

Delineation of Ground Water Potential Zones Using GIS and Remote Sensing Techniques in the Case of Korahe zone, Somali regional state, Ethiopia

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DOI: 10.29322/IJSRP.11.08.2021.p11653

<http://dx.doi.org/10.29322/IJSRP.11.08.2021.p11653>

Abstract

The integration of GIS and remote sensing was applied to delineate ground water potential zone by interpreting nine thematic layers. The parameters like drainage density, elevation, geology, geomorphology, land use and land cover, lineaments, rainfall pattern, slope gradient and soil texture were used for identification of ground water potential within the study area. The selected parameters are prepared and classified in the GIS environment, then the analytical hierarchy process is used to assign weights to each parameter and its class, and finally the results are found in the weighted overlay analysis that is common in ArcGIS. The result of the study reveals that, about 169631.71ha (4.89%) of the study area having very high, 334818.58ha (9.65%) having high, 587658.05ha (16.93%) having moderate, 1194164.18ha (34.41%) having low and 1184005.67ha (34.12%) having very low potential of ground water. The integration of GIS and Remote sensing technique in ground water analysis from various thematic maps proves to be very important to map the groundwater occurrence and movement for recharge potential mapping and management plan on a scientific basis in the study area.

Keywords: GIS, Remote sensing Analytical hierarchical process, Weighted Overlay, groundwater zone

1. Introduction

According to National Groundwater Association (NGWA) Report, GW (Ground water) is the most widely used source of fresh water and extracted as raw materials with withdrawals rate currently in the estimate range of 982km³ /year in the world. About 60% of groundwater withdrawals worldwide is used for agriculture, which is globally about 38% of irrigated land is equipped for irrigation with groundwater and about of 25% to 40% was used for domestic and the rest is used for industry (Siebert *et al.*, 2010).

In Ethiopia, the annual water resources potential is estimated to be 122 BCM with 40 BCM of groundwater potential and 28-36 BCM of annual groundwater recharge (Puertas, 2015). According to MoWR (2012) report, in Ethiopia, Groundwater potential is shaped by complex geological formation and the diversity of topography, climate, and soil. According to Berhanu *et al.* (2014), the difficulty in obtaining productive aquifers is an odd feature in Ethiopia, because it's characterized by the wide heterogeneity of geology, topography, and environmental conditions. Actually, the geology of the country provides usable GW and provides good transmission of rainfall to recharge aquifers, and produce springs and feeds perennial rivers. The geological formations/water bearing rock with sufficient saturated permeable materials are transmitted and yield water in significant quantity towards point of discharge (Bereket, 2017). In many parts of the country, GW is the major source of water supply for meeting domestic need, industrial, irrigation and other developmental initiatives, due to its longer resident time in the ground, low level of contamination, wide distribution, and availability (Sewnet *et al.*, 2016).

The occurrence, distribution and movement of groundwater resource in any place is not a matter of chance, but the interaction of different factors such as climate (rainfall), geomorphological (land feature, land use/cover), physiographical (topography), hydrological (drainage density, water bodies, etc.), geological factors, lineament density and soil (Murasingh and Jha, 2013). However, the extent to which the factors affect the ground water may differ from place and time. Considering this factor has significant potential to evaluate the groundwater resource and improve success in selecting the favorable sites for boreholes and wells (Badamasiet *et al.*, 2016).

Around the world, different methods have been used in delineating GWPZs such as integration of remote sensing and GIS with resistivity data (Selvarani *et al.*, 2016), influence factor (IF) (Selvam *et al.*, 2015; Magesh *et al.*, 2012 and , Nasir *et al.*, 2018), statistical methods (Machiwal *et al.*, 2011; Falah *et al.*, 2017), groundwater modeling (Sashikkumar *et al.*, 2017), and analytical hierarchy process (AHP) (Das *et al.*, 2018; Dar *et al.*, 2020, Saranya and Saravanan, 2020). These methods have been proven as reliable and effective, and have been used by many researchers. Among those, AHP is advisable in cases of segregating multiple substitutes to a set of pairwise comparisons followed by the incorporation of the result. As propounded by (Saaty, 1980), AHP is also recommended when there is a lack of sufficient valid data for analysis (Saaty, 2014 and Souissi, 2018). AHP approach has been broadly applied in many fields of natural resources management, regional planning, and environmental impact assessment (Kaliraj, 2014 and, Rahaman, 2015). In the present study, AHP is integrated with RS-GIS techniques for the identification of GWPZs in the Korahe zone. Similar to (Arshad *et al.*, 2020; Kumar, *et al.*, 2020, Bisson and Lehr, 2014; Naghibiet *et al.*, 2015 and Mallick *et al.*, 2019), weights are allocated to the different parameters and their feature classes based on extensive literature reviews and expert knowledge using the AHP method. The integration of RS-GIS with AHP results in the conversion of data to obtain valuable information for managers and policymakers (Malczewski *et al.*, 2006). Therefore the main objective of this study is to map and delineate groundwater potential zones of the Korahe zone through the integration of RS-GIS with AHP. For this purpose, we utilized nine thematic layers (i.e., geology, geomorphology (landforms), slope, elevation, soil texture, lineament density, drainage density and rainfall, land use/land cover) in the analysis. This study would be a useful for groundwater resources planners and managers when constructing sustainable groundwater plans in this region.

2. Study area

Korahey is one of the 11 zones of the Somali region of Ethiopia. It is bordered by the Gode zone to the southwest, Fiq to the northwest, Degahapur to the north, Werder to the east, and the Republic of Somalia to the southeast. The largest city in Korahe is Kebri Dahar. Astronomically, Korahe zone is found between 6°28'-7°68'-N Latitude to 43°53'-45°00' E longitude, respectively (Figure 2.1). Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), the Zone has a total population of 312,713, of whom 177,919 are men and 134,794 women. The largest ethnic group reported in Korahey was the Somali (99.22 percent) in which their livelihood was predominantly based on livestock production. Korahey Zone is well known for its endowment with huge potential of natural resources, the natural gas field of Calub lies in this zone, making petrochemical extraction potential area in the country (Abdulahi *et al* 2020). Moreover, the community is known for preserving and maintaining a wide-variety of cultural values and historical heritages, which are recognized to be its typical identities, and which need to be further promoted and strengthened. The zone is characterized by topography of predominantly lowland plain with an average altitude of 493 m above sea level with a few foothills of higher altitude. According to national meteorology agency of Ethiopia, the climate of Korahe zone is characterized as tropical semiarid in which temperature ranges from 23 to 36 °C. The area has bimodal rainfall pattern with two main rainy seasons in which the first is 'Gu' that occurs from mid-April to the end of June and second rainy season known as 'Deyr' occurs from early October to late December (Wudad *et al*, 2021).

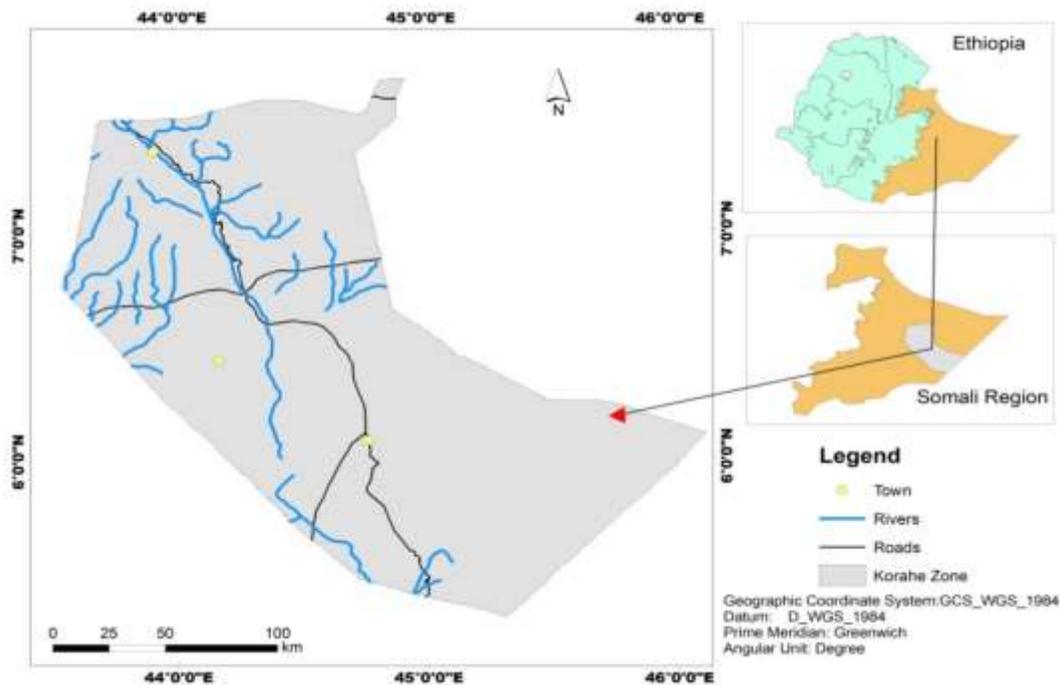


Figure 2.1. Location map of Koraha zone.

3. Methodology

To delineate ground water zone of the study area we developed a thematic layers from different factors such as geology, slope, lineaments density, soil, elevation, drainage density and land cover using GIS-MCDA techniques. The data layer for each of these factors was generated and classified using a series of satellite data, existing maps, and data from related governmental organizations, all these thematic layers were integrated using GIS and MCDA methods (Table3.1).

Soil data was in shape file form representing polygons of different soils texture. They were imported into ArcGIS 10.8 platform where they were explored and displayed in map format. It was ensured also that the data adequately covered the area of study. The climate data obtained from national meteorology agency were in Excel file format. They were scrutinized on excel spreadsheet to ensure that all the values representing both temperature and rainfall were free from obvious errors and mistakes. In the MS Excel file containing the climate data, spatial data in terms of latitudes and longitudes of the locations of weather stations were entered into corresponding climate data. In the climate data, averaging was done starting from the year 1980 up to the year 2018 in the excel spreadsheet. The results were exported to the ArcGIS 10.8 software for further manipulation. To generate raster image from the data we used a geostatistical method of interpolation called ordinary kriging to interpolate point data into a continuous surface. The resultant image was then clipped to the study area by use of the Koraha zone boundary. Elevation map was generated from SRTM 30 meter resolution Digital Elevation Model (DEM), and then clipped to the study area using the existing Koraha zone administrative boundary. From the elevation data, slope and drainage density was derived by using Spatial Analyst Tool in ArcGIS environment.

Sentinel-2A image were downloaded from USGS and imported into ERDAS IMAGINE 2015 software then mosaicked into a continuous image, projected into UTM zone 37N and WGS84 datum, and clipped to the study area extend. Radiometric correction was done for image correction to reduce atmospheric effects. The final task involved carrying out supervised classification comprising of six classes namely: Trees cover areas, Shrubs cover areas, Grassland, Cropland, Vegetation aquatic or regularly flooded, Lichen Mosses / Sparse vegetation, bare areas, built up areas and Open water. Landsat 8 image (OLI) of the study area was downloaded from USGS to prepared lineament map using the line module of PCI Geomatica (Hashim *et, al* 2013).

After processing, all data sets were imported into the geodatabase in feature class and raster formats. By using data stored in geodatabase, standardization of the various criteria into a common standard was possible. To perform weighted overlay, the criteria which is in different units need to be in same units and hence needed to be standardized.

Standardization makes the measurement units uniform, and the scores lose their dimension along with their measurement unit (Effat and Hassan, 2013). Therefore in this study all criteria maps have been reclassified into five classes (very low, low, moderate, high, and very high) values ranging from 1 to 5, where 1 represents very low and 5 represents veryhigh.Their levels of groundwater availability were decided supported data collected from the varied scientific literature (Table 3.2).For each criterion; weights were derived in IDRISI software using AHP methods. Supported the relative importance, values starting from 1 to 9 were assigned to every factor to construct AHP matrix as described by Saaty (1980). Same as size 1 means equally important, 9 means extremely important. The matrix is created, to calculate priority weights from the pairwise comparison matrix and eigenvector values as shown within the following formula.

$$\text{eigen vector} = A_{ji} = \frac{\sum_{i=1}^n \left(\frac{w_1}{w_1} * \frac{w_1}{w_2} * \dots * \frac{w_1}{w_n}\right)^{1/n}}{\sum_{i=1}^n \left(\frac{w_1}{w_1} * \frac{w_1}{w_2} * \dots * \frac{w_1}{w_n}\right)^{1/n}} \quad (1)$$

Where w1 is the sum of row for pairwise comparison and n is the size of matrix

The consistency ratio (CR) was calculated to verify the consistency of comparison as:

$$CI = \frac{(\lambda_{max} - n)}{n - 1} \quad (2)$$

Where CI is the consistency index, n is the number of elements being compared in the matrix,max is the largest or principal eigenvalue of the matrix.

$$CR = \frac{CI}{RI} \quad (3)$$

Where CR is the consistency ratio, CI is the consistency index, RI is the random index

Matrix size	1	2	3	4	5	6	7	8	9	10
Random consistency index(RI)	0	0	0.58	0.9	1.12	1.24	1	1.41	1.45	1.49

Random Index (Staay,1980)

If the $CR \leq 0.10$, it means the pairwise comparison matrix has a suitable consistency. Otherwise, If $CR \geq 0.10$ it implies that pairwise consistency has inadequate consistency (Bozdag *et al.*, 2016). Following the standards weight, the standardized criteria were aggregated by using weighted overlay, and suitability maps were then produced according to:

$$s = \sum_{i=0}^n (W_i X_i) \quad (4)$$

Where S is the suitability, W_i is the weight of factor i, and X_i is the criterion score of factor i.

Table 3.1.Summary of data types and their sources.

Data Types	Data	Source of data	Scale/Resolution /Format	Functions
Primary Data	Landsat operational land imager (OLI) satellite image	United States Geological Society	30*30m	Used to generate lineament density map of the study area
	Sentinel-2A image	Ethiopian geospatial information	10*10m	Used to generate Land use Land cover map of the

Secondary Data	agency			study area
	A Digital Elevation Model (Dem)	Shuttle Radar Topography Mission	30*30m	Used to derive slope, elevation, Geomorphology and drainage density map
	The rainfall data of 36 years(1980-2016)	National Meteorology Agency	Excel Format	Used to generate Rainfall map of the study area
	Geological data	Ethiopian geological survey	at a scale of 1: 250,000	Used to generate Geological map of the study area
	Soil Texture	Food and agricultural organization	Shape File	Used to develop Soil map of the study area

Table3.2.Criteria considered for Groundwater potential zone selection.

Criteria	Unit	Class	value	Ground water availability	Reference
Geomorphology	Class	Hills, Badland	1	Very low	(Allafta et al.,2021;Nagaraju, 2016;Mahalingam& Vinay, 2015;Arumaikkani et al., 2017)
		Structural landform	2	Low	(Lammersa, 2017)
		Pediment/Pedi plain, Foot slopes	3	Moderate	(Ghodratbadi&Feizi, 2015;Nagaraju, 2016)
		Valley/flat, Plain surfaces between 500 and 1000 m	4	High	(Jeyappabha et al.,2014 ;Nagaraju, 2016;Ghodratbadi &Feizi, 2015)
		Mountain with an altitude of 500 meters.	5	Very High	(Ghodratbadi&Feizi, 2015)
Geology	Class	Pyroclastic	1	Very low	(Oboko et al., 2021)
		Plutonic Igneous, Volcanic Igneous	2	Low	(Allafta et al.,2021)
		Limestone	3	Modearte	(Aryanto&Hardiman, 2018).
		Sandstone/conglomerate	4	High	(Barik et al., (2017).
		Unconsolidated Sediments	5	Very high	(Allafta et al.,2021)
LULC	Class	Bare-land and Settlement	1	Very low	(Das, 2017)
		Shrub land	2	Low	
		Farmland and Grassland	3	Moderate	
		Forest	4	High	

		Waterbody and Wetland	5	Very high	
Soil Texture	Class	Clay	1	Very low	(Tripathiet <i>al</i> ,2017; Ibrahim-Bathis and Ahmed, 2016)FAO, 1998)
		Clay loam	2	Low	
		Sandy clay loam,Loam	3	Moderate	
		Sandy loam	4	High	
		Sandy and wetland	5	Very high	
Drainage density	Km/km2	Areas with low drainagedensitywas characterized as high groundwater			(Ibrahim-bathis and ahmed, 2016; ; Rahmati <i>et al.</i> , 2015; Yildiz, 2004; rajaveniet <i>al.</i> , 2017; Andualem and demeke, 2019; Tolche,2020)
Lineament density	Km/km2	Areas having high lineament density Was characterized as High groundwater recharge areas			(Yeh et al., 2016; Naghibi et al., 2017; Rajaveni et al.; 2017;
Rainfall	Mm	The ground water is high if the rainfall is high and it is low if rainfall Is low			(Mahalingam&vinay, 2015)
Elevation	M	The, lower the elevation, the higher the ground water potential			(Gedebo,2005)
Slope	%	the flat slopes decrease the runoff and increase the infiltration of surface water intoground which can increase the ground water recharge			Tolche, 2020;;mahalingam&vinay, 2015; Andualem and Demeke, 2019)

4. Result and Discussions

4.1 Drainage density

The drainage density of the study area was prepared from the digital elevation model (30 m x 30 m resolution) in ArcGIS 10.5 platform. The result shows that about 26.26% of the total area has very high ground water availability followed by 24.4% which have moderate ground water availability. The remaining 22.43%, 18.09% and 8.76% of the total area has low and very low water availability respectively (Table 4.1 and Figure 4.1). The drainage density has an inverse relation with the permeability of aquifers and plays a significant role within the runoff distribution and level of infiltration (Rahmati *et al.*, 2015; Yildiz, 2004; Rajaveni *et al.*, 2017).

Table 4.1. Drainage density class with respective Ground water availability.

Drainage density class(km/km ²)	Ground water availability	Value	Area (%)
0.16 - 0.29	very low	1	307248.11
0.11 - 0.16	Low	2	634745.25
0.07 - 0.11	Moderate	3	858142.00
0.03 - 0.07	High	4	787014.31
0 - 0.03	very High	5	921479.84

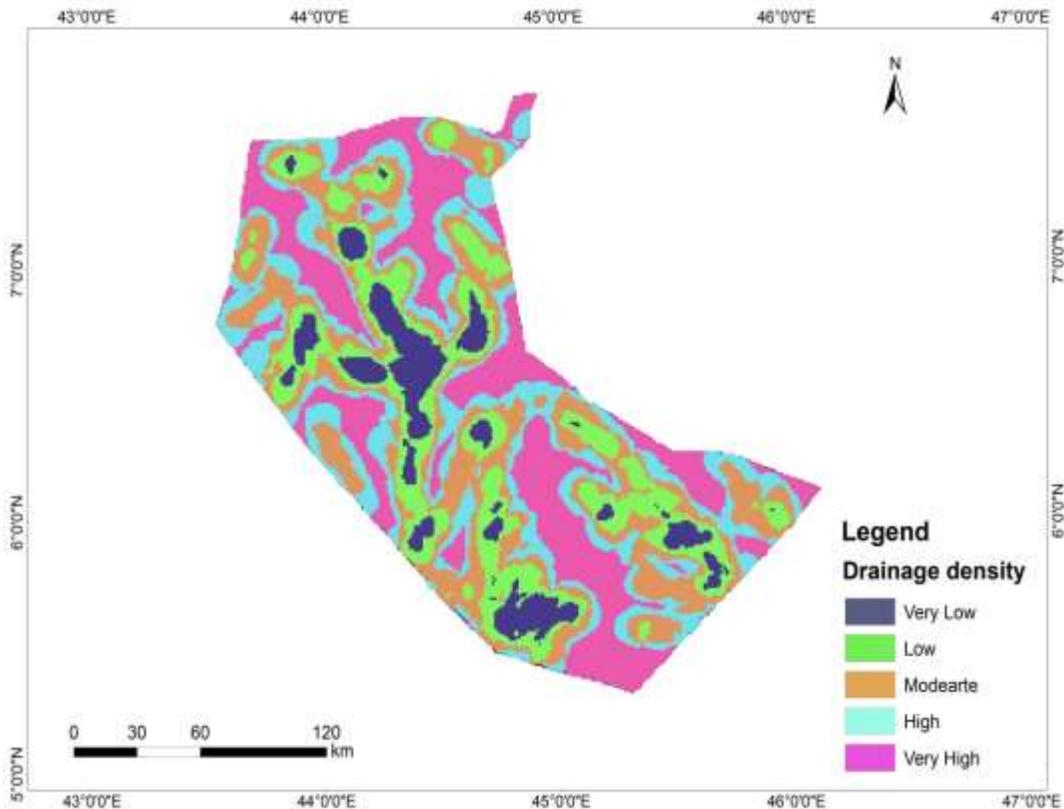


Figure 4.1 Reclassified Drainage density map.

4.2 Lineament density

Various Studies reveals that lineament density has a direct relation with ground water availability. For example Yehet *et al.*, (2016); Naghibi *et al.*, (2017); Tolche, (2020) stated that areas with high lineament density are good for groundwater potential zones. In this study the result of lineament density of the study area which was prepared from Landsat 8 (OLI) satellite image reveals that 74.24% of the study area has very low ground water. 8.32% low, 8.20% moderate, 5.62% high

and 3.62% very high respectively. From this we can infer that the ground water availability of the study area is very low with respect to lineament density.

Table 4.2. Lineament density class with respective Ground water availability.

Lineament class(km/km ²)	Ground water availability	value	Area(Ha)	Area (%)
0 - 0.02	very low	1	2606696.78	74.24
0.02 - 0.05	Low	2	292225.61	8.32
0.05 - 0.09	Moderate	3	287834.56	8.20
0.09 - 0.14	High	4	197454.76	5.62
0.14 - 0.23	very High	5	127072.95	3.62

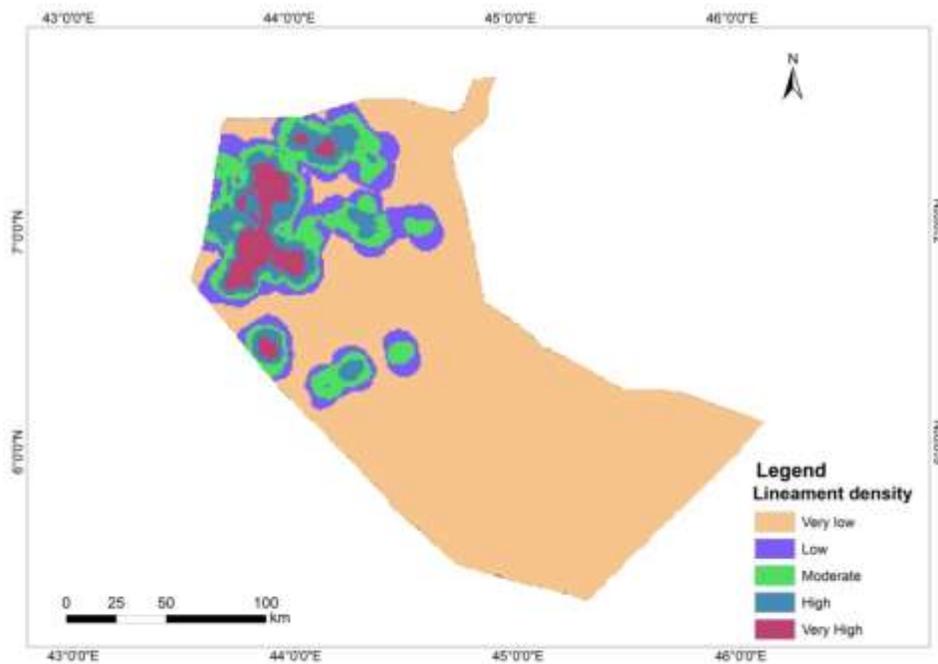


Figure 4.2 Reclassified Lineament density map.

4.3 Rainfall

In relation to rainfall, the ground water potential zone is again very low due to minimum amount of the rainfall availability in the study area. The possibility of ground water availability is high if the rainfall is high and it is low if rainfall is low (Mahalingam and Vinay, 2015). This study has considered the annual mean rainfall from the year 1980 to 2018 and the result indicates about 50% of the total area is characterized by very low and low ground water availability. 18.55, 17.91% and 13.59% is identified as the areas having moderate, high and very high ground water potential respectively.

Table 4.3. Rainfall class with respective Ground water availability.

Rainfall class(mm)	Ground water availability	value	Area(Ha)	Area (%)
236-258	very low	1	908670.83	25.87
254-284	Low	2	845246.55	24.07
284-312	Moderate	3	651521.54	18.55

312-337	High	4	629127.20	17.91
337-375	very high	5	477357.36	13.59

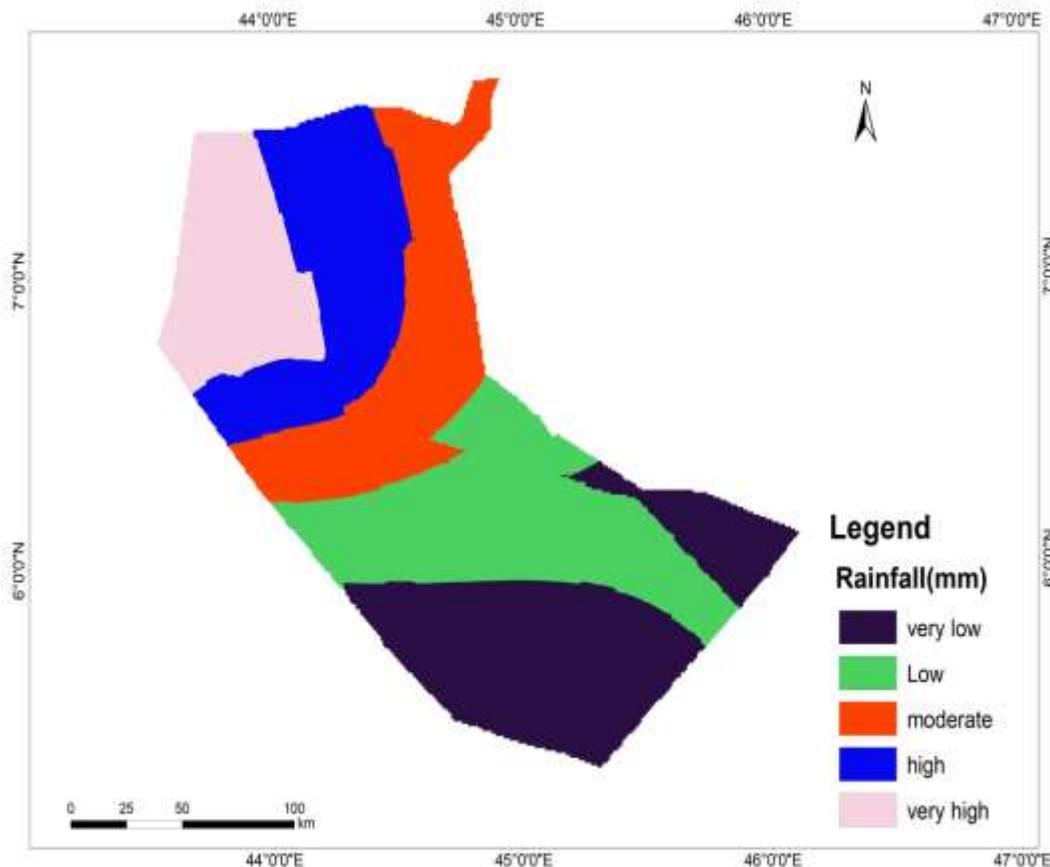


Figure 4.3.Reclassified Rainfall map.

3.4 Elevation

With respect to elevation class, the study area has high potential of ground water. This is mainly due to the lower elevation of the area since water tends to store at lower topography instead of the upper topography. Higher the elevation lesser the ground water potential and the other way around (Gedebo, 2005: Vinay, 2015). For this study elevation data having 30meter spatial resolution has been created supported by the ASTER DEM and the result shows around 60% of the area has very high and high potential of ground water availability followed moderate ground water availability which accounts for 15.28%. An area having low and very low ground water availability is accounted for 13.09% and 11.80% respectively.

Table 4.4.Elevation class with respective Ground water availability.

Elevation class(m)	Ground water availability	Value	Area(Ha)	Area (%)
879 – 1101	very low	1	414702.69	11.80
710 – 879	Low	2	459959.42	13.09
556 – 710	Moderate	3	537038.60	15.28
439 – 556	High	4	1170027.68	33.30
270 – 439	Very high	5	932318.11	26.53

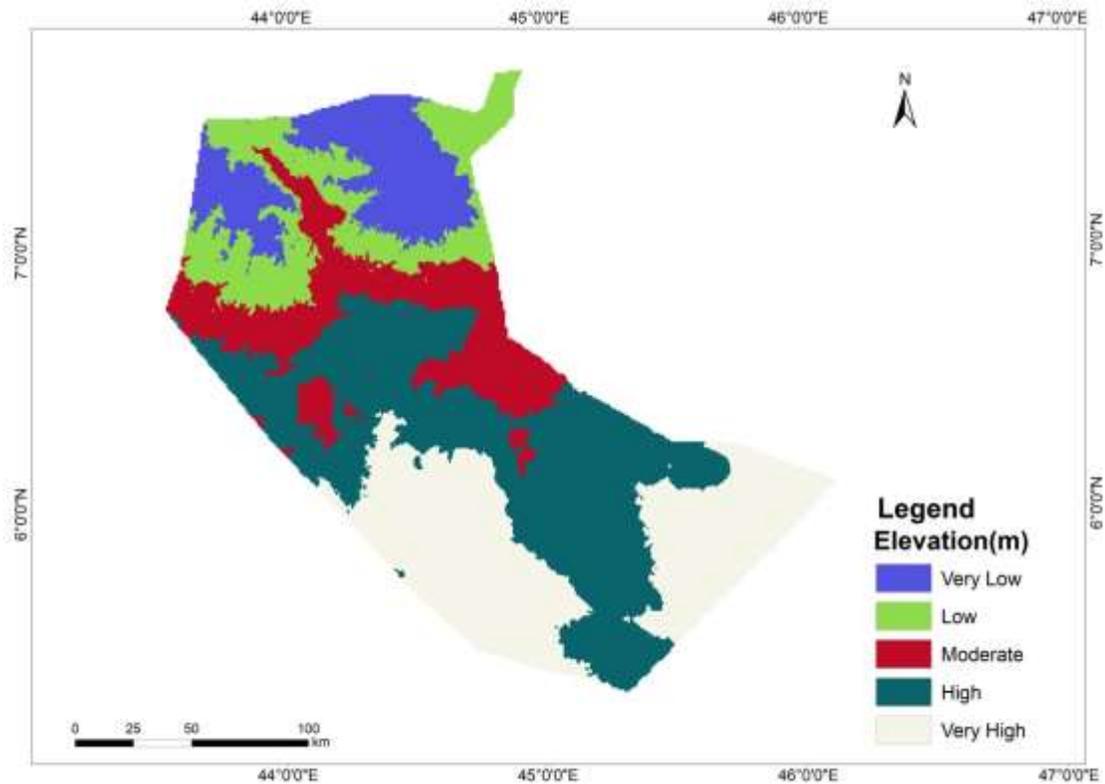


Figure 4.4.Reclassified Elevation map.

4.5. Slope

Slope determines the speed of infiltration and runoff of surface water, the flat surface areas can hold and drain the water within the bottom, which might increase the ground water recharge whereas the steep slopes increase the runoff and reduce the infiltration of surface water into ground (Mahalingam and Vinay, 2015). The result of the reclassified slope indicates 70.9% of the study area has very high potential of ground water availability. Around 18.55% of the area has high availability of ground water followed by moderate, low and very low which accounts for 7.5%, 2.45% and 0, 61% respectively.

Table 4.5. Reclassified slope class with respective Ground water availability

Slope class (%)	Ground water availability	Value	Area(Ha)	Area (%)
11-31	very low	1	21476.76	0.61
6-11	Low	2	86255.82	2.45
3.6	Moderate	3	263664.56	7.50
1-3	High	4	651691.37	18.55
0-1	Very High	5	2490957.98	70.89

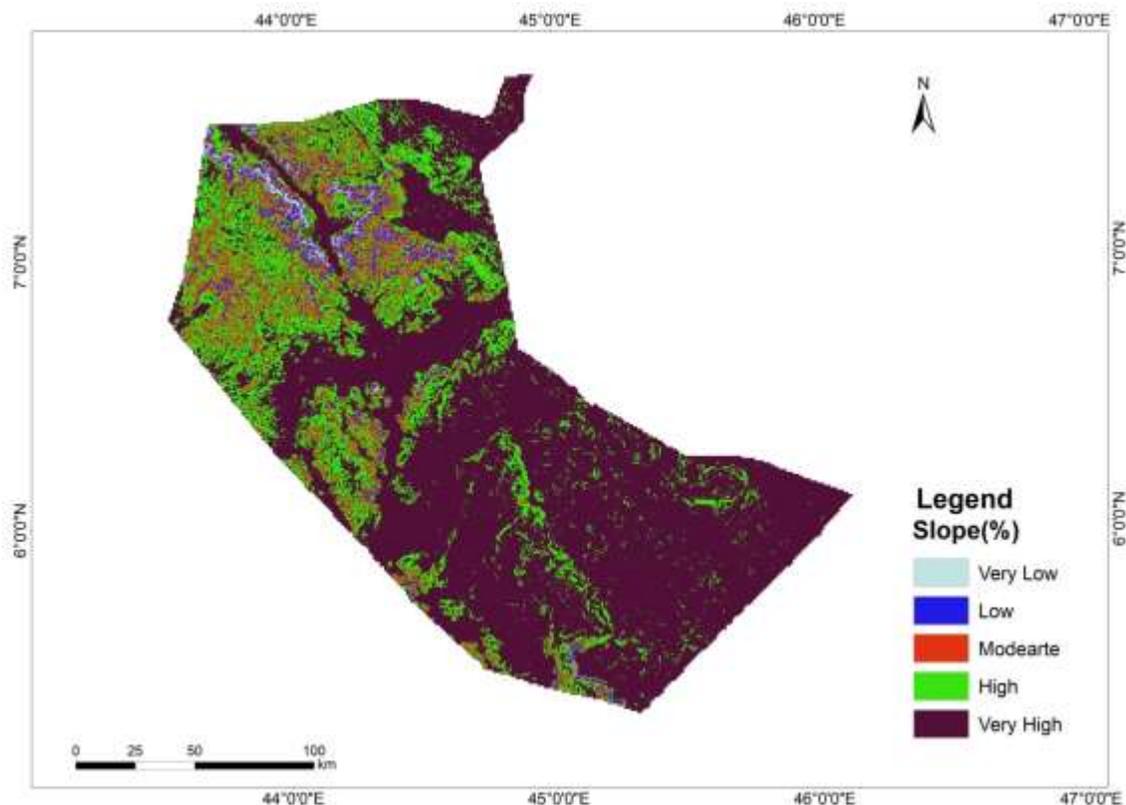


Figure 4.5.Reclassified Slope map.

4.6 Soil Texture

Six soil texture class in the study area namely clay, clay loam, loam, sand clay loam, sandy loam and sand were identified. Rank of soil has been assigned on the premise of their infiltration rate. The result indicates 53.34% of total area of Korahe zone has moderate ground water availability. 30.08% and 8.07% of area has low and very low respectively. Only small area (7.52% and 1%) of Korahe zone have very high and high ground water availability.

Table 4.6.Soil texture class with respective Ground water availability.

Texture class(class)	Ground water availability	Value	Area(Ha)	Area (%)
Clay	very low	1	283343.40	8.07
Clay loam	Low	2	1056335.82	30.08
Loam, sand clay loam	Moderate	3	1873371.41	53.34
Sandy loam	High	4	35169.29	1.00
Sand	very High	5	264042.50	7.52

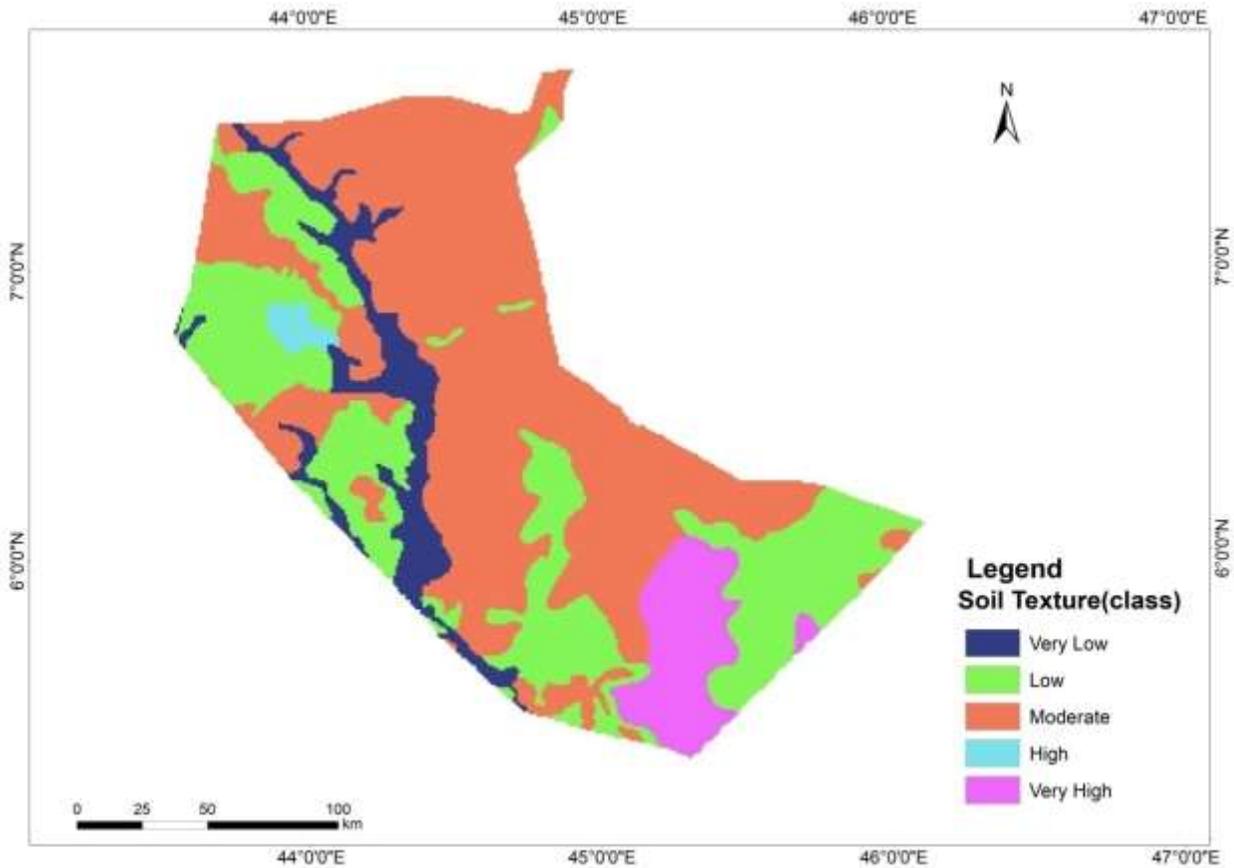


Figure 4.6.Reclassified Soil texture map.

4.7 Land use and Land cover (LU/LC)

Land-use/Land-cover plays a vital role in groundwater searching. Land-use type gives the necessary information on infiltration. The rate of recharge, runoff and evapotranspiration are influenced by the type of LU/LC. Land-use/Land-cover of the study area was prepared from sentinel-2A using maximum likelihood classification technique with the integration of field and google earth verification. The type of LU/LC includes Trees cover areas, Shrubs cover areas, Grassland, Cropland, Vegetation aquatic or regularly flooded, Lichen Mosses / Sparse vegetation ,Bare areas, Built up areas and Open water (Figure 4.7). From the total study area, Grassland covers most of the area and water body covers small area relative to others (Table 4.7).

To classify land use/cover, and its accuracy, it needs another sample size and the training sites and representative samples for accuracy assessment from each land use/cover class was also selected using random sampling. According to Congalton (2009), at least 30 sample points per class are preferred for accuracy assessment, even if, collecting reference samples, especially ground survey locations, can be extremely expensive. For most positional accuracy assessments minimum of 30 samples per land use/cover class were taken to assess accuracy of land use/cover classification of this study. Therefore, the sample size to assess accuracy of land use/cover was = LU/C Class * 30 for the purpose of this study. These points were checked in two ways; those that were accessible and observed in the field and the second means were using Google Earth as a reference. Accordingly, the following error matrix (Table 4.8) for the 270 sample points is presented.

Table 4.7: Land-use/Land-cover types and coverage of the study area

LU/LC class	Area(ha)	Area (%)
Trees cover area	41900.76	1.193593
Shrubs cover areas	1546121	44.04309
Grassland	1772569	50.49375
Cropland	122618.4	3.49293

Vegetation aquatic or regularly flooded	404.396	0.01152
Lichen Mosses / Sparse vegetation	20631.36	0.587709
Bare areas	5772.154	0.164427
Built up areas	436.1882	0.012425
Open water	19.4126	0.000553

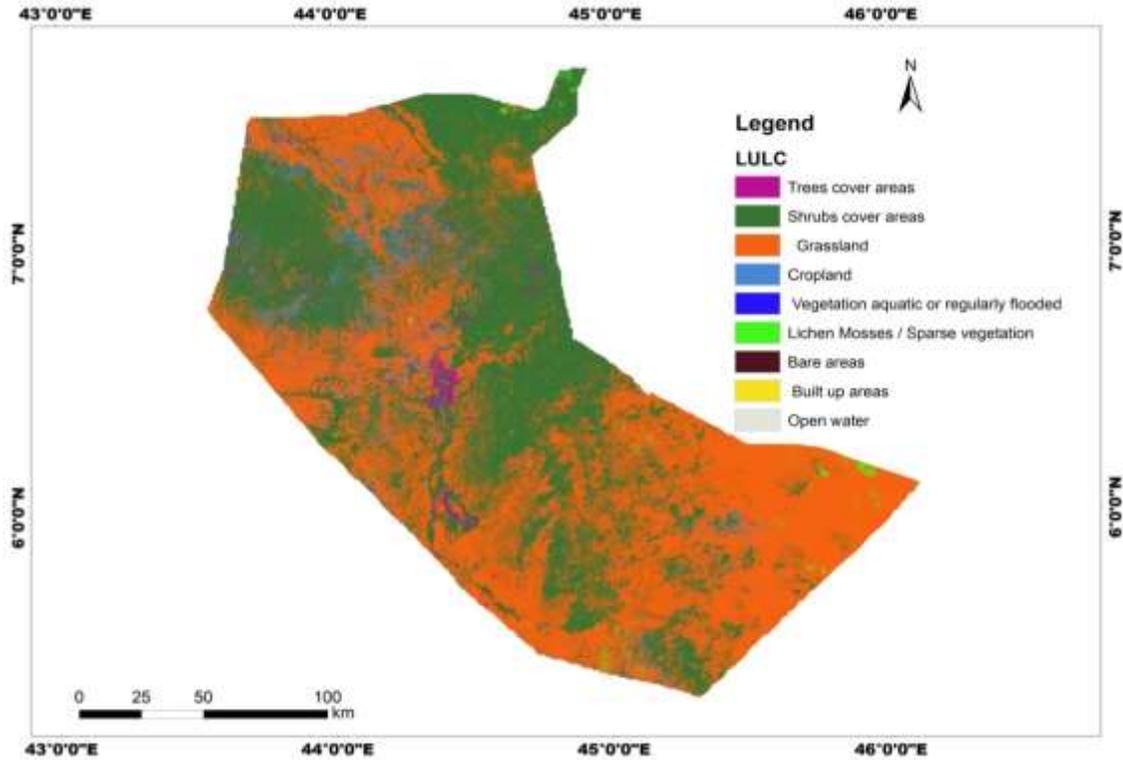


Figure 4.7 LULC cover of the study area

Table 4.8: Accuracy assessment

Reference (GPS) Data

Classified data	Reference (GPS) Data									Total	User accuracy
	Trees cover areas	Shrubs cover areas	Grassland	Cropland	Vegetation aquatic	Sparse vegetation	Bare areas	Built up areas	Open water		
Trees cover areas	27	0	0	0	0	6	0	0	0	33	81.8
Shrubs cover areas	0	29	2	0	0	0	0	0	0	31	93.5
Grassland	0	1	27	0	0	3	0	0	0	31	87.1
Cropland	0	0	1	26	0	0	4	3	0	34	76.5
Vegetation aquatic	1	0	0	0	28	1	0	0	3	33	84.8
Sparse vegetation	2	0	0	0	0	19	0	0	0	21	90.5
Bare areas	0	0	0	4	0	1	24	2	0	31	77.4
Built up areas	0	0	0	0	0	0	2	25	0	27	92.6

Open water	0	0	0	0	2	0	0	0	27	29	93.1
Total	30	30	30	30	30	30	30	30	30	270	
Producer accuracy	90.0	96.7	90.0	86.7	93.3	63.3	80.0	83.3	90.0		

The overall accuracy and kappa analysis were used to perform a classification accuracy assessment and accordingly over all accuracy of the data is 86% and kappa coefficient was computed which is 0.84 and from the result the interpretation can be taken as accurate result for further analysis. The occurrence of groundwater is affected by the type of LU/LC. Considering this, LU/LC of the study area reclassified into five (Table 4.9 and Figure 4.8) as per suitability rank of recharge information.

Table 4.9.LULC class with respective Ground water availability.

LULC class	Ground water availability	value	Area(Ha)	Area (%)
Bare land, Built-up area	very low	1	6205.59	0.18
Shrubs area	Low	2	1544249.84	43.99
Grassland, cropland	Moderate	3	1897143.34	54.04
Tree cover, sparse vegetation	High	4	62854.43	1.79
Open water	very High	5	19.41	0.0005691

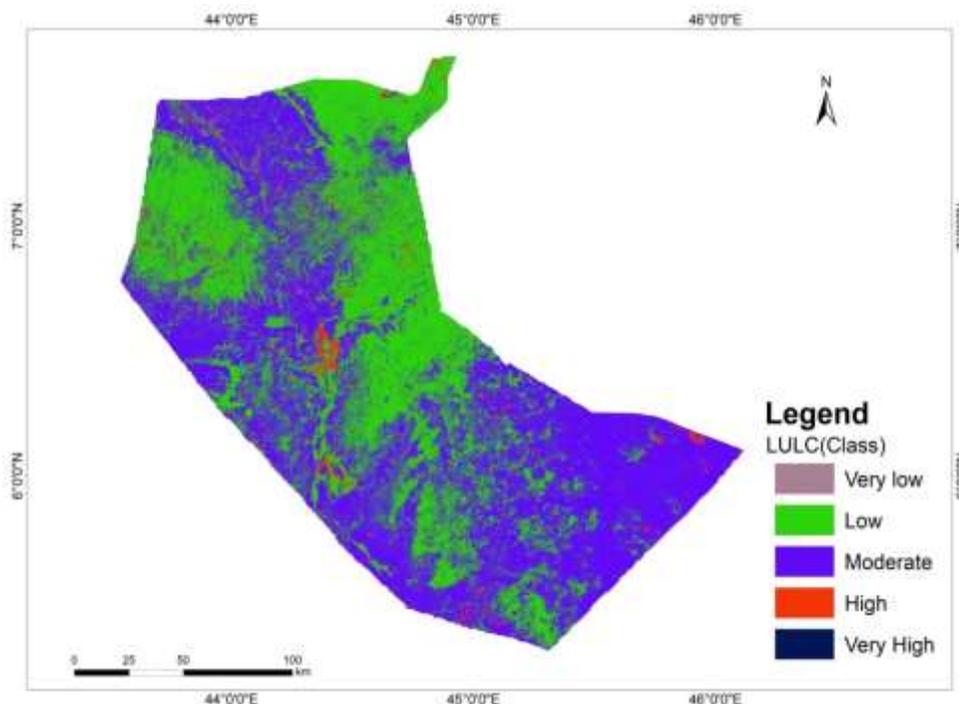


Figure 4.8.Reclassified LULC map.

4.8 Geomorphology

With respect to geomorphology, majority of the study area have high ground water availability (69.73%). Area having moderate ground water availability is accounts for 29.80%. This result shows there are only few significant areas of Korah zone which have very high, low and very low water availability.

Table 4.10 Geomorphology class with respective Ground water availability.

Geomorphology class	Ground water	Value	Area(Ha)	Area (%)
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	availability			
Hills	very low	1	2802.12	0.08
Complex Landforms	Low	2	13712.29	0.39
Foot slopes, Bad Lands & Piedmont Plains	Moderate	3	1045292.82	29.80
Plains Valleys/Minor Valleys	High	4	2445881.33	69.73

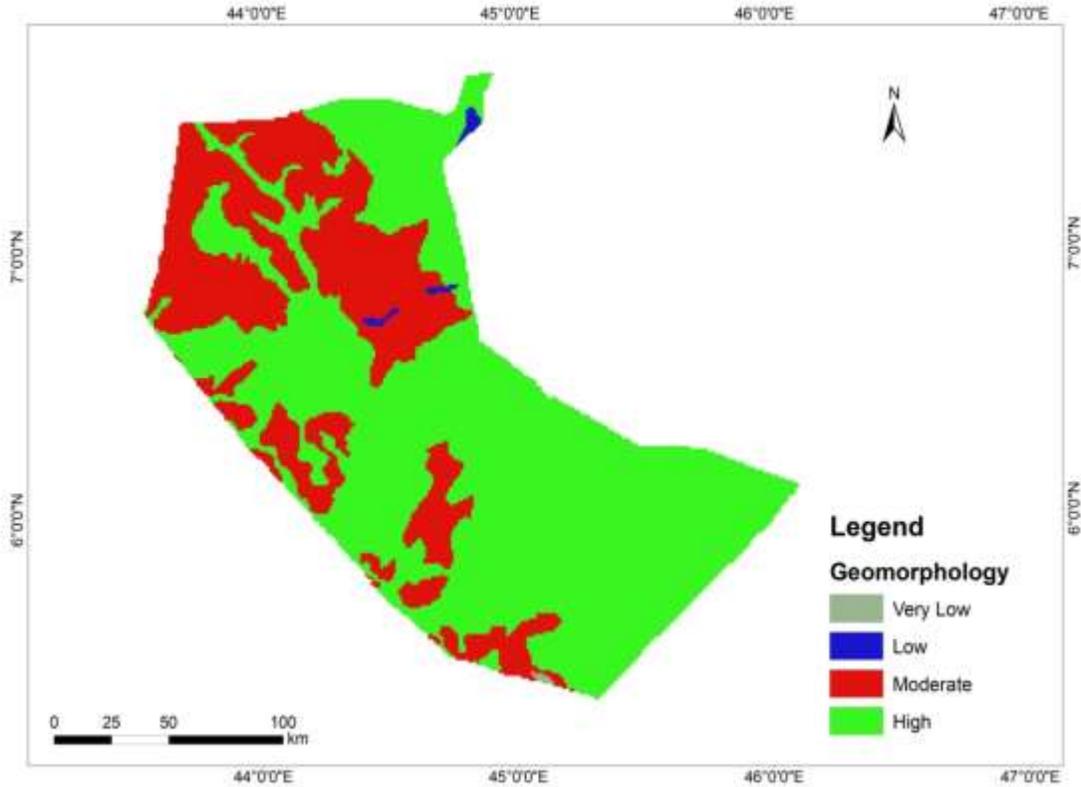


Figure 4.9. Reclassified Geomorphology map.

4.9 .Geology

The result of the geological features of the study area which is classified in terms of groundwater potentiality indicates 63.02% of the study area has high ground water availability. Very high and very low ground water availability accounts for 10.04% and 26.94% respectively.

Table 4.11. Geology class with respective Ground water availability.

Geology class	Ground water availability	value	Area(Ha)	Area(%)
Basic and ultrabasic rocks/Undifferentiated igneous rocks	very low	1	945021.11	26.94
Crystalline limestones/Marls (calcareous mudstones)/Grains, relatively rich sandstones	High	4	2210231.24	63.02
Undifferentiated unconsolidated sediments/Cover sands (Aeolian deposits etc.)	very high	5	352150.55	10.04

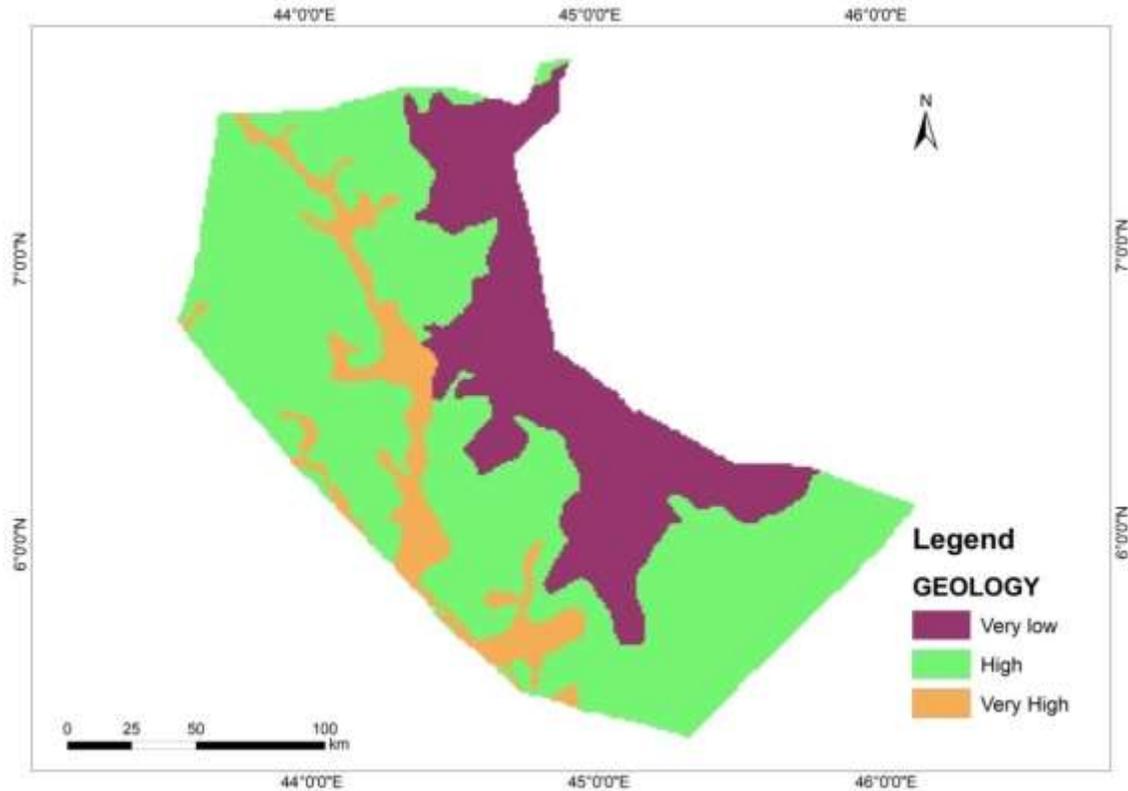


Figure 4.10 .Reclassified Geology map.

4.2. Weight assignment to parameters

The selected parameters are prepared and classified in the GIS environment, and then the weight of each parameter and its class is assigned through the analysis and layering process. Finally, the weighted overlay analysis is usually performed in ArcGIS to find the results. Based on the IDIRISI_AHP weight derivation module, the following eigenvector weights for all criteria considered for groundwater potential zone selection were generated (Table 4.12). In summary, the results of the AHP weight derivation reveals that parenthetically, lineament density plays an important role with the best score weight of 30.7% followed by soil texture, LULC, Geomorphology, Geology, Rainfall, drainage density, elevation and slope with score weight of 21.8%, 15.4%, 10.9%, 7.64%, 5.33%, 3.7%, 2.59% and 1.89%, respectively. A region having high lineament density was given high weight and the other way around (Ibrahim-Bathis and Ahmed, 2016; Naghibi *et al.*, 2017). A part having high drainage density was assigned very low weight (Tolche, 2020; Andualem & Demeke, 2019 ;) whereas steep slope area assigned to low weight (Hussein *et al.*, 2016).

Table 4.12. Pair-wise comparison matrix

Criteria	Lineament	Texture	LULC	Geomorphology	Geology	Rainfall	Drainage	Elevation	Slope
Lineament	1	2	3	4	5	6	7	8	9
Texture	0.5	1	2	3	4	5	6	7	8
LULC	0.33	0.5	1	2	3	4	5	6	7
Geomorphology	0.25	0.33	0.5	1	2	3	4	5	6
Geology	0.2	0.25	0.33	0.5	1	2	3	4	5
Rainfall	0.17	0.2	0.25	0.3	0.5	1	2	3	4

Drainage	0.14	0.17	0.2	0.3	0.3	0.5	1	2	3
Elevation	0.13	0.14	0.17	0.2	0.3	0.33	0.5	1	2
Slope	0.11	0.13	0.14	0.2	0.2	0.25	0.33	0.5	1
Sum	2.83	4.72	7.59	12	16	22.1	28.8	37	45

Table 4.13. Normalized pair-wise comparison matrix

Criteria	Lineament	Texture	LULC	Geomorphology	Geology	Rainfall	Drainage	Elevation	Slope	Weight	%
Lineament	0.35	0.42	0.4	0.35	0.31	0.27	0.24	0.2	0.2	0.31	30.7
Texture	0.18	0.21	0.26	0.26	0.25	0.23	0.21	0.2	0.2	0.22	21.8
LULC	0.12	0.11	0.13	0.17	0.18	0.18	0.17	0.2	0.2	0.15	15.4
Geomorphology	0.09	0.07	0.07	0.09	0.12	0.14	0.14	0.1	0.1	0.11	10.9
Geology	0.07	0.05	0.04	0.04	0.06	0.09	0.1	0.1	0.1	0.08	7.64
Rainfall	0.06	0.04	0.03	0.03	0.03	0.05	0.07	0.1	0.1	0.05	5.33
Drainage	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.1	0.1	0.04	3.7
Elevation	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0	0	0.03	2.59
Slope	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0	0	0.02	1.89

Table4.14. CI and CR worksheet

Criteria	Lineament	Texture	LULC	Geomorphology	Geology	Rainfall	Drainage	Elevation	Slope	Sum	Sum/Weight
Lineament	0.31	0.44	0.46	0.44	0.38	0.46	0.26	0.21	0.17	3.12	10.16
Texture	0.15	0.22	0.31	0.33	0.31	0.27	0.22	0.18	0.15	2.13	9.78
LULC	0.1	0.11	0.15	0.22	0.23	0.21	0.19	0.16	0.13	1.5	9.72
Geomorphology	0.08	0.07	0.08	0.11	0.15	0.16	0.15	0.13	0.11	1.04	9.55
Geology	0.06	0.05	0.05	0.05	0.08	0.11	0.11	0.1	0.09	0.71	9.34
Rainfall	0.05	0.04	0.04	0.04	0.04	0.05	0.07	0.08	0.08	0.49	9.17
Drainage	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.06	0.34	9.08
Elevation	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.04	0.24	9.1
Slope	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.17	9.22
										λ_{max}	9.46
										CI	0.05
										RI	1.45
										CR	0.039

4.3 Delineation of groundwater potential zones

Groundwater potential zones of Koraha zone were delineated by integrating all the thematic maps. After the weightage of each parameter has been determined, a spatial overlay method in Arc GIS environment is employed to conduct overlay analysis to get the intended result. The results of overlay analysis has been classified into five classes as very low, low, moderate, high and very high (figure 4.11). The results of reclassified thematic map found that, about 169631.71ha (4.89%) areas have very high, 334818.58ha (9.65%) area have high, 587658.05ha (16.93%) have moderate, 1194164.18ha (34.41%) have low and 1184005.67ha (34.12%) area are have very low potential of ground water (Table 4.15). Very high and high groundwater potential zones are concentrated within the area where, high lineament density was illustrated of the basic factors for groundwater potential zonation (Ibrahim-Bathis& Ahmed, 2016).The low to very low potential zones are mainly distributed within the areas having high drainage density. Hence, the groundwater potential in these areas may be not sufficient for irrigation and other livelihood requirements. Therefore, groundwater development activities preferred to be performed in high groundwater prospective zones.

Table 4.15. Groundwater potential area and percentage of the study area.

Ground water availability	Value	Area (ha)	Area (%)
very low	1	1184005.67	34.12
Low	2	1194164.18	34.41
Moderate	3	587658.05	16.93
High	4	334818.58	9.65
very high	5	169631.71	4.89

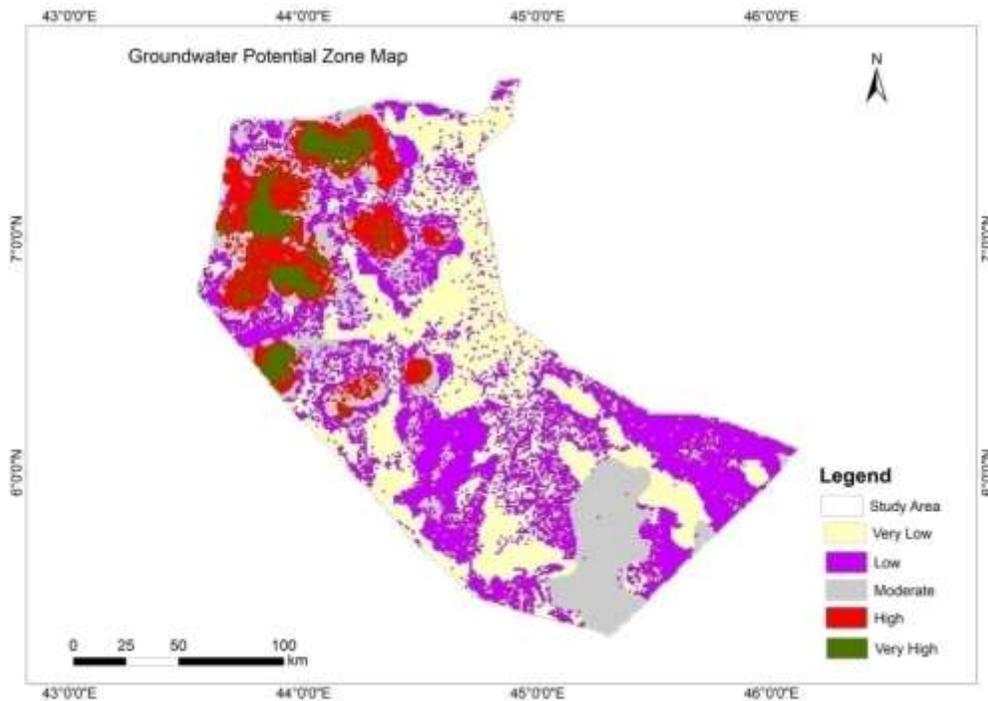


Figure 4.11 Groundwater Potential zones of map of Koraha zone

Conclusion

The study focused on groundwater potential zone mapping through integration and weightage overlay analysis in GIS environment using physical parameters. The methodology begins with the preparation of thematic layers from different data sources and next deriving the weights using overlay analysis to search out groundwater potential. The weightage is assigned to different layers and overlaid to realize the intended result groundwater potential zones of Koraha zone. First,

assign weights to the thematic layers to support the precise importance of the categories in each parameter. These layers are then overlaid and classified into five categories that support groundwater availability; very high, high and moderate, low and very low. The study found that, about 169631.71ha (4.89%) areas have very high, 334818.58ha (9.65%) area have high, 587658.05ha (16.93%) have moderate, 1194164.18ha (34.41%) have low and 1184005.67ha (34.12%) area have very low potential of ground water. The integration of GIS and Remote sensing technique in ground water analysis from various thematic maps proves to be very important to map the groundwater occurrence and movement for recharge potential mapping and management plan on a scientific basis in the study area.

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