ADAMA SCINECE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

DEPARTMENT OF GEODESY AND GEOMATICS ENGINEERING

Identification of Groundwater Potential Zone using Remote Sensing and GIS Techniques in Sede River Watershed in Hulet Eju Enesie District: Blue Nile Basin, Ethiopia

BY:

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(GSR/5551/06)

This thesis Submitted to the Geodesy and Geomatics Engineering department, Adama Science and Technology University, in Partial Fulfillment of the Requirements for the Award of a Master of Science Degree in Geodesy and Geomatic Engineering.

MARCH, 2016
ADAMA, ETHIOPIA

DECLARATION

I, **Demeke Sewnet,** Registration Number **GSR/5551/06** do hereby declare this Thesis is my original work and that it has not been submitted partially or in full by any other person for an award of a degree in any other Universities.

Name of Participant, **Demeke Sewnet** Signature………………..…Date……………..……

This Thesis has been submitted for examination with my approval as university Supervisor.

Name of Advisor………………………………Signature…………………Date…………

APPROVAL

The undersigned certify that they have read and hereby recommend to the Adama Science and Technology University to accept the Thesis submitted by **Demeke Sewnet**, and entitled "Identification of Groundwater Potential zone using Remote Sensing and GIS Techniques at Sede River Watershed in Hulet Eju Enesie District: Blue Nile Basin, Ethiopia" in partial fulfillment of the requirements for the award of a Master's Degree in Geodesy and Geomatic Engineering.

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ABSTRACT

Water plays a vital role in the development of activities in an area. Despite Blue Nile Basin, water supply is largely obtained from surface water, which is highly dependent on the seasonal inputs from rainfall. Due to this case it is inadequate to fulfill the water demand. Productivity through groundwater is quite high as compared to surface water, but groundwater resources have not yet been properly exploited. Keeping this view the present study attempts to identify groundwater potential zones in the Sede River Watershed of the Blue Nile Basin using remote sensing and GIS techniques. Integrated remote sensing and GIS have been used in the present study to prepare thematic maps such as lithology, topography/elevation, drainage density, lineament density, rainfall, soil type, slope and land use/ land cover. On the basis of relative contribution of each of these maps towards groundwater potential, the weight of each thematic map has been assigned based on the Saaty's analytical hierarchy process. These weights were assigned each thematic map to obtain a unified weight map. The thematic layers were finally integrated using weighted overlay analysis method in GIS software to delineate groundwater potential map of the study area. Thus from the present study it is observed that an integrated approach involving remote sensing and GIS technique can be successfully used in identifying potential groundwater zones in the study area. Five categories of groundwater potential zones, namely very good, good, moderate, fair and poor zones have been demarcated. The very good groundwater potential zones correspond to quaternary alluvial, it is residual and transported soils occupying flat lying and gentle topography area covered by grass land. It is occurred in central part of the area, which is the nearest to the intersection of Ayibar river and Sede River, Addis Alem, Debre Selam and Abiyote Selam kebele administration. The good potential zone are concentrated along the lineament line having high density area and covered in spares vegetation area. Moderate zone is covered largest area, it is present on the steep slope area which is occupied by sparse forest, shrub land and bare land area. It is highly dominated on the north and south part of the study area. Fair zones are available on the cultivated land throughout the study area. The area is dominated by gentle topography and far from lineament. Poor zone mainly presented on mountains and escarpments with steep cliff, where the area have high run-off. Finally, the resulted groundwater potential zoning map validated based on NDWI, NDMI and existing borehole data of the study area.

Key words: Sede Watershed, Groundwater potential, GIS and remote sensing, NDWI, NDMI

ACKNOWLEDGEMENT

Above all, I thank Almighty God, the Alpha and Omega, who is always with me in all my endeavors and giving me endurance to complete my study.

I express my deepest appreciation to my advisor Dr, Hassen Naqvi for his quick responses with valuable and very constructive comments and professional advice from the beginning to completion of the thesis. I also owe my warmest gratitude to Ato Danial Alemayehu for his technical support from the very beginning of the study up to compilation.

I express my deep appreciation and special thanks to my elder sister Tsehay Alemayehu for her encouragement, material and moral support and internet access in her office up to completion of the study.

I am also grateful to Adama Science and Technology University for offering me postgraduate study grant and financial assistance. I would also thank the Debre Markos University for their immense support in diverse ways.

Last but not least, I would like to thank my family and classmates those who are always beside me and played a great role in the completion of this work.

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AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization
GIS	Geographical Information System
IDW	Inverse Distance Weight
IRS	Indian Remote Sensing
KM	Kilometers
LISS	Linear Imaging Self Scanner
M	Meter
NDMI	Normalized Difference Moisture Index
NDWI	Normalized Difference Water Index
NIR	Near-Infrared
SRTM	Shuttle Radar Topography Mission
TM	Thermal Mapper
USGS	United State Geological Survey
IWMI	International Water Management Institute

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

Water is one of the most important natural resource occurring both as surface water and groundwater. It is vital for all life on the earth. Developments of our society are dependent on the availability and use of adequate water. Groundwater is one of the most valuable natural resources, which supports human health, economic development and ecological diversity. In addition, groundwater supports freshwater ponds, wetlands, streams, and sound environments, all of which represent specific and important habitats for flora and fauna (Abriham, 2009). Almost 37 Million km^2 of freshwater present on the earth and out of that 22% exists as groundwater, which constitutes about 97% of all liquid freshwater potentially available for human use (Punithavathi, et al., 2011). Ethiopia has abundant surface and ground water resources potential of which groundwater has a lion-share. The preliminary estimated amount of yearly groundwater recharge of the country is about 28×10^9 m^3. Recent research highlighted that the potential is much greater than this amount and it plays an important role in Ethiopia as a major source of water for domestic uses, industries and livestock (Ministry of water and Energy, 2015).

The water resources potential of the country pre-supposes a good scientific and technical capability for its judicious and sustained development Ethiopia, with a very limited experience in irrigation, hydropower, reliable water supply for community and other areas of water resources development needs to exert a concerted and systematic effort to raise its capability in water resources assessment and development.

The fast growing population and the recurrent drought has demanded such an effort more than ever. The country has enormous surface water and groundwater resources, although the distribution is uneven. Groundwater utilization has been limited to community water supply using shallow hand dug wells and unprotected springs. In rural areas where more than 85% of the population lives water shortage problems can be solved by proper utilization of groundwater (Tamiru, 2006).

Tremendous increase in the agricultural, industrial and domestic activities in recent years has increased the demand for good quality water to meet the growing needs. Groundwater is mostly preferred to meet this growing demand because of its lower level of contamination and wider distribution. It can be delivered to poor communities more cheaply, quickly and easily than the conventional canal irrigation water (IWMI, 2001)

The occurrence of groundwater at any place on the earth is not a matter of chance but a consequence of the interaction of the climatic, geological, hydrological, physiographical and ecological factors (Davoodi, et al., 2013). The variability of these factors in Ethiopia strongly influences the quantity and quality of the groundwater in different parts of the country. The geology of the country provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers (Tamiru, 2006).

In developing countries like Ethiopia most of geological, hydrogeological and mineral exploration works have been done with the absence of the application of Remote Sensing and Geographic Information System. Satellite remote sensing provides efficient data and effective method for geological mapping, groundwater and mineral exploration (Tewodros, 2005).

1.2 Statement of the Problem

Within Blue Nile Basin, water supply is largely obtained from surface water, which is highly dependent on the seasonal inputs from rainfall. Successive years of low and inconsistent rainfall have left large areas of the region in severe drought that resulted in crop failure and drinking water shortages (Gadisso, 2007). The Blue Nile River Basin, which is a region that is characterized by extreme climatic events such as droughts and floods. Since the basin is susceptible to climatic changes, the local people suffer from climatic variability. The Government of the Federal Republic of Ethiopia has thus undertaken several resettlement programs from highly vulnerable areas to the lowlands where water is available (Tamiru & Seifu, 2011).

In the present study area, Sede Watershed is located in the Blue Nile Basin which is not widely used Surface water for water supply because of its marked seasonality and lack of proper technology to retain it. Groundwater is the most important source of water for domestic supply, especially in the dry season where surface water is scarce. The most rural population of the study area have been utilized shallow dug wells and unprotected spring for water supply. But the dug wells and unprotected springs were an inadequate yield and no longer resist drought while most of them might be completely dried out and never easily recovered after the prolonged drought time.

The occurrence of groundwater is mainly influenced by the geology, topography and climate of the country. The variability of these factors in Ethiopia strongly influences the quantity and quality of the groundwater in different parts of the country (Tamiru, 2006).

Since uneven spatial and temporal occurrence and distribution of rainfall, the fast growing population and the recurrent drought has demanded such an effort more than ever. Under those mentioned above challenges the people are required to utilize the groundwater resource for domestic supply as well as irrigation agriculture to mitigate food security. But, there is no detailed study done about groundwater resource well in the study area and consequently there is poor knowledge of groundwater, their location, quantity and quality. At present there is no available detailed geophysical and hydrogeological information on the study area and therefore there is poor knowledge of aquifers zones.

This study therefore intends to use secondary data such as soil, land use land cover, topography/Elevation, rainfall, slope steepness, lithology, lineament density and drainage density data and available remote sensing data to delineate groundwater potential zones of the study area using GIS and remote sensing techniques.

Therefore, this study will generate better information for groundwater developer to solve the water and related problems of the woreda due to the cause of increasing population, uneven distribution rainfall and recurrent drought.

1.3 Objective of the study

1.3.1 General Objective

The main objective of this research is to identify groundwater potential zone in the Sede River Watershed in Hulet Eju Enesie Woreda, Blue Nile Basin using remote sensing and GIS techniques.

1.3.2 Specific objective

The specific objectives:

- ❖ To prepare different thematic layers for groundwater potential zones.
- ❖ Identify and delineate groundwater potential zones through integration of various thematic layers.
- ❖ To find out the relation between the NDWI, NDMI and ground water potential zones.
- ❖ To validate the result using existing borehole data.
- ❖ To provide appropriate recommendations for future work and provide guidelines for groundwater prospective.

1.4 Scope of the Study

The research was conducted in Sede River Watershed, which is found in the Blue Nile Basin in Amhara Regional State. The study focuses on the Identification of Groundwater Potential zone using Remote Sensing and GIS Techniques, which consider drainage density, lineament, elevation, slope, rainfall, land cover, geology and soil factors.

1.5 Methodology

In order to achieve the above-mentioned objectives, the generation of new data and collection of secondary data have been carried out for the study area. These are drainage density, lineament, elevation, slope, rainfall, land cover, geology and soil types. They were processed through remote sensing and GIS technique. After all necessary thematic layers were prepared, weight was assigned to individual class based on their significance (capability to store and transmit water) to the occurrence of groundwater whereas each map weight was assessed based on Satty's Analytic Hierarchy Process along with a paired comparison matrix. All thematic maps were integrated using GIS weighted overly analysis to identify ground water potential zone. Then groundwater potential map was reclassified and correlated with the NDWI and NDMI map which are prepared from Landsat 8 imagery, to verify the availability of groundwater. Lastly validate the combined map result using the existing borehole data, which were collected from Hulet Eju Ensie woreda Water Resource and Development Office.

1.6 Significance of the Study

The research study is expected to produce a groundwater potential zone map that demarcates the study area into different zones according to their groundwater potential. The result detail map of the area can be one input for understanding hydrogeological systems of the area, and used as data for further research work.

The generated, collected and digitized data organized into the logical groups of entities concerning geological factors (lithology and lineament), drainage density, and physiographic factor (topography, slope, land use/land cover) to produce properly organized Geodatabase which will enable the responsible officers to make decision and review by concerned stakeholders and subsequent researchers to properly use water resources in the area.

1.7 Limitation of the study

Usually, there is no definite smooth road of conducting a research. The limitation of the study are lack of well-organized data, unable to obtain detail geology data, Unwillingness of some officials to give data due to carelessness, very limited budget for conducting field data collection and analysis was the major constraint for the researcher.

However the researcher tried to solve the above limitation with a systematic way to achieve the objective of the study, which identify the groundwater potential of the Sede Watershed. The data collection period was very difficult by endless meeting of the officials and some bureaucratic staff, but the researcher solved it by frequently asking them. The geology was solved using the recent geological logging test report of the area from Water Well Drilling Enterprise, 2015 and visual inspection of the area. Finally the researcher correlated the drilling test report, geological map of Ethiopia data and visual inspection information to obtained detail geological information.

1.8 Organization of the Thesis

This thesis includes six chapters. The first chapter presents the introductory part, which introduce the background of the study, statement of the problem, the objectives of this research, significance of the study, scope of the study, limitation of the study and organization of the thesis. Chapter two mainly focuses on the previous research works related to global overview of groundwater, groundwater in Ethiopia, application of remote sensing and GIS technique method for delineation of groundwater potential zone, review the previous work from many researchers around the globe, multi criteria analysis and NDWI were observed. The third Chapter describes about the geographical location of the study area, topographic, climate condition, soil types, geology of the area and land use /cover were defined on the study area. The forth chapter is explains the data acquirement, software, the approaches of the data process and also the determination of criteria and factor weights computation are key parts of this chapter. The chapter five is results obtained from different objective were analyzed and the results are properly discussed below in this chapter. Chapter six provides the summary, important conclusions derived from present study and provides recommendations to improve the identified groundwater potential zones.

CHAPTER TWO
LITERATURE REVIEW

2.1 Conceptual definition of Groundwater

There is valuable definition for groundwater in different fields. Agronomists define groundwater as any water below the ground. On the other hand, for Engineers, groundwater is often termed as sub surface water and occurs below the ground. For hydro-geologist, ground water is a water in a saturated zone. A number of other names are attributed to ground water (Seifu, 2013). This includes: sub surface water, underground water and groundwater. Rocks in which ground water occur are named differently. Aquifer is a rock that holds and transmits water at economical rate. Aquiclude is a rock that doesn't holds or transmits water at economical rate. Awuitard is a rock that holds water but doesn't transmit the water to wells at economical rate. Groundwater exists inside fractures of rocks or inside open spaces called porosities of rocks (Seifu, 2013).

Groundwater is the water that is found underneath the Earth's surface at profundities where all the pore (open) spaces in the soil, sediments, or rock are completely stacked with water. Groundwater of any structure whether from a shallow well or a significant well, devises and is refilled (energized) by precipitation. Groundwater is a piece of the hydrologic cycle, beginning when a piece of the precipitation that falls on the Earth's surface sinks (infiltrates) through the soil and enters (seeps) diving to wind up groundwater. Groundwater will at long last come back to the surface, discharging to streams, springs, lakes, or the oceans, to complete the hydrologic cycle (Murasingh, 2014).

Groundwater is the water located beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater (Greenburg, 2005).

2.2 Global overview of Groundwater

In the last three decades, most water source globally has been from groundwater. In several countries the intense use of groundwater has turned the tide – economically and socially. At present an estimated 70% of the world's population depends on groundwater for its basic domestic water services. Groundwater has been at the base accelerated agricultural production in rural economies in India, South Asia, China, North Africa and the Middle East. Even in the extensive large surface irrigation systems in South Asia and North Africa 30-50% of the water at farm gate comes from groundwater. Intensive groundwater development in Sub Saharan Africa still has to take off. In comparison Sub Saharan Africa does not have the large high yielding shallow aquifers that are found in Asia, but even where the groundwater potential exists it is not yet used intensively. The same is true for Ethiopia (Minstry of Water resource Ethiopa, 2011).

2.3 Groundwater in Ethiopia

Groundwater is the most important source of water supply for the great majority of the population and in some arid and semi-arid regions in Ethiopia. The main sources of groundwater in the country are springs, hand-dug wells and drilled boreholes. For the last few decades, deep boreholes in peripheral regions the rift, and in some urban areas provide water for many small towns and rural villages (Pavelic, et al., 2012). Other main groundwater tapping systems are springs, widespread in the escarpment and the highlands, which supplies the great majority of the rural community, particularly in the rugged mountainous regions. According to Pavelic *et al*. (2012), in the rural settings, each spring is tapped to serve 200-500 people.

Hand-dug wells and springs often do not survive long droughts. The droughts have affected the livelihoods of the very poor members of the rural population and created large water supply problems, which characterize most parts of Ethiopia. This emphasizes to utilized groundwater in drilling shallow and deep wells, even if there are possibilities of developing springs and hand dug wells in order to acquire water security for drought mitigation and preparedness ((Tamiru, 2006) and (Pavelic, et al., 2012)).

Groundwater is used for domestic purpose, irrigation, Livestock watering, industrial purpose and others. While it's enormous importance, the government has given less attention to the groundwater sector. As a result, the hydrogeology of the country is poorly understood as compared to surface water systems. The only source of hydrogeological information at the national level is the hydrogeological map of Ethiopia at 1:2,000,000 scale and very few areas are mapped in detail. The available studies of the groundwater resources are very limited. Therefore, studies of the groundwater resources of the country in terms of quantity, quality, management, aquifer characteristics and water balance are of great importance (Pavelic, et al., 2012).

In many parts of the country, groundwater is an important source of potable water. This is especially true for rural areas as well as for towns. However, the occurrence of groundwater is not uniform because it depends on various environmental and geological factors (Tamiru, 2006). The occurrence of groundwater is mainly influenced by the geology, geomorphology and climate of the country. The variability of these factors in Ethiopia strongly influences the quantity and quality of the groundwater in different parts of the country (Tamiru, 2006). It is discuss as follows.

2.3.1 Hydrogeology

The hydrogeological conditions of the country are linked with the occurrence and distribution of the various hydrostratigraphic units, the topography, the recharge and discharge conditions which, in turn are related to the spatial and temporal variation of rainfall. These hydrostratigraphic units include the Precambrian basement, Palaeozoic rocks and Mesozoic sediments (Tertiary and Quaternary volcanics and the Tertiary and Quaternary sedimentary rocks and sediments) (Pavelic, et al., 2012).

i. Precambrian basement: The Precambrian basement complex rocks upon which all younger rock formations are deposited contain relatively low groundwater reserves. The main water bearing formations of the Precambrian are found within the structural discontinuities of various crystalline rocks of the lower complex (high grade gneiss, migmatites, granulites and metamorphic granitoids), in the upper complex, syn-tectonic and post-tectonic granitoids. Since metamorphic rocks are subjected to several orogenic episodes, they are strongly folded, foliated and fractured. These structures play an important role in the movement and occurrence of groundwater. Some geological structures of hydrogeological importance in the Precambrian rocks include: (i) the intersection of the main regional tectonic structures; (ii) occurrence of post crystalline tensile and shear fractures; and (iii) the structural heterogeneity due to the occurrence of migmatites and granulites in the gneiss, or quartz and pegmatite dikes. Generally, Precambrian intrusive igneous rocks and metamorphic rocks have very low (less than 1%) primary porosity. As a result, permeability is small and in most practical cases serve as an aquiclude. Water-bearing properties of these rocks are believed to be dependent on the extent of weathering and occurrence of fractures. In these rocks, the deeper the weathered zone, the greater is the amount of water. The weathered layers can have porosities of up to 50 percent and therefore act as a major reservoir. The success and failure of well site locations depend very much on the proper understanding of the complex structures of the Precambrian metamorphic and intrusive rocks and the existence of thick permeable weathered zones. Even though crystalline rocks are generally impermeable, groundwater occurs mainly in the weathered and creviced zones.

Generally the groundwater potential and the current development in the Precambrian basement complex rocks of Ethiopia are very low (Pavelic, et al., 2012).

ii. Palaeozoic rocks: The Paleozoic and Mesozoic rocks are entirely sedimentary. Both the primary and secondary permeability in these rocks play an important role in the occurrence and movement of groundwater. In the clastic sedimentary rocks, the main water-bearing horizon is constituted by interstitial spaces. The water holding capacity may be conditioned by the degree of assortment, grain size, cementation and jointing. Precipitates arising from percolating water readily close interstices of clastic sediments. Cementation and resulting consolidation provides favourable condition for the development of joints. Carbonate rocks are among the most productive aquifers in the Mesozoic rocks even though their permeability and porosity vary considerably. This variation is related to their mode of origin and environment of deposition. Paleozoic sediments contain water mainly in the conglomeratic horizons and in weathered zones.

Generally the Paleozoic do not have groundwater reserves comparable to that of the Mesozoic and Cenozoic volcanic rocks (Pavelic, et al., 2012).

iii. Mesozoic sediments: The Mesozoic sedimentary rocks can make good aquifers when they are found under more favorable climatic conditions. They outcrop in the north western plateau, mainly in Tigray, in the Blue Nile Gorge in south eastern Ethiopia, in Harrghe, Bale and southern Sidamo. The main aquifers in the Mesozoic formations include the arenaceous type formation (Adigrat sandstones), calcareous-dolomitic layers very often fossiliferous (Abay beds and Antalo limestones), Agula shales and Amba Aradam formation (more arenaceous conglomeratic). Generally Mesozoic sediments (upper sandstone, middle limestone, and lower sandstone) have varied hydrogeological characteristics. In the lower sandstone, groundwater can be saline in zones where it is in hydraulic contact with the overlaying saline aquifers. In the south east of the country, the formation is too deep for economical drilling. Limestones (Hamanlei and Antalo) are generally permeable, fractured and karstified. Antalo limestone is one of the major aquifers in Ethiopia (Pavelic, et al., 2012).

iv. **Tertiary and Quaternary volcanics:** Tertiary and Quaternary volcanic rocks cover extensive areas. The volcanics of Tertiary, known as the Trap Series, overlie the Mesozoic sedimentary rocks. They usually form the highlands or the plateaux. They are highly weathered and form thick residual soils. The simplified stratigraphy, from the oldest to the youngest of the Cenozoic volcanics are the Ashenge group, Shield group, Makdala group and the Aden volcanic series. Generally important aquifers could be formed in the Ethiopian volcanic province by occurrence of paleosols, interbedded loose pyroclastic materials and reworked agglomerates, buried paleovalleys, structural discontinuities, contraction joints within thick lava flows, thick residual soils, many permeable zones between the contact of the different generation of lava flows and inter-trappean beds (Pavelic, et al., 2012).

v. **Tertiary and Quaternary sedimentary rocks and sediments:** Though not extensive, there are some sandstone outcrops of Cenozoic age in the Afar and eastern Ogaden. These are variegated sandstone (Jessoma Sandstone), biogenic massive limestone (Auradu series), gypsum, dolomite, cherty limestone and clays (Taleh Series), and fossiliferous limestones with marly and clayey intercalations (Karkar series) and the Red bed (Garat formation). In these rocks important aquifers can be located in channels filled by younger sediments, coarse sandstone and conglomeratic layers interbedded with shales, the contact between clastic and chemical sediments, interstratifications of basaltic lava flows with loose sediments and the alluvial sediments on flood plains.

2.3.2 Groundwater recharge

The recharge to the groundwater system is also variable as the rainfall over Ethiopia is extremely variable in both space and time. The main source of recharge for the vast groundwater system is the rainfall on the highlands, particularly northeastern and southwestern plateau. Rapid infiltration occurs in areas covered by fractured volcanic and to a lesser extent in sedimentary rocks and thick permeable soils (Tamiru, 2006) and (Pavelic, et al., 2012).

2.3.3 Climate

Ethiopia has a tropical monsoon climate with a wide climatic variation induced by varying topography. The climate of Ethiopia ranges from equatorial desert to hot and cool steppe, and from tropical savannah and rain forest to warm temperate highlands. In Ethiopia, rainfall has an uneven distribution both in time and in space. This is partly due to the presence of one major and one small rainy season, in large part of the country. A subsidiary effect is that a large amount of rainfall on the highlands is concentrated as runoff in river alleys, which drain into the low-lying areas where annual rainfall is low. In almost all river basins in Ethiopia, some 80% of the runoff results from annual precipitation falling in four months from June to October (Tamiru, 2006).

2.4 Remote Sensing and GIS applications in groundwater delineation

Groundwater potential maps are useful to planners and engineers seeking suitable locations at which to implement resource explorations. The tedious methods used to prepare groundwater potential zones are mainly based on field survey. In order to determine the location of aquifer, quality of groundwater, physical characteristics of aquifers, etc., in any basin, test drilling and stratigraphy analysis are the most reliable and standard methods. However, such an approach for groundwater investigations is very costly, time-consuming and requires skilled manpower (Sander *et al.,* 1996 cited by Hutti & Nijagunappa. R, 2011). In contrast, remote Geoinformatics technology, with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has emerged as a very useful tool for the assessment, monitoring and management of groundwater resources (Jha, et al., 2006).

Satellite remote sensing provides efficient data and effective method for geological mapping, groundwater and mineral exploration. Satellite remote sensing data are useful because they provide up-to-date information on the accessibility of an area to be surveyed particularly, concerning land use, general topography, the presence of surface water and drainage system. The use of remote sensing data allows effective localization of targets and reducing costs and time spent during geophysical, geochemical and fieldwork prospecting (Rokos *et al.,* 2000 cited by (Tewodros, 2005)).

Apart from image interpretation, remote sensing are used by many researchers for deriving geological, structural and geomorphological details. The various thematic layers generated using remote sensing data like lithology/structural, geomorphology, land use/cover, lineaments etc, can be integrated with slope, drainage density and other data in a Geographic Information System (GIS) framework and identify groundwater zones as well as artificial recharge sites (Abiy, 2007).

GIS applications in groundwater studies are facilitate the data input, data storage, data manipulation and analysis and data output for both spatial and attribute data to support decision making activities. In this study GIS was used to

- Input and store spatial and attribute data captured through GPS and digitization,
- make different analysis on input data to produce final factor maps,
- create continuous surface from point data (geo-statistical analysis),

- integrate data from different sources (remote sensing, existing maps & field survey),
- conduct multi-criteria analysis to determine class and factors maps weight,
- Produce output thematic layers. In multi-criteria analysis Analytic Hirerarchy Process was used to determine the factor maps weight. The assignment of factor maps weight was based on Saaty's 9 point continuous scale.
- Produced groundwater potential map based on weighted overly analysis in GIS. This mentioned above activities was carried out by GIS technique, hence it has vital role to identify groundwater potential zone using the given thematic map.

2.5 Review Related Previous Works

There are a variety of previous researches undertaken in the application of Remote Sensing and GIS technique in groundwater resources assessment. Very few of the relevant literatures reviewed are summarized below.

In the (Varughese, et al., 2012) was carried out a study to identified groundwater potential areas in Thuthapuzha sub basin of Bharathapuzha River India was done using GIS technology. The Resource sat (IRS P6 LISS III)) data and survey of India Toposheets were used as basic data sources for the study. The hydro-geological factors like slope, land use, drainage density, aquifer depth and soil texture, on which Ground water potential is dependent were considered and the respective maps were generated using GIS. The ground water potential zones were identified after assigning weightages and ranks to these factors. The generated groundwater potential zone map was verified with the water level data of the area. It gives a more realistic representation but the geological parameter was not considered to identify the groundwater potential area and the each thematic map weight was assigned by personal judgment. It was not applied pair comparison matrix.

In addition, (Hutti & Nijagunappa. R, 2011) were carried out delineated possible groundwater potential zones in the Ghataprabha sub basin of Krishna river, Karnataka using geoinformatics technology. The thematic layers considered in this study are lithology, landform, drainage density, recharge, soil, land slope and surface water body, which were prepared using the Google Earth imagery and conventional data. All these themes and their individual features were then assigned weights according to their relative importance in groundwater occurrence and the corresponding normalized weights were obtained based on the Saaty's analytical hierarchy process. The thematic layers were finally integrated using Autodesk map and MapInfo GIS software to yield a groundwater potential zone map of the study area. But the produced groundwater potential zone was not verified with the water yield data of the area.

In order to, Identification of Groundwater Potential Zone using Geoinformatics in Ghataprabha basin, North Karnataka, India, it is possible to take number of different thematic maps of the same area and overlay them on top of one another to form a new integrated layer (Shivaji & Nitin, 2014). This study was aimed to identify the groundwater recharge potential zones, to be used for better and improved groundwater resources. The thematic layers considered in this study are geomorphology, soil, land use land cover, slope (%), drainage density and lineament density, which are prepared using satellite imagery and other conventional data. The thematic layers were first digitized from satellite imagery, supported by ancillary data such as topo sheets and field investigation data, finally all thematic layers were integrated using ArcGIS software. Despite it was used remote sensing and GIS technique to identified groundwater, they were not considered the rainfall and geology parameters, which are highly influence the groundwater movements and occurrence. The weightage of all thematic map was assigned without applied Saaty's analytical hierarchy process.

In Ethiopia, (Tewodros, 2005) was used remote sensing and GIS for groundwater potential zone identification in southeastern part of Ethiopia plateau, the Bale Mountains and the surrounding areas. In this work thematic layers like drainage, lineament, elevation, slope, land cover, soil, rainfall, and biological factor (burrowing rodents) generated from satellite image and existing maps were combined in GIS environment for mapping groundwater potential zones within the study area. However the generated map technique were the same to others researchers, the map was not proved with the existing water yield of the area or it did not crosschecked with other technique.

Similarly (Sisay, 2007) was applied similar approach to generate thematic maps such as geology, geomorphology, lineament, soil, rainfall, land use/cover, slope and drainage for producing groundwater potential map of northern Ada'a plain (Mojo catchment).The groundwater potential zones was carried out validity tested with the borehole data. But lineament density, land use, and others data are extracted from satellite image without use detailed maps and ground verification and accuracy assessment. But, the mainly control factors the occurrence of groundwater such as geology, geomorphology and lineament was produced from satellite image without verified with Ethiopia Geology Survey. It lead in wrong conclusion.

In (Tesfaye, 2010), an attempt has been made to delineate and classify possible groundwater potential zones in the Bilate River catchment of the south Ethiopian rift escarpment, found in South Nation and Nationality People Region (SNNPR) using integrated remote sensing and GIS techniques. The thematic layers considered in this study are lithology, geomorphology/landform, drainage density, lineament density, rainfall, soil, slope and land use/ land cover were prepared using the Landsat ETM+ imagery and ArcGIS software. All the thematic layers were then he assigned weights according to their relative importance in groundwater occurrence and the corresponding normalized weights were obtained based on the Saaty's analytical hierarchy process. These weights were applied in linear summation equation to obtain a unified weight map containing due weights of all input variables. The thematic layers were finally integrated using ArcGIS and IDRISI software to produce a groundwater potential zone map of the study area. Despite the presentation and the technique used to produce the ground water potential zone is similar to the above researcher, he was not verified the result with different techniques like NDWI and NDMI.

2.6 Multi Criteria Analysis.

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with multi criteria decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process (Coyle:, 2004).

The AHP generates a weight for each evaluation criteria/factors according to the decision maker's pairwise comparisons of the criteria. The higher weight, the more important the corresponding factors. The AHP is a very flexible and powerful tool, the decisions may be inconsistent, and how to measure inconsistency and improve the decisions, when possible to obtain better consistency is a concern of the AHP.

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. According to (Saaty, 2008) the comparison scale is consisting of values ranging from 1 to 9 which describe the intensity of importance (preference/dominance). A value of 1 expresses "equal importance" and a value of 9 is given for those factors having an "extreme importance" over another factor (Table 2.1).

Table 2.1: The Saaty Rating Scale for comparisons

Intensity of importance	Descriptions
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6	Intermediate values
Reciprocals	Values for inverse comparison

2.7 Normalized difference water index (NDWI)

Today the Remote Sensing (RS) and Geographical Information System (GIS) have widely been applied for the purpose of analysis of earth surface with changing space and time. It is necessary, a spatial as well as an environmental analysis of an area towards the regional as well as national planning and management (Abhay, 2014). Remote sensing satellites with different spectral, spatial, and temporal resolutions provide huge amount of data which are used as primary sources and are regularly used for show vegetation liquid water status from space, wetland feature extraction, water resources assessment and coastal management (Ashraf & Nawaz, 2015). These applications have involved the delineation of water resources area using thematic information from remote sensing imagery, which according to the number of bands used. For example, the Normalized Difference Water Index (NDWI) was developed for the extraction of water features from Landsat imagery (Rokni, et al., 2014).

The Normalized difference water index (NDWI) is derived from band rationing and normalization of the spectral bands (Equation1 below). The design of Spectral Water Index was based on the fact that water absorbs energy at Near-Infrared (NIR) and reflects mainly within the visible spectrum with a maximum value in the green band. The selection of NIR and Green bands was decided for water detection after testing available Landsat-8 bands for quite a few methods like rationing with different band combinations (Panda, et al., 2014).

$$\frac{\text{Band }3-\text{Band }5}{\text{Band }3+\text{Band }5} \quad \text{OR} \quad \frac{\text{Green}-\text{NIR}}{\text{Green}+\text{NIR}} \text{.............equation 1}$$

2.7.1 Data Pre-Processing

The parameters used in NDWI require physical units, such as at-sensor radiance or top-of atmosphere (TOA) reflectance, rather than the raw quantized calibrated pixel value (DN). According to Wenbo Li et al, 2013, there are three advantages to using TOA reflectance instead of at-sensor spectral radiance when comparing images from different sensors. First, TOA reflectance removes the cosine effect at different solar zenith angles due to the time difference between data acquisitions. Second, TOA reflectance compensates for different values of the exo-atmospheric solar irradiance arising from spectral band differences. Third, TOA reflectance corrects for the variation in the earth-sun distance between different data acquisition dates. Therefore, we used the TOA reflectance of the ALI, TM, ETM+ and landsat8 data to be used. TOA reflectance can be obtained from the quantized calibrated pixel value, as given by (Chander, G et al, 2009 cited by (Wenbo Li, et al., 2013)).

CHAPTER THREE

GENERAL DESCRIPTION OF THE STUDY AREA

3.1 Location and accessibility of the study area

Sede watershed lies within latitude 10^0 48’00”N to 11^0 09’00”N and longitude 37^0 48’ 00’’E-$38^0$06’00’’E. In administrative terms, it is located Hulet Eju Enesie district (figure: 2.1). Hulet Eju Enese is one of the districts (woreda) in the Amhara Region of Ethiopia. It’s part of the East Gojjam Zone, it is bordered on the south by Debay Telatgend woreda, on the west by Bibugn and Gonji kolela, on the northwest by the west Gojjam Zone, on the north by the Blue Nile River (which separates it from the South Gondar Zone), on the east by Goncha Siso Enese woreda, and on the southeast by Enarj Enawga. Among the towns in this administrative division are Keraniyo, Mota and Sede. The area is accessible by four-wheel drive vehicles, and it is about 370 kms from Addis Ababa, 120kms from Bahir Dar (the regional capital) and 196 kms from Dabre Markos (the zonal capital). There is a feeder dry weather access roads that connect different parts of the study area. But during rainy seasons especially starting from June to October most part of the catchment area is inaccessible. The study watershed is covered 380 km^2 area, which contains 21 rural kebeles and 2 urban kebeles administration. It is characterized by diverse topography conditions. The elevation ranges from 1302 to 3527m above sea level.

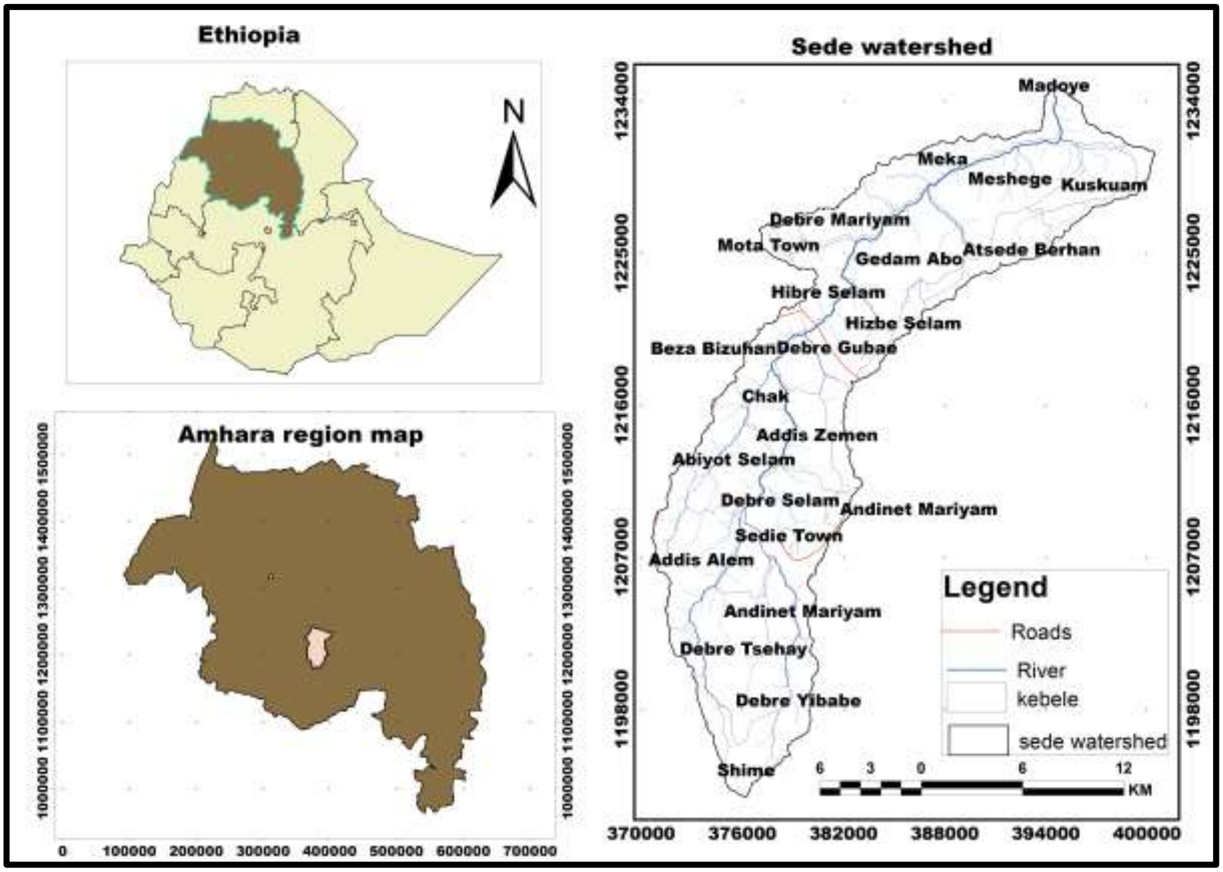


Figure 3.1: Location map of Study area

3.2 Climate

According to the traditional agro climatic classification system, which is consider only temperature and altitude, the watershed lies within “dega” (temperate) and “wurch”,“woynadega”, and “kola” climatic zones.

3.2.1 Rainfall

In the study area, there is one meteorological station which are located in Motta town. The station coordinate is (377754, 1224585). 11 years of rainfall data was collected from the National Meteorological Agency for the stations from 2004 to 2014. Summary of the mean rainfall (mm/month) data is given in the table 2.1 and table 2.2 below.

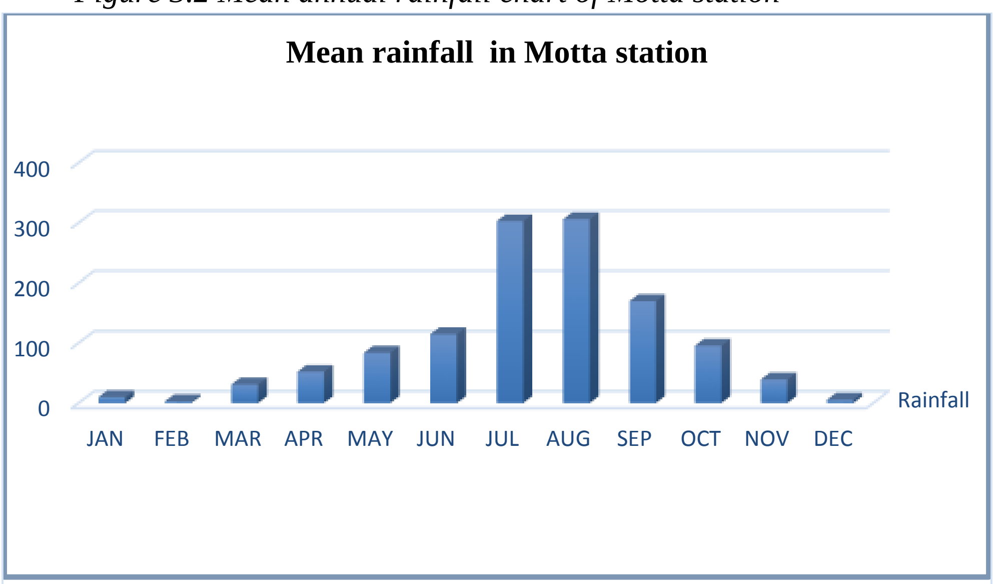
Table 3.1 Summary of mean rainfall data of Motta station (2004-2014)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rainfall (mm)	9.7	2.9	30.8	52.0	83.8	114.7	302.4	305.7	169.9	95.6	39.2	5.4

Table 3.2 Motta station monthly Rainfall data (2004-2014)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2004	0.0	7.4	7.0	59.0	14.2	141.8	202.8	258.2	181.3	91.9	23.9	0.0
2005	3.8	4.5	50.7	27.9	20.3	138.5	261.3	226.2	204.5	195.6	61.4	0.0
2006	0.0	2.2	27.9	76.9	106.3	164.1	366.2	339.0	158.0	80.3	49.1	36.8
2007	26.2	0.0	32.4	16.5	116.6	175.5	225.8	295.7	136.4	42.5	0.2	0.0
2008	41.7	0.7	0.0	78.9	143.9	94.2	363.1	279.8	209.7	0.0	15.4	0.0
2009	0.0	13.2	28.5	30.2	9.0	0.0	273.1	108.4	109.4	160.9	28.4	0.3
2010	7.2	0.0	27.0	37.5	63.5	34.1	364.4	450.4	212.7	84.5	22.1	3.0
2011	21.8	0.0	48.0	53.0	94.4	69.4	260.9	408.9	197.0	32.1	126.1	0.0
2012	2.7	0.0	16.3	3.5	37.2	157.7	355.3	322.5	147.9	50.0	23.6	19.8
2013	3.1	0.0	14.5	61.3	77.4	193.0	370.1	381.6	135.6	195.0	54.0	0.0
2014	0.2	4	86.5	127.1	239.5	93.9	283.7	292.1	176.8	118.3	26.9	0

Figure 3.2 Mean annual rainfall chart of Motta station



According to the rainfall data (table 3.1 and figure 3.2) the study area has received a mean annual rainfall of 1212 mm per year, from analysis result observed that in summer season (July-September) which receives higher precipitation amount.

3.2.2 Temperature

The temperature of the project area is the mean monthly temperature exceeds 23.3^{o}C. The monthly average minimum temperature registered is 6.3^{o}C in the month of December in Motta Station while the hottest season extends from March to late May. The summary of mean monthly air temperature of the stations is given below.

Table 3.3 Mean Monthly Temperature data of Motta station (2004-2014)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Min T(^oC)	7.4	9.5	11.1	12.1	11.6	10.3	11.6	12.2	8.9	7.3	8.0	6.3
Max T(^oC)	24.1	25.9	26.4	26.5	26.1	22.1	21.1	20.6	21.9	20.6	23.2	21.3

3.3 Types of Soils

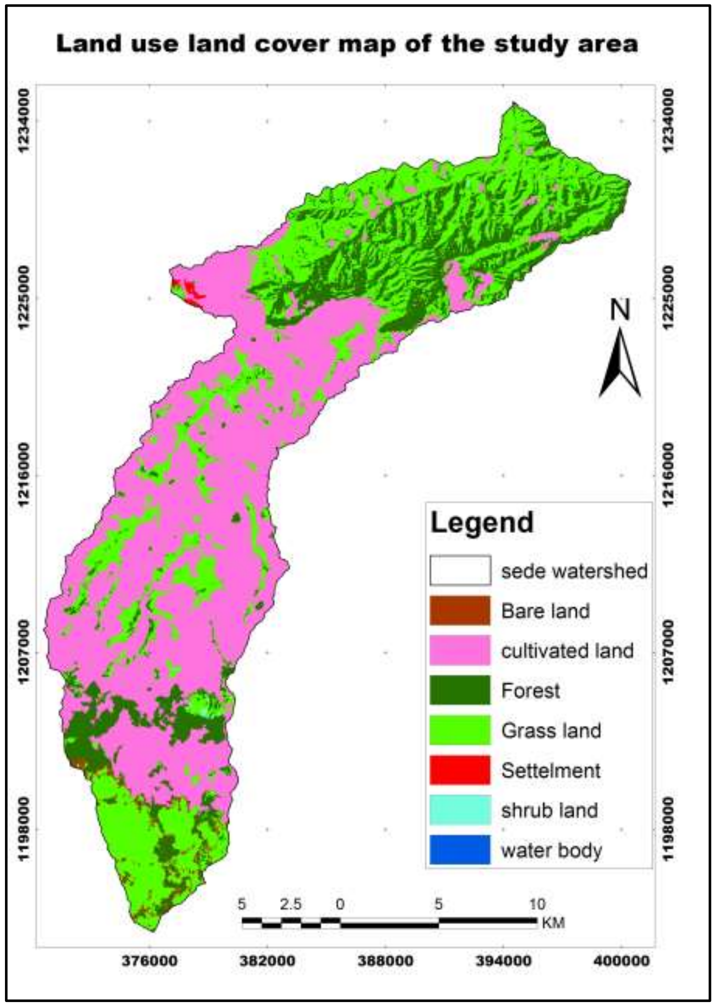
The groundwater potential assessment and development project requires a proper understanding of the soil properties. Soil information is of paramount importance for assessing the potential infiltration, percolation and ground water recharging capacity. The study area are entirely covered by four types of soil classes. These are Eutric Leptosols, Haplic Alisols, Eutric Vertisols and Haplic Luvisols. In low lying areas, particularly central part of the area, and along parts of the Motta town, soils have been dominated with Eutric vertisols soils. The soil map of the sede watershed suggests that soils are mainly vertisoils in the flood plains and luvisols in the upper catchment areas (figure 5.7).

3.4 Land use/ Land Cover

Land use/ land cover highly control the runoff and evapotranspiration, identification and interpretation of land use pattern of the area. There are major differences in the intensity and patterns of land use of the Sede Watershed area. These differences could be attributed to differences in population density and land use systems. Most part of the watershed is densely populated and intensively cultivated for growing a variety of annual crops. The Sede Watershed area of about 48.6% covered in different crop production activities. The remaining land area is covered by grasslands/grazing areas, shrub-lands, forestlands, water body, and built up/settlement areas (figure 3.3).

In addition, the north and central part of the study area, consisting of parts of Meshegie, Kuskuam and Debr Meakel kebele, are dominantly covered by grass land, open woodland and sparse forested grass land. While the south part of the watershed is covered bare land, grass and shrub land. However, a significant portion of these parts of the area has been and being converted to cultivated lands and settlement areas.

Figure 3.3 land cover of the study area



Source: National Geomatics center of China, 2014

3.5 Geology of the study area

The geology of the area forms part of the Northwestern Ethiopian plateau volcanic belonging to the Palaeozoic, Mesozoic, Tertiary and Quaternary geological times. The study area geology lies on tertiary and quaternary geology period ((Workineh, et al., 2010), (Ferede, 2015)). The Tertiary rocks are dominated lower lava flows; consists, lava flows interlayered with pyrocastic flows, the middle basalt flows consists mainly basalts flows and rare pyroclast, flood basalt (Debremarkose basalt, Lumame basalt) and choke shield volcano contains (Rob Gebeya basalt and Arat Mekeraker basalt). Only minor areas to the study is covered by younger Quaternary alluvial deposits.

Major structures observed in the area are normal faults trending EW and SN direction occurring to the north and south part of the study area. Observed faults are local and the majority of structures are interpreted lineament.

CHAPTER FOUR

METHODOLOGY

In this chapter, it describes about the different data used, software, methodology data analysis adopted for present study; regarding the preparation of a report on groundwater potential, application of remote sensing and GIS techniques analysis, The details methods are described below.

4.1 Data Used for Study

In this study, different data was generated, collected and digitized data in order to accomplish objective of the study. These are concerning lithology, lineament density, rainfall, topography; slope, drainage density, land use/land cover, and soil were collected to identify the occurrence groundwater potential zone on the study area (table 4.1). The collected relevant data, in the initial stage of GIS spatial database development various analogue maps, which were in different scales obtained from different organizations, converted into digital format using digitization method in ARC map 10.2 software. Then, individual entities are converted to characteristic spatial representation format in order to make them suitable for analysis.

Table 4.1: data used for the study

Data	**Content**	**Source**	**Scale**
Meteorological data	Rainfall data	Meteorology agency of Ethiopia	
Soil map	FAO soil covering the study area	FAO soil classification	
Geological Maps	Regional geological unit	Geological Survey of Ethiopia	1:250,000
Land use/cover map	Map of the different land use of the study area	National Geomatics center of China (Global Land 30)	30m
Landsat 8 Imagery	NDWI	(USGS, 2014)	30m
Digital Elevation Model	Elevation	(USGS, 2014)	30m
Drainage network	Stream	Extract from DEM	30m
Watershed shape file	Boundary of study area	Extract from DEM	30m
Existing borehole data	Location and yield	Hulet Eju Enese Water Resource Development Office	

4.2 Software Used

Software used in this study is selected based on the capability to work on the existing problems in achieving the predetermined objectives

4.2.1 ARCGIS10.2

ArcGIS have been used to create the geodatabase, data input, data editing, data management and storage, georeferencing data from different sources, performing spatial multi criteria, generating criteria maps and assigning weight for each criterion, overlaying, analysis and visualization of output data, and etc. The groundwater availability factor map development was carried out using Arc Map10.2 software package. The factors that are input to multi-criteria analysis should be preprocessed in accordance to the criteria set to develop groundwater occurrence map.

4.2.2 ERDAS IMAGINE 2014

Erdas Imagine is a comprehensive geographic analysis and image processing system that has been developed by Hexagon Geospatial. The software has been used to perform preprocessing of satellite image, layer stake and produced NDWI data.

The other software such as IDRISI 32, Microsoft office and Google earth and others were facilitated to achieve the objective of the study, which is identify ground water potential zone of the study area (table 4.2).

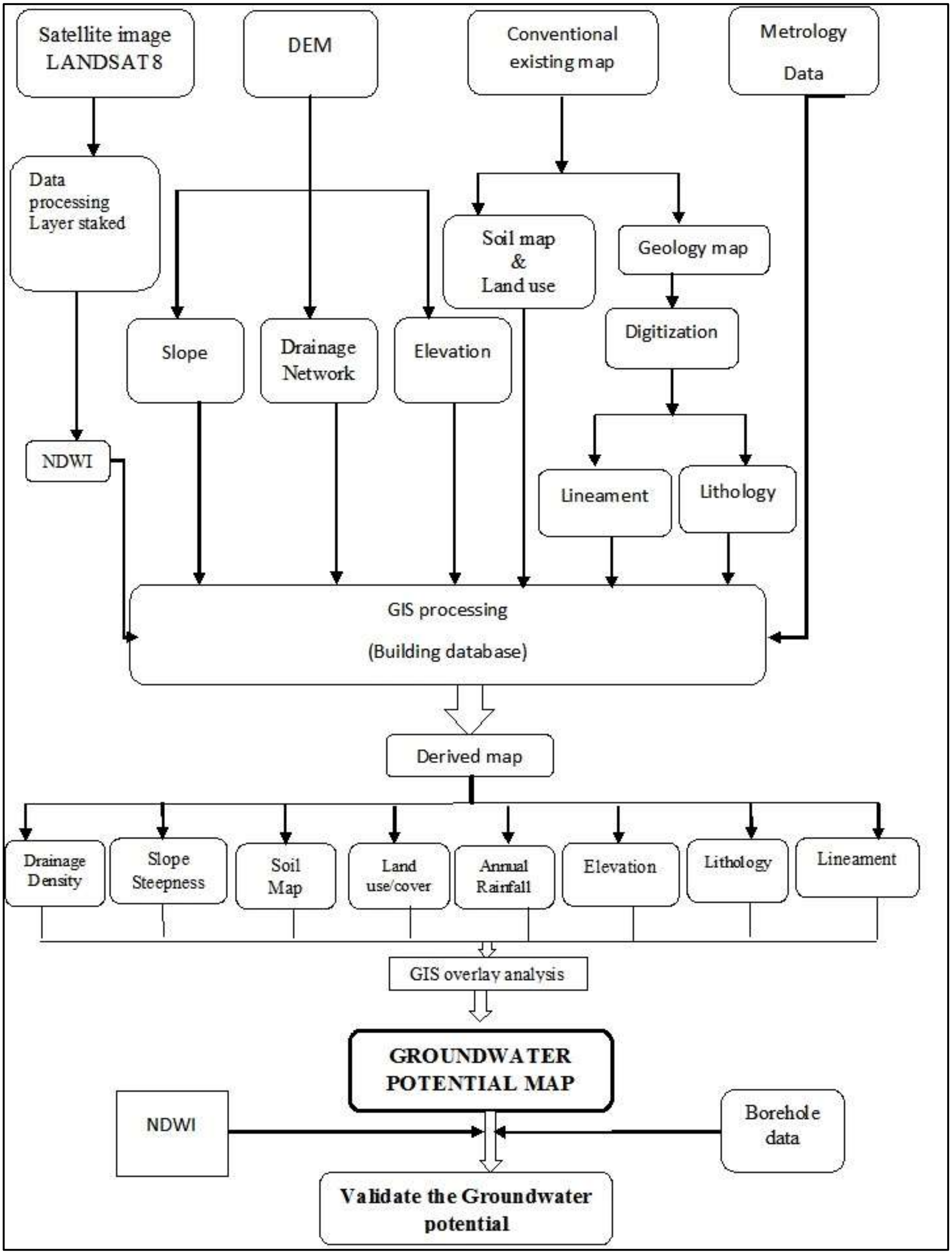
Table 4.2: Software and material used

Soft ware	**Purpose**
ERDAS Imagine 2014	Image Processing
ArcGIS 10.2	Spatial analysis and layout preparation
Global Mapper	Generating DEM in compatible format
Microsoft Office	Documenting(.doc) and statistical analysis(.xlsx)
Google Earth	Visual interpretation of biophysical setting
IDRISI 32	For calculation of weight.
3DEM	Patch the missed data of DEM

4.3 Methodology

The study was carried out in several stages to delineate potential groundwater using remote sensing and GIS technique, the methodology employed was summarized the flow chart (figure4.1).

Figure 4.1: flow chart of the Methodology

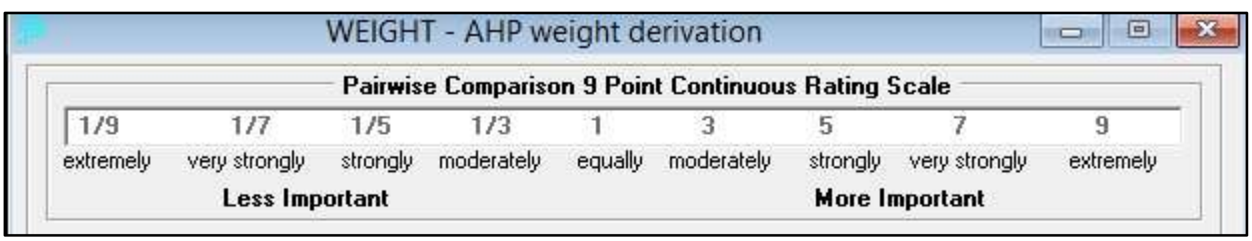


4.4 Data Analysis

In this stage, the collected data were processed to extract relevant information to identify the groundwater potential in the study area. The thematic map were generated such as drainage density, Topography map, slope map, land use/cover, soil map, rainfall map, lithology and lineament density map and make their integration through remote sensing and GIS technique.

After all necessary thematic layers were prepared, rank was assigned to individual class based on the literature upon their significance to groundwater and map weight was assessed based on Satty's Analytic Hierarchy Process where a pair – wise comparison matrix prepared for each map using nine point scale. Then all thematic layers was overlay by using GIS weighted overly analysis to find the final integrated output of groundwater potential zones. The weight values this final map further logically was classified to arrive at groundwater potential zone map. This provides a broad idea about the groundwater prospect of the area. Next, the final groundwater potential map was correlated with the NDWI and NDMI map which is produced from Landsat 8 imagery, to verify the availability of groundwater. Finally validate the combined map result using the existing borehole data, which was collected Hulet Eju Ensie woreda Water Resource and Development Office.

Table 4.3 Ratings on Satty's 9 – point continues scale.



WEIGHT - AHP weight derivation

Pairwise Comparison 9 Point Continuous Rating Scale

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
Less Important					More Important			

In this study, Topography/elevation, slope, drainage density, Land use and land cover, geology and lineament density are considered for the identification of groundwater potential zone.

CHAPTER FIVE
DATA ANALYSIS AND RESULTS

5.1 Introduction

The occurrence of groundwater initially involves the application of remote sensing and GIS before conducting any fieldwork, geophysical prospecting, and drilling test. This will reduce effort, time and money used in exploration and also increases the accuracy of finding groundwater (Tewodros, 2005).

The present study has attempted to apply integrated remote sensing and GIS for generating new thematic data layers as well existing data for delineating potential groundwater zone in Sede Watershed. The eight factors could be used for the final analysis to achieve the proposed objectives. These are: drainage density, rainfall, slope steepness, topography/elevation, land use /cover, soil types, lineament density and lithology. All thematic layers have the same raster information and spatial reference as shown table 5.1.

Table 5.1: Coordinate System of the all thematic layers

Property	**value**
Coordinate system	Adindan UTM Zone 37N
Projection	Transvers Mercator
datum	Adindan
False Easting	500,000.000
Central Meridian	39^0
Pixel Size	30m
Extent	Left 370626.74 and Right 400446.74 Bottom 1192797.09 and Top 1234977.09
Resampling Technique	Nearest

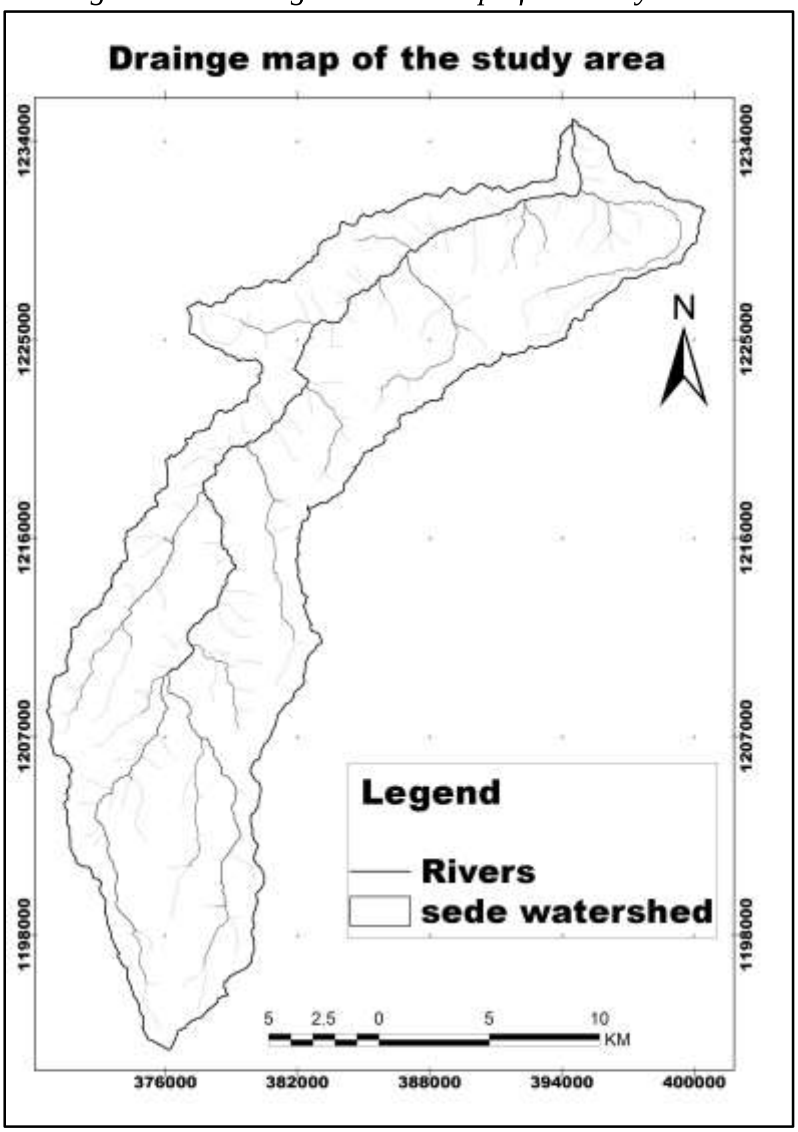
5.2 Factors Controlling Groundwater Occurrence in the Study Area

Groundwater distribution and occurrence on the study area have highly influenced with different factors. The main factors that were considered to map groundwater in the study watershed are rainfall, Lithology, lineaments, land use/ cover, drainage network, Topography/elevation, slope and soil. Thematic maps for each parameter prepared as follows:

5.2.1 Drainage map

The drainage density depends on the slope, nature and attitude of bedrocks and the existing regional and local fracture patterns (Tewodros, 2005). The study area is high altitude and steep slope on southern part of the area and gentle slope at the center part of the study. The escarpment, Abay cut valley area and low land area presented in the north of study area, due to this topographic features the stream flow is south to north direction. The drainage network of the area is dominated by the seasonal streams flowing towards perennial rivers. The major rivers present in the study area are Sede River, Aybar, Ahyo and Tiwa River, which are runs from south to north towards Nile River. Sede River consider to be the principal drainage system of the study area (figure 5.1).

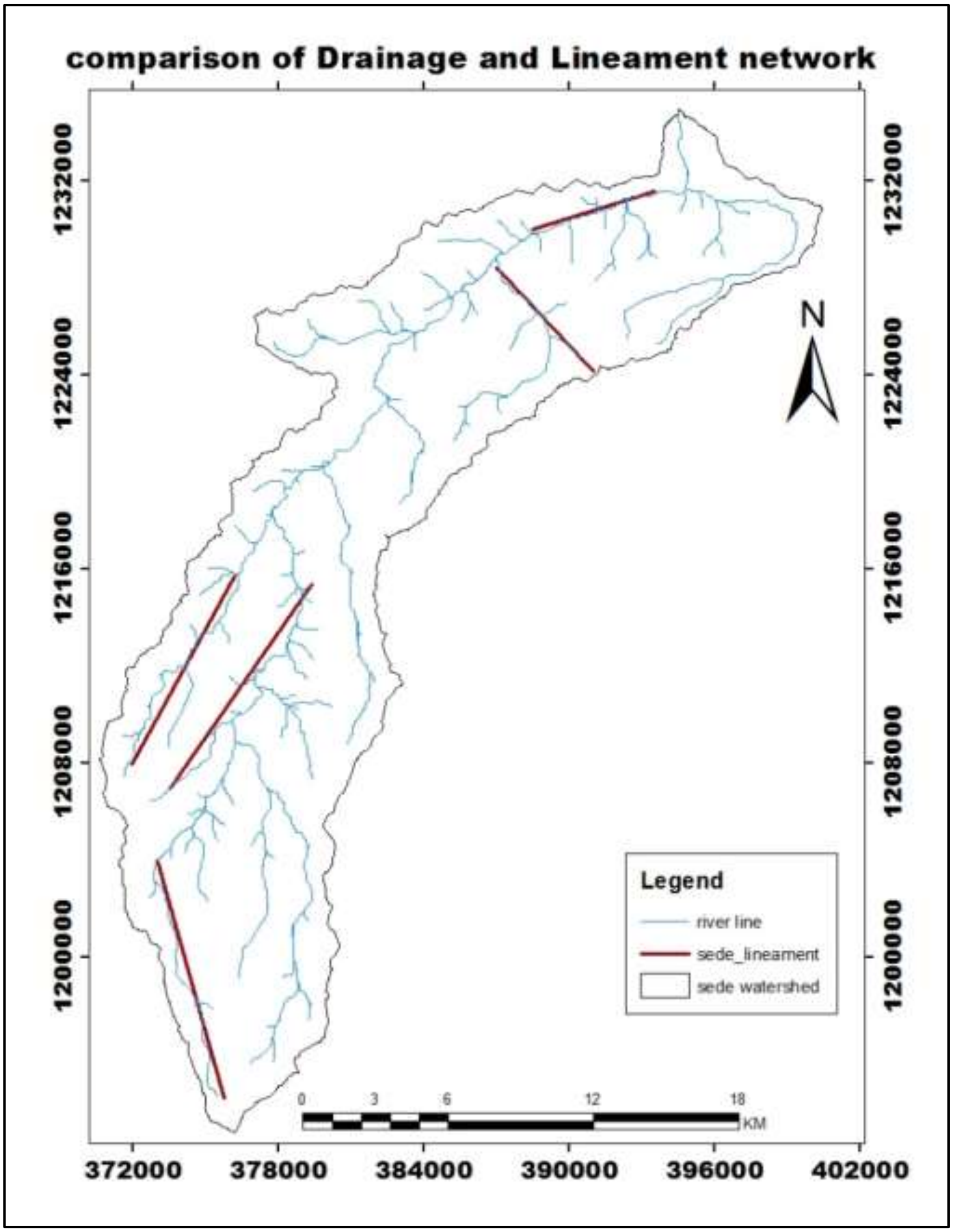
Figure 5.1 drainage network map of the study area



Source: derived from SRTM DEM, 2014

Drainage of the study area is one of the practical approaches to know the lithological and structural control of land form evolution. Comparison of the drainage system and structure of the area has shown that the drainage system of the area is structurally controlled following lineaments directions (figure 5.2).

Figure 5.2 comparison of Drainage and Lineament orientation



Source: Geological survey of Ethiopia, 2014

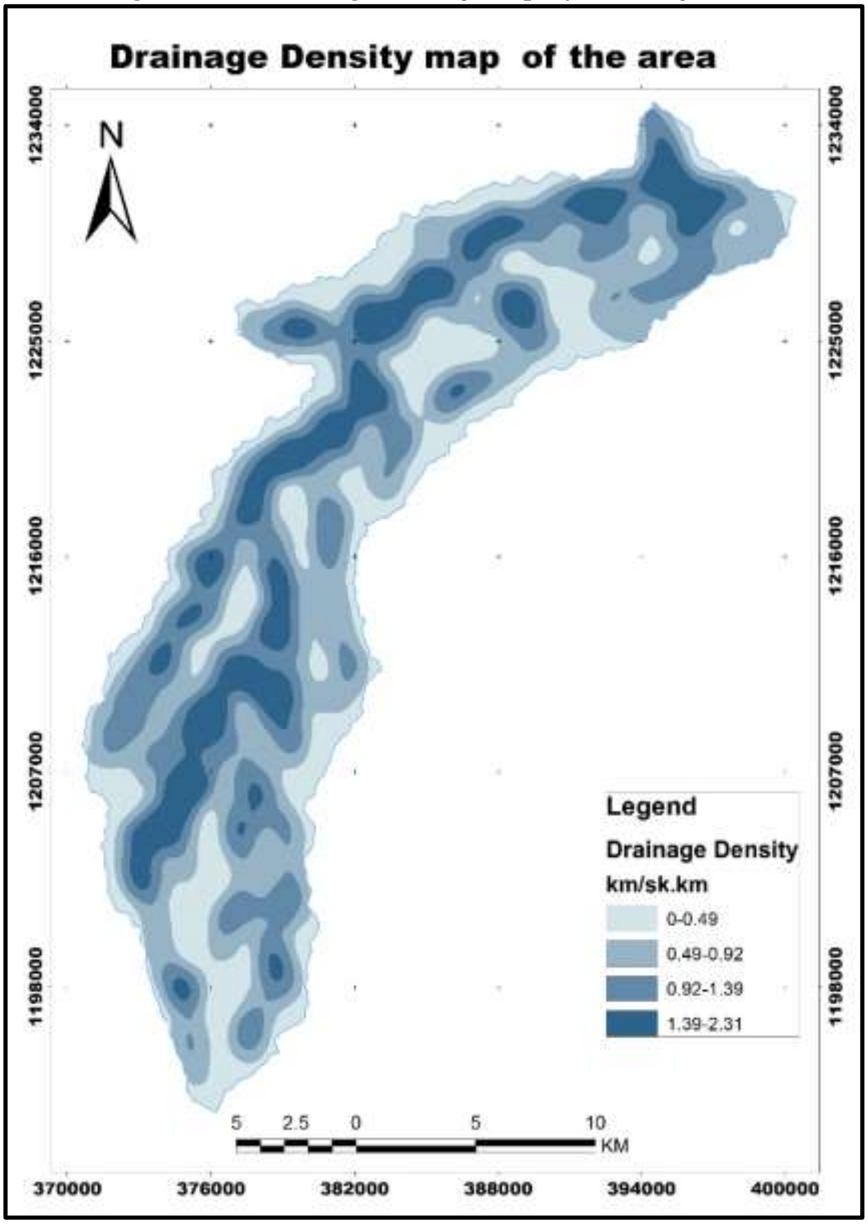
5.2.2 Drainage density

Drainage density is defined as the closeness of spacing of stream channels. The drainage density is an inverse function of permeability (Hutti & Nijagunappa. R, 2011). Drainage density indicates rock permeability, infiltration rate and recharges capacity (Tesfaye, 2010). They are reflection of the rate that precipitation infiltrated compared to surface runoff. Where rocks are highly permeable, infiltration to groundwater is high, and less water is transported in rivers as surface water, but where rocks have low permeability there is little infiltration and more surface water runoff (Tesfaye, 2010). Low drainage density is therefore related to higher recharge and higher groundwater potential (M.Thangarajan, 2007cited by (Tesfaye, 2010).

Drainage density delineated using GIS in hydrology tools of SRTM DEM data of the study area after consecutive processes such as Importing of SRTM data, filled sinks for undefined values created Flow Direction, Created Flow Accumulation, created Stream network, generated Stream Order and finally converted Stream Order to drainage density. Finally, it was calculated using kernel density analysis tool in ArcGIS software and the area has been reclassified into four classes: 0.00-0.49, 0.49-0.92, 0.92-1.39 and 1.39-2.31 as shown (figure 5.2).

A low drainage density region causes higher infiltration rate and it yields in better groundwater potential zones as correlated to a high drainage density region (Murasingh, 2014). The higher weight was given to the low drainage density regions and the lower weight to the high drainage density areas, shown in (table 5.2).

Figure 5.3: Drainage density map of the study area



Source: derived from SRTM DEM, 2014

Table 5.2 Weightage of Drainage density for Groundwater availability

Criteria	Classes	Ranking with word	Weight
Drainage density	0.00-0.49	Very good	9
	0.49-0.92	Good	7
	0.92-1.39	Moderate	5
	1.39-2.31	Poor	3

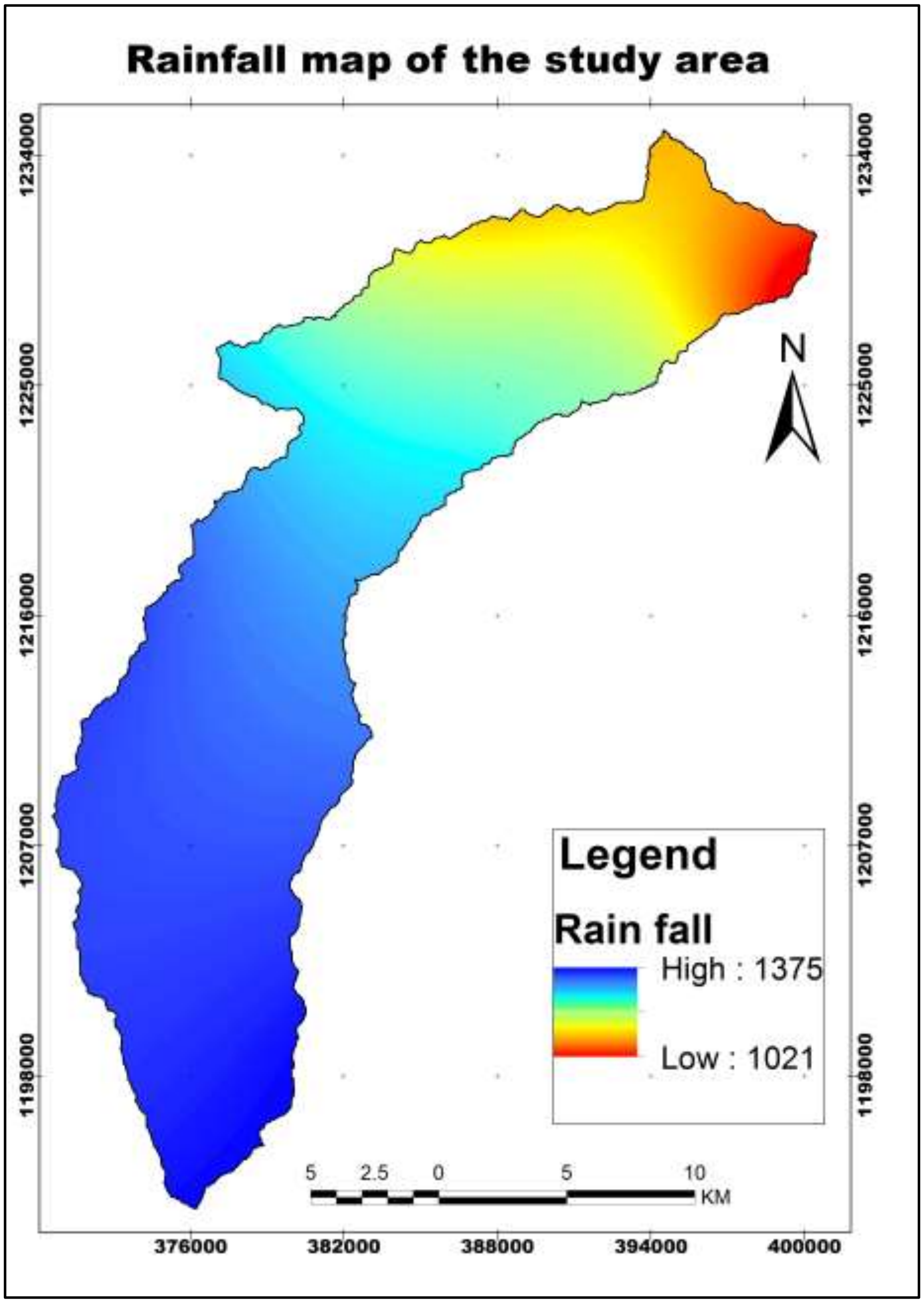
Source: derived from SRTM DEM, 2014

5.2.3 Annual Rainfall

Rainfall is one of the major sources for groundwater, particularly in the Blue Nile Basin. The high rainfall amounts imply the possibility of high groundwater recharge and vice versa. The area characterized by high rainfall amount shows high groundwater potential zones. The relationship of rainfall to groundwater occurrence is governed by the rainfall distribution, topography, land use /land cover, soil and geology etc. all these factors affect the quantity of water that gets underground (Tesfaye, 2010). All the water that precipitated may be absorbed in a flat sand dune area. With respect to different surface condition which affect the amount of water that goes to the ground, annual rainfall should be taken in order to average the amount of water that infiltrates in to the ground regardless of surface condition. In general the high rainfall amounts imply the possibility of high groundwater potential zone (Sisay, 2007).

For analysis of rainfall effect in groundwater occurrences, the data were collected from Meteorological Service Agency for last 11 year's record data (2004-2014) at four stations. The rainfall stations are located in Motta, Gundwoyen Debre markos and Adet station. Due to uneven distribution of the stations in the study area data were interpolated using IDW nearest neighbor interpolation techniques (Tewodros, 2005). After interpolation the study area raster map was clipped the study area, then reclassified into four classes and final rainfall map was produced (Figure5.4).

Figure 5.4 Rainfall map of the study area



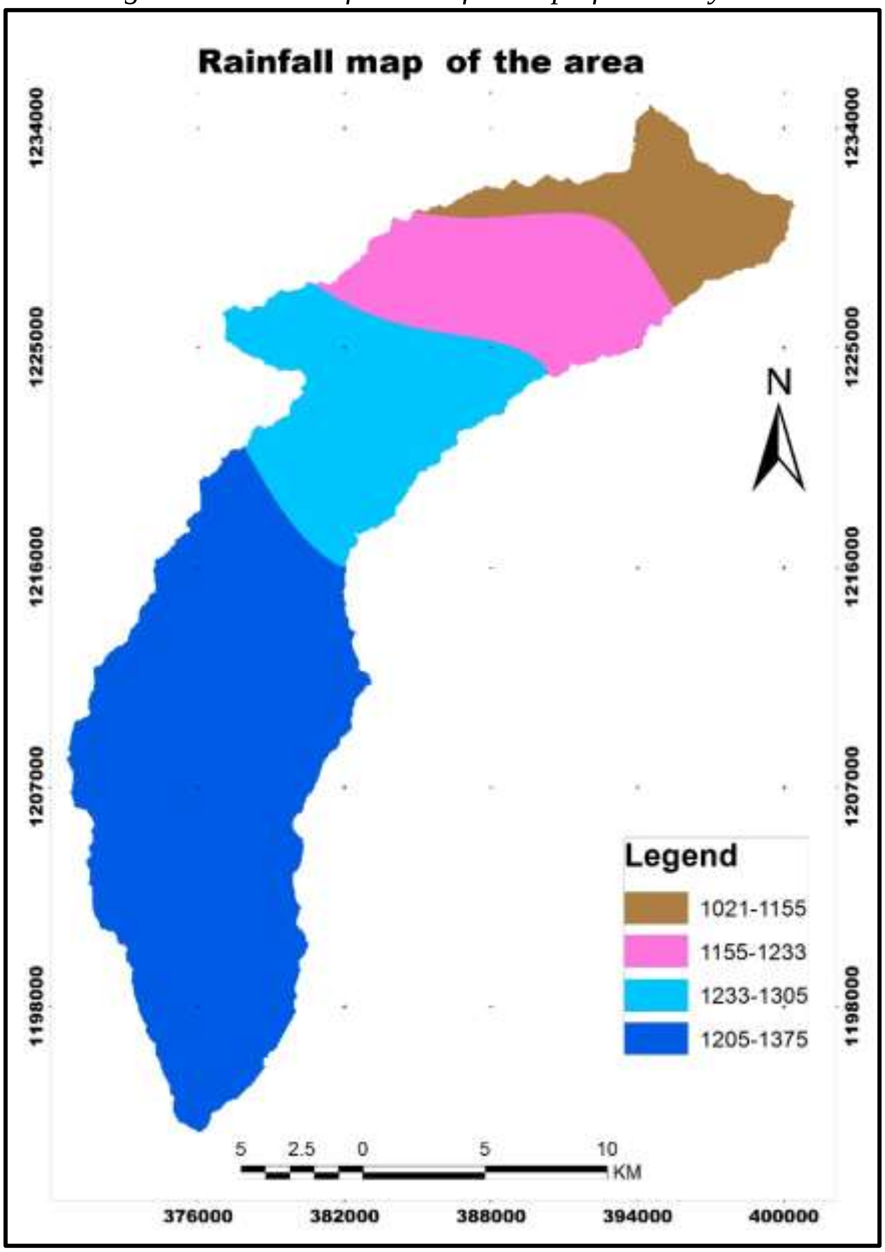
Source: Bahir Dar Meteorology agency, 2014

From the figure 5.4 shows that high amount of rainfall are raining on the highlands area which are in south of the area. Mean annual rainfall gradually decreases towards the north part of the study area. Centre of the area around Motta Town the annual amount is moderate. Generally it has been observed that high amount of rainfall is related to high occurrence of groundwater and based on this fact weight was assigned accordingly (Table5.3).

Table 5.3 weightage of Rainfall for groundwater potential

Criteria	Classes	Weight
Annual Rainfall (mm)	1021-1155	3
	1155-1233	5
	1233-1305	7
	1305-1375	9

Figure 5.5 Reclassified Rainfall map of the study area

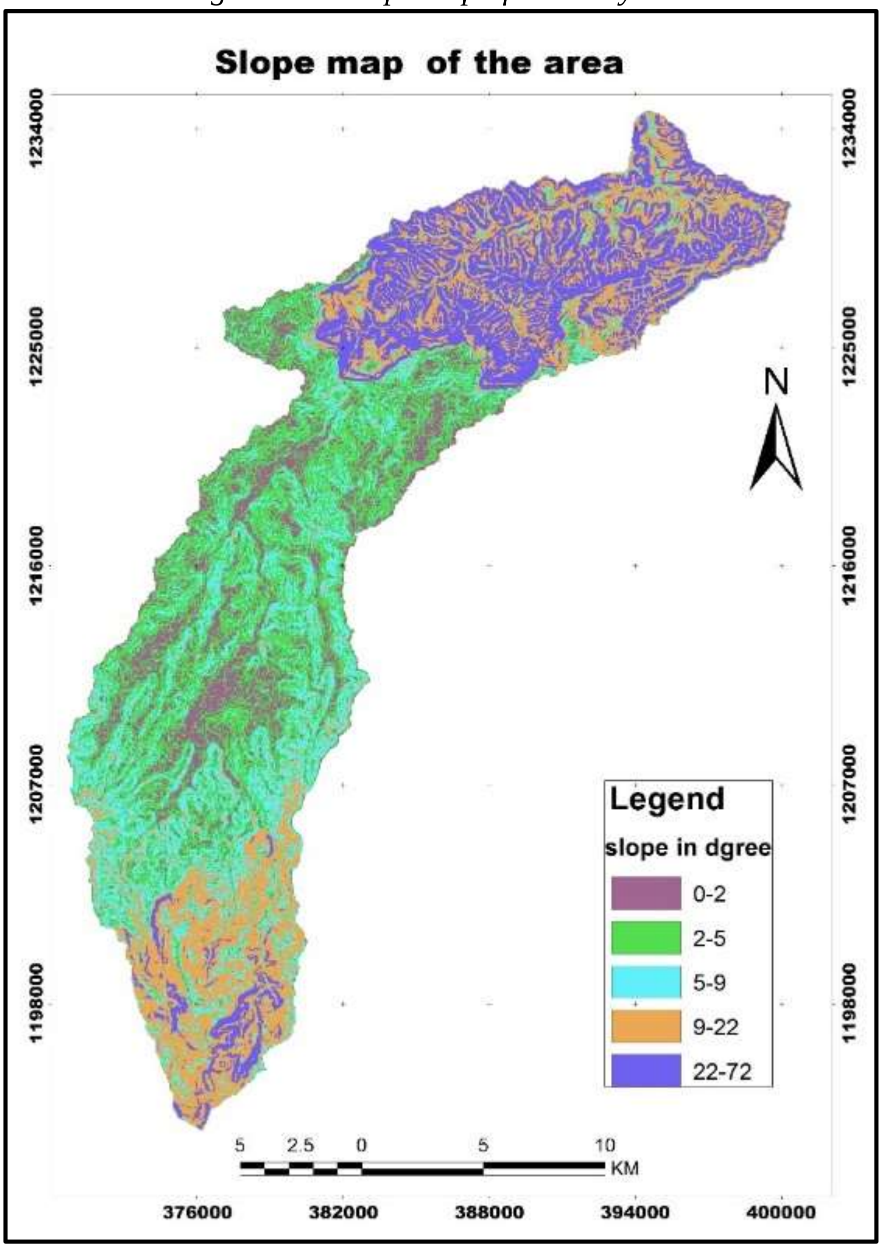


Source: Bahir Dar Metrology agency, 2014

5.2.4 Slope

Slope is an important factor for the identification of groundwater potential zones. Slope of any terrain is one of the factors allowing the infiltration of groundwater into subsurface or in other words groundwater recharge. In the gentle slope area, the surface runoff is slow allowing more time for rainwater to percolate, whereas, steep slope area facilitates high runoff allowing less residence time for rainwater to percolate and hence comparatively less infiltration ((Sisay, 2007), (Shivaji & Nitin, 2014)).

Figure 5.6: Slope map of the study area



Source: derived from SRTM DEM, 2014

The slope map of the study area is derived from SRTM DEM 30 m using the slope analysis tool in Arc map10.2 (Figure 5.6). Based on the slope, the study area can be classified into five slope classes. The areas having 0-2 degree slope fall into the 'very good' category because of the nearly flat terrain and relatively high infiltration rate. The areas with 2-5 degree slope are considered as 'good' for groundwater storage due to slightly undulating topography with some runoff. The areas having a slope of 5-9 degree cause relatively high runoff and low infiltration, and hence are categorized as 'moderate' and the areas having a slope 9-22 are considered as ' fair' due to higher slope and runoff. The area having a slope 22-72 degree is considered as 'poor" due to the very steep slope area and highest runoff and low infiltration rate.

The classified slopes were assigned weights to the individual slope class, according to its respective influenced of groundwater occurrence, holding and recharge capacity, as per table 5.4 below.

Table 5.4 weightage of slope in study area

Criteria	Slope in degree	Description	weight
Slope in degree	0-2	Very good	9
	2-5	good	7
	5-9	Moderate	5
	9-22	fair	3
	22-72	poor	1

Source: derived from SRTM DEM, 2014

A score of nine is given to the plain region with lower slope because low runoff is usually a good recharge zone. These areas are mainly located in the central and North West of study area, which is Motta, Debre Selam, Addis Alem, Chak, Wonber Zufan and Cheba Tiwa kebele administration area are flat as it is shown from slope 0°-5°. Towards southern, northeastern and northern of the study area starts to change its elevation sharply into very rugged escarpment, which has slope ranges dominantly from 9°-72° (figure 5.6). This part of the study have rugged topography which is covered Kuskuam, Meshegie, Meka, Asede Birhan, Gedam Abo and Debre Mariyam kebele administration.

5.2.5 Soil Types

Soil properties influence the relationship between runoff and infiltration rates which in turn control the degree of permeability, the principal factor in hydrogeology that determines the groundwater potential (Tesfaye, 2010). The soil forming factors, climate, parent rock, vegetation and other factors are responsible for the type of soil formed and plays an important role on groundwater recharge through infiltration and loss through run-off (Tewodros, 2005). The soil classes used for the groundwater investigation are based on the hydrologic property of soil classification of (FAO, 2001). Based on FAO soil classification, the study areas are entirely covered by four types of soil classes. These are Eutric Leptosols, Haplic Alisols, Eutric Vertisols and Haplic Luvisols.

5.2.5.1 Vertisols

The name Vertisols (from Latin vertere, to turn) refers to sediments that contain a high proportion of swelling clays, or products of rock weathering that have the characteristics of swelling clays. Vertisols soil is commonly known as black cotton soil containing smectic clay that characterize sticky nature and have high water holding capacity and low infiltration capacity. These soils form become very hard and deep wide cracks from the surface downward when they dry and are sticky and plastic in the wet season (Tewodros, 2005). The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess. Excess water in the rainy season must be stored for post-rainy season (water harvesting) on Vertisols with very slow infiltration rates (FAO, 2001). Vertisols soil is found in central part of the study area, which is covered 138.95 km^2 (figure 5.7).

5.2.5.2 Leptosols

Leptosols accommodates very shallow soils over hard rock, within 25 cm from the soil surface, mostly it is found elevated region with non-level topography. Leptosols are found in all climatic zones, particularly in strongly eroding areas. It is found the north and south part of the study area, which is steep slope area. It used to wet-season for grazing and as forest land sometimes utilize as cultivated land. Steep slopes with shallow and stony soils can be transformed into cultivable land through terracing, the removal of stones by hand and their use as terrace fronts. Leptosols are genetically young soils and evidence of soil formation is normally limited to a thin A-horizon over an incipient B-horizon or directly over the unaltered parent material. Stagnic properties can occur in Leptosols on gentle slopes or in pockets but are rather exceptional. Their shallowness and/or stoniness, and implicit low water holding capacity. Swelling and shrinking smectitic clays in the mineral residue are accountable for the dominance of blocky structures. The excessive internal drainage of the area, Leptosols can cause drought even in a humid environment (FAO, 2001)

5.2.5.3 Luvisols

Luvisols have distinct clay accumulation horizon. Most Luvisols are well drained but Luvisols in depression areas with shallow groundwater may develop gleyic soil properties in and below the argic horizon. Stagnic properties are found where a dense illuviation horizon obstructs downward percolation and the surface soil becomes saturated with water for extended periods of time (Tewodros, 2005). Soils in which clay is washed down from the surface soil to an accumulation horizon at some depth.

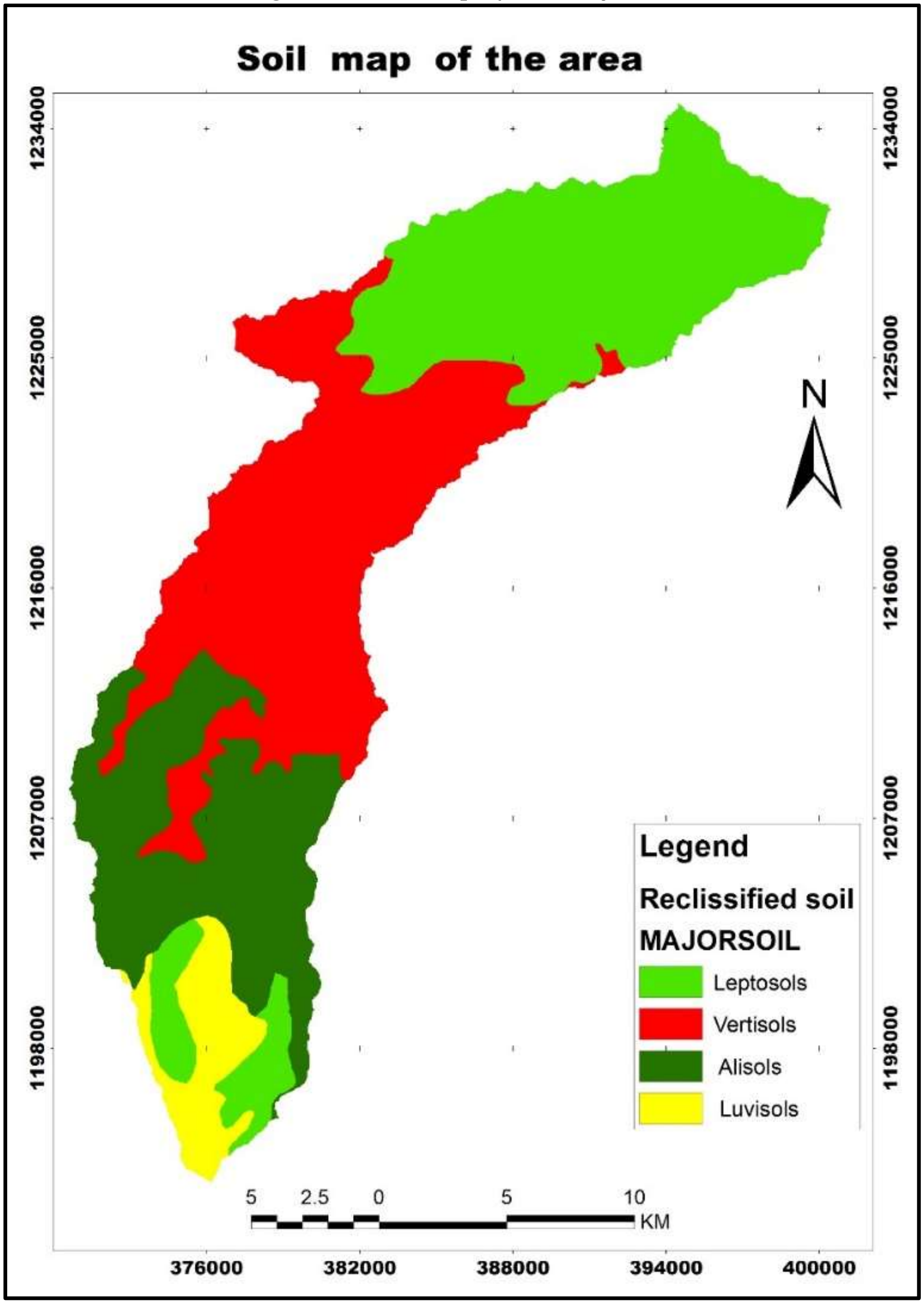
According to (FAO, 2001) Luvisols are moderately weathered soils and favorable physical properties, they have granular or crumb surface soils that are permeable and well aerated. The available moisture storage capacity is highest in the argic horizon (15 to 20 volume percent). The argic horizon has a stable blocky structure but surface soils with a high silt content may be sensitive to slaking and erosion. Luvisols with a good internal drainage are potentially suitable for a wide range of agricultural uses because of their moderate stage of weathering and high base saturation.

5.2.5.4 Alisols

The Alisols soils are consists of strongly acid soils with accumulated high activity clays in their subsoils. Hence, Alisols are unproductive soils under all but acid-tolerant crops. They occur commonly in old land surfaces with a hilly or undulating topography, in humid, sub- tropical and warm temperate regions. The Alisols are directly related to the relative contents of high-activity clays, low-activity clays and iron oxides. Where swelling and shrinking clays dominate the mineral accumulation, specific physical features may develop that resemble elements of *'vertic'* horizons.

Telltale signs are: distinct cracks, rapid bypass flow of water in dry soil and slow infiltration of water in wet soil, shining faces of structural peds, prismatic structure elements in the subsurface horizon and generally few macro-pores. Alisols in weathering materials from basic rock tend to have more iron oxides and more stable structures, particularly in the subsurface horizon. In many Alisols, textural differentiation between surface and subsurface horizons imparts different physical properties. Surface horizons tend to have an unstable structure (slaking) and reduced permeability, in particular where the subsurface horizon is dense and massive as is the case in Alisols that have relatively low contents of high activity clays and iron oxides. This restricts internal soil drainage and increases the danger of erosion in sloping lands. In cropped lands, the low level of biological activity, a direct consequence of the acid and nutrient-poor environment, further enhances the adverse physical properties of the surface horizon (FAO, 2001).

Figure 5.7 Soil map of the study area



Source: FAO soil classification.2001

Table 5.5: Weight for soil map of the study area

Layer	Classes	Area(sq.km)	rank
Soil Types	Vertisols	138.949	**7**
	Luvisols	22.802	5
	Alisols	86.612	3
	Leptosols	131.54	1

5.2.6 Land Use/Land Cover

One of the parameters that influence the occurrence of groundwater occurrence is the present condition of land cover and land use of the area. The effect of land use / cover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf. Water droplets trapped in this way go down to recharge groundwater. Land use/cover may also affect groundwater negatively by evapotranspiration, assuming interception to be constant (Tesfaye, 2010).

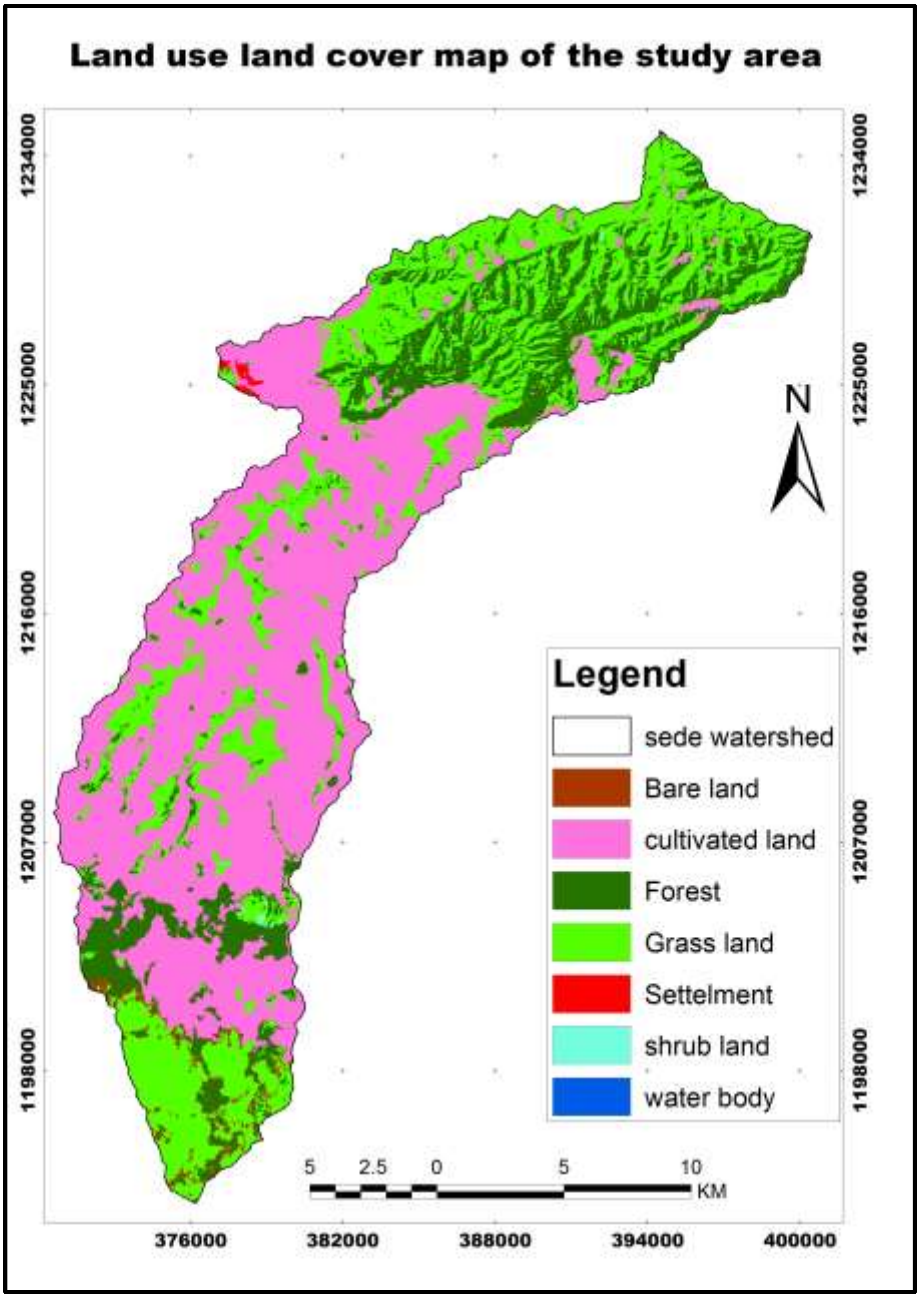
The land use/cover map of the study area was obtained from Ministry of science and Technology of China (National Geomatics center of China, 2014). It has launched the National high Technology research and Development program of china (863Program), named "remote sensing mapping and research on key technologies of Global Land cover" in 2010. As an outcome of the project, GlobaLand30-2010, mapping product of global land cover at 30 meter resolution derived from remote sensing images in 2010 is produced.

Global Land 30-2010 are mainly 30m multispectral images, including Landsat TM and ETM+ multispectral image and multispectral images of Chinese Environment Disaster Alleviation satellite (HJ-1). HJ-1A is a Chinese remote sensing satellite, aiming at environmental monitoring and disaster prevention and reduction. Hj-1 satellite carries multispectral camera (CCD) and hyper spectral image (HIS). Hj-1B satellite is loaded with multispectral camera(CCD) and infrared multispectral imager(IRS). 1465 senses of multispectral images of HJ-1 were used to derive land cover information, covering 60% of total land area of the globe (National Geomatics center of China, 2014).

The study area contained various land cover classes, namely cultivated land, forest, grass land, shrub land, water bodies, built up area and bare land (Figure 5.8), because of high population density in the rural area most part is covered by cultivation land. It covers an area of 184.65km^2

out of the total area of 380 km^2. It is evident from this below table 5.6 that the cropland takes largest share of the study area.

Figure 5.8 land use /cover map of the study area



Source: National Geomatics center of China, 2014

Classification of land use/cover for analysis was done based on their character to infiltrate water in to the ground and water hold capacity on the ground. The water bodies were given the highest weight over other land use features since its incessant recharge to ground, ensued by Evergreen forest only, which pull maximum amounts of water from the deep root zone for sustaining, resulting the present of water below the ground surface (Tesfaye, 2010 and Murasingh, 2014).

The grassland was given less weighted after cultivated land since is a crop which required huge amount of water and thus it act as a good groundwater recharge. Shrub land is a land that is covered with small bushes and tree whereas bare land is lack of vegetation cover. The land which was periodically sparse vegetation cover, sandy fields, bare rocks, saline and alkaline lands etc. For this reason it was given less weight than shrub land. Generally settlements are found to be the least suitable for infiltration (Table 5.5).

Table5.6: Weight for land use land cover map of the study area

Land cover	**Content**	**Area(km^2)**	**Rank**
Water bodies	Land including river, reservoir etc	0.0027	9
Forest	Land covers with tree, vegetation cover over 30%, including deciduous and coniferous forests, and sparse woodland with cover 10-30%	68.4540	7
Grass land	Lands covered by natural grass with cover over 10% etc	121.5036	5
Cultivated Land	Land used for agriculture	184.6503	3
Shrub land	Lands covered with shrubs with cover over 30%, including deciduous and evergreen shrubs and desert steppe with cover over 10%	0.4716	3
Bare Land	Vegetation cover lower than 10% including desert, sandy fields, gobi bare rocks, saline and alkaline lands etc	3.9348	3
Settlement	land modified by human activities Built up area,	0.9144	1

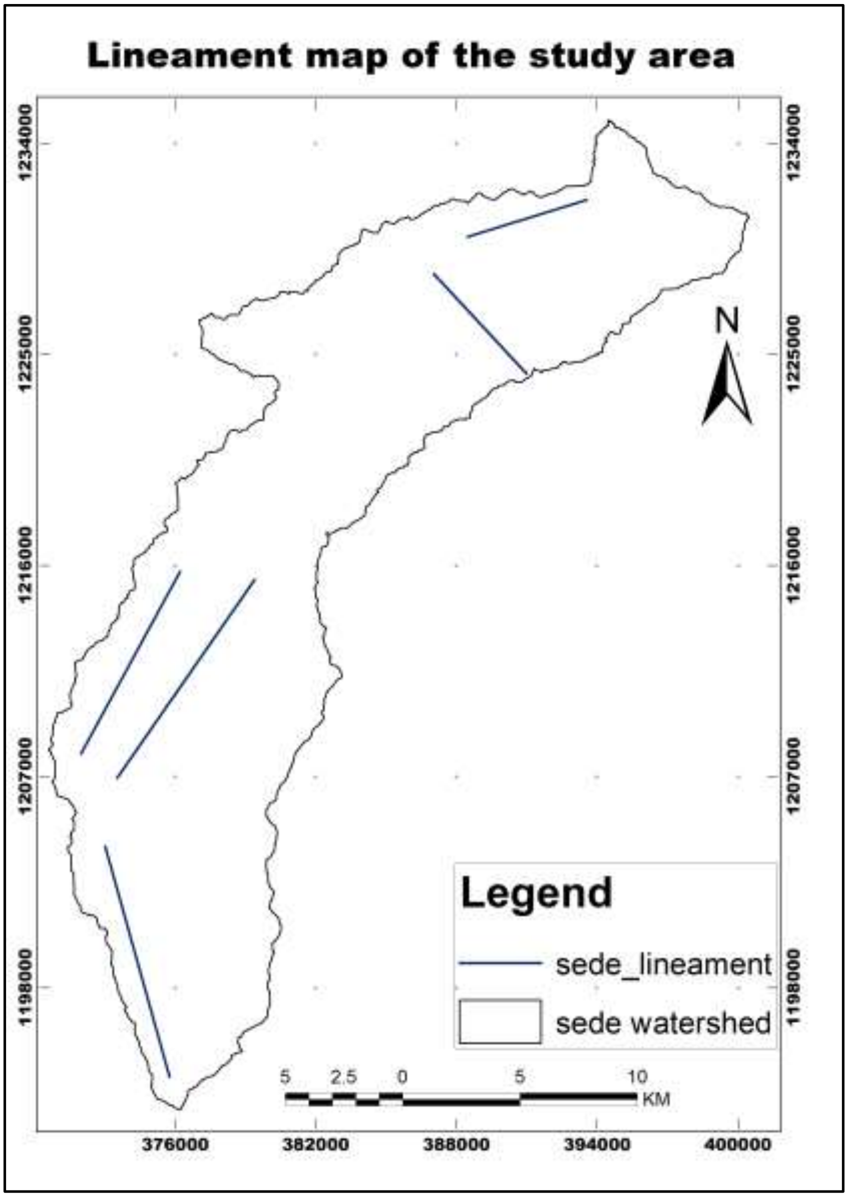
5.2.7 Lineament density

Lineaments are linear geomorphic features that are the surface expression of zones of weakness or structural displacement in the crust of the earth (Shivaji & Nitin, 2014). Lineaments are structural lines such as faults, which often represent zones of fracturing and increased secondary porosity and permeability, and therefore of enhanced groundwater occurrence and movement (Tesfaye, 2010). The characteristic of lines features may represent deep seated faults, fractures and joints sets, drainage lines and boundary lines of different rock formations

(Shivaji & Nitin, 2014). The hard rock terrain the storage and movement of groundwater is controlled by the secondary porosity i.e. presence of lineaments and fractures.

The lineament data was provided important information on subsurface fractures that may control the movement and storage of the groundwater in the study area. As observed from figure 5.9 the distribution of the lineaments was presented on north part, which is found the valley cuts of Abay and south part nearest to Choke Mountain area. The structure may act as pathways for water movement, it is overlay one to another as shown (Figure 5.2).

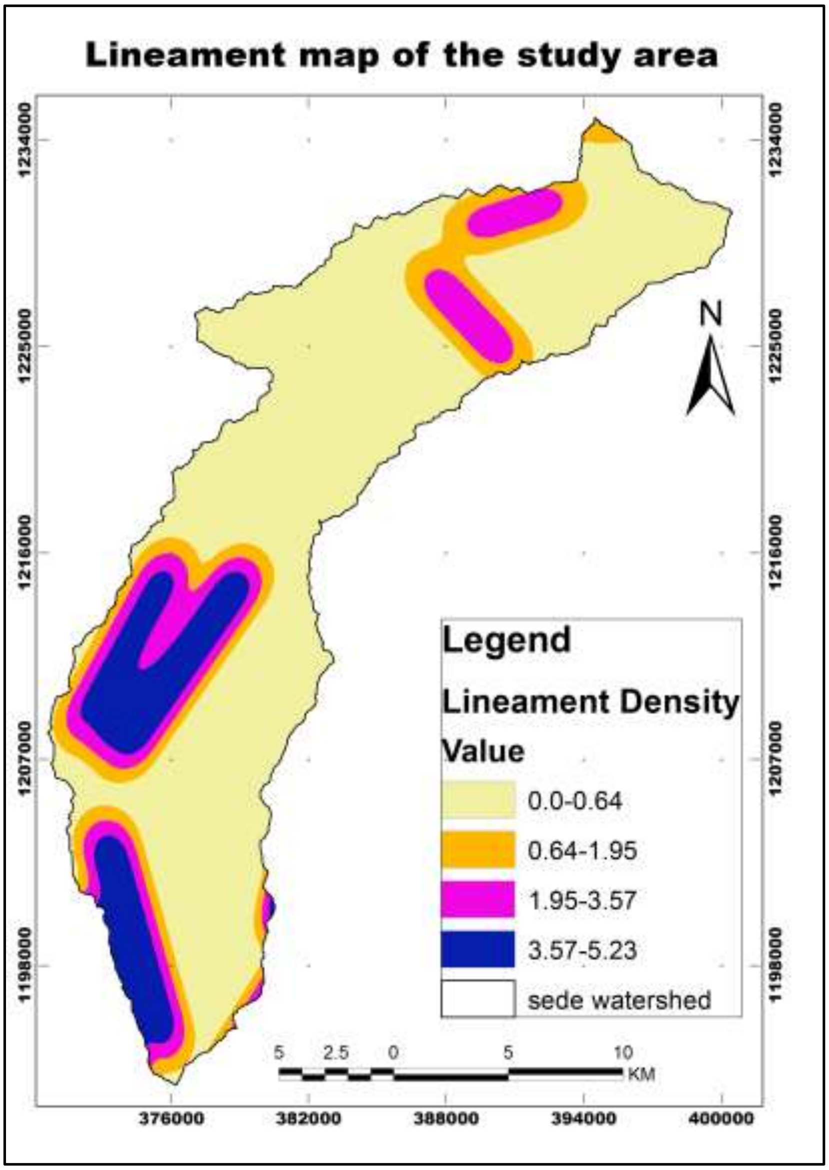
Figure 5.9: lineament map of the study area



Source: geological survey of Ethiopia, 2015

The study area lineament features was generated from geological map of Debre Markos and Debre Tabor sheet based on digitization method using GIS and have prepared the lineament map. Then, lineament density of the study area was calculated using kernel density analysis tool in GIS software and the area has been reclassified into four classes (0-0.64, 0.64-1.95, 1.95-3.57, 3.57-5.23) were produced (Figure 5.10). Reclassified map of lineament was assigned weight based on the fact that high lineaments density area are the highest zone of increased porosity and permeability which intern have greater chance of accumulating groundwater.

Figure 5.10: Lineament Density of the study area



Source: geological survey of Ethiopia .2015

Table 5.7: weightage of Lineament density map

Criteria	Classes	Lineament density	Ranking
Lineament Density	0-0.64	Very low	1
	0.64-1.95	Low	3
	1.95-3.57	Moderate	5
	3.57-5.23	High	7

5.2.8 Elevation

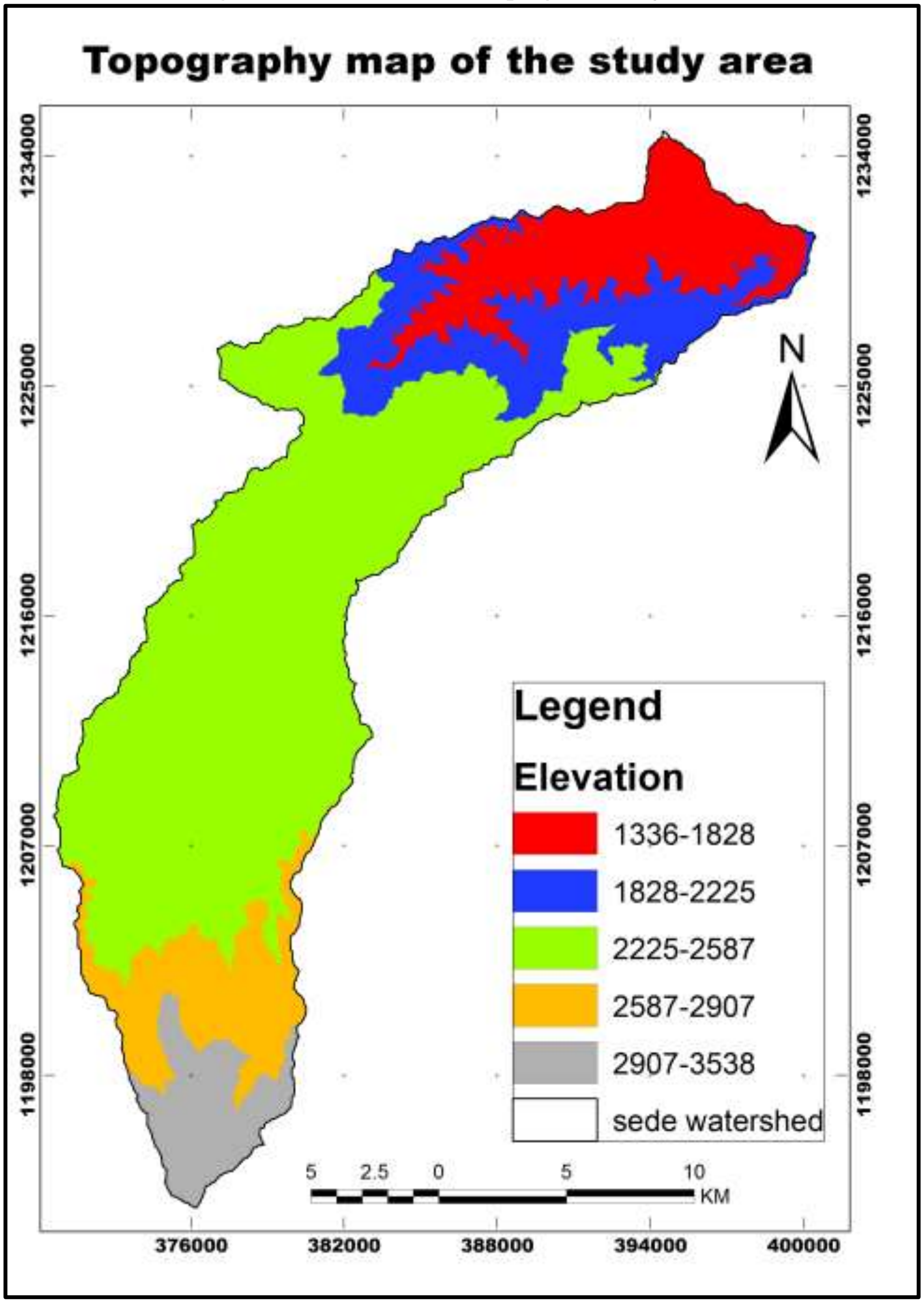
Topographic information has been derived from SRTM DEM 30 m resolution data. In the study area the elevation ranges starting from 1336 m to the highest peak at Choke Mountain part, 3538m. The central part of the study area is plain which is suitable for agricultural activity, the south side of the area have elevated area which is shared some parts of choke mountain that source of many rivers. But north part of the study area is gorge which is cut valley of Abay.

The topographic map was reclassified in to five classes of elevation were made. These are 1336-1828m, 1828-2225m, 2225-2587m, 2587-2907 and 2907-3538m. Many springs emerges out at lowlands are originated from highland area (Tewodros, 2005). Water tends to store at lower topography than at higher topography as a reason high weight is assigned for lower elevation areas as compared to higher elevations (Table 5.8) and Figure 5.11.

Table 5.8: Elevation map of the study area

Criteria	Classes	weight
Elevation in (meter)	1336-1828	9
	1828-2225	7
	2225-2587	5
	2587-2907	3
	2907-3538	1

Figure 5.11: Elevation map of the study area



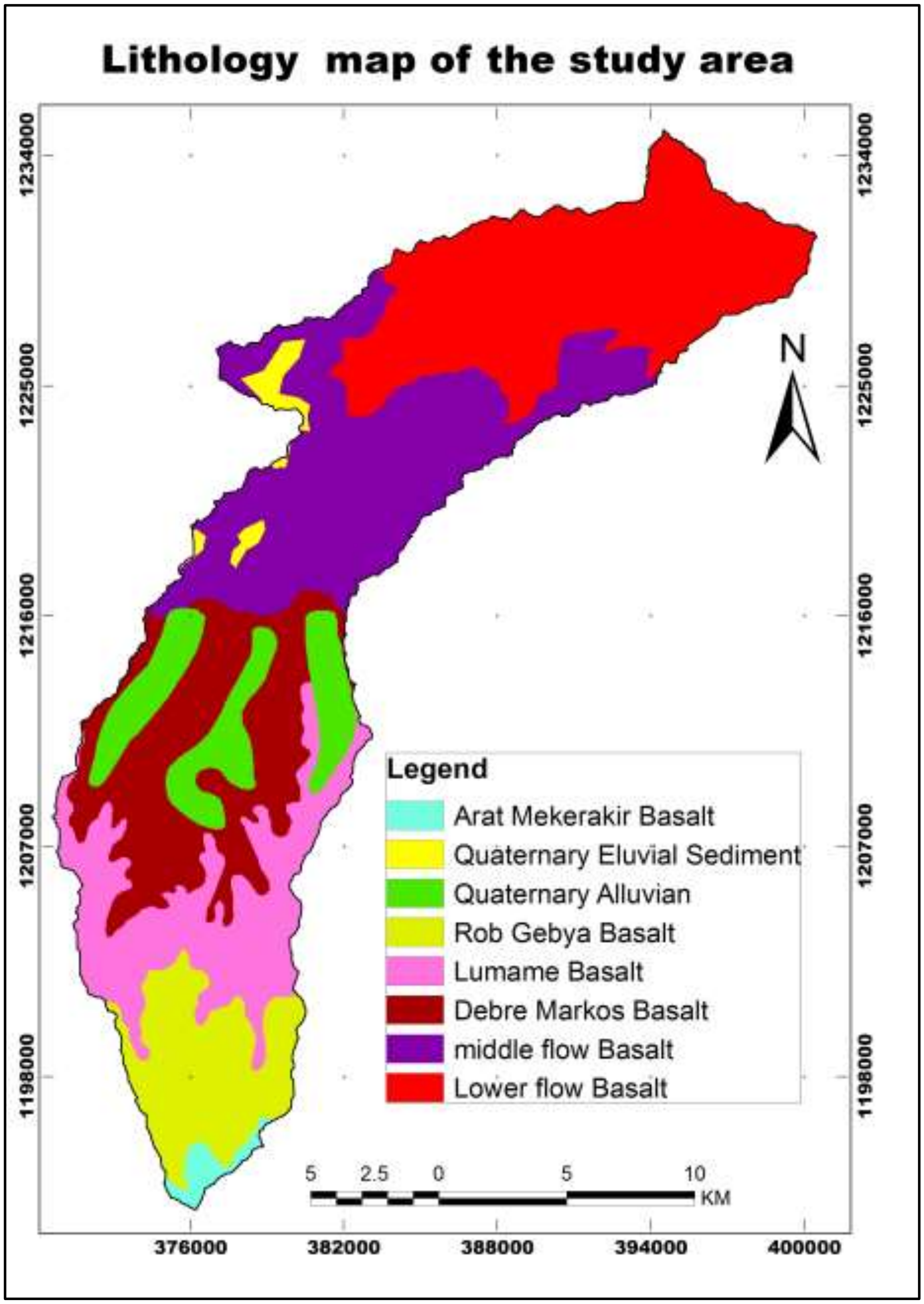
Source: SRTM DEM, 2014

5.2.9 Lithology factors

Groundwater inevitably occurs in geological formations that require knowledge of how these earth materials formed and the changes they have gone to understanding the distribution of geologic materials (Fitter, 1994 cited (Tesfaye, 2010)).

This study was utilized the preliminary geological maps, which is prepared by Ethiopia geological survey at 1:250,000 scales. The general lithology of the Sede Watershed which has been under fall on the Debre Markos and Debre Tabor geological sheets, which is derived from these map using digitization method after georeferenced and mosaic two sheets. The geology information area is describe as follows:

Figure 5.12 Geological map of the study area



Source: Geological survey of Ethiopia, 2015

a. **Quaternary Eluvlal Sediments**

The eluvial sediments in the study area developed from all rock types from the incipient alteration of the bed rocks to 4 m thick. These sediments covers about of the study area and exposed in central parts of the area the south and east of Mota. It is residual and transported soils occupying flat lying and gentle topography represented by sand, silt, clay, and gravels in various proportions. Infiltration is particularly good in areas where the plateau is covered by thick elluvial sediments (Seifu, 2013). The alluvium is relatively transported soil and lacks coarser sand or gravel or pebbles and is mainly massive brownish clayey-silty soil. They are devoid of any sedimentary structure. Probably fine sediments have been accumulated in young wider valley and later also changed to soil insitu soil (preexisting). These are fertile for agriculture, but the local people kept them for pasture. The percentage of voids of the sediments, their porosity varies from region to region, but on the national scale more than 50 percent of the sequence are suitable for yielding water (Dr. A RONAl, 2010). An aquifer is geologic units that can store and transmit water at rates fast enough to supply reasonable amounts to wells (Fetter C.W., 2001). To account for varying geology alluvial deposits, volcano –sedimentary rocks, recent basalts and lacustrine sediments were assigned highest weightage due to their higher porosity and impermeability. The most important characteristic features governing the groundwater movement and accumulation in unconsolidated pyroclastic materials are related to fragment size, sorting and degree of cementation. In the study area loose pyroclastic material includes ash and agglomerates (Addis Ababa University Department Of Geology & Geophysics, 2003).

b. **Middle Basalt Flows**

This unit is exposed in various localities lying above the Lower lava flows with distinct unconformity, marked by paleosoil. They are thin relative to the lower lava flows (Workineh, et al., 2010). Even though, thick volcanic successions are recognized, south of Abay River near Ezana village, most of the times they make 4 to 6 lava units are commonly recognized. Lava layers show 7 to 10 metres thick, but at places one layer can measure 40 to 50 metres. The general thickness of middle basalt flow can reach up to 300 metres and at places pinch out to zero meters. The middle basalt flows covers an area of 96.03 km^2 of the study area.

According to (Workineh, et al., 2010) report, these basalts are also stratified and form continuous basalt layers with rare pyroclast intercalation. To the west of Motta (study area) differentially weathered basalt layers are more or less horizontal and show jointing which are mainly vertical.

The middle basalts to the south of Abay around Mota to Gonj cover plateau surfaces, and to the west the topography is covered by pyroclastic flow, containing rock blocks of basalts, scoria boulders and cobbles. The layered basalts forming cliffs are mostly deeply weathered on top of each layer giving different weathering colors.

According to (water well drilling Enterprise, 2014) report of Mota Town Borehole(BHI-04), the major aquifer of the well as can be seen from the lithological log is basalt. The borehole geology is mainly basalt; massive basalt, and weathered and fractured basalt up to the final depth. The geology and the Hydro geological setting of the area indicate mainly fractured flow in fractured and weathered zones. Based on the physical parameters, i.e. Transmissivity, hydraulic conductivity and well efficiency calculate from the pumping test data, the aquifer shows good groundwater potential presented on the area (water well drilling Enterprise, 2014). The lithological formation for this borehole is shown below.

Ttable 5.9: Lithological Description of Motta borehole around Sede Town

Drilled Depth (m)		***Lithological Description***	***Thickness***	***Remark***
From	To			
0	2	Top Soil	2	
2	4	Sticky clay	2	
4	10	Silt	6	
10	22	Decomposed basalt	12	
22	28	Weathered basalt	6	
28	36	Fractured basalt	8	
36	46	Slightly fractured basalt	10	
46	52	Fractured basalt	6	
52	62	Slightly fractured basalt	10	
62	66	Silt	4	

66	70	Highly fractured basalt	4	
70	92	Massive basalt	22	
92	102	Highly weathered basalt	10	
102	118	Slightly fractured basalt	16	
118	124	Fractured basalt	6	
124	128	Slightly weathered basalt	4	
128	144	Slightly fractured basalt	16	
144	150	Sand	6	
150	158	Weathered basalt	8	
158	164	Massive basalt	6	
164	166	Fractured basalt	2	
166	170	Massive basalt	4	
170	174	Slightly fractured basalt	4	
174	180	Fractured basalt	6	
180	186	Weathered basalt	6	
186	192	Slightly fractured basalt	6	
192	194	Tuff	2	

Source: Water Well Drilling Enterprise,2014

c. **Lumame Basalt**

This unit covers about 53 sq.km and is exposed in the western, northwestern, northern and central part of the study area. It forms hills, ridges, escarpment/cliffs, moderate slope and flat-lying topography and columnar jointed. This unit locally inter layered with pyroclastic tuff. The top most part of this unit overlain by the Choke shield volcano. These basalt is dark, porphyritic with maximum of 1.1 cm size plagioclase phenocrysts and occasionally aphyric; sometimes vesiculated and amygdaloidal with silica amygdules. The seriate texture is the dominant type porphyritic texture and the minors are vesicles and silica. The trachytic texture has observed from some thin sections. Weak to moderate alterations (chemical weathering) change the olivine and pyroxene minerals to clay minerals along fractures and at rims and the rock has green color due the alteration effect in mesoscopic scale. The origin, flow and chemical constituent of groundwater is controlled by the type of lithology, distribution, thickness and structure of hydro geological units through which it moves (Ferede, 2015).

d. **Debre Markose Basalt**

This unit covers about 57.78 km^2 and is exposed in southern parts of the study area, which are mainly located on Addis Alem, Abiyote Selam, Debre Tsehay and Debre Selam kebele administration area. It forms escarpment/cliffs, ridges, hills, moderate slope, gentle slope and flat-lying topography, and columnar jointed. This basalt is occasionally interlayered with pyroclastic tuff. The top most part of this unit overlain by hill forming pyroclastic tuff, lithic tuff and the associated siltstone. The columnar joints with its horizontal failure line folded and, due to the folding effect the columnar joints fan to downward and convex into upward or fan to upward and convex into downward and sometimes folded. These basalt is dark with porphyritic (maximum plagioclase phenocryst is 8 mm) and aphyric texture and, has blocky appearance and spheroidal weathered. Occasionally it is vesiculated and amygdaloidal with calcite amygdules (Ferede, 2015). The boulders of the debre markos basalt mantled the down slope surface, where the topography is steep slope and moderate slope.

The seriate type texture dominates in porphyritic texture. The plagioclase laths in some thin sections form trachytic texture. The chlorite has been derived from pyroxene and olivine. The idding site has been derived from olivine along fractures or at rims. Calcite has filled the vesicles. In some thin-sections the calcite has been derived from plagioclase, pyroxene and olivine.

The area forms gently undulating plain that receives adequate rainfall and has moderate run-off resulting in good direct rainfall infiltration and formation of extensive and moderately productive or locally developed and highly productive fissured aquifers (Seifu, 2013).

e. Rob Gebeya Basalt

This unit covers about 36.84 km^2 of the study area and is exposed at the base of the Choke mountain shield volcano. The pyroclastic tuff and trachyte sills interlayered with Rob Gebeya basalt. Pyroclastic tuff are forms hills on flat lying area. The thick pyroclastic tuff has overlain by the thin basalt layer. The pyroclastic tuff is white, very fine-grained (volcanic ash), light weight and very thinly bedded. The basalt is aphyric and occasionally contains plagioclase phenocrysts as minor (Ferede, 2015). In these basalt, the interlayer of acidic lava and ash components with fractured basaltic layers create a unique feature for groundwater storage in movement (Seifu, 2013). The area have normal fault to form the contacts between different lava flow units and leads to enhancing permeability and storage properties of the shields (Seifu, 2013). Highly permeable but fractured lava act as excellent conduits but have themselves only limited storage. Due to these the choke mountain shied volcano has a source of more than 59 rivers and 273 small springs which are the main tributaries of Blue Nile (Getnet, 2012).

f. **Arat Mekeraker Basalt**

This unit covers about 3.95sq.km of the study area and overlying the Rob Gebya basalt unit. At places the top most position of the Arat Mekeraker basalt overlaid by pyoclastic lithic tuff, basaltic agglomerate and pyroclastic tuff with thin layer of coal seam, which are cross-cut by the basalt dyke. The Arat Mekeraker basalt is dark, porphyritic and aphyric, occasionally vesiculated and amygdaloidal with silica amygdules (Ferede, 2015). From petrographic study the Arat Mekeraker basalt basalt represents plagioclase phyric basalt and olivine-plagioclase phyric basalt. The groundmass is composed of opaque, pyroxene, olivine and plagioclase laths. The seriate and trachytic textures present in a rock. The volcanic, especially basalts (usually Cainozoic age) extending over large parts of the high lands, can transmit or store water depending on several facrors such as extent of weathering , fracture pattern and suitability of geomorphology and other factors (Pavelic, et al., 2012).

g. **Lower Lava Flows**

These basalt flows cover the lower most parts of volcanic successions of the map area. They are mainly found in the valley cuts of Abay, and its tributaries Sede and others in the study area. The basalts are generally stratified and cover laterally extensive areas. In many of its exposure it is intercalated with pyroclastic flows (mainly scoria flows). Rarely lahars expose at localized areas for example to the north of Mota. The basalts are generally variable in composition, color, grain size and vesicularity along stratigraphy and lateral extent. They are often aphanitic, medium grained, coarse grained vesicular basalts. The coarse grained ones are plagioclase phyric basalts, olivine phyric basalts or pyroxene phyric basalts. In some localities west of Mota dolerite dikes/ vesicular basalt have been recognized. The scoria flows are reddish with rock fragments of coarse sand, cobbles, boulders cemented by lesser size materials. The porphyritic pyroxene basalt is coarse grained, black and compact with vesicles filled with zeolite and calcite. Aphanitic basalt is dark grey, and very fine grained and often slightly weathered. Sections of lower basalts are in most cases covered by slope deposit. The rhyolite is massive (70 m. thick) but at places show flow banding of few millimeter to centimeter. The scoria flows are coarser and boulder, and may represent near source facies in between the widely occurring fissure related flood basalts. The lower lava is terminated by tuffs or ash-flow tuffs or trachytic obsidian in some places. Changes in slope character and the occurrence of tuffs or trachytes are features to differentiate them from the overlying middle basalts. Low values were assigned for peralkaline Dino formations less affected by faulting and Fracturing (Tesfaye, 2010).

Generally the quaternary Eluvial and Alluvial sediments units that can store and transmit water at rates fastest than other types of lithological unit on the study area. In addition Middle basalt flows are highly weathered and fractured basalts, which are facilitate Infiltration rate as well as holding water on subsurface. According to water well drilling Enterprise, 2014 lithological logging report Middle basalt flows have a good groundwater potential presented on the area. But Lumame basalt and Debre Markos basalt unit locally inter layered with pyroclastic tuff. Lumame basalt are takes placed weak to moderate alterations change, therefore infiltration rate and porosity are increased due the alteration effect Whereas Debre Markos basalt unit has folded due to the case of the columnar joints horizontal failure. These forms gently undulating plain and that receives adequate rainfall and has moderate run-off resulting in good direct rainfall infiltration and formation of extensive and moderately productive aquifers.

In Rob Gebeya basalt, the interlayer of acidic lava and ash components with fractured basaltic layers leads to enhancing permeability but have themselves only limited storage. In the Arat Mekeraker basalt covered in small area, which are cross-cut by the basalt dyke. The volcanic, especially basalts can limited transmit or store water relative to the above lithological unit. In the lower lava flows cover the lower most parts of volcanic successions of the study area and mainly found in the valley cuts of Abay. The area has obtained low amount of rainfall, the steepest topographic area and covered with massive basalt. The basalts are generally less affected by faulting and Fracturing, which is low storage rainwater and limited transmit compared to others units on the study area. Based on the influenced on the of groundwater occurrence, weight was assigned for each classes of lithology as follow:

Table 5.10: weightage of lithotogy map of the area

Layers	**classes**	**weight**
Lithology	Quaternary Eluvlal Sediments	9
	Quaternary Alluvium	9
	Middle basalt flow	7
	Debre markos basalt	5
	Lumame basalt	5
	Rob gebya basalt	3
	Arat mekerakir basalt	3
	Lower flow basalt	1

Table 5.11: Rank and % of influence of different thematic layers

No.	**Theme**	**Weight %)**	**class**	**weight**
1	lithology	**34**	Quaternary Eluvlal Sediment	9
			Quaternary alluvium	9
			Middle basalt flow	7
			Debre markos basalt	5
			Lumame basalt	5
			Rob gebya basalt	3
			Arat mekerakir basalt	3
			Lower flow basalt	1
2	Lineament density	**22**	0.00-1.43	1
			1.44-2.86	3
			2.87-4.29	5
			4.30-5.72	7
3	rainfall	**15**	1020-1156	3
			1135-1235	5
			1236-1307	7
			1308-1376	9
4	slope	**10**	0-2	9
			2-5	7

			5-9	5
			9-22	3
			22-71.13	1
5	Drainage Density	**7**	0-0.27	9
			0.28-0.66	7
			0.67-1.00	5
			1.1-2.31	3
6	Elevation	**5**	1302-1828	9
			1828-2225	7
			2226-2586	5
			2587-2905	3
			2906-3727	1
7	soil	**4**	Vertisols	7
			Luvisols	5
			Alisols	3
			leptosols	1
8	Land use	**3**	Waterbody	9
			Forest	7
			Grass land	5
			Cultivated land	5
			Shrub land	3
			Bare land	3
			settlement	1

5.3 Integrated Analysis in GIS

The main objective of the study is to generate groundwater potential zone of the study area by integrating different thematic maps. In order to produce the potential groundwater zone map using remote sensing and GIS analysis of eight thematic maps was used. The thematic maps were rasterized, reclassified and given appropriate weight in order to integrate them to produced final groundwater potential map.

The weights of each thematic map were assessed based on Satty's Analytic Hierarchy Process (AHP) with pairwise comparison. In this method the relative importance of each factor map were

compared to other in the contribution of ground water occurrence on the study area. Hence, the important matrix and calculated weight of the factors was computed in IDRISI 32 software.
These matrices have the property of consistency known as consistency ratios (CR). Satty indicates that the matrices with consistency ratio ratings greater than 0.1 should be re-evaluated. In this case the consistency value was 0.07 which is accepted (table 5.12). This way it helps to analyses the matrix to determine the inconsistency in defining the interrelationships. The weights derived from this method were normalized after multiplying them by 100 and rounded to integer value to avoid complexities of computation in further analysis. These weights were applied in Weighted overlay analysis to obtain a unified weight map containing due weights of all input variables, which was further reclassified to arrive at groundwater potential map.

Figure 5.13 Weights of parameters determined using analytical hierarchy process

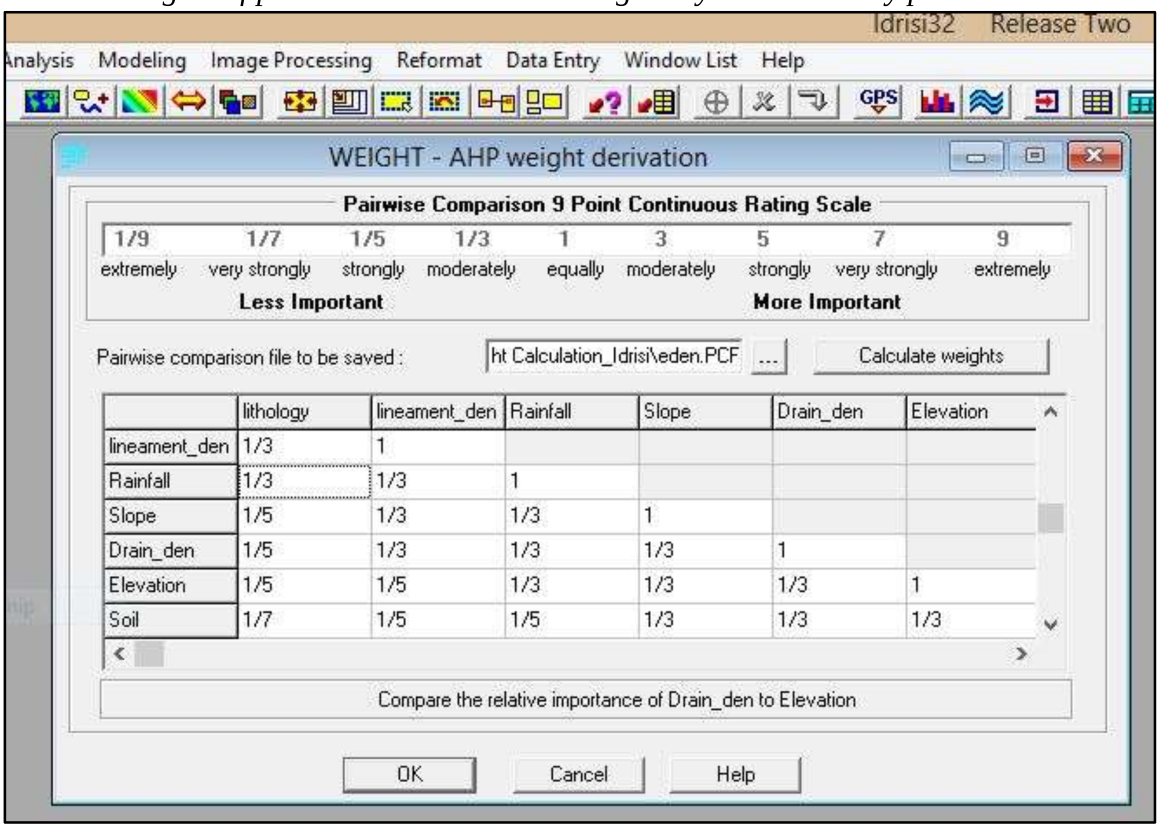


Table 5.12: Pair wise Comparison matrix

	litho	Line	Rain	Slope	Drain	Elev	soil	Land	weight	Weight (%)
Litho	1								0.3445	34
line	1/3	1							0.2202	22
Rain	1/3	1/3	1						0.1509	15
slope	1/5	1/3	1/3	1					0.0976	10
Drain	1/5	1/3	1/3	1/3	1				0.0733	7
Elev	1/5	1/5	1/3	1/3	1/3	1			0.0523	5
Soil	1/7	1/5	1/5	1/3	1/3	1/3	1		0.0356	4
Land	1/7	1/7	1/5	1/3	1/3	1/3	1/3	1	0.0256	3

Consistency ratio = 0.07 Consistency is acceptable

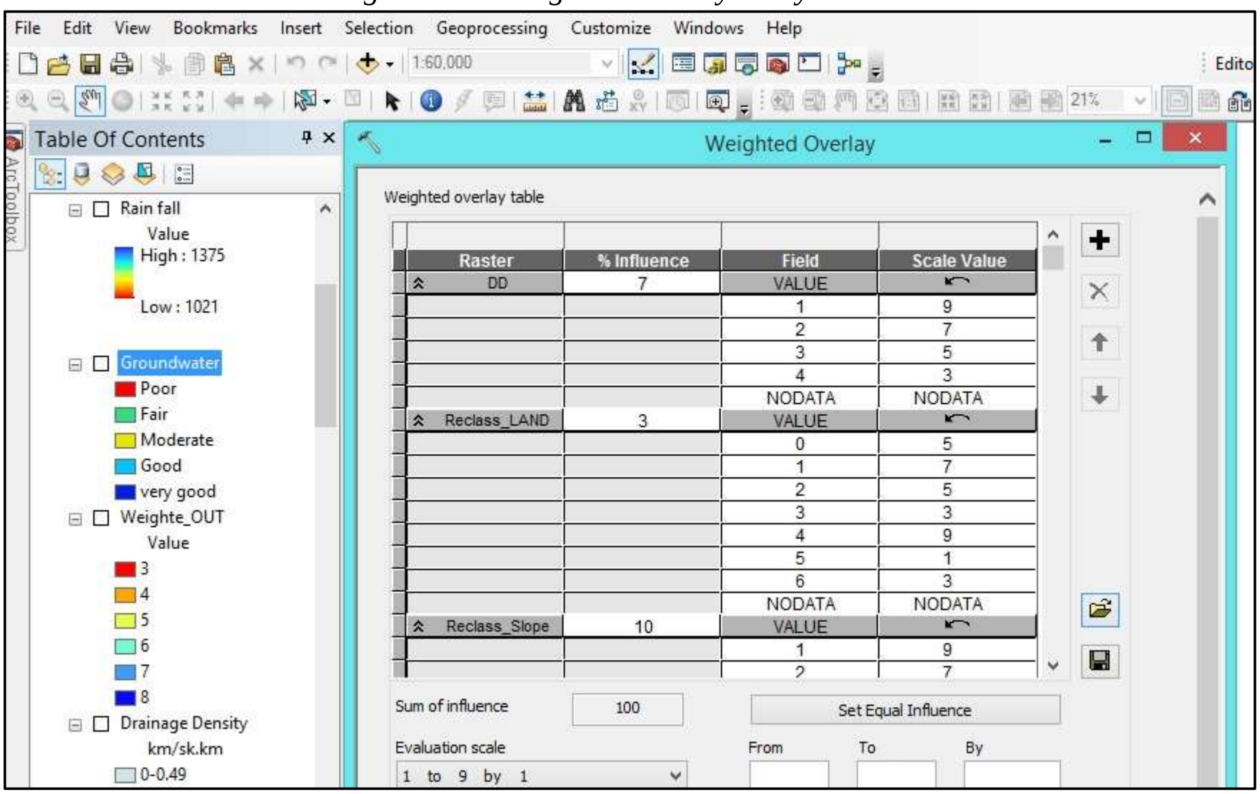
Key

Litho = Lithology Line = Lineament density rain =rainfall

Rain = Rainfall Drain = drainage Density slope= slope

Elev= Elevation Land = land use/cover

Figure 5.14: weighted Overlay analysis table



5.4 Result

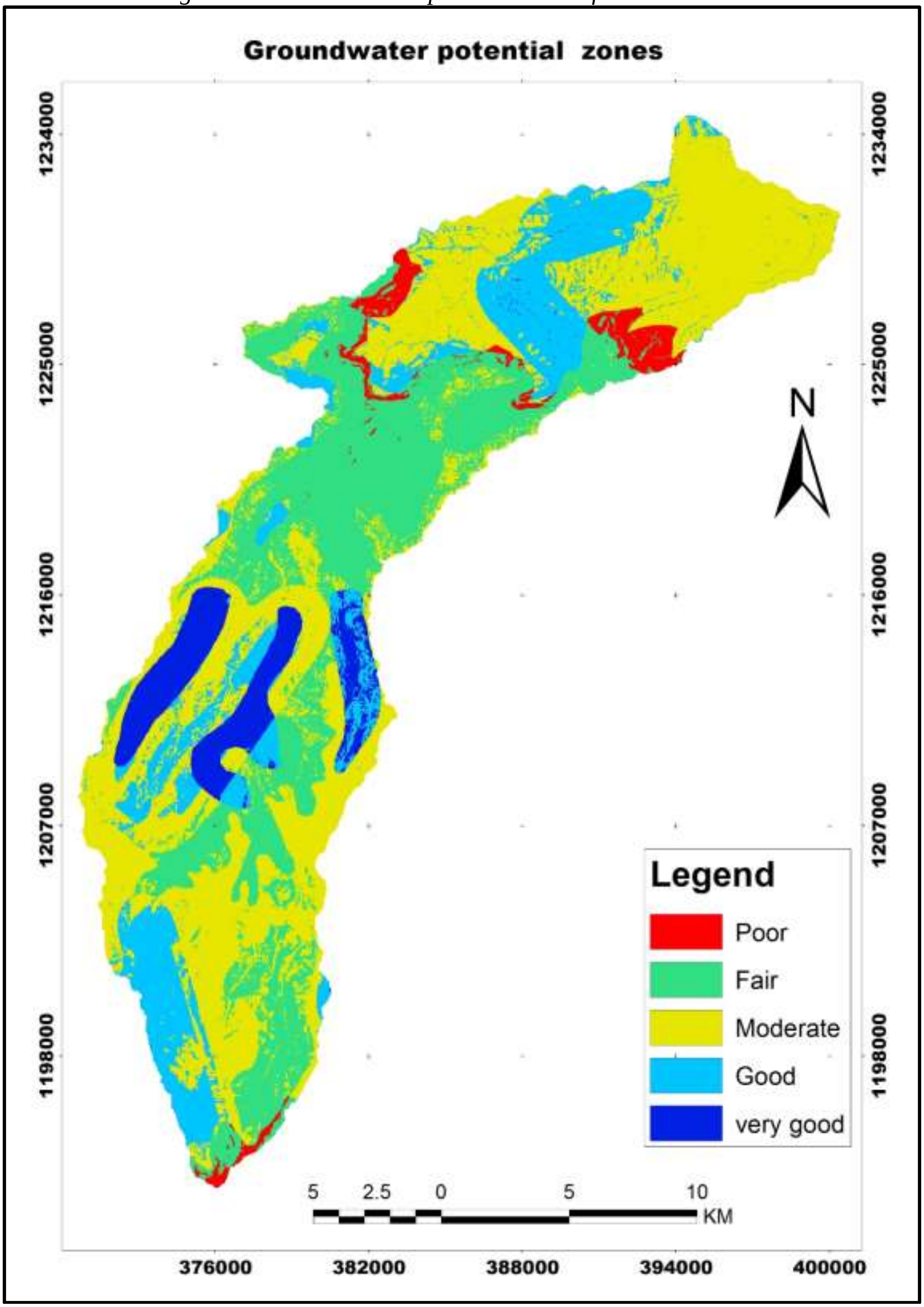
The analysis would give meaningful results without the need of conducting fieldwork, geophysical and test drilling which are time, effort and cost consuming activities. This technique would give broad ideas about the groundwater potentiality of the areas. By the integration of all the thematic maps, groundwater potential zones were delineated and classified as: very good potential, Good, Moderate potential, fair potential and poor potential zones, which are covered 24.3855, 68.3325, 164.3526, 111.3453 and 10.8963 km^2 area respectively (Figure 5.15 and table 5.12).

The very good groundwater potential zones are correspond to flat lying and gentle topography area and coincide with quaternary alluvial sediments. which is occurred mainly along the river channels containing residual and transported soils like clay and silt to coarse sand and gravel, is various composition have high water storing and transmitting capacity. The land use of the area covered by grass land, occurred in central part of the area, which is the nearest to the intersection of Ayibar River and Sede River and covered Addis Alem, Debre Selam and Abiyote Selam kebele administration. The good potential zones also matched with high lineament density area and the land use is covered with spares forest area and occupied by the quaternary aluvial sediments and fractured middle basalt flows. Moderate potential zone is the largest area, which are covered 164.3526 km^2. It is present on the slightly slope area which is occupied by sparse forest land, shrub land, bare land and few cultivated area. It is highly dominated on the north and south part of the study area. Fair Groundwater potential zones are highly available on the cultivated land throughout the study area. The area is flat and gentle topography and covered by veritosls soil, which are low infiltration rate. The poor potential is mostly presented on mountains and escarpments with steep cliff, where the area have high drainage density and high run-off area.

Table 5.13 Groundwater potential zones of sede watershed

No.	Groundwater potential zone	Area coverage $(km)^2$	Area in %
1	Very good	24.3855	6.43
2	Good	68.3325	18.01
3	Moderate	164.3526	43.33
4	Fair	111.3453	29.35
5	Poor	10.8963	2.87

Figure 5.15 Groundwater potential zone of Sede watershed



5.5 Result validation

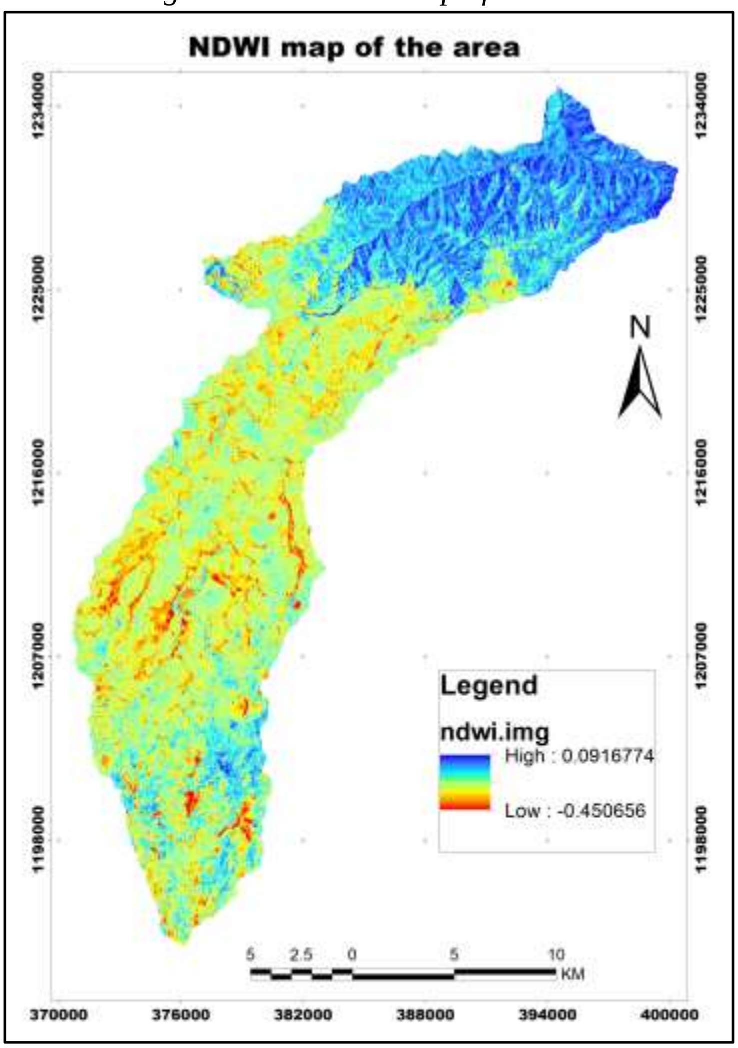
The validation of the groundwater potential zone generated using GIS and remote sensing techniques were crosschecked through overlay method with NDWI, NDMI and existing boreholes data which is collected from Hulet Eju Enesie woreda water resource and development office.

5.5.1 Normalized Difference Water Index

The Normalized Difference Water Index (NDWI) of the area derived from USGS Landsat 8 imagery, dated of 2014-11-09, which was developed for the extraction of open water features of the study area. Which is to achieve the signature differences between water and other targets through analyzing signature features of each ground target among different spectral bands. The NDWI is calculated through the following equation suggested by (Abhay, 2014).

$$\text{NDWI} = \frac{\text{Band 3} - \text{Band 5}}{\text{Band 3} + \text{Band 5}} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}} \text{……………………………equation 1}$$

Figure 5.16: NDWI map of the area



The results showed that there is no pixels which shows the permanent open water body (figure 5:16). The river is seasonal that depends on the rainfall. Therefore the result clearly indicated that the area has surface water scarcity except the rainy season. Usually the water pixels shows the value above +0.2 till 1 and it has been found through the value that there is no water pixel in study area.

5.5.2 Normalized Difference Moisture Index (NDMI)

According to Crist and Cicone (1984) and Wilson and Sader (2002) cited by (Abhay, 2014), NDWI and NDMI are theoretically similar to each other for detection of spatial variation of surface wetness. As it discussed above that there is no water pixels have been identified through NDWI. Therefore the NDMI was needed to check the wetness present in soil. The wet/moisture pixels are given the idea about these regions where the water can resist for long time often finishing the rainfall event. Because the water cannot resist on uplands, therefore the result also showed the moisture pixel flat and valley regions, which is allowing more time for rainwater to percolate the subsurface. The NDMI is calculated in Landsat 8 image through the following equation suggested by (Rokni, et al., 2014).

$$\text{NDMI} = \frac{\text{Band 5} - \text{Band 6}}{\text{Band 5} + \text{Band 6}} = \frac{\text{NIR} - \text{SWIR 1}}{\text{NIR} + \text{SWIR 1}} \text{......................equation 2}$$

In NDMI, the high values indicate the existence of more soil moisture under massive water bodies and low values denote low soil moisture content. The NDMI value more than +0.20, the result it indicates moist soil surface with very good potentiality of ground water and from +.20 to +0.10 indicates wet to dry soil with moderate potentiality (Wilson and Sader 2002, Goodwin et al. 2008 cited by (Abhay, 2014)). The values of NDMI showed the range from -0.246 to +0.39. Therefore, high values represent the moisture content of the area (figures 5.17). Moreover, the NDMI were also overlaid on ground water potential zones to relate both maps where the groundwater is occurred (figure 5.18). These together highlight the area of water potential that can be stored after the rainfall season and be utilize for the domestic purpose for community.

The NDMI are present mainly along the river channels and seasonal streams containing various soil composition that have high water storing capacity. NDMI also occurred in south part of highland area which is recharged with precipitations and having closest to lineament give rise to have high permeability and productivity.

Figure 5.17 NDMI map of the study area

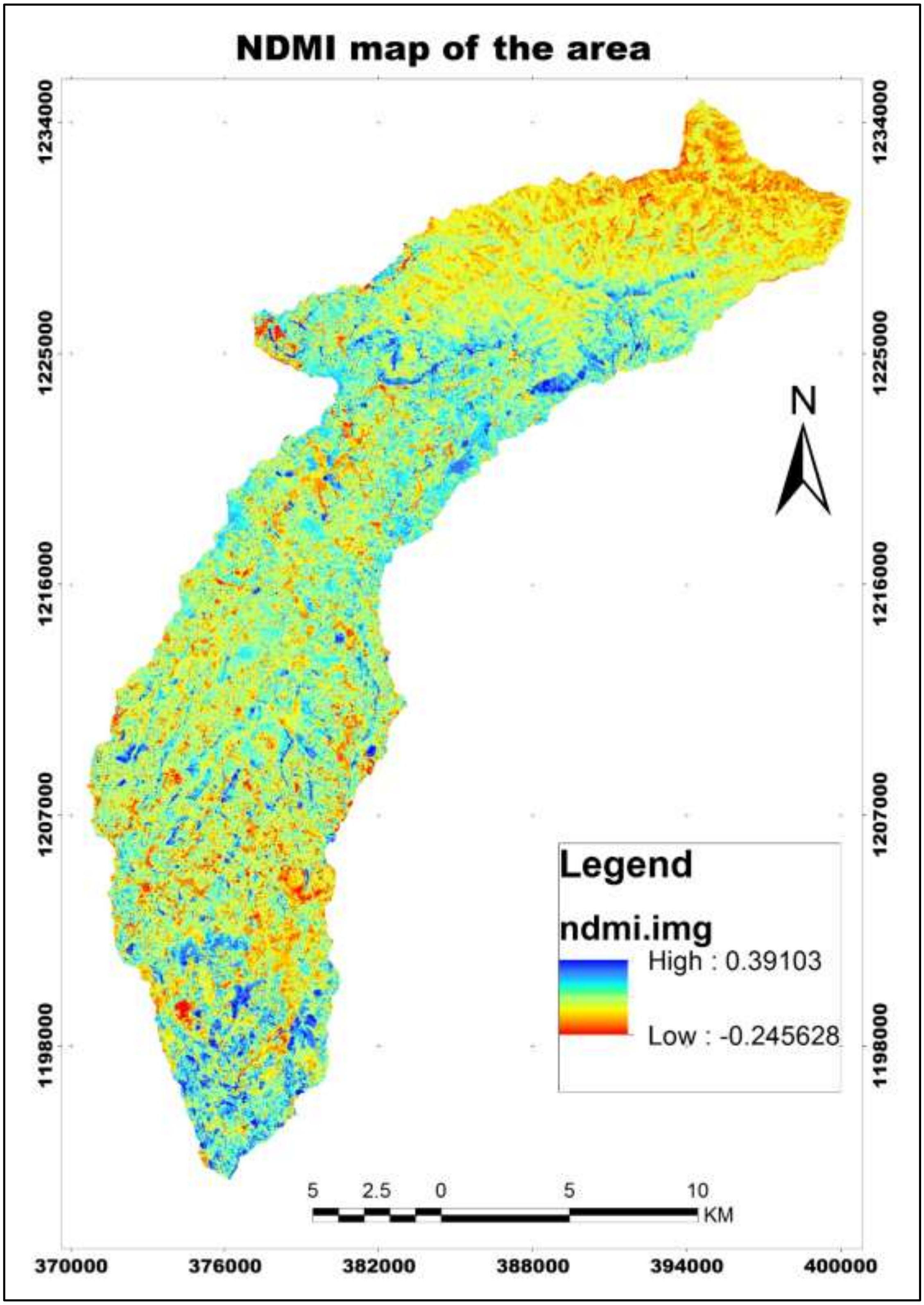
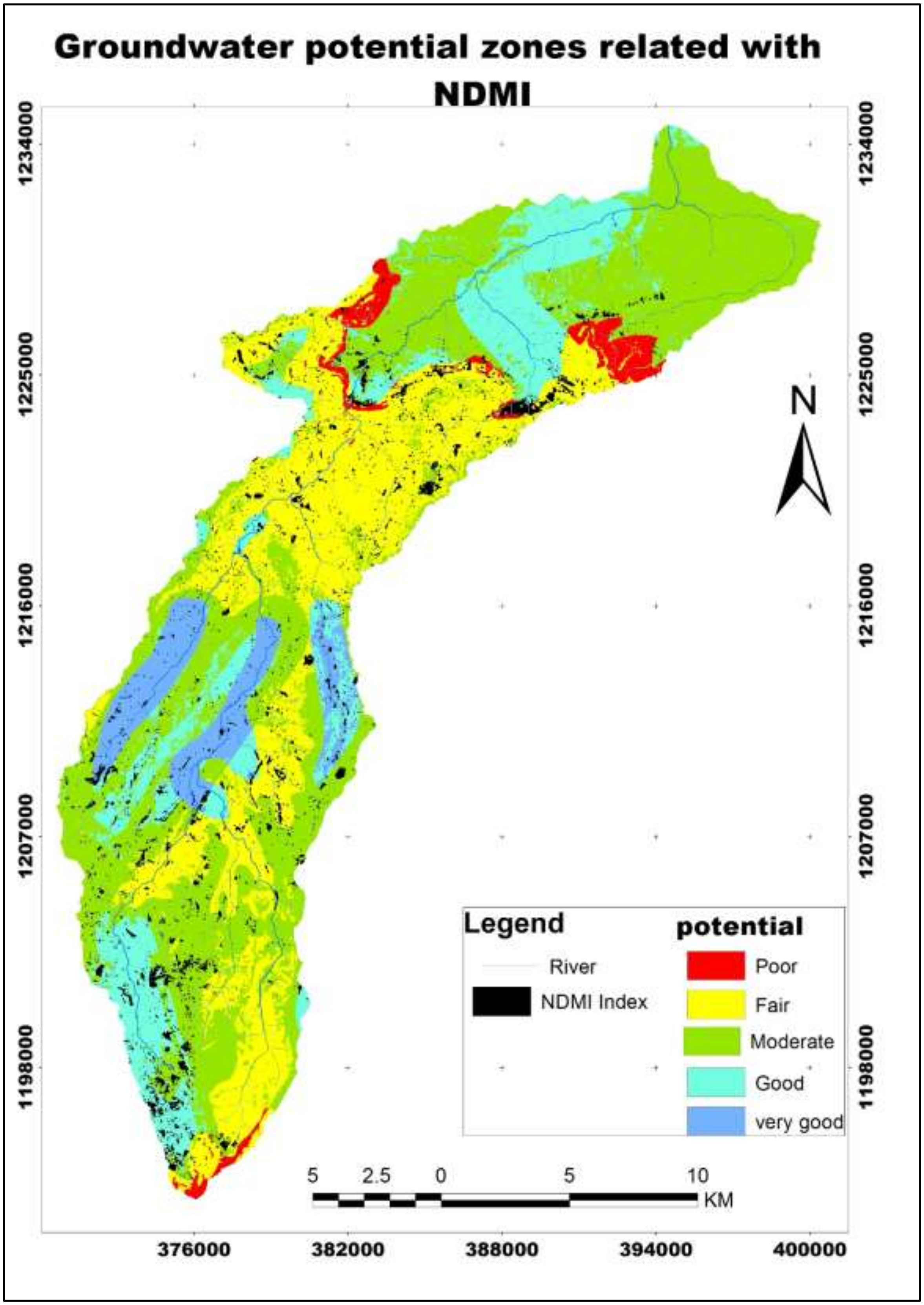


Figure 5.18: Groundwater potential zones related with NDMI

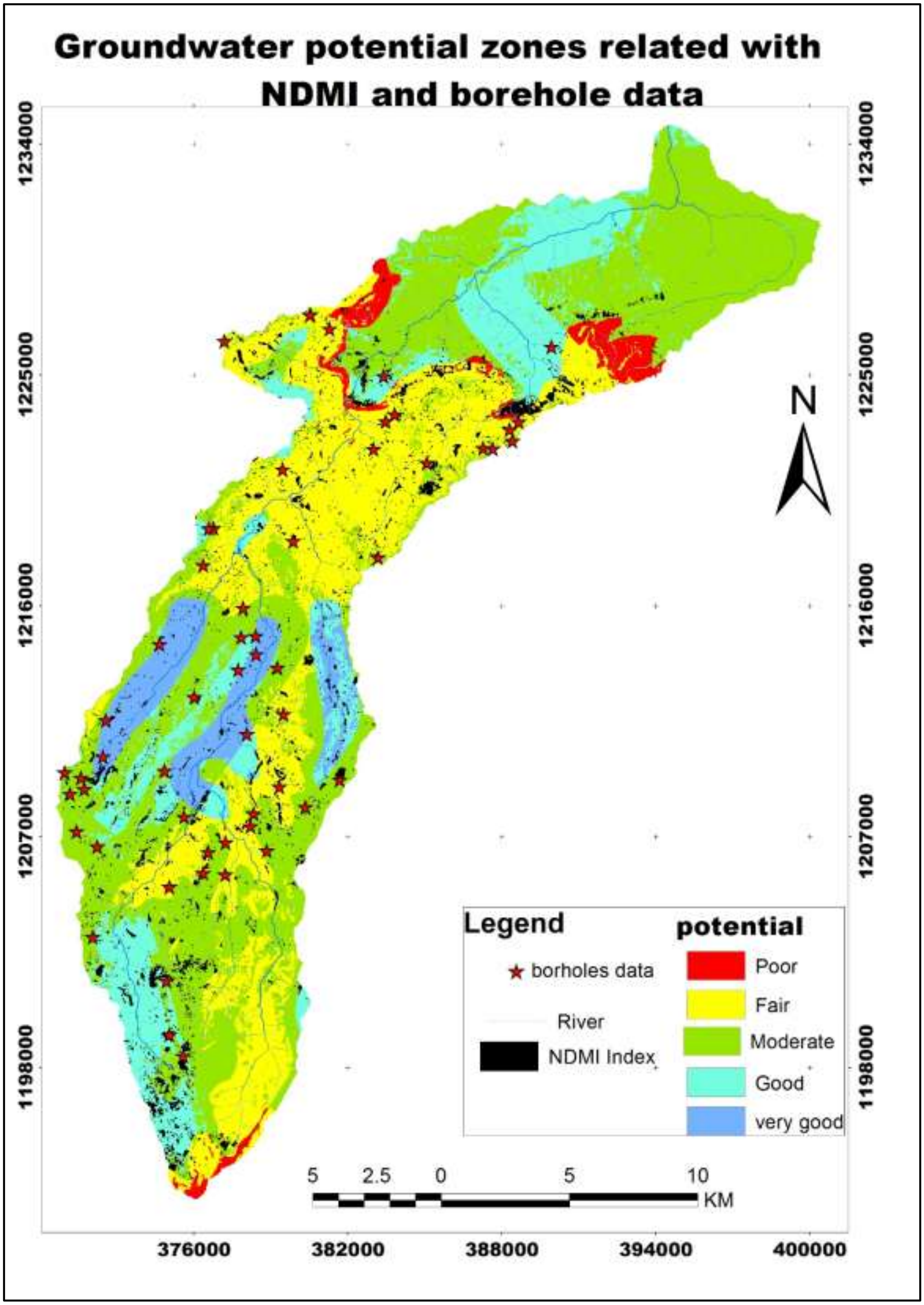


5.5.3 Validate with existing borehole

It was found that the zonation of groundwater potential by integrated GIS and remote sensing techniques was in close agreement with the existing boreholes data. It was verified with 58 existing borehole data that collected from Hulet Eju Ensie Woreda Water Resource and Development Office. Which are hand dug well and protected spring, utilized as water supply for local people. Moreover, the boreholes were also overlaid on groundwater potential zone to find out where the groundwater can accumulated and there is more chance to get the water easily comparative to other place. Out of 58 boreholes data, 6 are on very good potential, 9 are under good zones, and 24 are falling in moderate zone and 19 are in fair zone (Annex I). The relatively high yield value (1.05-2.36 l/s) fall on good and very good potential zone and no wells are exist in the poor potential zone, that validate the groundwater potential zones results perfect. In addition the most borehole data has close relationship with NDMI, they are presented on or closest to NDMI result (figure5.19).

In general, the area have inadequate surface water that highly depends on the precipitation. According to the field observation as well as the borehole data distribution (figure 5.19) is concentrating in central part of the study area in different potential zones. But the well yields not exceed to 2.36 l/s due to the compact/massive lithology, clay soil composition and far from lineaments. On the northern part and highland area in south part have not existing borehole data, because of topographic nature and geology of the area. The compact/massive basalt unit and shield volcanic unit on southern and northern part respectively. Therefore these area are in adequate to dig the borehole because of its topography and geology nature. So it is difficult to do the borehole by labor.

Figure 5.19: Groundwater potential zone related to borehole and NDMI



CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this study, the groundwater potential zones using remote sensing and GIS technique in Sede Watershed at Hulet Eju Enesie the Blue Nile Basin were identified. Sede Watershed water supply is largely obtained from surface water, which is highly dependent on the seasonal inputs from rainfall. As a consequence, most of the area in high ranges faces shortage of water supply especially in dry season. It was found that ground water potential was dependent on various geological factors like lithology, structure/lineament, rainfall, slope, drainage density, topography, soil types and land use/cover. The thematic maps of all the above parameters were generated using remote sensing and GIS technique. Each classes in a single factor map were assigned weight based on the significant of availability of groundwater and each thematic map were assessed based on Satty's Analytic Hierarchy Process (AHP) along with pairwise comparison. In this method the relative importance of each factor map were compared to other in the contribution of ground water occurrence on the study area. Hence, the important matrix and calculated weight of the factors was computed in IDRISI 32 software.

The groundwater potential zones were delineated and classified as: very good, good, moderate, fair and poor potential zones, which are covered 24.3855, 68.3325, 164.3526, 111.3453 and 10.8963 km^2 area respectively.

The results of groundwater potential zones were also compared with NDWI, NDMI and existing borehole data. The NDWI has not shown any pixels of water bodies. The river is also seasonal that highly depends on rainfall. Therefore the result clearly indicates that the area has surface water scarcity except the rainy season. As we need to identify the permanents water bodies, therefore the satellite data have been taken after a month of rainfall event to find out the permanent water bodies instead of temporary water features. It has been found that the moisture index showed the range between -0.2456 to +0.39. These pixels of NDMI shows the water resistance and holding capacity after the rainfall. Most of NDMI lie along streams and closest to borehole data. The groundwater potential was verified with existing borehole data. Out of 58 boreholes data of the study area 6 are on very good, 9 are under good, and 24 are fall in moderate potential zones. No wells are fall under the poor potential zone that indicates good correlation of groundwater potential zones, NDMI and existing borehole results.

Therefore it is needed to find out the groundwater potential zones for sustainable water conservation, especially in these region which have water scarcity that is Blue Nile basin, Ethiopia. Through such program it can find out the potential area and conserve this precious resources. The water conservation cannot solve the water scarcity problem totally, but for the time being community can utilize it for domestic purpose and it can increase water table.

6.2 Recommendation

In the light of the findings obtained and conclusions reached the following recommendations are forwarded.

- Results obtained from the present study work is good, related to time, cost and accurate result an identification of groundwater potential zone. Therefore, more studies such as geological, hydrogeological and water studies should be done with the application of Remote Sensing and GIS is highly recommended.
- Remote sensing data has a great role to improve our understanding of groundwater systems. On the study areas are utilize recent and high spatial resolution image is recommended.
- Geology and lineament are mainly control the occurrence and movement of groundwater on this study, analysis of these parameters should be supported by detail maps which is large scale map and it is required to take laboratory tested result.
- When an assigning weight is important to calculate by professional judgments using pair-wise comparison for each data set in a single map as well for all factor maps to avoid confusions, individual biasness and to produce better results.
- Despite various thematic map and different techniques are used to produced detailed maps, ground verification is essential to increase the accuracy of the interpretation results. The result obtained from this study should be supported by geophysical investigations and electrical resistivity test are recommended.

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I. ANNEXS

No	kebele	Village Name	Easting	North	Elevation	Type of supply	Yield L/S	potential
1	Abiot selam	Kesmender	376007	1212440	2470	Hand dug well	1.06	good
2	Addis Allem	wogelal	374851	1209568	2461	Hand dug well	0.84	moderate
3	Addis Allem	Girarbet	375608	1207769	2447	Hand dug well	0.84	moderate
4	Addis Allem	Meri	372054	1203093	2591	Hand dug well	0.87	moderate
5	Addis zemen	Ejagrie	379243	1213579	2450	hand dug well	0.90	moderate
6	Hagere birhan	badedgim	371165	1208665	2488	spring	0.94	moderate
7	Hagere birhan	Enamora	371592	1209299	2470	hand dug well	0.92	moderate
8	Hagere birhan	Aniko	371417	1207193	2488	spring	0.75	moderate
9	Hagere birhan	yinach	372561	1211538	2444	hand dug well	1.78	very good
10	Hagere birhan	school	370965	1209504	2525	hand dug well	0.86	moderate
11	Hagere birhan	Enamora	372444	1210126	2462	hand dug well	1.83	very good
12	Andinet mariam	Mehalmender	381674	1209212	2563	Hand dug well	0.87	moderate
13	Abiot selam	Meklit	374654	1214509	2414	Hand dug well	2.09	very good
14	chakc	feleg	378399	1214816	2436	hand dug well	1.85	very good
15	chakc	chebeb	377911	1215923	2432	spring	0.20	fair
16	chakc	cherekebo	378413	1214106	2437	hand dug well	2.36	very good
17	chakc	Astera	376753	1219025	2447	hand dug well	0.20	fair
18	chakc	Ayfanos	376352	1217583	2434	hand dug well	0.22	fair
19	chakc	feleg	377841	1214777	2430	hand dug well	1.08	good
20	chakc	cherekebo	377715	1213505	2449	hand dug well	1.27	good
21	chakc	Astera	376580	1219019	2440	hand dug well	1.41	good
22	Debre Guby	Zelan	382995	1222113	2424	Hand dug well	0.23	fair
23	Debre Guby	Tach mender	379873	1218515	2462	Hand dug well	0.49	fair
24	Debre selam	Kete wonze	375037	1199273	2959	spring	1.34	good
25	Debre selam	Keskiros	376547	1206396	2502	Hand dug well	0.85	moderate
26	Debre selam	kes mender	377236	1206775	2400	hand dug well	0.39	fair
27	Debre selam	lebasie	378193	1207401	2491	hand dug well	0.33	fair
28	Debre selam	bushe	378840	1206456	2520	hand dug well	0.83	moderate
29	Debre selam	wabin	380349	1208153	2560	hand dug well	0.80	moderate
30	Debre selam	zebeno	379480	1211769	2455	hand dug well	0.80	moderate
31	Debre selam	kelemo	378053	1210996	2435	hand dug well	2.22	very good
32	Debre selam	kes kiros	376547	1206396	2502	hand dug well	0.84	moderate
33	Debre selam	kes kiros	376363	1205585	2504	hand dug well	0.29	fair
34	Debre selam	alivo	375044	1205043	2507	hand dug well	0.84	moderate
35	Addis Allem	woyzazir	372226	1206610	2503	hand dug well	0.82	moderate

36	Debre selam	woyzazir	377217	1205514	2492	hand dug well	0.29	fair
37	Debre selam	matebo	378322	1207893	2479	hand dug well	0.81	moderate
38	Debre selam	shimie	379322	1208944	2479	hand dug well	0.29	fair
39	Debre Tshay	Meskelmider	375579	1198447	3024	Protected spring	1.20	good
40	Debre Tshay	Mehal gott	374930	1201373	2866	Protected spring	1.13	good
41	Debremariam	Diro gebya	381277	1226796	2430	hand dug well	0.39	fair
42	Debremariam	kolisa	377181	1226317	2430	hand dug well	0.42	fair
43	Meshege	kayawuha	389930	1226096	2450	hand dug well	1.06	good
44	Debremariam	A/wuha	380540	1227350	2440	hand dug well	0.89	moderate
45	Debremariam	woyinmidr	380519	1227335	2428	hand dug well	0.94	moderate
46	Gedam Abo	Gidangd	383814	1223454	2245	hand dug well	0.44	fair
47	Gedam Abo	coma	383398	1224953	2476	hand dug well	1.05	good
48	Gedam Abo	woyinwha 2	383474	1223187	2439	hand dug well	0.44	fair
49	Gedam Abo	Kechin shet	388645	1223167	2423	hand dug well	0.29	fair
50	Gedam Abo	Kechin shet	387645	1222131	2445	hand dug well	0.80	moderate
51	Gedam Abo	Enesie	387268	1222135	2447	hand dug well	0.84	moderate
52	Gedam Abo	Enesie	388412	1222424	2456	hand dug well	0.84	moderate
53	Gedam Abo	Kechin shet	388291	1222870	2474	hand dug well	0.34	fair
54	Gedam Abo	coma	385073	1221576	2472	hand dug well	0.75	moderate
55	Gedamabo	Gedagid	383814	1223454	2245	Hand dug well	0.12	fair
56	Agere birhan	Enamora	371718	1208853	2462	Hand dug well	0.89	moderate
57	Hibre selam	Jima No.2	379458	1221316	2409	Hand dug well	0.13	fair
58	Hizbe selam	Arat Agam No.2	383169	1217879	2425	Hand dug well	0.15	fair