Global Research in Environment and Sustainability
April 2023, Vol. 1, No. 2, pp. 17-34.

Dynamics of Groundwater Resources of Upper Benue River Basin, Nigeria

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Abstract:
This study has examined the dynamics of groundwater resources of Upper Benue River Basin in Nigeria. The study adopted field survey design using both primary and secondary data. Data on groundwater such as geo-location, depth of water table and season of the year) was acquired from Upper Benue River Basin Development Authority (UBRBA) office in Yola, Adamawa State, and State Water Agencies of Plateau, Taraba, Bauchi and Borno States. Geospatial techniques were used to delineate the groundwater potential zones of the basin area. The findings of the study reveals that a larger portion of the basin area has low Ground Water Potential (GWP) (44,488.4 Km2) while the poor GWP covered (42,926.5Km2), moderate GWP was 25,732.6 Km2 and high (GWP) potential covered 11,417.3Km2. The result of the findings shows that areas of high GW potential have the least coverage while areas of low and poor GW potential had the highest areal coverage. The findings of the study reveal that the predicted groundwater depth has minimum range of 42.3m - 52.7m while the maximum range is 75.8m - 83.3m. The result shows that the water table depth is lowest at the southern part of the basin, while the northern area has high depth or lower water table heights. This reveals that access to ground water resources is relatively better in the southern part of the catchment as it coincides with the pattern of climatic variables spread across the area. Climate variability will affect the status of ground water significantly in the next 50 years and negatively impact availability and access in the basin. Based on the findings, the study recommended deliberate policy to protect the land and conserve vegetation in the basin and establishment of groundwater gauging station to help in monitoring the ground water level.

Keywords: Climate variability, Groundwater, River Basin, Upper Benue & Watershed.

INTRODUCTION

Groundwater is the critical underlying resource for human survival and economic development especially in extensive drought-prone areas of south-eastern, eastern and western Africa. Groundwater is the largest and most important water resource in Africa (MacDonald, Bonsor, Dochartaigh, & Taylor, 2012). It is often more reliable, in closer proximity to users, less vulnerable to pollution, and more resilient to climate variability than surface water (McDonald et al., 2011; Lapworth et al., 2017). Access to safe and reliable water is critical for improving health and livelihoods for low-income communities in Africa and elsewhere globally (Hunter, MacDonald, & Carter, 2010). It is estimated that about 100 million rural populations throughout Sub Saharan Africa are serviced by groundwater for domestic supplies and livestock rearing (Adelana & MacDonald, 2008; MacDonald *et al*., 2012), with most of the villages and small towns having access to groundwater supplies (Masiyandima & Giordano, 2007; Pavelic *et al*., 2012). Groundwater development has tended to flourish most in the drier western, eastern and south eastern parts of Africa, where annual precipitation is less than 1,000 mm yr-1 (Brown, Demargne, Seo, & Liu, 2010; Foster, Tuinhof & Van Steenbergen, 2012).

Water resources in Nigeria are already under stress and the country is slowly becoming a water-scarce nation. According to Population Reports of 1998, water is an essential and necessary natural resource, and its shortage puts human society at risk and under stress. Without responsive water development, lengthy and extreme droughts, seasonal volatility in rainfall, and resource degradation, growing water scarcity is projected to worsen under population pressure (Adesina & Odekunle, 2011; Adejuwon & Adelakun, 2012). Nigeria is among the 48 countries expected to face water shortage by the year 2025 (Population Reference Bureau, 2007). With an estimated population of 111.7 million people in 1995, the water per capita in Nigeria stood at 2,506 m3 yr-1. The per capita water availability is expected to drop to 1,175 m3 in 2025 with a projected population of 238.4 million people (Population Reference Bureau, 2000). Water stress, or a lack of sufficient per capita available freshwater, has a significant impact on communities including the Upper Benue River Basin (Ojeh & Semaka, 2021). Water stress can occur as a result of abuse of available freshwater resources or a decrease in the amount of available water as a result of decreased rainfall and stored water supplies (Parish et al., 2012). Rapid urbanization is straining urban water resources (Bandari & Sadhukhan, 2021), and this is evidence in the study area. Shortages of water could become a major obstacle to public health and development. Thus, the need for integrated water management to safe guard the future is paramount.

The degree of water stress experienced is further threatened by the vagaries of climatic variability. In its Fourth Assessment Report, the Intergovernmental Panel for Climate Change (IPCC) project that Africa will be disproportionately affected by climate change (Bates *et al*, 2008). The projected warming in Africa is 1.5 times the global average (Taylor, Koussis & Tindimugaya, 2009). The availability and sustainability of groundwater in many aquifers in Nigeria, like many principal aquifers around the world (US Geological Survey, 2009; Brekke et al., 2009; Alley et al, 2002), may be under threat in the next few decades because of depletion of the resource imposed by human and climatic stresses.

Increased variability in precipitation and more extreme weather events caused by climate change can lead to longer periods of droughts and floods, which directly affects availability and dependency on groundwater (Watson et al., 1998; Lehner *et al*.,2006). In long periods of droughts there is a higher risk of depletion of aquifers, especially in case of small and shallow aquifers. People in water-scarce areas will increasingly depend on groundwater, because of its buffer capacity (Lehner *et al*, 2006).

The Benue River basin which originated from the Mandara mountains in Cameroun is the major tributary of the Niger River (it empties its water into the Niger at Lokoja where confluence is formed). The major tributaries of the Benue River in Nigeria are Rivers Katsina-Ala, Donga, Taraba, Gongola and Pai (Nkeki, Henah, & Ojeh, 2013; Evans & Sunday., 2018; Usman et al., 2019). Though most studies have concentrated on the geomorphological characteristics (Overare et al., 2015; Ezekiel et al, 2015; Adebola et al, 2018), while several other studies have focused on the flooding implication (Tanko & Agunwamba, 2008; Nwilo et al, 2012; Izinyon and Ajumuka, 2013; Bello & Ogedegbe, 2015), less focus has been on the ground water potential of this significant region.

Although groundwater plays a large role in supporting social and economic development in the study area, the water resource-base is far from being adequately understood. There is a lack of systematic data and information on groundwater across Sub-Saharan Africa, with studies occurring on an ad-hoc basis without strategic oversight or coordination. The Upper Benue River

Basin (UBRB) in Nigeria lies in the semi-arid regions of the country which represent areas of significant water shortage amidst growing demand and diverse uses. The basin also suffers from occasional drought over the years. In most situations, groundwater monitoring in the basin is limited or non-existent. Furthermore, despite the huge number of wells drilled each year, groundwater monitoring systems for obtaining, compiling, and analysing information have failed in various sub regions in several nations (Allaire, 2009; Foster & MacDonald, 2014) leading to losses on the huge amount of money invested to drill such wells and boreholes since it failed to yield the relevant information for research, policy and socio-economic development. It is against this background that this study examines the dynamics of groundwater resources of the Upper Benue River Basin in Nigeria.

DESCRIPTION OF STUDY AREA

The Upper Benue River Basin, which crosses seven states of the Nigerian Federation (Adamawa, Gombe, Bauchi, Plateau, Yobe, Borno and Taraba State), is situated between latitudes 6°29′N and 11°46′N and longitude 8°55′E and 13°30′E. The basin spans 480 kilometers from West to East and 532 kilometers from north to south. The basin spans 154,328.9 km2 of land. Upper Benue River Basin is bounded to the north by Lake Chad basin, to the east and south by Republic of Cameroon, and to the west by Lower Benue and Upper Niger basins. The Upper Benue River Basin falls under the jurisdiction of the Upper Benue River Basin Development Authority (UBRBDA) which is an agency of the Federal Government of Nigeria created in 1976 for the management of the water and agricultural resources of the country (Adebayo, 1997). The UBRBDA authority also performs other tasks to raise the living standards of rural residents in the basin, such as building dams and boreholes and processing and selling agricultural products there.

The river Benue, which originates in the Adamawa Plateau in northern Cameroon and runs south-west to meet the River Niger in Lokoja, is the principal river in the basin. The Gongola River, the Mayo Kébbi, the Taraba River, and the river Katsina-Ala are among the important tributaries that join the river Benue (Nkeki, Henah, & Ojeh, 2013). The Upper Benue River Basin has a dendritic drainage pattern and is a seventh stream order system (Odiji *et al*., 2021). The basin's qualities give it a special capacity for ground water and enable it to adjust to climatic changes.

The Upper Benue River Basin falls within the tropical continental climate type with distinct wet and dry seasons. The dry season runs from November to April, whereas the rainy season lasts for around six months (May to October) (Umar, 2006). The mean annual rainfall in the basin area varies from 2000 mm in Gembu (on the Mambilla plateau) in the south to 800 mm in Nafada in the northern part of the basin area (Adebayo,1997). As a result, rainfall decreases from south to north along the latitude, giving the southern portions of the basin more rainfall than the northernmost portions (Umar, 2006). This pattern is also followed by decrease in length of rainy season northward with a difference of about 170 days between the southern and the northern parts of the basin (Adebayo, 1997).

Due to the existence of harmattan winds that blow from the interior of the continent, the Upper Benue River Basin experiences seasonal temperature variations as well. The hottest month is April, while the coldest month is December or January with a mean temperature of approximately 17^{o}C.

On the other hand, due to the influence of the region's high altitude, the southernmost half of the basin has relatively low temperatures throughout the year.

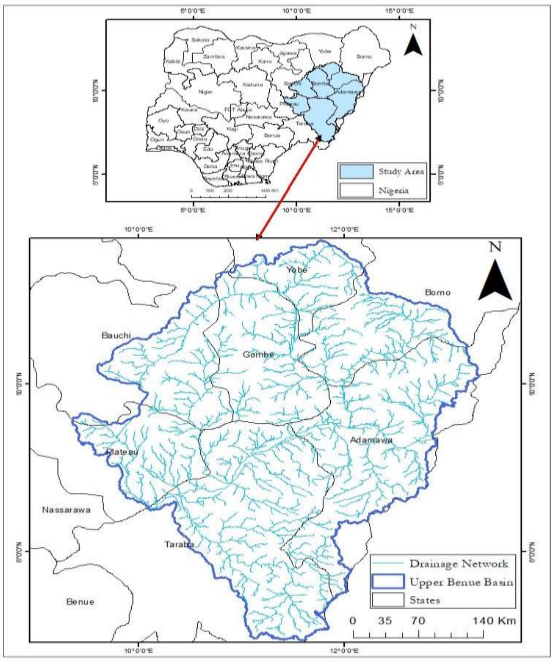

Figure 1: Map of the Study area

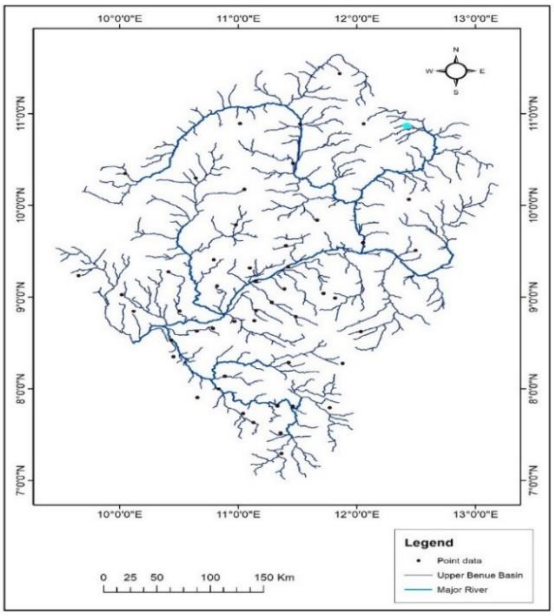

Fig. 2: Water Table data point of the study area

MATERIALS AND METHODS

This study used the field survey research design. This design allows for the collection of quantitative data and subjected to rigorous statistical analysis. This study made use of both primary and secondary data to achieved the set objectives. The primary data used include depth of water table and geographical coordinate of identified wells and borehole in the study area. The secondary data include published journals, books, online materials and archival records of government Ministries and parastatals. The data on the groundwater depth (the geo-location, depth to water table and the season of the year) was acquired from Upper Benue River Basin Development Authority (UBRBA) in office in Yola, Adamawa State, and State Water Agencies of Plateau, Taraba, Bauchi and Borno States. These agencies have partial data covering some part of the basin where they are located, thus, the data collected from all the sources were integrated to cover the entire basin. During the field survey, 32 boreholes and 19 wells were identified (fig. 2), their depth and coordinates measured. Geospatial techniques were used to delineate the groundwater potential zones of the basin area. The results of the study are presented in the form of maps, graph, and tables where appropriate. Maps were mostly chosen because it is best suited in presenting spatial relations of hydrogeomorphic characteristics.

RESULT OF THE FINDINGS

Ground Water Potentials of the Upper Benue River Basin

This section highlights the factors leading to ground water potential and recharge within the study area. The various factors are rainfall, temperature, elevation, slope, drainage density, lineament density, soil types and the landuse/landcover as presented in figs. 3 -16. As input to multicriteria analytic function, thematic maps of the various environmental variables considered were generated from the various data sources employed. The maps were further reclassified ranked according to the outcome of the AHP. The thematic and reclassed layers is presented subsequently.

Precipitation

The importance of precipitation to ground water potential cannot be overemphasized. The rainfall variation for the years considered has been presented in fig. 3 and for the purpose of further analysis, the result was reclassified as presented in fig. 4. From fig. 3, it is seen that the Southern part of the catchment experiences the highest amount of rainfall followed by moderate rainfall in the central part of the study area which spans across the East and West areas. The Northern part has very low rainfall regime. The result of the study agrees with Jan, Chen and Lo (2006) which showed that residual groundwater level, was found to linearly depend on the effective accumulated rainfall amount. Similarly, the result is in agreement with the findings of the study by Wotany *et al* (2021) which established the link between rainfall and groundwater recharge in the Rio del Rey Basin in Cameroon and posited that the isotopic similarity between groundwater and June - August rains suggest a significant recharge during this period and therefore a strong determinant of level of recharge.

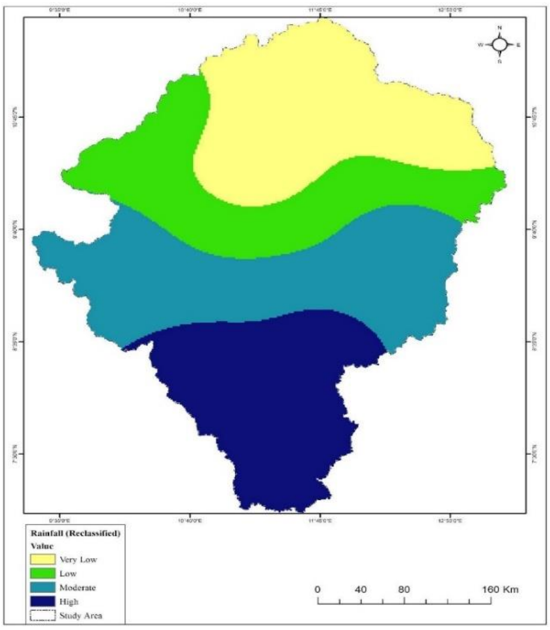

Fig 3: Rainfall Reclassified Map of the study area

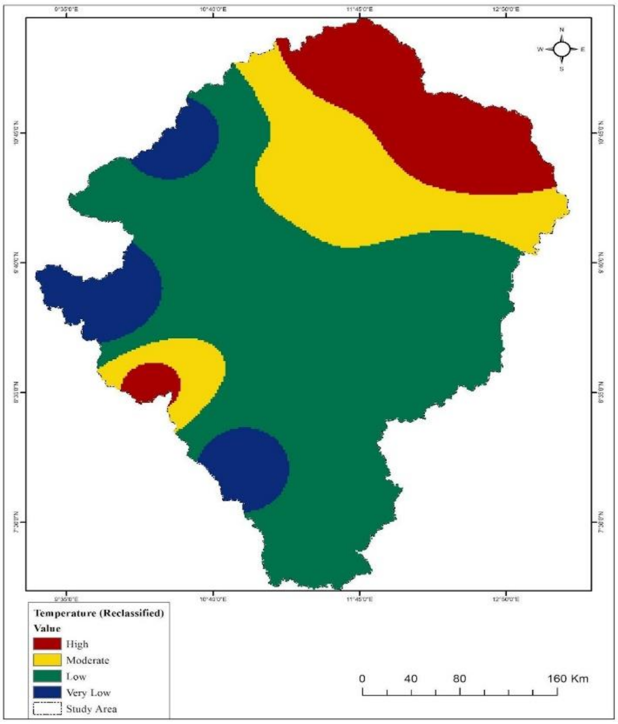

Fig 4: Temperature Reclassified Map of the study area

Temperature

As a contributor to hydrologic cycle, the temperature variation for the years considered has been reclassified as presented in fig. 4. From fig. 4, a major part of the study area has low temperature, the Northern part of the catchment area majorly has high temperature, while few areas have moderate or very low temperature. The areas of the basin with very low and low temperature are attributed to the presence of water body and parches of vegetation around the axis since these has the potential to moderate land surface temperatures. The areas with moderate and high temperature at the southwestern part of the map are areas with bare surface interspersed with rock outcrops as these could absorb so much heat with slow ability to release such heat. An *et al* (2015) observed that there is a high-temperature anomaly around the basin-bottom stagnation point where two flow systems converge due to a low degree of convection and a long travel distance, but there is no anomaly around the basin-bottom stagnation point where two flow systems diverge. In the complex basin, there are also high-temperature anomalies around internal stagnation points. Temperature around internal stagnation points could be very high when they are close to the basin bottom (An *et al*, 2015).

Elevation

The elevation of the Upper Benue River Basin is presented in fig 5.

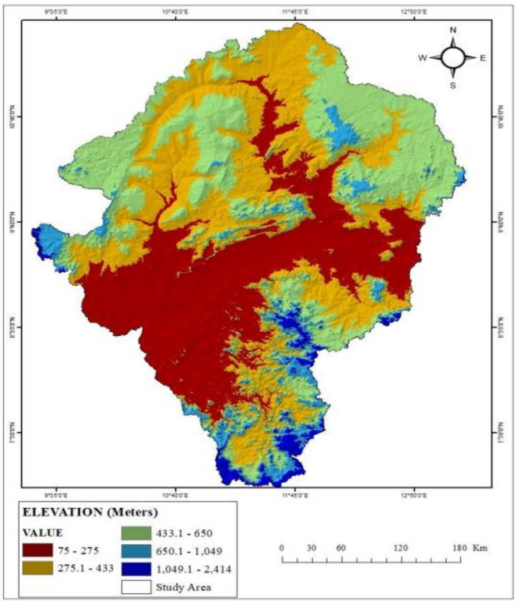

Fig. 5: Elevation Map of the Study area

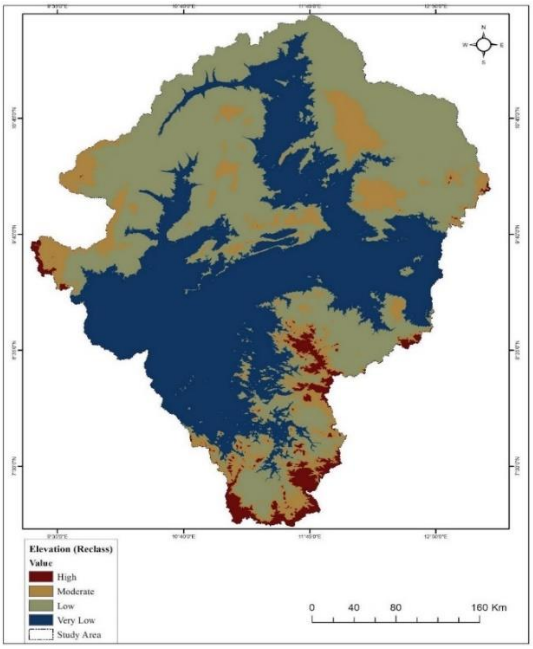

Fig 6: Elevation Reclassified Map of the study area

From fig. 5, it was observed that the lowest elevations occur in the mid-eastern to western part and high elevations in the south-eastern part and north-eastern montane flank. High elevations do not favour groundwater recharge compared to low elevations. The elevation of the study area ranged from 75m to 2414m. However, the adjoining areas around most part of the southern end of the basin with higher elevation are indicative of the numerous mountain ranges surrounding the basin such as the Mambilla and Biu plateaus. For the ease of further visual interpretation, the elevation map was further reclassified and presented in fig. 6 as it relates to groundwater potential of the basin. Fig. 6 reveals four classes of elevations which were made with their respective weight according to their effects on groundwater potential in the basin. Here, the lower the elevation, the higher the potential for groundwater recharge and on the other hand, the higher the elevation, the lower the ground water potential. Groundwater is affected by multiple factors such as land use, slope, lineament and elevation (Maqsoom *et al*, 2022)

Slope

The nature of slope directly influences infiltration and runoff. Steeper slopes result in lesser recharge due to high runoff, so it does not have sufficient time to infiltrate the surface and recharge the saturated zone. On the other hand, gentle slopes allow for infiltration and lesser runoff velocity. Figs 7 and 8 shows the slope values and reclassification map of the slope respectively.

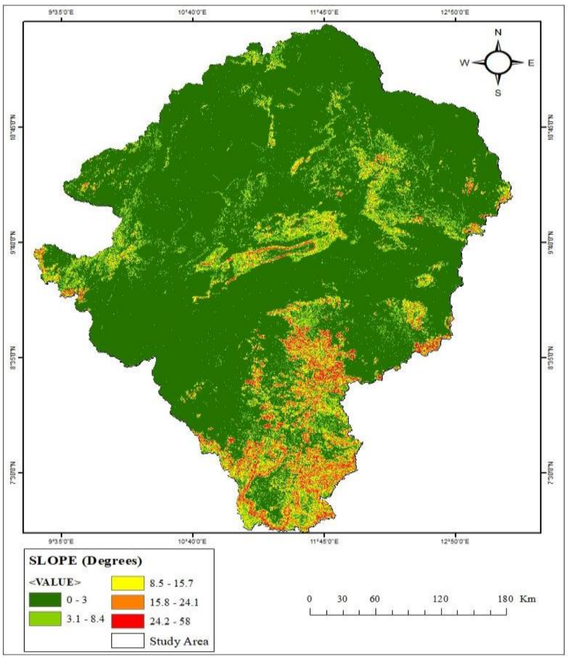

Fig 7: Slope Map of the Study area

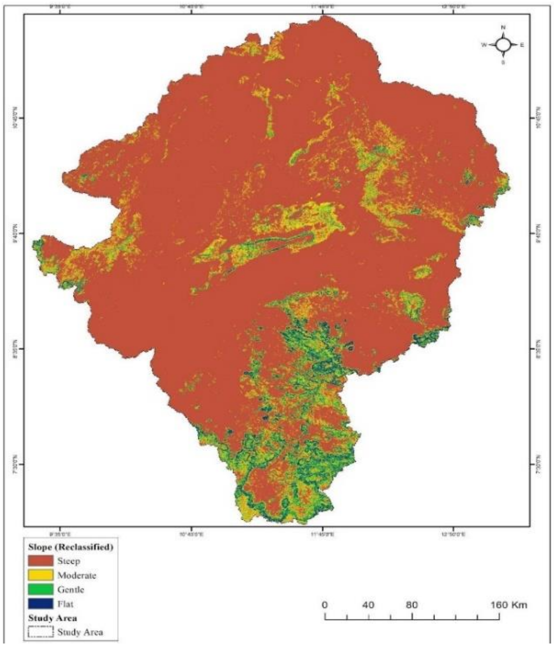

Fig 8: Slope Reclassified Map of the Study area

From fig. 7, the values of the slope ranged from 0-3 to 24.2 - 58 degrees. Between the lowest and highest values, the slope was classed as 3.1 -8.4, 8.5 -15.7, 15.8- 24.1 degrees respectively. For the purpose of better visual interpretation, the slope of the basin was reclassified as presented in fig. 8. In the reclassified map in fig. 8, it shows that a vast portion of the study area is steep with few areas being moderate and gentle, while relatively lesser portions of the land are flat. This implies that water will flow from the northern part of the basin with steep to gentle slope to the southern part which are relatively flat or undulating in nature.

Drainage Density

The drainage system of the study area was observed to be structurally influenced by the terrain. Dendritic patterns were obvious in the outcrops while parallel was common in the gentle slope in the lowlands. Figs. 9 and 10 shows the drainage density pattern of the study area and reclassified values accordingly. Drainage density refers to the proximity of stream channels and a measure of the overall length of the stream segments per unit area (Magesh *et al*, 2011). Drainage density is inversely proportional to the groundwater infiltration, thus a vital index in delineating groundwater recharge potential. The result of the findings of this study agrees with that of Abdullateef *et al* (2021) whose assessment of recharge zones in Bauchi revealed that a high percentage of the southwestern part of the study area are characterized dominantly by poor groundwater recharge potential, attributable to high elevations and impervious rock outcrops with associated steep slopes, thus limited infiltration owing to the high velocity of runoff.

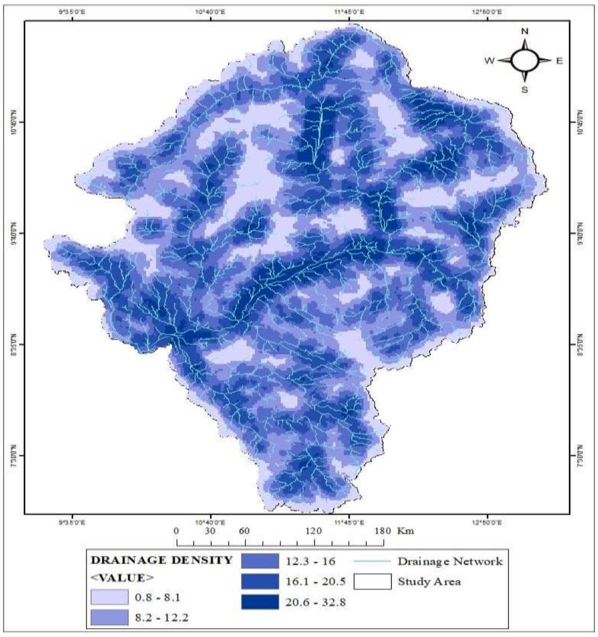

Fig. 9: Drainage Density Map of the Study area

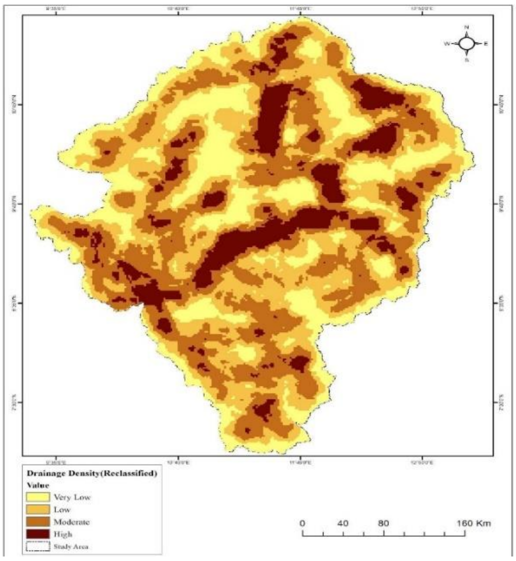

Fig. 10: Drainage Density Reclassified Map of the Study area

The result of the findings in Fig 9, while depicting the hydro-morphology, the ranges for drainage network concentration by area was classified into 0.8 -8.1, 8.2-12.2,12.3 -16, 16.1 - 20.5, 20.6 - 32.8 measured as length of channels per area (Km/Km^2). As shown in Fig. 10, the values of the drainage density are reclassified to reflect the levels of density as a factor of ground water potential. Here, the areas with high density will positively contribute to the recharge rates while lower drainage density will imply lesser ground water recharge rates. The suitability of groundwater potential zones is indirectly related to drainage density because of its relationship with surface runoff and permeability (Murasingh & Jha, 2013).

Lineament Density

Usually, lineament density represents a measure of quantitative length of linear feature per unit area which can indicate groundwater recharge potential, as the presence of lineaments usually indicates levels of permeable zones. Figs. 11 and 12 reveals the spatial variation in lineament density and reclassified map of same values. Areas with high lineament density are good for groundwater potential zones (Haridas *et al*, 1998).

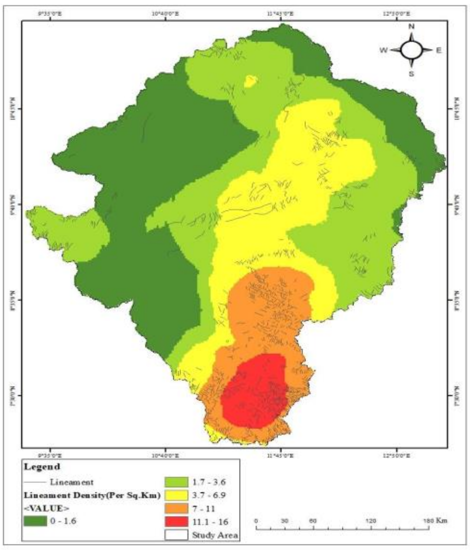

Fig. 11: Lineament Density Map of the Study area

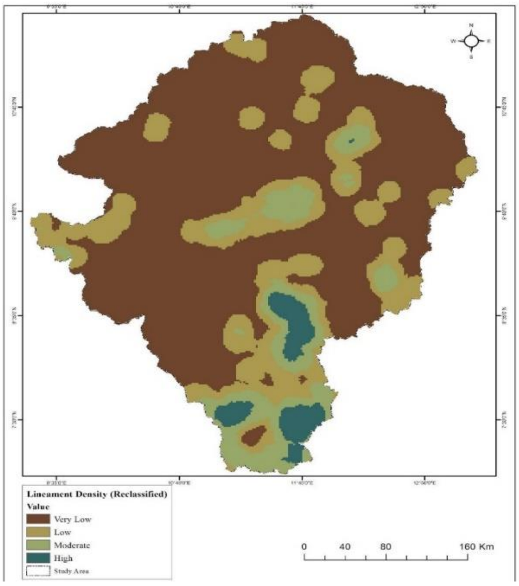

Fig. 12: Lineament Density Reclassified Map of the study area

As presented in fig. 11, the reclassified lineament density of the basin indicates that there is a higher linear density in the southern part of the catchment and it decreases towards the northern parts. The areas with lowest density had values ranging from 0 - 1.6 lineament length per area (Km/Km^2). The areas with highest lineament density ranged from 11.1 -16 Km/Km^2. The range of values were further reclassified in fig. 12 and as visualized, a larger part of the area has very low lineaments density, while the southern parts have moderate and high levels of lineament density, indicating permeable zones.

Soil Type

The accumulation of groundwater through infiltration is a direct effect of permeability. The soil type plays a critical role in infiltration rates and ground water accumulation. Fig. 13 and 14 reveals the spatial pattern of soil classes and reclassification respectively. Soil is an important factor for delineating the groundwater potential zones. The increase in water entry into the soil is affected by soil type, which is determined by the activities of pore saturation or desaturation (Saha *et al*, 2020).

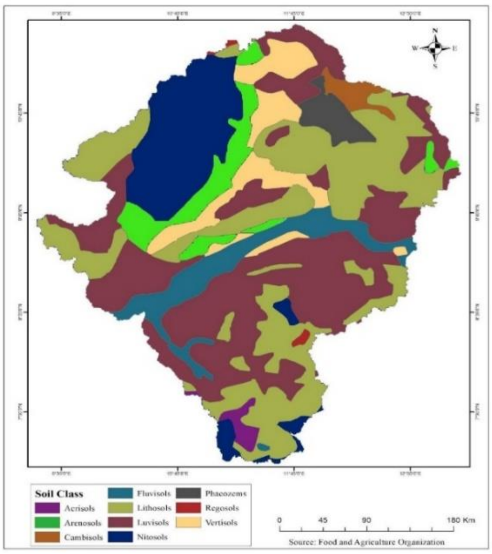

Figure 13. Soil Map of the Study area

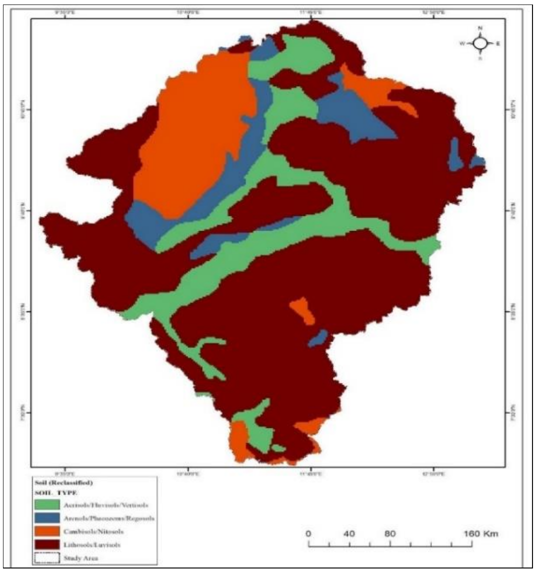

Fig. 14: Soil Reclassified Map of the Study area

As presented in fig. 13, the study area is composed of ten soil classes unevenly distributed across the area. The soil classes include: Lithosols, Luvisols, Cambisols, Nitisols Aerosols, Phaozems, Regosols, Acrisols, Fluvisols, Vertisols. As presented in fig. 14, it indicates that Luvisols and Lithosols which apparently cover a larger expanse of the catchment relatively supports higher infiltration and recharge rates, as they are typically well drained. Based on infiltration capacity, Cambisols and Nitisols moderately allow for ground water recharge. Conversely, Fluvisols, Vertisols, Acrisols and others relatively possess lower porosity and consequently lower infiltration rates. Water transport into the ground is controlled by the porosity of the soil categories. Soil type with coarse-grained matrix (e.g., lithosols) has good groundwater potential (Ifediegwu, 2021), whereas soil type with fine-grained matrix (ferralsols) has poor groundwater potential (Ifediegwu *et al*, 2019)

Ground Water Potential Generation (GWP)

Using Analytical Hierarchy Process (AHP), the results of the thematic layer earlier are integrated into weighted overlay. The outcome of the AHP computation is seen in fig. 15.

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	LULC	6.4%	6	2.3%	2.3%
2	Elevation	8.8%	5	3.8%	3.8%
3	Drainage Density	11.0%	3	5.0%	5.0%
4	Slope	5.2%	7	1.8%	1.8%
5	Soil type	4.3%	8	0.8%	0.8%
6	Lineament density	10.8%	4	3.7%	3.7%
7	Rainfall	35.8%	1	11.9%	11.9%
8	Temperature	17.6%	2	7.4%	7.4%

Number of comparisons = 28
Consistency Ratio CR = 4.9%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3	4	5	6	7	8
1	1	1.00	1.00	1.00	2.00	0.50	0.12	0.25
2	1.00	1	1.00	1.00	2.00	1.00	0.17	1.00
3	1.00	1.00	1	2.00	2.00	2.00	0.50	0.50
4	1.00	1.00	0.50	1	1.00	0.33	0.20	0.17
5	0.50	0.50	0.50	1.00	1	0.50	0.14	0.20
6	2.00	1.00	0.50	3.00	2.00	1	0.33	1.00
7	8.00	6.00	2.00	5.00	7.00	3.00	1	3.00
8	4.00	1.00	2.00	6.00	5.00	1.00	0.33	1

Principal eigen value = 8.479
Eigenvector solution: 5 iterations, delta = 9.6E-9

Fig. 15: AHP computation for thematic layers

After pairwise comparison of the eight parameters considered, the result of the AHP (Fig. 15) indicates that Rainfall was ranked first with a priority of 35.8%, seconded by Temperature with priority value of 17.6%, followed by drainage density with 11%. Soil type ranked lowest with priority value of 4.3%. With consistency ratio of 4.9% < 10%, and principle eigen value of 8.5, the ranks for every criterion remains consistent and significant for the purpose of further analysis. The overall result of the AHP indicates the ground water potential of the basin as presented in fig. 16 and Table 1.

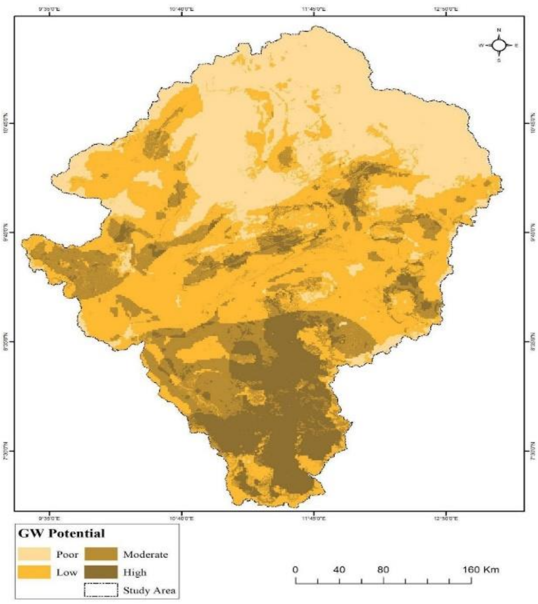

Fig 16: Ground Water Potential Map of the Study area

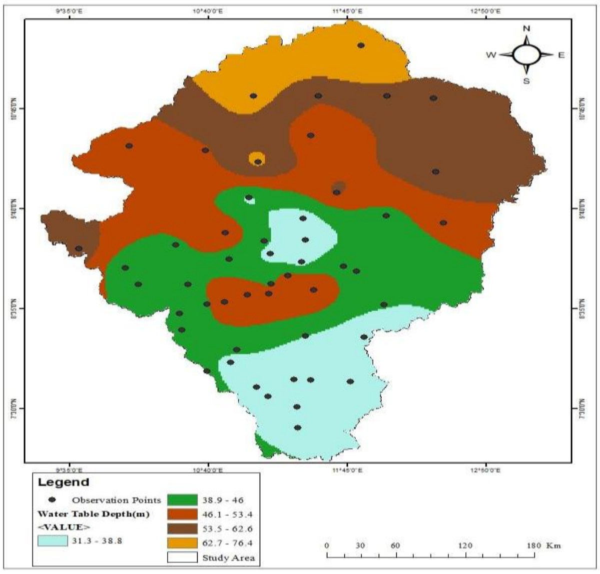

Fig. 17: Groundwater Depth of the Study area

As indicated in Fig. 16, the ground water potential is seen to be high southwards and poor at the northern end of the basin. Also, the ground water potential tends to be moderate east to west with little disparity of being low in some areas.

Table 1: Groundwater Potential Levels by Coverage

GWP Level	Area (Km2)	Area (%)
Poor	43,315.7	34.5
Low	44,822.4	35.7
Moderate	25,863.8	20.6
High	11,550.9	9.2
Total	125,552.8	100

A further breakdown of the areal coverage of various GWP levels (Table 1) reveals that a larger portion of the area has low GWP with an area of 44,822.4 Km^2, while 43,315.7 Km^2 was the area covered by Poor GWP. 25,863.8 Km^2 was experienced moderate GWP, areas of high potential covered 11,550.9Km^2. The results imply areas of high potential culminated the least coverage and conversely, areas with low and poor potential had the highest areal coverage. This result is congruent with the study of Sikdar *et al* (2004) in Bardhaman district of West Bengal who observed the groundwater potentiality of the Raniganj area to be medium (25-50 m^3/hr) with high potentiality (>50 m^3/hr) along the Damodar River.

Ground Water Recharge Performance

The Ground water table or peizometric height was used as indices for ground water recharge performance. Ground water depth data from various sources was collated and analysed in line with third objective. The result is presented in fig. 17. As presented in fig. 17, the spatial variation is generated from 52 observation points spread across the study area. As visualized, the water table depth is majorly lowest at the south part of the study area with the northern area having the high depth or lower water table heights The lowest groundwater depth range was seen to be 31.3 -38.8 meters, while the highest range was 62.7 -76.4 meters. These ultimately reflects the ease of accessibility and utilization of groundwater resources across the area.

Prospects of Groundwater Potentials in the Upper Benue River Basin

In this section, the coefficients of the joint and partial relationship between climatic variable (Precipitation and Temperature), LULC and ground water depth as was presented in Table 2, were fitted into a multiple regression model as follows:

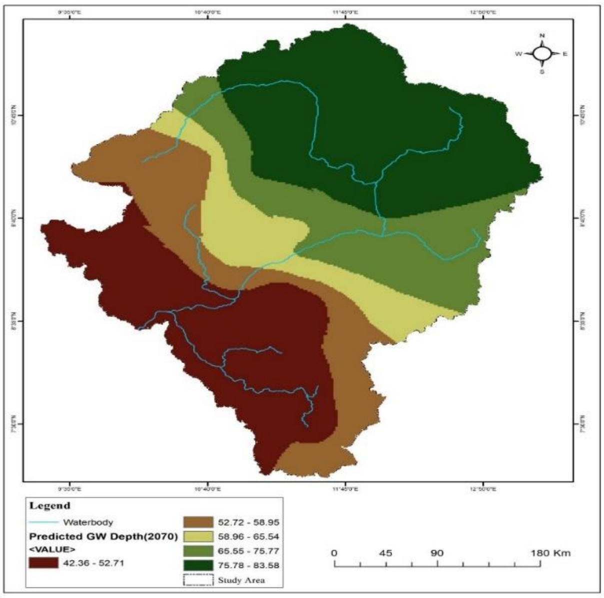

Fig 18: Predicted GW Depth for 2070

GW Depth = -378.22 - 0.028 Rainfall + 16.181 Temperature

This was subjected to raster calculation using year 2070 projected Rainfall and Temperature data from IPCC. The outcome of the raster calculation using the regression model is reflected in the prediction of the GW depth for the basin in the year 2070 (Fig. 18 and Table 2)

As seen in Fig. 18, for the predicted GW depth, the minimum range is 42.3m -52.7m while the maximum range is 75.8m - 83.3m. As observed, the water table depth is lowest at the southern part, with the northern area having the high depth or lower water table heights. This implies that access to ground water resources is relatively better in the southern part of the catchment as it coincides with the pattern of climatic variables spread across the area. This result is similar to the one obtained by Ifediegwu (2021), whose result showed good groundwater potential in the southern part of Lafia district of Nasarawa State.

Table 2. Comparison between Actual and Predicted GW Depth

Statistic	**2021**	**2070**	**Difference**
Min GW Depth	31.3m	42.3m	11m
Mean GW Depth	48.9m	65m	6.1m
Max GW Depth	76.4m	83.3m	6.9m

Comparing the minimum, mean and maximum values of actual and predicted ground water depth was pertinent to appreciate the long-term changes in the ground water regime. As observed in Table 2, from the 2021 data, the minimum value is predicted to increase from 31.3m to 42.3m, with an 11m difference. The mean value is also predicted to rise from 48.9m to 65m, an addition of 6.1m by 2070. The maximum values are also predicted to rise by 6.9m, as the predicted value is 83.3m, varying from the 2021 value of 76.4. This implies a relatively deeper water table which will impinge on accessibility of ground water in the future. Climate variability will affect the status of ground water significantly in the next 50 years and negatively impact availability and access. Ojeh and Semaka, (2021) observed that there is an existing challenge of access to household water in the Upper Benue Basin. This will adversely affect all socio-economic activities such as water production, beverage production etc. which depend largely on water availability as access for production.

CONCLUSION

This study has examined the dynamics of groundwater resources of Upper Benue River Basin in Nigeria. The study used survey design method. The findings of the study on the areal coverage of the various GWP levels reveals that a larger portion of the area has low GWP (44,488.4Km2), while the poor GWP was 42926.5Km2, the moderate GWP (25,732.6Km2) and the high GW potential covered 11,417.3Km2. The results imply that areas of high ground water potential have the least coverage while areas with low and poor ground water potential had the highest areal coverage. The result reveals that the water table depth is lowest at the southern part, while in the northern part of the basin have high depth or lower water table heights. Thus, access to ground water resources is relatively better in the southern part of the basin than in the northern part.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are suggested;

i. There is need for deliberate policy to protect the land and conserve vegetation in the basin to reduce forest degradation especially in the northern zone of the basin. Ground water abstraction by means of borehole should be regulated.
ii. There is the need to establish groundwater gauging station to help in monitoring the gound water level. This can be done by holistically collecting data for the different sections of the basin and integrating them into a single database.

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