Jimma University

Jimma Institute of Technology

School Of Post Graduate Studies

Faculty of Civil and Environmental Engineering

Hydraulic and Water Resources Engineering Department

Master of Science Degree in Hydraulic Engineering

Delineation of Groundwater Potential Zone Using Geographical Information System Based Analytic Hierarchy Process Technique: Case of Chiro River Watershed, Oromiya, Ethiopia

By: Osman Omer

A Thesis Submitted To The School Of Graduate Studies Of Jimma University, Jimma Institute Of Technology In Partial Fulfillment Of The Requirements For The Degree Of Masters of Science In Hydraulic Engineering.

November, 2021

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Main Advisor: Dr.-Ing. Fekadu Fufa (Avoc.prof)

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ABSTRACT

Groundwater has greater significance in major portion of world as fresh water resource. It is one of the major components of the entire water supply for drinking and irrigation purposes. Groundwater is the only water sources for the community of study area. So, a thoughtful and proper evaluation groundwater potential area zoning is required for the utilization and management of groundwater. The general objective of this study was to delineate groundwater potential zones of Chiro river watershed using Geographical Information Systems and Analytical Hierarchy Process (AHP) techniques. The thematic layers considered in this study are extracted from existing maps lithology, geomorphology, lineament density, soil and land use/ land cover and pre-processed data which derive from SRTM DEM used for extraction of elevation, slope and drainage density map of the study area, prepared using ArcGIS software, its extension tool and Global-mapper software. The assigned weightage of influence of the various thematic layers using, the AHP method, used to allocate weightage, according to their relative importance and contribution to the availability of groundwater potential zone and finally to generate a combined map of groundwater potential in study area. GIS has ability such as users to store, document, and analyze the spatial and temporal groundwater data sets, provides decision support for groundwater management, saves much time of collecting large number of geographical data, can handle large datasets through integration with Database Management System The final result map was classified into five groundwater potential zones by integrating GIS weighted overlay analysis with AHP methods. Weighted overlay sub module from ArcGIS environment was used to integrate all thematic layers to prepare the groundwater discharge potential zones of the study area. The classifications are very high, high, moderate, and low and very low groundwater potential zone. The results show 10, 8, 42, 21.5 and 18.5 per cent of the watershed classified as very high, high, moderate, low and very low respectively The study concludes that majority of the area covered by very high potential zones as it is shown the new generated predicted groundwater potential map. The study concludes that majority of the area 42% of the area (57 Km^2) covered by Moderate groundwater potential zones. The study suggested that, generated groundwater potential zone map will serve as useful guidelines for planners, engineers and decision makers providing quick decision- making in the management of groundwater resources.

Keywords: AHP, GIS, Groundwater Potential Zone, Thematic Layers

DECLARATION

I, Osman Omer, declare that this research is my own original work that has not been presented and will not be presented by me to any other University for similar or any other degree award. A research submitted to the School of Graduate Studies of Jimma University in partial fulfillment of the Master of Science degree in Hydraulic Engineering.

Osman Omer

Signature _____________

Date _____________

APPROVAL PAGE

The following examiners have approved this thesis entitled **"DELINEATION OF GROUNDWATER POTENTIAL ZONE USING A GEOGRAPHICAL INFORMATION SYSTEM (GIS) BASED ANALYTIC HIERARCHY PROCESS (AHP) TECHNIQUE" (THE CASE OF CHIRO RIVER WATERSHED)** together with chairperson and department head in the partial fulfillment of the requirement for the degree of Master of Science degree in Hydraulic Engineering at Jimma University.

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   Internal examiner Signature Date

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   Chairperson Signature Date

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
DBMS	Database Management System
DEM	Digital Elevation Models
DTA	Digital Terrain Analysis
GIS	Geographical Information System
GWP	Groundwater Potential
masl	Meters Above Sea Level
mcm	Million Cubic Meters
OWWDSE	Oromiya Water Works Design & Supervision Enterprise
RS	Remote Sensing
SRTM	Shuttle Radar Tomography Mission

1 INTRODUCTION

1.1 Background

The water source on the earth can be conventionally divided in two types, surface water (oceans, lakes, rivers, etc.) and subsurface water (groundwater). Groundwater is the water exists in the subsurface saturated zone of the earth aquifers and it is a limited natural resource that has limits and boundaries to its available and sustainable for use (Al-Abadi and Al-Shamma'a, 2014; Tesfaye, 2015). Groundwater was recognized as one of the most valuable natural resources, immensely important and dependable source of water supply in all climatic region of all over the world (Tamiru, 2019).

Nowadays, there are significant factors that affect the effective and sustainable utilization, development and management of the groundwater. Some of the factors are urbanization, a lack of adequate investigation of the groundwater, lack of knowledge about GW, hydrologic uncertainty, economic limitations, rapid growth of population, the effect of global warming on climate change and a lack of observed data (Ramu et al., 2014; Hussein et al., 2016). In addition the expected location of groundwater potential is not a straight forward process because of its location out sight. Because of the above factors the decrease existing in water supply source potential and increase of the water demand. So, a systematic evaluation and prediction of groundwater is required for the utilization and management of groundwater.

Ethiopia is one of the countries in Africa known by abundant water resource but there is minimum utilization to ground water for irrigation, domestic life, and lively wood (Bane, 2017). Groundwater availability is an essential component in poverty reduction, socio-economic development and human growth, especially in study area it’s is the only alternative potable water supply source of human being. Even if the exploration of water source has been continually done, still there has been insufficiency of potable water supply for study area. Hence systematic and proper evaluation groundwater discharge area zoning is required for the utilization and management of groundwater.

There are various conventional methods for groundwater investigation like preliminary and geophysical method such as electrical resistivity methods are expensive and time-consuming (Aneesh and Paresh, 2015; Hindeya, 2020). Generally, the previous approaches for water resources investigation and development are time consuming, high cost, uneconomical and sometimes poorly successful. To solve these problems the uses of other technologies including GIS and remote sensing, that can help investigate large areas in a short period of time with limited resources have been adapted to delineate groundwater potential zones (Bane, 2017;

Hindeya, 2020). It is very easy, faster and more efficient method for mapping groundwater potential zone in different geology conditions and large areas (Aduojo and Tanko, 2018; Tamiru, 2019; Hindeya, 2020). The RS and GIS approaches have been applied to delineate groundwater potential zones throughout the globe by various researchers (Al-Abadi and Al-Shamma'a, 2014; Arivalagan et al., 2014; Ramu et al., 2014; Liu et al., 2015; Tesfaye, 2015; Sara et al., 2016). Remote sensing and geographic information System techniques have been effectively utilized as a tool to delineate groundwater potential zones in various parts of Ethiopian (Bane, 2017; Madhumitha, 2018; Muse et al., 2018; Argaz et al., 2019; Tamiru, 2019).

The present study focused on the delineation of groundwater potential zone in the Chiro river watershed found in west Hararghe zone, in awash-basin which is one of the major Ethiopian basins, based on GIS techniques. The thematic layers considered in this study are limited to Geology, Geomorphology, Land use Land cover, Lineament Density, Soils, Drainage Density, Slope and Elevation for delineating groundwater potential zones. The various methods that are commonly used in this study were Analytical Hierarchy Process, Weight Overlay Analysis and reclassification adopted for delineating of groundwater potential zones. Analytical Hierarchy Process (AHP) is considered as a simple, transparent, effective tool for pairwise comparison in Multi Criteria Decision Analysis System (dependable system) by significantly reducing the mathematical complexity of decision-making based on systematic expert judgment for delineating of groundwater potential zones (Adel, 2020; Bane, 2017; Tamiru, 2019; Hindeya, 2020). The advantage of AHP over other method is that the statistical analysis for the consistency of weightage assigned can be measured and corrected when necessary (Silwal and Pathak, 2018). GIS based analytic hierarchy process (AHP) is the promising methods for groundwater exploration and allows decision makers to give the judgments in order to reduce complexity in decision- making processes.

1.2 Justification (Rationale of the study)

Groundwater availability is an essential component in poverty reduction, socioeconomic development and human growth, and it's is also the only alternative of potable water supply source in the study area. To investigate the ground water directly from the field is very costly, time-consuming and requires skilled manpower. In contrast, space technology-with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has appeared as a very valuable tool for the assessment, monitoring and management of groundwater resources. Delineating the potential groundwater zones using remote sensing and GIS is an effective tool.

1.3 Statement of the Problem

There was groundwater potential study conducted in the study area and its surroundings by west hararghe zone water and energy resource development office but, there was a gap on using modern technology such as GIS during previously works for delineation of groundwater potential zones. The previous methods for groundwater investigation such look at the site and meeting with the chief or head of the village to ask about well location, springs, place where vegetation is greenest and remain green during the dry season and location where existing water resource have higher outflow in all seasons, looking the topography and geophysical method (Aneesh and Paresh, 2015). In addition to this, the groundwater potential zone is not delineated in previous studies by using GIS separately. Poor drilling site allocation makes unsuccessful borehole drilling is one of the challenges encountered in study area. Generally, the previous approaches for groundwater potential investigation and development are time consuming, high cost, uneconomical and sometimes poorly successful. Since there is a limitation of previously working done in the area of the potentials zone in details, the present study fills the gap by applying GIS based analytic hierarchy process (AHP) technique. These techniques were very easy to access, delineate groundwater potential zone of large and inaccessible areas and also helps to formulate environmental protection policy; management policy and the utilization of delineate groundwater potential zones.

1.4 Objectives of the Study

1.4.1 General Objective

The objective of this study is delineating of groundwater potential zone using a geographical information system (GIS) based analytic hierarchy process (AHP) technique for Chiro river watershed.

1.4.2 Specific Objectives of the Study

i. To identify the main factors that influences the delineation of groundwater potential zone of the study area.
ii. To adopt GIS software as a systematic tools in developing spatial data that help in decision making and planning GWP.
iii. To produce spatial map of the study area that indicate the groundwater potential zones for future detailed groundwater exploitation work.

1.5 Research questions

- What are various factors that influence the groundwater potential of the study area?
- Which Software has to be carrying out in order to developing spatial data?

- What will be the spatial map of groundwater potential zones in the study area look like?

1.6 Significance of the study

The significance of the study is delineation of groundwater potential map and for future to store, document, and analyze commonly used spatial and temporal groundwater data sets that is used as a good starting for planner, decision makers, stakeholders and any concerned person. Ethiopia is one of the countries in Africa known by abundant water resource but there is minimum utilization to ground water for irrigation, domestic life, and lively wood. The main parts of Ethiopian rift valley are characterized by shortage of rainfall. Especially lower and middle awash basin areas have a shortage of rainfall and water scarcity due to a fluctuation of climate and currently rapidly growing population make the water demand increasing and high (Bane, 2017). The population of study area uses waters for drinking and livestock consumptions from groundwater, surface waters and the others by going long travel to fetch the water from rivers. But groundwater is the only alternative potable water source of the study area. Hence systematic and proper evaluation groundwater discharge area zoning is required for the utilization and management of groundwater. Therefore, groundwater discharge location predictions using GIS software (technology) are essential in increasing the effectiveness in the technical ability of preventing or solving problems and to achieving sustainable development plan for water supply needs.

1.7 Scope of the study

The study focuses on the delineation groundwater potential zones in Chiro river watershed found in Chiro town and adjoin village's west Hararghe zone . The issues under consideration in this study are only delineating ground water potential zones. The thematic maps on surface and sub-surface features consider for delineating ground water potential zone the study area is limited to lithology, geomorphology, lineament density, soil and land use/ land cover, elevation, slope and drainage density, prepared using ArcGIS software, its extension tool and Global-mapper software. The various methods that are commonly used in this study were Analytical Hierarchy Process, Weight Overlay Analysis and reclassification will be adopted for the study.

1.8 Limitation of the study

The limitations and obstacles faced during preparing this research proposal and the consequence of these obstacles are: DEM resolution and lack of exiting borehole data that affect the scientific quality of the result.

2 LITERATURE REVIEW

For this study review from different author experience and practical result give the supportive idea for necessities of this study, identification data, and applicability and effectiveness of GIS based analytic hierarchy process (AHP) technique for delineating groundwater potential zone.

In keeping with the tradition in research, relevant technical papers were collected and reviewed. A brief review of each one of them is furnished.

2.1 Description of Groundwater

Water resource classifies in Surface water and Groundwater. Groundwater is one of the most important natural resources and the major accessible source of fresh water. The flow of groundwater into rivers as seepage through the river bed, known as base flow, can be essential to the health of wildlife and plants that live in the water Based on this conceptual model, discharge zones are generally located in topographically low areas that receive groundwater from regional, intermediate and local-scale flow systems and where lakes, rivers or groundwater-fed wetlands often exist. So, elevation is one of factor affect groundwater potential zone study area (Sass et al., 2014; Lalbiakmawia, 2015)**.** Rapid urbanization, growth of population and extensive uses in domestic and agricultural sectors increase the demand for good quality of water supply.

As fresh water resource groundwater has greater significance in major portion of world. It is one of the major components of the entire water supply for drinking and irrigation purposes (Aneesh and Deka, 2015).

Hussein et al., (2016) shows the issue of unsustainable groundwater utilization is becoming increasingly an evident problem and the key concern for many developing countries. One of the problems is the absence of updated spatial information on the quantity and distribution of groundwater resource. Like the other developing countries, groundwater evaluation in Ethiopia has been usually conducted using field survey which is not feasible in terms of time and resource. This study was conducted in Northern Ethiopia, Wollo Zone, in Gerardo River Catchment district to spatially delineate the groundwater potential areas using geospatial and MCDA tools.

2.2 Factor Affect Groundwater Potential

Several studies supported assessment of groundwater potential zones using satellite data along with conventional maps and rectify ground truth data. The thematic layers considered as the factor affect groundwater potential zone assessment studies was realized by many workers are geology/ lithology, geomorphology, lineament (fault) density, soil, land use/ land cover processed data, slope, Elevation and drainage density (Al-Abadi and Al-Shamma'a, 2014; Arivalagan et al., 2014; Liu et al., 2015; Tesfaye, 2015; Sara et al., 2016).

Different researcher have made use of remote sensing and GIS technique for delineating potential areas for the analysis of potential groundwater zones different parameters have been considered for the study such as, drainage density, elevation, geology, geomorphology, land use and land cover, lineaments, rainfall pattern, slope gradient and soil texture (Ramu et al., 2014; Hussein et al., 2016)

Annadurai, (2013) his study attempts to select and delineate various groundwater potential zones for the assessment of groundwater availability in Moalleman, using the remote sensing and GIS technique. Satellite images such as Landsat 8, Aster and SRTM DEM data have been used to prepare various thematic maps, such as geology, geomorphology, soil hydrological group, land use/land cover, and drainage maps.

Dilip and Pramendra, (2014) generated the groundwater potential areas in parts of Mandakini River Basin, Chitrakoot district, Uttar Pradesh by using thematic maps of lithology, geomorphology, lineaments, slope, soil and land use/land cover and integrated data with raster based Geographical Information System (GIS) to identify the groundwater potential zones.

Ramu et al., (2014) generated analysis the Groundwater potential zones in Mysore Taluk. Totally nine parameters have been consider for the study such as drainage density, elevation, geology, geomorphology, land use and land cover, lineaments, dykes, rainfall pattern, slope gradient and soil texture.

kamal et al., (2016) study attempts to delineate groundwater potential zones for the assessment of groundwater availability in the Kallar watershed, South India using remote sensing and GIS technique. Using the various thematic maps such as: - geological, geomorphology, drainage density, lineament density, land use / land cover and soil permeability.

2.3 Thematic layers of groundwater availability in study area

1. Geology/Lithology

The most suitable groundwater potential areas are found in the lithology class of Tarmaber formation more than Alaji rhyolite because of its good capacity of infiltration (Tesfaye, 2015). According to (Seifu and Von, 2016) on age wise transmissivity variation analysis shows that the younger trap basalts have higher aquifer productivity than the older and both the older and younger volcanic products shows decreasing aquifer productivity trend with increased well depth Alaji (32-15 Ma) and Termaber (30-13 Ma) productivity aquifers

Dilip and Pramendra, (2014) has presented the lithology influences on both the porosity and permeability of aquifer rocks accordingly, the result is put in order as follows: Tarmaber formation is higher permeability and higher productive aquifer than Alaji rhyolite, respectively.

2. Geomorphology

The word landform denotes the structure, process and stage that shape the earth surface features (Kumar, 2016). Geomorphology maps describe landforms relating to groundwater occurrence as well as to groundwater prospects (Tesfaye, 2015).

3. Lineament density

Lineaments are structurally controlled linear or curvilinear enlarged fracture or Faults (Madhumitha, 2018). 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, 2015). Areas with higher lineament density facilitate infiltration and recharge of groundwater and, therefore, have good potential for groundwater development (Hussein et al., 2016) Lineament density for groundwater exploration was important because that the joints and fractures serve as conduits for movement of groundwater and have a high water-holding capacity. Hence, the high weight value for a groundwater potential area was assigned to the areas with high lineament density (Sara et al., 2016).

4. Soil

Different researcher classify soils layer in influence of groundwater occurrence. Cambisols and leptosols soils are found the most dominant in terms of area coverage and more determinant in groundwater occurrence and movement as compared to leptosols and regosols (Hussein et al., 2016). Clay <Clay loam, Sand, Sandy clay< Loamy sand <Sandy clay loam, Sandy loam but loamy sand are generally high potential of groundwater infiltration (Rajkamal et al., 2014). The infiltration characteristic is also directly connected with groundwater resources as the infiltration increases, the groundwater resource are also getting flourished (Madhumitha, 2018).

Table 2-1 Infiltration rate from soil textural class (Madhumitha, 2018)

Texture Class	Minimum infiltration rate in mm/hr
Sand	210
Loamy Sand	61
Sandy loam	26
Loam	13
Silt loam	7
Sandy clay loam	4.5
Clay loam	2.5
Silty clay loam	1.5
Sandy clay	1.3
Silty clay	1.0
Clay	0.5

5. Drainage Density

Drainage density indicates rock permeability and infiltration capacity, and therefore recharges capacity. Low drainage density is therefore related to higher recharge and higher groundwater potential. The drainage density is high in the plateau and escarpment and very low in the rift floor (Tesfaye, 2015). Groundwater potential is poor in areas with very high drainage density as it lost majority in the form of runoff. Areas with low drainage density allow more infiltration to recharge the groundwater and, therefore, have more potential for Groundwater occurrence.

Murasingh, (2014) also noted that low drainage density region causes higher infiltration and it yields in better groundwater potential zones as correlated to a high drainage density region. In contrast, high drainage density values are favorable for runoff, and hence indicates low groundwater potential zone (Hussein et al., 2016). Drainage density was considered as a negative factor to permeability, which means the high density class takes a low weight while the low density area gets a high weight (Sara et al., 2016).

6. Land use and Land cover

The effect of Land use/Land cover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf (Rajkamal et al., 2014). Classification of land use/cover for analysis was done based on their character to infiltrate water in to the ground and to hold water on the ground (Tesfaye, 2015).

7. Slope

Slope determines the rate of infiltration and runoff of surface water (Ghodratabadi and Feizi, 2016). in relation to groundwater flat areas where the slope is low are capable of holding rainfall, which in turn facilitates recharge whereas in elevated areas where the slope is high, there will be high run-off and low infiltration(Rajkamal et al., 2014) Topographic setting relates to the local and regional relief situation and gives an idea about the general direction of groundwater flow and its influence on groundwater recharge and discharge(Tesfaye, 2015).

8. Elevation

One of the most widely used digital elevation model (DEM) data sources is the elevation information provided by the shuttle radar topography mission(SRTM) Different researcher extract relevant features for groundwater potential mapping from Shuttle Radar Topography Mission data was used to derive a Digital Elevation Model (DEM) and to delineate the Watershed area and drainage map, elevation and slope gradient (Ghodratabadi and Feizi, 2014; Ramu et al., 2014; Liu et al., 2015; Sara et al., 2016)
Water tends to store at lower topography rather than the higher topography. Higher the elevation lesser the Groundwater potential and vice versa (Gedebo, 2005)

2.4 GIS and (AHP) Techniques for Groundwater potential zones Studies

Many researchers have come out with procedures and techniques of generating the groundwater potential zone maps by identifying remote sensing based on spatial layers of groundwater controlling parameters using a geographical information system (GIS) based analytic hierarchy process (AHP).

Several researches Validated result show that GIS technique can be successfully used in identifying potential groundwater zones.GIS Techniques for groundwater exploration are quick and inexpensive way of getting information on the occurrence of Groundwater aids to select promising areas for further groundwater exploration thus reducing field work and provide information on prospects in one map. (Eskelinen, 2011; Annadurai and Pandiyan, 2013).

Different researcher work show the use of GIS for the prediction the groundwater discharge location can help to identify all possible combinations thematic layer in a much more structured and systematic fashion. It can handle large datasets through integration with Database Management System (DBMS) component which provides foundation for all analysis techniques can utilize a satellite image to extract useful information (Ashraf and Ahmad, 2012).

Several researches have utilized the GIS technology for water resources management, groundwater assessment and modeling. Geographic Information Systems (GIS) have become important tools in efficiently solving many problems in which spatial data are important. And demonstrate the ability of GIS to perform analysis on spatial data and corresponding attribute information and to integrate different types of data and at high speeds is unmatched by manual methods. The most significant difference between GIS and other information systems and databases is the spatial nature of the data in a GIS. The analysis functions in a GIS allow manipulation of multiple themes of spatial data to perform overlays, buffering, and arithmetic operations on the data (Engel and Navulur, 1999;Bera and Bandyopadhyay, 2012;Kumar, 2016).

Different researcher work show successful results show raster overlay analysis and is known as multi criteria evaluation techniques (MCE), of several methods of available for determining interclass/intermap dependency, The total weights of the final integrated map were derived as sum or product of the weights assigned to the different layers according to their suitability. The maximum value is given to the feature with highest Groundwater prospects and minimum being to the lowest potentially features. in the procedure for Multi-Criteria Evaluation using a weighted linear combination, the weights sum to one or combine thematic layers, and the Analytical Hierarchy Process (AHP) Saaty's technique, a pairwise comparison method advantages of providing in setting the decision making criterion weights (Eastman, 2003; Perzina and Ramik, 2012; Kumar, 2016).

Dilip and Pramendra, (2014) generated the groundwater potential areas in parts of Mandakini River Basin, Chitrakoot district, Uttar Pradesh by using different thematic maps and integrated data with raster based Geographical Information System (GIS) to identify the groundwater potential zones. This process involves raster overlay analysis and is known as multi criteria evaluation techniques (MCE), of several methods of available for determining interclass/intermap dependency, a probability weighted approach has been adopted that allow a linear combination of probability weightage of each thematic map (Wt) and different categories of derived thematic maps have been assigned scores (Lalbiakmawia), by assessing the importance of it in groundwater occurrence. The total weights of the final integrated map were derived as sum or product of the weights assigned to the different layers according to their suitability. The “Raster Calculator” used to prepare the integrated final Groundwater potential map (GPM) of the area.

Venkateswaran et al., (2014) has investigated groundwater potential zones for the assessment of groundwater availability in Salem and Namakkal districts of Tamil Nadu have been delineated using remote sensing and GIS techniques. Survey of India toposheets and SRTM satellite imageries are used to prepare various thematic layers viz. lithology, slope, lineament, drainage, soil, were transformed to raster data using feature to raster converter tool in Arc GIS. The raster maps of these factors are allocated a fixed score and weight computed from

GIS technique. Moreover, each weighted thematic layer is statistically computed to get the groundwater potential zones.

Ramu et al., (2014) generated analysis the groundwater potential zones in Mysore Taluk. Totally nine parameters have been prepared and classified in GIS environment, then weightage for each parameter and its classes have been assigned using Analytical Hierarchical Process, and then weighted overlay analysis in ArcGIS used to find out the result. The comparison of his study's result and the collected sample data has given 95 per cent accuracy. The accuracy of study's result with the sample data proves Satty's Analytical Hierarchical Process is one of the suitable methods for assigning the weightage for the Groundwater studies. The study also recommends the use of GIS technology with RS data for the further study of ground water, which can minimize the cost, time, human power with higher accuracy.

Different researcher work show the main advantages in using remote sensing techniques for groundwater exploration are quick and inexpensive way of getting information on the occurrence of Groundwater aids to select promising areas for further groundwater exploration thus reducing field work and provide information on prospects in one map. This type of information is very helpful in the areas where more emphasis is on groundwater for the irrigation and drinking purposes. By integration of all the maps and further analysis of data on water table water depth Groundwater potential (Annadurai and Pandiyan, 2013; Ramu et al., 2014),

Annadurai and Pandiyan, (2013) work result show the use of GIS technology with RS Remote sensing have advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in assessing, monitoring and conserving groundwater potential. In this paper, a case study was conducted to find out the groundwater potential zones in Kancheepuram dist., Tamil Nadu, India with an aerial extent of 153 km. Thematic layers such as drainage, Geology, geomorphology, lineaments, well inventory, DEM, Drainage density, land use/land cover and water level/quality have been generated. An index model for groundwater potential zones was obtained by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS 9.2. During weighted overlay analysis, the ranking has been given for each individual parameter of each thematic map and weights were assigned according to the influence

Kumar, (2016) proves GIS technique can be successfully used in identifying potential groundwater zones. The utilization of GIS based analytical hierarchy process (AHP) technique for identification of the groundwater potential recharge zones in Bengaluru urban district, Karnataka, India. Various factors that influence the occurrence, movement, yield and quality of groundwater in an area are Lithology, Geomorphology, Drainage and Lineaments density, Soil, Elevation, Slope, Lu/Lc and Rainfall. Because of the different weightage of influence on various themes and their feature on the presence of groundwater recharge potential zones in an area AHP technique is introduced to allocate weightage. Weighted overlay sub module from ArcGIS environment was used to integrate these thematic layers to prepare the groundwater recharge potential zones of the study area. Overall result demonstrates that the integrated RS & GIS technique offer powerful tool to study groundwater resource and propose a suitable exploration plan for recharge of groundwater in his study area. Compared to conventional technique of groundwater inquiry remote sensing data which provide accurate spatial information can be utilize cost effectively. Saaty's AHP is one of the appropriate methods for assigning the weightage for the groundwater study. The multi parameter approach carried out by means of GIS and an AHP technique was economical and stress free work method (Aneesh and Deka, 2015).

Many researchers have used remote sensing and GIS techniques for groundwater exploration and identification of groundwater potential zones with successful results through different methodologies8. Remote sensing and geographic information System techniques have been effectively utilized as a tool to delineate groundwater potential zones in various parts of Morocco. The combination of GIS, remote sensing and Multi-criteria decision analysis techniques has been proved to be a successful tool to appreciate the behavior of groundwater in any area, consequently, multi-criteria analysis approach using raster based GIS may provide more and better information about decision making situations. The mathematical method of analytical hierarchy process (AHP), which was developed by Saaty has been applied in many hydrogeological studies by integrating multi-criteria decision analysis(MCDA) with remote sensing and GIS techniques, the method of MCDA consists to organize spatial problems and to decide which (Argaz et al., 2019)

Groundwater potential zones delineation for Abaya Chamo basin using AHP and Geospatial techniques is found to be powerful methodology. It is also cost effective and time saving method. Its cost effectiveness is in terms of less amount of data requirement and easiness of accessibility of the data used in this method (Muse etal., 2018)

Integrated GIS and remote sensing techniques were very helpful, time and cost effective tools for the identification and delineation of groundwater potential and analysis. For fast, cost effective and accurate result in delineation of groundwater potential zones investigations model validation of predicted groundwater potential zones with the groundwater borehole wells data shows 80% of accuracy whereas about 16 borehole wells correctly agreed with predicted groundwater potential zones (Tamiru, 2019).

AHP techniques have gained attention as useful approaches for groundwater prediction for rapid, precise and cost-effective assessment of groundwater potential by significantly reducing the mathematical complexity of decision-making based on systematic expert judgment (Adel, 2020; Bane, 2017; Tamiru, 2019). Analytical Hierarchy Process (AHP), which is a effective tool for pairwise comparison in Multi Criteria Decision Analysis (MCDA) System (Madhumitha, 2018).

2.5 Previous Groundwater Potential Study in the Study Area

In Ethiopia, most of hydrogeological investigations and groundwater potential evaluation have been done traditionally, using in situ measurement which is not feasible. In the study area, some studies had been conducted earlier for different purposes. The present study focused on the delineation of groundwater potential zone in Chiro river watershed using GIS and the mathematical method of analytical hierarchy process (AHP). Groundwater in the study area is scarce when it considered with other part of Ethiopia. In general, there is scarcity of groundwater in the study area rather there were the lack of delineating groundwater potential zone that shown the area which having or having not enough groundwater by using modern technology which was time saved and cost effective.

3 METHODOLOGY

3.1 Description of the Study Area

The study area is Chiro river watershed, found in East Ethiopia, Oromiya National regional state, Awash-basin, Arba- Kurkura -Doba sub basin, West Harerghe zone, Chiro town and adjoins at a distance from Addis Ababa to zone capital town Chiro at 347km of asphalt road. Geographically, the study area is found at longitude (west and east) is between 40° 48' 58.49" E and 40° 54' 49.12" E and latitude (north and south) is between 9° 08' 45.09" N and 8° 59' 17.28" N and with an elevation ranges from 1470-3017m a.s.l.. West Hararghe is traditionally characterized into three broad agro-ecological zones namely lowlands or ‘Kola’ the mid highlands or ‘Weyna Dega’ and the highlands or ‘Dega’. There are two rainy seasons: ‘Belg’ (March to May), ‘Meher’ (June to September) (OWWDSE,2010) .

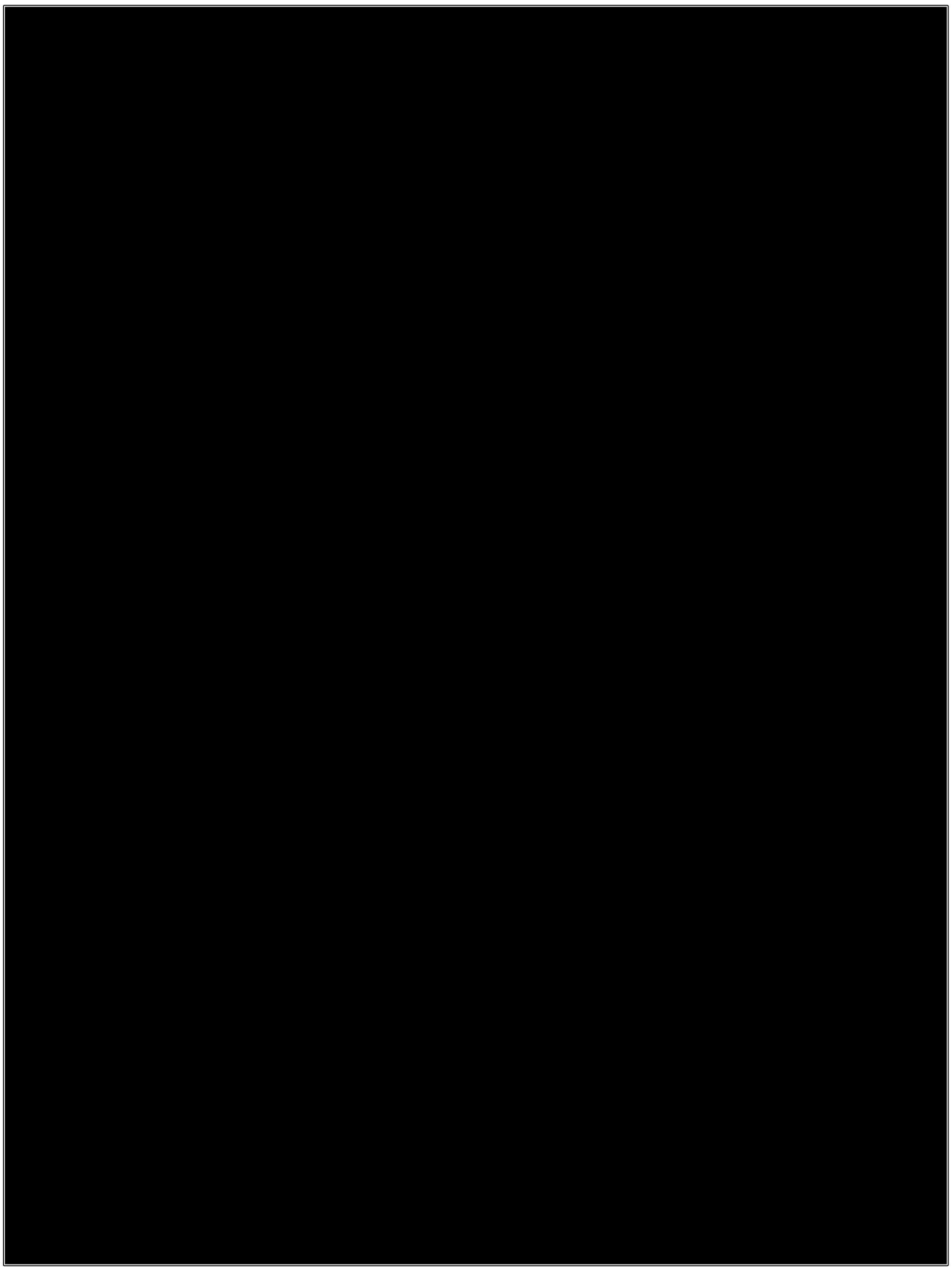

Figure 3-1 Location map of Chiro river watershed

3.2 Material and Methods

The study was carried out in several stages to delineate groundwater zones that reveal the capability of using GIS in groundwater exploration study the methodology adopted in the study described in the following steps. 1) Data collection. 2) Analysis and Integration of thematic data layers.

3.2.1 Data Collection

The tasks of finding, creating, assembling (i.e. data identification and collection) and integrating these data may collectively be termed database development. In addition to identifying the themes that are necessary, then determine resolution (precision) and accuracy required. It involves the preparation and collection of thematic maps from 30m*30m resolution Digital elevation model (DEM) derived from Shuttle Radar Topographic Mission (SRTM) used for extraction of elevation, drainage density and slope using Global-mapper 11 and Geographic Information System (GIS). And from existing data such as geomorphology, lineaments, land use/ land cover, and soil shape files are collected from Oromiya Water Works Design & Supervision Enterprise (OWWDSE), (2010), and the lithology is collected from Ethiopian Geological survey. These thematic layers were prepared using Arc GIS 10.3.1 platform. The thematic layers that are in vector are converted to raster using feature to raster converter tool in ArcGIS10.3.1., these issues explained in the following procedure for thematic layers generation.

3.2.1.1 Derive DEM from SRTM

From Shuttle Radar Topographic Mission (SRTM) a data source of cropping DEM for an area containing project area extracted using Global Mapper software. Then export the selected area as DEM using Export Elevation Grid Format to working place. Then Importing DEM in to ArcGIS using Conversion tools found under the ArcTool Box > To Raster > DEM extracted to Raster. Next using Spatial Analyst Tools used to prepare the following thematic layers.

Preparations of Watershed area and drainage map using Hydrology tools are found in Arc Toolbox Spatial Analyst Tools. The Drainage density map of study area is generated from drainage map using the Arc GIS 10.3.1 spatial analysis tool. The Density toolset in the Spatial Analyst toolbox includes tools for creating density surfaces for line features and reclassification in to appropriate classes.

Extract and develop Elevation and Slope map using watershed area map from DEM extracted develops above using Spatial Analysis and reclassification in to appropriate classes.

3.2.1.2 Prepared Thematic Maps from Existing Maps

The thematic layers considered in this study extracted (using watershed area map develops above) from existing maps are: - lithology, geomorphology, lineament (i.e. fault) density, soil, land use/ land cover shape file, then converted into raster format for future analysis through a vector to raster conversion procedure using a pixel size of 30x30m. This cell size was selected in order to match the spatial resolution of the DEM.

3.2.2 Material /Software Used

- GIS software of ArcMap 10.3.1 version was used for analysis and mapping.
- Globalmapper 11 was used for extraction of DEM, which is produced from SRTM.
- Microsoft excels for implementation of pairwise comparisons of a decision making process known as the Analytical Hierarchy Process (AHP) developed by Saaty (1980).

3.2.3 Analysis and Integration of Thematic Data Layers

The present study has attempted to apply GIS for generating thematic data layers from preprocessing as well existing data for delineating potential groundwater zone in Chiro town–zaria kebele, west Hararghe zone of Oromiya regional state. The eight thematic layers drainage density, slope steepness, land cover/use and lineaments density, geomorphology, soil, elevation and geology were used for the delineation of groundwater potential zone in the study area. Before integration of the data sets, all data layers derived were converted to raster data sets having the same pixel size and reclassification of each map was done based on the weights produced using the procedure described below according the relative importance of each individual class with in the same map and combined were compared by each other by pair-wise and their importance matrices were prepared for assigning weight to each class. The procedure to make assigning weight and integration of the theme explained in the following steps

1. Analytic Hierarchy Process (AHP)

The AHP facilitates decision making by organizing perceptions and judgments into a multi-level hierarchical structure that accounts for the forces that control a decision through assessing multiple factors (Adel et al., 2020). The AHP is used as a complex multi-criteria decision-solving method to determine the weights assigned to different thematic layers and their respective features. This technique breaks down the multi-criteria decision problem into a hierarchy based on a pair-wise comparison of the importance of different criteria and sub-criteria within the judgment matrix (Haas and Meixner, 2012). The hierarchy allows analysis to consider each of several properties separately for the selection of potential discharge zones from competing sets of parameters. The method was implemented in five steps to delineate potential discharge zones in the study area: (1) selecting factors that influence groundwater discharge zones (2) developing pairwise comparison matrix, (3) estimating relative weights (4) calculate matrix consistency and (5) Consistency analysis.

1.1. Selection of Factors Influencing Groundwater Discharge Zones

In the first step of the AHP, each factor that influences discharge was given a score between 1 and 9, depending on its significance compared to other factors in pairwise comparisons (Al-Abadi and Al-Shamma'a, 2014; Arivalagan et al., 2014; Liu et al., 2015; Tesfaye, 2015; Sara et al., 2016). For this, a standard Saaty's 1–9 scale was used (Table 2) to describe the relative influence of parameters, where score 1 denotes equal influence of parameters and score 9 denotes extreme influence of a parameter on groundwater discharge compared to the other parameters (Engel and Navulur, 1999; Bera and Bandyopadhyay, 2012; Kumar, 2016).

1.2. Developing Pairwise Comparison Matrix

The pairwise comparisons of a decision making process known as the Analytical Hierarchy Process (AHP) developed by Saaty (1980) technique described here and implemented in Microsoft excels is that of. The procedure developed outside the GIS software using Microsoft Excels (Eastman, 2003; Bunruamkaew, 2012; Radomir and Ramik, 2012). The procedure to make pairwise comparison (AHP) is as follows:

The first step in the procedure is to make pairwise comparison Analytical Hierarchy Process (AHP) (Saaty, 1980), is Construction a pairwise comparison matrix, where each criterion is compared with the other criteria, relative to its importance, on a scale from 1 to 9 shown in Table 3-1. To fill the lower triangular matrix, i use the reciprocal values of the upper diagonal. If aij is the element of row i column j of the matrix, then the lower diagonal is filled using this formula = $C_{ij} = 1/C_{\mathbf{ji}}$. The second step is construction normalization matrix, each entry in pairwise comparison matrix the column is then divided by its column sum to fill normalize the matrix, sum of each row then divided by order/number of criteria to yield its normalized score.

Table 3-1 Continuous rating scale developed by Saaty (1980)

More important ≠1 Numeric Rating	Less important ≠1 Reciprocal	AHP Scale of Importance for comparison pair (aij)	Explanation
1	1	Equal Importance	Two activities contribute equally to the objectives
2	1/2	Equally to Moderately	more than Equal less than Moderate Importance
3	1/3	Moderate Importance	Experience and judgment slightly favor one activity over another

4	1/4	Moderately to Strong	more than Moderate less than Strong Importance
5	1/5	Strong Importance	Experience and judgment strongly favor one activity over an other
6	1/6	Strongly to very strong	more than strong less than Very strong Importance
7	1/7	Very strong Importance	An activity is strongly favored and its dominance is demonstrated in practice
8	1/8	Very strong to extremely	more than very strong less than extreme importance
9	1/9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation.

The AHP method integrates and transforms spatial data (input) into decision (output), where qualitative information of individual thematic layers and features are converted into quantitative scores based on Saaty's scale. Then, a pairwise comparison matrix (PCM) (Bunruamkaew, 2012; Eastman, 2003; Radomir and Ramik, 2012) is constructed (Equation (1)) using Saaty's scores obtained in the previous step. In the PCM, the matrix column is constructed based on a descending order of parameter influence on discharge. The first element is assigned a score of 1 when compared to itself (see Table 3.2). Other elements of the rows are filled using the actual Saaty's scores when a more influential parameter is compared with a less influential parameter or the reciprocal of the Saaty's scores score when a less influential parameter is compared to a more influential parameter.

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{C11} & \boldsymbol{C12} \dots. & \boldsymbol{C1n} \\ \boldsymbol{C21} & \boldsymbol{C22} \dots. & \boldsymbol{C2n} \\ \boldsymbol{Cn1} & \boldsymbol{Cn2} \dots. & \boldsymbol{Cnn} \end{bmatrix} \qquad \textbf{(1)}$$

Where, A is a pairwise comparison matrix (PCM), element C_{nn} denotes relative significance of a parameter for discharge compared to another parameter.

Table 3-2 provides the PCM for the parameters examined in this study. Lithology was selected as the first parameter of the matrix because has a higher influence on discharge potential compared to the other factors. Thus, lithology was assigned the value 8. Land use/land cover was selected as the second most important parameter influencing discharge followed by soil, slope, geomorphology, lineaments, drainage and finally elevation parameter in a descending order of influence. Each parameter in the selected set was assigned a Saaty's score based on its influence on discharge relative to lithology.

Table 3-2 Assigned the value of pairwise comparison matrix

Parameter	Litho	Geom.	Lin	Slope	Soil	Drain Den	LULC	Elev
Litho	**1**	2	3	4	5	6	7	8
Geom.	1/2	**1**	2	3	4	5	6	7
Lin	1/3	1/2	**1**	2	3	4	5	6
Slope	1/4	1/3	1/2	**1**	2	3	4	5
Soil	1/5	1/4	1/3	1/2	**1**	2	3	4
Drain Den	1/6	1/5	1/4	1/3	1/2	**1**	2	3

LULC	1/7	1/6	1/5	1/4	1/3	1/2	**1**	2
Elev	1/8	1/7	1/6	1/5	1/4	1/3	1/2	**1**
Total	2.72	4.59	7.45	11.28	16.08	21.83	28.50	36.00

1.3. Normalization /Estimating Relative Weights

This step is to normalize the matrix by totaling the numbers in each column .Each entry in the column is then divided by the column sum to yield its normalized score. The sum of each column is 1. Weights were assigned to the variables based on ‘expert’ opinion to estimate the relative importance of variables compared to other variables and to quantify the relative influence of each variable on discharge. The layers were assigned weights derived by normalizing the pair comparison matrix (NPCM) (Bunruamkaew, 2012; Eastman, 2003; Radomir and Ramik, 2012). The NPCM elements were computed by dividing thematic element values by their corresponding total column values from the PCM (Equation (2)) (see Table 3-3):

$$\boldsymbol{Xij} = \frac{\boldsymbol{Cij}}{\boldsymbol{Lij}} \qquad \textbf{(2)}$$

Where X_{ij} is normalized pair-wise matrix value at ith row and jth column, C_{ij} is the value assigned to each criterion at ith row and jth column and L_{ij} is the total values in each column of the pair-wise matrix.

Table 3-3 Normalized weight of combined eight different themes

Parameter	Litho	Geom.	Lin	Slope	Soil	Drain Den	LULC	Elev	$\sum X_{ij}$	AHP Weight/ Average
Litho	0.37	0.44	0.40	0.35	0.31	0.27	0.25	0.22	2.61	0.33
Geom.	0.18	0.22	0.27	0.27	0.25	0.23	0.21	0.19	1.82	0.23
Lin	0.12	0.11	0.13	0.18	0.19	0.18	0.18	0.17	1.25	0.16
Slope	0.09	0.07	0.07	0.09	0.12	0.14	0.14	0.14	0.86	0.11
Soil	0.07	0.05	0.04	0.04	0.06	0.09	0.11	0.11	0.59	0.07
Drain Den	0.06	0.04	0.03	0.03	0.03	0.05	0.07	0.08	0.40	0.05
LULC	0.05	0.04	0.03	0.02	0.02	0.02	0.04	0.06	0.27	0.03
Elev	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.19	0.02
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	1.00

Key Litho = Lithology, Slope = Slope, Geom. = Geomorphology/Land form, Soil = Soil, Lin = Lineament density, DDen = Drainage density, LULC = Land use/ Land cover, Elev= elevation

Then, a standard weight was calculated for variable i by dividing each normalized pairwise matrix elements by criterion number (n) (Equation (3) (Bunruamkaew, 2012; Eastman, 2003; Radomir and Ramik, 2012).

$$\boldsymbol{W_i} = \frac{\sum \boldsymbol{X_{ij}}}{\boldsymbol{n}} \qquad \textbf{(3)}$$

Where, W_i is standard weight.

1.4. Principal Eigen Vector and Calculate Matrix Consistency

Eigen vector and eigenvalue calculations help determine the percentage of effect of the thematic layers and the classification of the constraints (Table 3-3). The eigenvector was calculated by dividing column elements by the column sum in Table 3-2. The principal Eigen vector was obtained by averaging across the rows to quantify relative weights of each parameter. A consistency vector was obtained by multiplying two different matrix values from selected thematic layers (Equation 4), namely, pair-wise comparison matrix value and normalized pair-wise matrix value (Bunruamkaew, 2012; Eastman, 2003).

$$\boldsymbol{\lambda_{max} = L_{ij} W_{\ i}} \qquad \textbf{(4)}$$

Where, λ_{max} is the consistency vector.

The sum of eigenvalues called principal eigenvalue (λ max) is a measure of matrix deviation from consistency. According to Saaty (1980), for a pairwise comparison matrix to be consistent it must have a principal eigenvalue (λ max) greater than or equal to the number of the parameters considered (n). In order to check the weight assigned to each parameter in Table 3-4, the normalized principal Eigen vector value (λ_{max}) was computed to drive the formula of consistency ratio (equation 6). This was done by multiplying the weight of the first criterion (as shown in Table 3-3 with the total value /column sum that was found in the pairwise comparison matrix table 3-2. Finally, the summation of these values gives the consistency vector (λmax of = 8.42) as shown in Table 3-4 for calculating consistency index.

Table 3-4: Normalized Principal Eigen vectors

Thematic Map	(1) Total Relative Weight of Each Factor (from Table 3.2)	(2) Eigenvector Value of Each Factor (from Table 3.3)	Eigenvalues (1) x (2)
Lithology	2.72	0.33	0.89
Geomorphic units	4.59	0.23	1.04
Lineament Density	7.45	0.16	1.17
Slope	11.28	0.11	1.21
Soil	16.08	0.07	1.18
Drainage Density	21.83	0.05	1.09
Land use/Land Cover	28.50	0.03	0.97
Elevation	36.00	0.02	0.87
Total			8.42

1.5. Consistency analysis

Consistency analysis is the next Step to make sure that the original ratings were consistent preference. The consistency ratio (CR) is a measure of consistency of the pair-wise comparison matrix and Consistency index (CI) is a measure of consistency or degree of consistency of the judgment (Kindie et al., 2019). Consistency index (CI) and Consistency Ratio (CR) (Argaz et al., 2019; Kindie et al., 2019) calculated as:

$$\mathbf{CI} = \frac{\lambda_{max} - n}{n-1} \qquad \textbf{(5)}$$

$$\mathbf{CR} = \frac{CI}{RI} \qquad \textbf{(6)}$$

Where: - n = order of matrix, CI: consistency index,   n: number of variables (thematic layers), CR: consistency ratio and RI: Random Index value based on the number of variables.

A perfectly consistent decision maker should always yield CI = 0 but small values of inconsistency may be tolerated if the CI < 0.1. I obtained an acceptable CI value of 0.06. Also, if the CR is greater than 0.1, the pairwise comparison judgments must be re-evaluated. With a matrix of eight variables, the RI is 1.41 is a random index shown in Table 3-5). The applied weighting yielded a CR of 0.04, which shows that the weights (Table 3-3) assigned to GIS thematic layers of parameters are consistent.

Table 3-5 Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.91	1.12	1.24	1.32	1.41	1.46	1.49

2. Reclassification of the Thematic Layers Maps

Parameters influencing groundwater potential and their relative importance were reviewed from previous literature and from hydrological experts. These study uses lithology, geomorphology, land use land cover, lineaments, slope, soil, drainage density, elevation, slope, geomorphology, drainage density, geomorphology and lithology for groundwater discharge which affects groundwater potential. All the thematic layers maps have been reclassified to integer values instead of factor weighting ranges to be used as inputs in the weighted model. To reclassify these maps the reclassification of the thematic layers was done by ranking the various classes contained in each map. This gives an output which is far easier and accurate to analyses the groundwater prospects of a region studied. Moreover in the reclassification certain classes were merged together to form single class. All the primary vector thematic map-layers presented in the abovementioned paragraphs were converted into raster format for future analysis through a vector to raster conversion procedure using a pixel size of 30x30m. This cell size was selected in order to match the spatial resolution of the DEM.

3. Overlay Analysis the Thematic Layers

Finally groundwater potential map was prepared based on GIS analysis. Overlay analysis is carried out, using weighted overlay analysis tool provided in the ArcGIS software Spatial Analyst Tools > Overlay > Weighted Sum (Map Algebra_ Raster Calculator has the same result), to integrate various thematic maps viz. lithology map, geomorphology map, lineament (i.e. fault) density map, soil map, land use/ land cover map, elevation map, slope(%) map and drainage density map, polygon maps were converted into raster format Reclassification of each map was done based on the weights produced and superimposed by weighted overlay method, which consists of weightage wise thematic maps and integration of them through GIS. To delineating groundwater potential zones, all the thematic layers after assigning weights are integrated (overlaid) using overlay analysis of ArcGIS extension (Spatial Analyst Tools > Overlay > Weighted Sum). Overlays all the thematic layers (raster) were multiplying each by their given weight and summing them together, (Eastman, 2003;Bunruamkaew, 2012; Radomir and Ramik, 2012; Dilip and Pramendra, 2014).calculated as:

$$\boldsymbol{GWP} = (\mathbf{ELw} * \mathbf{0.02}) + (\mathbf{DDw} * \mathbf{0.05}) + (\mathbf{LIw} * \mathbf{0.30}) + (\mathbf{LDw} * \mathbf{0.16}) + (\mathbf{SLw} * \mathbf{0.11}) + (\mathbf{SOw} * \mathbf{0.08}) + (\mathbf{GEw} * \mathbf{0.25}) + (\mathbf{LULCw} * \mathbf{0.03}) \quad \textbf{(7)}$$

Where:

GWP = groundwater potential, w= the normalized weight of the individual features of each theme, EL= elevation, DD= Drainage Density, LI= Lithology, LD= Lineament Density, SL= Slope, SO= Soil, GE= Geomorphology, LULC= Landuse/Landcover

4. Methodology Summary

Methodology of groundwater potential zone mapping was summarized in the following flow chart (Figure. 3-2).

Figure 3-2: Methodology for groundwater potential zone mapping

4 RESULTS AND DISCUSSIONS

Using GIS and Analytic Hierarchy Process (AHP) techniques, the expected result of the model is a map which shows the groundwater discharge potential zone classified into five different groups. These Classes were set to “very low”, “low”, “medium”, “high” and “very high”. Where very high presents most likely the high groundwater discharge potential area. For the successful completion of study, groundwater potential discharge zonation of Chiro River watershed, using eight different thematic layers were prepared as mentioned in the methodology such as, Soil Map, Drainage density Map, Geomorphology Map, Lithology Map, Lineament density Map, Land use Land cover Map, Slope Map, Elevation Map

4.1 Soil

Major Soils in the study area according to the classification system results obtained from (OWWDSE, 2010) are classified into different soils texture: - sandy clay loam, loam, clay and Rock Surface. It is one of the factors favorable for occurrence of groundwater consider in this study. High weight value is assigned to sandy loam area and low weight value is assigned to rock surface area. The result from AHP for all factors are compare pail-wise in terms of the intensity of their importance and influence of each factor on the occurrence groundwater weightage were assigned to each of using a continuous 1 to 9 point scale shown in Table 4-1 Consistency ratio=0.04<0.1

Table 4-1 Assigned weights to soil map

	L	SCL	C	RS	Weight	Weight%
L	**1**	3	5	7	0.56	55.8
SCL	1/3	**1**	3	5	0.26	26.3
C	1/5	1/3	**1**	3	0.12	12.2
RS	1/7	1/5	1/3	**1**	0.06	5.7

Where:-

L=loam, SCL=Sandy clay loam, C=Clay, RS=Rock Surface

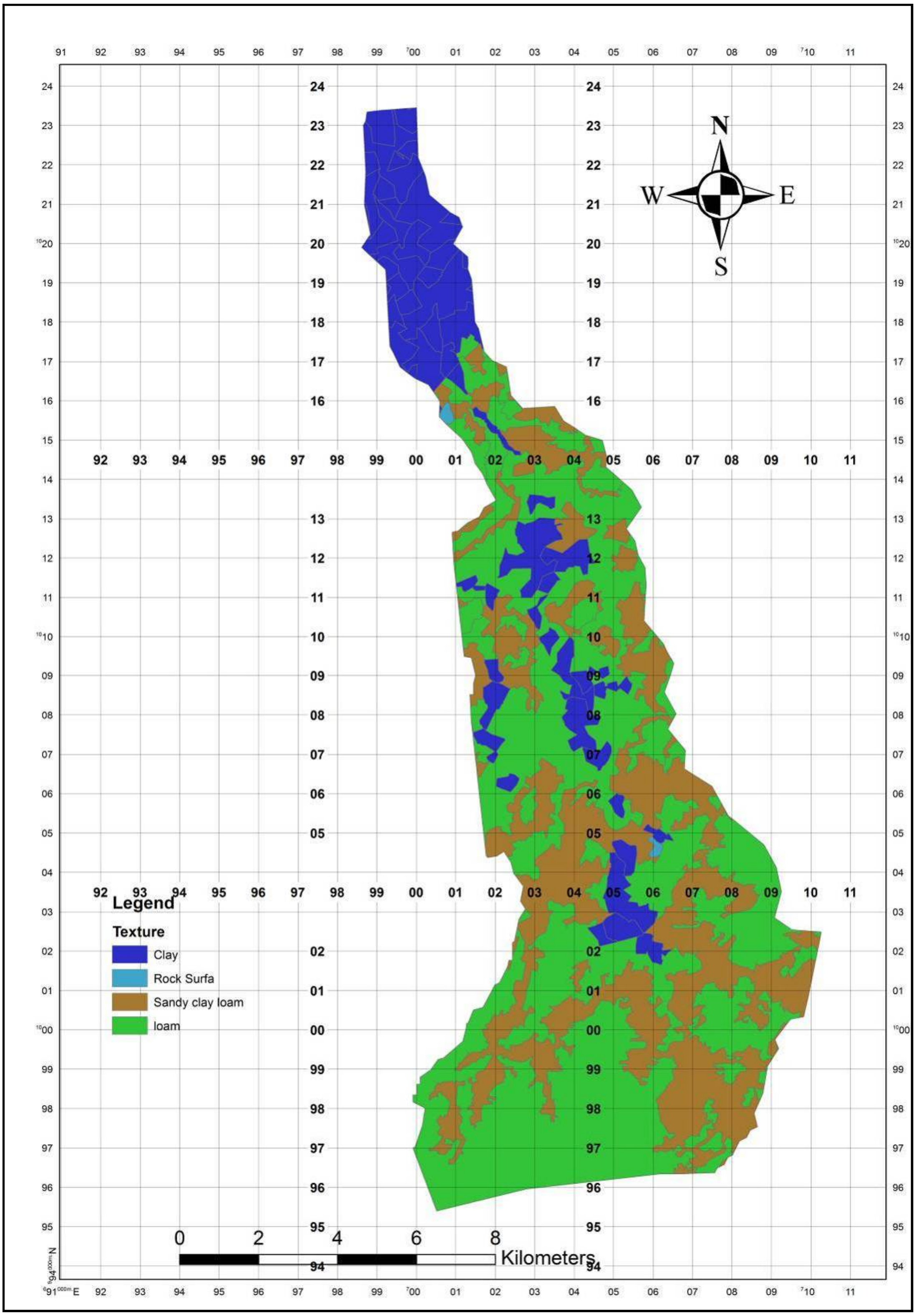

Figure 4-1 Soil map of Chiro river watershed

4.2 Drainage Density

The main River of the Study area is Chiro River. The river flows from south direction to the north direction. The source of water of this river is rainfall during spring, summer and autumn seasons. During the rainy season the river carries huge amount of water and in the dry season it carries low quantity of water. The tributaries originate from the surrounding plateau and flow towards the north direction and join the Chiro River from the left and right side of the river. The Drainage density map shown in (figure 4-2) of study area as described in methodology generated from the digital elevation model (DEM) using the Arc GIS 10.3.1 spatial analysis tool. The Density toolset in the Spatial Analyst toolbox includes tools for creating density surfaces for line features. Line Density search around each cell (within a neighborhood you specify), calculate the density for that neighborhood, and assign the density value to the cell and categorized into five classes. Drainage density can indicate the permeability of the area thus had close relation to groundwater potential mapping. High drainage density values (6.54 - 8.17) are favorable for runoff low groundwater Potential zone, low drainage density values (0 - 1.63) are favorable for highest availability of groundwater Potential zone. A drainage basin is a natural unit draining runoff water to a common point. This map consists of rivers, tributaries, perennial & ephemeral streams. High weight value is assigned to low drainage density area and vice versa. The result from AHP for all factors are compare pail-wise in terms of the intensity of their importance and influence of each factor on the occurrence groundwater weightage were assigned to each of using a continuous 1 to 9 point scale shown in Table 4-2 Consistency ratio=0.08<0.1

Table 4-2 Assigned weights to drainage density map of study area

	0-1.63	1.63-3.27	3.27-4.9	4.9-6.54	6.54-8.17	Weight	Weight%
0-1.63	**1**					0.484	48.4
1.63-3.27	1/3	**1**				0.294	29.4
3.27-4.9	1/5	1/5	**1**			0.123	12.3
4.9-6.54	1/7	1/6	1/3	**1**		0.065	6.5
6.54-8.17	1/9	1/7	1/5	1/3	**1**	0.034	3.4

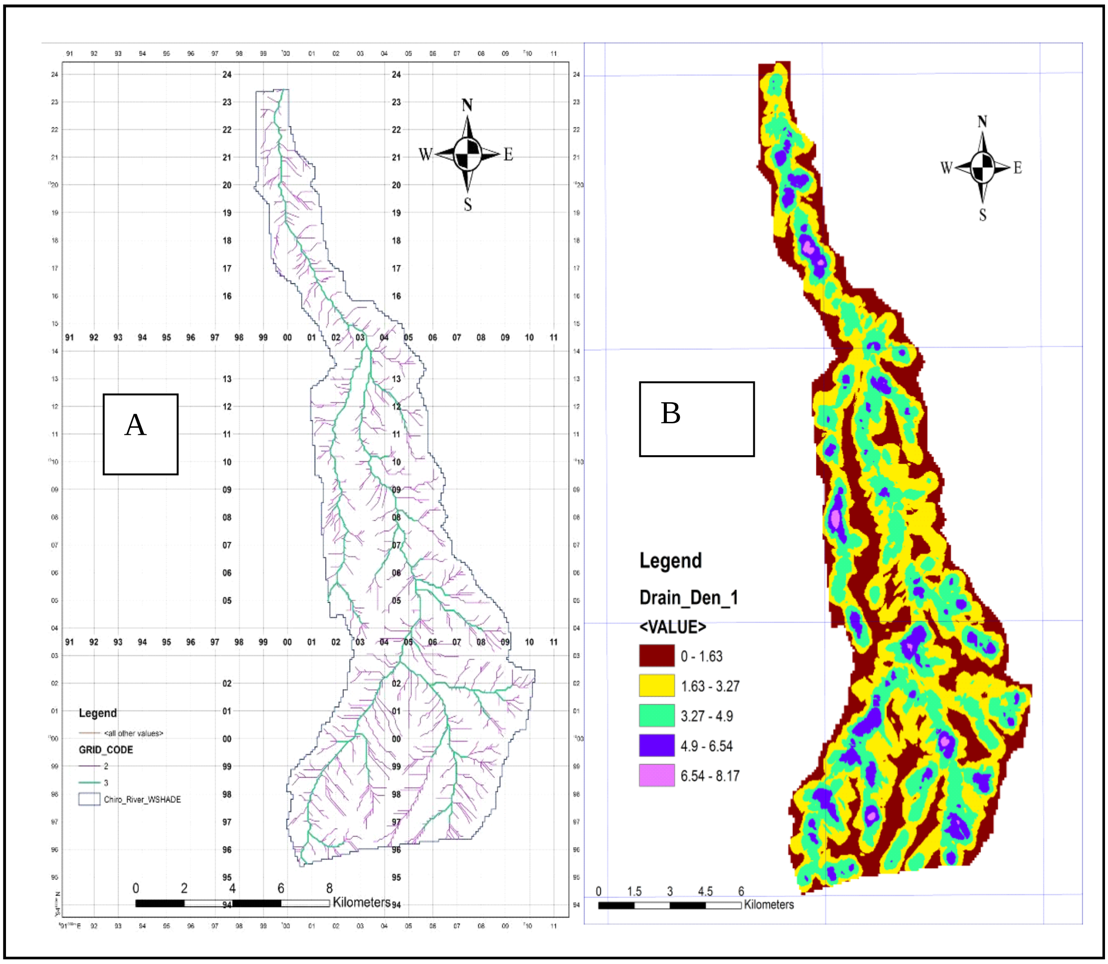

Figure 4-2 (A) Drainage network and (B) drainage density map of study area

4.3 Geomorphology

The identification and characterization of various landforms and structural features are favorable for occurrence of groundwater and are classified in terms of groundwater discharge potentiality .The study area has categorized under three physiographic land types; theses are Structural Landform(Sl) of moderately to high mountainous relief hills and ridges with intermountain valleys and escarpments (it is steep; runoff is relatively fast, while infiltration is limited) of altitude (1821-3021 m.a.s.l), Residual Landforms (Rl) of moderately steep side slopes and piedmonts of altitude (1429-2417 m.a.s.l), Volcanic Landform(Vl) of altitude (1304- 1534 m.a.s.l)is the flat and gently sloping of the plateau plains are occupying the study area shown in (Figure 4-3). Weight factor is assign using, the Analytic Hierarchy Process (AHP) method, developed by Saaty (1980). The result from AHP for all factors are compare pail-wise in terms of the intensity of their importance and influence of each factor on the occurrence groundwater weightage assigned to each of using a continuous 1 to 9 point scale shown in Table 4-3 Consistency ratio=0.06<0.1

Table 4-3 Assigned weights to geomorphological map of study area

landforms	Vb	Rl	Sl	Weight	Weight%
Vb	**1**			0.643	64.3
Rl	1/3	**1**		0.283	28.3
Sl	1/7	1/5	**1**	0.074	7.4

Where: Structural landform (SL), residual landforms (Rl), volcanic landform (Vb)

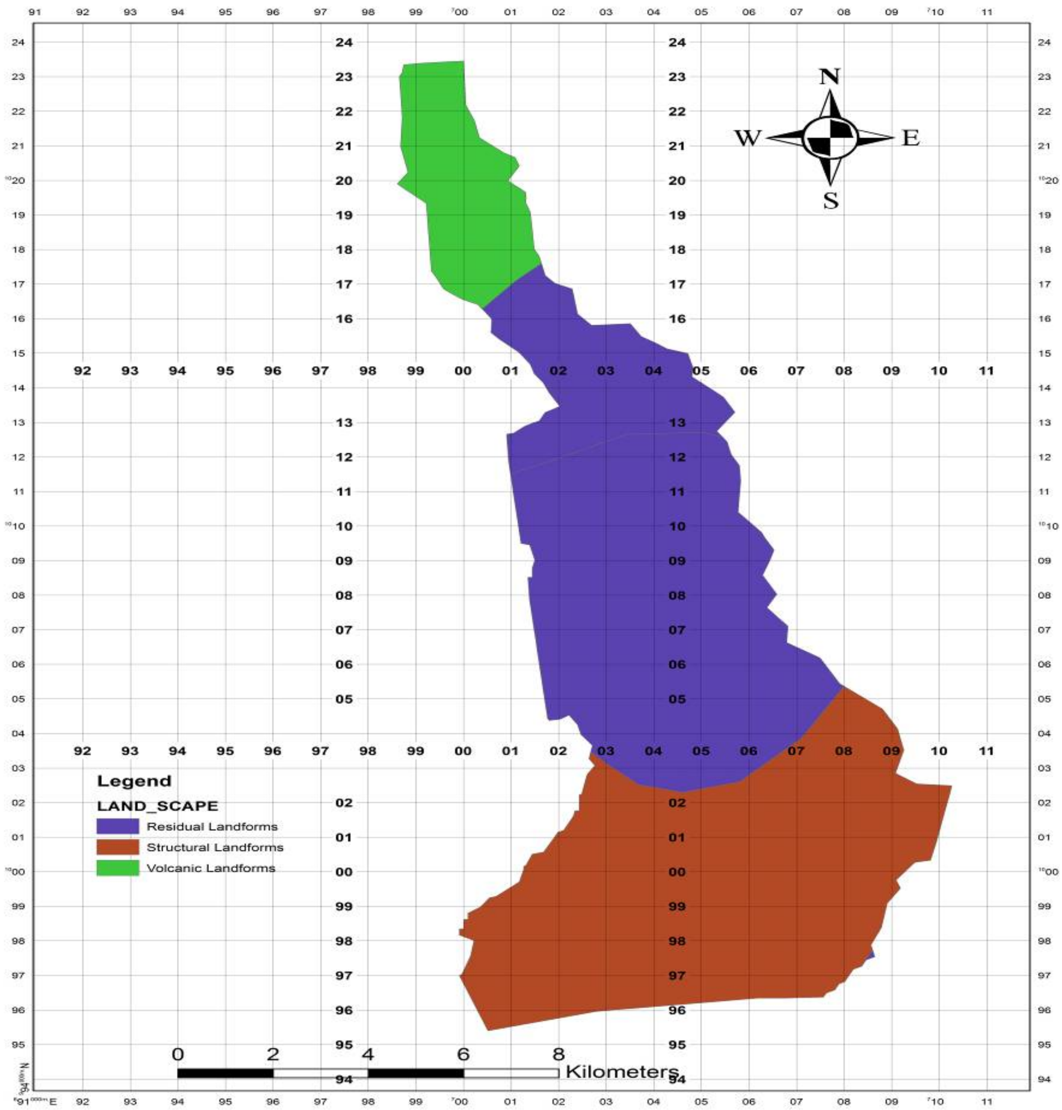

Figure 4-3 Geomorphological map of study area

4.4 Lithology Map

Lithology refers to an individual rock type, which is a basic geologic unit. Geology is one of the most important factor which plays significant role in the distribution and occurrence of groundwater. Based on their age, lithology plays an important role in the occurrence and distribution of groundwater (Alemayehu, 1992; Seifu and von, 2013; Abbate et al., 2015;Tesfaye, 2015). The geology of the study area consists of a variety of geological formation, categorized based on their property and age period (range of age) million years ago

(Ma) the younger trap basalts have higher aquifer productivity than the older and both the older and younger volcanic products. They are Alaje formation (PNa), mainly consist of a phyric flood basalts associated tertiary basalt with age period of oligomiocene 36-13 million years ago. Tarmaber-Megezez formation (Ntb) represents basaltic shield Upper-Afar Basalt with age period of middle Miocene 16-7 million years ago. Afar series (Na) is a thick succession of stratified flood basalt Tertiary Silicics with age period of Mio-Pliocene 8.4-0.37 million years ago and Mabla and Arba Guracha formation (Nmr) Tranchyte/Rhyolite with age period of middle Miocene 14-10 million years ago, trachytic and rhyolitic volcanic flows and domes are categorized in to low productive aquifers shown in Figure blow. The assigned weight of each Lithology factor are as shown in Table 4-5 and the Lithology category shown in Table 4-4 of study area. Consistency ratio=0.04<0.1

Table 4-4 Lithology category of study area

Unit Name	Unit	Age Period	Age_Ma	Lithology
Afar Series	Na	Mio-Pliocene	4.5 to 0.37	Tertiary Silicics
Tarmaber-Megezez Formations	Ntb	M. Miocene	10 to 9	Upper-Afar Basalt
Mabla and Arba Guracha Formations	Nmr	M. Miocene	14 to 10	Tranchyte/Rhyolit
Alajae Formation	PNa	OligoMiocene	36-13	Tertiary Basalt

Table 4-5 Assigned weights to lithology map of Chiro river watershed

	Na	Ntb	Nmr	PNa	Weight	Weight *100
Na	**1**				0.558	55.8
Ntb	1/3	**1**			0.263	26.3
Nmr	1/5	1/3	**1**		0.122	12.2
PNa	1/7	1/5	1/3	**1**	0.057	5.7

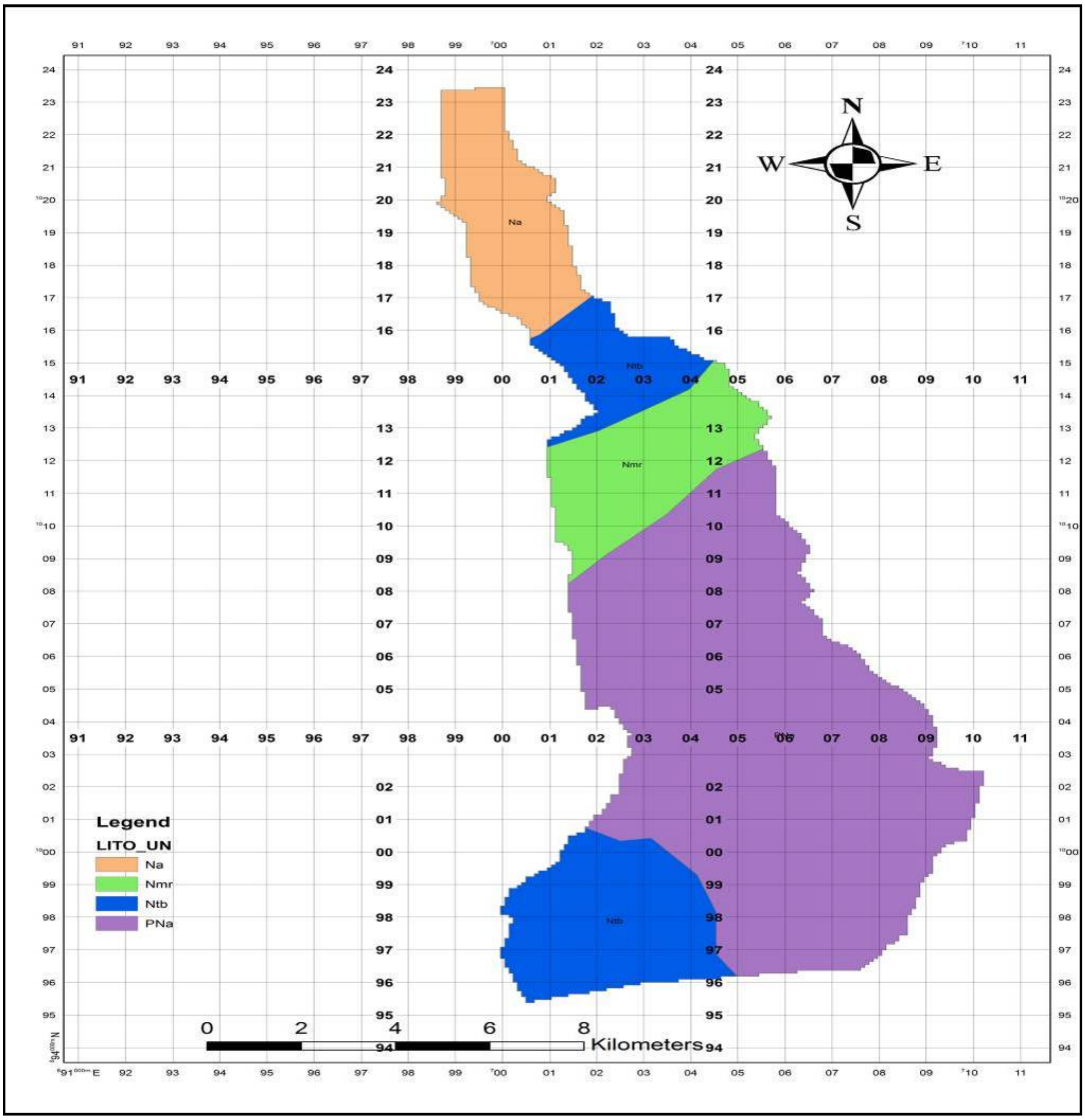

Figure 4-4 Lithology map of Chiro river watershed

4.5 Lineaments Density Map

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. The major Geological Structure or lineaments of study area seems to be controlled by volcanism and tectonics. The tectonic history of the study area is mainly related with the development of the Main Ethiopian Rift and Afar in the Cenozoic Era. So, faulting is the major structural process during Cenozoic time. The faults trending in NE-SW is observed in the area. The NW-SE trending faults serve as groundwater transmission and storage structure for the weathered and fractured aquifer (Figure 4-5) (OWWDSE, 2010). Weight of each factor is assign using, the Analytic Hierarchy Process (AHP) method, developed by (Saaty, 1990). The result from AHP for all factors are compare pair wise in terms of the intensity of their importance and influence of each factor on the occurrence groundwater weightage were assigned to each of using a continuous 1 to 9 point scale shown in Table 4-6. Lineament density of an area has direct influence on groundwater potential. Lineament density classified in the present study area, with very high lineament density (>0.32) was having good groundwater potential but, area with very low lineament density (0-0.08) having poor groundwater potential. The entire map classified in to five groups lineament density as shown in Figure-4-5 below. Consistency ratio=0.05<0.1

Table 4-6 Assigned weights to lineament density map of study area

	0-0.08	0.8-0.16	0.16-0.24	0.24-0.32	0.32-0.4	Weight	Weight%
0-0.08	**1**					0.503	50.3
0.8-0.16	1/3	**1**				0.260	26.0
0.16-0.24	1/5	1/3	**1**			0.134	13.4
0.24-0.32	1/7	1/5	1/3	**1**		0.068	6.8
0.32-0.4	1/9	1/7	1/5	1/3	**1**	0.035	3.5

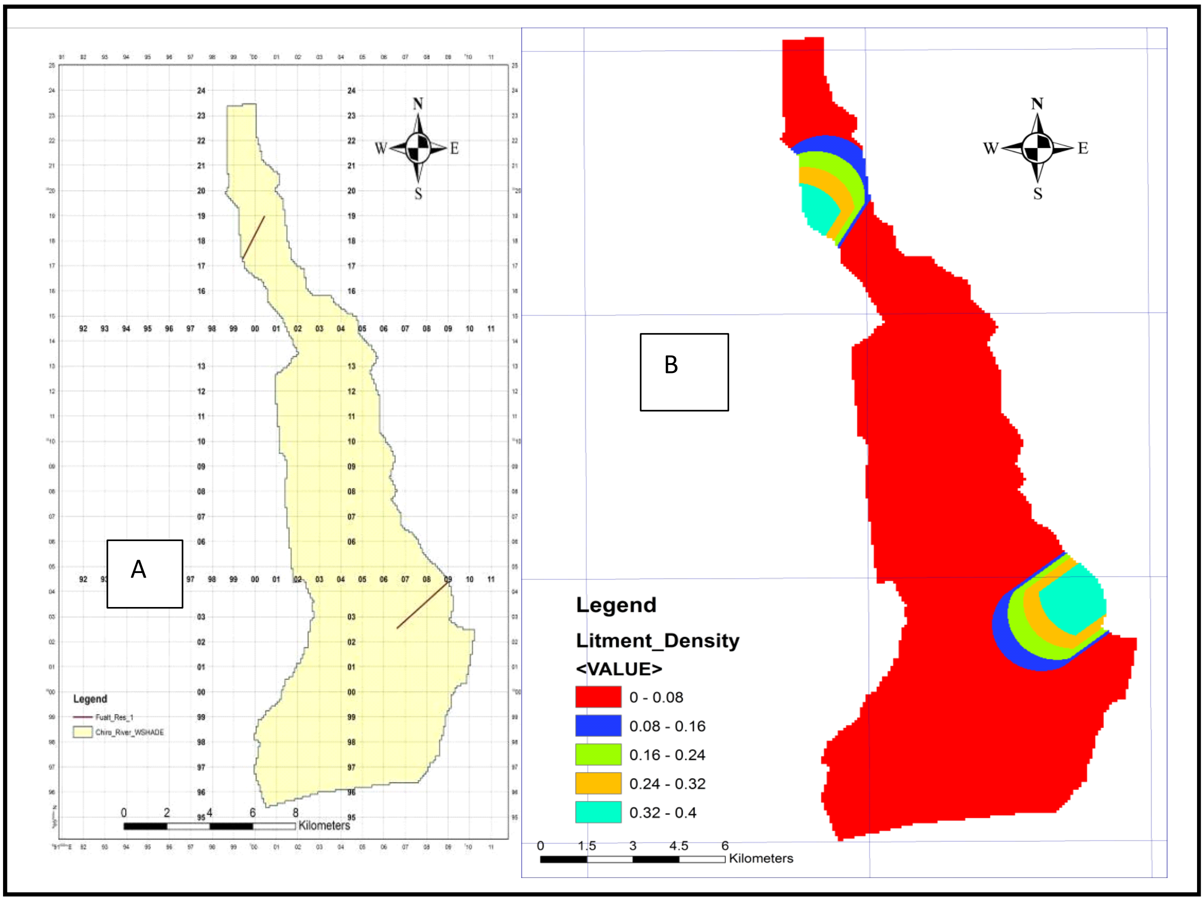

Figure 4-5 Lineaments map (A) and lineaments density (B) of the study area

4.6 Land use/Land cover

The Study area was extensively forested with seasoned trees in the recent past. The watershed region is Forest, Dense Shrub Land, Dense Bush Shrub Land, Open Shrub Land, Cultivated Land, Exposed rock surface with scattered shrubs, Settlements. On the basis of the alteration/change of land cover areas some urban centers have coming up on the margin of road ways track of the Chiro town watershed Land use/Land cover (OWWDSE, 2010). For groundwater investigation the land use land cover study was necessary because the surface covered by vegetation like forests, plantation and cropland traps and holds the water in root of plants whereas the built-up and barren land use affects the discharge potential of groundwater by increasing runoff during the rain. So, it is one of the factor affects the discharge potential of groundwater and consider in this study. The Assigned Weight of each factor and Land use/Land cover category shown in Table 4-7 of study area. Consistency ratio=0.03<0.1

Table 4-7 Assigned weights to land use/land cover

	F	DS	DBS	OS	C	ER	S	Weight	Weight *100
Forest(F)	**1**							0.35	35
Dense Shrub Land(DS)	1/2	**1**						0.25	25
Dense Bush Shrub Land (DBS)	1/3	1/2	**1**					0.16	16
Open Shrub Land (OS)	1/5	1/4	1/2	**1**				0.11	11
Cultivated Land (C)	1/6	1/5	1/3	1/3	**1**			0.06	6
Exposed Rock Surface with scattered Shrubs(ER)	1/7	1/6	1/5	1/4	1/2	**1**		0.04	4
Settlements(S)	1/9	1/7	1/6	1/5	1/3	1/2	**1**	0.03	3

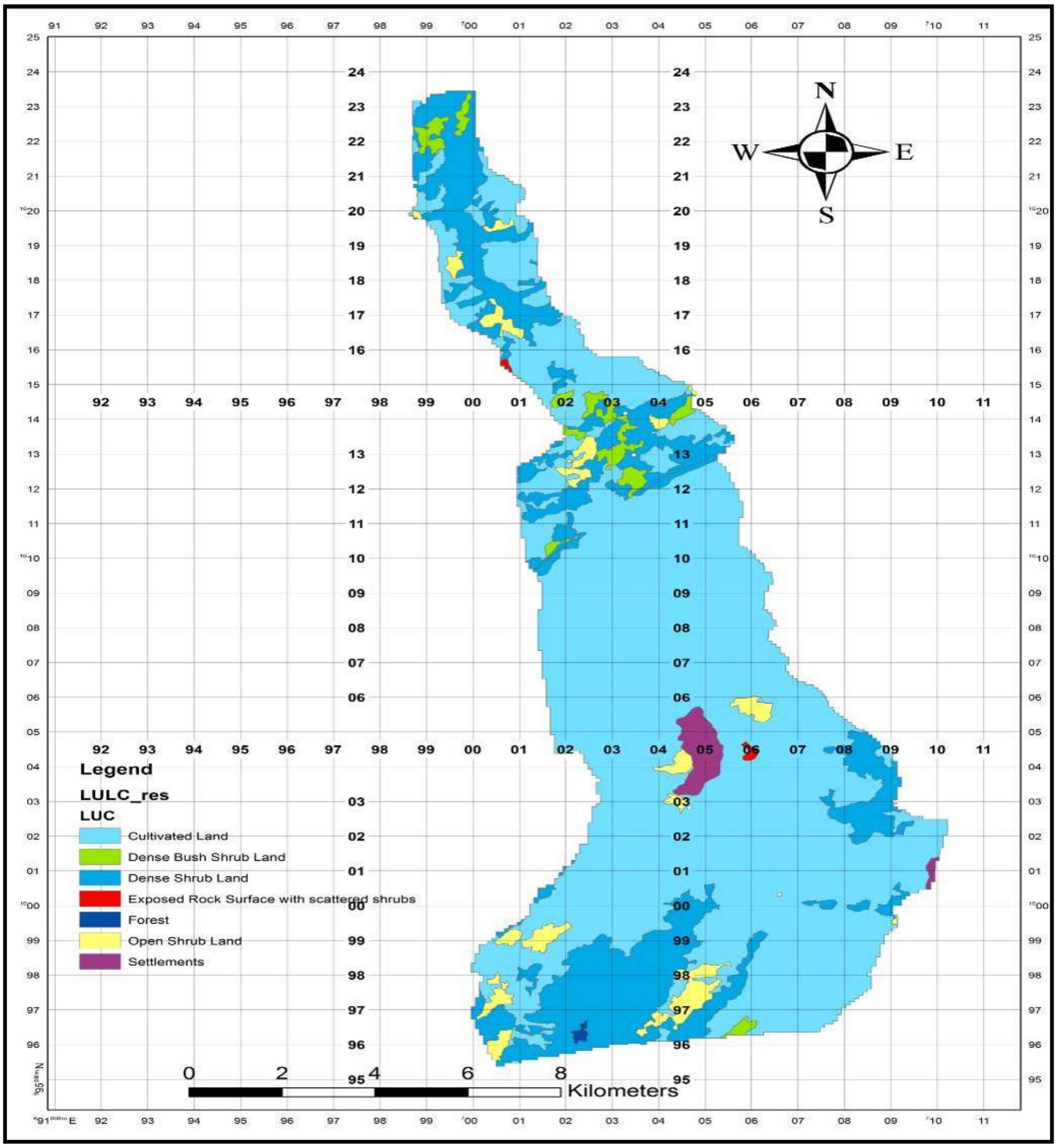

Figure 4-6 Land use/land cover map

4.7 Slope Map

The slope map shown in (figure 4-7) of study area was generated as described in methodology from the digital elevation model (DEM) using the Arc GIS 10.3.1 spatial analysis tool and categorized into six classes as per the OWWDSE classification. The following slope classes were mapped for the study area; the higher values of slope resembles to steeper terrain and lower GWP, whereas the lower slope values indicate the flatter terrain or surface and higher GWP. Result shows that slope gradient of the study area varies from 0% to >30% (figure 4-7). The Assigned Weight of each factor shown in Table 4-9 and slope category shown in Table 4-8 of study area. Consistency ratio=0.02<0.1

Table 4-8: Slope category of study area

Sl. No.	Slope Category	Slope (%)
1	Nearly level And Very gently sloping	0 - 2
2	Gently sloping	2 –5
3	Moderately sloping	5 – 8
4	Strongly sloping	8– 15
5	Moderately steep to steep sloping	15 – 30
6	Very steep sloping	> 30

Table 4-9 Assigned weights to slope map of study area

Slope Class%	0-2	2-5	5-8	8-15	15-30	>30	Weight	Weight *100
0-2	**1**						0.404	40.4
2-5	1/2	**1**					0.249	24.9
5-8	1/3	1/2	**1**				0.179	17.9
8-15	1/5	1/3	1/3	**1**			0.084	8.4
15-30	1/7	1/5	1/5	1/2	**1**		0.050	5.0
>30	1/9	1/7	1/5	1/3	1/2	**1**	0.033	3.3

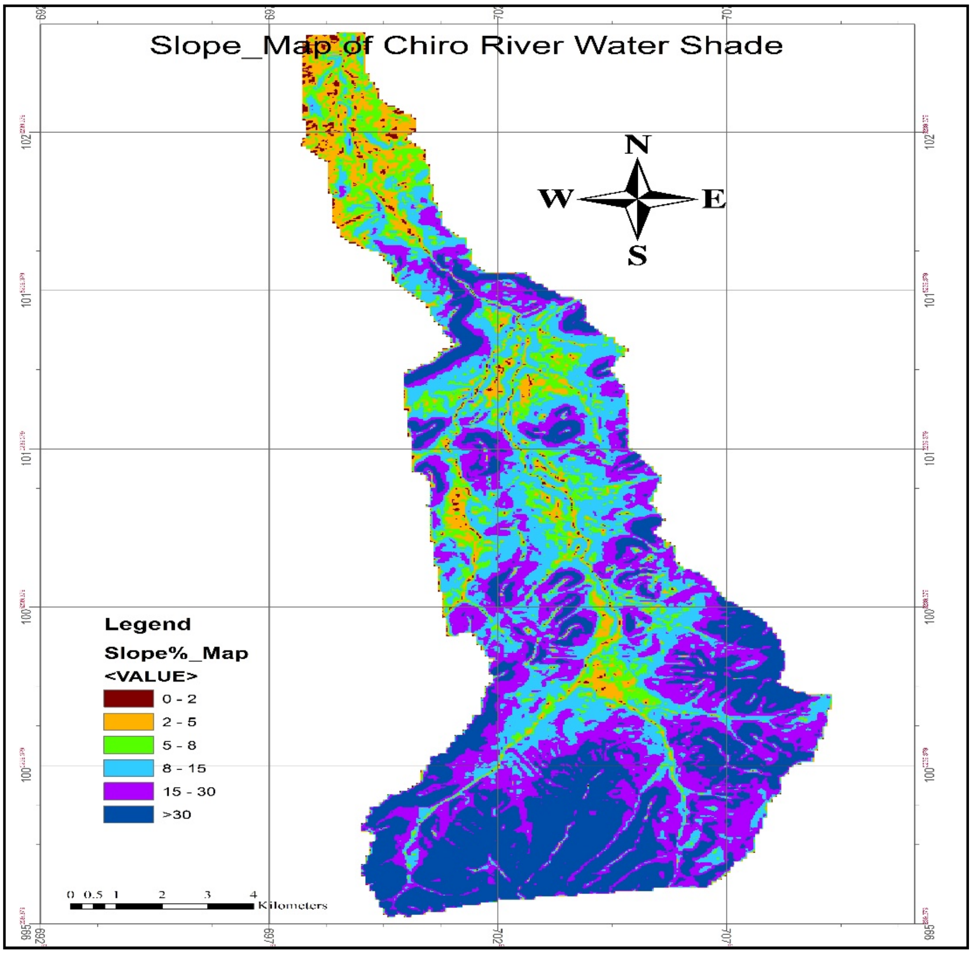

Figure 4-7 Slope map of Chiro river watershed

4.8 Elevation

For the present study the elevation data as described in methodology mapped from DEM of 30m x 30m spatial resolution. A Digital Elevation Model (DEM) indicates a digital geographic dataset of elevations in three dimensions. Water is always preferred to stay at lower topography than the higher topography. The higher elevation lesser will be the groundwater potential and vice versa. Elevation map of Chiro river watershed is shown in Figure 4-8. In Chiro river watershed it is clear from the map that elevation of topography was in the range between 1304 m and 3021 m from mean sea level. Most of the region is in the range between 1304 m to 2021 m. Lower elevation were identified at northern part of the study area. The assigned weight of each factor and elevation category of study area is shown in table 4-10. Consistency ratio=0.08<0.1

Table 4-10 Assigned weights to drainage density map of study area

	1304 - 1552	1552 - 1787	1787 - 2051	2051 - 2376	2376 - 3021	Weight	Weight *100
1304 - 1552	**1**					0.491	49.1
1552 - 1787	1/3	**1**				0.271	27.1
1787 - 2051	1/5	1/4	**1**			0.139	13.9
2051 - 2376	1/7	1/5	1/4	**1**		0.065	6.5
2376 - 3021	1/9	1/7	1/5	1/3	**1**	0.034	3.4

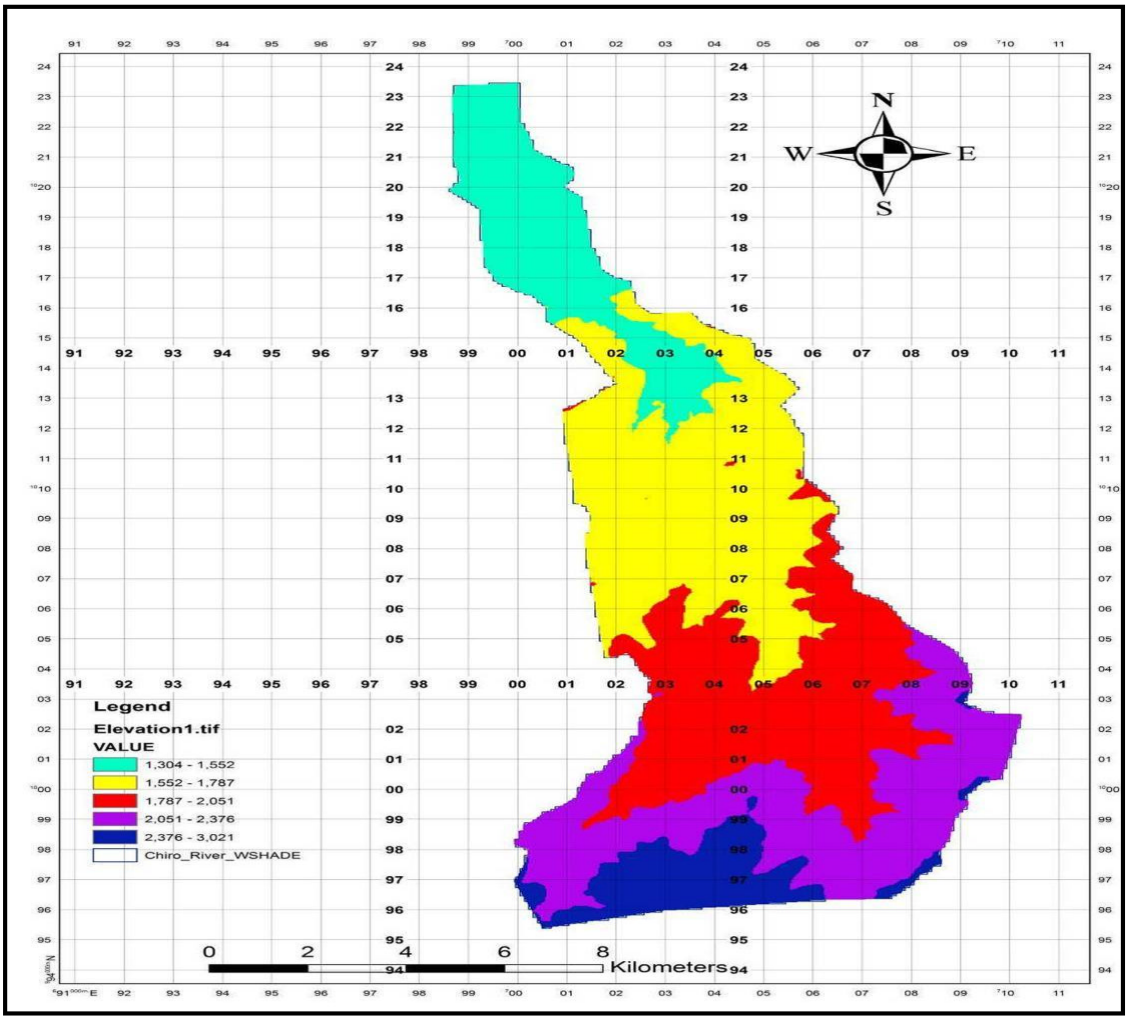

Figure 4-8 Elevation map of Chiro river watershed

4.9 Weight Assignment for Groundwater Potential Zone Mapping

Method to obtain the normalized weights of the combined and individual themes described in methodology. Suitable weights were assigned to the eight themes and their individual features after understanding their importance in causing groundwater occurrence in the study area. The normalized weights of the individual themes and their different features were obtained through the Saaty's analytical hierarchy process (AHP). The weights assigned to different themes are presented in the above from Tables 4-2 to Table 4-10. The normalized weight of combined eight different themes is presented in Table 4-11. After deriving the normal weights of all the thematic layers and each feature under individual themes, all the thematic layers were integrated with one another using GIS software in order to demarcate groundwater potential zones in the study area.

Table 4-11 Normalized weights of the combined thematic layers

Parameter	Litho	Geom.	LD	Slope	Soil	DD	LULC	Elev	Weight	Weight (%)
Lithology	1								0.33	33
Geom.	1/2	1							0.25	25
LD	1/3	1/2	1						0.10	16
Slope	1/4	1/3	1/2	1					0.10	10
Soil	1/5	1/4	1/3	1/2	1				0.08	8
DD	1/6	1/5	1/4	1/3	1/2	1			0.06	6
LULC	1/7	1/6	1/5	1/4	1/3	1/2	1		0.05	5
Elevation	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	0.03	3

4.10 Groundwater Discharge Potential Zone Maps

To generate groundwater potential zone map of the area, all eight different thematic layers were integrated with weighted overlay in GIS. Each thematic map was assigned a weight on depending on its influence on the groundwater potential availability. The weight for respective thematic maps was calculated based on weight normalization using the principal component analysis followed by pair-wise comparison matrix using Saaty's analytical hierarchy process (Saaty,1990). This process is done in such a manner that higher weightage represents better influence whereas and lowest weightage represent poorer influence towards the availability of groundwater.

The occurrence of groundwater potential in the study area is prominently controlled by the lithology, geomorphology, lineament (i.e. fault) density, soil, land use/ land cover, elevation, slope and drainage density as revealed from GIS analysis. All the thematic layers integrated spatially to determine groundwater potential. The results indicate that the most effective groundwater discharge potential zone is located on the map of the study area. The most suitable region of groundwater discharge potential zone are Tertiary Silicics (Na), volcanic landform, Upper-Afar Basalt (Ntb), lineament density (0-0.08), Residual landforms, slope (0-2) and lineament density (0.8-0.16) have high infiltration ability. The poorly suitable of study area is least effective for groundwater recharge, mainly due to its steep sloping topography.

Weight factor for single or combined thematic layers assigned using, the AHP method, developed by Saaty (1980), was selected as the decision analysis tool for the evaluation of the relative weight factor, according to their relative importance and contribution to groundwater discharge potential zones. On the basis of weightage assigned to these maps and bringing them into the function of spatial analyst for integration of these thematic maps, a map indicating groundwater discharge potential zones is obtained, which is as per Figure 4-9 below. This map has been categorized into five different groups which show the availability of groundwater discharge potential zone classes were set to “very low", "low”, “Moderate ", "high" and "very high" where "very high" presents most likely discharge potential location. Percentage of each groundwater potential zones is shown in table 4-12.

Table 4-12 Groundwater potential categories of the study area

Value	Groundwater Availability	Area Km^2	Area Percentage
1	Very high	13	10.0
2	High	11	8.0
3	Moderate	57	42.0
4	Low	29	21.5
5	Very low	25	18.5
Total		**135**	**100**

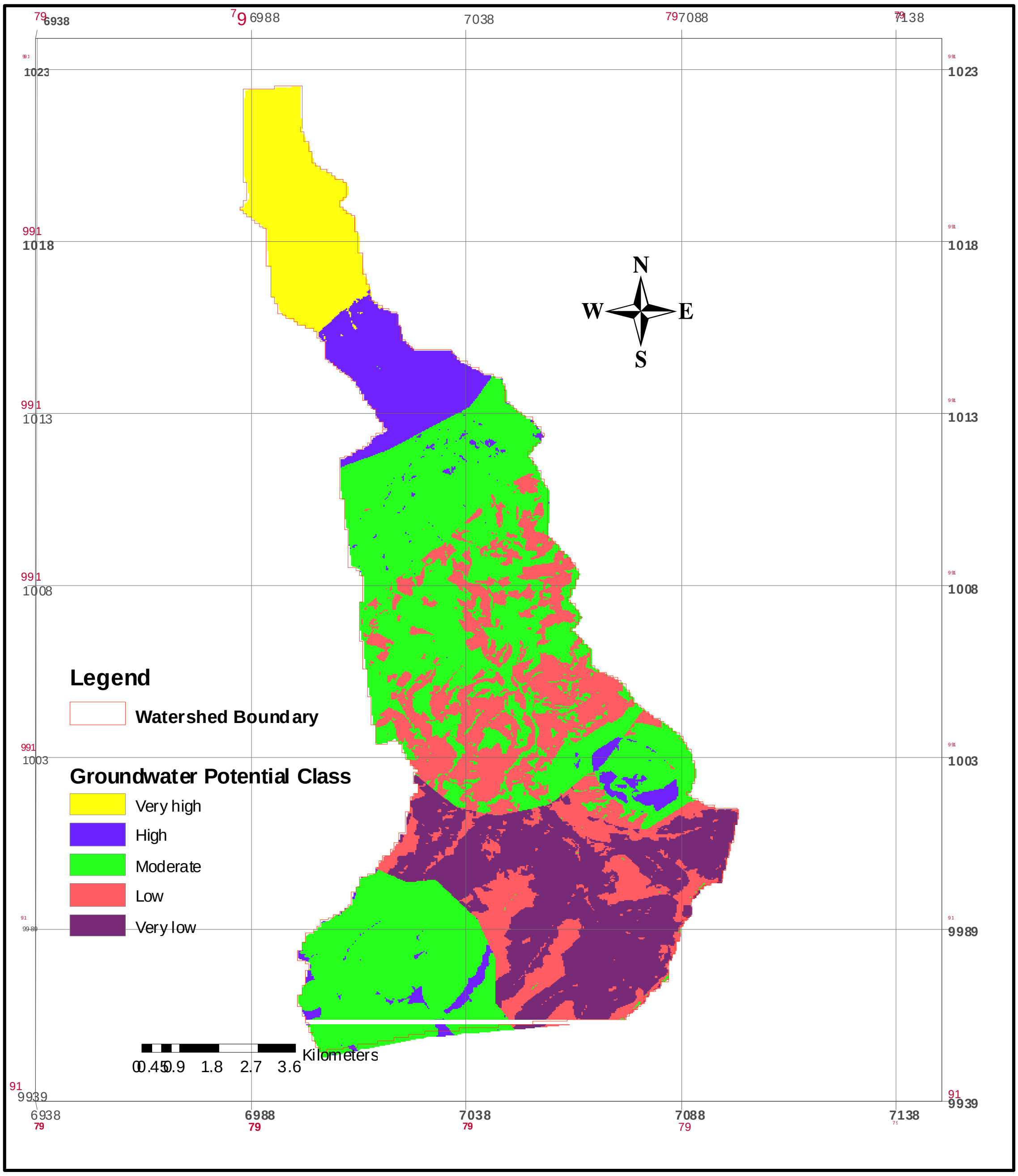

Figure 4-9 Groundwater potential zone map of the study area

5 CONCLUSIONS and RECOMMENDATION

5.1 Conclusions

This study produced a groundwater discharge potential zone map for study area. GIS and multicriteria analysis have been successfully used for evaluation and delineation of groundwater potential zones by combination of eight thematic layers such as: lithology map, geomorphology map, lineament density map, soil map, land use/ land cover map, elevation map, slope (%) map and drainage density map. All thematic layers were assigned different ranks and their classes assigned different weight according to their importance for groundwater occurrences. So GIS-based multi-criteria evaluation based on (Saaty, 1980) Analytical Hierarchy Process (AHP) was used to compute the rates for the classes and weights and ranks for thematic layers (Arivalagan, et al., 2014). The resulted potential groundwater map showed that the zones with very low, low, moderate, high, and very high groundwater potential cover 13, 11, 57, 29, and 25 km2 of the study area, respectively. In other words, they cover almost 10, 8, 42, 21.5, and 18.5 % of the area, respectively. The most important variables affecting groundwater controlling were considered, namely, lithology, geomorphology, lineament density and slope with a weighted of value of 33, 25, 16 and 10 %, respectively. However, soil (8 %), drainage density (6 %), land use/ land cover (5 %) and elevation (3 %) were found separately the least factors controlling groundwater occurrence.

From result of the study Analytical Hierarchy Process (AHP) is considered as a simple, transparent, effective tool for pairwise comparison in Multi Criteria Decision Analysis System (dependable system) by significantly reducing the mathematical complexity of decision-making based on systematic expert judgment for delineating of groundwater potential zones (Adel, 2020; Bane, 2017; Tamiru, 2019; Hindeya, 2020).

Overall result demonstrates that the use of GIS technique provides powerful tool to study groundwater resources and design suitable exploration plan for discharge location of groundwater in study area. Finally conclude that GIS technique can be used effectively to delineate groundwater discharge potential zones map, which can be used for improvement in the groundwater discharge potential area and holding for the study area.

5.2 Recommendations

From the findings obtained and conclusions reached the following recommendations are proposed.

The study recommends the use of GIS technology with the AHP method, for the further study of groundwater, which can minimize the cost, time, human power with higher accuracy. GIS technique with the AHP method can be used effectively to delineate groundwater discharge potential zones map, which can be used for improvement in the groundwater potential study for future and later on, may be for various purposes like efficient groundwater management for betterment of the society. The validity of the illustrated map was also not checked by using available drilling data. Because of the luck of existing well data, so for further validation field geophysical investigations on sites and existing well data are recommended.

Reference

Abbate, et al. (2015). Geology of Ethiopia: A Review and Geomorphological Perspectives Landscapes and Landforms of Ethiopia, 1_2: 33p,10.1007/, 978-94-017-8025-4

Adel et. al., (2020). Using Analytical Hierarchy Process and Multi-Influencing Factors to Map Groundwater Recharge Zones in a Semi-Arid Mediterranean Coastal Aquifer. *water* , 28.

Aduojo and Tanko, (2018). Delineation of Groundwater Potential Zones in Gwarzo Local Government Area, Kano State. *International Journal of Scientific & Engineering Research* , 1-16.

Al-Abadi and Al-Shamma'a (2014). Groundwater Potential Mapping of the Major Aquifer in Northeastern Missan Governorate, South of Iraq by Using Analytical Hierarchy Process and GIS. Journal of Environment and Earth Science. 4: 29p,121-149.SSN 2225-0948,

Alemayehu (1992). Groundwater occurrence in Ethiopia.

Aneesh R and Deka (2015). Groundwater Potential Recharge Zonation of Bengaluru Urban District - A GIS based Analytic Hierarchy Process (AHP) Technique Approach. International Advanced Research Journal in Science, Engineering and Technology. Vol. 2.2394-1588,

Argaz et al. (2019). Application of Remote Sensing Techniques and GIS-Multicriteria decision Analysis for Groundwater Potential Mapping in Souss Watershed, Morocco. *Journal of Materials and Environmental Sciences* , Page 411-421.

Arivalagan, et al. (2014). Delineation Of Groundwater Potential Zones Using Rs And Gis Techniques: A Case Study For Eastern Part Of Krishnagiri District, Tamilnadu. IJARSE. 3: 51-59.ISSN-2319-8354(E),

Ashraf and Ahmad (2012). Integration of Groundwater Flow Modeling and GIS Water Resources Management and Modeling, .978-953-51-0246-5,

Atef Al-Mashagbah, et al. (2012). The use of Kriging Techniques with in GIS Environment to Investigate Groundwater Quality in the Amman-Zarqa Basin/Jordan. Research Journal of Environmental and Earth Sciences: 9p.ISSN: 2041-0492,

Bane Lammesa, (2017). Groundwater potential and Recharge zone mapping by using GIS and Remote sensing Techniques in the case of Middle Awash River Basins, Ethiopia. PP 1-78.

Bereket, Bezabih. (2017). Groundwater Potential Mapping using Remote Sensing and GIS in Rift Valley Lakes Basin, Weito Sub Basin, Ethiopia. *International Journal of Scientific & Engineering Research* , pp 1-8.

Bunruamkaew (2012). How to do AHP analysis in Excel. Division of Spatial Information Science, University of Tsukuba. Graduate School of Life and Environmental Sciences: 22p,.

Dilip and Pramendra (2014). Groundwater Potential Zone Identification of Karwi Area, Mandakini River Basin, Uttar Pradesh Using Remote Sensing and GIS Techniques. International Journal of Engineering Science Invention,. Volume 3,: PP.10-19.ISSN: 2319 -6726,

Dr.Annadurai and Pandiyan (2013). Groundwater Potential Zoning at Kancheepuram using GIS Techniques. An International Journal (ESTIJ). 3: 10p.ISSN:2250-3498,

Eastman (2003). IDRISI Kilimanjaro Guide to GIS and Image Processing. Production. Worcester, MA, Clark University.

Engel and Navulur (1999). The Role of Geographical Information Systems in Groundwater Engineering. The Handbook of Groundwater Engineering. Delleur, CRC Press LLC.

Eskelinen (2011). Development and Utilization of GIS Based Groundwater Discharge Prediction Method: 70p

G. Z. Sass , et al. (2014). Regional-scale mapping of groundwater discharge zones using thermal satellite imagery. Hydrological Process: p28, 5662–5673

Ghodratabadi and Feizi (2015). Identification of Groundwater Potential Zones in Moalleman, Iran by Remote Sensing and Index Overlay Technique in GIS. Iranian Journal of Earth Sciences. vol.7: 142-152 pp

Hindeya et. al., (2020). Identification of Groundwater Potential Zones Using Analytical Hierarchy Process (AHP) and GIS-Remote Sensing Integration, the Case of Golina River Basin, Northern Ethiopia . *International Journal of Advanced Remote Sensing and GIS* , pp. 3289-3311.

Hussein, et al. (2016). Evaluation of groundwater potential using geospatial techniques. Appl Water Sci.DOI 10.1007/s13201-016-0433-0

Kamal Kumar Barik, et al. (2016). Hydrogeological Mapping and Identification of Groundwater Recharge Potential Zone of Reamal Block Deogarh District, Odisha A

Geospatial Technology Approach. International Journal of Advanced Remote Sensing and GIS. Volume5,: pp.1829-1843.ISSN 2320 - 0243,,

Kindie et. al., (2019). Spatial Analysis of Groundwater Potential Using GIS Based Multi Criteria Decision Analysis Method in Lake Tana Basin, Ethiopia. *Institute for Computer Sciences, Social Informatics and Telecommunications Engineering* , pp. 439–456.

Madhumitha et. al., (2018). Delineation Of Groundwater Potential Zones Of Kongu Uplands, Tamilnadu. *International Journal of Research and Analytical Reviews* .

Muse et al. (2018). Delineation of Groundwater Potential Zones of Abaya Chamo Basin using Geospatial Techniques. *International Journal of Science, Engineering and Technology* , 9.

Lalbiakmawia (2015). Application Of Geo-Spatial Technology For Groundwater Quality Mapping Of Mamit District, Mizoram, India. International Journal OF Engineering Sciences & Management Research. 2: 8.ISSN 2349-6193,

Liu, et al. (2015). Extract relevant features from DEM for groundwater potential mapping. International Workshop on Image and Data Fusion. The International Archives of the Photogrammetry. Kona, Hawaii, USA. XL-7/W4: 14p.

Mr. Kartic Bera and Bandyopadhyay (2012). Groundwater Potential Mapping in Dulung Watershed using Remote Sensing & GIS techniques, West Bengal,. International Journal of Scientific and Research Publications.Volume 2,: 7p.ISSN: 2250-3153,

OWWDSE (2010). Oromiya Land and Environmental Protection Bureau East & West Hararge_Zones Land Use Plan Study Project. Addis Ababa. 1.

Radomir Perzina and Ramik (2012). DAME - Microsoft Excel add-in for solving multicriteria decision problems with scenarios. Proceedings of 30th International Conference Mathematical Methods in Economics.

Rajkamal U, et al. (2014). Investigation Of Groundwater Potential Zones Using Rs & Gis In Western Part Of Krishnagiri District. International Journal of Advance Research In Science And Engineering IJARSE. Vol. No.3: 9P.ISSN-2319-8354(E),

Ramu, et al. (2014). Identification of groundwater potential zones using GIS and Remote Sensing Techniques: A case study of Mysore taluk -Karnataka. International Journal Of Geomatics And Geosciences,. Volume 5,: 9pp

Saaty (1990). The Analytic Hierarchy Process AHP: How to make a decision. Joseph M. Katz Graduate School of Business,. Pittsburgh, University of Pittsburgh: 18p.

Saaty (2008). Decision making with the analytic hierarchy process. Int. J. Services Sciences. vol.1,: p16

Sara, et al. (2016). Delineation of Groundwater Potential Zones in Nuweiba Area (Egypt) Using Remote Sensing and GIS Techniques. International Journal of Signal Processing Systems Vol. 4, No. 2

Seifu Kebede and von (2013). Groundwater in Ethiopia. Springer Hydrogeology. Verlag Berlin Heidelberg

Sethi (2015). Literature Review: 30p.

Shayan Ghodratabadi and Feizi (2015). Identification of Groundwater Potential Zones in Moalleman, Iran by Remote Sensing and Index Overlay Technique in GIS. Iranian Journal of Earth Sciences Vol.7: 142-152

Tamiru Tolcha, (2019). Groundwater Potential Zone delineation using GIS and Remote sensing Techniques in Sululta and Surrounding Watershed, Ethiopia. pp 85.

Tesfaye Tessema Gintamo (2015). Groundwater Potential Evaluation Based on Integrated GIS and Remote Sensing Techniques, in Bilate River. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS).Volume 10,: 85

Todd and Mays, (1980). Groundwater Hydrology, 3rd Edition. *John Wiley and Sons Inc* , 636.