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GIS and Remote Sensing Application for Groundwater Potential zone Delineation: the case of East Belesa district in Tekeze river basin Amhara Region Ethiopia,

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GIS and Remote Sensing Application for Groundwater Potential Zone Delineation: The Case of East Belesa district in Tekeze River Basin Amhara Region Ethiopia

BY

Abiyot Taye Birhanu

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in Partial Fulfillment of the Requirements for the Degree of

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Advisor Name: Asegdew Gashaw (Ph.D.)

August,2022

Bahir Dar ,Ethiopia

DECLARATION

I hereby declare that this thesis submitted for the partial fulfillment of the requirements for the Master of Science in Hydraulic Engineering is the original work done by me under the supervision of Asegdew Gashaw (Ph.D.). and this thesis is my original work and has not been published or submitted elsewhere for the requirement of a degree program to the best of my knowledge and belief. Materials or ideas of other authors used in this thesis have been properly acknowledged and referenced

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Abstract

Groundwater is the primary source of domestic, agricultural and industrial use in many regions of the world. this study aimed to use the time and cost-effective remote sensing (RS) and geographical Information system (GIS) techniques for assessing groundwater potential Zone in East Belesa District area. Thematic map derived from Landsat 8, existing borehole, Digital Elevation Models (DEM), and Rainfall data were utilized in this research. The thematic layers considered in this study were soil texture, Geology, geomorphology, drainage density, lineament density, rainfall, slope, and land use/cover. The weights have been assigned according to their relative importance in groundwater occurrence and the corresponding normalized weights were obtained based on Saaty's analytical hierarchy process. The thematic layers were finally integrated using Weighted Overlay analysis, then to produce a groundwater potential zone map of the study area. Three different groundwater potential zones were identified;40.80% High, 58.57% moderate, and 0.63% Low groundwater potential zones have been identified. The resulted groundwater potential zoning map was validated using NDWI, NDMI, and 53 water point data. Interestingly 36 data were overlaid.9 water point data were validated on the high, 18 water point data were overlaid on Moderate zone, and 9 water point data overlaid in low potential zone. Generally, in this study, it was found that high groundwater potential was found on the north-western side of the study area; so, groundwater can be exploited more in these areas. Hence to meet the increasing demand, new well fields may be formed in high groundwater potential zones, especially on the northwestern side of the study area.

Keywords: AHP ,Groundwater potential, GIS, Remote Sensing

List of Abbreviations

ADSWE	Amhara Design and Supervision Works Enterprise
AHP	Analytical Hierarchy Process
a.m.s.l	above mean sea level
CI	Consistency Index
CM	Consistency Measure
CR	Consistency Ratio
GIS	Geographic Information system
GSE	Geological Survey of Ethiopia
GWSS	Gondar Water Supply Service
HWSD	Harmonized World Soil Database
LULC	Land Use Land Cover
MCDM	Multi-Criteria Decision Making
MoWIE	Ministry of Water, Irrigation, and Energy
NMA	National Meteorological Agency
OLI	Operational Land Imager
PCM	Pairwise Comparison Matrix
RS	Remote Sensing
SRTM	Shuttle Radar Topographic Mission
NDWI	Normalize difference water index
NDMI	Normalize difference moisture index
NRB	Nile River Basin

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1. Introduction

1.1. Background

Both urban and rural regions mostly rely on groundwater as their source of drinking water. In many parts of the images, groundwater is the main supply for residential, agricultural, and industrial use. When surface water is not accessible for consumption or irrigation, groundwater is used as a substitute resource(Grönwall and Danert ,2020).and to identify or address a place or zone where is the ground water potential are available.and identify the reason why most of the wells are dried. Hydrology and hydrogeological investigations are increasingly using GIS and remote sensing techniques(Arefin, 2020). The current study's objectives are to define, evaluate, and appraise the groundwater potential map. It is one of the most important natural resources on which the survival and movement of mankind depend to a great extent. Groundwater is a renewable resource as it is being recharged. It is a life-threatening resource in many parts of the world, especially in the arid and semiarid drought-prone regions. It sets limits on the agricultural development via-a-vise the density of population and standard of living that can be sustained. The availability, accessibility, movement, and occurrence of groundwater depend on geology, slope, lineaments, drainage density, land-use/land-cover, Rainfall, and geomorphology of the area Geographical information system (GIS) and remote sensing (RS) are the optional methods to provide all parameters which influence the groundwater potential zone of one area they can access, manipulate, and analyzes the spatial and temporal data from satellite image (Aykut ,2021). Besides this, Explain the several decision analysis approaches such as Multicriteria Decision Making (MCDM) and Analytical Hierarchy Process (AHP) used to fill the gap of water scarcity caused by miss understanding or have no clear information where drill the well.Therefore, this study aims to identify or address a place for zone where is the ground water potential is available for water supplysurvice,

1.2. Statement of the Problem

Groundwater is a crucial resource in many parts of the planet**,** especially in the arid and semiarid regions. Groundwater is not found uniformly distributed; it may be restricted in hard rock terrains. It is a standard practice that groundwater exploitation is probabilistic which has successes and failures,in east belesa woreda money companys they are interving .howevr those companys not address satisfaction in very well,governmental and non- governmental xompanys draft hand dug well to the communitys ,however those hand dug wells have no sufficient discharge,there for the reason of this is related to miss understanding of or have no clear information where drill the well.my objective is to identify or address a place or zone where is the ground water potential is available for watersupply survice or irrogation. it occurs that groundwater is found deep within the subsurface; there is no direct method to facilitate observation of water below the surface. Its absence only could be inferred indirectly by studying the groundwater occurrence and distribution controlling parameters. Groundwater is required to satisfy the rapid water demand within the area to feed the growing population and for municipal uses. One of the issues within the study area is the absence of updated spatial information on the number and distribution of groundwater potential(Amiraslani and Dragovich, 2021). Groundwater assessment in Northern Gondar has been usually conducted using a field survey, which is not feasible in terms of your time**.** This study focus to assess Belesa wereda groundwater potential using GIS & RS, AHP, and MCDM tools. To do so, major factors like geomorphology, slope, rainfall, land use land cover (LULC), soil texture, lineament density, and drainage density are considered. Thus, as an area of filling the gap, integrated GIS and remote sensing techniques are used to assess the load factor of groundwater potential for every input parameter (slope, soil, drainage density, geology, rainfall lineament density, LULC ,and geomorphology) and to assess the groundwater occurrence and potential zone using MCDM techniques.

1.3. Objectives

1.3.1. General Objective

The main objective of this research is to identify groundwater potential zones in Belesa Woreda by using geographic Information systems (GIS) and remote sensing Techniques.

1.3.2. Specific Objectives

- To identify the woredas' prospective groundwater area using several thematic maps
- Identify the location of the well that is drill
- Develop groundwater level map.

1.4. Research Questions

- Why most of the wells are dried?
- Why most of the hand dug wells have no sufficient discharge?
- How much percentage of an area have good potential of groundwater?

1.5. Scope of the Study

The scope of the study is limited to covering only Belesa Woreda, which is found in the Tekeze Basin in Amhara Regional State. The study focuses on identifying and assessing groundwater Potential zone using Remote Sensing and GIS Techniques, which consider geology, geomorphology/ elevation, drainage density, lineament density, slope, rainfall, land cover, and soil texture.

1.6. Significance of the Study

The result of the study is to develop the groundwater potential zone map,and provide information about productive wells location to governmental and non_governmental organizations as well as the drilling companies in the study area. This could reduce the extra labor and time required in siting well locations for groundwater exploitation. The Provision of such maps may provide good information for well drillers and decision-makers. The produced and structured groundwater potential map may also be used as a geo-database which will permit decision makers, the liable stakeholders, and to appropriately use and cope with water resources in the study area. Future researchers may also find it useful for investigating groundwater conditions, geology, groundwater allocation, extraction patterns, etc. of the study area.

2. LITERATURE REVIEW

2.1. Global Overview of Groundwater

In the last three decades, most water source globally has been from groundwater. In several countries, the extreme use of groundwater has turned the tide economically and socially(Liu et al., 2020). 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 of 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(Wang and Liu ,2020), 30-50% of the water at farm gates comes from groundwater. Intensive groundwater development in Sub-Saharan Africa still has to begin. In comparison, Sub-Saharan Africa does not have the massive high yielding shallow aquifers that are found in Asia, but even where the groundwater potential exists, it is not yet used intensively(Walker et al., 2020).

The same is true for Ethiopia(Kumar, 2012)indicated that groundwater is a major source of water supply and food production in irrigated agriculture worldwide. It plays an important role in sustaining rivers, lakes, and wetlands during dry periods and is essential for many ecosystems. Water is naturally stored in land surfaces as lakes, streams, reservoirs, ponds, and oceans, and as groundwater in deep aquifers and saturated and unsaturated soils. The total groundwater of the world is estimated to be 10.53 Million km3, and the groundwater comprises 99% of the earth's available freshwater resources(Gebremeskel ,2017). The groundwater is therefore essential for storing the fresh water required by a human Groundwater can also be stored in the saturated zone of the soil, which serves as the largest reserve of drinkable water and irrigation water. This water can be accessed by humans by different mechanisms in the form of springs, tapped by wells, or drilled from boreholes.

2.2. Water resources potential and utilization in Ethiopia

According to the Ministry of Water and Energy report, among the total area of land in Ethiopia, the land area and water bodies are covered 99.3% and 0.7% respectively. those water bodies are included major 12 river basins of the country; 8 Rivers with the flow and one rift valley with water and the other 3 basins have no visible water flow due to they are located in the part of the country that is not getting enough amount of rainfall throughout the year. there are also 12 major lakes, reservoirs, and dams as well as a sufficient amount of underground water sources. the amount of water obtained from the major River basins is estimated to reach more than 124.4 billion cubic meters (BCM). But all the River basins except Awash are transboundary Rivers in which 97 percent of flows terminate in neighboring countries.(Ayalew ,2018)

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 in the rift, and some urban areas provide water for many small towns and rural areas (Demissie et al., 2022). other main groundwater tapping systems are springs, widespread within the escarpment and therefore the highlands, which supply the good majority of the agricultural community, particularly within the rugged mountainous regions. According to(Oddsson et al., 2004) within rural settings, each spring is tapped to serve 200-500 people. Hand-dug wells and comes 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 the utilization of groundwater in drilling shallow and deep wells, even if there are possibilities of developing springs and hand-dug wells to acquire water security for drought mitigation and preparedness(Basharat and Hassan,2014). Groundwater is used for domestic purposes, irrigation, Livestock watering, industrial purpose and others. While it is enormous of 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.

2.4. Previous groundwater studies in the Tekeze River Basin

Groundwater has always been essential for human survival throughout Africa, and this is the case in the Tekeze river Basin(MacAlister and Pavelic, 2013). Traditionally, groundwater was accessed first at naturally occurring springs and seepage areas by humans and animals; later, as human ingenuity increased, it was accessed via hand-dug wells, advancing to hand-pumps and then to boreholes and mechanized pumps. Throughout the NRB we can see all of these forms of groundwater access in use today. As the population's ability to develop and use technologies to access groundwater has grown, the scale of abstraction and human demand for groundwater resources have also increased(MacAlister, Pavelic et al. 2013).provide a good overview of the exploitation of groundwater in Africa. Groundwater uses the domestic water supply in rural and urban settings for drinking and household use and small commercial activities; industrial use and development for tourism; agricultural use for irrigation and livestock.

Groundwater is defined as all water that occurs in the soil and geological formations below the land surface. An aquifer is a geologic formation, group of formations, or a portion of a formation capable of yielding usable quantities of groundwater to wells or springs the amount and value of groundwater resources worldwide are vulnerable to unmanageable water extractions and intakes(Tadesse, 2017). This request for groundwater is the result of fast population and commercial development and growing urbanization and commercial farming and is uncontrolled by an effective governance structure. Groundwater demonstrates a crucial and increasing role in overall drinking water supply and food security stating that groundwater is frequently used in various countries. It is the principal source of drinking water and gives importance to irrigation, therefore towards food security in arid and semiarid areas. Consequently, it donates the significant elements of the water economy.

2.5. Geographic Information System (GIS)

GIS is a technological field that incorporates geographical features with tabular data in order to map, analyze, and assess real-world(Grigonis , 2011). It is an efficient tool to capture, store, update, manipulate, analyze and display all forms of geographically referenced data. GIS is used to store data about the world as a collection of thematic layers to be linked together in a spatial domain using a geographic reference system. In other words, GIS is often described as an organized collection of hardware, software, geographic data and personnel designed to show the geographic data into information to satisfy the users' needs. It uses three types of data to represent a map or any geo-referenced data. These are point type, line type and area or polygon type. It can work with both vector and raster geographic models. The vector model is generally used for describing the discrete features, while the raster model is used for expressing the continuous features. A GIS approach comprises three distinct phases' viz. data acquisition, data processing and data analysis. The data acquisition phase includes establishing control of the information quality, which consists of positional accuracy and reliability of observation. Data processing includes processes such as digitizing a map data for its incorporation in the GIS. The data are often directly digitized from the map employing a digitizing table or they are often digitized by tracing the outline of required classes on a transparent overlay in the image processing software. The last approach or the data analysis is common in the hydrogeological mapping(Šumanovac and Weisser ,2001).

2.6. Remote Sensing (RS)

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance . Such as scanners and cameras, located on mobile platforms such as aircraft or spacecraft followed by the analysis of acquired information using photograph interpretation techniques, image interpretation and image processing as described by Sabins (Sun, 2019).

The contact between the remote sensor and the target is through electromagnetic energy such as visible, thermal and infrared radiation, force fields that are gravity magnetic or acoustic waves. Remote sensors measure the relative variation of these forms of energy that are either emanating from the body or being reflected from it for recognition and detailed studies. For most of the atmospheric and earth surface observations, electro-magnetic energy is considered the supreme medium for two reasons. Primarily, this is the only form of energy that can propagate through free space and a medium. Further, its property to interact with the media and the target in a variety of ways ensures the sensor captures the subtle variations that exist like the features of the earth. Remote sensing works on the principle that every part of the earth reflects the incident light depending on its optical characteristics(Campbell and Wynne , 2011).

Different objects on the earth's surface return different amounts of reflected/emitted energy in different wavelengths of the electromagnetic spectrum pending on the atmospheric windows and this reflectance/remittance from each object depends on the wavelength of the radiation, the molecular structure of the object and its surface conditions(Dwivedi ,2018). Vegetation, in general, appears green during the daytime, because it reflects the green band of visible radiation preferentially while absorbing other color bands of the visible radiation. A wide variety of RS data are acquired from different types of satellites, viz. SRTM DEM, Landsat (Schmidt et al., 2012).

2.7. PCI Geomatica

PCI Geomatica is a remote sensing and photogrammetry desktop software package for processing earth observation data, Geomatica is aimed primarily at faster data processing and allows users to load satellite and aerial imagery where advanced analysis can be performed. Geomatica has been used by many educational institutions and scientific programs throughout the world to analyze satellite imagery and trends.

A very popular edition of Geomatica is known as Free view, which permits users to load multiple types of satellite images as well as geospatial data that is stored in different formats. The software is available for download over the web and has registered several thousands of downloads.

Lineaments refer to the natural lines that follow a series of rules in remote sensing images, The lineament density is generated using the line density analyst extension of ArcMap 10.8 (Bossennec and Frey ,2021)and PCI Geomatica Software to identify the lineament orientation. This pattern is classified based on its density and association as a weak zone from the geomorphological landscape which objectively shows the tectonic geomorphic landscape composed of various geological structures with different scales and forms while indicating the regional geological structure framework(algouti et al., 2022). With the development of image processing and spatial analysis technology, a beneficial basis is laid for rapid lineament extraction and geological structure analysis, thus facilitating the implementation of the exploration of mineral and hydrological resources, regional geology survey, and geological disaster prevention and ecological environment evaluation, etc.

2.8. Factors that affect Groundwater Potential

Parameters influencing groundwater potential zone and their relative importance will be taken from earlier works, the same factors are combined and only characteristic parameters will be selected. The lithology, geomorphology, land use land cover, lineaments, slope, soil, drainage density, and rainfall affects groundwater potential as the key parameters(Arulbalaji and Padmalal, 2019,).

2.8.1. Geology

Lithology plays an important role in the occurrence and distribution of groundwater since it is the controlling factor of infiltration rate and flow. Precambrian lithology of Ethiopia which is mainly of metamorphic rocks is considered as low-yielding regional aquicludes (Tolche, 2021) nevertheless, regolith and fractures are the main groundwater holding and transmitting media in a metamorphic terrain (Venkateswaran et al., 2019). Mesozoic sediments have better productivity because they have intergranular permeability and can have extensive aquifers (Murthy and Mamo ,2009).

2.8.2. Geomorphology

Geomorphology is the study of earth structures and also depicts the various landforms relating to the groundwater potential zones and structural (Saranya and Saravanan ,2020). Geomorphology controls the subsurface movement of groundwater, it is one of the most important features in evaluating the groundwater potential and prospects and then it can be utilized for the management of groundwater resources(Padmalal et al., 2019).

2.8.3. Land Use Land Cover

The land is a prime natural resource and the mapping of land use/land cover is essential for the planning and development of land and water resources (Van De Steeg et al., 2009). LULC includes the type of soil deposits, the distribution of residential areas, water bodies, and vegetation cover within a certain area. It is an important factor affecting groundwater recharge, groundwater occurrence, and availability (Kim et al., 2011).

2.8.4. Lineament

Geological lineaments are the manifestation at the earth's surface of deeper geological structures (faults and fractures that have obvious displacement, ruptures that have no significant fracture displacement) (Liu et al., 2018).

2.8.5. Slope

Topography and slope gradient directly influence the infiltration of rainfall and could be considered as one of the indicators of groundwater potential accessibility. It can also indicate the general groundwater flow direction(Paznekas and Hayashi, 2016). The slope has a dominant influence on the contribution of rainfall to the stream flow and recharges to the groundwater.

2.8.6. Soil

Soil type plays a vital role in controlling the infiltration rate of precipitated water and the water-holding capacity of the area. Consequently, it could be considered as one of the important factors for the delineation of groundwater potential zones(Tolche, 2021).

2.8.7. Drainage

Drainage density is one of the important indicators of groundwater and groundwater occurrence (Gupta and Srivastava, 2010).In fact; it is linked with water percolation properties of underlying lithology, consequently having a close relation with groundwater mapping. The drainage density is an inverse function of permeability. An area with a low permeable surface prone to high drainage density and water that comes from precipitation goes to a high runoff as well and vice versa. As a result, high drainage density implies low groundwater potential.

2.8.8. Rainfall

Rainfall is one of the important factors to delineate groundwater potential zones. (Mohammadi and Charchi ,2019). It is the main source of natural recharge to develop groundwater resources

2.9. Multi-Criteria Decision Analysis Using GIS Techniques

Multi-criteria decision analysis using Analytical Hierarchical Process (AHP) is the most common and well-known GIS-based method for delineating groundwater potential zones(Arulbalaji and Padmalal ,2019). This method helps integrate all thematic layers. A total of 8 different thematic layers were considered for this study. The association of these influencing factors is weighted according to their reaction to groundwater occurrence and expert opinion.

2.10. Geometrics Mean Method

The Geometric Mean is a special type of average where we multiply the numbers together and then take a root. The multiplicative approach to the AHP uses the familiar methods of taking the geometric mean to obtain the priorities of the alternatives for each criterion without normalization(Saaty ,2011), and then raising them to the powers of the criteria and again taking the geometric mean to perform synthesis in a distorted way to always that preserve the rank. The geometric mean method a mathematical process of the Analytical Hierarchy Process (AHP) is used for the analysis of functional layout parameters in the study watershed(Khan et al., 2019) i.e. whether it can be implemented or not under the condition consider.

In AHP, the candidate requirements are compared pair-wise, and to which extent one of the requirements is more important than the other requirement. Decision makers must first understand and determine the goal, criteria, and alternatives of the problem before a hierarchic structure can be developed. The AHP then requires the decision makers to carry out simple pair-wise comparison judgments. The judgments of the decision makers are generally based on the state of mind, situations, learning, and personal experience. The overall summary of implementing the AHP can be classified into three basic principles; Decomposing the problem is the problem can be decomposed by structuring it in a hierarchical form, Pair wise comparisons are constructed by comparing pairs of elements in each level of hierarchy concerning every element in the higher level. These pair wise are used to establish priorities for each set of elements in each level of hierarchy.

Comparing the pairs of elements will be generated by giving a comparative judgment of preferences for each pair of elements at every level using Saaty's nine-point scale (AHP). This comparison process is carried out to determine which of the element in a pair is more desirable or preferred compared to the others. These comparisons are positioned into a positive reciprocal or pair-wise comparison matrix. The derivation of the priorities from pair wise comparisons matrix is the main concept of the AHP. The AHP allows decision makers to derive ratio scale priority or weights from the pair-wise comparison matrices.

The priorities vector for every set is a level of estimating by using the prioritization method (i.e., eigenvector method, additive normalization method, geometric mean method). And also, the composition of the resulting priorities or synthesis of priorities, this principle was applied to attain the composite priority for the lowest level elements, which are the alternatives based on the overall preferences expressed by the decision-makers. Every priority vector (priorities) in the lowest level is weighted overlay by the higher-level priorities.

2.11. Geophysical method

Geophysical methods mean all geophysical data gathering methods used in mineral or coal exploration, including seismic, gravity, magnetic, radiometric, radar, electromagnetic, and other remote sensing measurements(Sundararajan, 2013).

Groundwater exploration is the investigation of underground formations to understand the hydrologic cycle, know the groundwater quality, and identify the nature, and type of aquifers. There are different groundwater exploration methods. The surface geophysical method is one of the groundwater investigation methods. One of the surface geophysical methods is therefore the vertical electrical sounding method. Vertical electrical sounding (VES) is one to provide valuable information regarding the vertical successions of subsurface geo-materials in terms of their thicknesses and corresponding resistivity values. The objective of this method was therefore to locate productive well site locations using surface geophysical methods for irrigation and water supply purposes. However, hydrogeological and geological investigations were also incorporated in addition to the geophysical surveying activities for the betterment of the project. Finally, the intended well site locations with their corresponding thickness and resistivity values were identified using the integrated approaches(Shishaye and Abdi, 2016). But it is not rapid and effective in estimating aquifer thickness of an area compared to GIS and RS thickness, and also it is a costly and time-consuming technique for groundwater study Some of the general disadvantages of geophysical methods include: Most methods work best for situations in which there is a large difference in stiffness between adjacent subsurface units. It is difficult to develop good stratigraphic profiling if the general stratigraphy consists of hard material over the soft material

2.12. Geoelectrical method

Geoelectric is one of the classical methods of exploration of geophysics. Main applications are groundwater investigation and soil-scientific studies, but the method also plays an important role in the search for cavities and faults and is applied for archaeological studies and borehole measurements(Spěváčková ,2018)

The model that geophysicists mostly use is therefore the layered subsurface.

In practical use, linear or 3D- electrode arrays are often used, i.e., many steel electrodes are hammered into the subsurface along a profile or in a defined area, which can be used both as current and voltage measurement electrodes. It is therefore possible to measure various electrode configurations without changing the position of the electrodes. Usually, soundings are carried out, which means primarily the changes in the resistivity with depth are studied. However, there are also electrode arrangements that provide detailed information about the lateral resistivity changes .Even if the most widely used investigation methods for groundwater are geoelectrical techniques but it is costly and time-consuming. By considering studies in terms of human power, cost and time,therefore GIS and remote sensing techniques for groundwater potential zone are easily characterized

2.13. Role of GIS and RS in Groundwater Potential

According to GIS and remote sensing techniques, groundwater potential zone are easily characterized. For example, conducted on Role of Satellite Sensors in Groundwater Exploration, satellite sensors can emphasize the open new systematic and efficient exploration of ground water(Singh et al., 2021), landform mapping, geological mapping, and mineral exploration and geo-hazard studies. In addition, it helps to understand various landforms, which are not easily observed. According to Geographical information systems and remote sensing, it is the most advanced technology for many scientific applications such as mining natural disasters, landslides, earthquakes, volcanoes and agricultural management, mineral and groundwater exploration, and can access large data at the same time which are impossible to reach such us cliff, mountains, and gorges.

(Tolche, 2021), explain the application of GIS and remote sensing; compares GIS and remote sensing applications on groundwater delineation with other methods such as geospatial, numerical modeling, and geophysical methods. He concluded that the above methods are very expensive, laborious, time-consuming, and destructive. In contrast to the above methods, according to (Adeyeye and Ikpokonte , 2019) groundwater cannot observe directly by our eyes because it is found beneath the ground many techniques give information about groundwater and recharge potential zones such us hydrological investigation, geophysical and geo-electrical or geophysical seismic refraction methods which are very expensive and time-consuming. GIS and remote sensings are the latest, time, and cost-effective technology for groundwater exploration by acquiring full information and accessing all parameters of factors that control groundwater potentials and recharge zone areas by using different software easily. Several works are done on the role of GIS and remote sensing on the groundwater potential and recharge zone., (Das, Pal et al. 2019)conducted integrated remote sensing and GIS-based for assessing ground water potential. To define when GIS and remote sensing techniques have increased for using ground water potential and recharge zone mapping conducted on groundwater potential. In addition, recharge zone is based on GIS and remote sensing and they identify different thematic maps for delineating groundwater potential and recharge zones like drainage density map, lineament map, and land- use land -cover map, hydrogeology map and soil map, and slope map. Additionally, done (Prasad, Mondal et al. 2008)on evaluation of groundwater potentiality using the integrated approach of remote sensing, geophysics, and GIS of Ojhala Sub-watershed, Mirzapur district, India. In generalizing different thematic layers like lineaments, slope, drainage, and overburden thickness were used to integrate without considering aquifer thickness.

3. Material and method

3.1. Description of Study Area

Belesa is situated in North Gondar Amhara region, Ethiopia. Geographically the woreda is found in Around Northwestern part of Ethiopia, $12^{0}24'54.17''$ N and $38^{0}04'38.9''$E. The average Elevation of the town is 1922.475m.a.s.l, bounded by Tekeze River tributaries. With an estimated area of 1848.289km^{2,} as shown in (Figure 3.1)

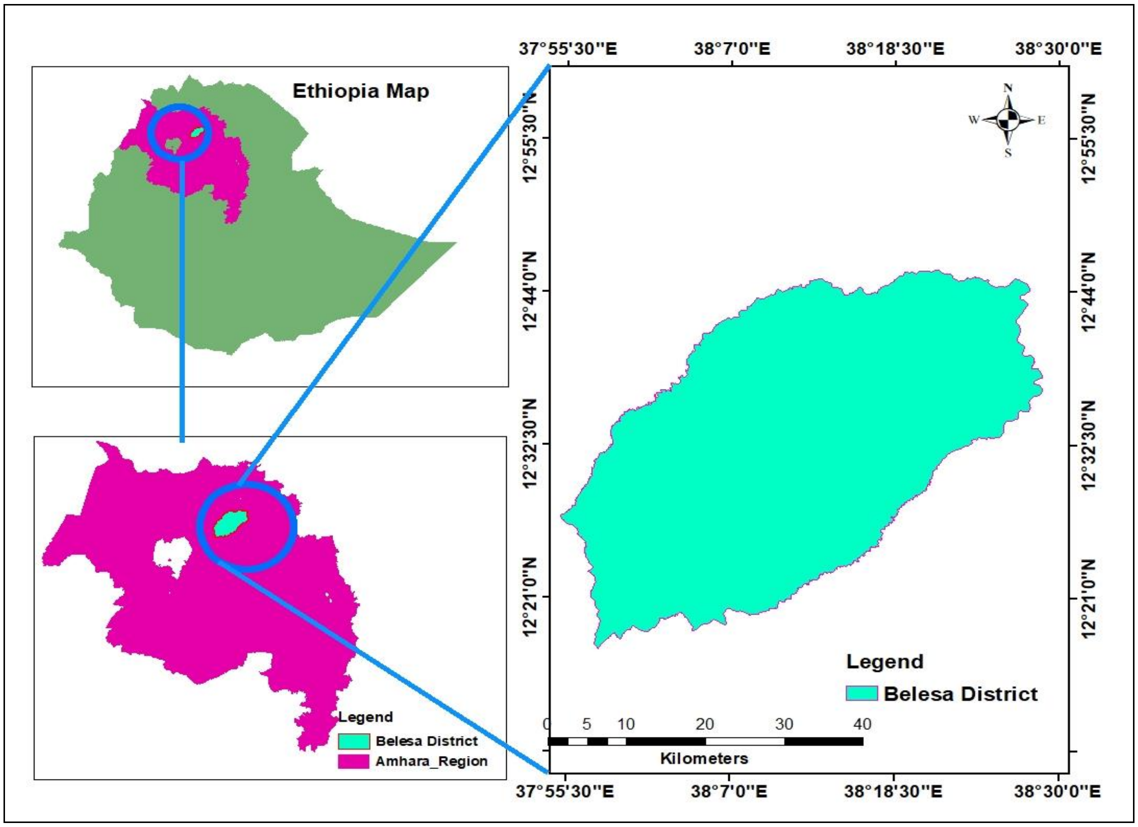

Figure3. 1 Location Map of The Study Area

Belesa woreda was part of the North Gondar Zone. It was bordered on the south by the Debub Gondar Zone, on the west by Gondar Zuria, on the northwest by Wegera, on the northeast by Jan Amora, and on the east by the Wag Hemra Zone. The population Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), Belesa woreda has an estimated total population of 191,000, of whom 93,207 are male and 97,761 are female; 10,121 or 5.30% of its population are urban dwellers. This is less than the average of 14.1% for the Zone (CSA, 2005)., Belesa has an estimated population density of 75 persons per Km2.

3.1.1. Climate

Guhalla town is situated in 90% Kolla and 10% woina Dega region of Ethiopia. The average temperature values of the Town are 320c and the average annual rainfall of the woreda is recorded to be 700mm(Nigusie and Azale , 2021).

3.1.2. Socio-Economic Activity

The livelihood of the population in Guhalla is based on Agriculture, trade, daily laborers, and others. Source of income in government employee's=28%, Trade=25%, Agricultures and other=47%, The main crops grown in the woreda are; sesame, Teff, Maize etc (Gizaw and Assegid, 2021).

3.1.3. Ethnic and Religious Composition

According to the information gathered from the woreda administration office, 97% of the the town population is Orthodox Christian,2% Muslim and1% pente. Amharic is the the dominant language is spoken in the area(Alemayehu ,2012)

3.2. Methods

GIS and RS techniques were applied to describe groundwater potential through the analytical hierarchy process. The methods included the following stages (Arshad and Zhang ,2020): i) identification and evaluation of parameters, ii) data collection, iii) preprocessing, iv) input dataset, v) reclassifying input layers (preparation of land use land cover map, lineament density, geomorphology, soil, slop, rainfall, drainage density, and geology map) then preparation map, vi pair wise comparison of criteria assigned weights according to their relative importance in groundwater occurrence can be obtained based on the Saaty's Analytical Hierarchy Process, vii weighted overlay analyses spatial analysis in ArcGIS tools and rank the final value and viii validation with borehole.

The overall methods are illustrated infigure3.2, The groundwater assessment in the study area needs to create several statistical maps. Such thematic maps considered were geomorphology, geology, drainage density, lineament density, land use land cover, soil, slope, and rainfall. All the thematic maps were assigned weights according to their relative importance in groundwater occurrence based on Saaty's Analytical Hierarchy

Process. These data have been integrated to produce groundwater potential factor maps such as geology, geomorphology, soil hydrological group, land use/land cover, drainage slop, lineament density, and rainfall map.

The maps were prepared and analyzed using GIS Arc Map, GIS Raster Calculator, and other GIS tools and RS data. GIS and Analytic Hierarchy Process (AHP) or Multi-criteria decision making was applied to assess groundwater potential zone. Integrated GIS and AHP were applied to delineate the groundwater potential map by considering the influential factors. The resulted groundwater potential map is reclassified to verify the availability of groundwater such as very good, good, poor, and very poor. The map result was combined with the existing borehole data to validate the groundwater potential.

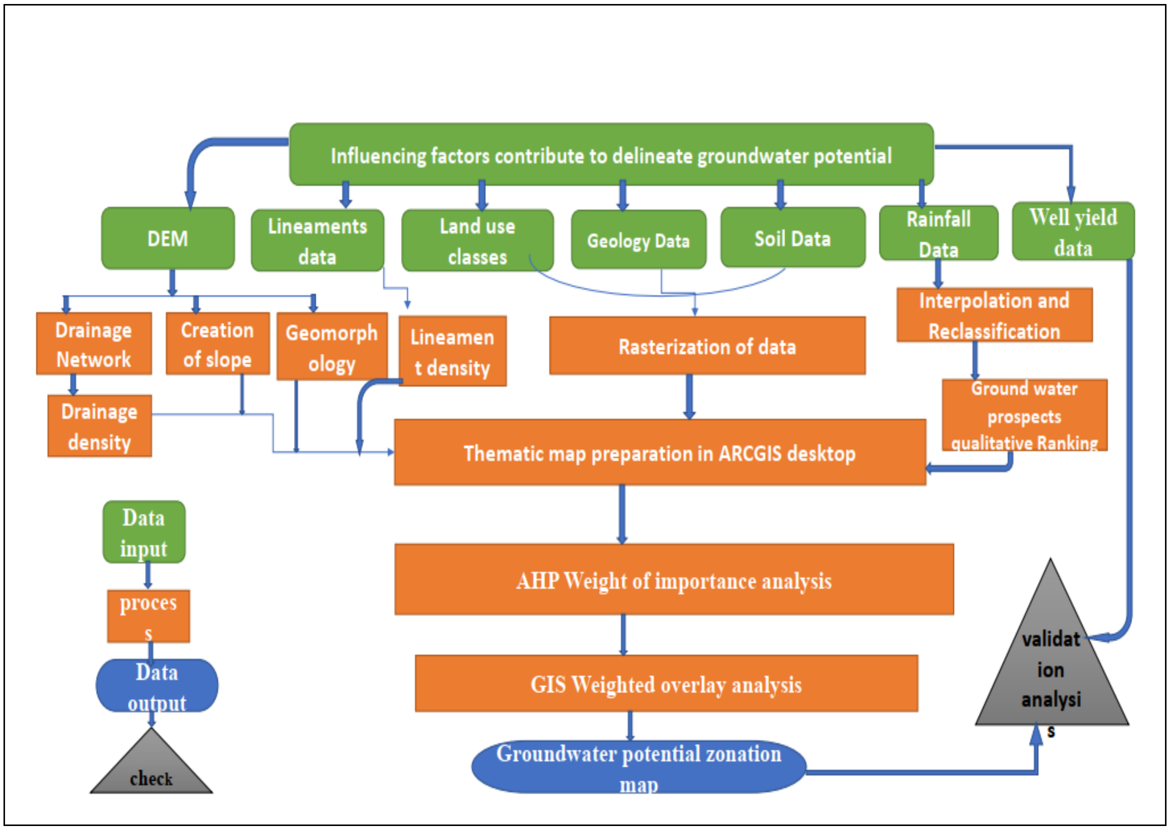

Figure3. 2 General Methodology Chart of the Study Area

3.3. Data collection and analysis

3.3.1. Data collection

Data collected included satellite images, digital elevation model (DEM), existing thematic maps, metrological station data (Belesa annual Rainfall values, and collecting well points. Various types of data and software have been used. a DEM with 30 m resolution was obtained from Shuttle Radar Topography Mission (SRTM) to derive slope, geomorphology, and drainage density map was obtained earthexplorer.usgs.gov and used to establish drainage density which contains filling sinks, flow direction, flow accumulation, and stream network. The drainage density map was produced using a line density analysis tool. The land sat 8 Operational Land Imager (OLI) satellite image was obtained from the Earth Explorer and used to generate lineament density. LULC is obtained from the USGS website The rainfall data of the study area was collected from the West Amhara methodological Agency and, it was used to produce the rainfall map using inverse distance weighted interpolation method, groundwater well such as deep well, spring, shallow and hand-dug well) data were provided from the Ethiopian Ministry of Water Energy and Electricity (Woreda level) for locating the specific location of well and, the data was transfer into spreadsheets and include the coordinates of wells, geological data was obtained from the Ethiopian geological survey, soil map of the study area can be prepared and used the soil texture, Soil Database (SD) from Amhara Design supervision work Enterprise(ADSWE) soil map 140m resolution. The data were collected in the category the groundwater potential within the study area.

Table 3.1 Data collection of Study Area

Data	Source of Data	Purpose
Existing wells/springs	Belesa water resource development office	For the output map validation for ground water potential
DEM (30m resolution)	earthexplorer.usgs.gov	elevation, drainage density, slope, and Geomorphologic map
Land sat 8 OLI/TIRS	https://earthexpl orer.usgs.gov/	Lineament map
Soil map	ADSWE 140m resolution	soil map
Geological map	Ethiopia geology survey	Geology map
annual rainfall	West-Amhara Meteorological Agency at woreda level	Areal rainfall map

3.3.2. Software and model used

Data were analyzed using different software and decision-making tools(Islam ,2020). Many types of software can be used for the assessment of Groundwater potential. From this software, GIS10.8, AHP sheet, PCI Geomatics, and line density analysis tool were used in this research.

3.3.2.1. ArcGIS 10.8

ArcGIS is used to create the geodatabase, data input, data editing, data management and storage, geo-referencing data from different sources, perform spatial multi-criteria, generate criteria maps, and assign a weight for each criterion, overlaying analysis, and visualization of output data(Mandal and Kumari, 2019). In the study area, the groundwater availability factor map developed was carried out using the Arc Map10.8 software package. The factors that are input to multi-criteria analysis were preprocessed by the criteria set to develop a groundwater occurrence map. In the study area, Arc GIS was used for GIS analysis**.**

3.3.2.2. PCI Geomatica

PCI Geomatics is a remote sensing and photogrammetry desktop software package for giving out earth thought data, designed by the PCI Geomantic Company. LINE tool in PCI Geomatic, the lineaments happened in the study area was extracted from the Land sat 8 OLI image used Geomantic LINE tool in PCI Geomantic from the Landsat 8 OLI/TIRS image having 11 bands, the lineaments extract from band 5 was taken due to its quality and the highest number of lineaments generate and nearly infrared band(Ban et al., 2020).

3.3.2.3. Landsat 8

The Landsat 8 image using the most popular and widely used automated processing tool in the study Landsat8 was used to process remote sensing analysis to create lineament density using band 5 for using different water indices, band 5 to use in their Lineament density can also be easily computed from the microwave remote sensing for extreme weather and climate(Liu et al., 2018).

3.3.2.4. AHP, GPS, and Arc Hydro

AHP best software was obtained to give weight for each thematic layer based on the importance to the final output groundwater potential zone map, GPS can be collected well point, Arc Hydro use for the drainage system of the landscape defines the direction of surface water flow according to land surface topography. Drainage boundaries may be delineated manually from a topographic map, digitized from a digital raster graphic map, or determined through the use of raster data from Digital Elevations Models.

3.4. Data Analysis

Irrigation and drinking water are obtained from groundwater that moves away from the river. Geographic Information System (GIS) based on multi-criteria decision-making (MCDM) analytic hierarchy processes (AHP) as a spatial prediction tool was used to explore the groundwater potential area. In the study area have been analysis 8 hydrological and hydrogeological criteria are considered as influence factors namely, geology, rainfall, drainage density, slope, lineament density, land use land cover, rain fall, and soil texture. The weights of these criteria were determined through the AHP method pair comparison method; the Arc GIS 10.8 program and its sub-modules were used. Finally, after all these thematic maps are organized, the weights value determinate for each factor is compute used GIS, AHP, and MCDM techniques groundwater-potential-zone assessments of the area are obtained as follows: very poor, poor, good, and very good groundwater potential zone (GWPZ) maps of the catchment are created. At last, all the factors were integrated, and compute the model used the weighted overlay so that potential groundwater areas are mapped and cross-validated by borehole data.

3.4.1. Thematic Map Preparation

A thematic map is an important source of GIS information. These tools were tools used to communicate geographical concepts in the form of a map. In the study area, thematic maps such as rainfall, land use land cover, geomorphology, geology, slope, soil, lineament density, and drainage density map are prepared by using GIS (digitization and spatial analysis tool), overlay analysis with the appropriate criteria. The groundwater assessment in the study area involves thematic map generation and their integration through GIS. Thematic maps were prepared in the scale with a spatial resolution pixel size from satellite imagery, topographical, geological mapping, and other hydro geological field data.

3.4.2. Analytical Hierarchy process

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 Saaty's 1–9 scale of relative importance. AHP is one of the multiple criteria decision-making methods that was originally developed by (Saaty, 1979), provides measures of judgment consistency, derives priorities among criteria and alternatives, and simplifies preference ratings among decision criteria. AHP method relays on the hierarchical structuring of the decision criteria which was incorporated in decision-making problems. AHP uses the pair-wise comparison matrix, to evaluate the hierarchy based on a fundamental scale of values ranging from 1 to 9. The AHP generates a weight for each evaluation criteria/factor according to the decision maker's pair-wise comparisons of the criteria/ factor. The higher weight, the more important the corresponding factors.

Table3.1 pair-wise comparison scale for AHP

Scale	Importance	explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate Importance	Experience and judgment slightly
4	Moderate Plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong Plus	
7	Very-Strong Importance	An activity is favored over strongly over another
8	Very, very Strong	
9	Extreme Importance	The evidence favoring one activity over another is of the highest

A pairwise comparison matrix was deriving used Saaty's nine-point importance scale supported by thematic layers use to work out the groundwater potential zone. The Analytical Hierarchy Process (AHP) captures the idea of uncertainty in judgments through the principal Eigen value and the consistency index. Saaty gave a measure of consistency called Consistency Index (CI) as deviation or degree of the consistency used the following method.

3.4.2.1. Normalization weight method

Normalization is used when the criteria depend on the alternatives or when the alternatives depend on the alternative. The criteria in the row are being compared to the criteria in the columns. This step is to normalize the matrix by totaling the numbers in each column. Each entry within the column is then divided by the column sum to yield its normalized score. Weight Assessment and Normalizations the pairwise comparison matrix was carried out using AHP techniques. The Cumulative weight of the main criteria was computed using the relative weight of their corresponding classes. Map Categorization and weight Assignment for groundwater potential and recharge parameters were selected for groundwater potential and nine parameters were selected for groundwater recharge potential zone. Categorization and weight assignment were conducted for both groundwater potential zones. Normalization was assigned weight using AHP based on Saaty's scale, considering two themes and classes at a time on the idea of their relative importance to working out the groundwater potentials zone. Thereafter, pairwise comparison matrices of assigned weights to different thematic layers and their classes were built using AHP and weights normalized by the eigenvector approach. Consistency Ratio (CR) was calculated to examine the normalized weights of various thematic layers and their classes (Rai et al.,2021). To compute the CR of various thematic layers and their classes, the following steps were carried out

$$P = \begin{vmatrix} p_{11} & p_{12} & p_{1n} \\ p_{21} & p_{22} & p_{2n} \\ p_{n1} & p_{n2} & p_{nn} \end{vmatrix} ----------------3.1$$

where *pn* displays the *n* the indicator unit and *it* is the judgment matrix element.

The eigenvalue and the eigenvector are calculated as:

$$Wn = GMn / \sum_{n=1}^{N} GMn \text{---------------------------------------} 3.2$$

where *W* is the weight vector (column) and *GMn* is the geometric mean of *I* the row of the judgment.

Consistency ratio (CR)

Calculate the consistency ratio (CI/RI), Where RI is a random index in the given criteria, Consistency index (CI). Consistency ratio (CR) is a measure of the consistency of the pairwise comparison matrix given by the equation. A serious pairwise comparison matrix is used for checking the consistency ratio (Saaty and Shang ,2011).This decision- makers use to reduce the bias in decision-making (Wind and Saaty, 1980)

CR is a measurement of consistency, of pairwise comparison matrix and it is considered using equation

CR= $\frac{CI}{RI}$-- 3. 3

Where CI and RI are consistency index and random consistency index respectively. RI is the ratio index; the value of RI for different 'n' values is given Saaty's ratio index for different values of N.

Consistency index (CI)

The Consistency Index is reflecting the consistency of one's judgment it multiplies each column of the pairwise comparison matrix (Bij) by the corresponding weight (Wn).

CI= $\frac{\lambda\, max - n}{n-1}$-- 3. 4

Random Index (RI)

The CI of a randomly-generated pairwise comparison metrics Random inconsistency indices for n = 10

Table3.2 Random index(AlArjani, Modibbo et al. 2021)

Matrices	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Calculate the consistency ratio (CI/RI), Where RI is a random index in the given criteria, Consistency index (CI). According to City, if the value of CR (Consistency Ratio) is lesser or equal to 10%, the consistency is acceptable/suitable, if CR is greater than 10%, the need to revise the subjective judgment. In the study area 8 criteria, the random index is 1.41.

3.4.2.2. Weighting and Ranking of Each Layer (AHP)

In the study area, all parameters do not have an equal effect on groundwater distribution, ranking of each parameter was needed. Weighting each factor and a pair-wise comparison matrix were prepared for each map based on multiple criteria decision making. The rate/rank for classes in a layer and weights for each factor are assigned and a pair-wise comparison matrix has been prepared for each map by using the Multi-Criteria Decision Analysis technique based on Analytical Hierarchy Process (AHP) by considering eight factors (geology, lineament density, soil, drainage, rainfall, slope, geomorphology and land use/cover). Square matrices are constructed, where each criterion is compared with the other criteria, relative to its importance, on City's scale from 1 to 9. The rate/rank for classes in a layer and weights for thematic layers of each factor are calculated by weighting each factor and a pair-wise comparison matrix was prepared based on each map.

3.4.2.3. Overlay Weight Model Analyses

the weighted overlay is one method of modeling suitability groundwater potential. Arc GIS was used in the following process for this analysis. Assigning a weight to an individual raster in the overlay process allows you to control the influence of different criteria in the suitability model. The consideration of thematic layers in the study area are geology, geomorphology, drainage density, lineament density, rainfall, soil, slope, and land use/ land cover, and groundwater potential zones are delineated by using Weighted Overlay Analysis in Arc GIS 10.8 software. In the thematic overlay analysis, individual parameters are assigned with rank considering more or less their influences on groundwater prospects. The Weighted Overlay was implemented within a single tool in several steps in the general overlay analysis process. The factor was reclassified values in the input raster into a common evaluation scale of suitability or preference or some similarly unifying scale, multiplies the cell values of each input raster by the raster's weight of importance, and adds the resulting cell values together to produce the output raster from equation 6. The weighted overlay tool scales the input data on a defined scale and the weights of the input raster are, added together. To different groundwater potential zones, scored maps of all the thematic layers after assigning weights can be integrated systematically using the spatial analyst tool of Arc GIS 10.8 software. After determining relative weights for each of the factors, the criteria for groundwater potential for each pixel were calculate used the mathematical equation.

GWPIM $= \sum_{i=1}^{n} \sum$ Wi × Xi) = (WRF*RF+Wg × GEO) + (Wsl× SL) + (WLD × LD) + (Wso × SO) + (Wg*GEOM) + (WD × DD) + (WC ×LULC) -------------------------------- 3. 5

where GWPI is the Ground Water Potential Index Map, its pixel number in the raster

n is the number of the factors; Wi is the weight assigned to each factor and xi is the groundwater potential raster parameter of each factor: or RF= rainfall, GEO = Geology, SL=Slope, LD= Lineament density SO = Soil, GEOM= Geomorphology, DD = Drainage density and LULC=land use land cover).

3.4.2.4. Validation of groundwater potential map

Validation of the groundwater potential zones was done using existing data on wells data and yield data(Berhanu and Hatiye ,2020), Aquifers have been classified according to their productivity (yield) with corresponding classes of groundwater potential zones, thus aquifers have a yield (productivity) of less than 2l/s, 2 to 4 l/s, and greater than 4 l/s yields were classified as low, moderate, and high productivity, respectively. In the area of study, there are 53 groundwater Borehole wells and springs that were used for validation. These data were classified into three categories depending on their number and yield data with the corresponding class of GWPZ map. The delineated GWPZs were validated using data on groundwater yield of exploration boreholes acquired from the National Groundwater Archive. The 53 data was overlaid on the GWPZ map to filter out the corresponding grid code identity of the borehole spot. The regression equation of the scattered diagram of the GWPZ grid codes against the groundwater yield was obtained to simulate the expected yield value. The coefficient of determination (R^2), coefficient of correlation (R), and the p-value of the relationship between the observed value and the simulated value were calculated in Microsoft Excel. R^2 was obtained using.

$$R^2 = \frac{\sum Ei - On}{\sum Oi - On} \text{ ---3. 6}$$

Where Oi is the observed value which is borehole yield (l/sec), Ei is the expected value drawn from the simulation of borehole yield, on is the mean borehole yield, and n is the sample size of the borehole yield involved.

3.4.3. Groundwater governing Parameters and preparation methods

Groundwater potential parameters of the study area were determined through analysis of available information combining the data of rainfall, slope, drainage density, geomorphology, geology, lineament density, land use/cover, and soil type are considered the main groundwater potential controlling parameters in the study area(Bhat et al.,2020). In the study area, eight factors were used for groundwater potential determination. These include; geology, slope, lineaments density, soil, geomorphology, drainage density, rainfall, and land use land cover. The thematic maps that represent the eight factors were extracted for the work out of the final map. The values' range was reclassified into five classes, based on the overlay weight modeling, with equal intervals. The reclassify is performed based on the groundwater potential values.

3.4.3.1. Rainfall

Rainfall plays an important role in the hydrologic cycle and controls groundwater potential. Knowing the nature and characteristics of precipitation, the amount of rainfall is not the same in all places and it varies based on the environmental conditions of the environment(Riedel and Weber ,2020). Therefore, in the study area will be used a hydrologic analysis model it is important to know the areal distribution of precipitation that may contribute to groundwater recharge and create potential area. The possibility of groundwater is high if the rainfall is high and it is low if rainfall is low. They will be applying for this purpose. Since the rainfall gauges measure the point data, it can be converted to the areal rainfall using some interpolation techniques to prepare the rainfall map of the study area. The interpolation technique IDW is used in this study. From ArcGIS in arc toolbox hydrology interpolation technique IDW method used to develop rainfall map. The minimum rainfall of the woreda is 591.224mm and the maximum rainfall map is 802.139mm.

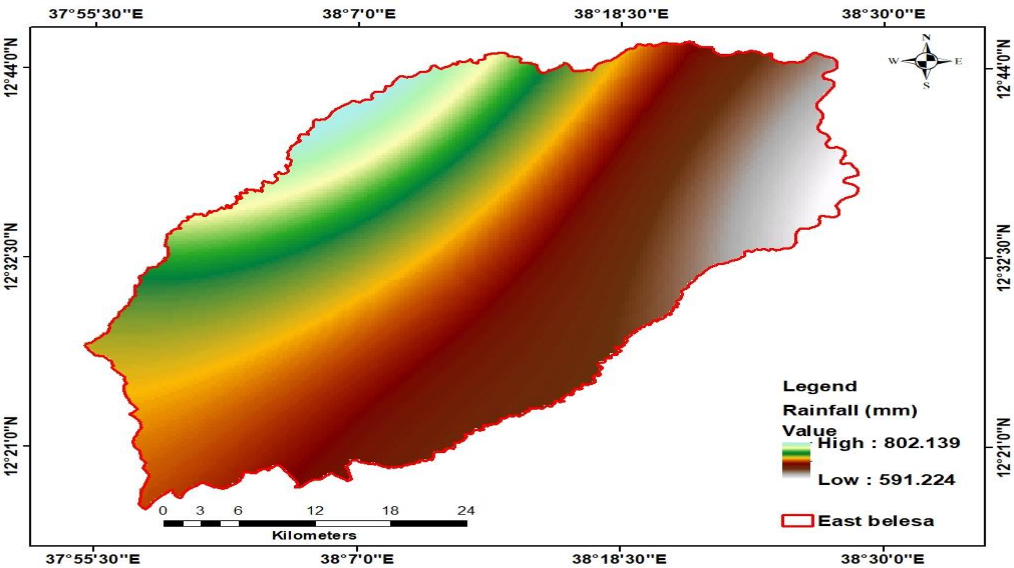

Figure 3.3 Rainfall map

3.4.3.2. Slope

The slope is one of the important topography parameters, which is explained by the horizontal spacing of the contours. The elevation raster has a slope value in every cell. the slope is measured by the identification of the maximum rate of change in value from each cell to neighboring cells(Domisch et al., 2018). The lower slope values indicate the flatter terrain (gentle slope), the lower slope areas of the flat terrain allow rainfall infiltration and percolation; they have high groundwater. Higher slope areas correspond to steeper slopes generating quick runoff from the terrain. As can be shown there are five classify of slopes identified in the study Watershed. The slope is an important factor in groundwater potential mapping slop determines the rate of infiltration and runoff of surface water, the plane surface areas can hold and drain the water inside the ground, which can augment the groundwater recharge whereas the steep slopes increase the runoff and decrease the infiltration of surface water into the ground. The slope of the study area has been calculated in degrees/percent based on the DEM model which is based on the SRTM data using the hydrology analyses model.

Table3.3 Role of slope for Groundwater Potential(Andualem and Demeke 2019)

Factors	Value (Degree)	Classification	Infiltration rate

Slope	0 - 7	Very gentle	Very high infiltration very high groundwater
	7- 13	gentle	High infiltration
	13- 120	moderate	Optimum infiltration
	20-28	steep	Low infiltration
	28-71	Very steep	Very low infiltration very low groundwater

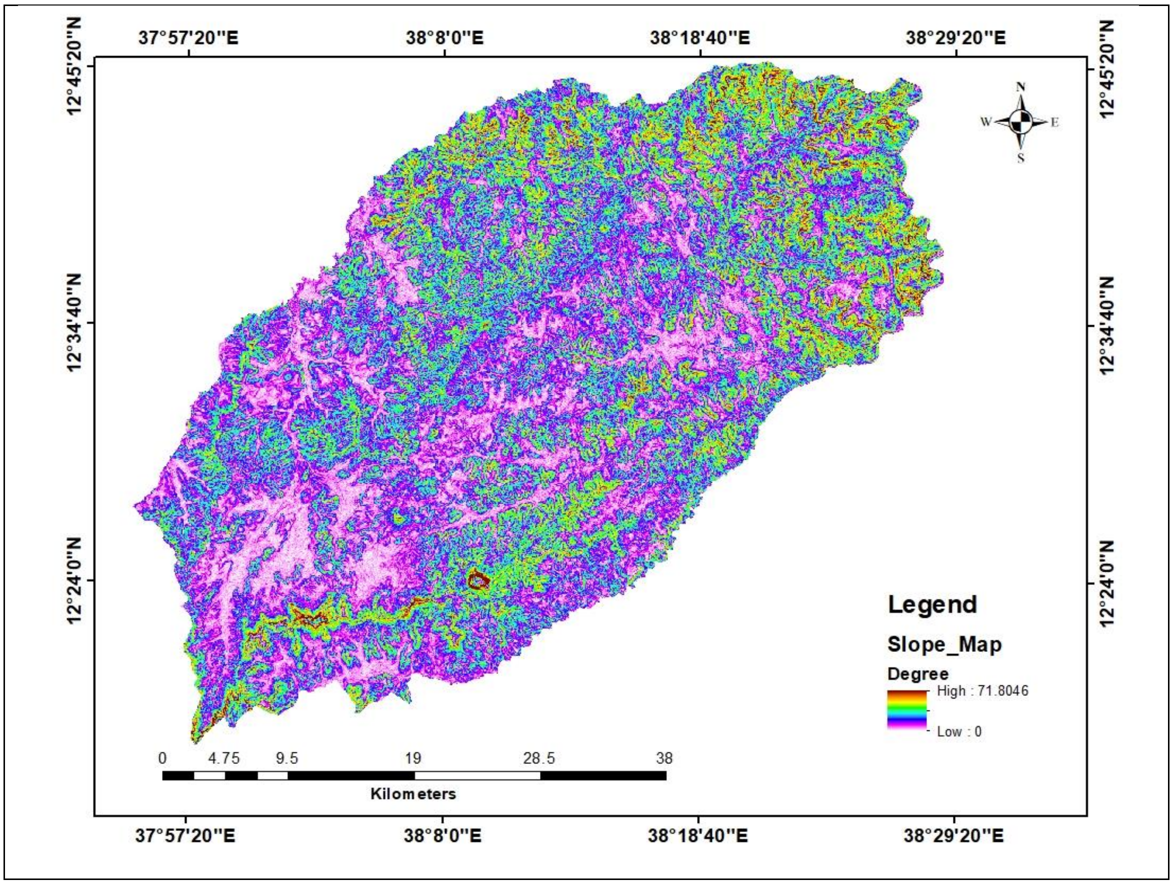

Figure3. 3 Slope Map

3.4.3.3. Drainage density (DD)

Drainage density is defined as the nearness of the spacing of stream channels(Berhanu and Hatiye ,2020). According to (Waikar and Nilawar, 2014), drainage density (DD) is the measure of the total length of the stream segment of all orders per unit area. Drainage Density is usually representing the sum of all the stream lines divided by the total study area, which shows drainage density in values.

DD= $\sum_{i=1}^{n} Li/A$--------------------------- 3. 7

Where ΣLi is the total length of all streams in the stream order Li (km) and A is the area of the watershed grid (km2). It is one of the factors, which play a major role in potential groundwater zone. High drainage density favors high runoff and thus less infiltration into the ground and percolation then. On the other hand, low drainage density areas have less surface runoff and consequently high infiltration into the ground. In the study area, the drainage densities were classified using the hydrology model from DEM. Drainage density is the total length of all the streams and rivers in a drainage watershed divided by the total area of the drainage watershed can be calculated as a ratio of the sum of streams/river lengths to the size of the area of the grid considered. The drainage network of the study area was created from the SRTM global elevation data through Arc hydro tools in Arc Map 10.8 / hydrology and its density is calculated using the Line Density command. Next, the study area can be grouped into five drainage density classes from very low to very high.

Table3.4 Role of Drainage for groundwater Potential (Amal et al., 2014)

Drainage density (km/km2)	Description	Suitability ground
0 - 0.24	Very Low density	Very Good groundwater
0.24-0.5	Low density	Good ground water
0.5 - 1.0	Moderate density	Moderate
1.0 - 1.2	High density	Poor
>1.2	Very high density	Very Poor

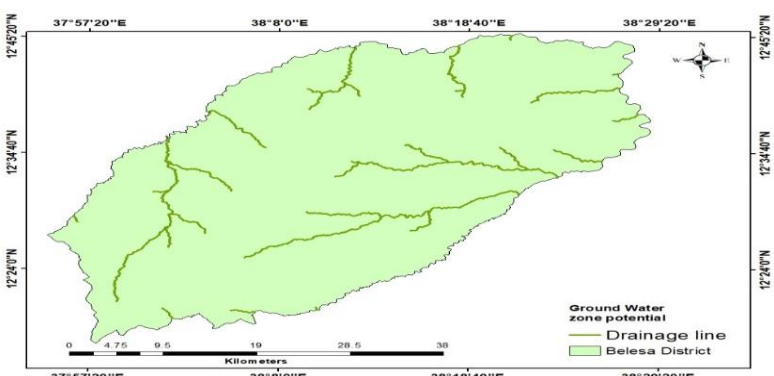

Figure3. 4 Drainage map

3.4.3.4. Geomorphology

Geomorphology is the study of earth structures and also depicts the various landforms relating to the potential ground water zones and structural features (Navane and Sahoo, 2020). For Geomorphology controls the ground surface movement of groundwater, it is one of the most important features in assessing the groundwater potential and prospects and then it can be utilized for the management of groundwater resources. In the study was prepared the geomorphology map of the landform classified technique from DEM.

Table3.5 Role of geomorphology for groundwater potential

(Lingarajuand Raja Naika, 2016)

Factors	Class	Rank	Groundwater potential
Geomorphology	hill	1	Very Poor
	Denudation hill	2	Poor
	Valley	3	Moderate
	Floodplain	4	Good
	Flat	5	Very good

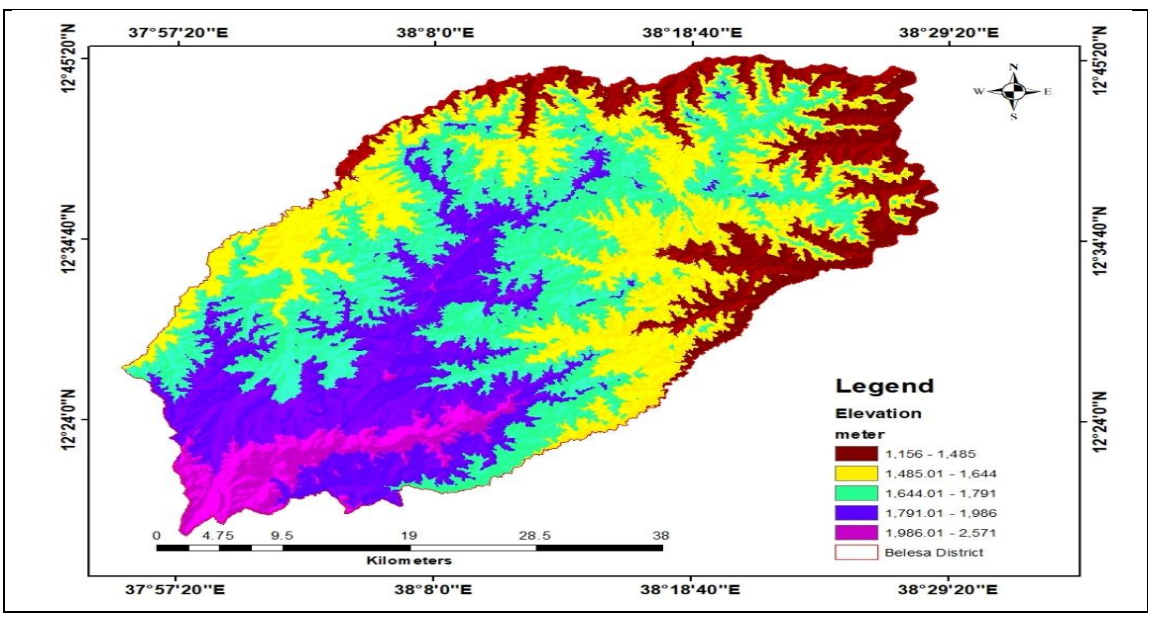

Figure3. 5 Elevation map

3.4.3.5. Geology

Geology influences both the porosity and permeability of aquifer rocks (Caine and Tomusiak ,2003). Therefore, it is one of the major factors which play an important role in the distribution and occurrence of groundwater. Geology/lithology thus is an important groundwater controlling parameter, which shall be, consider in the ground water study. The geology/lithology thematic map of the study area can be prepared by the study watershed, produced by the Geological Survey of Ethiopia (GSE). The geological factor weight was associated with the water permeability and the capacity of the formations to host groundwater.

Adigrat-Formation(Ja)

The adigrat sandstone includes the whole succession of classic rocks resting unconformable on the Precambrian Metamorphic. It comprises sandstone with minor lenses of siltstone and conglomerate with laterite up to 2m thick at the top. The formation is typically yellowish to pink in color and comprised of fine to medium grained, well sorted, crossbedded quartz sandstone. It is non calcareous except at the top near the contact with the overlying Antalo Formation (Jt). The age is Triassic to middle Jurassic(Tafesse and Konka . 2022).

Tertiary Volcanic Rocks

Much of the study area is covered by Tertiary volcanic rocks. These consists a number of different Tertiary Volcanic units which overlay the sedimentary and basement complexes.The volcanic vary in character based on composition, structure and degree of weathering.The major volcanic units recognized in the study area are:

Ashangi Basalt (P2a)

Ashangi basalt represents the earliest fissural flood basalt volcanism on the North West plateau. The basalts are thick strongly weathered, crushed, tilted basalts which lies below the major Pre-Oligocene unconformity(Tafesse and Alemaw, 2020) . The Ashangi formation consists of predominantly mildy alkaline basalt with interbedded pyroclastics and is commonly injected by dolerite sill and dykes.The upper part of Ashangi is more tuffceous and contains interbedded Lacustrian deposites with Lignite seams

Aiba Basalts (P_3a)

The Aiba Basalt represents the second major pulse of fussural basalt volcanic on the north western plateau. They are generally aphyric, compact rocks, in places showing stratification and contain rare interbedded basic tuffs. The Aiba Basalt conformably overly the Ashangi basalts and attain a thickness of about 200-600m. The basalt show distinctive theoleitic nature with transitions to mildy alkaline varieties(Asfaha, 2015).

Tarmaber Basalts (PNtb)

Tarmaber formation represents Oligocene to Miocene basaltic shield volcanism on the northwestern plateaus. Tarmaber basalts in contrast to tholeitic and mildly alkaline nature of the earliest Aiba flood basalts are typically alkaline in nature. On the North-western plateau theTarmaber shield volcanoes become progressively younger from the north to south. Thus the classification Tarmaber Gussa formation (PNtb) for shield volcano of the northern Ethiopia plateau with absolute age range of 26 to 16 MY(Tafesse and Alemaw, 2020) .

Table3. 6 Geology characteristics(Kamal, Adewunmi et al. 2017)

Factors	Geological unit	Aquifer characteristics
Lithology	Tarmaber Gussa formation (Pntb)	low
	Aiba Basalts(P3a)	Very low
	Ashangi Formation (P2a)	high
	Adigrat Formation (Ja)	Very high

3.4.3.6. **Lineament density** (LD)

A lineament may represent a fault, fracture, and master joint; a long and linear geological formation, topographic linearity, or straight course of streams(O'leary and Friedman,1976) also stated that the presence of lineaments usually signifies a permeable zone. Therefore, the lineament density of an area can ultimately expose the groundwater potential. Lineament density (Ld) can be defined as the total length of all record lineaments divided by the area of the catchment under consideration which is given as(Razandi and Pourghasemi, 2015). $LD = \sum_{i=1}^{n} Li/A$ -- 3. 8

Where ΣLi is the total length of all lineaments in kilometers and A is the area of the grid in square kilometers. Lineaments can be extracted from satellite images either by automatic or manual extract methods. In this study, the automatic lineament extraction method was preferred due to its time effectiveness and user-friendliness compared to the manual extraction. The lineaments can be identified by visual interpretation and automatic extraction from Landsat 8 images using PCI Geomatics from the images. Lineaments provide pathways for groundwater movement and are hydro geologically very important. Therefore, lineaments of the study area were extracted from the Landsat 8 OLI/ with zero cloud cover) using the most popular and widely use automated processing tool, the LINE tool in PCI Geomatics. From the Landsat 8 OLI/TIRS image having 11 bands, the lineaments extracted from band 5 are taken due to their quality and the highest number of lineaments generated, processes will be done in GIS 10.8 to assure the quality of the extract lineaments. The lineaments occurring in the study area were extracted from the Landsat 8 OLI image using Geomatica.

Table3. 7 Role of lineament density for groundwater potential(Charchi et al.,2019)

Factors	Criteria Value in km/km2	Classification
Lineament density	0 .0- 0.10	Very low
	0.1 - 0.2	Low
	0.2 - 0.25	Moderate
	0.25- 0.3	High
	> 0.30	Very high

Therefore, lineaments of the study area were extracted from the Landsat 8 OLI using the most popular and widely use automated processing tool, the LINE tool in PCI Geomatic. The lineaments extracted from band 5 are taken due to their quality and the highest number of lineaments generated, processes were in GIS 10.8 to assure the quality of the extract lineaments.

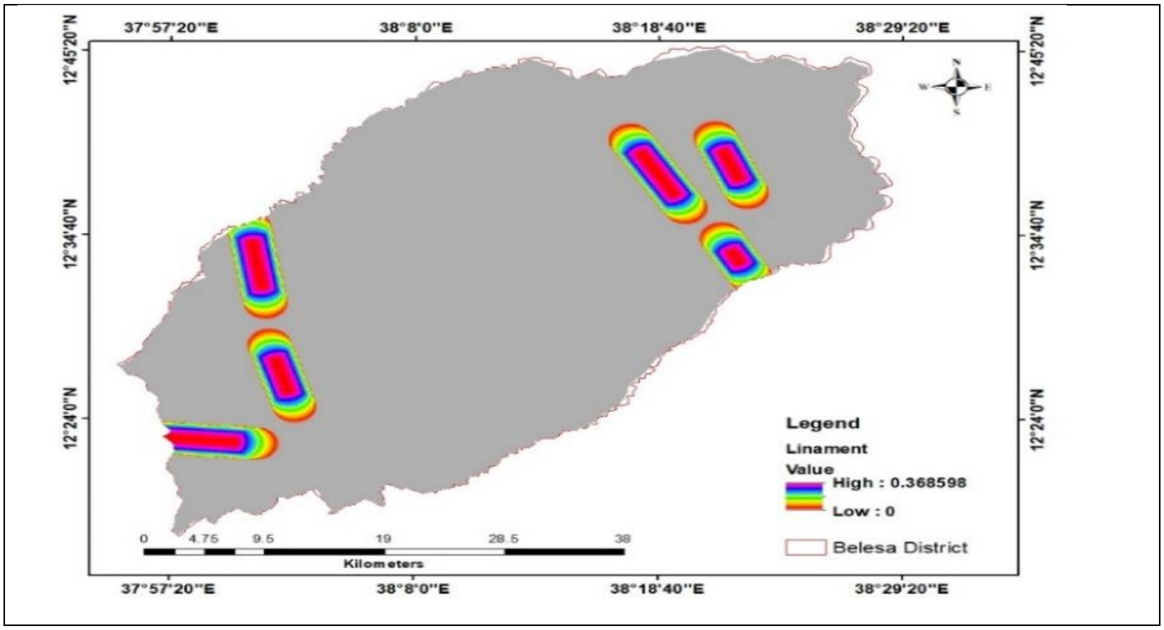

Figure3. 6 Lineament (Fault) Map

3.4.3.7. Land use/cover (LULC)

The surface covered by vegetation like forests and agriculture traps and holds the water in the roots of plants whereas the built-up and rocky land use affects the recharged of groundwater by increasing runoff during the rain(Berhanu and Hatiye, 2020). Therefore, it is necessary to study what features have covered the study area's land surface to carry out the groundwater potential study. To produce the LULC map of the study area, the LULC map of information. Land cover in the study area is providing important indicators of the extent of groundwater requirement and groundwater utilization. As well as being an important indicator in the selection of sites for the groundwater potential zone, it controls many hydro-geological processes in the water cycle, including evapotranspiration, infiltration, and surface runoff, the Land cover of the study area is characterized by the presence of agriculture, forest cover, vegetation, cropland, water, bare soil and also shrub lands.

3.4.3.8. Soil

Soil is an important factor in delineating the groundwater potential zones. The climate, physiographic, and geology characterize soil and play a significant role in groundwater recharge and runoff. The water holding capacity of the area depends upon the soil types and there. The soil map of the study watershed was prepared from the soil map of Ethiopia acquire from MoWIE using the geoprocessing clip tool in Arc GIS 10.8 by study area. The dominant soil types of the study area were the total area watershed providing more information(Elango et al., 2022).

The permeability of the soil types depends on texture. Therefore, the identified soil types of the study area were tabulated with the soil texture. Soil is the most important parameter that determines the infiltration capacity. Soil is one of the natural resources that is an important factor to determine potential groundwater zones and it plays a critical role in groundwater recharge. Soil is playing an essential role in encouraging or discouraging the recharge of groundwater and determining the quality parameters of groundwater. The soil type layer for the study area has been compiled from the Harmonized World Soil Database (HWSD) version 1.21, the Food and Agriculture Organization of the United Nations (FAO), the Ethiopia Soil Bureau Network, and the Institute of Soil Science. Soil is an important factor for the occupancy of the groundwater potential zones and the most important parameter that determines the infiltration capacity of the region. The water holding ability depends upon the soil types and texture and their permeability

(Khan and Govil, 2020)

Table3.8 Role of soil for groundwater potential

Percent clay	Percent silt	Percent sand	Textural class	permeability
60-100	0-40	0-45	Heavy clay	Poor
40-60	40-60	0-20	Silty clay	Poor
40-60	40-60	0-45	Clay	Poor
27-40	40-73	0-20	Silty clay loam	high
27-40	15-52	20-45	Clay loam	Poor
0-12	88-100	0-20	Silty	moderate
0-27	74-88	20-50	Silty loam	moderate
35-55	0-20	45-65	Sandy clay	moderate
7.0-27	28-50	23-52	Loam	High
20-35	0-20	45-80	Sandy clay loam	high
0-20	0-50	50-70	Sandy loam	Very high
0-15	0-30	70-86	Loamy sand	Very high
0-10	0-14	86-100	Sand	Very high

4. Result and Discussion

4.1. Groundwater potential parameters

4.1.1. Rainfall (RF)

In the study area, the minimum rainfall is 591mm and the maximum rainfall is 802mm. the classified rainfall results are as follows(Nigussie and Hailu, 2019).

Table 4. 1 Rainfall Rank and potential

Rainfall in mm	SCALE	Potential	AREA_KM2	Coverage (%)
591-646	1	Very Low	217.1	11.7
646-682	2	Low	472.6	25.6
682-712	3	Moderate	545.8	29.5
712-747	4	High	386.9	20.9
747-802	5	Very High	226.2	12.2

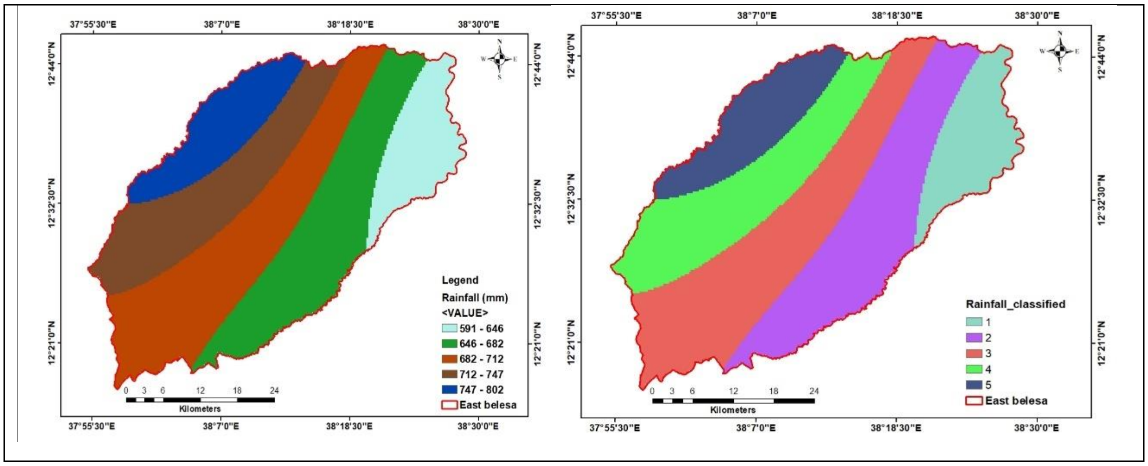

Figure 4-1.1Rainfall reclassified maps

4.1.2. Slope (S)

The slope of the study area was calculated in degrees/percent based on the DEM model which is based on the SRTM data using the hydrology analyses model. The slope map of the study area was prepared on this result, the slope of the study area was divided into five classes namely from Table4.2; flat (0- 7), gentle (7 -13), moderate (13- 20), high (20-28) and steep slope (28-71). The generated map was reclassified and ranking depend on its groundwater potential and influence as shown in Figure 4.2. The highest rank was given to the flat slope because flat areas can hold water which is very easy for infiltration of water into the ground and the lowest rank was assigned to the steep slope. After all, they result in high runoff and low infiltration which cause low groundwater recharge as shown in Table 4.2. About 30.71 percent of the study area are categorized as very good, 26.49 percent of the study area are categorized under good, 21.66 percent of the study area are categorized as moderate, 15.62 percent of the study area are categorized under poor and 5.51 percent of the study area are categorized under very poor for groundwater potential.

*Table 4. 2*Slope scale and potentials

Slope in degree	SCALE	Potential	AREA_KM2	Coverage (%)
0-7	5	Very High	565.681	30.71
7-13	4	High	487.989	26.49
13-20	3	Moderate	399.011	21.66
20-28	2	Low	287.703	15.62
28-71	1	Very Low	101.44	5.51

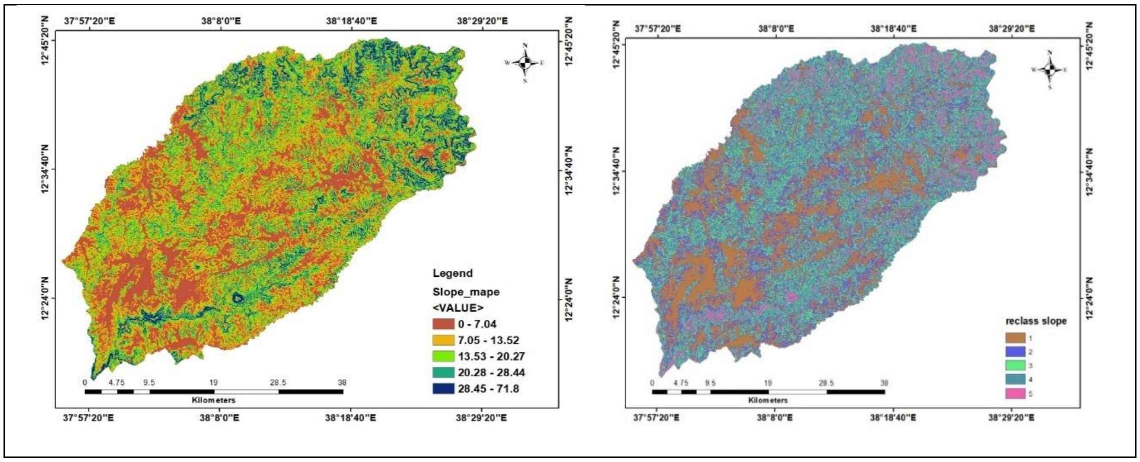

Figure 4-2 Slope reclassified maps

4.1.3. Drainage Density (DD)

In the study area, the drainage densities were classified using the hydrology model from DEM. The drainage network of the study area was created from the SRTM global elevation data through Arc hydro tools in Arc Map 10.8 / hydrology and its density is calculated using the Line Density from (Equation 7). Next, the study area can be grouped into five drainage density classes from very low to very high in shown figure4.3. Figure 4.3 illustrates the drainage density class in the study area. The class has been assigned according to its importance to the potentiality for groundwater storage, namely “very poor” (0.77_1.25 km/km2), “poor” (0.53-0.76 km/km2), “moderate” (0.33-0.52 km/km2), “good” (0.13-0.32 km/km2), and very good (0-0.13km/km2). In the study area landscape was found groundwater potential very good and good in 0–0.13 km/km2 and 0.25–0.5 km/km2 drainage density class, respectively. This implies the availability of good groundwater potential zones. Moreover, 31.187% was entitled under drainage class with very good potentiality for groundwater storage. The structure drainage network used to explain the characteristics of the groundwater potential zone as shown in Table (4.3)

Table 4. 3: Drainage Density scale and potentials

Drainage Density (Km/km2)	SCALE	Potential	AREA_KM2	Coverage (%)
0-0.13	5	Very High	569.47	31.187
0.13-0.32	4	High	400.96	21.959
0.33-0.52	3	Moderate	276.47	15.141
0.53-0.76	2	Low	432.76	23.700

0.77-1.25	1	Very Low	146.30	8.012

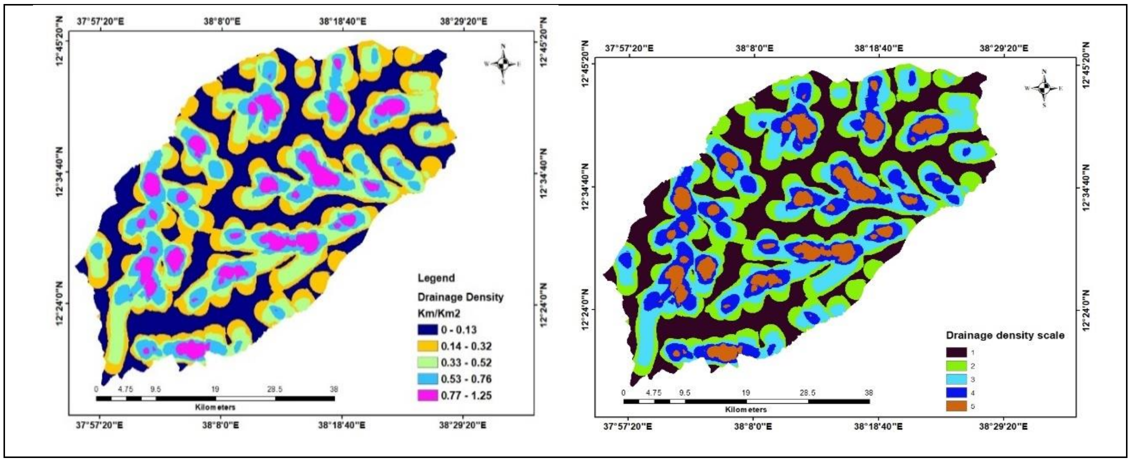

Figure 4-3 Drainage Density reclassified maps

4.1.4. Geomorphology (Gmh)

In the study area, geomorphology reflects various landform and structural features. Many of the features are favorable for the occurrence of groundwater and are classified in terms of groundwater potential. In the study area was prepared the geomorphology map of the landform was to classify the technique from DEM and classified into five such valleys, Flat or flood plain, denudation, hill, and plateaus. In the study area geomorphology, depending on elevation. Thematic map for geomorphology generated as shown in Figure 4.4 The rank assigned to the individual landform classification according to its respective influence of groundwater occurrence, holding, as presented in Table 4.4

Table 4. 4 study area geomorphology ranks as the suitable groundwater potential

Geomorphology	SCALE	Potential	AREA_KM2	Coverage (%)
Flat	5	Very High	261.20	14.13
Plain	4	High	474.05	25.65
Pedi plain	3	Moderate	599.57	32.44
Plateau	2	Low	402.74	21.79
Hill	1	Very Low	110.76	5.99

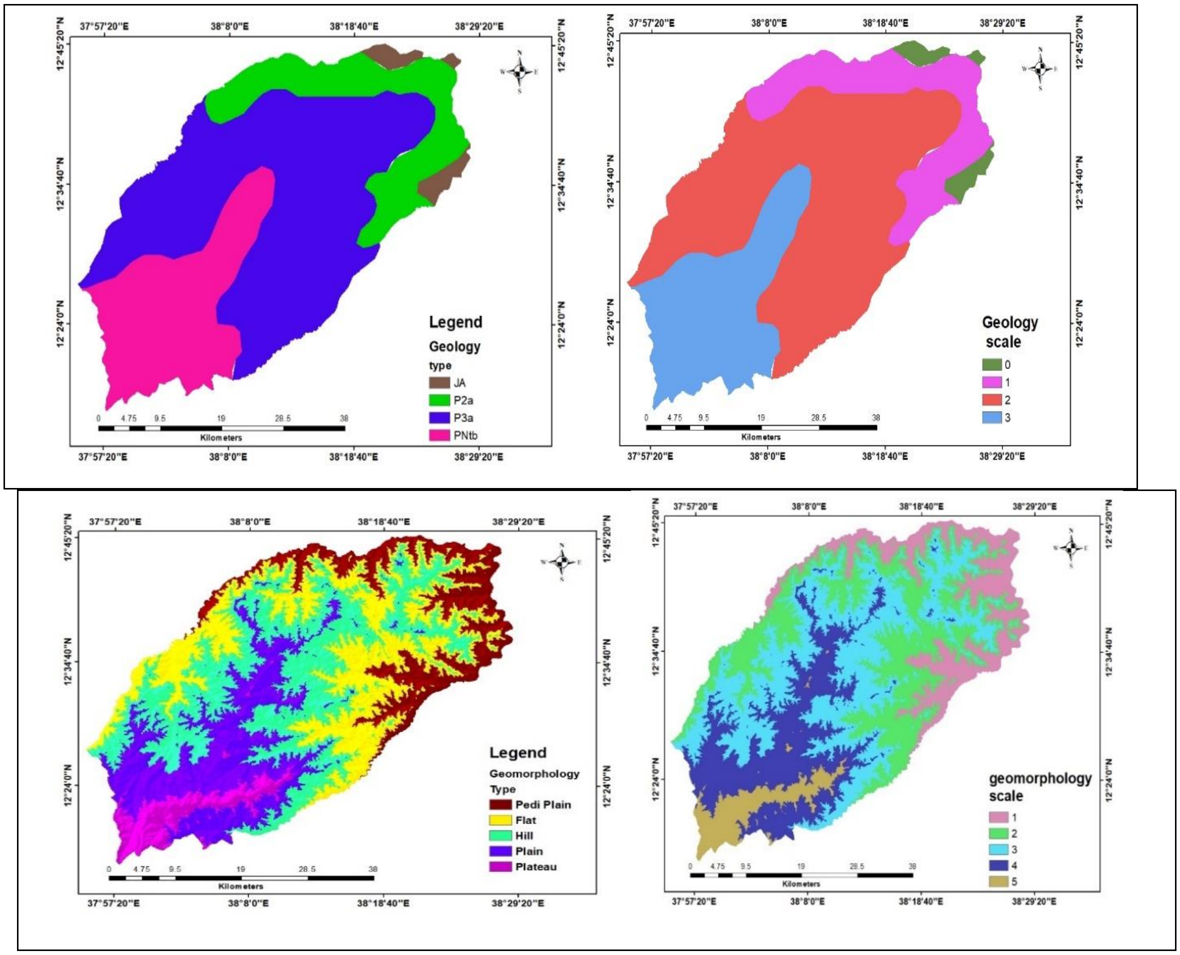

Figure 4-4 Geomorphology Reclassified maps

4.1.5. Geology/ Lithology (G)

The geology/lithology thematic map of the study area was prepared by study watershed, produced by the Geological Survey of Ethiopia (GSE). There are four major lithology types identified in the study area namely Aiba Basalts (P3a) (55.40%) Very low, Tarmaber Gussa Formation (Pntb) (24.68%) low, Adigrat Formation (Ja) (2.59%) very high, and Ashangi formation (P2a) (17.34%) High.

Table 4. 5 study area geology rank as the suitable groundwater potential

Geology	Scale	Potential	Area_Km2	Coverage (%)
Ja	4	Very high	47.02	2.59
P2a	3	High	315.33	17.34
P3a	1	Very low	1007.65	55.40
Pntb	2	low	448.83	24.68

Figure 4-5 Geology Reclassified maps

4.1.6. Lineament Density (LD)

In the study, area lineament is geological lineaments are the manifestation at the earth's surface of deeper geological structures (faults joints, bedding, road, and fractures. Areas with high lineament density denote a permeable zone so reveal good groundwater potential zones. Thanks to the USGS website for open accessibility Landsat 8 (OLI) satellite image captured in December 2021 was obtained to have a cloud-free image for the improvement of the results. In preceding studies for automatic lineament extraction, PCI Geomatic band

5 was used. To prepare a lineament density map High lineament density areas are good for groundwater and low lineament density is less suitable for groundwater potential. In the study area; lineament density is done by the line density in ArcGIS tools from (Equation 8) and classified into five categories in a table (4.6). The lineament density map of the
study area was classified into five classes (Figure 4.6).

The map exposes that the more densely distributed lineaments areas having a lineament density were considered excellent groundwater prospective zone covering about 3.29% and 2.41% of the landscape. Referring to the map, it is clear that the major part of the study area is having moderate, poor, and very poor lineament density which accounts for 2.26%, 1.94%, and 90.09%, respectively.

Table 4. 6 study area Lineament Density rank as the suitable groundwater potential

Lineament Density (km/km2)	SCALE	Potential	AREA_KM2	Coverage (%)
0-0.05	1	Very Low	1645.06	90.09
0.06-0.14	2	Low	35.46	1.94
0.15-0.22	3	Moderate	41.30	2.26
0.23-0.3	4	High	44.01	2.41
0.31-0.37	5	Very High	60.14	3.29

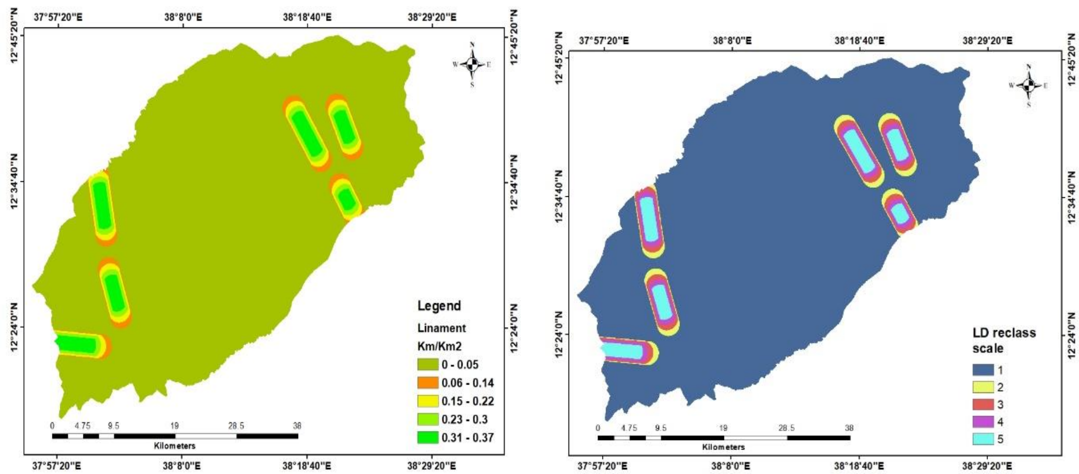

Figure 4-6 Lineament Density Reclassified maps

4.1.7. Land Use Land Cover (LULC)

Based on the land cover map, made by using the global land cover data from the Food and Agriculture Organization (FAO).

Table 4. 7 study area LULC rank as a suitable groundwater potential

Class name	Scale	Potential	Area_km2	Coverage (%)
Built-Up	1	Very Low	10.32	0.565
shrubland	2	Low	1633.45	89.457
farmland	3	Moderate	180.15	9.866
Forest	4	High	1.14	0.063
Water	5	Very High	0.89	0.049

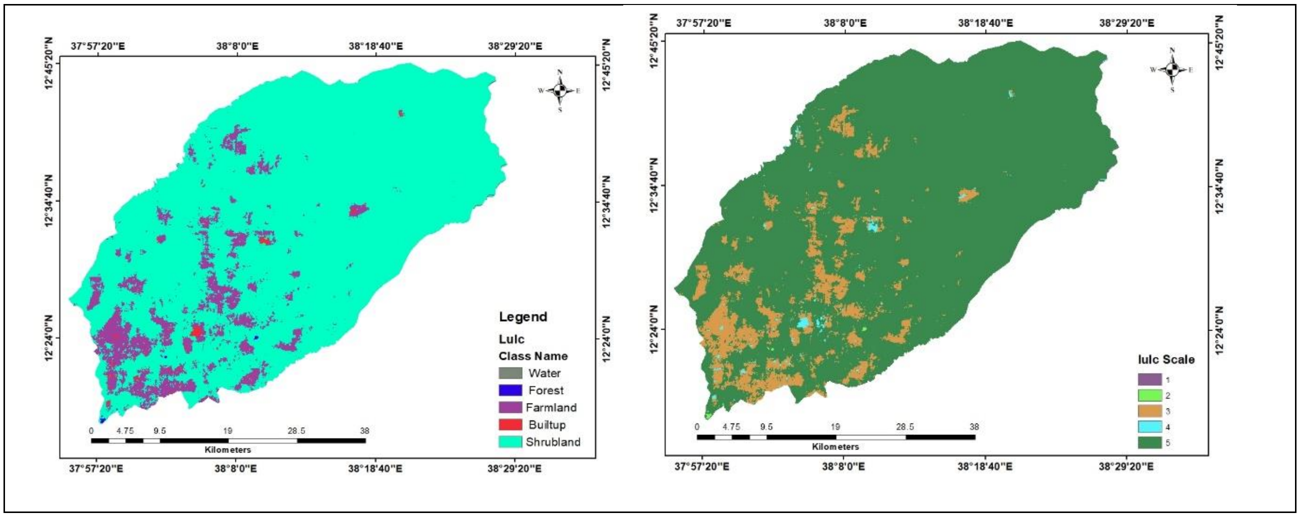

Figure 4-7 LULC classified maps

4.1.8. Soil (So)

statistical analysis of the soil type is Luvisols,

Luvisols are soils in which high activity clay has migrated from the upper part of the profile, generally grayish in color, to be deposited in an argic B horizon, commonly of a browner hue, these are mostly in the temperate zone(Stolbovoi, 2000)

sandy Clay

Sandy clay means soil material that contains 35 percent or more clay and 45 percent or more sand. A sandy clay-poor soil with an iron- or organic-rich subsurface horizon.

these soils are most suitable for leek cultivation. Harvesting is difficult in heavy soils in autumn and winter(Mahdi et al., 2015)

Sandy Soil

The first type of soil is sand. It consists of small particles of weathered rock. Sandy soils are one of the poorest types of soil for growing plants because it has very low nutrients and poor water holding capacity, which makes it hard for the plant's roots to absorb water. This type of soil is very good for the drainage system. Sandy soil is usually formed by the breakdown or fragmentation of rocks like granite, limestone and quartz

(Kalev and Toor ,2018).

Clay Soil

Clay is the smallest particle among the other two types of soil. The particles in this soil are tightly packed together with each other with very little or no airspace. This soil has very good water storage qualities and makes it hard for moisture and air to penetrate into it. It is very sticky to the touch when wet but smooth when dried. Clay is the densest and heaviest type of soil which does not drain well or provide space for plant roots to flourish(Belay and Adigrat, 2020).

Loamy Soil

Loam is the fourth type of soil. It is a combination of sand, silt and clay such that the beneficial properties of each are included. For instance, it has the ability to retain moisture and nutrients; hence, it is more suitable for farming. This soil is also referred to as agricultural soil as it includes an equilibrium of all three types of soil materials, being sandy, clay, and silt, and it also happens to have humus. Apart from these, it also has higher calcium and pH levels because of its inorganic origins(Belnap and Walker, 2014).

In the study area, statistical analysis of the soil type is predominantly covered by sandy loam with an area coverage of 4.77%, loam soil with an area coverage of 45.29%, clay loam soil with an area coverage of 2.87%, sandy clay soil with area coverage of 43.21%, and heavy clay soil with area coverage of 3.87%. Figure 4.8 shows the soil map of the study area. These five soil classes can be cataloged into five classes ‘very good, ‘good’ ‘moderate’ and ‘poor and very poor’ according to their influence on groundwater occurrence(Easton ,2021).

Table 4. 8 study area soils rank as the suitable groundwater potential

Class name	Scale	Potential	Area_km2	Coverage (%)
Luvisols, Clay Loam	1	Very poor	51.98,	2.85
Leptosols, sandy Clay	2	poor	788.57	43.21
Calcisols, Loam	3	Moderate	826.54	45.29
Vertisol, Heavey Clay	4	high	70.68,	3.87
Exp_ Rock, Sandy Loam	5	Very high	87.06,	4.77

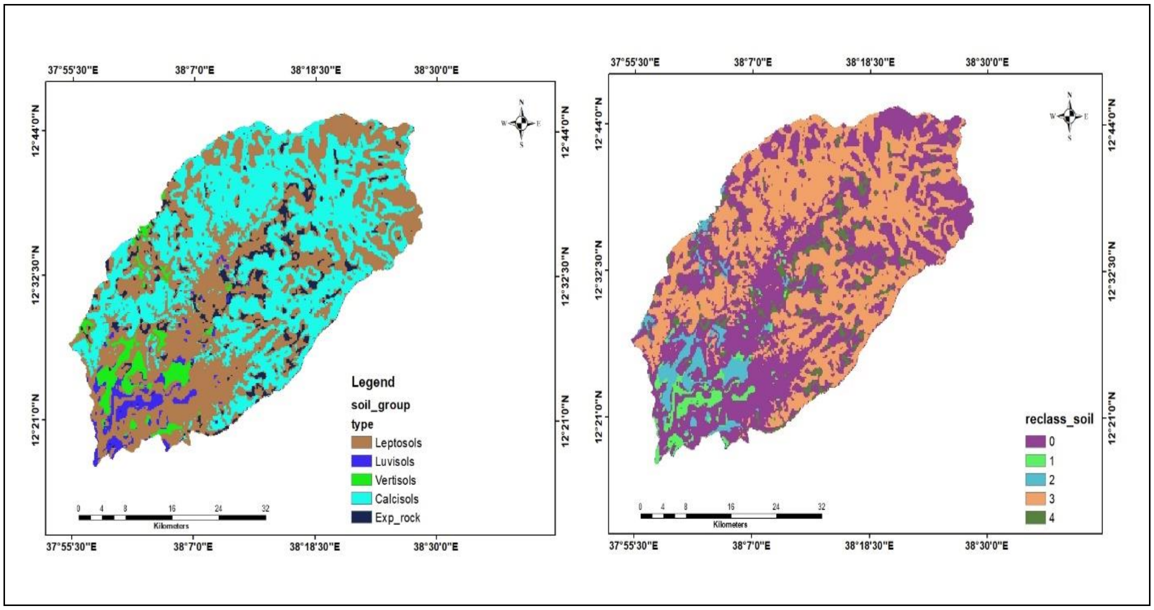

Figure 4-8 Soils reclassified maps

4.2. Groundwater potential

The result of current work on the groundwater potential was done by the analysis of thematic layers (rainfall, slope, soil texture, land- use/ land- cover, lineament, geomorphology, drainage density, and geology) and the values of the parameters are given based on the Saaty scale as shown in (Table 4.9). Based on the pairwise comparison matrix, the relative weight matrix and normalized Principal Eigenvector were calculated. The influence percentage of thematic layers and the rank for its parameters were assigned based on the judgment of works carried out by researchers or knowledge of experts gained.

4.2.1. Weight Assessment

The Relative weight for thematic layers (Rainfall, Slope, Geomorphology, Lineament density, Drainage density, Soil texture, Land-use/Land-cover, and geology) was assigned according to their relative importance for each analysis based on the judgment. To compare the importance of two-layer maps, show that one of them has more influence on the groundwater occurrence than the other.

Table 4. 1 Relative weight for selected thematic layer in the Study Area(Rai et al., 2021)

Matrix	RF	GO	SL	DD	LULU	LD	SO	Gmh
RF	1	2	7	7	5	5	5	3.00
GO	0.5	1	5	7	5	5	3	3.00
SL	0.14	0.2	1	3	3	0.33	0.33	0.33
DD	0.14	0.14	0.33	1	0.33	0.2	0.2	0.33
LULU	0.2	0.2	0.33	3	1	0.2	0.2	0.50
LD	0.2	0.2	3	5	5	1	0.5	3.00
SO	0.2	0.33	3	5	5	2	1	2.00
Gmh	0.33	0.33	3	3	2	0.33	0.5	1
Total	2.72	4.41	22.67	34.00	26.33	14.07	10.73	13.17

Where, RF = Rainfall, DD = Drainage density, LD = lineament density, SL = Slope, so = Soil texture, GO = geology, LULC= Land-use/land-cover, Gmh = Geomorphology and Wt. = Weight

4.2.2. Weight Normalization

The weights were normalized based on equation (2), which is calculated by averaging the values in each row to get the corresponding ranking, which gives the results of normalized weights of each parameter as presented in Table 4.9. From the result, observed rainfall has the highest value rather than other parameters. Because, it indicates high rainfall has the possibility of high groundwater recharge thus high groundwater potential zones, while low rainfall indicates low groundwater recharge thus low groundwater potential zones. In the study area more influence /weight/ for groundwater potential Rainfall (32%), Soil texture 13%), slope (5%), lineament density (12%), Drainage density (2%), Land-use/land-cover (4%), geology (24%), and Geomorphology (8%) respectively.

Table 4. 2 Pairwise comparison matrix and normalized weight

Matrix	RF	G	Sl	DD	LULU	LD	So	GMH	Wt. (average)	%
RF	0.37	0.45	0.31	0.21	0.19	0.36	0.47	0.23	0.32	32
GO	0.18	0.23	0.22	0.21	0.19	0.36	0.28	0.23	0.24	24
Sl	0.05	0.05	0.04	0.09	0.11	0.02	0.03	0.03	0.05	5
DD	0.05	0.03	0.01	0.03	0.01	0.01	0.02	0.03	0.02	2
LULU	0.07	0.05	0.01	0.09	0.04	0.01	0.02	0.04	0.04	4
LD	0.07	0.05	0.13	0.15	0.19	0.07	0.05	0.23	0.12	12
So	0.07	0.08	0.13	0.15	0.19	0.14	0.09	0.15	0.13	13
GMH	0.12	0.08	0.13	0.09	0.08	0.02	0.05	0.08	0.07	8

Total	1	1	1	1	1	1	1	1	1.0000	100

4.2.3. Principal Eigen Vector

To check the weight assigned to each parameter in Table 4.10, the normalized principal Eigenvector value (λmax) was computed depending on equation 3 to drive the formula of Consistency ratio (equation 4). This was done by multiplying the weight of the first criterion (for Example, Rainfall = 2.72) as shown in Table 4.9 with the total value that was found in the pairwise Comparison matrix (for example, Rainfall =.32) Table 4.10, This was applied for the rest of eight factors as per equation 8. Finally, the summation of these values gives the consistency vector λmax (Pairwise comparison matrix and normalized weight) of =9.0) as shown in Table 4.11 for calculating the consistency index

Table 4. 9 Normalization principal Eigen vetoes

Parameter	Normalized principal Eigenvector Wi	Wi'	Wi*Wi'
Rainfall	2.7	0.3	0.9
Geology	4.4	0.2	1.1
Slope	22.7	0.1	1.2
Drainage	34.0	0.0	0.7
LULU	26.3	0.0	1.0
Linament.D	14.1	0.1	1.7
Soil	10.7	0.1	1.4
Geomorphology	13.2	0.1	1.0
λmax			9.0

The consistency index was computed to overcome the formula of consistency ratio and this was done based on equation5

$$CI = \frac{(9-8)}{8-1} = 0.14 \text{ Which results CI} = 0.14.$$

Then, the consistency ratio was computed as per equation 4 and according to Saaty. In the study area have been 8 criteria so the random index is 1.41 the result of the consistency ratio is $\text{CR} = \frac{0.14}{1.41} = 0.099$

That is the result was less than 0.1and the given weights were legal for further analysis. Groundwater potential zone map (GWPZM) was computed after Checking all criterion as follows: GWPZM = (32*RF+ (2× DD) + (5× S) + (12× LD) + (13 × SO) + (24xG) + (8*Gmh) + (4×LULC from equation_6. In the study area rainfall, soil, and geology holds the highest value relative to the other parameters. The weight assigned for Rainfall was greater than the weight of other, which influenced the occurrence of groundwater potential zone than others parameters. The result of groundwater potential of the study area was done by integration of all thematic maps/8 factors to delineate groundwater potential zones. In the study area rainfall, soil, and slop holds the highest value relative to the other parameters. The weight assigned for Rainfall was greater than the weight of other, which influenced the occurrence of groundwater potential zone than others parameters.

Table 4. 10 Rank and % influence of different thematic layers.

No.	Parameters	Weight (%)	Class	Rank
1	Soil	13	Luvisols	1
			Leptosols	2
			Calcisols	3
			Vertisol	4
			Exp_ Rock	5
2	Geology	24	Pntb	2
			Ja	4
			P2a	3
			P3a	1
3	Lineament Density	12	0-0.05	1
			0.06-0.14	2
			0.15-0.22	3
			0.23-0.3	4
			0.31-0.37	5
4	Drainage Density	2	0-0.13	5
			0.13-0.32	4
			0.33-0.52	3
			0.53-0.76	2
			0.77-1.25	1
5	Rainfall	32	591-646	1
			646-682	2
			682-712	3
			712-747	4
			747-802	5
6	Slope	5	0-7	5
			7-13	4
			13-20	3
			20-28	2
			28-71	1
7	Geomorphology	8	Flat	5
			plain	4
			Pedi plain	3
			Plateau	2
			Hill	1
8	LULC	4	Built Up	1
			shrubland	2
			Farmland	3
			Forest	4
			Water	5

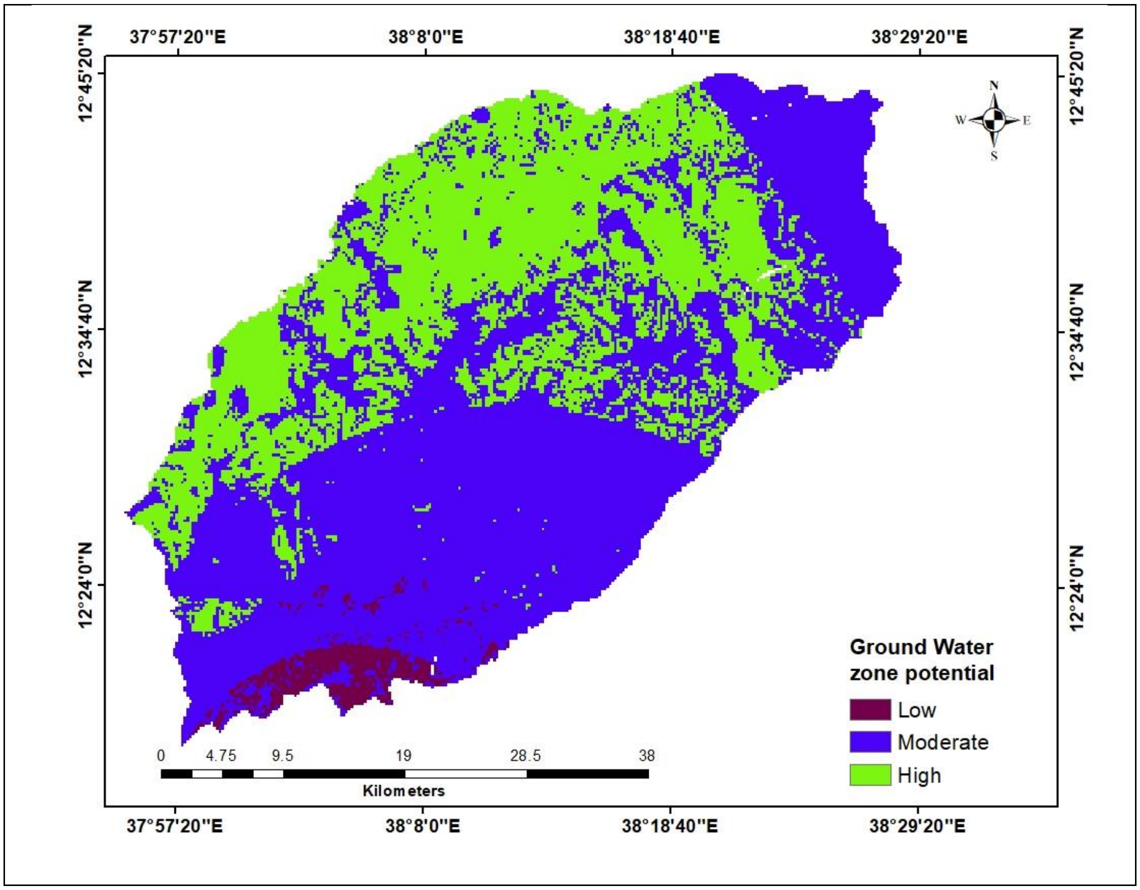

Figure 4-9 Groundwater Potential Zone Map of the Study Area

The result of groundwater potential of the study area was done by integration of all thematic maps/8 factors to delineate groundwater potential zones. The results are categorized into three categories namely: High, Moderate, and Low of groundwater potential zone (Figure 4.9). Low groundwater potentials cover 0.620% of the study area, Moderate groundwater potential covers 58.605% of the study area, and High groundwater potentials cover 40.775% of the study area as shown in Table 4.11.

Table 4. 11 Converge of groundwater potential in the study area

No.	Potential	Area_Km2	Coverage (%)
1	Low	11.61	0.620
2	Moderate	1096.96	58.605
3	High	763.22	40.775

Map overlay between predicted groundwater potential map and Groundwater storing controlling parameters found that the area having very high groundwater potential included the flat area of slope in degrees ranging from (0 to 7), low drainage density (0 to

0.13) km/km^2, and high lineament density (0.31-0.37) km/km^2 are favorable to groundwater potential due to high infiltration rate and high groundwater potential in geomorphology type of floodplain. Zones of moderate groundwater potential zones are characterized by slope degrees ranging from **1**3.0-20.0-degree, land use type of farmland, moderate drainage density 0.33-0.52km/km^2, and moderate lineament density 0.15 _ 0.22km/km^2.Lastly, low groundwater potential zones include geomorphology type of denudation hill, high drainage density 0.77-1.25km/km^2, slope degree more than 15degree, low annual rainfall intensity, soil type of clay, and land use type of clear land and urban areas.

4.3. Result Validation

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

4.3.1. validation of the result using NDWI

To extract the open water features in the research area, USGS Landsat 8 imagery was used to create the Normalized Difference Water Index (NDWI) for the region. This entails identifying the distinctive properties of each ground target across various spectral bands to distinguish the signatures of water from other targets. As stated, the following equation is used to determine the NDWI(Özelkan ,2020).

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

As a result of the water body's value being negative, the results revealed that there are no pixels that depict a permanent open water body (figure below). The river runs seasonally and is influenced by rainfall. Thus, the outcome made it very evident that, outside of the r ainy season, surface water is scarce in the area. It has been determined through the value t hat there is no water pixel in the research area since the water pixels typically exhibit the value above -0.4 to 0, there is a water pixel in the research area since the water pixels typically exhibit a value above 0 to 0.1

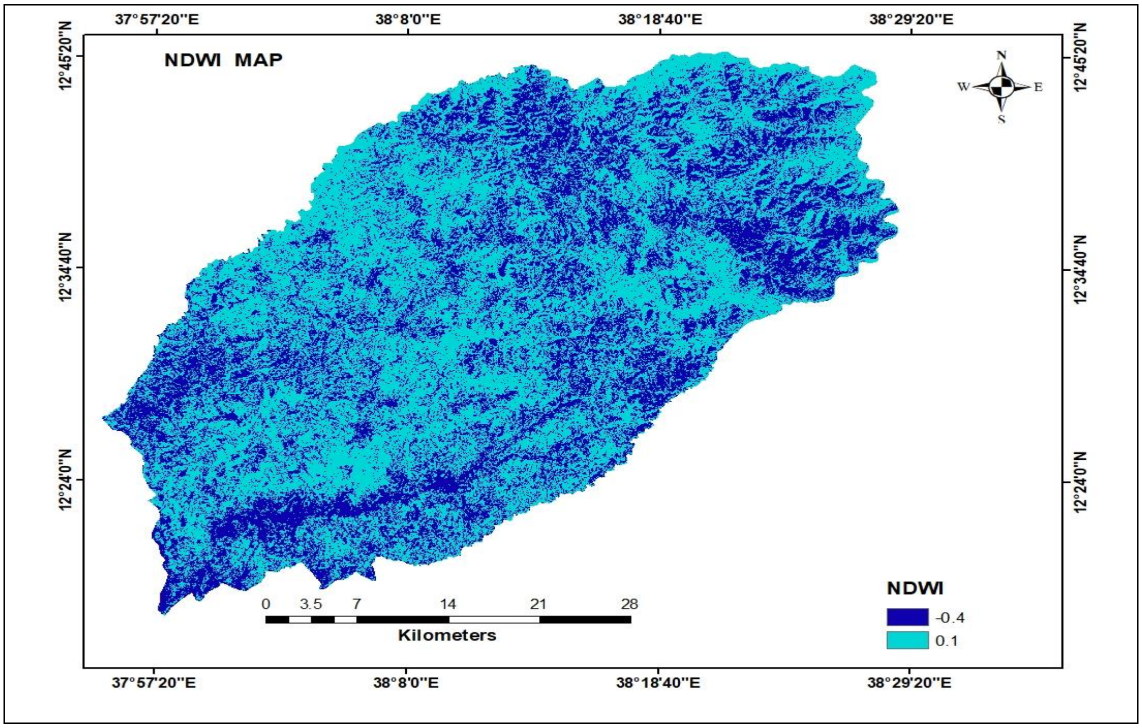

Figure 4-10 Normalized Difference Water Index

4.3.2. validation of the result using NDMI

In terms of detecting spatial variation in surface wetness, NDWI and NDMI are theoretic ally comparable to one another, according to (Wilson and Sader ,2002)

which were mentioned by (Sahu,2014)As mentioned above, NDWI was used to identify any waterfree pixels. Therefore, the NDMI was required to determine the amount of mois ture in the soil. The locations where the water can resist for a long time, frequently endin g the rainfall event, are indicated by the wet/moisture pixels.

As a result of the water's inability to resist on uplands, the moisture pixel results also indi cated flat and valley regions, giving rainwater greater time to infiltrate the subsurface. Th e following suggested equation calculates the NDMI in the Landsat 8 image:

NDMI = $\frac{Band\ 5 - Band\ 6}{Band\ 5 + Band\ 6} = \frac{NIR - SWIR1}{NIR + SWIR1}$

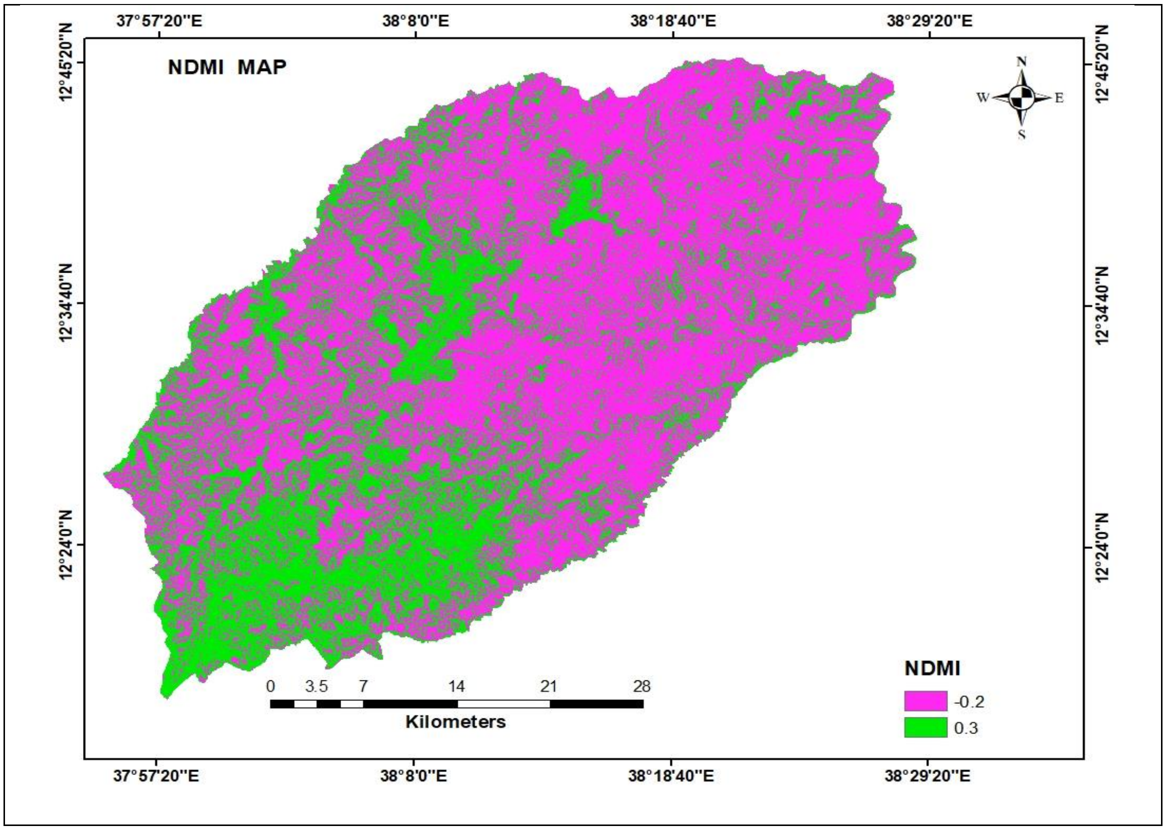

Figure 4-11 Normalized Difference moisture Index

In the NDMI, high values represent higher soil moisture under large bodies of water, and low values represent lower soil moisture content. According to (Malik and Pal et, 2020), an NDMI value in0 to 0.30 indicates a moist soil surface with very good potentiality of groundwater and -0.2 to 0 indicates dry soil with low moisture content potentiality. to link the locations of groundwater on both maps, the NDMI was additionally superimposed on groundwater potential zones. Together, these show the possible space for storing water after a downpour.

4.3.3. validate the result by using the existing borehole

Groundwater potential assessment using the GIS and RS techniques need to be validated by comparing the results with the existing ground data (water point) from deep well (DW), shallow well (SDW), spring (SP), and hand dug wells (HDW). The groundwater potential output map of the study area was validated using existing groundwater proxy data such as, deep well, shallow deep well, springs, and hand-dug wells from Figure4.12.

A total of 53 wells were used for validation. Therefore, the validity of the groundwater potential map was perfolrmed overlying the point data of springs, hand-dug, shallow deep well, and deep well with the map generated using weighted Index overlay analysis. The overlay analysis shows that 50 % of low yield wells with static wells equivalent to the ground surface were overlaid with low groundwater potential zones,81% of moderate wells well with ground surface were overlaid with moderate groundwater potential zones, 69.2% of high yield well with ground surface were overlapped a high groundwater potential zone. The overall validation of the well is that 68 % of well yields are fitted at the groundwater potential zones.

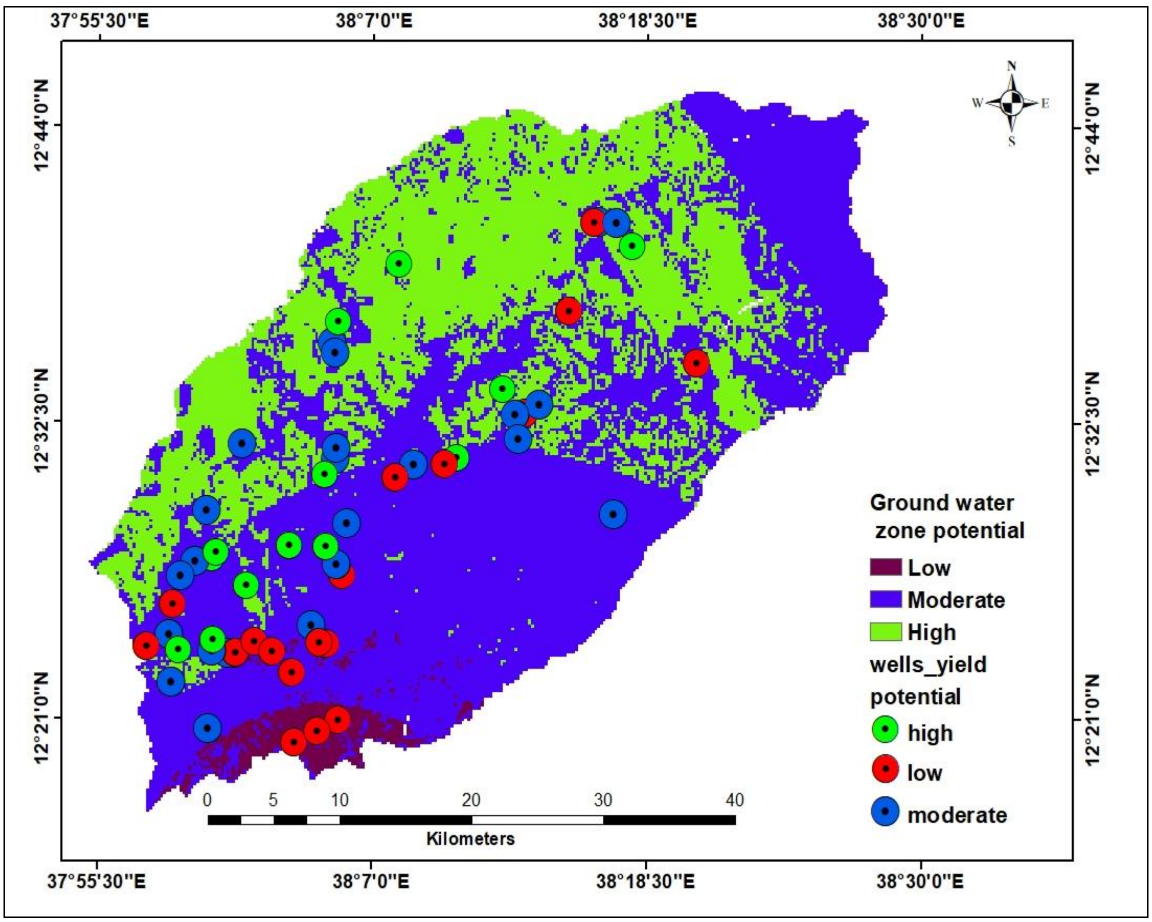

Figure 4-12 Groundwater potential zone with wells

Table 4. 12 overall validation of the well in Percentage

Potential	Reference Yields(l/s)	Field data	suitability	Fall to Maps	Percentage %
Low	0-2	18	low	9	50
			moderate	5	27.7
			high	4	22.3
Moderat	2-4	22	Low	0	0
			moderate	18	81.8
			high	4	18.2
High	>4	13	low	0	0
			moderate	4	30.8
			high	9	69.2
Total		53		36	68

4.3.4. Validate the result by demonstrating a well-yielding terrain map

Wells are the principal direct window to study the subsurface environment. Not only are wells used to pump groundwater for many purposes, but they also provide essential information about conditions in the subsurface. the following figure shows the number of well yields at various depths of the surface; the figure gives information about the productive well location. In the figure, those points in the legend with different colors indicate various yield surfaces in the vicinity of the wet and dry wells, there are productive wells (legend values with discharge) present indicating that geological structure control in the area has been identified in lineament map. Even if some wells exist in the poor potential zone also suggests good confirmation of the result. The numbers on the map attribute the discharge amount in liters per second. It can be observed that bore holes found in low potential zones have less discharge (0 to 2 l/sec.) than boreholes in the moderate zones (2 to 4 l/sec). and also, boreholes in the high zones are (>4l/sec)(Gintamo, 2014)

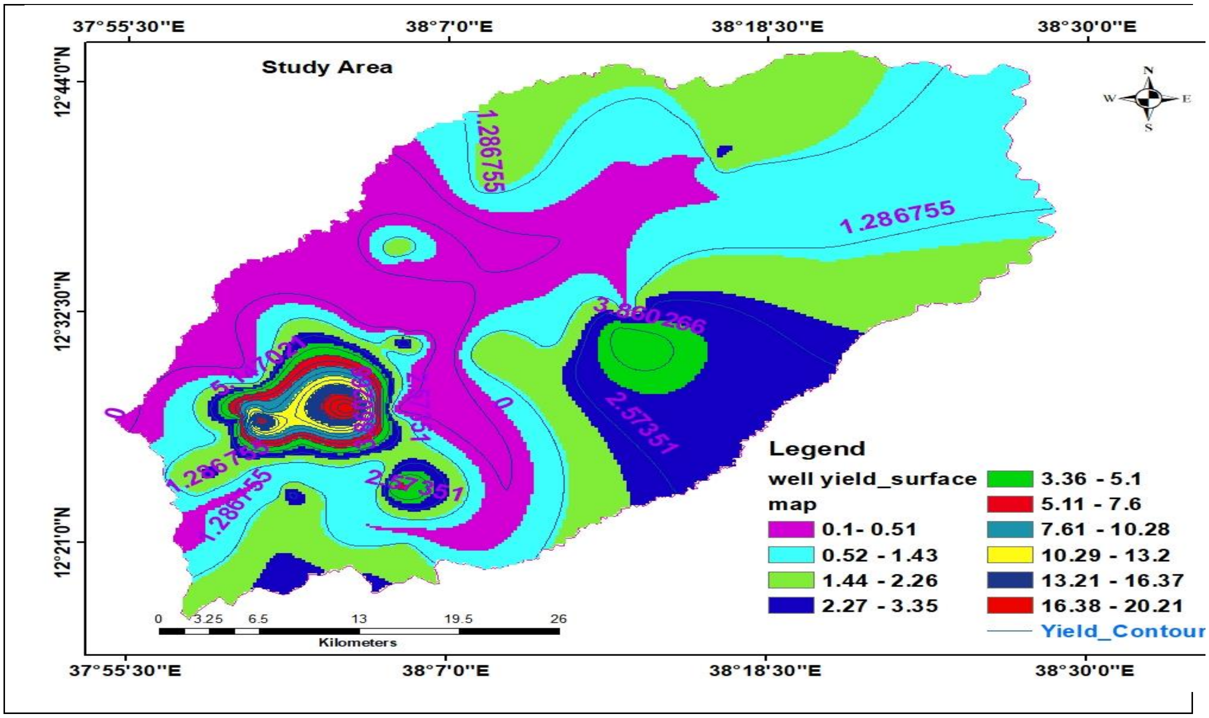

Figure 4-13 Groundwater well yield surface map

4.3.5. validation result by using Groundwater Depth Surface map

Well, depth is positively related to total well yield. The following figure shows the depth of the water surface Profile.

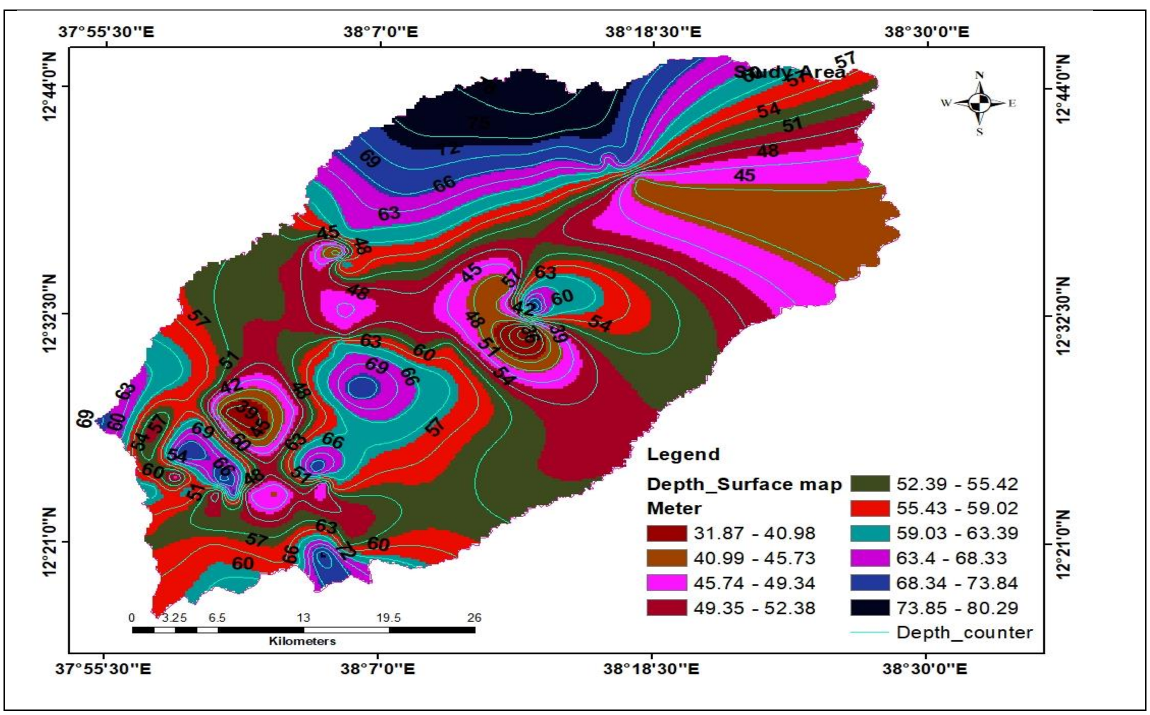

Figure 4-14 contour maps of the water-table surface

5. Conclusion and Recommendation

5.1. Conclusion

In the current study, the groundwater potential zone results obtained via the use of GIS and remote sensing techniques through Analytical Hierarchy process methods were identified and evaluated based on the groundwater potential zone's influencing elements. Eight characteristics that exhibit higher signs of the presence of a groundwater potential zone before overlay analysis was chosen for this study. It is feasible to make significant criteria have a bigger influence on the outcome than other criteria by allocating quantitative weights to them. Pairwise comparison was used in The AHP to adapt techniques to a given value for each factor. To make decision-making processes simpler, this method gives decision-makers the freedom to make judgments.

In this case, the consistency ratio in the study region for the groundwater potential zone was less than 0.1. The results of the consistency ratio in this study area were 0.099 for groundwater potential. The judge There are three different groundwater potential zones: "High," "Moderate," and "Low." The low zone demonstrates that the location is ideal for locating groundwater. While the high zone denotes the best location for groundwater exploration. Sandalwood loam soil has high potential areas, as do valley fills, which also have high lineament density and low slope drainage density in the research area. Because of the area's plateau landform, built-up areas, high slope, low lineament density, and high drainage density, the groundwater potential is low.

Rainfall, slope, geomorphology, lineament density, soil texture, land use, land cover, geology, and drainage density Pairwise are the important variables in the area for groundwater potential. The results of a comparison matrix analysis show that each parameter is important. Around 58.605 percent of the region is classified as having a moderate groundwater potential, 0.62 percent as having a low groundwater potential, and the remaining sections as having a high groundwater potential. By comparing the drill data with the research area's groundwater potential zone map, acceptable results were determined. By overlaying the point data from springs, hand-dug shallow deep wells, and deep wells with the map created using weighted Index overlay analysis, the validity of the groundwater potential map was tested.

According to the overlay analysis, groundwater potential zones with static water levels equal to the ground surface were overlaid in 69.2 percent of wells with static water levels equivalent to the ground surface were overlaid high groundwater potential zones, and in 50 percent of wells with ground surface were overlaid low groundwater potential zones, in 81 percent of wells with ground surface were overlapped Moderate groundwater potential zones, For optimal groundwater potential, springs and deep wells are crucial. In general, this study indicated that the northern part of the study area had a high groundwater potential, allowing for further groundwater exploitation there. Therefore, new well fields may be created in high groundwater potential zones, particularly on the northern side of the study area, to fulfill the growing demand.

5.2. Recommendation

- For the successful determination, protection, and management of groundwater potenti al, spring and deep well sites were found to be of utmost importance. whereas some researchers utili zed deep wells and groundwater springs.
- The results of the current study work are good in terms of timing, cost, and correct ass essment of the groundwater potential zone. As a result, it is strongly advised that further researc h be conducted using remote sensing and GIS, such as irrigation and drinking studies.
- Our understanding of groundwater systems has been improved because of data accessibility from remote sensing. But utilization of satellite images having Corser resolution leads to analysis error. Hence, it is advised to use recent, high spatial resolution images in the study areas.
- In this study groundwater occurrence and transport are primarily controlled by rainfall and geomorphology. Therefore, it is recommended to investigate those factors supplemented by detailed maps with high resolution and field surveys.

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