Geospatial and multi-criteria decision approach of groundwater potential zone identification in Cuma sub-basin, Southern Ethiopia

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ABSTRACT

Groundwater is an essential component of our country's freshwater supplies. It plays a critical role in satisfying the water demands of the nation's many user sectors. The groundwater resource cannot be exploited and sustained optimally unless prospective zones are identified prior to the drilling of wells. The current study intended to analyze groundwater potential possibilities in the Cuma sub-basin, Omo Gibe basin, southern Ethiopia, utilizing geospatial and multi-criteria decision analysis approaches. For this purpose, a range of thematic layers like geology, Rainfall, drainage density, slope, land use and land cover (LULC), Soil type, faults density, saturated hydraulic conductivity, Available water capacity, and soil depth were organized for the study area. The different sub-criteria of each theme layer were rated according to their effect on groundwater recharge, and a weight-age was assigned to each thematic layer based on the analytical hierarchy method (AHP). The identification of groundwater-potential regions of the sub-basin was one of the study's main results. The resulting groundwater potential zone map is further classified into five groundwater potential classes: very good (7.01%), good (19.49%), moderate (17.48%), poor (29.51%), and very poor (26.51%). The study's findings have important significance for developing sustainable groundwater strategies in the area.

1. Introduction

Groundwater resources are the primary supply of water for residential, agricultural, and industrial usage in many regions of the world (Burke and Moench, 2000). This is frequently due to the fact that groundwater supplies are of excellent quality, are naturally filtered, and are frequently abundant. Even if the total world water resources are estimated to be 1.36 billion km³ (Raghunath, 2006), their spatiotemporal distribution is erratic. Water is under peril these days due to increased population expansion, excessive pollution, higher living standards, and global warming. Anthropic effects have also played a significant part in endangering water supplies as a result of the unsustainable and reckless use of water resources during the last century (Riley et al., 1999).

The estimated groundwater potential of Ethiopia is known to be 2.6 Billion m³ which is small as compared to the surface water potential (Awulachew et al., 2007). This indicated that there is plenty of water concerning its topographical situation. However, owing to the effects of global climate change, this water potential has become jeopardized. It is necessary to identify the possible groundwater zones in order to utilize and manage the available groundwater resource efficiently, as well as to incorporate specific recharge methods. Several approaches are used to provide evidence concerning the possible existence of groundwater, either directly or indirectly. Previously, ground surveys were used to identify groundwater potential zones, which required more effort and time (Nampak et al., 2014). However, the advancement of remote sensing and GIS has made it simpler to locate prospective sites (Mukherjee et al., 2012). Several studies have recently been done to evaluate groundwater potential zones utilizing GIS, and analytical hierarchy method, and a multi-criteria decision approach (Andualem and Demeke, 2019; Celik, 2019; Chowdhury et al., 2010; Fashae et al., 2014; Jha et al., 2010; Magesh et al., 2012; Solomon and Quiel, 2006; Yeh et al., 2016).

The development of groundwater potential maps will have a major impact on the enhancement of community livelihood from a variety of viewpoints. The creation of a groundwater prospective map has a significant impact on the long-term management of groundwater resources in the study basin and throughout the country. The generated groundwater potential map may assist water-resource managers in developing accurate management plans and making better use of groundwater resources. For groundwater prospective zone mapping, several thematic...
layers are utilized (Andualem and Demeke, 2019). Slope, land use, fault density, geology, soil type and texture, drainage density, rainfall, elevation, and stream power index are all elements that influence groundwater movement and are taken into account in this research. The groundwater potential in the Cuma Sub-basin has not been studied, and no promising study on groundwater resources potential has been conducted. The purpose of this research was to demarcate groundwater prospective zones using GIS and a multi-criteria decision method for the proper management and sustainable use of groundwater resources within the sub-basin.

2. Study area

Cuma Sub-basin is a sub-basins of the Omo Gibe Basin, Southern Ethiopia (Figure 1a). It has a total area of 1397.99 km² and a circumference of 174.67 km and it is located between the geographic coordinates of 35° 32’ 30” to 35° 56’ 00” E and 5° 59’ 00” to 6° 28’ 00” N (Figure 1b). The elevation also ranges from 412 to 2529 m above mean sea level with the annual rainfall ranging between 1265 and 1315 mm (Figure 1c). The soil texture is dominated by loam with an aerial extent of 886.48 km² (63.41%), followed by loamy sand with an area of 246.95 km² (17.66%), sandy loam (199.57 km², 14.28%), and clay with an area of 64.99 km² (4.65%) of the basin with a variable depth, available water capacity, and saturated hydraulic conductivity (Figure 4c). The study area is characterized by several land-use types dominated by shrubland (799.57 km², 57.19%), forest land (426.85 km², 30.53%), grassland (76.49 km², 5.47%), and cropland, bare land, and water body together covering an area of 95.06 km² (6.8%) of the total area (Figure 3c). So far, the research region has been distinguished by slope gradients ranging from flat (0–3.98) to very steep (24.32–74.19) slopes in degree (Figure 3b). The drainage density of the region ranges from 0 to 15.20 km/km².

3. Materials and methods

During this work, geospatial approaches were used to demarcate the groundwater prospective zones of the Cuma sub-basin utilizing knowledge-based correlational analysis. This study made use of about ten theme levels that contribute to groundwater potential. The thematic layers utilized for groundwater deciphering included geology, slope, land use and land cover (LULC), rainfall, drainage density, faults density, soil type (1:250,000), saturated hydraulic conductivity, available water capacity, and soil depth. To determine the slope and drainage density of the research region, a Digital Elevation Model (DEM, 20 × 20 m resolution) was used. Soil data gathered from Ethiopia’s Ministry of Water, Irrigation, and Electricity was used to analyze soil properties linked to groundwater potential. The geology and fault map were obtained from the Ethiopian Geological Survey. Land use/land cover data were derived from satellite images (30 × 30 m resolution) which were downloaded from the USGS Earth Explorer Website and classified using ERDAS Imagine 2014.

3.1. Parameter weighting using AHP

The AHP approach was utilized to generate decision matrices for allocating weights to thematic layers and assessing their relative weight

| Intensity of Importance | Meaning | Clarification |
|-------------------------|---------|---------------|
| 1                       | Equal importance | Two factors contribute equally to the objective |
| 2                       | Intermediate | When compromise is needed |
| 3                       | Extremely less importance | The parameter slightly favor over another |
| 4                       | Essential or strong importance | The parameter strongly favor over another |
| 5                       | Demonstrated importance | The parameter strongly favored and its dominance demonstrated in practice |
| 6                       | Absolute more importance | The evidence favoring one parameter over another is the highest possible order of importance |
| 7                       | Intermediate values linking the two adjacent decisions. | |

Table 1. Satty’s scale of the relative importance.

Figure 1. Location of the Cuma sub-basin a) Ethiopian Basins b) Omo-Gibe basin c) Topography of Cuma Sub-basin.
using Saaty’s 1 to 9 scale (Saaty, 1980; Arshad et al., 2020) (Table 1). Weights were assigned to various variables based on field experiences and a study of previous research studies. The following procedures were taken in order to determine the indicator’s weight and consistency ratio (CR):

a. Identify the problem statement and select influencing factors.
b. Create the hierarchy framework and the pairwise comparison matrix for each thematic layer.
c. Performing decisions based on an expert’s judgment and assigning subjective weights from the relative scale of significance.
d. Assigning the maximum rank to the factor that has an important influence on the result in contrast with the other factors considered; it is true to take up the inverse value for the factors not having an important influence on the results (Magesh et al., 2012; Prasad et al., 2008; Shaban et al., 2006; Thapa et al., 2017; Yeh et al., 2009, 2016).
e. Determine the consistency index and consistency ratio for the matrix (Eqs. (1) and (2)).
f. Check whether the consistency ratio is <0.1. If satisfied, then the mean weights for each criterion could be finalized. If not satisfied again, the judgment has to be revised.

\[ CI = \frac{\lambda_{max} - n}{n - 1} \]  

(1)

\[ CR = \frac{CI}{RI \times 100\%} \]  

(2)

where CI is the consistency index, n is the number of parameters (in this study 10 parameters used) (Table 13), RI is the random index value based on Saaty (1980) scale which is dependent on the number of parameters used and it was 1.49 for this study (Table 2), \( \lambda_{max} \) the maximum Eigenvalues.

The thematic maps have been developed and the weights were allocated to the factors prompting groundwater occurrence and movement. GIS environment weighted index overlay analysis was used to produce the groundwater prospective map. The groundwater potential index was calculated using a weighted linear combination approach (Eqs. (3) and (4)). The general methodology followed and adopted is presented in the figure below (Figure 2).

\[ GWPI = G_r G_w + S_l S_lw + L_u L_w + R_f R_fw + D_d D_dw + F_d F_dw + S_r S_rw + K_r K_w + W_c W_{cw} + S_d S_dw \]  

(3)

where; GWPI is the groundwater potential index, G is geology, Sl is Slope, Lu is LULC, Rf is rainfall, Dd is drainage density, Fd is fault density, S is soil, K is saturated hydraulic conductivity, Wc is available water capacity and Sd is soil depth. The suffixes r and w represent the rank and weight of each layer respectively.

Further Eq. (4) can be simplified as;

\[ GWPI = \sum_{w=1}^{n} \sum_{i=1}^{m} (X_{ij} \times W_{ij}) \]  

(4)

Table 2. Random consistency index (RI).

| n  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|----|----|----|----|----|----|----|----|----|----|----|
| RI | 0  | 0  | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Table 3. Areal coverage of Geologic group in the Cuma Sub-basin.

| Geology           | Area \((km^2)\) | % of coverage |
|-------------------|-----------------|---------------|
| Quaternary Sediments | 315.39          | 22.56         |
| Ext bound         | 1082.60         | 77.44         |
where; $X_i$ is the normalized weight of the $i^{th}$ feature of the thematic layer, $W_j$ is the normalized weight of the $j^{th}$ thematic layer, $m$ is the total number of thematic layers, and $n$ is the total number of features of a given theme.

3.2. Thematic map preparation

3.2.1. Geology

Groundwater occurrence and distribution in every area are heavily influenced by the geologic setting (Yeh et al., 2016). Geology encompasses all soil and rock materials, both natural and man-made. The geologic material ranges from loose granular soil to soft cohesive soil to highly hard, unjointed rock. The availability of groundwater in a region is determined by its surface and subsurface geology. Groundwater availability in aquifers is governed by surface and subsurface geology. A geologic formation’s porosity and permeability reflect its capacity to retain and transfer water inside the aquifer.

Groundwater recharge is indicated by geologic formations having a high permeability. The water can flow across the aquifer because of the interconnected interior holes and cracks. The occurrence, movement, and quality of groundwater are all influenced by geological units (Rajaveni et al., 2015). Geological features can have a big impact on groundwater flow and accumulation in the surface and subsurface, thus they should be taken into account in groundwater research. The geological features that govern the region have a considerable influence on the study area’s hydrology (Hamdan and Bahr, 1992). The geological characteristics of the Cuma sub-basin were obtained from the Ethiopian Geological Survey. The Quaternary Sediments and Ext bounds were the geological features in the sub-basin covering an area of 315.39 km² and 1082.59 km² respectively (Table 3 and Figure 3a).

Figure 3. (a) Geology, (b) Slope, (c) LULC, and (d) Rainfall map of the Cuma Sub-basin.
Areal coverage of Slope classes in the Cuma Sub-basin.

| No. | Slope (degree) | Area (km²) | % of coverage |
|-----|----------------|------------|--------------|
| 1   | 0.5-3.98       | 201.68     | 14.43        |
| 2   | 3.98-8.45      | 387.97     | 27.75        |
| 3   | 8.45-14.95     | 373.88     | 26.74        |
| 4   | 14.95-24.32    | 263.91     | 18.88        |
| 5   | 24.32-74.19    | 170.56     | 12.20        |

Areal coverage of LULC types in the Cuma Sub-basin.

| No. | LULC          | Area (km²) | % of coverage |
|-----|---------------|------------|--------------|
| 1   | Forest Land   | 426.85     | 30.53        |
| 2   | Bare Soil     | 24.94      | 1.78         |
| 3   | Shrubland     | 799.57     | 57.19        |
| 4   | Crop Land     | 69.68      | 4.98         |
| 5   | Grassland     | 76.50      | 5.47         |
| 6   | Water body    | 0.45       | 0.03         |

Areal coverage of Drainage density classes in the Cuma Sub-basin.

| No. | Drainage density (km/km²) | Area (km²) | % of coverage |
|-----|---------------------------|------------|--------------|
| 1   | 0.0-0.5                   | 702.60     | 50.26        |
| 2   | 0.5-2.5                   | 155.89     | 11.15        |
| 3   | 2.5-5.7                   | 247.43     | 17.70        |
| 4   | 5.7-8.8                   | 192.01     | 13.73        |
| 5   | 8.8-15.2                  | 100.07     | 7.16         |

Rainfall is one of several thematic layers used to define groundwater potential zones. It is, in fact, the primary source of natural groundwater recharge that contributes to the development of groundwater resources. The rainfall map was created using historical rainfall data collected for over 20 years (1998–2017) from meteorological stations throughout the research region.

The inverse distance weightage (IDW) method was used to interpolate and convert point rainfall to areal rainfall. The average annual rainfall in the sub-basin ranges from 1242 mm to 1315 mm, as indicated in Table 6 and Figure 3d. The pace of groundwater recharge is determined by the amount and duration of rainfall (Ibrahim-Bathis and Ahmed, 2016; Andualem and Demeke, 2019; Ahmad et al., 2020). Low intensity and long duration rain had high groundwater recharge rate than run-off. Higher annual rainfall magnitude received a higher weight.

Drainage density of the study area ranges from 0 to 15.2 km/km² (Table 7). Drainage density is negatively related to soil infiltration ability. Areas with poor drainage density were given a high weight, and vice versa (Andualem and Demeke, 2019; Harlin and Wijeyawickrema, 1985; Ibrahim-Bathis and Ahmed, 2016; Patra et al., 2018; Rahmati et al., 2015; Saravanan et al., 2020). The drainage line was created using the DEM and the flow accumulation, and the drainage density map for the research region was created using ArcGIS.

Using the DEM and also the flow accumulation the drainage line was developed, and further, the drainage density map for the study area was prepared within the ArcGIS environment using the line density tool. The drainage density of the study area ranges from 0 to 15.2 km/km² (Table 7 and Figure 4a).

Fault density

Geological faults are observed in most parts of the study area. The fault areas are also promising for groundwater recharge. The fault density is directly related to the infiltration of water into the ground. The infiltration and groundwater recharge became less as the distance from the fault increased and the density of faults decreased. Therefore, a fault density map was produced using the "Kernal density" method in the GIS environment. As shown in Figure 4b, the output raster value of the fault density varies from 0 to 35.64 km/km². The fault density was reclassified into five classes subject to the potential values associated with the contribution of groundwater occurrence and movement (Table 8).
3.2.7. Soil texture

The rate of infiltration is mostly determined by the type and texture of the soil (Gupta and Srivastava, 2010). Soil texture is an important factor in evaluating the physical forms of soil and is closely related to soil characteristics (McGarry, 2006). Texture impacts groundwater potential recharge because water penetration and permeability are directly dependent on soil texture. The Cuma sub-basin soil texture theme layer was prepared. Based on the soil texture of the area, loam with an aerial extent of 886.48 km² covers more than 63.41% of the Cuma sub-basin. The texture of the soil was determined to be loamy sand, sandy loam, and clay. There were areal extents of 246.95 km², 199.57 km², and 64.99 km² for loamy sand, sandy loam, and clay soil textures, respectively (Table 9 and Figure 4c). Depending on the penetration rate and other hydraulic characteristics of the texture, appropriate ranks were assigned to each texture class. The soil textures with higher porosity (high infiltration rate) were given better rankings than soils with lower infiltration capacity. This was owing to the concept that the higher the infiltration rate, the greater the groundwater recharge and potential in the aquifers.

| No. | Soil Texture    | Area (Km²) | % of coverage |
|-----|----------------|------------|---------------|
| 1   | Loam           | 886.48     | 63.41         |
| 2   | Sandy loam     | 199.57     | 14.28         |
| 3   | Loamy sand     | 246.95     | 17.66         |
| 4   | Clay           | 64.99      | 4.65          |

Figure 4. (a) Drainage density, (b) Fault density, (c) Soil Texture, and (d) Saturated hydraulic conductivity map of the Cuma Sub-basin.

Table 8. Areal coverage of Fault density classes in the Cuma Sub-basin.

| No. | Fault density (km/km²) | Area (km²) | % of coverage |
|-----|------------------------|------------|---------------|
| 1   | 0-7.13                 | 1099.97    | 78.68         |
| 2   | 7.13-14.26             | 183.69     | 13.14         |
| 3   | 14.26-21.38            | 104.54     | 7.48          |
| 4   | 21.38-28.51            | 8.26       | 0.59          |
| 5   | 28.51-35.64            | 1.54       | 0.11          |
3.2.8. Saturated hydraulic conductivity (Ksat)

The soil saturated hydraulic conductivity (Ksat) is defined as the inverse of the soil medium resistance to water flow through the soil. It demonstrates the ease with which water moves through the earth. As a result, the infiltration rate is a function of Ksat. The Ksat of the study area varies from 0.00036 – 360 (Table 10 and Figure 4d). The areas with lower Ksat values are less favorable for groundwater potential compared with higher Ksat values.

3.2.9. Available water capacity

The rainfall which reaches the earth’s surface infiltrates into the soil. The water infiltrated into the soil recovers the soil moisture shortage and contributes to groundwater recharge. Due to this, the wet soil needs no or less rainfall to recover from the wetness shortage as compared with dry soils. The available water capacity of the Cuma sub-basin varies from 15 to 150 mm of water per millimeter depth of soil (Table 11 and Figure 5a).

3.2.10. Soil depth

The soil depth of the Cuma sub-basin varies from 100 – 1000 mm (Table 12 and Figure 5b). Soil depth is also another major feature that influences the occurrence and movement of groundwater. Deep and well-drained soils with coarse structures are favorable for stormwater infiltration. In the Cuma sub-basin, sandy loam soils, which are known to have the highest infiltration rate, were found to be 100 and 300 mm deep from the surface. The loam with a moderate infiltration rate was found to be 100 mm deep. And the clay with a low infiltration rate was found to be 1000 mm deep.

4. Results and discussion

4.1. Weight assignment to groundwater contributing factors

The weight of selected groundwater contributing factors (geology, slope, drainage density, LULC, rainfall, available water capacity, fault density, soil texture, saturated hydraulic conductivity, and soil depth) was assigned to delineate the groundwater prospective zones (Magesh et al., 2012; Arshad et al., 2020) of the Cuma sub-basin. The selected factors weight was assigned based on their influence on the movement and occurrence of groundwater collected from expert knowledge and suggestions from works of literature (Andualem and Demeke, 2019; Yeh et al., 2016; Saravanan et al., 2020; Rahmati et al., 2015; Nampak et al., 2014; Patra et al., 2018; Pande et al., 2018; Magesh et al., 2012; Ibrahimbathis and Ahmed, 2016; Kumar et al., 2016; Arulbalaji et al., 2019).

The weight assigned to each element represents the percentage of its effect on identifying groundwater potential areas. The main impacting variables were given a larger weight (Table 13). To demonstrate, geology plays a crucial role with the highest assigned weight of 29% followed by slope, LULC, rainfall, drainage density, fault density, soil texture, saturated hydraulic conductivity, available water capacity, and soil depth, which have respective weights of 21%, 15%, 8%, 8%, 5%, 4%, 3%, 2%, and 2%, respectively.

| Table 10. Areal coverage of saturated hydraulic conductivity in the Cuma Sub-basin. |
|-----------------|-----------------|-----------------|
| No. | Saturated hydraulic conductivity (mm h⁻¹) | Area (km²) | % of coverage |
|-----|-----------------------------------------|------------|---------------|
| 1   | 0.00036–120                             | 951.49     | 68.06         |
| 2   | 120–240                                 | 199.55     | 14.27         |
| 3   | 240–360                                 | 246.95     | 17.66         |

| Table 11. Areal coverage of available water capacity in the Cuma Sub-basin. |
|-----------------|-----------------|-----------------|
| No. | Available water capacity (mm of water/mm of soil) | Area (km²) | % of coverage |
|-----|--------------------------------------------------|------------|---------------|
| 1   | 15                                               | 41.96      | 3.00          |
| 2   | 50                                               | 157.54     | 11.27         |
| 3   | 125                                              | 64.97      | 4.65          |
| 4   | 150                                              | 1133.53    | 81.08         |

| Table 12. Areal coverage of Soil depth in the Cuma Sub-basin. |
|-----------------|-----------------|-----------------|
| No. | Soil depth (mm) | Area (Km²) | % of coverage |
|-----|-----------------|------------|---------------|
| 1   | 100             | 157.58     | 11.27         |
| 2   | 300             | 41.97      | 3.00          |
| 3   | 1000            | 1198.44    | 85.73         |

Figure 5. (a) Available water capacity and (b) Soil depth map of the Cuma Sub-basin.
Table 13. AHP rank and weights for the factors influencing groundwater movement and occurrence within the study area.

| No. | Features               | Local Ranks | Area coverage (%) | Average weights |
|-----|------------------------|-------------|-------------------|-----------------|
| 1   | Geology                | Quaternary  | 0.567             | 22.56           | 0.29            |
|     |                        | Sediments   |                   |                 |                 |
|     |                        | Ext bound   | 0.443             | 77.44           |                 |
| 2   | Slope (degree)         | 0-3.98      | 0.419             | 14.43           | 0.21            |
|     |                        | 3.98-8.45   | 0.262             | 27.75           |                 |
|     |                        | 8.45-14.95  | 0.16              | 26.74           |                 |
|     |                        | 14.95-24.32 | 0.097             | 18.88           |                 |
|     |                        | 24.32-74.19 | 0.062             | 12.20           |                 |
| 3   | Land Use/Land Cover    | Water body  | 0.425             | 0.03            | 0.15            |
|     |                        | Crop Land   | 0.254             | 4.98            |                 |
|     |                        | Grassland   | 0.15              | 5.47            |                 |
|     |                        | Shrub land  | 0.088             | 57.19           |                 |
|     |                        | Forest Land | 0.052             | 30.53           |                 |
|     |                        | Bare land   | 0.031             | 1.78            |                 |
| 4   | Annual rainfall (mm)   | 1290-1515   | 0.54              | 56.87           | 0.11            |
|     |                        | 1265-1290   | 0.297             | 28.59           |                 |
|     |                        | 1242-1265   | 0.163             | 14.54           |                 |
| 5   | Drainage Density (Km/Km²) | 0-0.5       | 0.469             | 50.26           | 0.08            |
|     |                        | 0.5-2.5     | 0.267             | 11.15           |                 |
|     |                        | 2.5-5.7     | 0.141             | 17.70           |                 |
|     |                        | 5.7-8.8     | 0.082             | 13.73           |                 |
|     |                        | 8.8-15.2    | 0.041             | 7.16            |                 |
| 6   | Fault Density(Km/Km²)  | 0-7.13      | 0.033             | 78.68           | 0.05            |
|     |                        | 7.13-14.26  | 0.063             | 13.14           |                 |
|     |                        | 14.26-21.38 | 0.129             | 7.48            |                 |
|     |                        | 21.38-28.51 | 0.262             | 0.59            |                 |
|     |                        | 28.51-35.64 | 0.513             | 0.11            |                 |
| 7   | Soil Texture           | Sandy loam  | 0.566             | 14.28           | 0.04            |
|     |                        | Loamy sand  | 0.275             | 17.66           |                 |
|     |                        | Loam        | 0.112             | 63.41           |                 |
|     |                        | Clay        | 0.047             | 4.65            |                 |
| 8   | Saturated hydraulic conductivity (mm h⁻¹) | 0.00036-120 | 0.105             | 68.06           | 0.03            |
|     |                        | 120-240     | 0.258             | 14.27           |                 |
|     |                        | 240-360     | 0.637             | 17.66           |                 |
| 9   | Available water capacity (mm of water/mm of soil) | 15          | 0.045             | 3.00            | 0.02            |
|     |                        | 50          | 0.11              | 11.27           |                 |
|     |                        | 125         | 0.271             | 4.65            |                 |
|     |                        | 150         | 0.574             | 81.08           |                 |
| 10  | Soil depth with respect to Sandy loam (mm) | 100         | 0.071             | 11.27           | 0.02            |
|     |                        | 200         | 0.178             | 3.00            |                 |
|     |                        | 1000        | 75.1              | 85.73           |                 |

4.2. Identification of groundwater potential zone

A groundwater potential map for the Cuma sub-basin was created using a weighted index overlay technique, which involved adding the weighted value of the 10 influential thematic layers. The information for each contributing element was obtained from various sources and evaluated using the ArcGIS 10.3.1 environment. The criteria and their sub-characteristics were evaluated in a specific method and appropriate rankings and weights were allocated to each class. Each parameter's rankings and weights were allocated using the AHP method. A weighted overlay analysis approach was utilized to determine the groundwater potential index. Consequently, the groundwater potential zone acquired was categorized into five classes as very good, good, moderate, poor, and very poor based on the index value.

Figure 6. Groundwater potential zone map of the Cuma Sub-basin.
and reported that 34% of the area falls into a high groundwater potential zone. The results of this study reported a comparable result to other studies conducted in different parts of Ethiopia. Hence, the findings of this study can be used as an indicator for further detailed investigation of groundwater development projects.

5. Conclusion

Groundwater is an important part of our nation’s freshwater resources. It plays a key role in meeting the water requirements for various uses. Groundwater cannot be efficiently utilized and economically sustained unless prospective zones are identified before drilling of wells. This study attempted to demarcate groundwater potential zones in the Cuma sub-basin of Southern Ethiopia utilizing GIS and remote sensing techniques combined with AHP methodologies. The study integrated the impacts of several elements that influence groundwater occurrence and flow, such as geology, slope, LULC, rainfall, drainage density, fault density, soil texture, saturated hydraulic conductivity, available water capacity, and soil depth for demarcating the groundwater potential zones. The results revealed that about 70.01% and 19.49% of the sub-basin showed very good and good groundwater prospects respectively. Very poor and poor groundwater potential zones were largely located within the central part of the sub-basin, as well as in some northern and eastern parts of the sub-basin. This study will provide an insight into the design of sustainable groundwater development and management practices within the sub-basin. Accordingly, the quantitative investigation of groundwater recharge, hydro-chemistry, and its suitability for domestic and irrigation purposes is recommended for future study by installing and recoding data at test wells.

Declarations

Author contribution statement

Yonas Gehrbesiasle Hagos: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Tesfa Gebrie Andualem: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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