# GROUNDWATER POTENTIAL MAPPING OF THE CENTRAL REGION USING INTEGRATED GEOLOGICAL AND GEOPHYSICAL METHODS

Haoulata Touré[a], Cyril D. Boateng[b, f, *], Solomon S. R. Gidigasu[a], David D. Wemegah[b], Vera Mensah[a], Jeffrey N. A. Aryee[c], Marian A. Osei[c, d, e]

[a]*Department of Geological Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[b]*Department of Physics, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[c]*Department of Meteorology and Climate Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

[d]*Centre for Ecology and Hydrology, Crowmarsh Gifford, Oxfordshire, UK*

[e]*School of Earth and Environment, University of Leeds, Leeds, UK*

[f]*Caburu Company Ltd, P.O.BOX MD 2046, Madina, Accra, Ghana*

*Corresponding author: cyrilboat@knust.edu.gh (C.D Boateng)

## Statements and Declarations

### Funding

This work was supported by the Research Grant (109705-001/002) by the Responsible Artificial Intelligence Network for Climate Action in Africa (RAINCA) consortium made up of WASCAL, RUFORUM, and AKADEMIYA 2063 provided by the International Development Research Centre and received by C.D Boateng.

### Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

### Author Contributions

Conceptualization of the article was done by Cyril D. B. and Haoulata T. Data curation was done by Haoulata T., Cyril. D. B., Solomon S.R G and David D. W. The formal analysis was done by Haoulata T. The investigation was done by Haoulata T., Cyril D. B., Solomon S.R G., David D. Wemegah., Jeffrey N. A. A., and Marian A. O. The methodology was established by Cyril D. B., Haoulata T. The project administration was done by Cyril D. B. The resources were provided by

Cyril D. B. The work was supervised by Cyril D. B., Solomon S.R. G. and David D. W.. The validation was done by Haoulata T., Cyril D. B., David D. W., Solomon S.R. G., Vera M.. The Visualization was done by Haoulata T.. The original draft was written by Haoulata T. The written article was edited by Haoulata T., Cyril D. B., Jeffrey N. A. A., Marian A. O., David D. W., Solomon S.R. G., Vera M..

**Availability of Data and Materials**: Available on request

**Declaration Ethical Approval:** Not applicable.

**Consent to Participate:** Not applicable.

**Consent to Publish:** Not applicable.

**Acknowledgement**

Support for implementation of project activities was made possible by the Research Grant (109705-001/002) by the Responsible Artificial Intelligence Network for Climate Action in Africa (RAINCA) consortium made up of WASCAL, RUFORUM and AKADEMIYA 2063 provided by International Development Research Centre.

**Abstract**

Surface waters are deteriorating due mainly to poor farming practices, illegal mining activities and also climate change. In the Central region this has led to a rise in the need for groundwater as potable water supply. However, the Central region is known to be characterized by unsuccessful rate of borehole drilling, which usually results in waste of time and resources. The need to delineate groundwater potential areas in the region has long been known. This study sought to map and delineate the groundwater potential zones of the Central Region by integrating input variables such as lineaments map deduced from magnetic data, digital elevation model, geology, soil type, land use land cover, drainage density, slope and flow accumulation maps using Fuzzy Logic (an

Artificial Intelligence based algorithm) in a GIS software. The final map of groundwater potential was validated using borehole yield data and the reliability testing using the area under curve operation technique. Results of the study revealed that, the region is characterized by very low to high groundwater potential zones. About 3461.16 km$^2$ of the region representing 35.68% and 3176.88 km$^2$ (32.74%) were found to have low and very low groundwater potential respectively. Moderate groundwater potential zones cover about 1978 km$^2$ constituting 20.4%, and high groundwater potential zones covers the least of about 1083.7 km$^2$, representing 17%. The final output revealed that the high potential areas are mainly located in the central part of the region which is mainly occupied by granitoids rock types. The low areas are mostly encountered in the south eastern but are found also in the northern and central part of the region and fall mainly on metavolcanics rocks. It is recommended that the prospectively map can give valuable insights for sustainable water resource management and development in the Central region and also serve as guide for upcoming drilling campaigns in the region.

Keywords: Groundwater Potential, GIS, Fuzzy logic, Central Region, Ghana

## 1. Introduction

Groundwater serves as the principal potable water source for most Africans (MacDonald et al., 2012). According to estimates, around half of the total population depends on groundwater for domestic and drinking water as well as industrial purposes. The demand and dependance for groundwater are anticipated to increase significantly within the next ten years due to the increase in global population (rate of 80 million per year) and urbanization (Vörösmarty et al., 2000). This challenge is a matter of concern for underdeveloped and developing countries around the world, especially in Africa, where there is low water security.

Water security is defined by the United Nations of Environment Programme (UNEP) as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against waterborne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (Bigas, 2013). Water security is measured by assessing several parameters such as access to drinking water, water availability of a country and others. One or two indicators, each with a maximum score of 10, are used to measure each of the components. The sum of individual indicator scores is calculated to deduct the total score for national water security, with a maximum possible score of 100. This evaluation in Africa shows only 13 countries out of 54 (less than 25%) reached modest water security level in recent years. Approximately one third are considered to be below the threshold of 45 for water security level, with some of these countries depend on groundwater to meet their water demand.

Another notable issue is the difficulty of obtaining clean surface water due to increasing frequency of severe weather conditions. The contamination of surface water bodies from activities like the use of harmful chemicals for fishing, farming near water bodies, illegal mining and others, make them unsafe for drinking (Okrah et al., 2012). The poor quality of the surface waters available mainly due to poor agricultural practices and illegal mining activities as well as the impact of climate on the availability of surface water in the Central region has resulted in the increasing demand for groundwater as a source of potable water supply. Unfortunately, there is no detailed groundwater potential map of the Central Region of Ghana. This is a major factor affecting groundwater exploration, hence, water resource development and management in the region. Without accurate information about the distribution and availability of groundwater resources, decision-makers face difficulties in planning and implementing sustainable water supply projects. This knowledge gap hampers efforts to meet the increasing water demand and ensure the region's water security. Access to clean and reliable groundwater is crucial for several sectors such as farming, industry, and domestic use and there is a need for comprehensive groundwater potential mapping in the region to delineate areas with high potential for groundwater resources (Osiakwan et al., 2022).

Groundwater occurrence is affected by a wide range of parameters including geology, soil type, slope, land use land cover (LULC), precipitation and factors. This suggests that efficient methods must be used to explore and accurately quantify the available groundwater. Among the various methods, geophysical techniques have demonstrated their reliability over the time in groundwater exploration studies (Araffa et al., 2015; Yehualaw et al., 2023).One of the reasons why geophysical methods are becoming more popular for hydrogeological studies is because they allow us to create physical properties models in areas that are not easily sampleable using traditional hydrological approaches. These geophysical models often provide more detailed information compared to models based solely on hydrogeological data, like pump tests and hydraulic head observations.

Another advantage of geophysical methods is that they are less invasive and more cost-effective. The correct interpretation of the hydrogeological and geophysical data can greatly enhance our understanding of hydrogeological characteristics of an area (Araffa, 2013).

Among the available techniques, remote sensing is a valuable tool for efficiently assessing natural resources. It is a method that involves using satellite images and aerial photographs to gather Earth's surface information without direct physical contact. The core principles guiding remote sensing involve electromagnetic waves and their interactions with surroundings. These waves transport radiant energy across space within the electromagnetic field. This process results in capturing ground information providing valuable data for several applications such as urban planning, environmental monitoring, agriculture, and disaster management. Over time, it has shown its significance in creating thematic maps from satellite images for hydrogeological studies (Aouragh et al., 2017). This method offers various advantages like cost-effectiveness, easily accessible datasets, and high temporal and spatial resolution and overcomes challenges such as time-consuming visual interpretation in inaccessible areas by providing enhanced accuracy and reducing manual errors (Epuh et al., 2020; Rajaveni et al., 2017). Remote sensing integrated with GIS permit the processing of the aerial images to render them usable for interpretation purposes.

In Ghana, around 49% of the population of 24.6 million people living in rural zones heavily depend on groundwater for their daily needs and agriculture (Asare et al., 2016). In the coastal zones of Ghana, particularly the Central and Western regions, as well as the southern parts of the Volta region, most irrigation strategies rely on groundwater from shallow aquifer systems (Asare et al., 2016), which are replenished by sufficient rainfall, with a non-consistent distribution consistent the year (Ewusi et al., 2011). This represents the case in the Central region, where the most preferred source of water is groundwater. The rising demand for groundwater underscores its vital importance, necessitating advanced exploration techniques.

AI algorithms have notably excelled in groundwater mapping globally over the last decade (Tao et al., 2022). AI-based algorithms can examine large sets of data and highlight complex patterns to delineate good groundwater potential areas. As said by Mitchell (1997) “The impact of AI is certain to grow over the coming years, as more and more data come online, we develop more effective algorithms and underlying theories for machine learning (ML), the futility of hand-coding increasingly complex systems becomes clear, and human organizations themselves learn the value of capturing and using historical data".

In recent years, there have been various modeling techniques used in AI-based time series analysis. These techniques include artificial neural networks (ANNs), genetic algorithms (GA), neuro-fuzzy (NF) and fuzzy logic (FL) methods. The algorithms have demonstrated efficiency in several studies (Echogdali et al., 2022; Gaffoor et al., 2022; Kalu et al., 2022; Owolabi et al., 2020; Siabi et al., 2022) due to its ability to integrate several environmental parameters that impact the availability of groundwater, such as the characteristics of soil, topography, and rainfall patterns.

Given the advantages of geophysical methods, remote sensing tools and AI methods in groundwater exploration, an integration of these methods will be very effective in solving water management problems in communities in developing countries.

In this project, AI-based algorithms are employed to precisely map the groundwater potential of the Central Region. Variables affecting groundwater occurrence in the central region were gathered and thematic layers were derived from them using Geosoft and ArcGIS software's. These layers were processed and integrated in the Fuzzy Logic algorithm to generate the groundwater potential map of the study area, which was finally validated using boreholes data. This mapping project can give valuable information for sustainable water resource management and development. The following sections cover the study area description followed by the methodology, the results section and the discussion.

## 2. Study area

Located in the southwest of Ghana, the Central Region (Figure 1) is bounded to the North-East by the Eastern Region, to the North by the Ashanti Region, by the Greater Accra Region to the South-East and the West by the Western Region. Its boundary to the South is the Gulf of Guinea. The coastline of the region length is approximately 150 km, representing the longest in Ghana. The region's capital city is Cape Coast, which is famous for its colonial history and the Cape Coast Castle. The temperature in the region is relatively high and ranges between 24ºC in August and 34ºC in March to April. The amount of rain that falls each year ranges from 800 mm to 1,600 mm.

The rainfall pattern has two main peaks. The first season of rain usually occurs between May and July, with the highest amount of rain in June. The second rainy season occurs from September to October (Ewusi et al., 2011). The region has a relative humidity of between 50% and 85%.

Five main rivers drain the region namely the Ochi, Amisa, Kakum in the southern part, and Offin, with the Pra in the north. They all flow in a southern direction and eventually reach the Gulf of Guinea (Osiakwan et al., 2022). In the coastal plains, sandy beaches and lagoons are observable, while further inland, the topography becomes more undulating and densely forested, with portions of the region encompassing the verdant rainforests of the Central Forest Reserve (Manu et al., 2019).

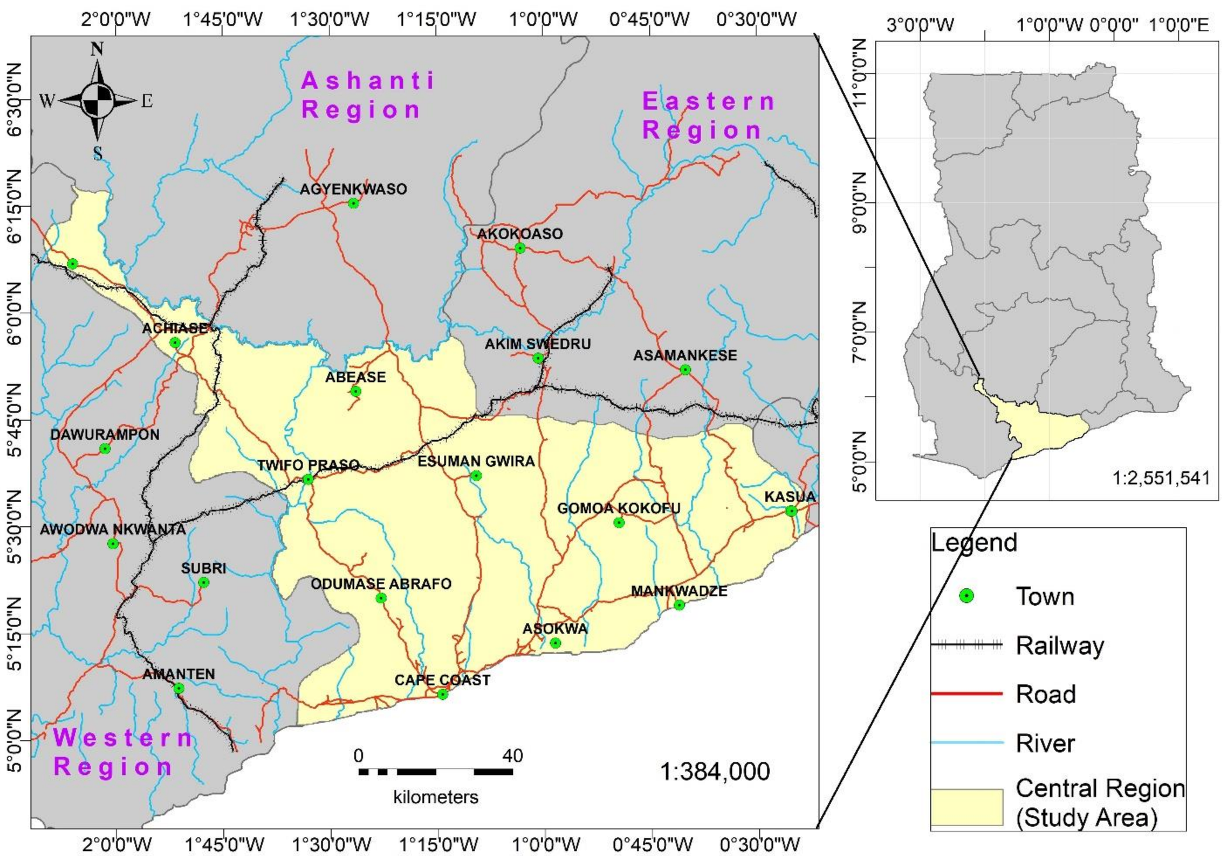


Figure 1 Location of the central region in Ghana

Metamorphic and Precambrian crystalline igneous rocks predominantly underlain the Central Region of Ghana. Figure 2 shows the different formations encountered in the area. They include the Birimian Supergroup intruded by the basin type granitoids (Asare et al., 2021), the Tarkwaian group, the Togo Structural Unit, and the Sekondian- Amisian sediments which are recent deposits.

The Birimian is divided into two main groups namely the metasedimentary and the metavolcanic rocks. The metavolcanic unit, characterized by lava rock types and metamorphosed tuffs, is associated with the Kibi-Winneba and Ashanti belts in a northeast-southwest trend. On the other hand, the metasediments units consist of metamorphosed and folded slate, schist, argillites and phyllite with interbedded greywacke. Throughout the Birimian formation, there are intrusions of biotite granitoids, gneisses, and migmatites (Osiakwan et al., 2022). The impermeable granitoids generally termed as 'Basin type granitoids' consist at times of well foliated often migmatic, high potassium content rocks and manifest as granodiorites, muscovite–biotite granite, porphyroblastic biotite gneiss, aplites, and pegmatites with some having medium grain size (Ewusi et al., 2011). The Tarkwaian represent products resulting from the erosion of the Birimian and are series of clastic sedimentary units.

The Togo Structural unit consisted originally of alternating sandy and clayey sediments. The Sekondian and Tertiary sediments are found along the coast. The Tertiary sedimentary rocks are mainly located between Anomabo and Mankessim, while the Sekondian rocks are found to the west of the region. The rocks found in the Sekondian exhibit a notable abundance of shale, clay, and some gravel. Other rock types include conglomerate, amphibolites, volcaniclastics, an assemblage of sandstone, schists and shale, as well as sediments with some forming the Mesozoic/Tertiary sedimentary basin along the Gulf of Guinea coastline. Mafic Mesozoic dykes mostly doleritic crisscrossed all these rocks (Asare et al., 2016).

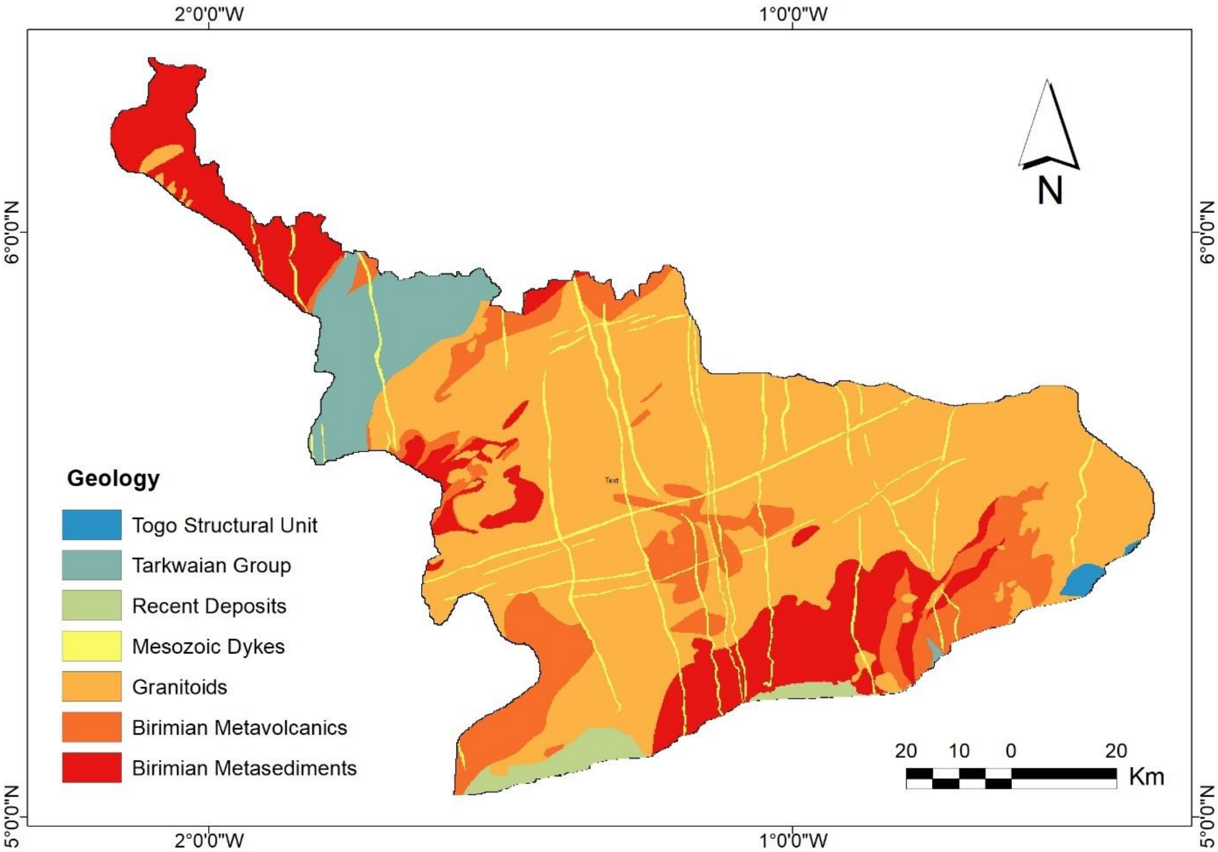


Figure 2 Geology of the Central region

## 3. Methodology

Groundwater availability is influenced by the interaction of multiple factors (Echogdali et al., 2022; Park et al., 2014). These factors include variations in lithology, slope, topographical features, soil type, drainage density, structural characteristics, the composition of the underlying bedrock, vegetation type, and land use patterns (Muthamilsevan et al., 2022). The workflow involves gathering the dataset, generating attributes to reflect the factors that affect groundwater, and merging the different attributes through the fuzzy overlay method.

A magnetic data analyzing approach, successfully used in various studies (Ilugbo et al., 2023; Muthamilsevan et al., 2022; Sultan et al., 2009; Yehualaw et al., 2023), is employed in this study to extract the lineaments of the study area. Several filters have been applied to the data to enhance it. They are Reduction to the Pole (RTP), First Vertical Derivative (1VD), Analytical Signal, and

Tilt derivative. The extracted lineaments are then associated with other geological data, which are chosen after reviewing the different variables that can affect groundwater, are integrated and processed using this combined geospatial approach. The data selected for this study comprises the fault density and the fault buffer of the region, the geology, soil type, DEM, land use land cover, drainage density, flow accumulation, and slope. Figure 3 shows the mapping approach and techniques employed in this study.

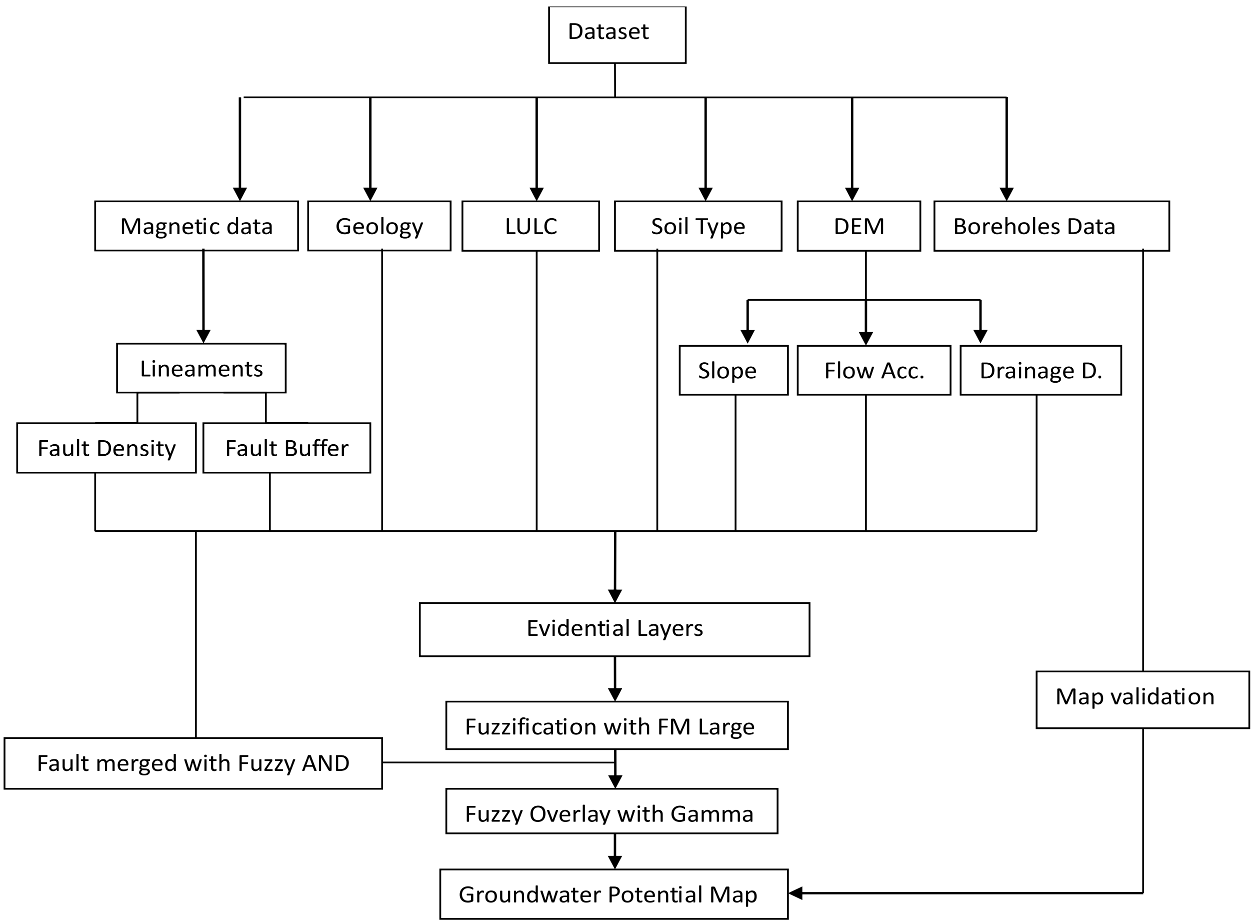


Figure 3 Study workflow

The magnetic data, soil type, land use/land cover and geology maps of the study area were acquired from the Ghana Geological Survey Authority. The magnetic data was acquired as part of a high-resolution airborne geophysical surveys of southwestern Ghana conducted by Aerodat Inc. from 1997 to 1998. A Piper Chieftan (C-FESC), a Cessna Titan 404 (C-FYAU) and a Scintrex Cesium SC-2 were the equipment used to collect the geophysical data. The Shuttle Radar Topography

Mission (SRTM) was downloaded from the United States Geological Survey (USGS) Earth Explorer in a GeoTIFF format with the images in geographic coordinate system. The downloaded SRTM DEM data was re-projected to the Universal Transverse Mercator (UTM) projection to match the study area's extent. After obtaining the raster format for all the layers, they were classified utilizing the Jenks natural classification technique. This classification is done considering the water-retention capacity of each of the attributes within the layers. The values are from 1 to 9, with high ones indicating a higher likelihood of groundwater presence.

## 4. Results

### Geology

Figure 4 a show the geological map of the Central region. From the map the granitoids which are generally impermeable occupy about 5570 $km^2$ (57%) the largest part of the study area. This result implies that 57% of the area is impermeable (if no consideration is given to any other parameters). The Metavolcanics and the Mesozoic dykes are also considered to be impermeable. They cover 1731 $km^2$ (17.8 % of the study area) and 35.28 $km^2$ (0.36% of the study area) respectively and, these rock formations are classified as being very poor for accumulation of groundwater because of the absence of primary porosity consequently low values are given to them. sandstones, phyllites and slates. These sediments group occupies about 6.75% of the study area (0.36$km^2$) and have moderate Fuzzy Membership (FM) values. The highest values go respectively to the recent deposits forming 2% of the study area (195.6$km^2$) made of series of interbedded, conglomerates, micaceous sandstones, arkose and clay, and to the Birimian metasediments occupying 1527.76 $km^2$ representing 15.72% of the study area. The Tarkwaian Group is known to be a shallow water continental origin derived from the Birimian and associated granites (Osiakwan et al., 2022). They consist entirely of conglomerates,

### Soil type

The different soils distribution is presented in Figure 4 b. A big part of the area (approximatively 49%) is covered with leptosols soil type (4782.68 $km^2$). This soil type falls on the high elevation areas of the study region, covering the granitoids. Its sandy and free-draining characteristics makes it a potential water infiltration zone, but the external characteristics associated to it can render it impermeable. Acrisols and Vertisols form the second major soil cover of the area (4169.06 km2), accounting for about 43% of the area. With the solonchaks (14.6 $km^2$ corresponding 0.15%) barely seen in the area, they are areas of least interest in terms of their capability to bear groundwater. They are attributed to the lowest FM values, which rank from 0.0003 to 0.9497. The high FM values are represented by Lixisols covering 72.6 $km^2$ (i.e. 0.74% of the region), Luvisols covering 87.16 $km^2$ (i.e. 1% of the study area) and Fluvisols covering 231.04$km^2$ (i.e. 2.37% of the region). These soil types have in common their capacity to absorb surface water but at different rates. Aeronosols soil type is also found in a small part of the study area (i.e. covering 360.04 $km^2$ which is 4% of the study region).

**Slope**

Figure 4 c shows the slope map of the study region calculated in degrees, which ranges from 0° to 18.98°. The high surface gradient (slope) zones, varying from 3.38° to 18.98°, occupy more than 600 $km^2$ representing approximately 7 to 8 % of the study area. 50% of the study region ranging from 1.34° to 3.38° and covers 4889.56 $km^2$. Low surface gradient (slope) zones vary from 0° to 1.34° and occupy 4107.08 $km^2$, which is 42 % of the region. The FM has values ranking from 0.0003 for gentle slopes to 0.9497 for the steep slopes.

The steep areas, representing the least part of the study area, indicate low groundwater prospectivity due to high runoff of surface water in those areas. Majority of the area, in terms of slope gradient, is considered to be gentle, consequently the area will have moderate runoff leading to moderate infiltration. This situation provides conditions for moderate groundwater prospectivity. The flat areas in our study area are of interest because they are favorable to water infiltration into the subsurface and can therefore, indicate high groundwater potential.

**Land use/Landcover**

Figure 4 d shows the LULC map of the study area. Among the different types of LULC in the region, moderately closed trees, a canopy with herb and bush cover dominates, covering 46.40% of the study area (4509.44 $km^2$). They also constitute the most favorable LULC type for high potential in the area. Consequently, they have the highest FM value of 0.9214. They are followed by shrub thickets with or without trees covering 104.76$km^2$ which is 1.07% of the study area, followed by closed forest, planted cover, mosaic of thickets and grass with/without scattered trees. These LULC types together constitute 18% of the area, and covers 1749.6 $km^2$. They have moderate FM values as well as the closed savanna which is barely found in the study area (6.28 $km^2$) and the moderately dense herbs/bush with scattered trees found in the center to the south of the study region and covers 3074.28$km^2$ (i.e. 31.63% of the region).

The lowest FM values are attributed respectively to grass/herb with or without trees (2.6% of the area) and the settlement areas which are concluded to be the most improbable zones to find groundwater. They cover 18.32 $km^2$ which represents 0.19% of the study region.

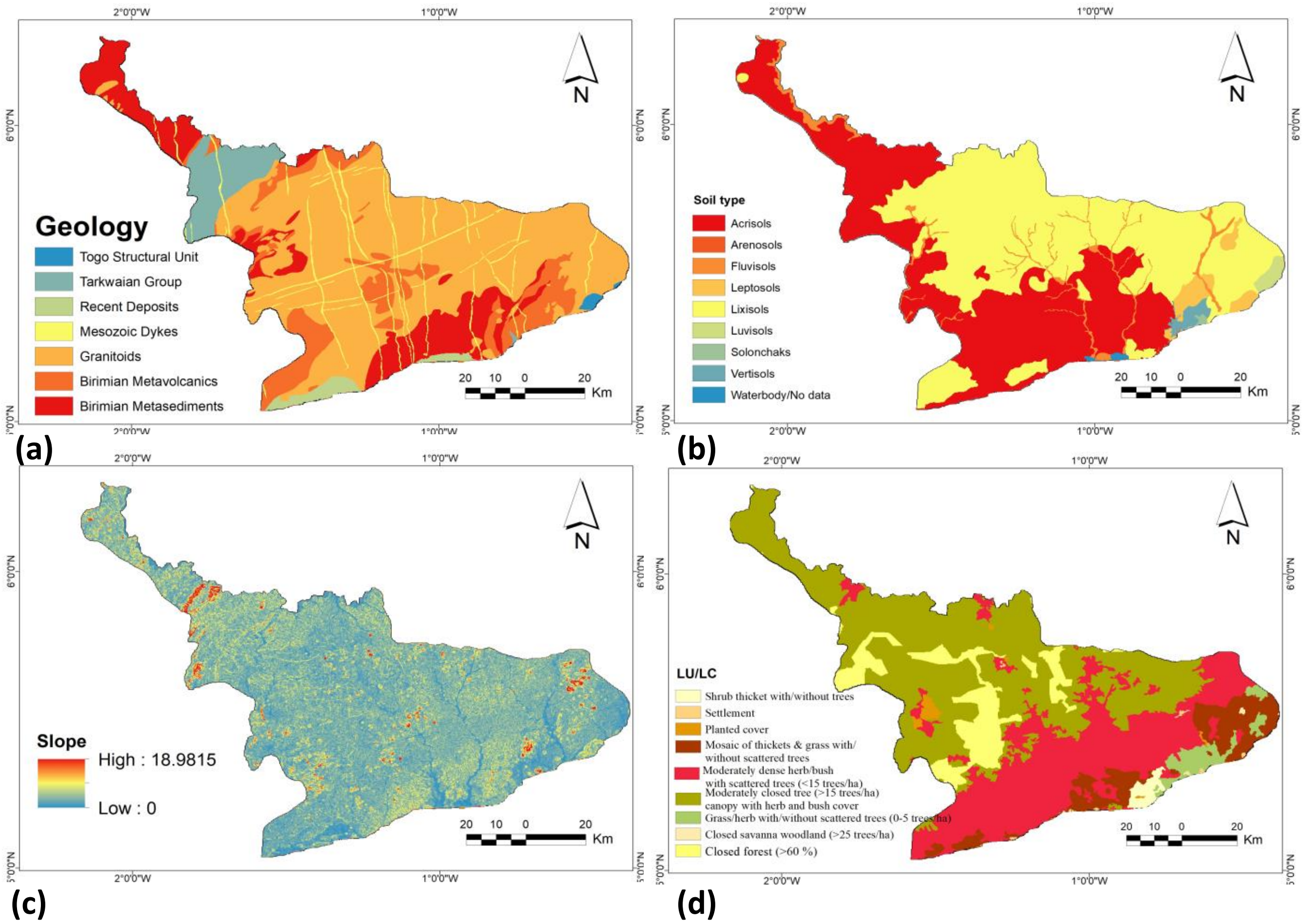


Figure 4 (a) Geology map of the study area (b) Soil type map of the study area (c) Slope map of the study area (d) LULC map of the study area

**Digital Elevation Model**

The region has ground elevation values ranging from -2 m to 380 m (Figure 5 e). Areas with ground surface situated at lower elevated areas range from -2 m to 89 m above the sea level. They account for 39.5% of the study area (more than 3900 $km^2$). They represent the areas with high potential due to high groundwater holding times that enhance the opportunity for higher recharge of groundwater. These zones are encountered in the eastern part of the study region.

Groundwater flows from high contours to lower contours due to higher elevated areas promoting higher runoff of rainfall water. The high elevations are mainly found in the center and northern part of the study region varying from 380 m to 133 m. They account for 26.8% of the study area (2639.24 $km^2$), representing a smaller portion compared to the low-elevation areas. The remaining 33.26% is considered to be moderately elevated and covers around 3281.12 $km^2$. Therefore, relatively higher FM values correlate to the area with elevation inferior to 89m.

**Drainage density**

The drainage density of the study region varies from 0 to 1.099 $km^{-1}$. After classification (Figure 4 f), it is noticed that a large portion of the area falls in the range of 0 to 0.215 of drainage density values, accounting for more than 5900 $km^2$ of the study, which represents approximately 60% of the study region. Also, drainage density values ranking from 0.295 to 1.08 meters occupy a smaller part of the study region covering 2578 $km^2$ (i.e. 26% of the study area). The moderate drainage values occupying 16% of the study area (1382.52 $km^2$) rank from 0.215 to 0.295 meters.

The predominance of low drainage density values in the study zone suggests a lower presence of subsurface waterways compared to other regions. These areas tend to have limited runoff, increasing the potential for infiltration and making them favorable for groundwater occurrence. The maximum and minimum FM values observed within the study area are 0.0003 and 0.9497, respectively.

**Flow accumulation**

Figure 5 g illustrates the flow accumulation pattern of the study region. Areas likely to accumulate the maximum of water cover 7086 $km^2$ which represents a large portion of the study region (72%). The remaining part of the study area is divided as follows: moderate flow accumulation area (624.2 $km^2$, which is 6.32% of the study area), followed by low flow accumulation area (2153.4 $km^2$, which is 21.8 % of the study area.).

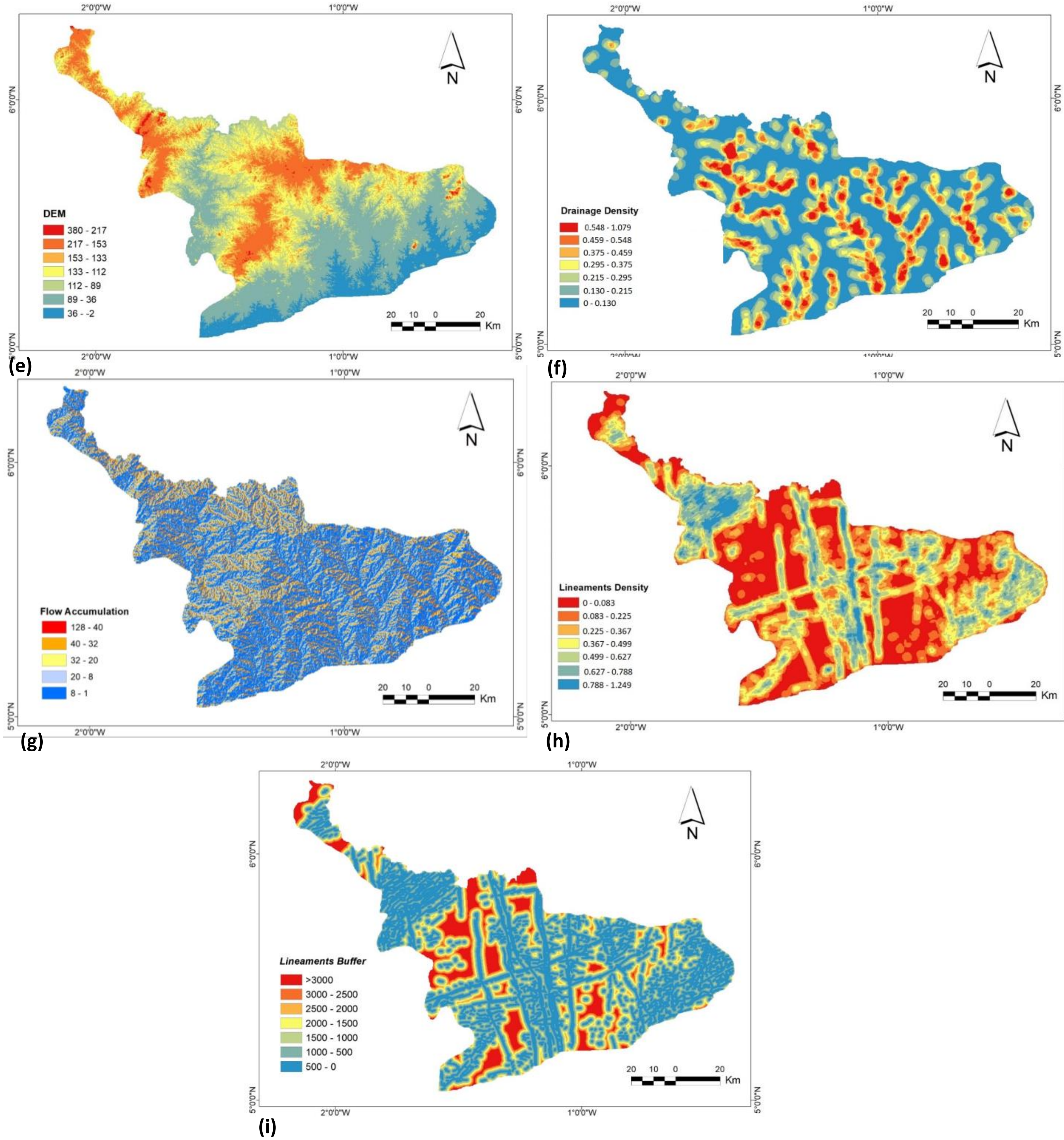


Figure 5 (e) DEM map of the study area (f) Drainage Density map of the study area (g) Flow accumulation (h) Lineaments Density map of the study area (i) Lineaments Buffer map of the study area

**Lineaments density**

The areas that can indicate potential groundwater occurrence cover about 2131 $km^2$ which is 12.32% of the study region and are characterized by high lineament density. They are found along the Mesozoic dykes, in the Birimian metavolcanics and the Tarkwaian (Figure 5 h). The rest of the study area varies from moderate, covering 2840 $km^2$ (28.79%), to low lineament density values 5808 $km^2$ (58.89%).

The high lineament density showcases the most probable areas for surface water to infiltrate. However, overlaying with the various other layers is essential to understand the behavior of water in the other zones in the study region. The values, after conversion, rank from 0.0003 for the areas of least interest to 0.9497 for the areas considered to have high groundwater potential.

**Lineament buffer**

The proximity to lineaments goes from 0 to >3000 m as shown in Figure 4 i. A vast part of the study region (7428 $km^2$) was ranking from 0 to 1500 m away from the lineaments. Due to their proximity to the lineaments, these proximal areas represent areas of interest. They are followed by 1500–2000 m (778 $km^2$), 2000–3000 m (895 $km^2$) and >3000 m (763 $km^2$). The FM map spatial distribution values range from 0.006 to 0.921 in the zone (Figure 4.24). Areas closer to the lineaments are consequently those with the higher membership values allocated as recharge is possibly high more than the areas located at long distance from water sources.

**Groundwater Potential map**

The overlay process of the nine layers was then carried out in ArcMap 10.8 as a summation of their effective influence based on their criterion scores. The result is a groundwater potential map of the Central region shown in Figure 6. The map was classified into four classes utilizing the function of natural break Jenks in ArcGIS. Generally, the high groundwater potential zones tend to follow the structures present in the region. They are mostly situated in the central part of the region which is mainly occupied by granitoids rock types. Granitoids in general have very low primary porosity hence are not suitable for water infiltration. This study, in addition to rock types take into account the structures in the study region and seven other layers. The high prospectivity area was characterized with high lineament density, high proximity to the lineaments and also suitable LULC type for water infiltration. The least potential areas are mostly situated in the south eastern part of the region but are also found in the central and northern part of the region and fall mainly on metavolcanics rocks. The central region lineament map shows highly fractured aspect of the region. Based on that, the region can be classified as being high in groundwater potential. The result of this study demonstrate that the region is suitable to be classified as a region with high groundwater potential. This shows the importance of incorporating various and accurate layers likely to affect groundwater occurrence in a particular region. The choice of the thematic layers should be based on the geology and hydrogeology parameters of the investigated study area.

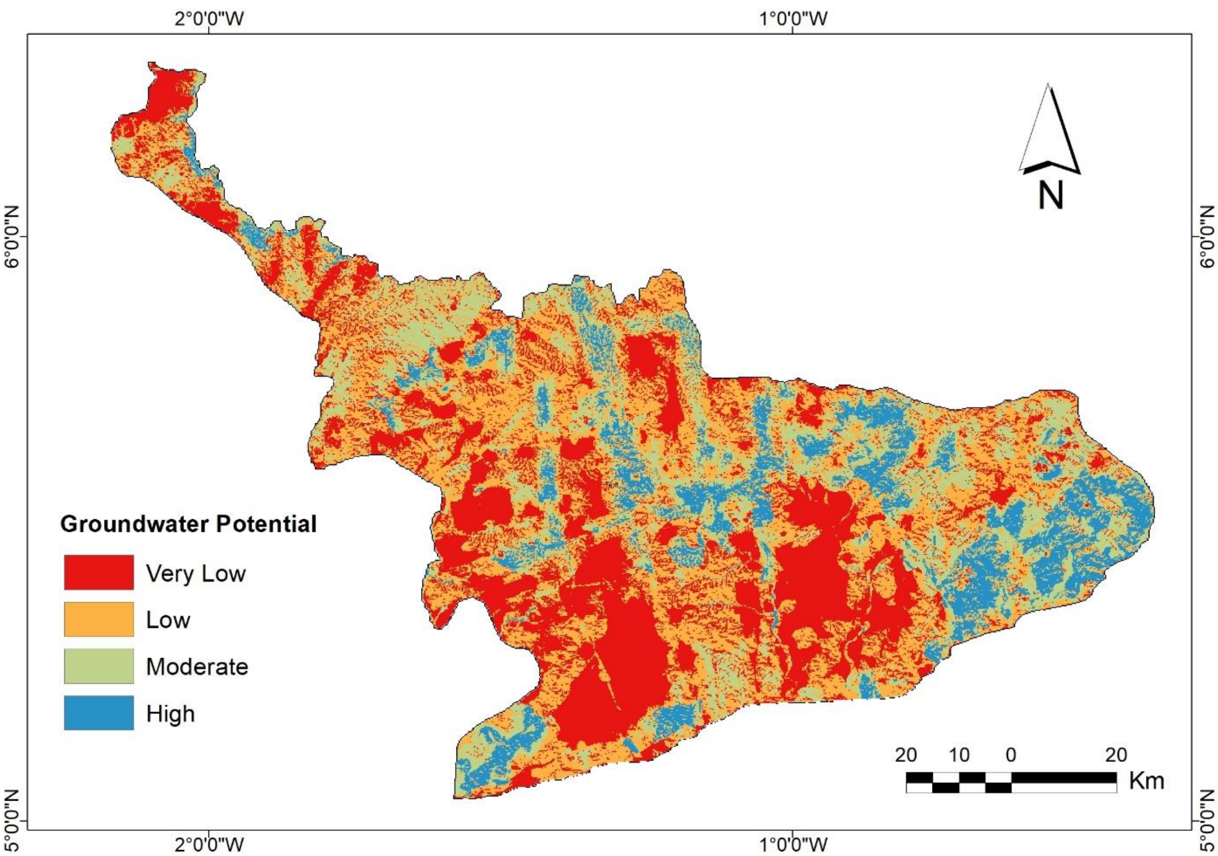


Figure 6 Groundwater potential map

**Validation**

Validation of the final output is crucial when it comes to mapping groundwater potential. One commonly used approach is to interpolate the boreholes yield onto the groundwater map (Echogdali et al., 2022; Githinji et al., 2022; Osiakwan et al., 2022). This not only provides insights into the accuracy of the employed method but also helps identify highly suitable areas based on groundwater presence and yield. In this study, this approach was utilized to validate the obtained groundwater potential map. The obtained map was validated using a set of 104 boreholes with yields ranging from map 0 (dry) to 100 L/min. About five of the boreholes exhibit high yields (61-100L/min). An interpolation of the boreholes on the potential map revealed that these five boreholes coincide with the area captured by the map as high to moderate for groundwater potential (Figure 7). Few boreholes (seven) yielding from 33-60L/min also fell on moderately potential areas. The majority of the boreholes yield from 32-0 L/min and mainly fell on low to very low potential areas.

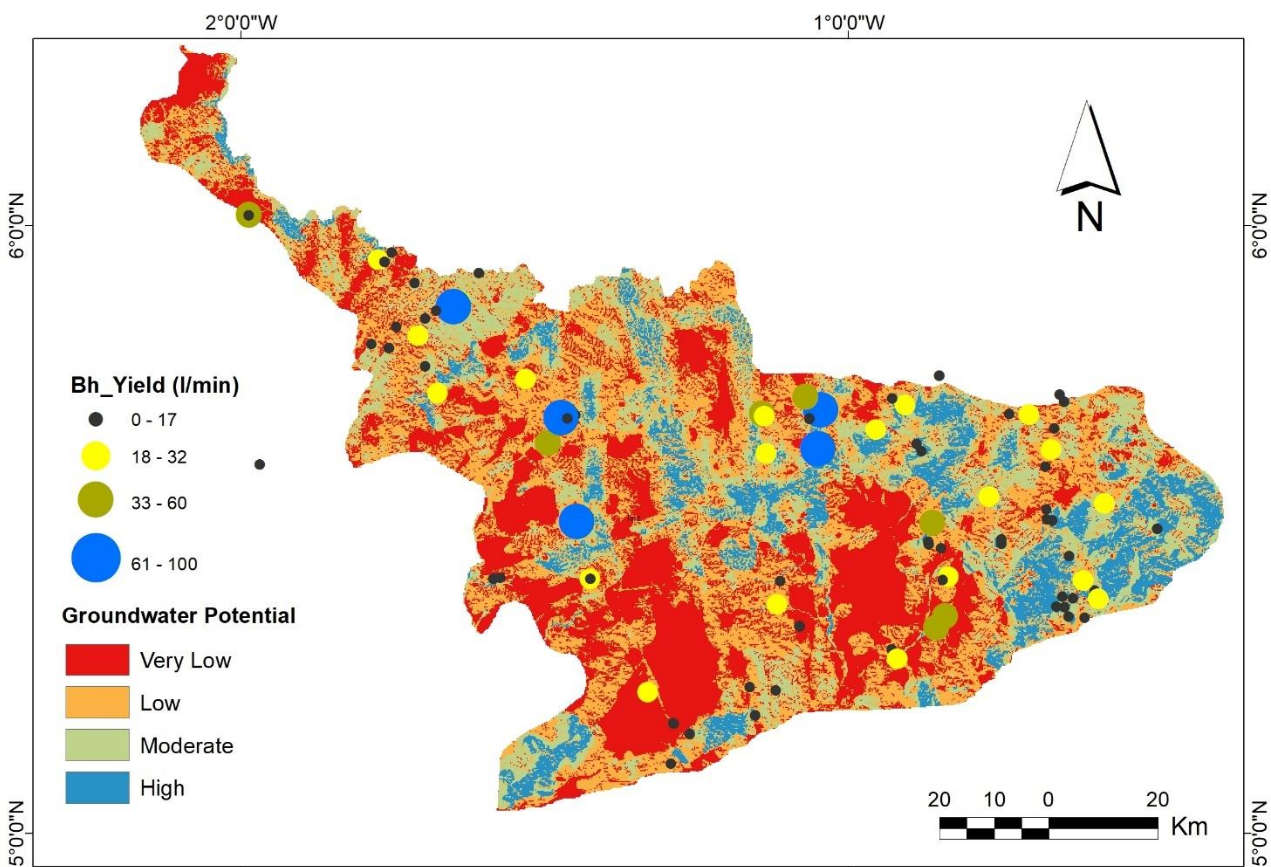


Figure 7 GWP and Boreholes map

The general agreement between high-flow boreholes with high potential values in the map imply reliability of the methodology used in this study. The receiver operating characteristics (ROC) was employed to assess the precision of the produced map. It is effective for arranging classifiers and displaying their effectiveness. Furthermore, it aids in evaluating and comparing algorithms by determining the area under curve value (AUC) (Githinji et al., 2022). The AUC curve demonstrates how well an algorithm can differentiate between classes in a binary problem by showcasing the diagnostic ability of a binary classifier system across different discrimination thresholds (Gómez-Escalonilla et al., 2022). The ROC/AUC operation revealed the satisfactory result of 61% of the final output (Figure 8).

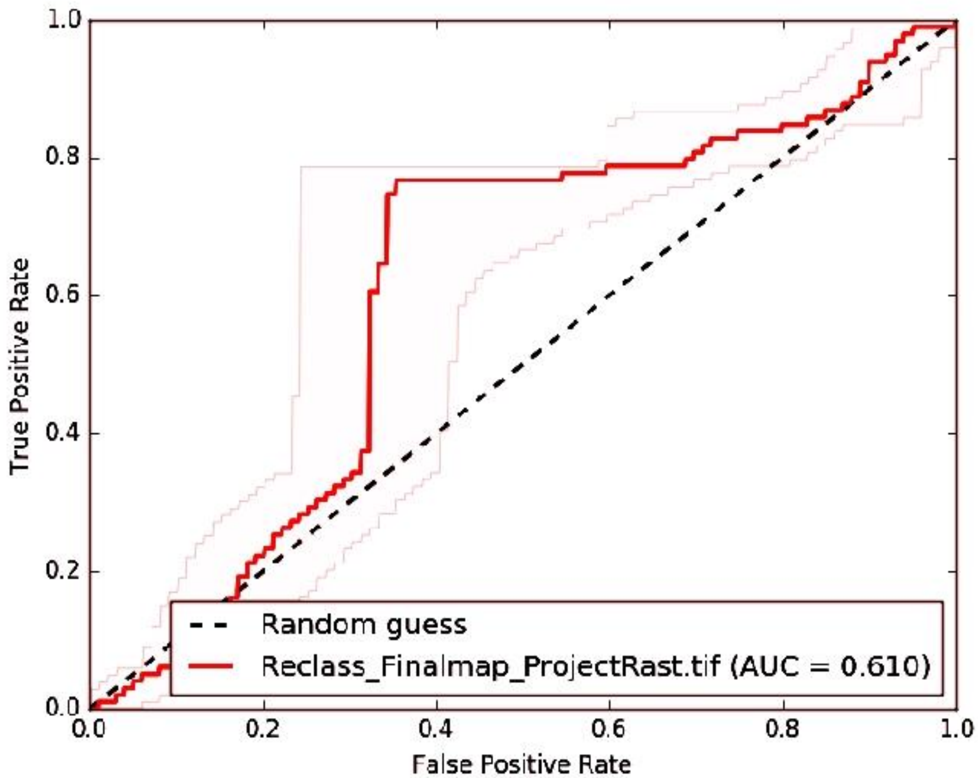


Figure 8 ROC/AUC curve

## 5. Discussion

In this research, the integration of variables using remote sensing data in the GIS environment is a very useful, time, and cost-effective tool as compared to techniques involving measurements taking over very large areas such as done by Ewusi & Kuma, (2011) in the Central region. Groundwater occurrence is controlled by the interaction of a set of various factors related to structural, geological, geomorphological, hydrological and hydrogeological conditions of an area (Echogdali et al., 2022). In the Central region the main factor controlling the occurrence of groundwater is found to be the lineaments due to the absence of primary porosity (A. Asare et al., 2021). Literature revealed that studies that attempt to map groundwater in the Central region neglected this important factor (Gumma & Pavelic, 2013; Osiakwan et al., 2022). This study provides a new framework integrating this variable with other relevant ones to accurately map the groundwater potential of the study area. Another particularity of this study is the dissociation of Geology as input variables from lineaments. Geology of an area is a very important component when it comes to the occurrence of groundwater. This study used the geology factor to generally investigate the area for suitable geological formations where infiltration can occur while lineaments factor was utilized as an independent factor for details about secondary porosity, dissociating the two different variables.

In this study we proved that the integration of different factors is crucial for delineating groundwater zones because the occurrence of groundwater is a result of the interaction of different factors. Based on the scores assigned to the attributes of each of the variables, the best groundwater retention areas were selected and integrated in the GIS software using the Fuzzy Logic algorithm. This also shows that for accurate results, integration of the maximum factors possible each being important, is crucial for accuracy of the results.

The groundwater recharge potential map produced in this study can serves as resource information database for decision-making processes, water resource managers, and policymakers. Along with other thematic maps such as climate related variables, hydrogeological parameters the produced map can be updated for a better accurate outcome.

## 6. Conclusion

The main goal of this research was to create a comprehensive map of the groundwater distribution in the Central Region. To achieve this, various evidential layers controlling groundwater occurrences derived from geological and geophysical datasets were integrated based on their weighting. One of the key techniques employed was lineament extraction using magnetic data later utilized to create the lineaments density and the lineament buffer maps. In addition to the lineament data, seven other thematic layers were incorporated into the analysis. The layers included geology, slope, drainage density, DEM, soil type, land use land cover and flow accumulation. Each of these layers was classified based on their ability to bear groundwater, with high and low values being assigned accordingly. To further refine the results, the obtained map was reclassified within the Fuzzy environment using the GIS software. This step was crucial as it allowed the map to be used in the overlay function of the Fuzzy algorithm. The values in the map were ranked on a scale from 0 to 1, indicating the relative groundwater potential across the study region. By overlaying the various layers utilizing the fuzzy gamma function, the final groundwater potential map was generated classifying the potential into four different classes: high, moderate, low and very low. Interestingly, the analysis revealed that approximately 68.5% of the study region falls under areas having low to very low potential classes. To validate the accuracy of the map, borehole data was used. This comparison helped confirm the reliability of the approach utilized in this project, which is a commonly employed method in similar studies.

Overall, this project successfully mapped the potential of groundwater of the Central Region using a combination of geological and geophysical techniques. The resulting map gives valuable information into the availability and classification of groundwater potential in the region, which can greatly be useful in informed decision-making and sustainable water resource management.

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