioned by spatial or distance variable (barrier or facilitator of access) and pattern generated has the most direct geographic manifestation. Some scholars declare that they used the term spatial accessibility because they want to gain the favor and supported by literature published in health care GIS category (Luo and Wang, 2004; Guagliardo, 2004). Spatial accessibility has been studied and developed in various disciplines. Spatial accessibility is critical consideration both public and private services provision (Murray and Wu, 2003).

Bhatt and Joshi (2013) discussed population over distance relationship or population potential as a generalized notion of accessibility. According to Hansen (1959), an empirical examination of residential development patterns conducted in various disciplines. Many other empirical studies have been conducted and new concepts developed. The development of computer, mathematical and spatial statistical approaches and Geographic Information System (GIS) added new dimension in the development and application of accessibility measures in many different disciplines.

In the literature, the terms spatial accessibility and spatial patterns of accessibility are sometimes used with no discrimination (Hays et al., 1990). Majority of the researchers taken the term spatial accessibility to mean physically be able to reach from a potential location of the health care user's to healthcare facilities location via a transportation network, and the term spatial patterns of accessibility to mean the spatial distribution of certain spatial accessibility measures. Therefore, this study used both physical and spatial accessibility interchangeably.

## 2.5 Accessibility to Healthcare

According to Tansera et al. (2006), having access to healthcare may result from the availability of services while gaining access refers to whether individuals have the resources to overcome financial, organizational and socio cultural barriers and utilize that service. Thus, any study that investigates accessibility needs to examine issues surrounding affordability, physical accessibility and acceptability. They further suggest that the availability of services and barriers to access to be considered in the context of health need, material and cultural settings of diverse groups in the society. Beliefs and expectations of different groups in different geographical and cultural settings will also influence such trends (Andersen and Aday, 1978).

According to Abdulkader (2011), distinguish potential and revealed accessibility or utilization. The former assess the nature and pattern over space of physical access to service facilities. The measure adopts the term potential accessibility because no actual interaction between the two sides of the demand supply equation is implied.

The measure generally assumes that given a maximum range for the service being offered at facility and assuming that every member of the population is a potential user of the service, the pattern of physical accessibility will depend only on the relative location of the population and service facilities. This could be represented as travel time and road distance.

Al-Taiar (2010) recognizes Utilization of services, or the actual entry into the system, is dependent on barriers and facilitators of both the service system and the potential users.

## 2.6 Factors Affecting Healthcare Accessibility

Healthcare accessibility is affected by different factors like availability of roads, land cover type, topographic condition, population distribution and mode of transportation used to reach health facilities.

### 2.6.1 Road

Availability of modern transportation facilities can bring positive impact on health condition by increasing option for commuters, and creating connections to health services. On the other hand, lack of access to affordable transportation facilities is main contributor to health disparities (LCEF, 2011).

Availability of roads allows covering an extensive catchment area, which are located very far from existing health facilities. Its presence increases areal coverage, and number of population served by health facility, and vice versa.

### 2.6.2 Topography

Topography is an important barrier to healthcare services. It can influence both positively and negatively, the speed of travel time for land cover types. Its impact is more pronounced if patients are walking or using bike to reach health facility from their home. The effect of topography will be positive if patient is walking or biking downward from his home to health care facilities. Such type of effect is called anisotropic effect and analysis of such effect is anisotropic analysis (Murad, 2008).

### 2.6.3 Landuse Land Cover

Land cover types and their spatial distributions have its own impact on healthcare accessibility. Different land cover types have different traveling speed as indicated in Table 1. As an example, WHO uses the next table to indicate travelling speeds for different land cover types.

Table 1: WHO standard of traveling speed in different land cover types

| Classes | Label | Maximum traveling speed (km/h) |
|---|---|---|
| 1 | Bare area(Walking) | 5 |
| 2 | Dense Vegetation or Forest (Walking) | 3 |
| 3 | Irrigated Cropland(Walking) | 2 |
| 4 | Low density Vegetation (Walking) | 4 |
| 5 | Urban (Walking) | 5 |
| 6 | Road (Vehicle) | 60 |

Source: (WHO, 2012)

### 2.6.4 Population Distribution

Population distribution is a central issue on healthcare service delivery. Population is the demand for health care services and any work in health care services (it can be planning, establishment of new health care services etc.) need to consider the spatial distribution as well as spatial separation of population. In this case, populated areas are beneficiaries while less populated are disadvantaged.

This spatial distribution and profiling of population (representing potential demand for health care) is major importance for evaluating health care supply in developing countries. Public authorities can use this information to structure healthcare system, in terms of both capacity of facilities and their location (supply) for the attendance of Population (Costa et al., 2011).

The type of health facilities for a population is mostly determined by its size. In the case of Ethiopia, 5000 people are needed for a health post, 25,000 are for health center, and 250,000 and above are required for hospital (MoH, 2010).

## 2.7 The Role of GIS in Measuring Access to Healthcare

Geographic Information System (GIS) has been used extensively in health sector for a couple of decades. Literature shows that, how GIS has been used to examine spatial patterns of disease and environmental correlation through geo-techniques such as spatial clustering. Geographic Information System has been used to examine spatial patterns of health services as well as planning new location for health facilities. These studies involve using standard GIS function such as buffering and catchment delineation as physical or travel time distances as well as network analysis to gauge how long it takes patients to access health facility (Higgs and Gould, 2001). However, researchers are incorporating more sophisticated spatial analytical techniques not currently available within exclusive packages in order to examine different aspects of accessibility. Limitation of such studies is that, measures tend to be calculated from demand point where patients reside typically derived from their residential area and not from where they work.

Albert et al. (2005) states that GIS necessarily emphasize geographical dimension of access. The majority of studies to date have been used GIS to measure potential accessibility of primary and secondary health services to examine spatial inequalities in health care delivery (Phillips et al., 2000). There have also been a number of studies that have taken an area based approach to measuring accessibility using GIS including some that have incorporated access to health services as a key domain in an overall index, usually census or administrative tracts (Higgs and White, 2000). Latter study, for example, the researchers developed community resources accessibility index for urban area. This in turn can be compared for different areas of city to identify areas with poor access to health resources. Area based measures are also dependent on exact nature of areal unit in case of relatively coarse administrative areas, may hide significant intra-zonal variations in accessibility. Nevertheless, such measures can provide useful tool to identify areas where there are gaps in service provision prior to more detailed qualitative studies. In developed countries GIS has been used to identify primary care shortage areas in relation to federally funded programs (Juarez et al., 2002). There is great potential for using GIS to identify vulnerable populations and examine geographical access to quality services and treatment before drawing attention to the relative lack of published studies that take service quality into account (Phillips et al., 2000). Therefore, the study analyze accessibility of health facility using geographic information system.

## 2.8 Models to Measure Accessibility to Health Care

### 2.8.1 Measures Based on Travel Impedance

The two most common types of distance measure used for determining spatial accessibility are Euclidean distance (more often known as straight line distance) and Manhattan distance, distance along two sides of a right angled triangle, the base of which is the Euclidian distance. Ingram (1971) suggests that Manhattan network distance measure is more appropriate than Euclidean distance in measuring gridded road network in urban areas. Apparicio et al. (2008) argues that shortest travel time network is more accurate than any other distance measures.

Spatial accessibility to service facilities from population points have been determined using travel time where travel time is often calculated using the existing road network, the distance is converted to travel time and dependent on mode of transportation used (Burt and Dyer, 1971).

From a user's perspective the journey can be more complex on public transport, and factors such as walking between transport stops or stations, waiting for the next available transport and other scenarios need to be considered.

Travel cost is an alternative method for measuring spatial accessibility (Pearce and Witten, 2006). Like the shortest network distance by time travel cost also uses the road network system and is measured by using the distance travelled and a suitable conversion algorithm. Calculating the travel cost for travel between the user's location and health service provider is therefore relatively simple.

Another example is GIS based accessibility model developed by Liu and Zhu in 2004. This model provides a general framework for integrated use of GIS, travel impedance measurement tools and accessibility measures to support the accessibility analysis process. It includes formulating the concept of accessibility, selecting or developing accessibility measures, specifying the accessibility measures, deriving the accessibility values using the selected or developed accessibility measures, and presenting and interpreting accessibility values. This model measures accessibility by peoples travel to shopping centers, healthcare services, public schools, banks, post-offices, parks and community centers. This model also develops a composite index combining these different measures (Liu and Zhu, 2004).

However, this model does not consider walking modes in measuring accessibility. In another wings literatures emphasized on least developed countries walking mode of transportation have been major mode of transportation for them. Such as:

“Walking is the predominant form of transportation in rural Africa as a result of the lack of infrastructure and motorized transport services (UNECA, 2009)”. Thus, because of this contradiction it does not considered in this study.

### 2.8.2 Measure Based on AccessMod Model

World Health Organization (WHO) has been working to develop models to measure physical accessibility of healthcare in developing countries using diverse variables integrated into GIS system (Black et al., 2004; Ebener et al., 2005). This model takes into account not only travelling time but also availability (supply) of health care provided by a particular unit. According to Black et al. (2004); Ebener et al. (2005), unlike others this model incorporates different variables to estimate catchment population within specified travel time.

AccessMod also take into account population distribution, maximum capacity of each health facility in the network and travel scenarios which take into account different modes of transportation in an isotropic or anisotropic way to design theoretical catchment area attached to each health facility. By incorporating demand (population) and supply (capacities of heath care facilities), AccessMod provides unifying tool to efficiently assess geographic coverage of health care facilities. This tool should be particular interest to developing countries having relatively good geographic information on population distribution, landuse, terrain, and health facility locations. Thus, use of this standardized model eliminates subjectivity in analyzing physical accessibility to healthcare (Ray and Ebener, 2008). Due to these benefits this study relay on this model.

## 2.9 Health Service Delivery in Ethiopia

The health service system of Ethiopia is federally decentralized along nine administrative regions with a total health infrastructure of 14000 health facilities. From this number 143 hospitals, 690 health centers, 9914 health posts, 1662 health stations and 1578 are private clinics, and the remaining are owned by others such as NGO and traditional method. The differentiations of various services level is made by population size (Nada, 2007).
In Ethiopia healthcare services are provided by public, private, and NGO sector as well as traditional healers. From these sectors, public sector provides majority of healthcare service both in urban and rural areas.

### 2.9.1 Public Sector

Before the implementation of health sector development program the public health system was structured in to six-tier system. These six tiers in the system consist of central referral hospital serving a total population of 588,000 persons, regional hospitals, rural hospitals, and health centers serving a total population of 223,000 people, health stations serving 45,000 persons and community health posts serving a total population of 21,000 people (World Bank, 2004).

After the implementation of first health sector development program the six-level system of healthcare delivery is reduced to a four levels. The main change is replacement of clinics by a primary health care unit (PHCU). Each primary healthcare unit has a health centers surrounded by five satellite community health clinics or health posts. Each health post has to serve 5,000 people and a primary healthcare unit has to give services for 25,000 people (MoH, 2010).

The most important functions of primary health care units include giving maternal and child health care immunization, family planning services, nutritional, health and micro nutrient supplementations and curative services for very common diseases like diarrhea, parasitic infections, tuberculosis and acute respiratory infections. They also provide minor surgery and lifesaving operations, give technical assistance in establishing and monitoring environmental and occupational health standards within their catchment area, undertake disease surveillance, record basic statistics and train community health agents like traditional birth attendants (MoH, 2010).

The second structure above primary healthcare unit is a district hospital, which serves as referral and training center for 10 primary healthcare units. The total number of population a district hospital is supposed to serve is about 250,000 people. To serve this amount of population, it is equipped by 50 beds, 33 technical and 35 supportive staff. Third structure is Zonal hospitals, which provide specialist services and training with one million-population coverage. It has 100 beds, 60 technical and 35 supportive staff. The last structure is specialized hospitals, which give specialist services and serves as centers for research and post basic training. It has to serve 5,000,000 people with 250 beds, 120 technical and 50 supportive staff (World Bank, 2004).

## 2.10 Healthcare Accessibility in Ethiopia

In Ethiopia, 64.7, 40.1, 38.0 and 14.2 percent of households are within the five-kilometer radius from nearest health posts, clinic, health center and hospital, respectively (Table 2). From the total households 83.9, 63.1, 59.6 and 20.8 percent are within a distance of less than 10kms from health posts, clinics, health centers and hospitals, respectively. There are also rural urban disparities in health facility distribution. In urban areas health posts, clinics, health centers and hospital are available within a distance of less than 5kms for about 88.2, 87.7, 87.7 and 49.4 percent of the household, respectively (CSA, 2012).

Table 2: Percentage distribution of households by distance in kilometers to the nearest health services and place of residence

| Type of institution | | Below 1 km | 1-4km | 5-9km | 10-14km | 15-19km | >20km | Not stated |
|---|---|---|---|---|---|---|---|---|
| Country | Health post | 15.29 | 49.39 | 19.23 | 4.06 | 1.71 | 0.72 | 9.61 |
| | Health center | 9.42 | 28.56 | 21.63 | 11.53 | 9.67 | 10.28 | 8.91 |
| | hospital | 2.39 | 11.87 | 6.56 | 4.63 | 5.93 | 64.83 | 3.83 |
| Rural | Health posts | 14 | 48.6 | 20.4 | 4.3 | 1.8 | 0.8 | 10.0 |
| | Health center | 5 | 19.3 | 26.1 | 14.6 | 12.3 | 13.1 | 9.5 |
| | hospital | 0.3 | 1.2 | 4.7 | 5.1 | 6.3 | 78.9 | 3.7 |
| Urban | Health posts | 30.1 | 58.1 | 3.5 | 1.2 | 0.2 | 0.3 | 4.7 |
| | Health center | 25.4 | 62.3 | 5.3 | 0.3 | 0.1 | 0.1 | 6.6 |
| | hospital | 8.2 | 41.8 | 11.9 | 3.4 | 4.8 | 25.6 | 4.4 |

Source: (CSA, 2012)

## 2.11 Health Service Coverage and Distribution in Ethiopia

Health service distribution is a geographical and demographic allocation or availability of a specific type of health service(s). It mainly focuses on the geographical availability of the service(s). Health service coverage, on the other hand, is the level of availability, accessibility and utilization of a given health service(s) in a specified population and geographical area. It is the interaction and outcome of service(s), service providers, and people targeted for the service(s).

The health service coverage as well as distribution in the country is relatively poor when it is compared to other developing nations. This can be clearly illustrated if one sees the health and health related indicators of the country.

Health service facilities in the country have stayed being centralized and neglecting the majority of the population. Hence, health service coverage and distribution is inadequate and needed to improve.

## 2.12 Healthcare Policies and Strategies of Ethiopia

In the field of health, there was no detailed policy up to the fifties. Towards the end of the Imperial period, a comprehensive Health Services Policy was adopted through initiatives from the World Health Organization. However, the downfall of the regime prevents the possibility of putting this scheme to the test. The Dergue regime that came into power in mid-seventies formulated a more elaborate health policy that gave emphasis to disease prevention and control, priority to rural areas in health service and promotion of self-reliance and community involvement. However, the totalitarian political system lacked the commitment and leadership quality to address and maintain active popular participation in translating the formulated policy into action (Richard, 2009).

After the downfall of Dergue regime, the transitional government formulates its own health policies to solve health and health related problems in the country. The first policy is developed and implemented during the transitional period.
The major goals of the policy include:

- Democratization and decentralization of the health service system.
- Development of the preventive and promotes components of healthcare.
- Development of equitable and acceptable standard of health service system that will reach all segments of the population within the limits of recourses.
- Promoting and strengthening of inter sectorial activities.
- Promotion of attitudes and practices conducive to the strengthening of national self-reliance in health development by mobilizing and utilizing internal and external resources.
- Assurance of accessibility of healthcare for all segments of the population.
- Working closely with neighboring countries, regional and international organizations to share information and strengthen collaboration in all activities

contributory to health development including the control of factors detrimental to health.

- Development of appropriate capacity building based on assessed needs.
- Provision of health care for the population on a scheme of payment according to ability with special assistance mechanisms for those who cannot afford to pay.
- Promoting participation of the private sector and nongovernmental organizations in health care.

## 2.13 Health Sector Development Program of Ethiopia

The current government of Ethiopia employs four consecutive programs to solve problems of health sector in the county. These programs are termed as a Health Sector Development Program (HSDP). The initial HSDP was drafted in 1993/94, which is designed for a period of 20 years with a gradually developed five years program period.
HSDPI: was implemented from 1997 to 2002 with the aim of increasing access to healthcare from 40 percent to 50 to 55 percent, improve the technical quality of primary healthcare unit.

It also has intention to improve services like restructuring of pharmaceutical sector and expanding supply and productivity of health personnel. Other important areas are information, communication and education plan to communicate from Primary Health Care Unit (PHCU) to remote areas in order to improve health system management at all levels. The implementation of HSDP I resulted with an increment in potential health coverage from 33 percent to 52 percent due to increment in number of health facilities. Other increment is number of health personnel’s especially nurses. The third improvement is the rise of family planning services and national contraceptive rose from 9 percent in 1996/1997 to 14.6 percent in 2001/2002 ( World Bank, 2004).

HSDP II: this program covers three years period from 2002 to 2005. It is a transitional plan covering three years until the start of HSDP III. In HSDP II, health extension package (HEP) was employed at the national level to realize the aim of universal primary health coverage and institutionalization of community health services at health post level.

HSDP III: This is third program, which covers a five-year period from 2006 to 2010. Family health services, prevention and control of communicable diseases, prevention and control of non-communicable diseases, integrated disease surveillance and public health emergency, hygiene and environmental health, health extension program, medical services and nutrition are the most important areas of the third health sector development program. In this phase, number of health posts reached 14,446, health centers reached 2,689 and 195 hospitals (Table 3).

Table 3: Trends of Health Facilities Construction

| Facilities | HSDP I (1996/7) | HSDP II (2003/2004) | HSDP III (2010) |
|---|---|---|---|
| Health post | 76 | 2,899 | 14,416 |
| Health Center | 412 | 519 | 2689 |
| Hospital | 87 | 126 | 195 |

Source: (WHO, 2010)

# CHAPTER THREE

## 3. DATA SOURCES, MATERIALS AND METHODS

### 3.1 Description of the Study Area

Geographically, the study is conducted in North Shewa Zone, Amhara Regional State of Federal Democratic Republic of Ethiopia, which is one of the eleven administrative Zones found in Amhara region, and about 130 kilometers north of Addis Ababa to the capital city of the Zone, Debre Birhan (Figure 1). Absolute location of the study area found in latitude $8^0$ 43' 06" – $10^0$43' 58" N and longitude $38^0$ 39' 50' ' – $40^0$ 06' 32' ' E.

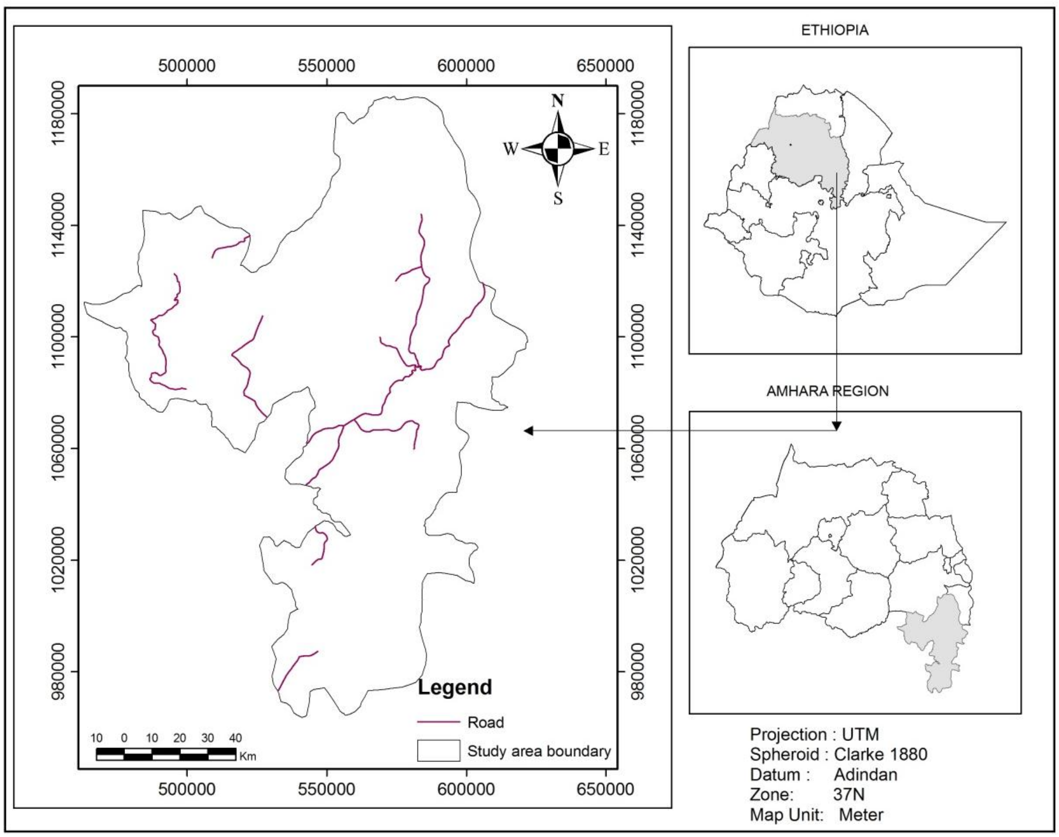


Figure 1. Study Area Map

Administratively, the Zone is further divided into 23 Woredas with total Kebeles of 478. The Zone is bordered to the South and West by Oromia region, to the North by Debub Wollo and Oromia Zone, to the East by Afar region, and covers an area of 15936 $km^2$ (Table 4).

### 3.1.1 Topographic Characteristics

Topography of the study is characterized by rugged, mountainous and flat land. The minimum and maximum elevation ranges is 856 to 3605 meter above sea level, and is shown in Figure 2. North Shewa Zone is located in the Shewan highland, which is the smallest Ethiopian highland. Shewan plateau is bounded by Ethiopian rift on the East and South East side while Abay and Omo gorge border to North West and South West side.

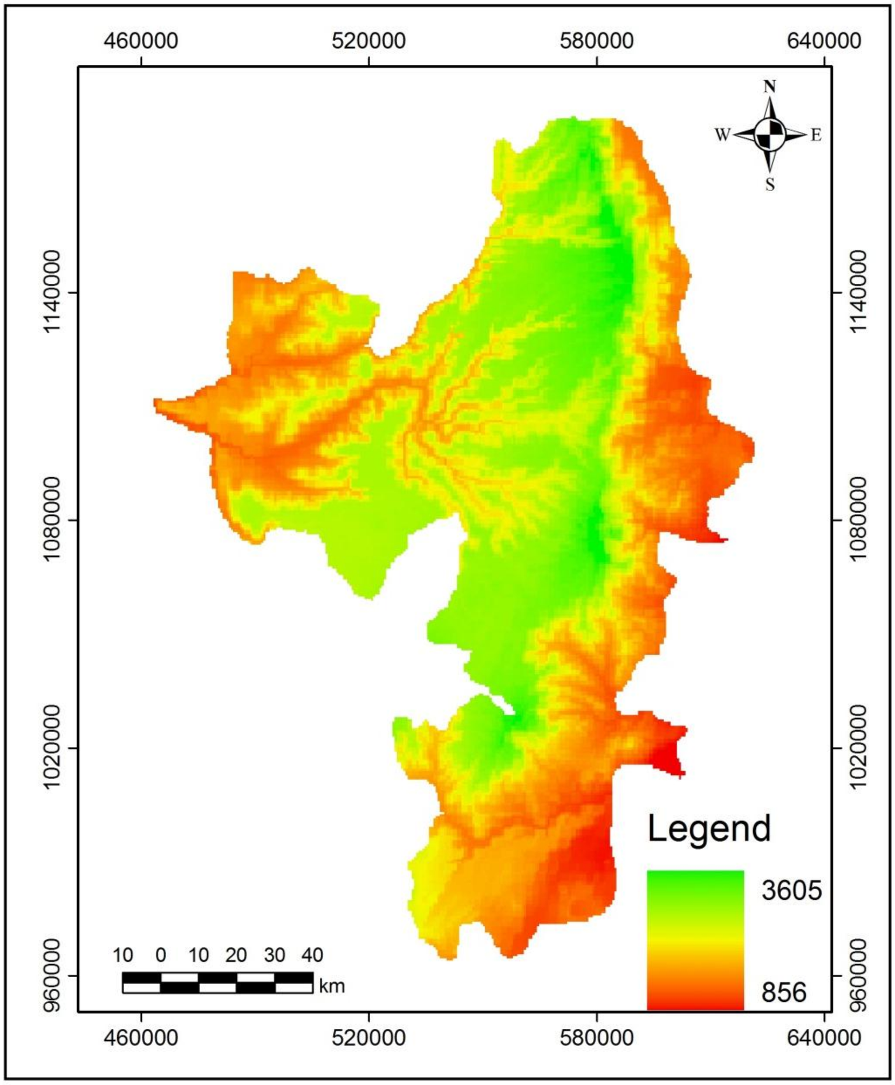


Figure 2. Elevation Map of Study Area

### 3.1.2 Population of Study Area

North Shewa Zone has an estimated total population of 1,821,797 (CSA, 2013).

Distribution of population at Woreda level extends from 10,404 to 130,211. On an average, 79,209 dwellers distributed over twenty-three Woredas in the Zone. Minjar Ena Shenkora, Merhabite and Menz Gera Ena Keya are the three largest Woreda interms of population number having 130,211, 123,920 and 123,401 people with population density of 86.24, 117.11 and 110.94, respectively While 10,404 people found in Menz Selalo Meder Woreda, which is lowest in population number shown in Table 4.

Table 4: Population and their density at Woreda level

| Sr. No | Woreda Name | Area(Sq.km) | Population 2013 | Population Density |
|---|---|---|---|---|
| 1 | Angolela ena Tera | 782.49 | 81520 | 104.180 |
| 2 | Ankober | 672.8 | 75054 | 111.555 |
| 3 | Ansokiya ena Gemza | 372.18 | 79025 | 212.330 |
| 4 | Asagirt | 500.31 | 48251 | 96.442 |
| 5 | Basona Worena | 1208.17 | 122402 | 101.312 |
| 6 | Berhet | 791.44 | 30080 | 38.007 |
| 7 | Debre Birhan | 146.27 | 72158 | 493.321 |
| 8 | Efirata ena Gidim | 516.85 | 113205 | 219.029 |
| 9 | Ensaro Ena Wayu | 442.1 | 55152 | 124.750 |
| 10 | Gishe Rabel | 658.78 | 58659 | 89.042 |
| 11 | Hageremariyam Ena Kesem | 689.87 | 51820 | 75.116 |
| 12 | Kewet | 785.85 | 122145 | 155.430 |
| 13 | Menz , Gera ena Keya | 1112.28 | 123401 | 110.944 |
| 14 | Menz Keya Gebriel | 544.54 | 42168 | 77.438 |
| 15 | Menz mama ena Lalo Midir | 650.42 | 84652 | 130.150 |
| 16 | Menz Selalo Meder | 381.65 | 10404 | 27.261 |
| 17 | Merhabite | 1058.19 | 123920 | 117.106 |
| 18 | Mida ena Woromo | 836.81 | 94000 | 112.331 |
| 19 | Minjar ena Shenkora | 1509.93 | 130211 | 86.236 |
| 20 | Mojana Wadira | 618.35 | 67384 | 108.974 |
| 21 | Moret ena Jiru | 661.16 | 93437 | 141.323 |
| 22 | Saya Deber ena Wayo | 452.35 | 58412 | 129.130 |
| 23 | Tarma Ber | 543.33 | 84337 | 155.222 |
| | Total | 15936 | 1821797 | |

Source: (CSA, 2013)

### 3.1.3 Population Density

Population Density refers to relative proportion between population and land they occupied.

In North Shewa Zone an average Population density is about 131 inhabitants per square kilometer. Population density of each Woreda shows the proportion of inhabitants to the total land area of particular Woreda. Debre Birhan, Efirata Ena Gidim and Ansokiya Ena Gemza have the highest population density accounts 493, 219 and 112 person per square kilometer, respectively, and are shown in Table 4.

Menz Selalo Meder, Berhet and Hageremariyam Ena Kesem Woredas have lowest population density with 27, 38 and 75 population per Square kilometer, respectively. Population density may either be high or low depending on the number of people, and area coverage of Woreda. Generally, high population density occurs when there are many people in limited areas, which lead to over population.

### 3.1.4 Socio-economic Condition

Study area is located in North east part of the country and characterized by high population growth rate. This led to much stressed economic activity through farming and transforming the natural environment into serious condition. This in turn, led to accelerated land degradation, mass wasting and reduction in productivity. Nevertheless, the rate of change of land degradation which can be caused by the land use land cover change may or may not match to the recurrence interval of the landslides and other mass wasting processes in the area.

Subsistence of local community depends on rain fed agriculture and some irrigation scheme. Major crops produced are Barely, Wheat, Sorghum, Teff, Pea and Lentil. Also fire wood and forest products are marketed extensively contributing to the destabilization of the already critically standing steep slope of soil developments and weathered and jointed rocks.

## 3.2 Sources of Data

This study uses both spatial and tabular data are gathered. These data were collected from both primary and secondary data sources. Primary data were generated from the analysis of satellite image, field observation and informal discussion with health sector personne. On the other hand, secondary data were obtained about the study area from different sources are mentioned in Table 5. Besides, published materials including books, journals, research articles and census reports were reviewed.

Table 5: Data and their sources

| No | Data | Sources |
|---|---|---|
| 1 | Satellite image path 168 raw 053 and path 168 raw 054 | USGS website |
| 2 | 30 meter DEM | SRTM |
| 3 | Road | ERA |
| 4 | Population | CSA |
| 5 | Health facility location | MoH |
| 6 | River | Ethio-GIS |

Table 6: Data type and their descriptions

| Type of data | Name | Descriptions |
|---|---|---|
| Raster | Population distribution grid | Spatially explicit distribution of population over the area. Point estimates coming from smallest administrative units would need to be appropriately spread over the subunit surface of the administrative units |
| | Land use grid | Spatial distribution of the different categories of land use on which travelling speed may be different. This grid can be combined in AccessMod with additional landscape elements (e.g. roads, rivers) to obtain the final land cover grid |
| | DEM | Altitude distribution used to consider in the analysis |
| Vector | Health facilities locations | This point shape file contains the geographic locations of the existing network of health facilities. Its attribute table contains the population coverage capacity and the maximum travelling time for each health facility |
| | road network | This line shape file contains the road network. |
| | barriers to movements | River line shape files can be treated as complete barriers to movement and can be integrated in the final land cover grid |
| Tabular | travelling scenario | This data defines the travelling speed and mode of transportation of each land cover |

The study incorporates various data types to analyze physical accessibility of health facility. Accordingly, Raster, vector and tabular data type are involved to analyze physical accessibility to health facility elaborated in Table 6.

## 3.3 Software used

**ERDAS IMAGINE 9.2** is digital image processing of remotely sensed data software with editor abilities designed by ERDAS for geospatial applications. It aimed primarily geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping usage in Geographic Information System (GIS) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions. Therefore, this software is used for landuse land cover classification which is one important layer for the analysis.

**ArcGIS 9.3.1** is also used as main tool for all GIS based analysis included in the study. This is because; AccessMod is compatible with this version. It is ESRI product working with maps and geographic information. Additionally, used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, wide range of applications, and managing geographic information in database.

This study used an extension called AccessMod 4.0 extension for ArcGIS 9.3.1, it is modified version developed by World Health Organization in collaboration with ESRI in 2012. This GIS based software tool used for modeling population coverage based on the capacity utilization of each facility. AccessMod 4.0 have capable to model the expansion of catchment area with the existing healthcare network and thus to estimate the population coverage within the network. It is available on World Health Organization official website for noncommercial purpose only.

## 3.4 Methods

This part describes the technique independently and wholly involved in the study (Figure 3). Accordingly, methods that encompass preparing of major factors involved in physical accessibility to healthcare, travel time and spatial coverage of healthcare are discussed in the following section.

The study uses enhanced thematic mapper plus Landsat satellite image of 2013 for landuse land cover mapping.
Layer stacking of each scene was conducted which was the first activity that involve for raw satellite image before any process. Then, mosaicking the two scenes and, clipping the image based on boundary shape file of study area was conducted.

Since the image had geometrically corrected from the sources there was no geometric correction undertaken. Radiometric enhancement technique that of noise and haze reductions was employed in order to removes small haze from the image.

Additionally, color composite (false color composite) was processed to increase its interpretability prior to main land use land cover classification.

Land cover data for the study area is prepared using supervised method of classification and accuracy assessment was carried out. Total of 190 points (38 points for each class) was taken from field for accuracy assessment analysis.

Generally, landuse land cover of the study area was prepared starting from downloading image from USGS website to final accuracy assessment report. In between preprocessing, enhancement and classification was involved in the image.

Grid based populations are essential for the implementation of spatial accessibility to health cares. As stated in Ebener et al. (2005), population data can be derived from existing global data sets such as the Gridded Population of the World (GPW) data set provided by Centre for International Earth Science Information Network (CIESIN) at Columbia University or the Land scan database. However, the required grid based dataset at finer resolution were not available for the study area. This is because Gridded Population of the World (GPW) data set available at national, continental and global level or at small scale.

Thus, preparing population grid based on local or Central Statistics Agency population data has been led to obtain relatively detail population data for this specific study area. Literatures suggested that to get more accurate result the population date should store in smallest unit. This is because, as the number of point increase, accuracy of interpolation result also increases. For this purpose, population data should take from smallest population unit. In Ethiopia, the smallest population unit available at Keble level. Thus, Keble census population data of study area converted to population grids. Then, Keble shape file joined with 2013 population table with join and relate option available in ArcGIS. This is possible because both had common attribute. After that, this shape file convert to point data through technique called feature to point conversion. This is because; interpolation is possible with point data only. So that, population distribution grid with population field at kebele level was produced by Kriging interpolation (Equation 1).

$$Z\ (S_o) = \sum_{i=1}^{N} \lambda\, i\ Z\ (S_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(equation 1)}$$

where: $Z\ (s_i)$ = the measured value at the $i^{th}$ location

$\lambda_i$ = an unknown weight for the measured value at the $i^{th}$ location

$S_o$ = the prediction location

N = the number of measured value

Digital elevation model is also takes into considerations. Digital Elevation Model (DEM) was used to process an anisotropic analysis (the analysis of accessibility by considering influence of slope on speed of travel to all direction). Thus, 30 meter DEM of area extracted based on the study area shape file through spatial analysis tools extension in ArcGIS.

Geographic location of health facilities are most important layer in measuring accessibility. Thus, health centers and hospitals location obtained from Ministry of Health. Three hospitals and twenty four health centers that are found in the study area were considered for analysis.

Road network is another important layer in accessibility analysis because speed of travel time determined by nature of road network. In this study, Asphalt type of road was considered and set their speed based on Ethiopian road authority guideline. Accordingly, 60 kilometer per hour was set.

Travelling time scenario table was prepared and includes type of land cover, speed per hour as well as mode of transport. Accordingly the study area was classified into five main land cover types that were presumed to influence traveling speed. These land cover type are bare land, forest, shrubs, agriculture and settlement. By reviewing different literatures regarding traveling speed of each land cover type, traveling speed of 3km per hour was considered as traveling speed for the forest, 2km per hour was considered for agriculture, 5km per hour was for bare land, 4km per hour was for shrubs and 5 km per hours used for settlement areas.

Combined land cover distribution grid was created by using land cover distribution grid, table that contains code of each land cover and road network data through the tool called combine land cover available in AccessMod 4.0 extension.

In addition, the combined land cover distribution grid is used with location of health facilities, DEM, traveling scenario table and maximum traveling time for patients to produce a traveling time grid by travel time distribution grid analysis tool available in AccessMod 4.0 software. It assumes that the travelling time from any location to the health facility is always obtained by travelling along the optimum (i.e. fastest) route. This algorithm is the same as the one used in the cost distance function of ArcGIS, except that it can be used in AccessMod in anisotropic conditions (the DEM allows the incorporation of slope into the analysis), which is important because the topography of the terrain may accelerate or impede the speed of travelling, especially when walking or vehicle. With the view that if relatively higher elevation is available around the health facilities then travelling time become increase and vice versa.

Moreover, health facility location, the combined land cover distribution grid, population distribution grid, digital elevation model, population coverage capacity of health facility, and traveling scenario table was used to produce health facility population coverage table, network of catchment areas for the health facilities, covered and uncovered population distribution grid. It used AccessMod software, which determines the spatial extent of the catchment areas corresponding to an accumulated cost surface using the standard cost distance function available in ArcGIS. In this case, cost given to each cell is the travelling time to cross the cell, which is determined by travelling speed attributed to land cover and Asphalt road. Thus, travelling speed per hour for each landuse land cover and Asphalt road set for the study area. Health facilities that have reached their catchment population before reaching one hour of travelling time are operating at their maximum capacity. The model utilizes least-cost algorithm whereby the location of health facility is selected as origin and maximum travel time of 60 minutes as destination for determining the corresponding catchment area.

The reliability of these estimates of health service coverage depends critically on how accurately distance is measured and how this predicts actual use of health services. In order to analyze the spatial coverage of existing healthcare facilities traveling time was used. This parameter, expressed in minutes, is used as a limit when drawing the catchment area for each health facility.

Federal Ministry of Health is working to provide curative healthcare services within 1hour travel time. In additions, literatures also support this standard as a measure of accessibility.

"For international comparisons and national disparity assessment the common yardstick used is the 1-hour to health services criteria of spatial access (World Bank, 2001)". Therefore, an hour travel time is used to analyze accessibility and potential health care coverage at Zone level. The population outside this range is considered as inaccessible.

Other factor considered is population coverage capacity of health centers and hospitals. Ethiopian health policy states that population coverage capacity of hospitals and health centers are 250,000 and 25,000 respectively. In this study these figures used as population coverage capacity of hospitals and health centers and attributed to each health facilities with add field function in the attribute table.

The situation of health care accessibility is examined only for health centers and hospitals because Health posts only work for attitudinal changes in a society. They do not provide any curative health services for the society. Curative healthcare treatment is only provided by Health centers and Hospitals. In geographic coverage analysis of healthcare facilities, people are assumed as users of both walking and motor vehicles. In other words, this study considered that people would be walking outside of the road network then taking vehicle when reaching it.

The whole maps involved in the study used Adindan_UTM_37N projected coordinate.

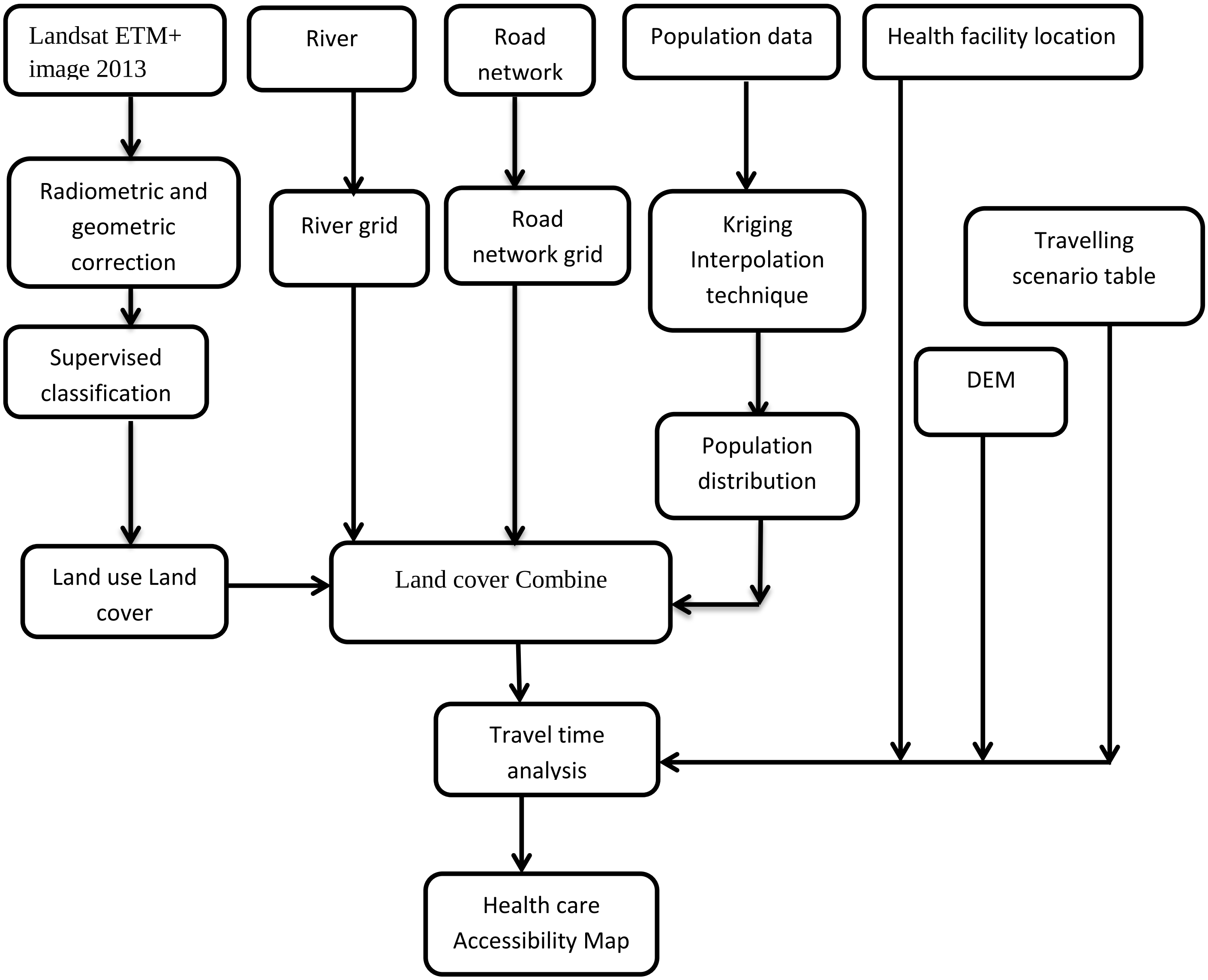


Figure 3. Methodology flow chart

CHAPTER FOUR

# 4. DATA PROCESSING AND ANALYSIS

## 4.1 Land Use Land Cover Data Analysis

The major information of land use/land cover types of the study area has been extracted from Landsat satellite imagery.

### 4.1.1 Digital Image Preprocessing

Preprocessing functions involve those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as radiometric or geometric corrections. Radiometric corrections include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Striping and line dropout are the main radiometric distortion occur on the image but the image involved in the study is free of such problems.

Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface. Some of these errors are commonly removed at the sensor's data processing center. So, no need of geometric correction was done except converting the image into coordinate system.

### 4.1.2 Image Enhancement and Visual Interpretation

To increase the visual interpretability of image in determining major landuse land cover types of the area under investigation, color combination technique employed.

Hence, both TCC (when bands 1, 2 and 3 /or blue, green and red bands are combined through transmission in blue, green and red filters) and FCC (combination of 4, 3 and 2 color filters other than the case in TCC) were produced and analyzed.

Table 7: Appearance of various surface features in different color composites

| Features | TCC(3:2:1)<br>Red: Band 3<br>Green: Band 2<br>Blue: Band 1 | FCC(4:3:2)<br>Red: Band 4<br>Green: Band 3<br>Blue: Band 2 |
|---|---|---|
| Trees and bushes | Oliver green | Red |
| Urban areas | White to light blue | Blue to gray |
| Wetland vegetation | Dark green to black | Dark red |
| Bare soil | White to light gray | Blue to gray |
| Crops | Medium to light green | Pink to red |

Source: (Lillesand and Kiefer, 2000)

Bands 4, 3, 2 create conventional false color composite. False color composites appear similar to an infrared photograph where objects do not have same colors or contrasts as they would naturally. For instance, in an infrared image, vegetation appears red; water appears navy or black, etc. due to shifting of colors.

On the basis of Table 7, original image was prepared as true and false color composite to make it clear for classification.

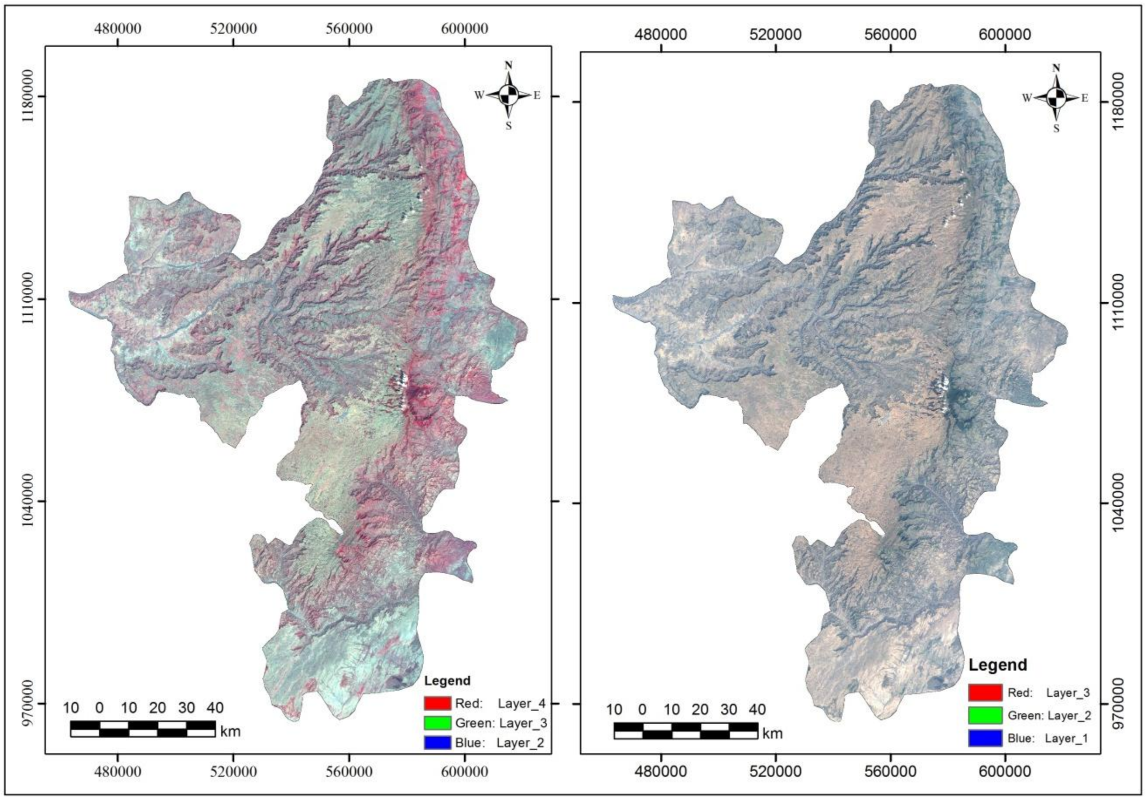


Figure 4. False color composite (Left) and True color composite (Right) images

The techniques optimized visibility of data structure of interest in each case and made the image visually and spectrally more interpretable. In this case, deep red represent for forest and light red color for shrubs. Settlement identified as Blue to gray. Agriculture appears lighter to reddish pink color, and bare land as gray color (Figure 4). Land use land cover category of the study area is visually more interpretable after enhancements made to the original image data.

### 4.1.3 Image Classification and Accuracy Assessment

#### 4.1.3.1 Image Classification

Image of the study area was first classified through computer automated unsupervised method in ERDAS IMAGINE 9.2 classifier. The output classes, though not exactly related to the direct meaningful characteristics of the scene, were assigned with names.

It was this unsupervised classified image, that has been analyzed during the preliminary field visit and aid the subsequent supervised classification.

Moreover, during preliminary field visit, representative points in the study area, which were believed to represent the existing landuse/land cover category, were recorded using GPS (GARMIN 72).

The combination of visually interpretable data, field (GPS) data, pattern of spectral profile and the unsupervised classification, made supervised image classification possible.

Accordingly, 5(five) major land use/land covers classes namely: agriculture, forest, settlement, shrubs and bare land were identified from the images (Figure 5). The land use/land cover category of the area has been discussed here under:

1. Agriculture: This category involves both intensively and moderately cultivated agricultural lands. It appears with lighter to reddish pink color in FCC involving bands 7, 4 and 2 on ETM+. The area characterized by this category distributed uniformly in the study area. The area had been extended to some patches of rugged terrain with mid altitude and lowland parts of the study area. During the field visit, it has been realized that, the category is an area of crop cultivation.

2. Bare land: This includes areas covered by soil, sand or rocks. It appears yellowish red to human eye in TCC of the Landsat Imageries.

3. Settlement: are those areas composed of intensive use with much of the land of rural villages, town’s residents.

4. Shrubs: This land covers grasslands, short tresses, bushes, pasture lands, grazing areas dominantly covered with grasses.

5. Forest: are those areas dominated by long trees and highly distributed along central part of the study area.

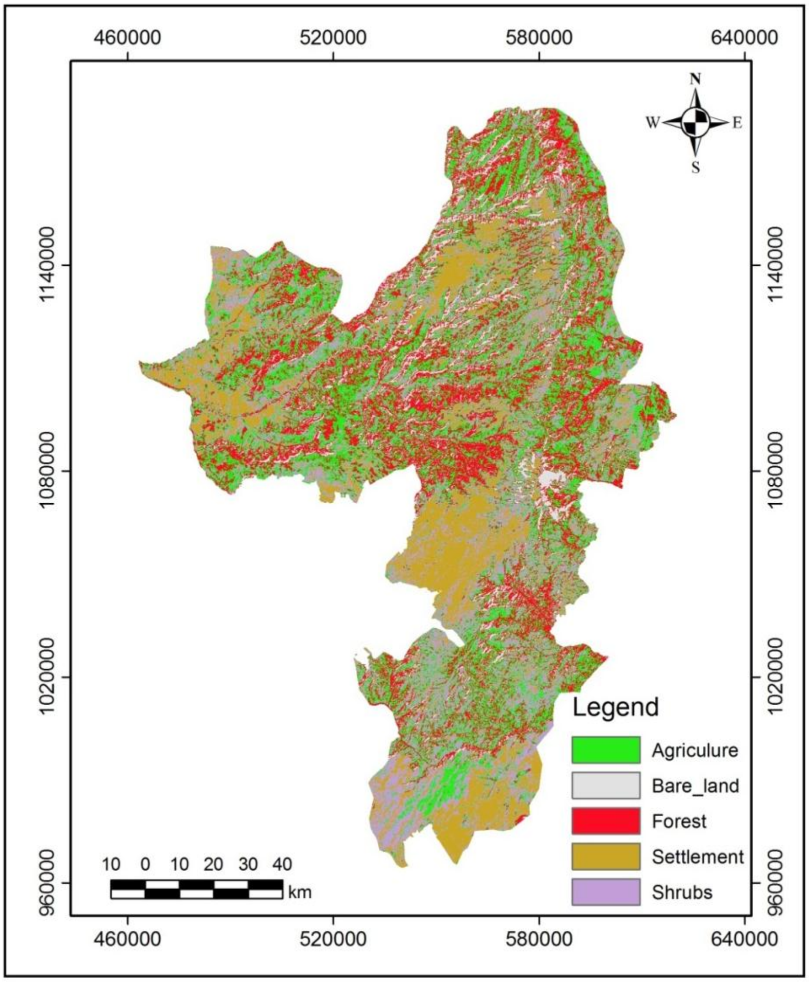


Figure 5. Landuse land Cover Map of Study Area

#### 4.1.3.2 Classification Accuracy Assessment

Land cover maps derived from remote sensing always contain some sort of errors due to several factors which range from satellite data capture to classification. In order to wisely use land cover maps, which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. Whether the output meets expected accuracy or not is usually determined by the users themselves depending on the type of application. Accuracy levels that are acceptable for certain task may be unacceptable for others.

Common means of expressing classification accuracy is preparation of classification error matrixes. An error matrix (confusion matrix) is a square array of numbers organized in rows and columns, which express number of sample units assigned to particular category relative to the actual category as indicated by reference data. These tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage and the kappa coefficient, an index that estimates the influence of chance (Congalton et al., 1999).

Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another. These values are based on a sample of error checking pixels of known land cover that are compared to classifications on the map. Errors of commission and omission can also be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed while producer's accuracy represents the percentage of a given class that is correctly identified on the map. One of the problems with the confusion matrix and the kappa coefficient is that it does not provide a spatial distribution of the errors (Foody, 2002).

The quality and sufficiency of reference data are important if reliable accuracy assessment is required. A reference data that is not verified thoroughly should not be expected to set accuracy standard. Insufficient number of verified data also affects the quality of the assessment (Congalton et al., 1999).

Accuracy assessment is essentially a measure of how many ground truth pixels were classified correctly.

The kappa value is a measure of the agreement between classification and reference data with the agreement due to chance removed. None of the kappa values in any of the images were very high.

Landis and Koch (1977) ranked the kappa values, ranging from -1 to 1, into 3 groups: 1) those greater than 0.80 represented strong agreement between the classification and reference data; 2) those between 0.40 and 0.80 represented moderate agreement; and 3) those less than 0.40 represented poor agreement. The low kappa also was a product of classifying the imagery into just 2 classes. If there had been more classes, the kappa values probably would have been higher.

The Kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. This implies that the Kappa value of 0.8618 implies that the classification process is avoiding 86% of the errors that a completely random classification generates, and shown in Table 8.

This study revealed an overall accuracy of 88.95% and a kappa index of agreement of 0.8618. For the detail of accuracy assessment report (see Appendix I).

Table 8: Accuracy Assessment

| Classified data | Reference data | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bare land | Forest | Agriculture | Shrubs | Settlement | Users Accuracy | Producers Accuracy |
| Bare land | 33 | 2 | 3 | 0 | 0 | 86.84 | 97.06 |
| Forest | 1 | 33 | 3 | 1 | 0 | 86.84 | 91.67 |
| Agriculture | 0 | 1 | 35 | 1 | 1 | 92.11 | 79.55 |
| Shrubs | 0 | 0 | 3 | 34 | 1 | 89.47 | 85.00 |
| Settlement | 0 | 0 | 0 | 4 | 34 | 89.47 | 94.44 |
| Overall accuracy | | | | | | 88.95% | |

## 4.2 Population Data Analysis

This is the analysis for preparing population with grid structure. A grid is spatial data structure that defines spaces as an array of cells of equal size that are arranged in rows and columns.

### 4.2.1 Interpolation Techniques

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, population, chemical concentrations, noise levels, and so on.

There are two categories of interpolation techniques: deterministic and geo-statistical. Deterministic interpolation techniques create surfaces based on measured points or mathematical formulas. Method such as Inverse Distance Weight (IDW) is based on the extent of similarity of cells while methods such as Trend fit a smooth surface defined by a mathematical function. Geostatistical interpolation techniques such as Kriging are based on statistics and are used for more advanced prediction surface modeling that also includes some measure of the certainty or accuracy of predictions.

#### 4.2.1.1 Kriging

Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variations in the surface. Kriging fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data.

Ordinary Kriging is the most general and widely used methods and is the default. It assumes the constant mean is unknown. This is a reasonable assumption unless there is some scientific reason to reject this assumption. It is often used in population study. Based on the recommendation, this study used geo-statistical interpolation technique in general Kriging in particular.

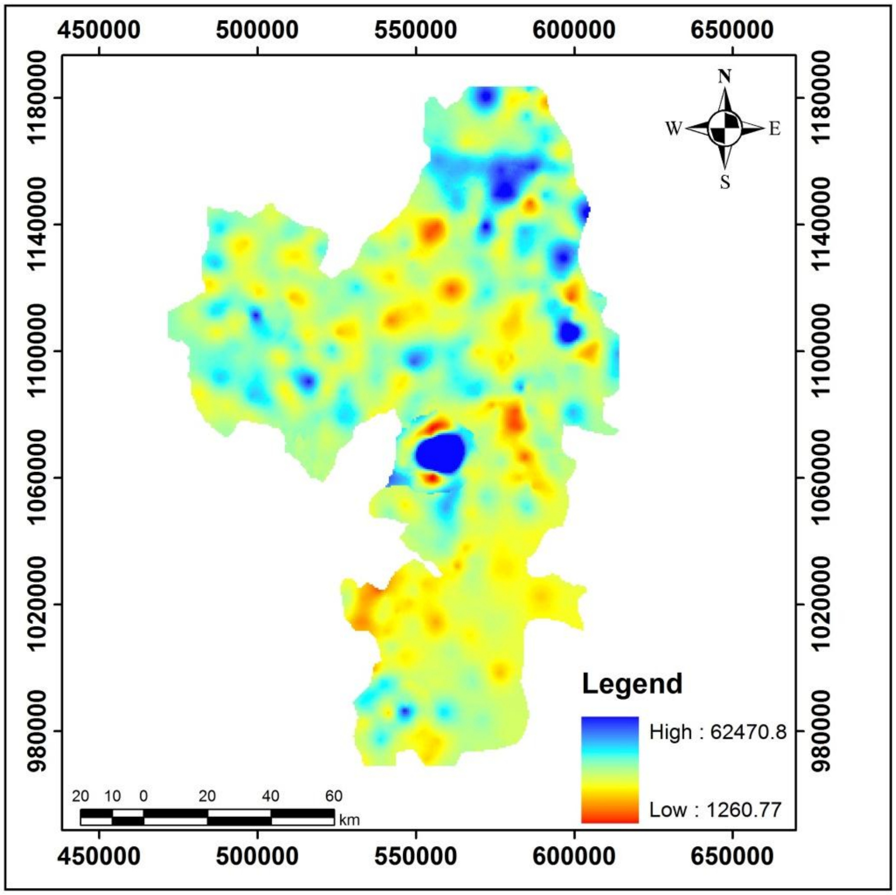


Figure 6. Population grid map of study area

Population are highly concentrated in North, north east, west and central part of the Zone, and is shown in Figure 6. However, most of southern areas are characterized by low population distributions.

## 4.3 Health Facility locations

Both health centers and hospitals are analyzed and mapped based on their geographic location. For the detail of their location see Appendix III.

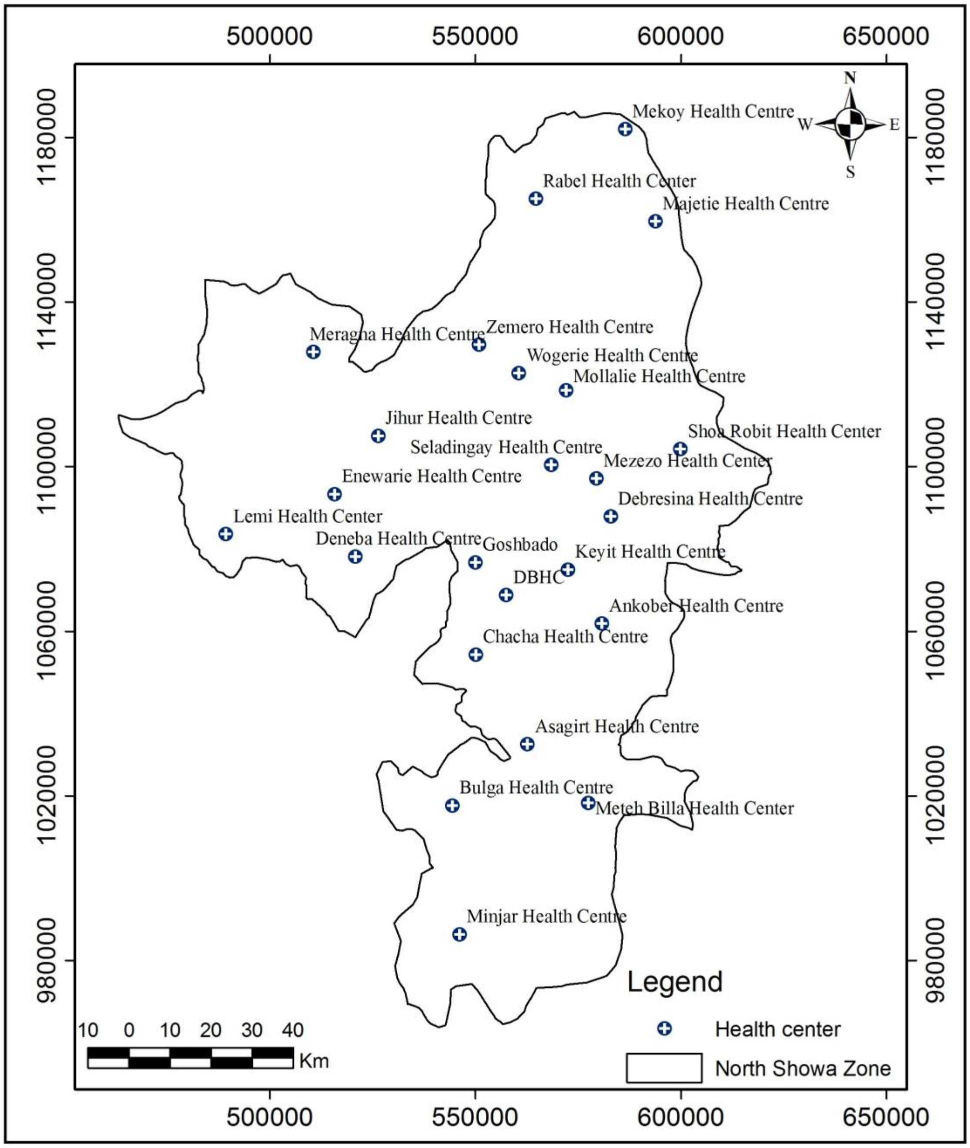

Figure 7. Health Centers Distribution Map of Study Area

The above figure represents health center distributions in North Shewa Zone. As illustrated in Figure 7, most health centers are concentrated in the central part of the Zone. This result shows that the maximum populations of the area are located at the middle zonal places. Whereas the people found in the edge part of the place may get challenge to access health care. Additionally, this result incites that health centers are not uniformly distributed in the entire zonal area.

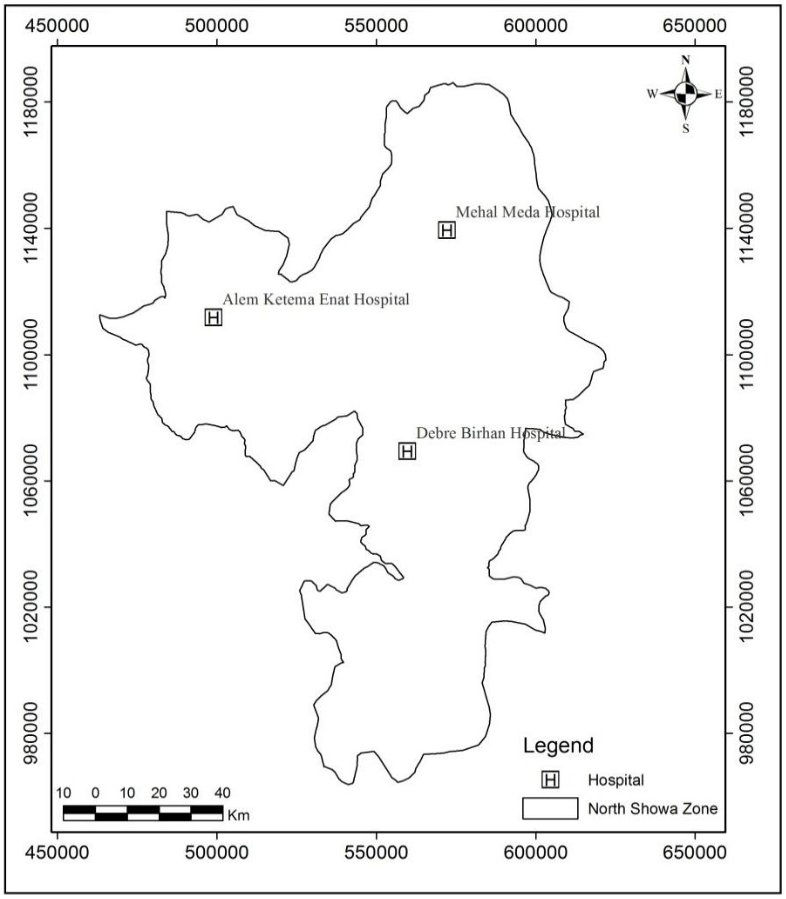


**Figure 8. Hospital Distribution Map**

Identifying the distribution of hospitals in the specified Zone helps to measure the accessibility of hospitals. Hence, hospitals are identified and mapped according to their geographical location (Figure 8). The distribution map shows that one of the hospitals (Alem Ketema Enalt) is found in the western part of the Zone, and the other hospital (Mehal Meda) is found in the northern part of the area. Additionally, the remaining hospital (Debre Birhan) is situated in the central part of the Zone. Nevertheless, southern parts of zonal areas do not have accesses of hospitals.

## 4.4 Travelling Scenario Table

Travelling scenario table used for describe the speed and means of transport for specific landuse land cover and road. Land cover distribution grids show the type of land cover that characterize the area and believed to affect travelling time for the patient while they crossing this area to reach a given healthcare.

Table 9 Travelling Scenario Table

| Landuse land cover | Speed (km/h) | Means of transportation |
|---|---|---|
| Bare land | 5 | Walking |
| Forest | 3 | Walking |
| Agriculture | 2 | Walking |
| Shrubs | 4 | Walking |
| Settlement | 5 | Walking |
| Asphalt | 60 | Vehicle |

Five major landuse land covers and Asphalt road are identified in the previous section. Therefore, speed per hour and means of transportation was assigned for each identified LU/LC and Asphalt road for the study area (Table 9). This is the base for travel time analysis which considers traveling scenario table.

## 4.5 Travel Time Distribution Grid

The creation of this grid first required the definition of the different travel scenarios utilized by the population to attend the nearest primary health facility. There are various travels or mode of transportation in which the societies utilized based on their level of economy. Modes of transports in developed countries are different than least developed countries. This is clearly described in literatures. Accordingly, study conducted by UNICA (2009), argued that walking is the predominant form of transportation in rural Africa as a result of the lack of infrastructure and motorized transport services. Thus, this paper considered both walking and vehicle travel scenarios in which patients are travelling towards the health facilities. This is because this study incorporates both rural and urban area. Assigning of different travel speeds for different landuse land cover classes are recommended.

Considering these scenarios, a raster surface of travel time between health facilities and population was developed in AccessMod version 4.0.

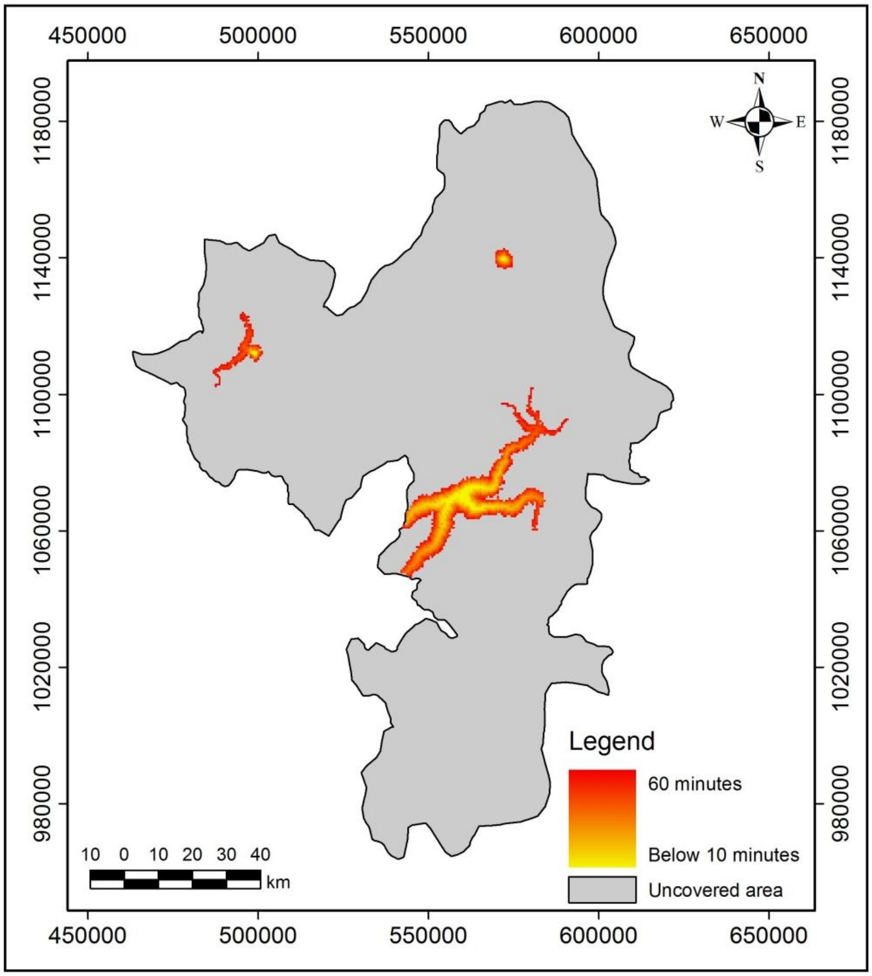

Figure 9. Hospitals travel time within 60 minutes travel time both walking and vehicle

Both Figure 9 and 10 shows that, travel time distribution of hospitals and health centers within 60 minutes both by walking and vehicle, respectively. Peoples around yellow colors access health facilities within few (less than ten minutes) travel time while the red indicates those peoples access within 60 minutes travel time. Therefore, it is possible to say that, as peoples far from the health care, they are expected to travel long time.

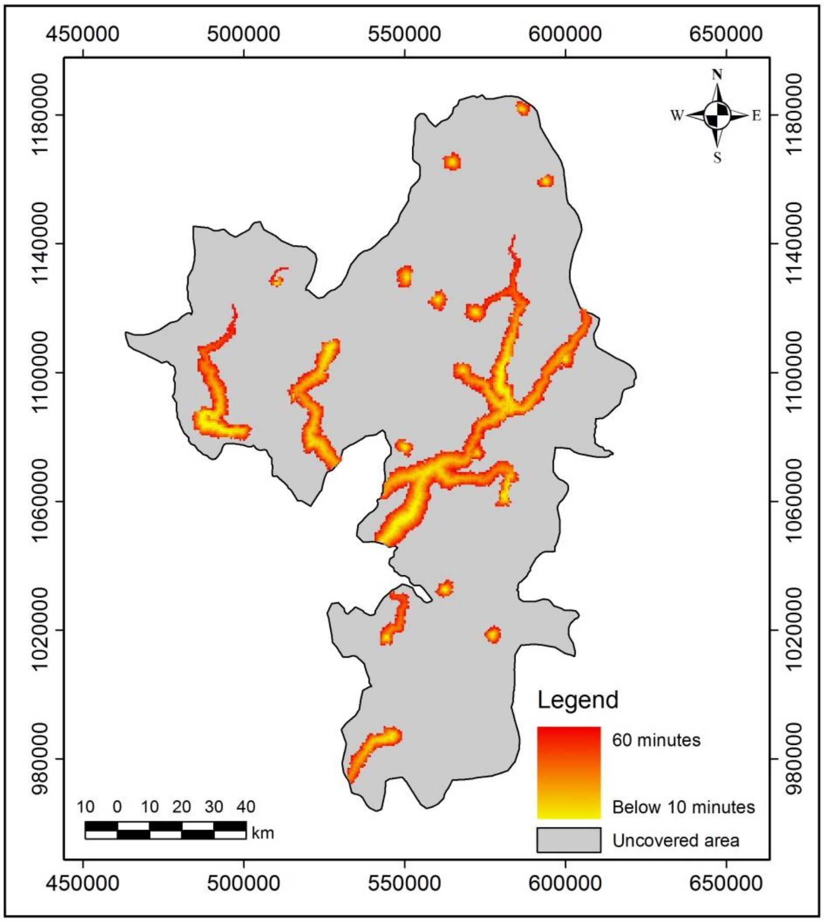


Figure 10. Health centers travel time with an hour travel time both by walking and vehicles

# CHAPTER FIVE

## 5. RESULTS AND DISCUSSIONS

## 5.1 Results

### 5.1.1 Health center accessibility with an hour travel time both by walking and vehicles

This study reveals that, there are five health centers, which give services beyond their population coverage capacity. Accordingly, maximum catchment population was recorded in Mezezo health center, which serve about 26,100 people followed by Ankober (25,982), Debre Birhan (25,733), Lemi (25,339), and Jihur (25,049) health centers (Table 10).

Table 10: Result of health centers catchment population and area

| Health facility Name | HFPCC | Catchment area ($km^2$) | Catchment population | population above HFPCC | Calculated travel time(minutes) |
|---|---|---|---|---|---|
| Ankober HC | 25000 | 87 | 25982 | 982 | 56 |
| Asagirt HC | 25000 | 290 | 2607 | 0 | 60 |
| Bulga HC | 25000 | 454 | 6271 | 0 | 60 |
| Chacha HC | 25000 | 90 | 10496 | 0 | 60 |
| Debre Birhan HC | 25000 | 34 | 25733 | 733 | 50 |
| Debresina HC | 25000 | 23 | 9023 | 0 | 60 |
| Deneba HC | 25000 | 28 | 3505 | 0 | 60 |
| Enewari HC | 25000 | 30 | 10605 | 0 | 60 |
| Goshebado HC | 25000 | 321 | 2861 | 0 | 60 |
| Jihur HC | 25000 | 205 | 25049 | 49 | 56 |
| Keyit HC | 25000 | 178 | 1704 | 0 | 60 |
| Lemi HC | 25000 | 234 | 25339 | 339 | 41 |
| Majetia HC | 25000 | 69 | 4330 | 0 | 60 |
| Mekoy HC | 25000 | 45 | 2648 | 0 | 60 |
| Meragna HC | 25000 | 35 | 7604 | 0 | 60 |
| Meteh Billa HC | 25000 | 590 | 2094 | 0 | 60 |
| Mezezo HC | 25000 | 22 | 26100 | 1100 | 35 |
| Minjar HC | 25000 | 550 | 15604 | 0 | 60 |
| Mollalie HC | 25000 | 189 | 4928 | 0 | 60 |
| Rabel HC | 25000 | 269 | 5303 | 0 | 60 |
| Seladingay HC | 25000 | 120 | 4349 | 0 | 60 |
| Shoa robit HC | 25000 | 239 | 11768 | 0 | 60 |
| Wogerie HC | 25000 | 29 | 3613 | 0 | 60 |
| Zemero HC | 25000 | 36 | 2957 | 0 | 60 |
| Total | | 4,167 | 240,473 | 3,202 | |

Mezezo, Lemi and Debre Birhan health centers fill their population coverage capacity (25, 000) at 35, 41 and 50 minutes travel time, and expected to serve an additional population of 1100, 339 and 733, respectively. At the same time, Ankober and Jihur health centers fill their population coverage capacity at 56(fifty-six) minutes travel time, and serve an additional population of 982 and 49, respectively. Therefore, these five health centers serve total of 3,202 additional people. On the contrary, the remaining health centers serve below their population coverage capacity with a full of one hour travel time. Keyit health center (1704 peoples) got lowest population coverage.

The size of catchment areas in one hour traveling time ranges from 590 $km^2$ for Meteh Bila health center to 22 $km^2$ for Mezezo health center. Meteh Bila, Minjar and Bulga Health Centers have the largest catchment areas with the catchment area of 590 $km^2$, 550$km^2$ and 454$km^2$, respectively. The three smallest catchment areas are catchment area of Mezezo health center with 22 $km^2$, Debresina health center with 23 $km^2$ and Deneba health center with catchment size of 28 $km^2$. The real view of the result depicted in Appendix II.

Table 11: Result of statistical summary of health center with an hour travel time both by walking and vehicle

| STATISTICS | VALUE |
|---|---|
| Total population | 1,821,797 |
| Total covered population | 240473 |
| Percent of covered population | 13 |
| Mean Realized traveling time(minute) | 57 |
| Minimum realized traveling time (minute) | 35 |
| Maximum realized traveling time (minute) | 60 |
| Number of health facilities realized maximum traveling time | 19 |
| Percent of health facilities realized maximum traveling time | 79 |
| Number of health facilities not realized maximum traveling time | 5 |
| Percent of health facilities not realized maximum traveling time | 21 |
| Number of health facilities realized their maximum capacity | 5 |
| Percent of health facilities realized their maximum capacity | 21 |
| Number of health facilities not realized their maximum capacity | 19 |
| Percent of health facilities not realized their maximum capacity | 79 |

The realized traveling time of total health center distribution per 60 minutes through walking and vehicles mode of transportations measured as minimum (35), mean (57), and maximum (60) minutes. From the total number of health centers, 19 of them are realized their maximum travel time, which accounts 79% whereas five health centers are not realized maximum travel time, which is 21%, and is shown in Table 11. With regard to population coverage capacity, 5 (21%) are realized their maximum capacity and 19 (79%) are not.

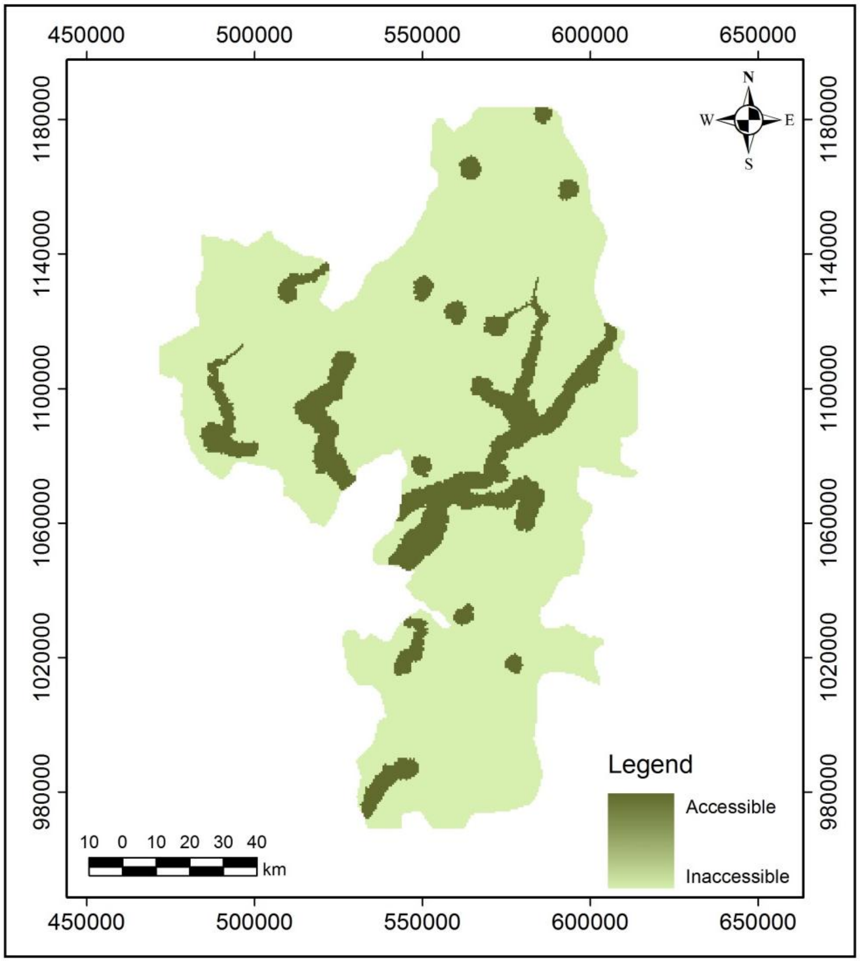

Figure 11. Health Centers Accessibility Map

The total population of North Shewa Zone is about 1,821,797. When the health center accessibility is measured with a standard of an hour travel time, it covers 240,473 (13%) both in walking and vehicle (Figure 11). On the contrary, 87% of the populations do not access health centers with the specified standard.

### 5.1.2 Hospitals accessibility with an hour travel time both by walking and vehicles

Hospitals are mapped as accessible and inaccessible area with standard of an hour travel time both by walking and vehicles. From the total populations of the Zone, about 72,937 (4%) are accessible to the nearest Hospitals with the defined standard (Figure 12).

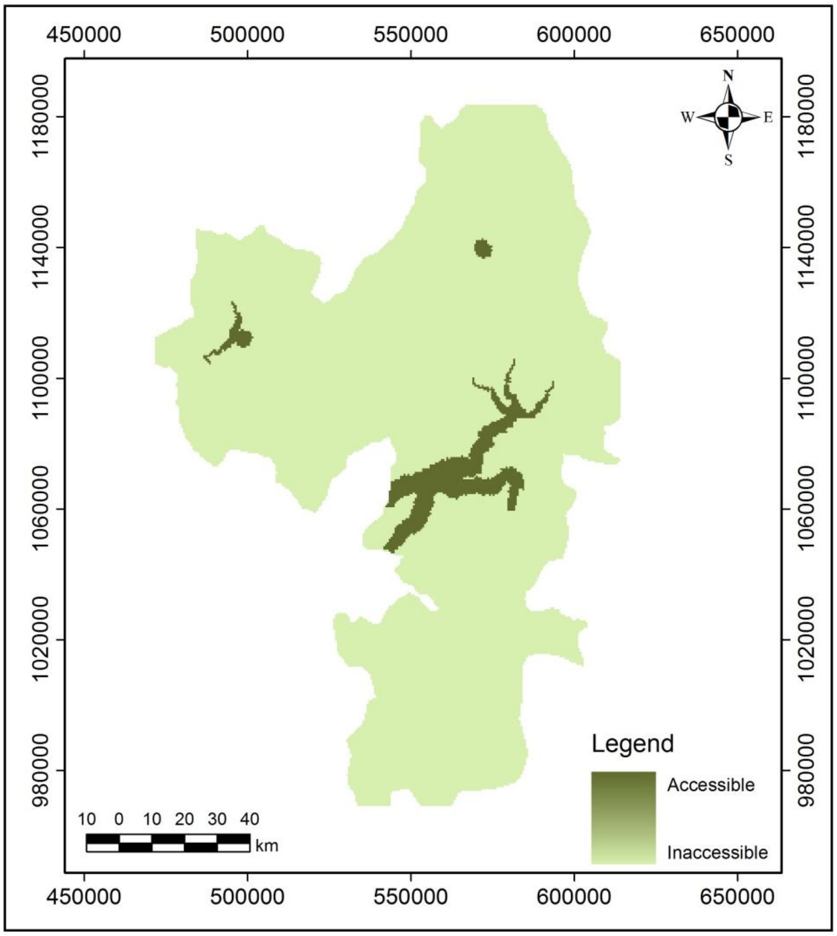


Figure 12. Hospital Accessibility Map

Table 12: Result of hospitals spatial accessibility with an hour travelling time (Walking and Vehicles)

| Hospital Name | HFPCC | Catchment population | Catchment Area ($km^2$) | Calculated travel time(minute) |
|---|---|---|---|---|
| Debre Birhan Hospital | 250000 | 60732 | 619.50 | 60 |
| Alem Ketema Enat Hospital | 250000 | 8633 | 61.24 | 60 |
| Mahal Meda Hospital | 250000 | 3572 | 24.17 | 60 |
| Total | | 72937 | 704.91 | |

With regard to area coverage of hospitals in an hour travel time both by walking and vehicles, Debre Birhan Hospital covers 619.5 $km^2$, which is largest than the rest (Table 12). This is due to better road accessibility in the area (see Appendix IV). On the other hand, Alem Ketema Enat and Mahal Meda Hospitals cover an area of 61.24 $km^2$ and 24.17 $km^2$, respectively.

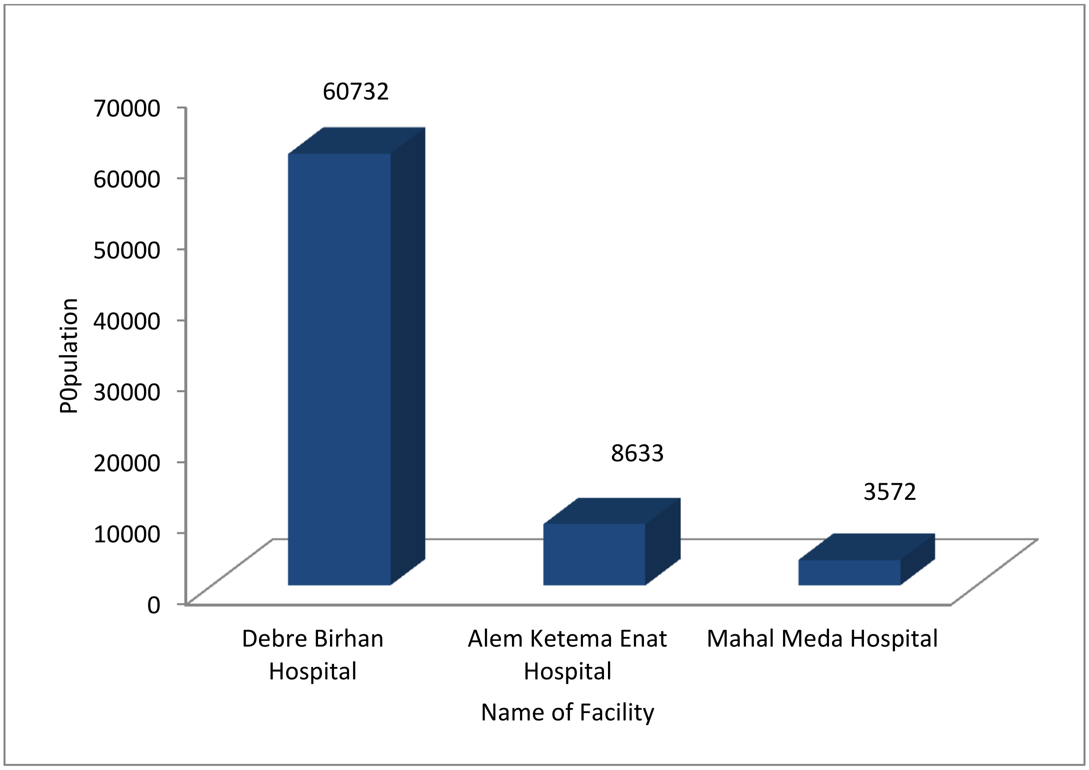


Figure 13. Catchment population of Hospitals Within an hour travelling time (Walking and Vehicles)

Debre Birhan hospital serve total population of 60,732, which is relatively higher than the two, and followed by, Alem Ketema Enat and Mahal Meda hospitals with population of 8,633 and 3,572, respectively (Figure 13).

Table 13: Statistical summary for hospitals in an hour traveling time by walking and vehicles

| STATISTICS | VALUE |
|---|---|
| Total population | 1,821,797 |
| Total covered population | 72937 |
| Percent of covered population | 4 |
| Mean Realized traveling time(minute) | 60 |
| Minimum realized traveling time (minute) | 60 |
| Maximum realized traveling time (minute) | 60 |
| Number of health facilities realized maximum traveling time | 3 |
| Percent of health facilities realized maximum traveling time | 100 |
| Number of health facilities realized their capacity | 0 |
| Percent of health facilities realized their capacity | 0 |

Generally, Debre Birhan, Alem Ketema Enat and Mahal Meda hospitals are realized maximum travel time and thus, mean, minimum and maximum travel time is 60 minutes (Table 13). However, none of them realized their maximum population coverage capacity.

## 5.2 Discussions

According to Anderson et al. (1976), minimum level of accuracy for identification of land use/land cover categories from remote sensor data should be at least 85 %. The result of landuse land cover accuracy assessment (88.95%) of this study fits to the above view.

"For international comparisons and national disparity assessment the common yardstick used is the 1-hour to health services criteria of spatial access (World Bank, 2001)". This study used an hour travel time in line with World Bank standard.

Once again, in literature, no GIS based analysis has been carried out in the study area to analyze physical accessibility of healthcare. Thus, discussion should be with different reports of CSA.

According to CSA (2012), accessibility to healthcare is about 11.53% and 4.63% population covers with 10 to 14 km distance (1 hr. travel time) from respective health centers and hospitals, respectively.

Result of this study shows that, out of the total populations only 13% and 4% are accessible within an hour travel time to health centers and hospitals, respectively. There are slight differences from Central Statistical Agency report. This is because; CSA report considers only population to health facility ratio regardless of identifying mode of transport, and this study is considered population, Digital Elevation Model (DEM), road, landuse land cover, and mode of transportation.

# CHAPTER SIX

# 6. CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

This study emphasize on analysis of physical accessibility to health facilities interms of an hour travel time both by walking and vehicles in North Shewa Zone, Amhara Regional State of Ethiopia. Analysis of spatial coverage calculates the extension of catchment area of each facility. The spatial extent of catchment area for each health facility is determined once the maximum population capacity and/ or the maximum travel time have been reached. The results provide important evidence that travelling time over which to define catchment population within an hour time limit.
Geographic Information System based analysis of healthcare accessibility is valuable for describing and understanding relationships between healthcare and health outcomes. Health sector accessibility planning considering population, slope, road, and mode of transportation parameters provide more fruitful result, and GIS is believed to be efficient to measure healthcare accessibility.

Using advanced GIS tools has important to visualize and conceptualize health concept by researchers and planners. In addition, applying such tools by public administrator is able to provide mapping of health facilities, and base for evidence based decision, and saving their time and resources.

The analysis also demonstrates that mode of transportation has significant impact on area coverage of health facilities. Roads and modern means of transportation help health facilities to realize their health facility population coverage capacity at reasonable travel time.

## 6.2 Recommendations

Based on the findings described above, the following recommendations have been forwarded.

- In order to reduce the burden of existing healthcare facilities, and increase healthcare accessibility in the study area, additional hospitals and health centers should be constructed, and priority must be given to areas characterized by higher health facility to population ratio, and areas where there are access limitations within the defined scenario. In constructing new facilities, it is better to apply GIS based site selection techniques, which have capable of integrate different variables in logical manner.

- Increasing health care accessibility is not only about constructing new healthcare institutions but also about expanding road network and assigning permanent modern means of transportation in the area.

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# APPENDICES

**Appendix I** classification accuracy assessment report and geographic coordinate point

ERROR MATRIX
-------------

Reference Data

| Classified Data | Unclassifi | Bare_land | Forest | Agriculture |
|---|---|---|---|---|
| Unclassified | 0 | 0 | 0 | 0 |
| Bare_land | 0 | 33 | 2 | 3 |
| Forest | 0 | 1 | 33 | 3 |
| Agriculture | 0 | 0 | 1 | 35 |
| Shurbs | 0 | 0 | 0 | 3 |
| Settlement | 0 | 0 | 0 | 0 |
| Column Total | 0 | 34 | 36 | 44 |

Reference Data

| Classified Data | Shurbs | Settlement | Row Total |
|---|---|---|---|
| Unclassified | 0 | 0 | 0 |
| Bare_land | 0 | 0 | 38 |
| Forest | 1 | 0 | 38 |
| Agriculture | 1 | 1 | 38 |
| Shurbs | 34 | 1 | 38 |
| Settlement | 4 | 34 | 38 |
| Column Total | 40 | 36 | 190 |

----- End of Error Matrix -----

ACCURACY TOTALS

----------------

| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| ---------- | ---------- | ---------- | ------- | --------- | ----- |
| Unclassified | 0 | 0 | 0 | -------- | --- |
| Bare_land | 34 | 38 | 33 | 97.06% | 86.84% |
| Forest | 36 | 38 | 33 | 91.67% | 86.84% |
| Agriculture | 44 | 38 | 35 | 79.55% | 92.11% |
| Shurbs | 40 | 38 | 34 | 85.00% | 89.47% |
| Settlement | 36 | 38 | 34 | 94.44% | 89.47% |
| Totals | 190 | 190 | 169 | | |

Overall Classification Accuracy = 88.95%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

---------------------

Overall Kappa Statistics = 0.8618

Conditional Kappa for each Category.

------------------------------------

| Class Name | Kappa |
|---|---|
| ---------- | ----- |
| Unclassified | 0.0000 |
| Bare_land | 0.8397 |
| Forest | 0.8377 |
| Agriculture | 0.8973 |
| Shurbs | 0.8667 |
| Settlement | 0.8701 |

----- End of Kappa Statistics ----

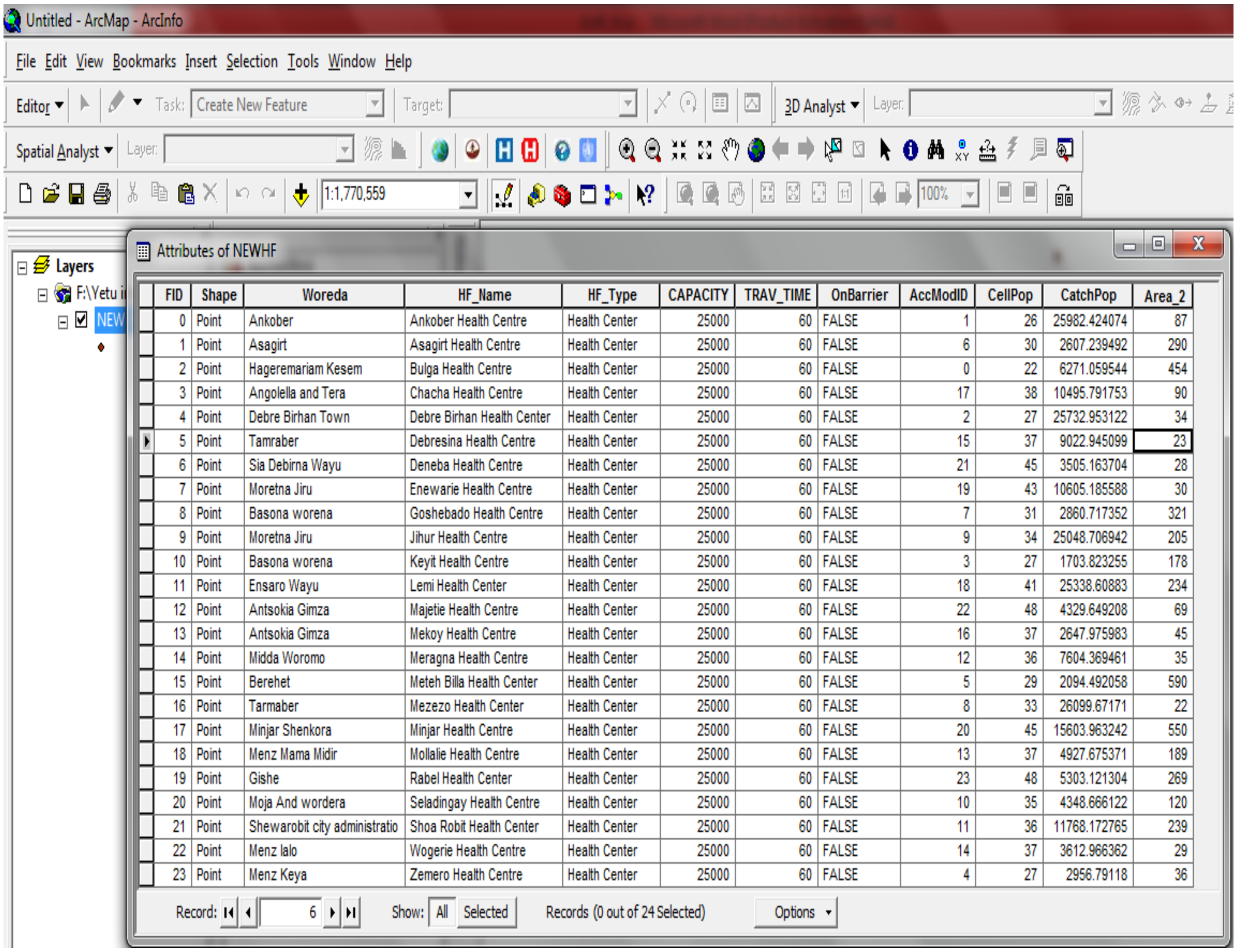
Geographic coordinate point

| Northing | Easting | LULC type | Northing | Easting | LULC type |
|---|---|---|---|---|---|
| 485210 | 1129210 | Bare_land | 555260 | 1040542 | Agriculture |
| 486620 | 1103204 | Bare_land | 555770 | 1035383 | Agriculture |
| 486920 | 1133440 | Bare_land | 557690 | 1033643 | Agriculture |
| 497780 | 1092255 | Bare_land | 559250 | 1065529 | Agriculture |
| 508250 | 1134880 | Bare_land | 559730 | 1097654 | Agriculture |
| 517010 | 1104014 | Bare_land | 560090 | 1119792 | Agriculture |
| 523340 | 1116882 | Bare_land | 560270 | 1065649 | Agriculture |
| 533120 | 1021555 | Bare_land | 560300 | 1055450 | Agriculture |
| 533390 | 983940 | Bare_land | 560840 | 1069098 | Agriculture |
| 533720 | 1122341 | Bare_land | 565520 | 1073478 | Agriculture |
| 536540 | 1002657 | Bare_land | 568850 | 1135359 | Agriculture |
| 537650 | 1095555 | Bare_land | 571370 | 1182573 | Agriculture |
| 543470 | 962822 | Bare_land | 572000 | 1060789 | Agriculture |
| 544580 | 1122461 | Bare_land | 575210 | 1128340 | Agriculture |
| 544940 | 1005657 | Bare_land | 575540 | 1078007 | Agriculture |
| 546500 | 1111423 | Bare_land | 575990 | 1060669 | Agriculture |
| 551780 | 1007066 | Bare_land | 576320 | 1127201 | Agriculture |
| 552620 | 1013246 | Bare_land | 580670 | 1137249 | Agriculture |
| 553430 | 1004247 | Bare_land | 584210 | 1143548 | Agriculture |
| 553640 | 980970 | Bare_land | 487880 | 1076327 | Shrubs |
| 556010 | 1146158 | Bare_land | 507230 | 1145528 | Shrubs |
| 556160 | 1067418 | Bare_land | 515660 | 1089076 | Shrubs |
| 559190 | 1131610 | Bare_land | 516770 | 1072998 | Shrubs |
| 559850 | 1051161 | Bare_land | 519170 | 1108993 | Shrubs |
| 562250 | 1106713 | Bare_land | 520370 | 1077377 | Shrubs |
| 563690 | 1010576 | Bare_land | 522920 | 1122311 | Shrubs |
| 564230 | 1107643 | Bare_land | 526280 | 1099184 | Shrubs |
| 566540 | 1091355 | Bare_land | 527180 | 1013456 | Shrubs |
| 568310 | 1002807 | Bare_land | 532310 | 1014565 | Shrubs |
| 569240 | 1161096 | Bare_land | 532730 | 1023744 | Shrubs |
| 572780 | 1126361 | Bare_land | 536810 | 1125371 | Shrubs |
| 574100 | 1133050 | Bare_land | 539990 | 1000797 | Shrubs |
| 582200 | 1025184 | Bare_land | 541130 | 1123601 | Shrubs |
| 582440 | 1049571 | Bare_land | 544760 | 1024434 | Shrubs |
| 591560 | 1131160 | Bare_land | 545780 | 1084066 | Shrubs |
| 592670 | 1072098 | Bare_land | 558980 | 1102064 | Shrubs |
| 593780 | 1151017 | Bare_land | 560360 | 1096605 | Shrubs |
| 621320 | 1101104 | Bare_land | 563390 | 1040482 | Shrubs |
| 516770 | 1095525 | Forest | 567260 | 1108783 | Shrubs |
| 518660 | 1123871 | Forest | 574760 | 1101164 | Shrubs |
| 537620 | 1085176 | Forest | 574790 | 1149608 | Shrubs |
| 537920 | 1019215 | Forest | 576020 | 1140129 | Shrubs |
| 541610 | 1121591 | Forest | 578210 | 1062289 | Shrubs |
| 542810 | 1010876 | Forest | 581030 | 1123451 | Shrubs |
| 545330 | 1103174 | Forest | 584180 | 1141599 | Shrubs |
| 546380 | 1094385 | Forest | 584480 | 1129300 | Shrubs |
| 549770 | 1008596 | Forest | 585770 | 1063579 | Shrubs |
| 550880 | 1145768 | Forest | 586970 | 1127321 | Shrubs |
| 554390 | 1084006 | Forest | 588230 | 1087696 | Shrubs |
| 555860 | 1083226 | Forest | 589100 | 1097355 | Shrubs |

| | | | | | |
|---|---|---|---|---|---|
| 557210 | 1100714 | Forest | 589250 | 1068078 | Shrubs |
| 557330 | 1121141 | Forest | 592040 | 1150657 | Shrubs |
| 558080 | 1125671 | Forest | 594950 | 1136619 | Shrubs |
| 559220 | 1095405 | Forest | 595580 | 1043602 | Shrubs |
| 560510 | 1159056 | Forest | 595640 | 1155187 | Shrubs |
| 561140 | 1017655 | Forest | 597050 | 1070838 | Shrubs |
| 563060 | 1021735 | Forest | 602450 | 1142229 | Shrubs |
| 566630 | 1147088 | Forest | 471920 | 1111063 | Residential area |
| 567890 | 1064899 | Forest | 480410 | 1080437 | Residential area |
| 567920 | 1177594 | Forest | 500270 | 1095795 | Residential area |
| 574610 | 1023564 | Forest | 501350 | 1111783 | Residential area |
| 574640 | 1042282 | Forest | 502610 | 1120451 | Residential area |
| 575420 | 1046781 | Forest | 503660 | 1146458 | Residential area |
| 575570 | 1054430 | Forest | 504170 | 1083826 | Residential area |
| 577910 | 1040992 | Forest | 508430 | 1122521 | Residential area |
| 581870 | 1062289 | Forest | 508580 | 1124861 | Residential area |
| 585050 | 1135809 | Forest | 519500 | 1126061 | Residential area |
| 586550 | 1153597 | Forest | 524090 | 1135359 | Residential area |
| 586850 | 1068228 | Forest | 528080 | 1099484 | Residential area |
| 587210 | 1062589 | Forest | 544940 | 985829 | Residential area |
| 590960 | 1078607 | Forest | 550910 | 1128970 | Residential area |
| 591080 | 1150268 | Forest | 557480 | 1028694 | Residential area |
| 592220 | 1118772 | Forest | 566270 | 977820 | Residential area |
| 592550 | 1149968 | Forest | 567470 | 989309 | Residential area |
| 597530 | 1050351 | Forest | 572360 | 979320 | Residential area |
| 605720 | 1083706 | Forest | 578300 | 1011746 | Residential area |
| 521240 | 1060789 | Agriculture | 581150 | 977340 | Residential area |
| 523340 | 1086436 | Agriculture | 583280 | 981570 | Residential area |
| 536810 | 1128070 | Agriculture | 583550 | 1012916 | Residential area |
| 541730 | 1049421 | Agriculture | 587210 | 1025124 | Residential area |
| 542840 | 1025124 | Agriculture | 591920 | 1023474 | Residential area |
| 543920 | 1015315 | Agriculture | 592790 | 1059170 | Residential area |
| 544250 | 1057970 | Agriculture | 594200 | 1120391 | Residential area |
| 546230 | 1063399 | Agriculture | 595910 | 1079897 | Residential area |
| 548600 | 1071348 | Agriculture | 596630 | 1123721 | Residential area |
| 549020 | 1045101 | Agriculture | 599390 | 1133920 | Residential area |
| 549350 | 1134310 | Agriculture | 600500 | 1133980 | Residential area |
| 551150 | 1055060 | Agriculture | 603440 | 1125731 | Residential area |
| 551690 | 1066459 | Agriculture | 603650 | 1017055 | Residential area |
| 551840 | 1050831 | Agriculture | 603890 | 1026594 | Residential area |
| 552200 | 1049871 | Agriculture | 604100 | 1087786 | Residential area |
| 552680 | 1027194 | Agriculture | 607520 | 1119822 | Residential area |
| 553400 | 1056530 | Agriculture | 609140 | 1088326 | Residential area |
| 554510 | 1138479 | Agriculture | 613640 | 1089076 | Residential area |
| 554810 | 1050921 | Agriculture | 616280 | 1090755 | Residential area |

# APPENDIX II

**Result table for health center catchment population and area using AccessMod 4.0**



Attributes of NEWHF

| FID | Shape | Woreda | HF_Name | HF_Type | CAPACITY | TRAV_TIME | OnBarrier | AccModID | CellPop | CatchPop | Area_2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Point | Ankober | Ankober Health Centre | Health Center | 25000 | 60 | FALSE | 1 | 26 | 25982.424074 | 87 |
| 1 | Point | Asagirt | Asagirt Health Centre | Health Center | 25000 | 60 | FALSE | 6 | 30 | 2607.239492 | 290 |
| 2 | Point | Hageremariam Kesem | Bulga Health Centre | Health Center | 25000 | 60 | FALSE | 0 | 22 | 6271.059544 | 454 |
| 3 | Point | Angolella and Tera | Chacha Health Centre | Health Center | 25000 | 60 | FALSE | 17 | 38 | 10495.791753 | 90 |
| 4 | Point | Debre Birhan Town | Debre Birhan Health Center | Health Center | 25000 | 60 | FALSE | 2 | 27 | 25732.953122 | 34 |
| 5 | Point | Tamraber | Debresina Health Centre | Health Center | 25000 | 60 | FALSE | 15 | 37 | 9022.945099 | 23 |
| 6 | Point | Sia Debirna Wayu | Deneba Health Centre | Health Center | 25000 | 60 | FALSE | 21 | 45 | 3505.163704 | 28 |
| 7 | Point | Moretna Jiru | Enewarie Health Centre | Health Center | 25000 | 60 | FALSE | 19 | 43 | 10605.185588 | 30 |
| 8 | Point | Basona worena | Goshebado Health Centre | Health Center | 25000 | 60 | FALSE | 7 | 31 | 2860.717352 | 321 |
| 9 | Point | Moretna Jiru | Jihur Health Centre | Health Center | 25000 | 60 | FALSE | 9 | 34 | 25048.706942 | 205 |
| 10 | Point | Basona worena | Keyit Health Centre | Health Center | 25000 | 60 | FALSE | 3 | 27 | 1703.823255 | 178 |
| 11 | Point | Ensaro Wayu | Lemi Health Center | Health Center | 25000 | 60 | FALSE | 18 | 41 | 25338.60883 | 234 |
| 12 | Point | Antsokia Gimza | Majetie Health Centre | Health Center | 25000 | 60 | FALSE | 22 | 48 | 4329.649208 | 69 |
| 13 | Point | Antsokia Gimza | Mekoy Health Centre | Health Center | 25000 | 60 | FALSE | 16 | 37 | 2647.975983 | 45 |
| 14 | Point | Midda Woromo | Meragna Health Centre | Health Center | 25000 | 60 | FALSE | 12 | 36 | 7604.369461 | 35 |
| 15 | Point | Berehet | Meteh Billa Health Center | Health Center | 25000 | 60 | FALSE | 5 | 29 | 2094.492058 | 590 |
| 16 | Point | Tarmaber | Mezezo Health Center | Health Center | 25000 | 60 | FALSE | 8 | 33 | 26099.67171 | 22 |
| 17 | Point | Minjar Shenkora | Minjar Health Centre | Health Center | 25000 | 60 | FALSE | 20 | 45 | 15603.963242 | 550 |
| 18 | Point | Menz Mama Midir | Mollalie Health Centre | Health Center | 25000 | 60 | FALSE | 13 | 37 | 4927.675371 | 189 |
| 19 | Point | Gishe | Rabel Health Center | Health Center | 25000 | 60 | FALSE | 23 | 48 | 5303.121304 | 269 |
| 20 | Point | Moja And wordera | Seladingay Health Centre | Health Center | 25000 | 60 | FALSE | 10 | 35 | 4348.666122 | 120 |
| 21 | Point | Shewarobit city administratio | Shoa Robit Health Center | Health Center | 25000 | 60 | FALSE | 11 | 36 | 11768.172765 | 239 |
| 22 | Point | Menz lalo | Wogerie Health Centre | Health Center | 25000 | 60 | FALSE | 14 | 37 | 3612.966362 | 29 |
| 23 | Point | Menz Keya | Zemero Health Centre | Health Center | 25000 | 60 | FALSE | 4 | 27 | 2956.79118 | 36 |

Record: 6 Show: All Selected Records (0 out of 24 Selected) Options

**APPENDIX III**

# Geographic location of health facilities

| Hospitals name | Northing | Easting | Health centers name | Northing | Easting |
|---|---|---|---|---|---|
| Alem Ketema Enat Hospital | 498816 | 1111830 | Ankober Health Center | 580706 | 1061883 |
| Debre Birhan Hospital | 559606 | 1069438 | Asagirt Health Centre | 562592 | 1032529 |
| Mehal Meda Hospital | 572068 | 1139579 | Ataye Health Center | 604683 | 1142608 |
| | | | Bulga Health Centre | 544328 | 1017652 |
| | | | Chacha Health Centre | 550087 | 1054364 |
| | | | Debre Birhan Health Center | 557420 | 1068799 |
| | | | Debresina Health Centre | 582967 | 1087910 |
| | | | Deneba Health Centre | 520785 | 1078203 |
| | | | Enewarie Health Centre | 515664 | 1093333 |
| | | | Goshebado Health Centre | 549942 | 1076784 |
| | | | Jihur Health Centre | 526336 | 1107504 |
| | | | Keyit Health Centre | 572449 | 1075019 |
| | | | Lemi Health Center | 489220 | 1083623 |
| | | | Majetie Health Centre | 593768 | 1159671 |
| | | | Mekoy Health Centre | 586393 | 1182089 |
| | | | Meragna Health Centre | 510514 | 1127919 |
| | | | Meteh Billa Health Center | 577425 | 1018274 |
| | | | Mezezo Health Center | 579378 | 1097118 |
| | | | Minjar Health Centre | 546144 | 986369 |
| | | | Mollalie Health Centre | 572026 | 1118620 |
| | | | Rabel Health Center | 564682 | 1165140 |
| | | | Seladingay Health Centre | 568438 | 1100451 |
| | | | Shoa Robit Health Center | 599867 | 1104262 |
| | | | Wogerie Health Centre | 560515 | 1122750 |

APPENDIX IV

**River and Road map of the study area**