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Research Article

Assessment of Groundwater Potential Zones of Winike Catchment, Omo-Gibe Basin of Ethiopia Using Geospatial Techniques

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Abstract

Water is one of the most necessary and essential natural resource which is found both in surface and subsurface areas of the earth to sustain human life, animals and plants. Expansion of population, agricultural activity leads to increment in requirements of freshwater. Groundwater is a major source of freshwater; it may serve as the base flow for rivers, or act as underground reservoir from which water can be extracted for different requirement. These days, the investigation of ground water potential zone mapping was conducted using geospatial approaches. Such applications were expanded and beneficial in identifying viable areas with minimal cost and short timelines, especially in underdeveloped countries where research funds were constrained. The research site experiences high shortage in satisfying the water requirements of the community. Therefore, it is necessary to investigate groundwater potential areas through low cost methods of geospatial techniques. For this reason, land use, soil, drainage density, lineament density, rainfall, slope, and geology of the catchments were considered as the governing parameters for the potential site identification. Analytic Hierarchy Process (AHP) was applied to select the major influencing factors for the site. Finally, weighted sum of overlay analysis was applied and the potential sites were validated through ground truth points (borehole data).

Keywords

GIS, Winike, AHP, Groundwater

1. Introduction

According to [1] harmless and mostly available source of water to satisfy the water requirements of domestic, irrigation, industries, municipality purposes is groundwater. Requirement of groundwater is highly increased due to its many natural quality, like; slow moving, large storage volume, long retention time, could be drawn on demand, less risk free than surface sources, consistent temperature, excellent natural quality, limited vulnerability, low development cost and drought reliability [2]. But, for developing countries like Ethiopia the advantage of groundwater for the socio-economic development cannot be overemphasized and the rechargeable groundwater resource of the country is controversial and there is no agreement so far as to the calculated exploitable ground water potential [3]. The integration of driving forces increase stress on water resource required for different purpose like; irrigation, energy production, industrial uses, domestic pur-

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pose and environment [4]. Due to expansion of world population and changes in life standards the need for freshwater is highly increased. In sub-Saharan Africa development of economic activity depends on availability of freshwater [5]. Research done by [6] in different zones of Gurage Administrative on livelihood vulnerability to climate variability and change shows some of the society under the study area are highly susceptible to water scarcity.

1.1. Groundwater

Groundwater is basic resource found under the earth's surface which matters municipal, agricultural, and economic activities [7]. In the subsurface strata there is an essential and limited freshwater resource, which is known as groundwater [8]. The continuous need of water for satisfying human necessity and other developments has forced huge effect on this resource. Expansion of population and modern industrial and agricultural practice is not only causing high requirement for groundwater resources due to the inadequate availability of surface water resources, but also polluting ground water resources by releasing untreated wastes. Consequently, these practices have resulted in an increase of research, not only with regard to ground water resources, but also an attention on siting groundwater of best quality for human consumption [9]. Due to its natural quality and continuous availability groundwater is the major natural resource in sustaining human life and economic development [10].

Water occurrences and access to water resources have contributed to the shaping of Ethiopian history and culture. Ancient and modern civilization in Ethiopia has been founded on areas where groundwater has been available mainly as springs. Many place names (e.g. names of settlements and settlements that have grown to ownership) are named after the water source that supplies them [11]. One of the fundamental conditions for the growth and development of a nation like Ethiopia is certainly the progressive fulfilment of its most urgent water needs. In rural areas where more than 85% of the population lives water shortage problems can be solved by proper utilization of groundwater [12]. As [13] the country Ethiopia has 122 billion m^3 of annual runoff volume from 12 river basin and 2.6 – 6.5 billion m^3 of groundwater resource which makes an average of 1575 m^3 of physically available water per person in a year, a relatively huge volume. Hence, unscientific exploitation and improper use of water policy are also possible factors. So, the investigation of groundwater resources is a key for sustainable management [14].

1.2. Groundwater Occurrence and Distribution Factor

Many factors affect the occurrence and movement of groundwater in a regions, including topography, lithology, geological structures, depth of weathering, extent of features, primary porosity, secondary porosity, slope, drainage patterns, landforms, land use/land cover, and climate [15]. According to [1] the occurrence, origin, movement and chemical constituents of groundwater are dependent on geology/lithology, geomorphology/landforms, drainage density, rainfall, geological structure/lineaments, slope, land use/land cover and soil of the area. According to [16] the most sensitive parameters to identify groundwater recharge zone of an area are lithology, land use/cove, and slope followed by geomorphology, lineament density, rainfall, drainage density and soil type. Also [10] use eight main biophysical and environmental factors in order to spatially delineate groundwater potential zone of Northern Ethiopia, Wollo zone, in Gerado river using geospatial and MCDA tools. The selected factors are geomorphology, lithology, slope, rainfall, land use land cover (LULC), soil, lineament density and drainage density. Research conducted by [17] uses remotely sensed data and available topo sheets to generate factors influencing occurrence of groundwater. These help to produce efficient data about the parameters such as geology, slope, drainage density, geomorphic units and lineament density.

One of the most necessary criteria that has a major role in identifying suitable sites of groundwater potential was rainfall. According to [10] rainfall is the major source of hydrologic cycle and groundwater recharge. High quantity rainfall areas are considered more suitable for groundwater potential than lower rainfall area. Groundwater contained in underground rocks, which contain and transmit water in economical rate generally referred to as aquifers. The amount and distribution of ground water is the function of amount of open special extent of these rocks [3]. All geological classes have no equal contribution in the occurrence of groundwater. Areas with alluvial deposits are the most groundwater potential areas due to their potential to infiltrate and recharge water [10]. Lineament is a linear feature in landscape which is an expression of an underlying geological structure such as faults [15, 18]. Based on [15, 16, 19] lineament-length density, defined as total length of lineaments per unit area. Areas with high secondary porosity have a high lineament density; thus, such areas have a high groundwater potential recharge. In addition, land use/cover was an important characteristic of the runoff that affects the recharge process and evapotranspiration. It includes natural, manmade population density.

Drainage density can indirectly indicate the suitability for groundwater recharge of an area because of the relationship between the surface runoff and the permeability. It is the ratio of total length of rivers in the drainage basin and total area of the drainage basin [15, 16, 19]. Based on research conducted by [1, 10] area with high drainage densities has lower groundwater potential. In addition, slope is one of the main factors that affect the occurrence of groundwater. Water velocity directly related to the slope angle of the ground. Slope of an area directly influences infiltration rate of a rainfall [15]. It predicts whether the runoff will stay on the surface enabling infiltration to the saturated zone. Areas with low slope have a greater probability of groundwater recharges than areas of higher slope. The flat and steep gradient of the area has significant impact on occurrence and movement of groundwater [10, 15]. Groundwater potential is lowered in steep area compared with flat areas. Rainfall holding and groundwater recharge capacity of flat area is higher than areas with steep slope.

1.3. Application of GIS in Groundwater Potential Assessment

GIS is an integration of computer hardware, software and geographic data for capturing, managing, analyzing and visualizing all types of geographically referenced data. It has ability to accumulate, order, retrieve, classify, manipulate, analyze and present large space oriented data and information in easy way [20]. Remote sensing is a strong tool to obtain data of large area in short period of time [16, 21]. Due to awareness and expansion of technology adequate and good quality water is required. In consequence peoples focused on assessment of groundwater through a number of methods [7, 22]. Currently implementation of groundwater resource zoning was applied more and more due to the expanded need of water [23].

Research conducted by [24] states that sustainable development of groundwater resources require application of scientific principles and modern techniques. A combined way is applied using remote sensing and geographic information system (GIS) based multicriteria evaluation to select possible areas of groundwater exploration in Raya Valley, northern Ethiopia. Application Integrated remote sensing (RS) and Geographic Information System (GIS) allows itself as the most effective and efficient method to solve difficulty in assessing groundwater of hard rock [9]. Also, it was advanced technology applied to map groundwater potential of an area [17]. Application of GIS and remote sensing data in assessing the groundwater potential in the inaccessible area saves time and money [10, 14].

In most parts of the world due to shortage of information and complex geology and hydrogeological nature of the site groundwater potential investigation is difficult task [18]. Many developing countries are confronted by shortages of funds, trained technicians and available data by which to evaluate groundwater resources through quantitative procedures. In developing countries with scarce of data for planning and management of groundwater resource the most applicable tool is Remote Sensing (RS) and Geographic information system (GIS) [1, 21, 23].

Unsustainable groundwater utilization is a basic concern in developing countries due to lack of updated spatial information on groundwater quantity and distribution. In Ethiopia groundwater potential has been usually assessed through filed investigation which is not practical in terms of time and resource [10]. Many parts of the Ethiopian regions have extreme shortage of hydrogeological data [25].

Table 1. *Researches conducted by GIS and RS on groundwater potential in Ethiopia.*

Research title and cite	Tools	Research area
Evaluation of groundwater potential [10]	RS, GIS and MCDA	Wollo zone, Gerado River Catchment
Spatial analysis of groundwater potential [19]	GIS based MDCA	Lake Tana Basin
Groundwater potential evaluation [1]	GIS and RS	Bilate River Catchment, South Rift Valley of Ethiopia
Groundwater potential mapping [14]	Geospatial techniques	Dhungeta-Ramis sub-basin, Ethiopia
Spatial analysis of groundwater potential [24]	RS and GIS based MCDA	Raya valley, northern, Ethiopia
Groundwater potential assessment [26]	GIS and RS	Guna tana landscape, upper Blue Nile basin, Ethiopia
Groundwater potential mapping [3]	RS and GIS	Rift valley lakes basin, Weito sub-basin, Ethiopia
Groundwater potential mapping [18]	SWAT and GIS based MCDA	Ketar watershed (Eastern lake Ziway), Main Ethiopian Rift (MER)

1.4. Multicriteria Decision Analysis (MCDA)

Reseaeches done by [18, 19, 26, 27] apply multi-criteria decision analysis (MCDA) to analyze effects of different groundwater occurrence and distribution governing parameters, since all groundwater occurrence influencing parameters do not have equal contribution. The Analytic Hierarch Process (AHP) defined by [28] is a basic approach to decision making. In this process, the decision maker carries out simple pairwise comparison judgments, which are used to develop overall priorities for ranking alternatives. From many alternatives to solve multicriteria decision making Analytical Hierarchy Process (AHP) suggested by Saaty's is the main approach that require a qualitative data [27]. Saaty's AHP is the most widely accepted method for scaling the rates of factors whose entries indicate the strength with which factor dominates over the other in relation to the relative criterion [24]. They use GIS based multi criteria evaluation based on Saaty's hierarchy process (AHP) to compute weights for the classes in a layer. Weights for parameters according to their relative importance in ground water occurrence was assigned based on Saaty's analytical hierarchy process [1].

Analytic Hierarchy process, Catastrophe and Entropy techniques were used for evaluating groundwater prospect of hard rock aquifer systems [29]. Eight thematic layers were prepared having significance on groundwater occurrence. Rates/weights of each thematic layers were computed through AHP, Catastrophe and Entropy techniques of weight assessment. The validation result revealed that the groundwater potential predicted by the AHP technique has a pronounced accuracy than Catastrophe and Entropy techniques. In order to assign weights six experts in the field of hydrogeology were interviewed through questionnaire to look for their opinions on the relative importance of selected parameters affecting groundwater occurrence in the study area.

Groundwater recharge zone of Korba aquifer in northeastern Tunisia using Analytical Hierarch Process (AHP) and Multicriteria Influencing Factor (MIF) was mapped [16]. Results obtained from AHP revealed that 69% of the study area is under very good and good recharge zones. Whereas, results from MIF shows 80.7% under good and very good zone. But the validation performed using 20 groundwater well data in the study area with the generated groundwater recharge zone by both methods. The validation result shows groundwater recharge zone produced by AHP method gives more correct outputs than the MIF.

1.5. Weight Linear Combination (WLC) and Validation

Generating groundwater potential zone map has a significant effect to enhance sustainable managements of groundwater resources in the study area as well as in the country [14]. Weighted linear combination (WLC) is a method to integrate many selected thematic layers into a single layer to give necessary information about an area. Research conducted by [30] applies weighted overlay analysis in order to integrate different groundwater occurrence influencing parameter and to generate groundwater potential zone map of in the Gerado river catchment. Also, the research uses point data of dug wells and bore holes in order to compare the GIS based generated potential map with the existing ground truth in the area. A research conducted on Lake Tana basin by [19] in uses weighted linear combination to demarcate the basin into different groundwater potential zones and the result was validated with bore hole and spring data in the basin.

In [14] research GIS and remote sensing techniques will be applied in Dhungeta-Ramis sub-basin, Wabi Shebelle basin, Ethiopia for qualitative analysis of groundwater potential zones. The delineated potential zone was classified qualitatively into five different zones namely, very good, good, moderate, poor and very poor. The result obtained from GIS software using overlay analysis was validated with spring and well data; proves a satisfactory correlation.

2. Methodology

2.1. Description of the Research Site

Winike catchment was found in South Nation and Nationality Peoples of Ethiopia at a projected coordinates of 345399.232302 m to 417636.732302 m East and 908851.443019 m to 864538.943019 m North. The catchment covers mostly Guraghe zones having a high water scarcity community.

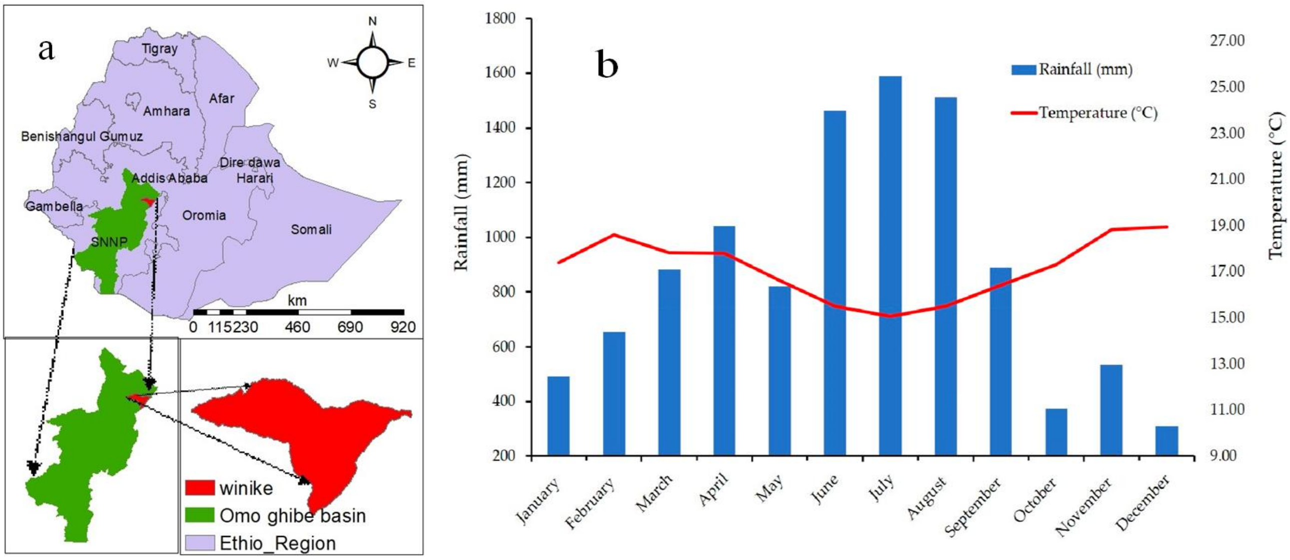

Figure 1. *(a) Location map; (b) Rainfall and temperature distribution; Source: [31].*

Based on of 30-year data the average annual rainfall varies from 856 to 1600 mm and the mean yearly temperature is 19.1 ◦C with the maximum and minimum values of 22.5 and 6.7 ◦C, respectively [31].

2.2. Methods

For this research, different types of data's were collected from different organizations and online sources. Ethiopia meteorological agency, Geological Survey of Ethiopia and Ethiopia land and water resource center were used to collect rainfall data, geological map and soil data respectively. Digital Elevation Model (DEM) with a resolution of 12.5m by 12.5m downloaded from online sources (Alaska earth facility) and land use land cover data at sentinel two (S2) from prototype map of Africa. Groundwater occurrence and distribution parameters were extracted from the collected data. Five rainfall stations (Gubre, Emdiber, Agena, Gunichre and Werabe) dates of inside and around the study area were analyzed to prepare the areal rainfall distributions of the catchment using proximity toolbox of ArcGIS. Gradients of the catchment were derived from the Digital Elevation Model (DEM) data. To extract the lineament density, hill shade for different Azimuth and Altitude (60_90, 100_60, 200_50 and 315_45) was extracted using ArcGIS from the DEM.

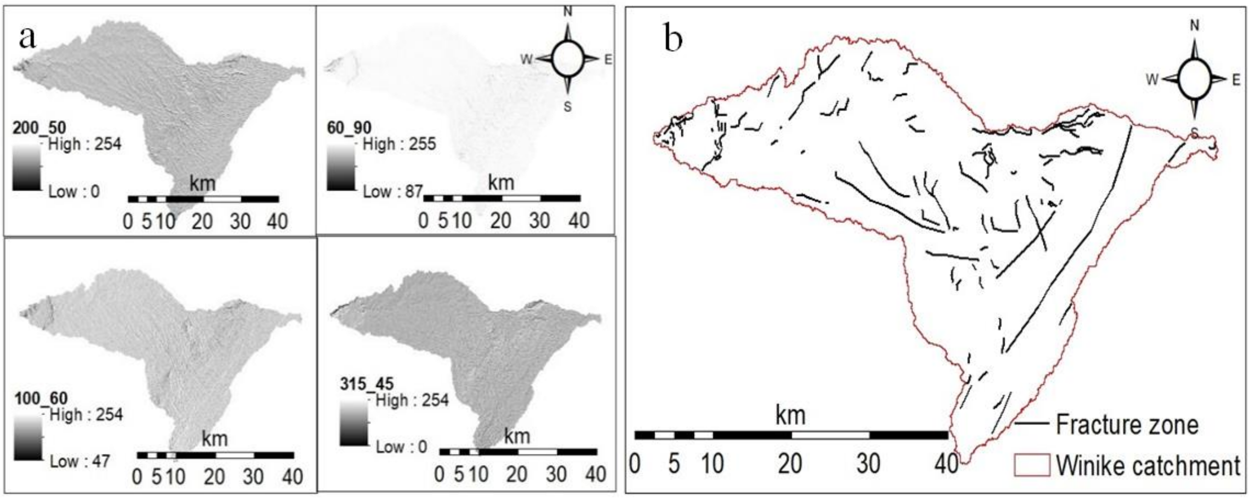

Figure 1. (a) Hillshade for varying Azimuth and Altitude (b) Digitized lineament line.

The variation in Azimuth and Altitude directs to determine different fracture zones and the zones are digitized using line create features in Editor Tool. Therefore, fractures were digitized for each Azimuth and Altitude; and merged into a single feature through ArcGIS. Using the fractured zone lineament density for the catchment was generated. It was the ratio of total length of lineament (L) to unit areas of (L^2) [15, 16].

$$\frac{\sum_{i=1}^{i=n} L_i}{A}$$

Where L_i denotes the total length of lineament (L) and A denotes the unit area (L_2). The higher the lineament density; there is high secondary porosity and the zone have a high potential of groundwater recharge.

Also, using the DEM drainage density for the site was generated as the ratio of the total length of drainage to the unit area [15, 16].

$$\frac{\sum_{i=1}^{i=n} S_i}{A}$$

Where Si denotes the total drainage length (L) and A denotes the unit area.

The other required data's; LULC, soil, geology and slope were generated and prepared in required format using ArcGIS environment.

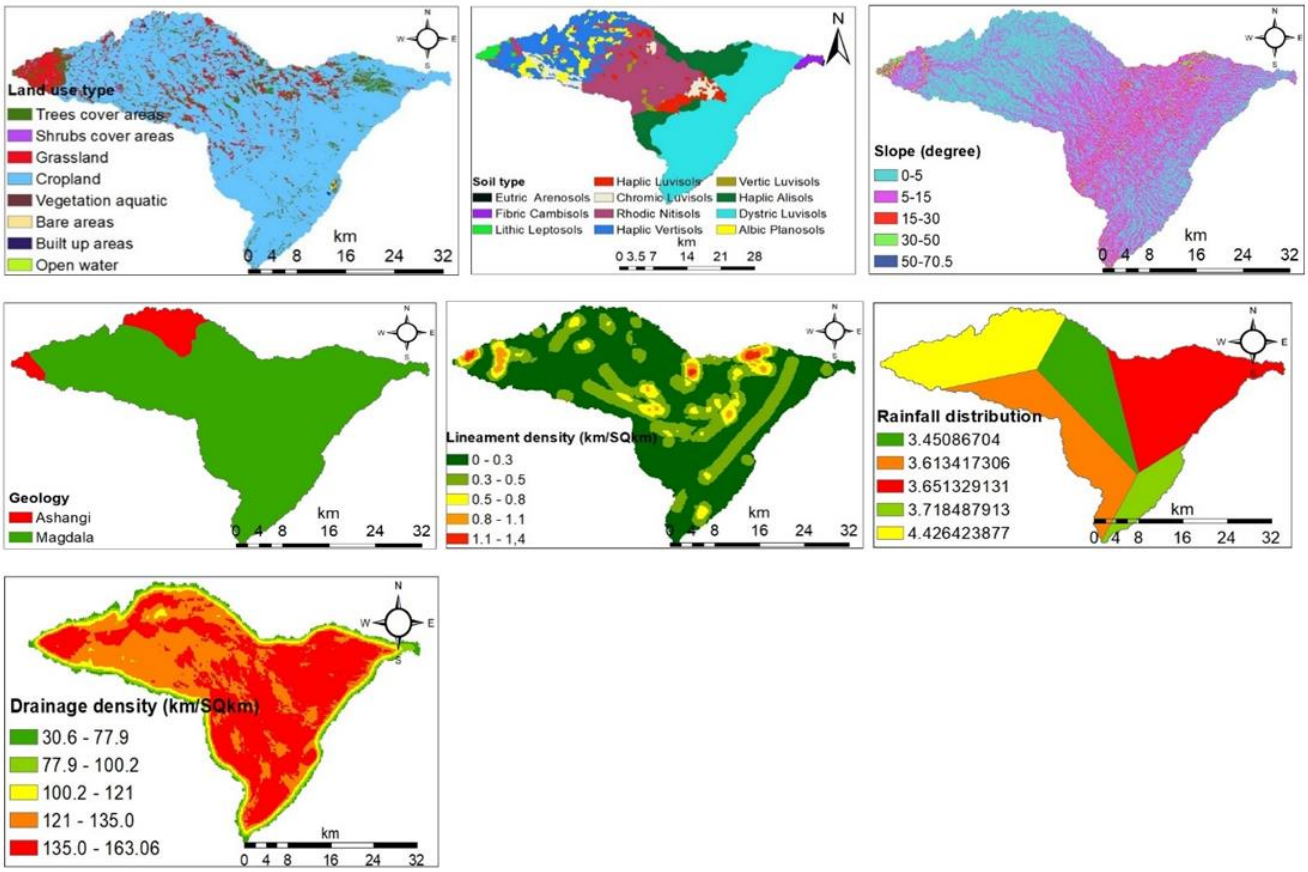

Figure 3. *Maps of the selected groundwater occurrence governing parameters.*

Soil properties were defined based on the soil unit characteristic given by FAO soil map of the world [32].

Table 2. *Soil units and their property; Source: [32].*

Soil unit	Properties
Arenosols	Weakly developed coarse textured soils
Vertisols	Connotative of turnover of surface soil Black earths, grey and brown soils of heavy texture
Cambisols	Connotative of changes in color, structure and consistence resulting from weathering in situ
Luvisols	Connotative alluvial accumulation of clay
Planosols	Connotative of soils generally developed in level or depressed topography with poor drainage
Nitosols	Connotative of shiny ped surfaces

After preparation of all required maps, classification was performed in required format to combine all the layers into one feature. For this research based on the generated map layers number class were done into 5 classes. In the classification layer 5 is given for areas having high groundwater recharge potential and 1 for areas having low groundwater recharge potential. In order to determine the groundwater potential areas weighted sum analysis was done using ArcGIS. Therefore, the groundwater potential zones were the product of weight of each parameter and feature class values.

$$GWPZ = \sum_{i=1}^{i=n} W_i P_i$$

Where GWPZ denotes groundwater potential zone, W_i for weight of each parameters and P_i class numbers for each parameter. To determine weight of each parameter multicriteria decision analysis method called Analytic Hierarchy Process (AHP) excel tool was applied.

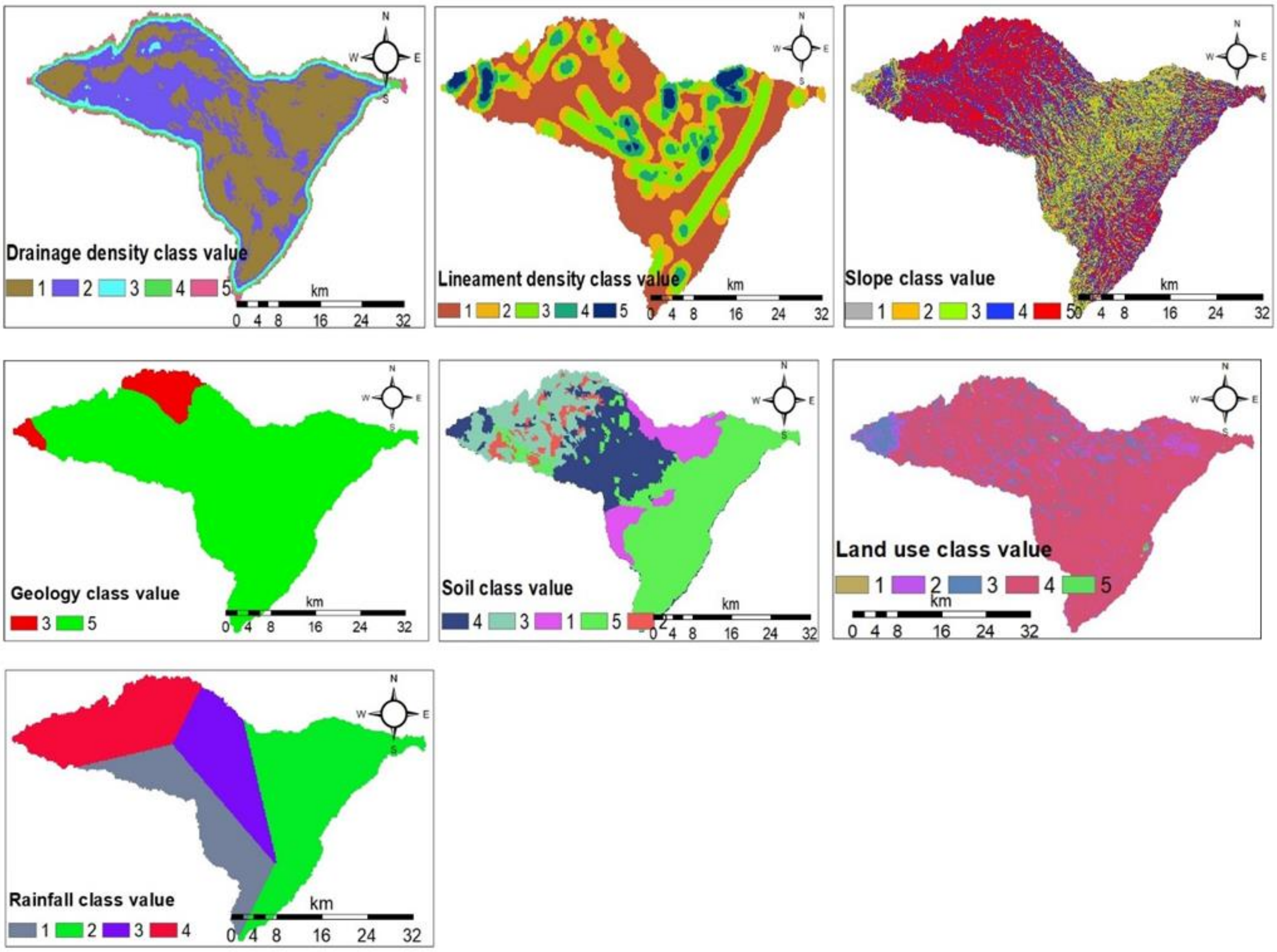

Figure 4. Governing parameters with class value.

In order to give scale value for each feature different literatures [1, 3, 14] were applied to avoid personal judgments.

It is an excel software that is used to give percentage influence and scale value. Percentage influence is the overall importance of each mitigation measure and the scale factor is the importance of each criterion. The basic procedures in the assessment of weight for each parameter were:

Construction of pairwise comparison matrix: For each criteria's and governing parameters, scores were assessed based on Saaty's Analytic Hierarchy Process (AHP).

Table 3. The fundamental scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another

Intensity of importance	Definition	Explanation
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If an activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Source: [28]

Computation of the criterion weight/priority vector: This process was achieved through three basic steps. The first step is values of ratio in each column of the pairwise comparison matrix were summed and written at the bottom of each relevant column. Then, each element in the matrix was divided by its column total. The resulting matrix is known as a normalized pairwise comparison matrix. The final step is the average of the elements in each row of the normalized pairwise comparison matrix were computed by dividing the sum of normalized scores for each row by the total number of criteria involved in the matrix. The relative weights of the criteria are the average values of the elements in each row of the matrix.

Estimation of consistency ratio: This is performed to check whether the judgments over the parameters are consistent or not. Initially, the weight of the first criterion is multiplied by the sum of the element in the first column of the original pairwise comparison matrix and the weight of the second criterion with the sum of the element in the second column of the original pairwise matrix and so on. Next, sum up the products and called the value principal Eigenvalue (λ_{max}) and consistency ratio (CR) was calculated using:

$$CR = \frac{CI}{RI}$$

Where: CI is consistency index of the parameters and obtained using an equation:

$$CI = \frac{\lambda_{max} - N}{N - 1}$$

λ_{max} = Principal Eigen vector,

N = number of criteria and,

RI = average random inconsistency index value applied based on the number of parameters (N).

Table 4. *Random consistency index (RI) values; Source: [28].*

Number of parameters (N)	1	2	3	4	5	6	7	8	9	10
Random consistency index (RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

In the consistency ratio (CR); the value must be less than 0.1 (CR<0.1) to say the pairwise comparison is consistent. The framework to conduct the overall process of the research is described below:

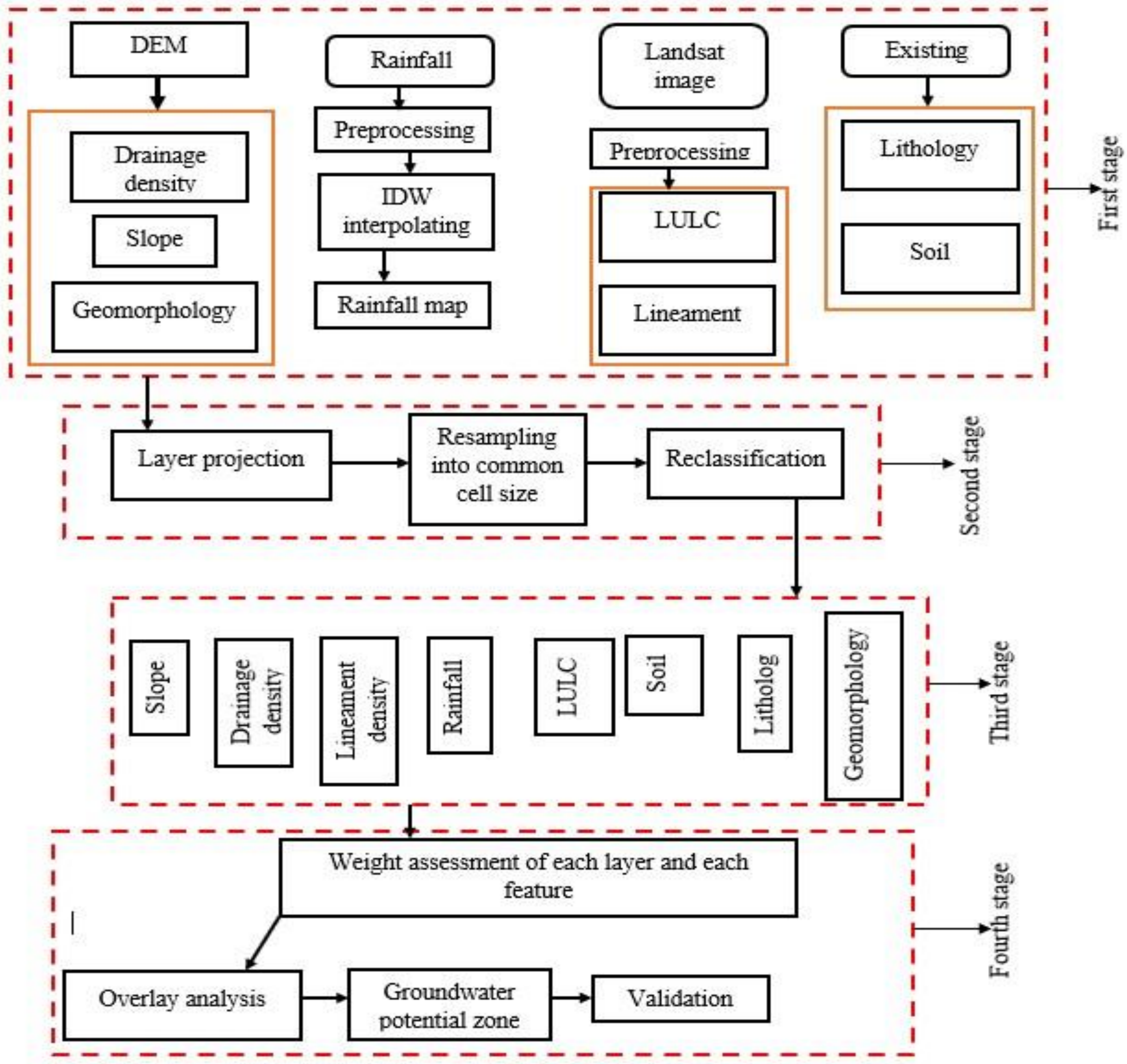

Figure 5*. Schematic diagram of the research.*

3. Results and Discussion

Based on the stated parameters stated in the methodology pairwise comparison was developed. Most researches conducted in Ethiopia show that geological characteristics of a site was the most governing factor for groundwater potential sites followed by rainfall characteristics of the site.

Table 5*. Pairwise comparison matrix.*

	Geology	Rainfall	Lineament density	Slope	Drainage density	Land use	Soil
Geology	1	3	4	5	5	7	7
Rainfall	0.33	1	2	3	3	5	5
Lineament density	0.25	0.5	1	3	3	5	7
Slope	0.2	0.33	0.33	1	1	3	3
Drainage density	0.2	0.33	0.33	1	1	5	5

	Geology	Rainfall	Lineament density	Slope	Drainage density	Land use	Soil
Land use	0.14	0.2	0.2	0.33	0.2	1	1
Soil	0.14	0.2	0.14	0.33	0.2	1	1
Summation	2.27	5.57	8.01	13.67	13.4	27	29

The fractional numbers in the above table 3 shows, the values for parameter in the first columns of table below the diagonal were the inverse of values above the diagonal in yellow color.

Table 6. Normalized pairwise comparison matrix and weight.

	Geology	Rainfall	Lineament density	Slope	Drainage density	Land use	Soil
Geology	0.441	0.539	0.499	0.366	0.373	0.259	0.241
Rainfall	0.147	0.180	0.250	0.220	0.224	0.185	0.172
Lineament density	0.110	0.090	0.125	0.220	0.224	0.185	0.241
Slope	0.088	0.060	0.042	0.073	0.075	0.111	0.103
Drainage density	0.088	0.060	0.042	0.073	0.075	0.185	0.172
Land use	0.063	0.036	0.025	0.024	0.015	0.037	0.034
Soil	0.063	0.036	0.018	0.024	0.015	0.037	0.034

The result shows that geology of the catchment has 38.8 percent influencing parameters for occurrence and distribution of groundwater. The least influencing parameters were soil and land use with percent influence of 3.3% and 3.4% respectively.

The weight and the sum of column values in the original pairwise matrix helps to assess the consistency of the comparison matrix.

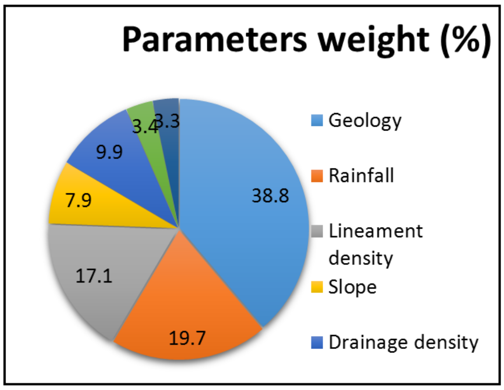

Figure 6. Weights of each parameter (percent).

Table 7. Consistency assessment.

Parameter	Total relative weight	Weight of each measure		Eigenvalue
Geology	2.27	0.388	38.84	0.881
Rainfall	5.57	0.197	19.67	1.095
Lineament density	8.01	0.171	17.07	1.367
Slope	13.67	0.079	7.89	1.078
Drainage density	13.40	0.099	9.93	1.330

Parameter	Total relative weight	Weight of each measure		Eigenvalue
Land use	27.00	0.034	3.35	0.905
Soil	29.00	0.033	3.25	0.943
			Sum (λmax)	7.600

The consistency ratio of comparison matrix was within the stated standard below 0.1. Therefore, the identified weights of parameters were applicable for the overlay analysis in GIS.

CI = 0.100
RI for N = 7 is 1.35
CR = 0.074 < 0.1 (OK!)

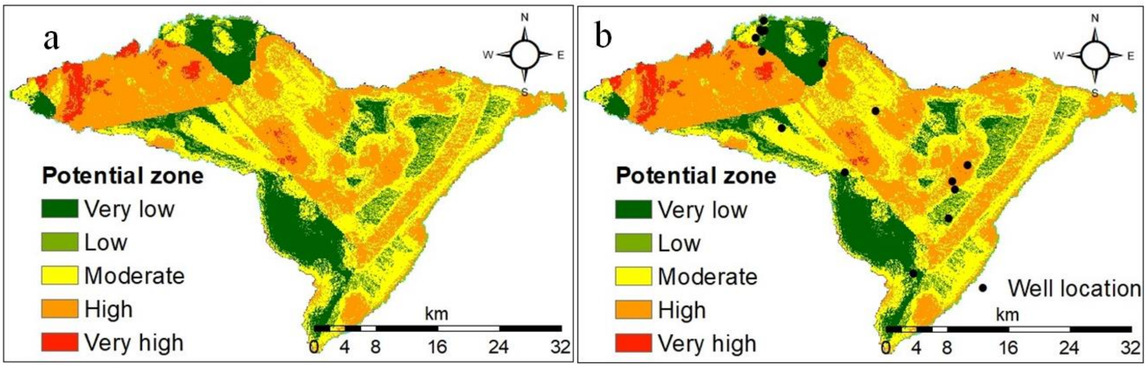

Figure 7*. (a) Different Groundwater potential zones of the catchment; (b) Potential sites with well location.*

The map shows there is high groundwater potential sites available in the catchment. From the total area 15.2%, 9.2%, 33.7%, 39.2% and 2.7% were covered by very low, low, moderate, high and very high groundwater potential zone. This shows almost 72.9 % of the area was demarcated by moderate and high groundwater potential area. The identified potential sites were validated using borehole sites found in the study catchment. For this purpose the potential zones distribution was examined using fifteen borehole locations.

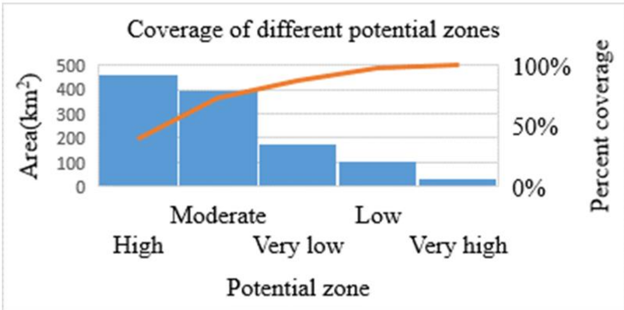

Figure 8*. Area coverage of each zone.*

Table 8*. Well data in the catchment.*

Site Id	X	Y	Z	Site Id	X	Y	Z
WBH1	395617	889264	2748	WBH9	368728	904114	1928
WBH2	379579	888307	2227	WBH10	368483	906917	1913
WBH3	393060	882228	2650	WBH11	369089	906736	1904
WBH4	388448	875071	2843	WBH12	368994	908126	1923
WBH5	371314	894009	1944	WBH13	383545	896231	2109
WBH6	393563	887124	2785	WBH14	376617	902505	1941
WBH7	368739	906671	1901	WBH15	393894	886062	2764

Site Id	X	Y	Z	Site Id	X	Y	Z
WBH8	367928	905831	1887				

Actually, the water manufacturing companies in the zone Guraghe indicates the area has a high groundwater potential. Many companies were there which extract groundwater and distribute into the whole country. In addition, this study proves the groundwater water potential of the catchment that covers most parts of Guraghe zone. The potential zone map shows there is high and moderate groundwater potential in the catchment and most of the wells 70.3% were found in this zone. Therefore, this study proves the groundwater potential of Winike catchment and applicability of geospatial techniques for demarcation of groundwater potential sites in data and material scarce areas.

Table 9. *Distribution of borehole in the catchment.*

Number of bore-hole	Location in potential map	Percent coverage
5	High zone	33.3
6	Moderate zone	40.0
3	Low zone	20.0
1	Very Low zone	6.7

4. Conclusion

The peoples in the catchment were highly susceptible to water shortage. However, many companies extract groundwater potential of the zone. This study shows there is a considerable amount of groundwater potential to prove the water problem of the community living in the study sites. From the total area, 39.2% was demarcated by high groundwater potential zones. In addition, in the collected borehole data 33.3% was found in this zone. The 73.3 % of collected borehole data were located in high and moderate groundwater potential zones. Therefore, it is possible to determine the groundwater potentials of any location where data's were in scarce.

Abbreviations

AHP Analytic Hierarchy Process
CR Consistency Ratio
DEM Digital Elevation Model
FAO Food and Agriculture Organization
GIS Geographic Information System
GWPZ Ground Water Potential Zone
LULC Land Use Land Cover
MCDA Multi-Criteria Decision Analysis
MER Main Ethiopian Rift
MIF Multi-criteria Influencing Factor
RI Random Inconsistency
RS Remote Sensing
SWAT Soil and Water Assessment Tool
WBH Winike Borehole
WLC Weight Linear Combination

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Author Contributions

Mezen Desse Agza is the sole author. The author read and approved the final manuscript.

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Data Availability

No new data are created.

Conflicts of Interest

I do not have any interests that might be interpreted as influencing the research.

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