Assessment of Ground Water Potential Zone based on Multi-Criteria Decision making model and Geospatial Techniques: The case of Lemo Woreda and Hossana town, Hadiya Zone, Southern Nation Nationalities

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Abstract

The objective of this paper is to assess and map groundwater potential zone in Lemo woreda and Hosana town by the integrating approach of Geospatial Techniques. For this purpose both primary and secondary data were used. Ground Control Points (GCP) were collected from Google earth; Digital Elevation Model (DEM) and Landsat 8 down loaded, besides, secondary data such as, soil data, rainfall, and Lithology were collected from different governmental institutions. Ground water controlling factors, namely, lithology, Geomorphology, slope, land use land cover (LULC), rainfall, lineaments, soil, and drainage density were generated. In order to map ground water potential area, Geographic Information System (GIS), Remote Sensing and Analytical Hierarchy Process (AHP) were used. AHP was used for computing weight for the parameters by comparing eight factors. The consistency ratio was less than 0.1(CR -0.03) which is acceptable weight to compute weighted overlay analysis in GIS environment .The weight derived for Rainfall, slope, Geomorphology, Soil type, lineaments density, drainage density , land use land cover (LULC) and lithology are:27%, 17%, 16%, 12 %, 9%, 8%, 6% and 5%, respectively, and the groundwater prospective of the area is qualitatively classified into five classes, namely, very high, High, moderate, low, and very low which account for 14.04%, 20.34%, 26.68%, 28.51%, and 10.44**%** the study area, respectively. The cross-validation of the resultant model was carefully carried out using spring, and water well data. The result tells most of spring and water well overlaying high and very high groundwater potential zones. As a result, the map generated using this platform could be used as a preliminary reference in selecting potential area for groundwater exploitation.

Introduction

Groundwater is water that exists underground in saturated zones beneath the land surface. This is one of the most valuable natural resources, which supports economic development, by assisting, human health, ecological diversity ,agricultural, and industrial use in many regions of the world (Burke & Moench, 2000; Hosseinifard & Mirzaei Aminiyan, 2015).It can be considered as the largest single freshwater source in many parts of the world, especially during prolonged dry periods (Assaf & Saadeh, 2008). According to (Chow, Maidment, and Mays, 1988) from the total freshwater to be present on the earth, almost 30 % exists in the form of groundwater, and less than 1% is available at lakes and rivers.

At least two billion people around the world rely on ground water as their only source of drinking water (UNEP, 2003). Because reliability of surface water is threatened by climatic condition, ground water is the best in abundance and its less susceptible contamination than surface water, and important source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Naghibi, Moghaddam, Kalantar, Pradhan, & Kisi, 2017).

Ethiopia is has been shown progressive fulfilment of its urgent water needs as past and recent studies describe (Tamiru, 2006). But it is has to be unable to satisfy all the necessities of all population yet.The role of groundwater for water supply and irrigation is increasing with time in Ethiopia (Bitsiet and Dessie, 2019).

Lemo woreda and Hosanna town administrative found near to and at heart of the Hadiya Zone. In the last ten years the population of this area has been increasing at exponential rate. This rapid growth of the settlement has brought about a tremendous increase in the demand for water supply.so that to overcome this problem groundwater is another alternative.

The common problem in utilization of groundwater is, well production and it requires huge amount of investment cost to utilize this valuable resources.in addition to this improper assessment of groundwater and site demarcation mostly expected to pose the problems. Since the groundwater occurs out of our sight, deep in the subsurface, there is no direct method to facilitate observation of water below the surface, but it can only be inferred indirectly by studying the groundwater occurrence and distribution controlling parameters. The parameters that control availability and occurrence of ground water are geology, slope, lineaments, drainage density, land- use/land-cover, Rainfall, surface runoff and geomorphology of the area (Shaban *et al*., 2005).

There are several methods that can be used to assess groundwater but can be grouped into two major categories these are conventional and advanced methods. Conventional methods of exploration may not be highly reliable due to assessment of diverse factors which affects the presence of groundwater (Biswajeet&Saro *et al*. 2012). In Ethiopia, most of groundwater potential zone assessment has been done conventionally, using in situ measurement which is not feasible and effective in cost and time (Bayessa et al. 2002; Tesfaye, 2012).

Nowadays, GIS and RS is an efficient tool to assess and storing large volumes of data, integrating spatial and non-spatial information in a single system, offering a consistent framework for analysing the spatial variation, and allowing manipulation of geographical information (Fares M. Howari, Mohsen M et al, .2017).It also help to Integrate all parameters which influence groundwater potential zone analysis including spatial and temporal data from satellite image (Kamal, 2017) .Besides to this, (Gupta and Srivastava, 2010) explain that several approaches such as Multicriteria Decision Analysis (MCDA), Analytical Hierarchy process (AHP) support in decision-making on ground water potential zone assessment and mapping. AHP is useful for weight assignment, pairwise comparison matrix and checking consistency ratio (Saraf and Choudhury, 1998).These decision makers use to reduce the bias in decision making (Saaty, 1980). Therefore the present study was focus on the assessment of groundwater potential zone in Lemo woreda andHossana town, of Hadiya Zone with integrated approach of geospatial technologies.

The main objective of the study is to assess and map groundwater potential zone in Lemo woreda and Hosana town by the integrating approach of Geospatial Techniques.

Study area

This study was conducted in Lemo woreda and Hossana town, the area located in Hadiya Zone, Southern Nation Nationalities and People's Regional State (SNNPRS), Ethiopia (Fig. 1). The study area is located in south of Addis Ababa the capital of Ethiopia and near to the administrative centre of Hadiya zone. The study area is 232 km away from Addis Ababa. Geographically, situated between 7°22'00"–7°45'00"N latitude and 37°40'00"– 38°00'00"E longitude. The study area has 39,879.00 hectares (398.7900 km^2). (Hadiya Zone Finance and Economic Development Office, 2020) 398.790063. According to Zonal report, the study area is characterized by topography of hills, valleys, plains and mountains. The altitude ranges from 1836 to 2700 meters above sea level. The study area weather conditions includes: Dega, Woine-dega and Kola .The mean annual rainfall ranges from1000-1200mm and the mean annual temperature ranges from 13-23ºc.According to the National Metrological Agency (NMA, 2021), the lowest temperature, (12.1°C) was records during summer (July) and the highest temperature (23°C) is records during March.

Materials And Methods

To achieve the objectives of this study, both primary and secondary data are used. Some of the data used in this research generated from different sources. The major data used in this study includes Soil (30×30 m resolution) and digital elevation model (30×30 m resolution) were collected from the ministry of water, irrigation, and electricity of Ethiopia (MOWIE),Satellite image (30 x 30 m resolution) downloaded from USGSEarth Explorer website (https://earthexplorer.usgs.gov), for January 2020 and the land cover map was prepared from landsat8 by classifying the satellite image and verifying with ground truth points. The geology and lineament map (at a scale of 1: 250,000) were collected from the geological survey of Ethiopia (GSE). Slope, drainage and elevation maps were derived from the digital elevation model (DEM); while drainage density and lineament density maps were derived from drainage and lineament maps respectively and Rainfall data taken from Ethiopia National Meteorology Agency. All the required thematic maps were developed from the collected datasets using ArcGIS 10.5 Software. The eight thematic layer maps such as Lithology, Rainfall, Geomorphology, slope, soil type, Lineament density, drainage density and land use land map generated were converted into the raster format using Arcmap 10.5 and used them for the overlay analysis. Groundwater potential zones were obtained by the weighted overlay analysis method using spatial analysis tools in ArcMap10.5. During weighted overlay analysis, a rank was given for each individual parameter of each thematic layer map, and weights were assigned according to the output of the MCDM (AHP) technique to that particular feature on the hydrogeological environment of the study area. The data used and their description are provided in Table1.

Material and Software to be used

The following software and equipment were used for in the process of analysis and generating Flood vulnerability map, these include: ERDAS IMAGINE 2014, Arc Map10.5, AHP and Google earth was used for collection of ground control points to validate for land use / cover map.

Analytic Hierarchy Process (AHP)

The groundwater delineation in the study area involved thematic map generation and their integration through GIS environments. Prior to integration of different information, individual class weights and map scores was assessed based on satty's Analytic Hierarchy Process (AHP) (Saaty, 1977). Where a pair-wise comparison matrix prepared for each map using a nine point important scale and weighted depending on relative importance. In general, nine objects are the most which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion. To ensure the credibility of the relative significance used, AHP also provides measures to determine inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.1 indicates that level of consistency in the pair wise comparison is acceptable. Saaty (1980) suggests that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable. But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful results. The result unified weight map containing due weights of all input variables. The weight values this final map further logically was classified to arrive at delineation of groundwater potential zone map. This provides a broad idea about the groundwater prospect off the study area. To achieve the final target of the study, delineation of groundwater potential zones, different thematic layers; Lithology, geomorphology, lineament density, drainage density, slope, soil, landuse/land cover and rainfall integrated using GIS and Remote Sensing techniques.

Lt = lithology; RF = Rainfall; Ge = geomorphology; SL = slope; DD = drainage density; Soil; LULC = land use land cover; LD = lineament density

Weight Normalization

To normalize the values, divided the cell value of comparison matrix by column total (sum) and calculated the priority vector or weight by determining the mean value of the rows (Saaty, 1980).Priority weight was 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 Table3.17.below.

Note: The weight values represent the priorities which are absolute numbers between 0 and 1. The eigenvector is an estimate of the relative weights of the criteria been compared. Because individual judgment will never agree perfectly the degree of consistency achieved in the ratings is measured by a Consistency Ratio (CR) it indicates the probability that the matrix ratings were randomly generated. The rule of thumb is that a CR less than or equal to 0.1 .reciprocal matrix, a ratio over 0.1 indicates that the matrix should be revised

$CR = \frac{CI}{RI}$……………… (Eq. 1)

$CI = \frac{(\lambda max - n)}{(n-1)}$ ……………… (Eq. 2)

$$CI = \frac{(7.69 - 8)}{(8 - 1)} = -0.044$$

…

RI = Random consistency

n = number of criteria.

λmax, = is Σ of the products between each element of the priority vector and column totals.

Based on the computed AHP value CR is lower than the threshold value of 0.1(CR= -0.03) and indicates a sufficient level of consistency in the pair wise judgments, and implies that the determined weights are acceptable. Each factor was prepared for the weighted overlay in Arc GIS with Weighed Linear Combination method (WLC).

Ranking Method and weighted overlay

To generate criterion values for each evaluation unit, each factor weighted according to estimated significance for identification of ground water potential area. There are two ways of doing this; straight ranking (very high =5; high= 4; moderate =3; low =2, very low = 1).

The criteria maps depicting different potential area of ground water are overlay on Arc GIS 10.5 These thematic Layers are such, as lithology ,Rainfall,Geomorpphology,Slope, drainage density, soil type, Lineament density, and land-use/land-cover, are reclassified and computing weigh based on their influence on availability of ground water.

Results And Discussion

Ground water potential area delineation

To assess ground water potential zones, important factor maps were considered, and the maps were prepared for each layer. Each factor determining the ground water potential zones in the study area is classified into five classes .Theses criteria maps were altered to raster data sets having the same pixel size (Resolution) and different weightage were assigned using AHP (Analytical Hierarchical process) as per their groundwater potential controlling capacity within the study area and reclassification of each map was done based on the weight values produced. The combination method follows the conventional scheme for GIS-based MCDA (Malckzewiski, 1999). It involves three main phases. First, the criterion maps were standardized/ reclassified using Spatial Analyst's Reclassify tool. This approach is important since the criterion maps include the ordinal values (very high, high, moderate, low and very low) indicate the level of potential area of ground water. Secondly, derivation of the weights of relative criterion importance using the pair wise comparison method (cf. assigning criterion weights-section). The criterion weights are automatically calculated once the pair wise comparison matrix is entered in the AHP weight derivation module. Third, the criterion weights and the standardized criterion maps were combined/ aggregated by means of the weighted overly analysis (WOA) operations. Finally the expected groundwater potential areas for the study area were delineated.

Presence of Ground water is strongly associated Lithology, Rainfall, Geomorphology, slope, soil type, Lineament density, drainage density and land use land. To assess potential ground water potential area using GIS and remote sensing, weighted overlay analysis were used. MCE is a procedure which needs several criteria to be evaluated to meet a specific objective.

Rainfall

Groundwater recharge is controlled by various factors with rainfall playing a key role since it represents the main source of groundwater recharge (Gebhardt, H.; Glaser, R.; Radtke, U.;2011 Reuber, P;Lakshmi, S.; Reddy, Y.2018;). The annual mean rainfall for the period from 2011 to 2020 in the study area was obtained from national meteorological agency (NMA) .The rainfall data were converted to a raster layer using the conversation Tools . We then converted the raster layer to points using the tools Conversion Tools > From Raster> Raster to point. These points were interpolated through the tools Spatial Analyst Tools >Interpolation > Kriging to obtain a rainfall contour map. The rainfall map for the study area was extracted using the tools Spatial Analyst Tools > Extraction > Extract by Mask. The rainfall map of the study area is shown in Fig.3. The northwest part of the study area receives rainfall of around 1076.5–1,250.4 mm/year; the eastern part receives rainfall of around 749.2–1,167.1 mm/year. In the southern part, the recorded rainfall is around 1,167.1–1,364.5 mm/ year, and in the northeast part, the recorded rainfall is around 1076.7–1,167.161 mm/year. The rainfall influence on groundwater occurrence likely depends on the southwest and central rainfall, which has a high amount of rainfall from June to September, about 1,250.5–1,364.5 mm/ year. The rainfall distribution along with the southwest part directly affects the infiltration rate and hence increases the possibility of groundwater potential zones in the study area.

Slope

It is a topographic setting relates to the local and regional relief situation and gives an idea about the general direction of groundwater flow and its influence on groundwater recharge and discharge. The slope is one of the crucial variables which is predictable to groundwater revive. It controls the ratio of penetration and surface spill-over. It gives awareness about the amount of groundwater recover dependent on the slope angles. Steeper the slope, greater will be the runoff and thus lesser is the groundwater recharge. Digital Elevation model (DEM) is derived using contour information from the topographical map for estimation of slope in degree. The identified slope category varies from 0° to 30^0 degree in the study area and area classified in to five classes like 0-3° (flat), 3 -6° (gentle), 6-10° (moderate), and 10.1-15° (steep) 15.1°-30° (very steep). flat slope (0–3°) indicates the presence of very high groundwater potential zones where as steep slope (>15°) shows the presence of poor groundwater potential zones as water runs rapidly off the surface and does not have sufficient time to infiltrate the surface, keeping other parameters constant.

The Geomorphology of the area

Geomorphology reflects many land form and structural landscapes and several topographies are inspiring the event of subsurface water and categorized in terms of groundwater possibility**.** Geomorphology i.e. landforms of the study area developed from SRTM 30m digital elevation model using land form mapping as presented by Morgan et al (2005) procedure in ArcGIS's spatial analyst tool. Land from is a combination of slope, relief and profile. The classification and description is adopted from Dikau's landform codes (Dikau, R etal., 1995). Technically a landform map is not complete without the, geologic history and the process that resulted in for the landforms presented in the maps. In this case, however, the map is satisfactory for the intended purpose.

The identification and characterization of various landforms and structural features in the study area are very important from geomorphological study point of view. Which are mandatory for groundwater potential zone mapping (Shifaji and Nitin, 2014).The geomorphology reclassified in terms of groundwater recharge and potential the geomorphology of the study area classified in to five units main geomorphic units identified in the area are flat plain, smooth plain, irregular plain, Escarpment, low Hill, Hills ,low mountain ,

Small Mountain and hills are the cover small area types of geomorphological class in the area; see Fig. 4.2.Groundwater occurrence map, those suitable areas are found with geomorphic class of Flat plain and irregular plain because of high infiltration rate: Escarpment, low hills, hill, low mountain landform, ground water is low. Locational, small hills to the north and south western part of the study area.. There is a maximum runoff associate with Landforms which characterized by hills slope. This shows poor Potentiality for groundwater potential and recharge possibility. However, there is a small portion of land, which has high elevation compared to local surrounding land.The rank assigned to the individual landform classification according to its respective influence of groundwater occurrence, holding and recharge, as presented in figure 5: Geomorphology and its rank as per suitable for groundwater potential and recharge.

Soil

The characteristics, types and distribution of soil for a certain area depend on geomorphology, geology, relief, time, and other factors. Soil properties influence the relationship between runoff and infiltration rates which in turn controls the degree of permeability, the principal factor in hydrogeology that determines the groundwater potential (Kumaret etal., 2016; Magesh et al., 2012;Tesfaye 2010). Soil type is a medium that controls the groundwater exposure which is an important in determining the intrinsic vulnerability. In line with FAO and according to the Ethiopian Ministry of Water Resource Soil Classification, the prevailing soil types in the study area were classified into six major groups, namely, loam(pellic vertisols, orthic solonchaks)soil which accounts for 57.12% area coverage, Clay(vitric Andosols, Eutric vertisols) which accounts for 57.12% area coverage , sandy Clay loam(Chromic luvisols) which accounts for 57.12% area coverage , clay Loam(Calcic xerosols, Eutric nitisols) which accounts for 57.12% area coverage as shown in Fig..6 The result showed that pellic vertisols and orthic solonchaks soils are found the most dominant in terms of area coverage with area coverage of 34.34%, 8.09%,and 0.45%, respectively and more determinant in groundwater occurrence and movement as compared to Calcic xerosols and vitric Andosols These soil types are characterized by poor to good infiltration property. Figure 6 shows the soil map of the study area.

Lineament Density

A lineament is usually defined as structural lines such as faults, which often represent zones of fracturing and increased secondary porosity and permeability, and therefore of enhanced groundwater occurrence and movement. In hard rock terrain the storage and movement of groundwater is controlled by the secondary porosity i.e. presence of lineaments and fractures. Lineaments for lineament density computation are extracted from SRTM (DEM) which downloaded from path 169, row 55. Lineaments of the study area from remotely sensed data provides important information on subsurface fractures that may control the movement and storage of the groundwater. The distribution of the lineaments is observed to be high on the escarpment and rift floor (Figure 7). These are normal faults having a NW-SE orientation. Faults may act either as pathways for water movement or as flow barriers. At the foot of some of the fault scarps which bound the basin there exist springs indicating that these faults act as drains. The faults in the escarpment areas which comprises the older undifferentiated rocks of Nazret Group and Dino Formation down faulted towards the rift floor resulted in the development of in the study area. High density of the faults is observed near northwest and southeast. Those, faults on the floor may possibly be filled with a weathered glassy volcanic ash. In such cases the faults could act as barriers (Nedaw, 1997). Most of the lineaments are identified Classified into lineament density map in to five categories, i.e. 0.902 -1.51(very high), 0.588 -0.901(high), 0.375 – 0.587(medium), 0.131-0.374(Low) and 0- 0.13 (very low) in the study area (Figure 7)

Drainage Density

Drainage density is one of the important indicators of groundwater recharge (Magesh et al., 2012) and groundwater occurrence (Sener et al., 2005). In fact, it is linked with water percolation properties of underlying lithology, consequently having close relation with groundwater mapping. The drainage density is an inverse function of permeability. An area with low permeable surface prone to high drainage density and water comes from precipitation goes to a high runoff as well and vice versa. As a result, high drainage density implies low groundwater potential. The Drainage density was delineated using SRTM(DEM with30m)resolution data of the study area after consecutive processes such as Importing of SRTM data, filled sinks for undefined values, created Flow Direction, Created Flow Accumulation, created Stream network, generated Stream Order and finally converted Stream Order to drainage density using a spatial analysis tool in ArcGIS 10.8. Afterwards, a drainage density map is produced using a kernel density analysis tool (Figure 8). As per the definition of preceding studies (Greenbaum, 1985; Magesh et al., 2012), drainage density (DD) is the total length of the stream segments divided by the unit area .The stream order values were regrouped to produce a drainage density map that was reclassified into five categories based availability of potential of Ground water i.e., namely “very good” (0–0.00005148 km/km^2), “good” (0.00005149–0.0001214 km/km^2), “moderate” (0.0001215–0.0001809 km/km^2), “poor” (0.000181–0.0002482 km/km^2), and very poor (0.0002483 –0.0003366 km/ km^2). In the study area, 1.73% and 25.07% of landscape were found in 0–0.00005148km/km^2 and 0.00005149–0.0001214 km/km^{2}drainage density class, respectively. This implies the availability of good groundwater potential zones. Moreover, 61.18% was entitled under drainage class with good potentiality for groundwater storage. (figure.8).

Land Use/Land Cover

LULC is an important factor affecting groundwater recharge, groundwater occurrence, and availability (Hussein et al., 2016; Kumar et al., 2016; Pande, Khadri, Moharir, & Patode, 2017; Yeh, Cheng, Lin, & Lee, 2016). Supervised image classification was conducted to classify and identify the type of LULC, where Landsat 8 (OLI) satellite image of 2020 with 30 m spatial resolution used. to increase visibility Image pre-processing are conducted in order to analyse remotely sensed images, the different images representing different bands must be stacked, that is, band 1 to 7 LULC 2020 satellite images and classified in ERDAS imagine 2014. Image classification the LULC change studies usually need the development and the definition of homogeneous LULC units before the analysis started. It is differentiated using the available data source such as remote sensing, Google earth, ground control points and the previous local knowledge. Following this, the tool, ERDAS imagine 2014 software was used for classification of the LULC image of the area. In remote sensing, there are various image classification methods, that is, supervised and unsupervised. For this study, we used the most common type of classification technique, supervised classification type. First, Google earth was taken as a signature for the classification. Second, we performed the classification using the maximum likelihood classifier. Lastly, the accuracy assessment was performed using Google earth image for the LULC

2021, 100 random points were generated in Arc GIS10.5. Following these procedures, random points were converted to KML to layer (Hengl et al., 2015). Whereas, the accuracy assessment of 2020 LULC map was used ground truth points as a reference and 100 points were taken to validate the classification; which was built in 12/05/2020. The analysis result was performed using confusion/ error matrix. The land use/cover map of the area was readily interpreted from Landsat image of the year 2020 by using visual interpretation, supervised classification using ERDAS 2014 software. On the result of Classification of land use/cover for analysis is used for identification of the ground potential area. The study area consists of five types of LULC (Figure 5) namely; agricultural area 203.88 (51.13%), forest cover area 112.27 (28.15%), grazing land area 21.64 (5.43%), shrub land area 33.28 (8.35%), urban area 27.72 (6.95%) total area of Land use/ Land cover map of the area398.79 km^2

Lithology

The way of Geologic formation and genetic type is essential condition for ground water flow, transport and mineral composition. Types of rocks determine peculiarities of hydrological crosssection structure, type of porosity values, the nature of permeability, geological structure geomorphology and character of spatial heterogeneity of flow and transport parameters. Lithology has a principal impact on the occurrence and movement of groundwater as it highly controls the infiltration and flow processes (Tolche, A, 2020) stated that the rock type can substantially influence the groundwater recharge potential. Similarly, (El-Baz, F.; Himida, I.; 1995) found that lithology affects the recharge by governing the water percolation. Some investigations have neglected the lithology parameter in ground water potential zoning by considering the drainage features and lineament density as a measure of primary and secondary porosity; however, we followed (Yeh, H etal,;2016)by including the lithology in our analysis to minimize the uncertainty in estimating drainage and lineament densities. The Geological map was then added to ArcGIS, and the study area was extracted using the tools Analysis Tools (Extract tool). Lithological categories classification was done according to the classes available in the lithology classification for Ground water potential zone assessment.

Mapping Ground water potential Areas

In this stage, the AHP results were integrated into a GIS system to map Ground water potential areas using Weighted Linear Combination (WLC). The WLC / simple additive weighting rely on the concept of a weighted average where continuous criterions are standardized to a collective numeric range, and then combined by means of a weighted average (Drobne and Lisec, 2009). The WLC technique can be carried out using any type of GIS system possessing the overlay. The output of this WLC method gave a map the most potential flood susceptible areas. To compute the groundwater potential areas, a weight linear combination was applied as shown in Equation (3).

GWPZM = (27 * RRf) +(16 *RGm) +(17*RSl)+(12 *RSt) +(9 *R Ld)+ (8 * R Dd)+(6 * RLulc) + (5 * R Lith)………………………… (Equation 7)

Where, **RRf**: Reclassified Rainfall Map, **RGm**: Reclassified Geomorphology Map, **RSl**: Reclassified Slope map, **Rst**: Reclassified Soil Texture Map, **RLd:** Reclassified Lineament density Map, **RDd**: Reclassified Drainage density Map, **RLulc**: Reclassified Land-use/land-cover Map and **RLith:** Reclassified Lithology Map.

Rainfall, geomorphology, slope, soil type and lineament density holds the highest value relative to the other parameters. The weight assigned for Rainfall were greater than the weight of other, which influence the occurrence of groundwater potential and recharge zone than others parameters (Mwega, 2013; Kamal et al., 2016). The result for groundwater potential zones was classified in to very high, high, moderate, low and very low Figure 11

The potential area is divided in to five classes. Those were, very high, high, moderately, low and very low groundwater potential areas (Figure 11). In the study area by very high and high ground water area potential areas covers 14.04% and 20.34%. The very high and the high ground water potential areas are found in the South west and Central part of the study area and very low ground water potential areas area a found at upper parts of the study area specifically in the Northern and North eastern part. Moderately ground water potential areas are found in the major near to urban area and included settlements as classified in the land use map.

As can be seen in Table 4.9, means more than 14.04% and 20.34% of the area was found in very high and high ground water potential areas and the remaining as moderately to very low ground water area potential areas. The Very High ground water potential areas a total coverage of 5385.51Ha (53.8551 km^2) of the total area. “High” ground water potential areas have total area of the district covers 7803.36 Ha(78.0336km^2) ,the “Moderately” ground water potential areas, covers 10240.11 Ha(102,4011$km^{2)}$ of the total area , “low” ground water potential areas covers 10939.59Ha(109.3959 km^2) and very low ground water potential areas covers 4005.19 Ha(40.0519km^2) (see table 14).

Conclusions And Recommendations

Conclusions

This study tried to assess in groundwater potential zone by using GIS and remote sensing techniques through Analytical Hierarchy process (AHP) to identify and delineate groundwater potential area. For this purpose eight parameters were selected which have more affects the occurrence of groundwater potential, prior to overlay analysis. The AHP design showed that rainfall has the highest weight in recharging Ground water through the spatial-weighted overlay. From all parameters (Lithology, Rain fall, geomorphology, Slope, drainage density, soil, Lineament density and LULC).also the geomorphology parameter was the most important parameter because it influences the infiltration water in to the soil, and flow direction. This approach allows decision makers to give the judgments in order to reduce complexity in decision making processes. The results of consistency ratio in this study were -0.03. If the result of consistency ratios are greater than 0.1, the value is unaccepted and it must be re-evaluated. In this case, the consistency ratio for groundwater potential a zone was less than 0.1 and the value was accepted for further analysis. The delineated Groundwater potential zone were classified into five zones namely, ‘very low’, ‘low’, ‘moderate’, ‘high’ and ‘very high’. Very low zone shows that the low suitable area for groundwater prospect. Whereas very high zone indicates the most suitable area for groundwater prospect. Very high potential areas present in flat plains, and lacustrine sediments, which coincide with the low slope and high lineament density of the study area. Very low groundwater potential falls in the area highland with, high slope and high drainage density. The acceptable results were done by comparing the borehole yield data with the Groundwater potential zone map of the study area. The effective parameters in the area for groundwater potential is Lithology, rainfall, slope, geomorphology, lineament density, and drainage density in Pairwise Comparison matrix analysis indicates that all parameters are significant. Around 14.04% zone under very high groundwater potential and the next high potential; area covers 20.34%, Moderate groundwater potential zone where 26.68 % covers, the low and very low coverage of groundwater potentials area shares 28,51% and10.44 % respectively.

Recommendation

High potential groundwater potential area was based on the findings obtained and conclusions reached the following recommendations were forward as follow:

- The same appropriate methods were recommended for complex areas to delineate groundwater potential zone in the small area.
- The groundwater potential map along with other thematic maps forms serve as resource information database that can be updated from time to time by adding new information.
- For further validation, field geophysical investigations on the potential well drilling sites are recommended.
- Identified to the north and north east of the study area are low suitable for groundwater potential zone but south western parts of the study area part of the study area is have better ground water potential . In this research, integrated GIS and remote sensing techniques are very useful, time and cost effective tool for the identification and delineation of groundwater potential zone analysis.

Generally even if the investigation of groundwater potential in certain areas is vital, but further investigation has to be performed to be assured of its reliabilities. Furthermore, the studies can be done on the quality and its suitability for different aspects such as drinking, agricultural and industrial activities should be considered for further Investigation

Declarations

Conflict of interest

There is no conflict of interest between authors.

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Tables

Table 1: Types of data used and their sources

Data Type	Data type	Scale/Resolution /Format	Source	Relevance
Primary Data	Landsat 8 (OLI)	OLI (30m*30m) (2020 year: path 169 and Row 55	United StatesGeological Survey (2020)	To prepare land use/land-cover,
	DEM	SRTM (30m*30m)	United States Geological Survey (2020)	Used to generate Slope, Drainage, Geomorphology and lineament maps of the study area.
	Rainfall data	Excel Format	NMA(1998-2020)	To generate rain fall map of the study are
	Borehole Data	Excel Format	Collectedby HandledGPS	Used to validate the groundwater potential map
Secondary Data	Geological map	1:250,000	EGS (2012)	Used to generate Geological Map of the study area
	Digital Soil type	Shape File	Ministryof Agriculture	Used to generate the soil map of the study area

Table 2: The types of Software and their application area

No	Software and Material to be used	Major application Area
1	Arc Map 10.3.1	thematic map generating, Reclassification, Area Calculation, map lay out and weighted overlay, accuracy
2	ERDAS IMAGINE 2014	Image processing and Land use/ cover classification
3	Microsoft Excel	Rainfall data Analysis, Interpolation and to calculate Return period and Probability of occurrence of flood.
4	Google earth	Ground truth for land use/cover classification
5	AHP	To compute weight for factors

Table 3: Satty's Analytic Hierarchy Process a nine point important scale

Rating	1/9	1/7	1/5	1/3	1	3	5	7	9
Qualitative Description	Extremely	Strongly	Strongly	Moderately	Equally	Moderately	Strongly	strongly	Extremely
	Less importance					More importance			

Weight Assessment and Normalization

Ranking of criteria of Ground water potential area parameters

Table 4: Comparison Matrix

Criteria	RF	Geom	Slope	Soil	LD	DD	LULU	Litho	Priority Weight%
RF	1	2	3	3	3	2	4	4	27
Geom	1/2	1	1	1	2	3	3	7/2	16
Slope	1/3	1	1	2	2	3	3	7/2	17
Soil	1/3	1	1/2	1	4/5	4/5	2	2	12
LD	1/3	1/2	1/2	5/4	1	1/2	2	2	9
DD	1/2	1/3	1/3	5/4	2	1	10/9	5/4	8
LULC	1/4	1/3	1/3	1/2	1/2	9/10	1	2	6
Litho	1/4	2/7	2/7	1/2	1/2	4/5	1/2	1	5
sum	3.4	6.4	6.9	10.5	11.8	12	16.6	21.2	100%

Table 5: Weight Normalization of comparison matri

Criteria	RF	Geom	Slope	Soil	LD	DD	LULC	Litho	Criteria weight
RF	0.28	0.31	0.43	0.28	0.25	0.16	0.24	0.18	0.26623
Geomo	0.14	0.15	0.14	0.09	0.16	0.25	0.18	0.16	0.15875
Slope	0.09	0.15	0.14	0.19	0.16	0.25	0.18	0.16	0.1650
Soil	0.09	0.15	0.07	0.09	0.06	0.06	0.12	0.09	0.09125
LD	0.09	0.07	0.07	0.11	0.08	0.04	0.12	0.09	0.08375
DD	0.14	0.05	0.04	0.11	0.16	0.08	0.06	0.05	0.08625
LULC	0.07	0.05	0.04	0.05	0.04	0.07	*0.06*	0.09	0.05875
Litho	0.07	0.04	0.04	0.05	0.04	0.06	0.03	0.04	0.04625
sum	1	1	1	1	1	1	1	1	1

Table 6: Random Consistency Index (RI) (Saaty, 1980).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 7: Reclassified Rainfall map of the study area

Factor	(mm	classification	Ground water potential	Rank
Rainfall	747.2-950.6	Very low rainfall	Very low	1
	950,7-1074	Low density	low	2
	1075-1164	Medium rainfall	moderate	3
	1165-1248	high rainfall	high	4
	1249-1365	Very high	Very high	5

Table 8: Reclassified Slope value of and its rank as per suitable for ground water potential

Factor	Slope degree	classification	Ground water potential	Rank
Slope	0-3°	Flat	very High	5
	3 -6°	gentle	High	4
	6 -10°	moderate	Moderate	3
	10.1 -15°	steep	Low	2
	15.1 -30°	Very steep	Very low	1

Table 9: Reclassified Geomorphology map and its rank as per suitable for ground water potential

Factor	Types	Rank	Ground water potential
Geomorphology	Small mountain	1	Very Low
	hills	2	Low
	Low Hills	3	Moderate
	Regular plain	4	high
	Flat plain	5	Very high

Table 10: Type soil and its hydrological properties

Factor	Classification	Ground water potential	Rank
Soil Type	clay	Very poor	1
	Clay loam	Poor	2
	Sandy clay loam	Moderate	3
	Sandy loam	High	4

Table 11: Reclassified Lineament Density map as per suitability of Ground water potential

Factor	Km^2	Rank	Ground water potential
Lineament density	0 – 0.13	1	Very low
	0.131 – 0.374	2	Low
	0.375 – 0.587	3	Moderate
	0.588 – 0.901	4	High
	0.902-1.51	5	Very high

Table 12: Reclassified Drainage Density map as per suitability of Ground water potential

Factor	Km^2	classification	Ground water potential	Rank
Drainage density	0-0.00005148	Very low density	very good	5
	0.00005149- 0.0001214	Low density	good	4
	0.0001215-0.0001809	Medium density	Moderate	3
	0.000191-0.0002482	high-density	Poor	2
	0.0002483-0.0003366	Very high density	Very poor	1

Table 13: Reclassified lulc map as per suitability of Ground water potential

Factor	lulc type	Ground water potential	Rank
LULC	Urban area	Very low	1
	Forest land	low	2
	Shrub land	moderate	3
	Grazing land	high	4
	Agricultural land	Very high	5

Table 14: Reclassified lithological map as per suitability of Ground water potential

Factor	Km^2	Rank	Ground water potential
Lithology	Nazret group	4	high
	Pumice& trachytic	3	moderate
	Rhyolitic &trachytic	2	low
	ignimbrites	1	Very low

Table 14: Relative area of Ground water potential zone in the study area

Ground water potential level	Area in km^2	Relative % Area
Very high	53.8551	14.04
High	78.0336	20.34
Moderately	102.4011	26.68
low	109.3959	28.51
Very low	40.0519	10.44
Total	383.7375	100 %

Figures

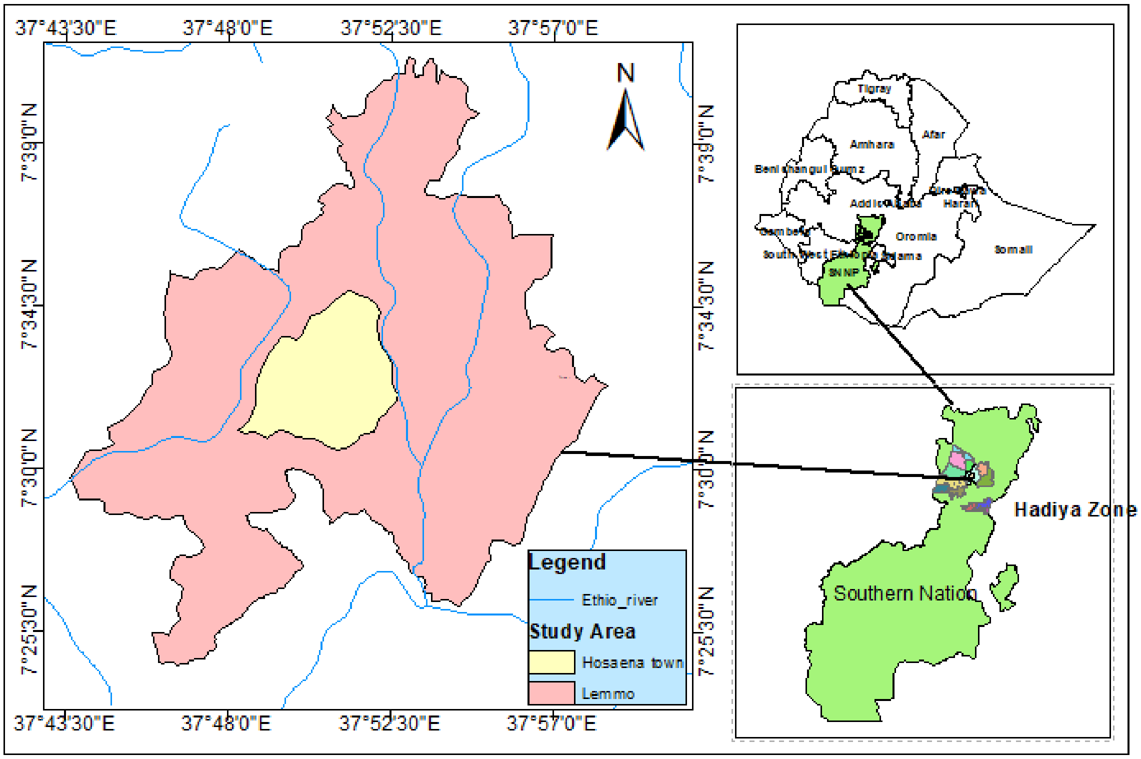

Figure 1

The location of the study area.

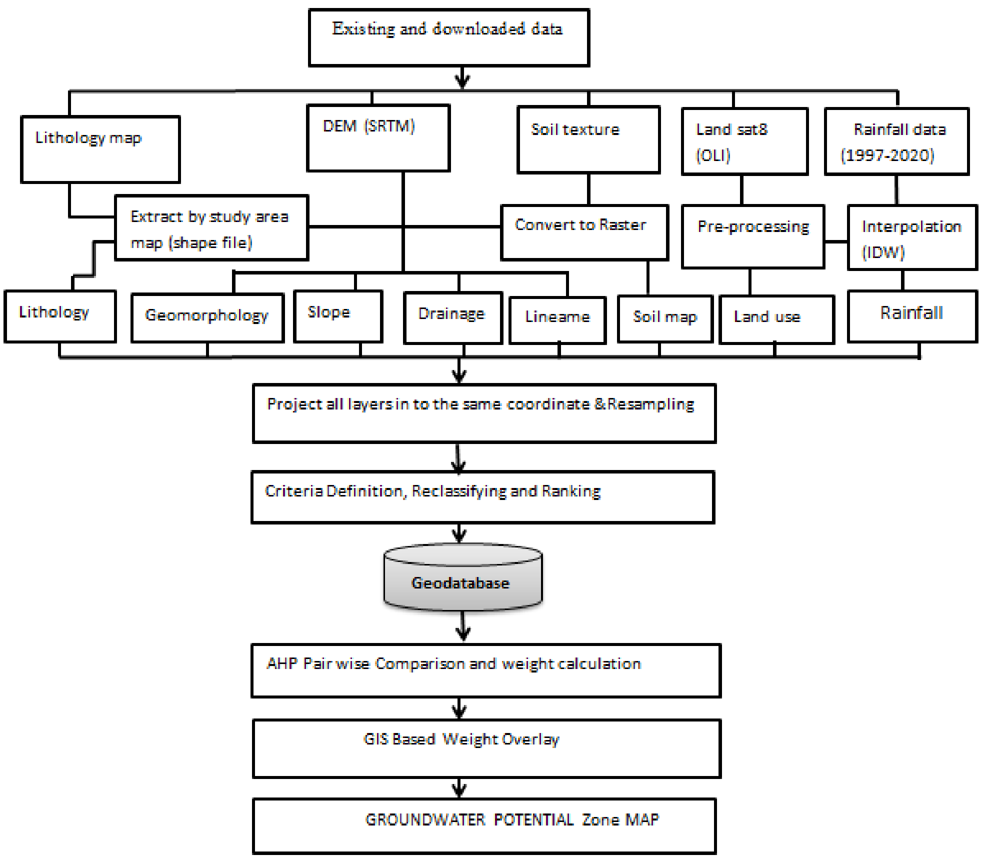

Figure 2

Methodological Flow chart of groundwater potential area assessment using Geospatial technique mapping methodology in Lemo Woreda and Hossana town

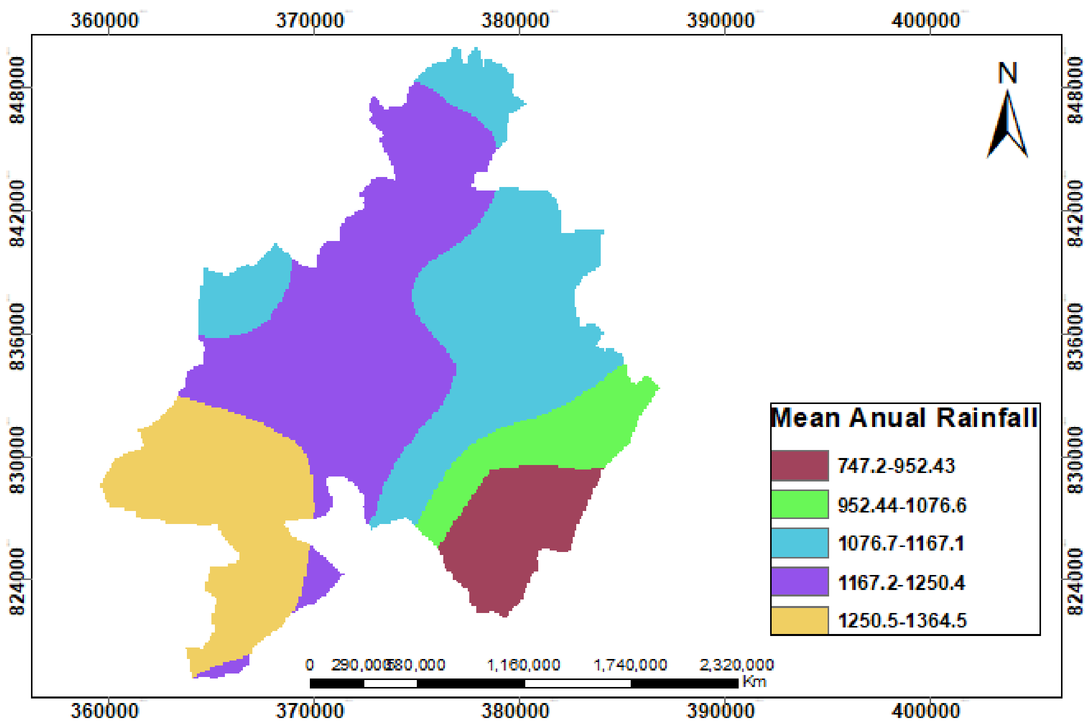

Figure 3

Reclassified Rainfall map

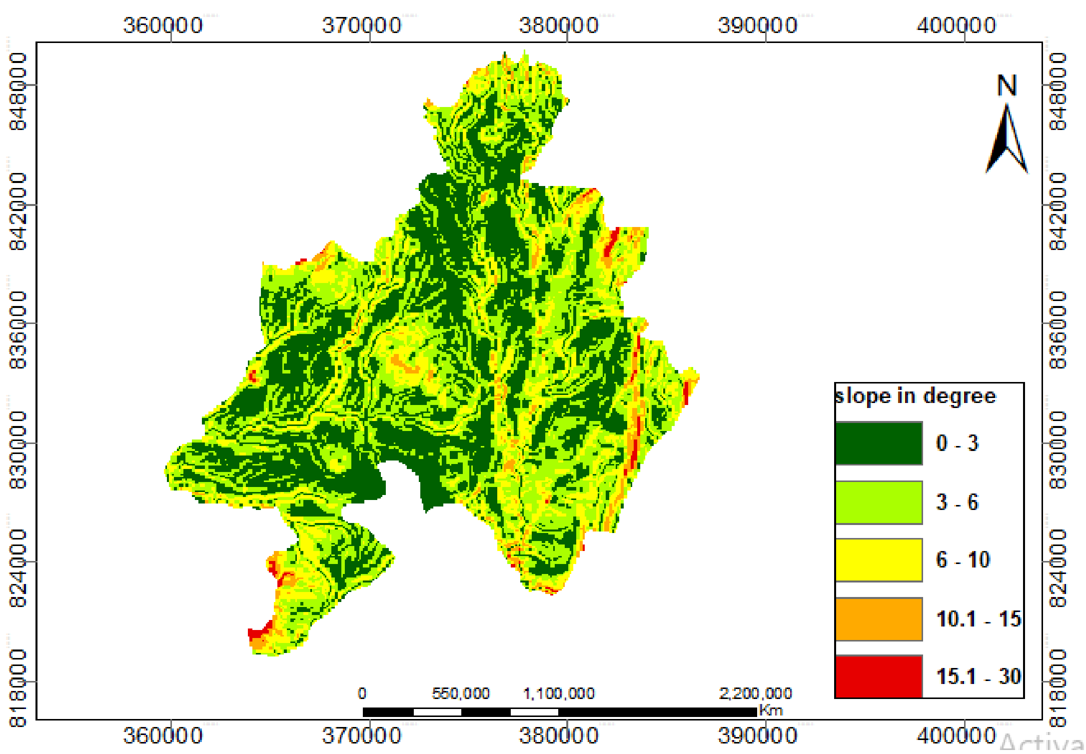

Figure 4

Reclassified Slope map of the study area

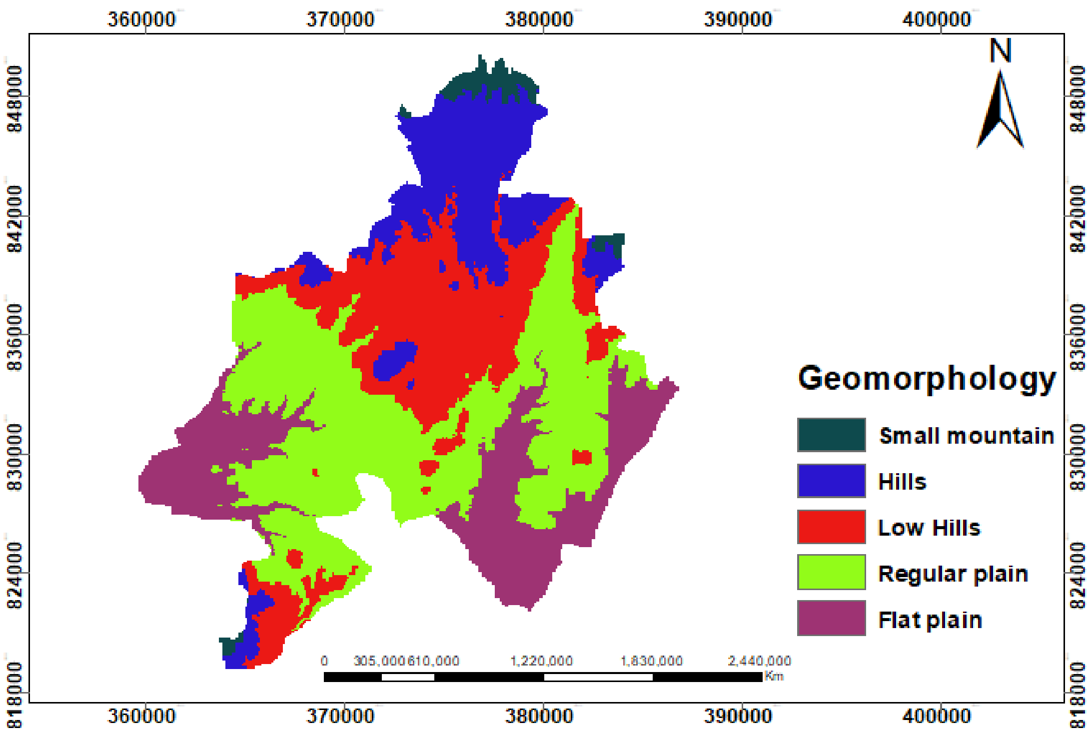

Figure 5

Reclassified Geomorphology map

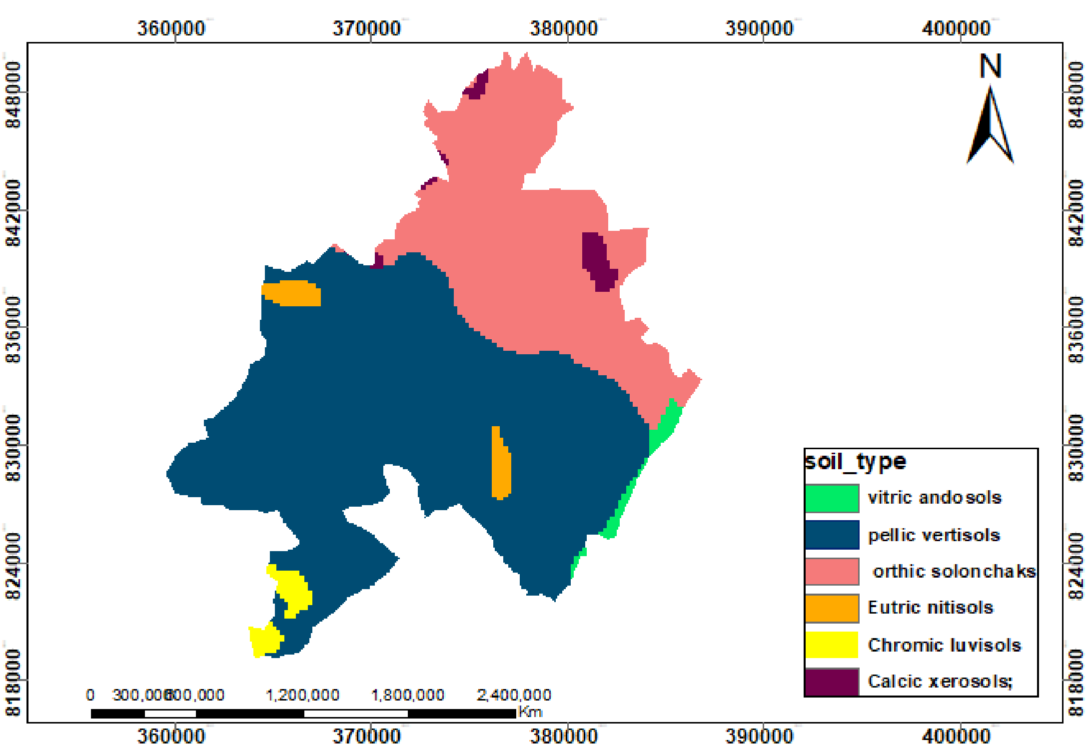

Figure 6

Soil map of the study area

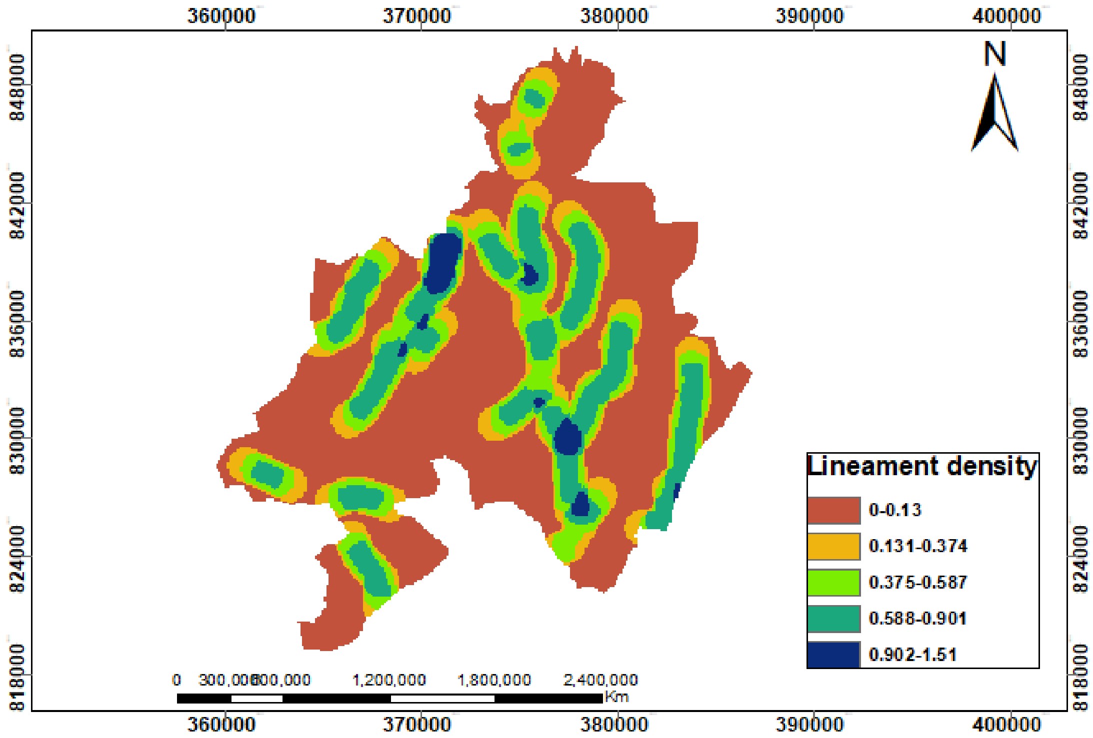

Figure 7

Lineament density map of the study are

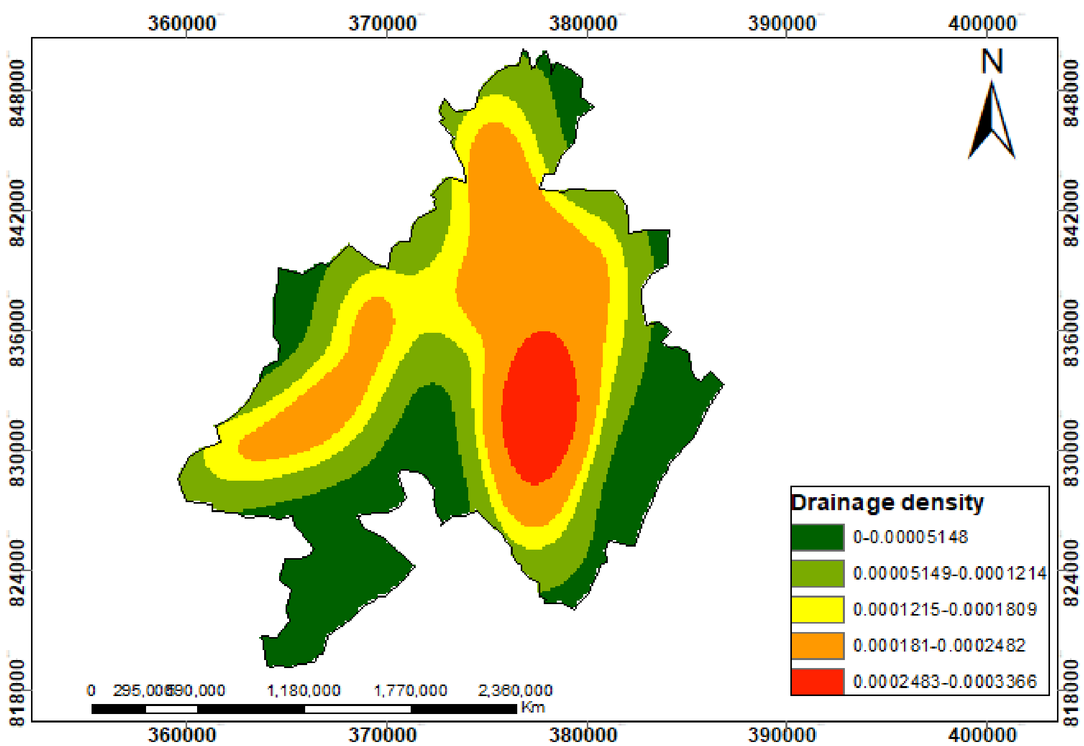

Figure 8

Reclassified Drainage density map of the study area.

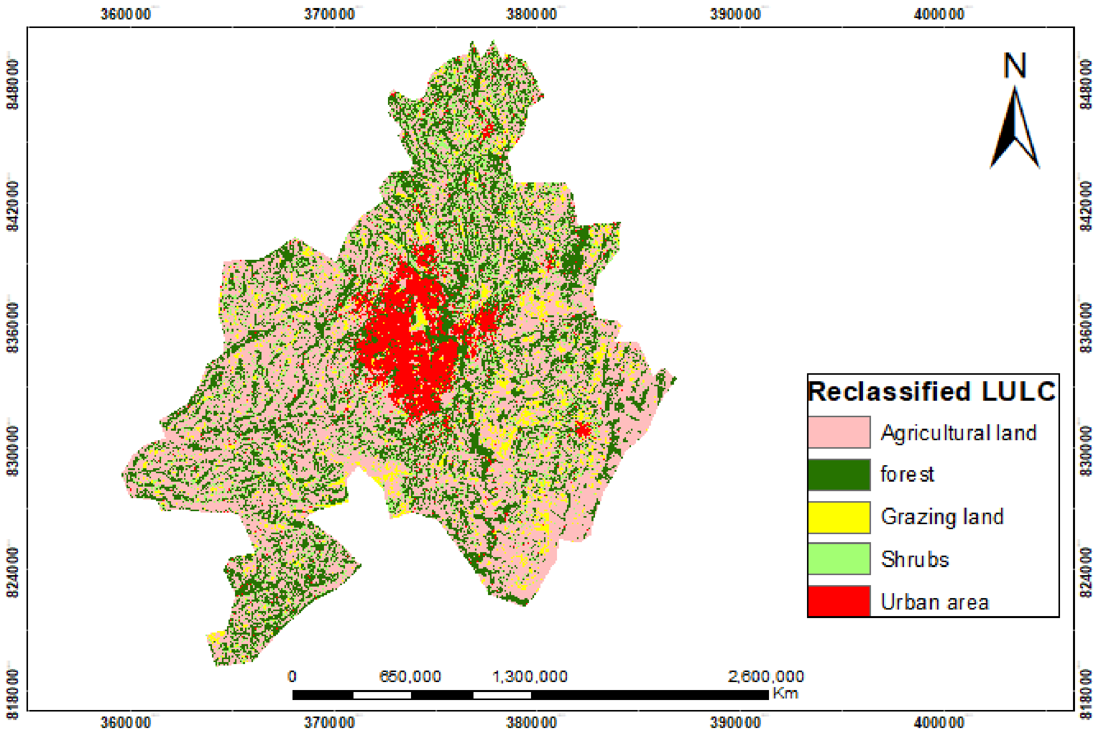

Figure 9

Land use land cover map of the study area

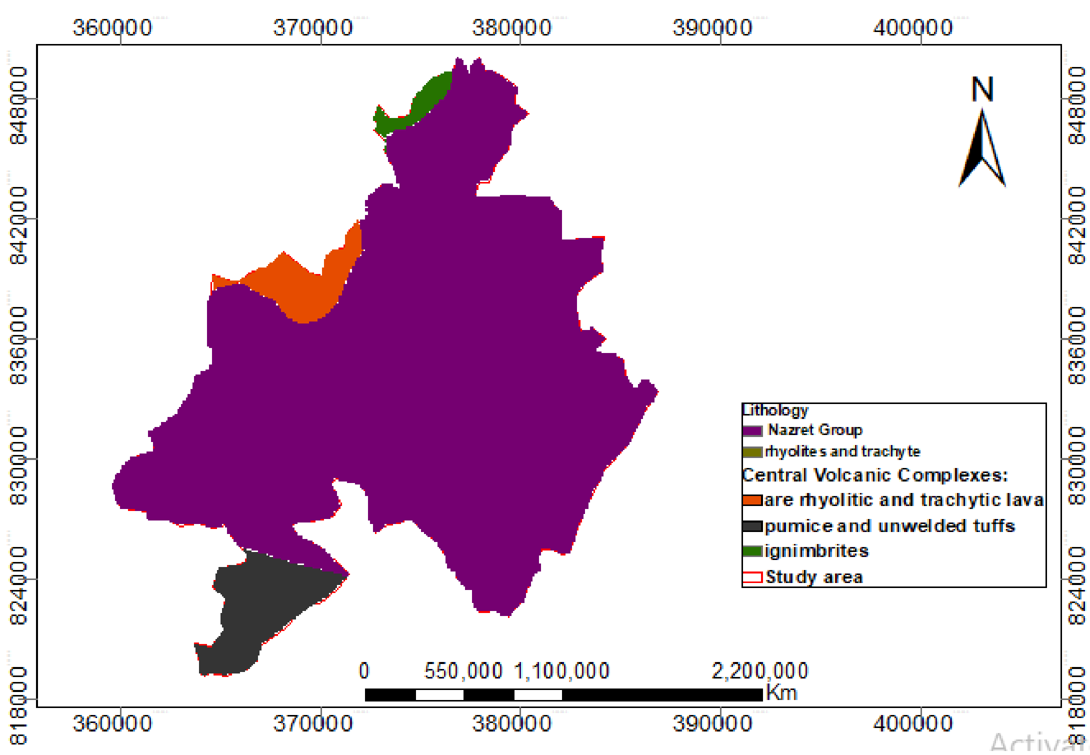

Figure 10

Reclassified geological map of the study area

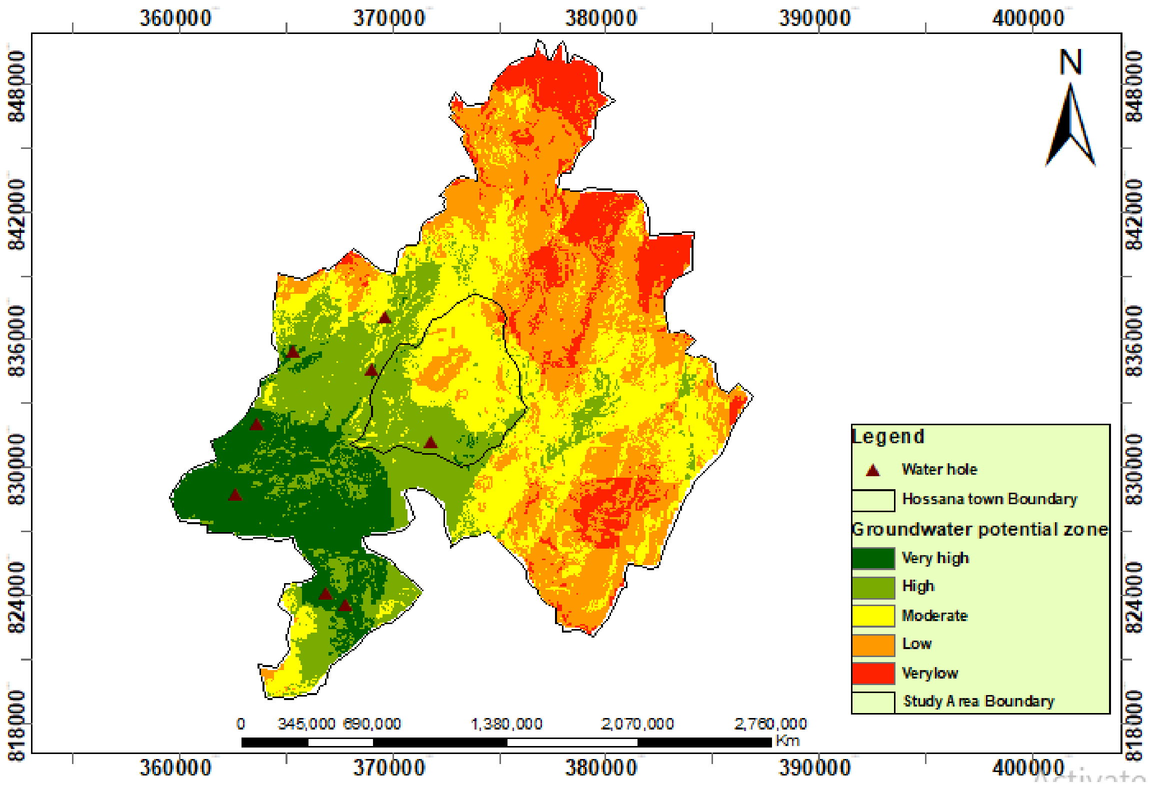

Figure 11

Groundwater Potential Zone Map of the Study Area