International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2016 IJSRCSEIT | Volume 1 | Issue 2 | ISSN : 2456-3307

Assessment of Groundwater Recharge Potential in the Northern Parts of Auchi and Environs, Edo State, Nigeria, Using Geospatial Techniques

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ABSTRACT

Groundwater accounts for about 30% of earth's freshwater, the demand for this natural resource is increasing due to rapid industrialization and population growth, leading to its scarcity in some regions, Auchi is an area experiencing groundwater stress, were water table depth decreases rapidly and boreholes have to be drilled to great depths to get this scarce resource. The replenishment of this resource to a groundwater flow system is groundwater recharge.

The study aims to delineate groundwater recharge potential zones of the northern part of Edo state comprising of Auchi and sorrounding communities, utilizing remote sensing, geospatial techniques and weighted index overlay analysis model. Six multi-influencing factors of lithology, soil cover, lineament density, drainage density, land use and land cover and slope were all generated from Landsat ETM, topographic map and shuttle radar topographic mission (SRTM) data, producing the various thematic layers. The multi-layers were then reclassed and weighed according to their varying influence to groundwater recharge.

The resultant groundwater recharge potential map revealed that majority of the study area, comprised partly of the hilly terrain of the north eastern and north western part and the gentle slope regions had moderate recharge, while parts of the south eastern and south western part of Auchi had low groundwater recharge. This research could serve as a base line study for future groundwater studies in the area.

Keywords : Groundwater Recharge, Remote Sensing, Weighted overlay, Geospatial.

I. INTRODUCTION

Water is one of the most important natural resource for the sustenance of life, the availability of water supply in terms of quantity and quality is essential to human existence. The distribution of water on earth is highly unbalanced with 97.41% confined in world oceans, the remaining 2.5 % is locked up in glaciers (1.953%) and beneath the surface as groundwater (0.614%) and 0.015% for lakes and rivers [11].

Groundwater accounts for about 30% of the earth's freshwater, whereas surface water resources from lakes and rivers accounts for less than 0.3% [23]. Demand for fresh water resources in the world is noticeably increasing as a result of rapid industrialization and population growth. Hence, groundwater extraction has become an integral part in many of the water management approaches, especially for rural areas [20], this is because it represents the largest available source of fresh water lying beneath the ground.

Basically "Ground-water recharge" is the the replenishment of water to a ground-water flow system [30]. Most water recharging the groundwater system moves relatively rapidly to surface-water bodies and sustains stream flow, lake levels, and wetlands. Over the long term, recharge is generally balanced by discharge to surface waters, to plants, and to deeper parts of the ground-water system. However, this balance can be altered locally as a result of pumping, impervious surfaces, land use, or climate changes that could result in increased or decreased recharge, It has become crucial to monitor, conserve this important resource also identify and delineate areas of potential groundwater recharge and its availability in order to sustain groundwater system and avoid their depletion.

Groundwater table depletion occurs whenever pumping rates are higher than the rate of replenishment. Hence, areas with excessive groundwater withdrawal rates experience a significant volume decrease in the groundwater reservoirs. This can cause depletion of water levels in wells, streams and lakes, deterioration of water quality, land subsidence and higher pumping costs [25] ,[29]

Auchi an area located in the northern part of Edo state Nigeria and some surrounding communities, in the region tend to experience water stress, and difficulty in accessing groundwater especially during the dry season were communities experience drying up of dug wells. For this reason, boreholes have to be drilled to great depths of approximately 250m -300m and sometimes above to get this scarce and essential resource. In Ikpeshi a community in Akoko-Edo, studies have shown that over the last few years, out of the total monitoring wells, 55% experienced depletion in water table depth especially during the dry season Leading to the associated problem of lowering tube well depth and drying of open dug wells in these areas. [7]

As a result of the decrease in this important natural resource, remote sensing and geographic information system (GIS) techniques have been employed in this research study to delineate prospective groundwater potential zones.

Geospatial technologies have become an important tool in water studies due to their capability in developing spatio-temporal information and effectiveness in spatial data analysis and prediction [5], [16], [26]. Various studies have been carried out throughout the world to identify the groundwater recharge potential zones by employing remote sensing and GIS techniques [10], [21], [22], [24] [28], [32], [19]. Most of these studies were based on knowledge-driven factor analysis, integrating different thematic layers such as land cover/land use, geology, lineaments, drainage density, slope, soil permeability with GIS techniques. Satellite remote sensing and image processing techniques were often employed in these studies for the preparation of necessary thematic layers. In addition, existing maps, data bases, aerial photographs and field data collection have been commonly used in factor layer preparation, Which when incorporated together can aid in identifying groundwater recharge zones.

STUDY AREA

The study area is in Auchi, Edo state Nigeria, it is located at the Northern part of Edo state, and lies between latitude 7’30’0”N and 7’00’00”N, Longitudes 6’00’00”E and 6’30’00”E , Figure 1a,1b. The research area comprises of Six (6) local government with major towns namely Auchi, Ososo, Ibillo, Igarra, Ikpeshi, Uzanu, Ogonmeri and Ebule.

Climatic conditions of the area is essentially tropical and favors rock weathering and soil formations, there are two major seasons the wet and dry season. The wet season starts in March and continues till October, during which rainfall is low to medium, the dry season starts in November and ends in March.

The relief is influenced by the underlying geology, it is characterized by rocky mountainous highlands mostly at northern fringes mainly the tall ranking older granites and low lying lands towards the southern part of the study area.

Vegetation in the area is typically guinea savannah grassland and lush vegetation of tall trees, shrubs and grasses.

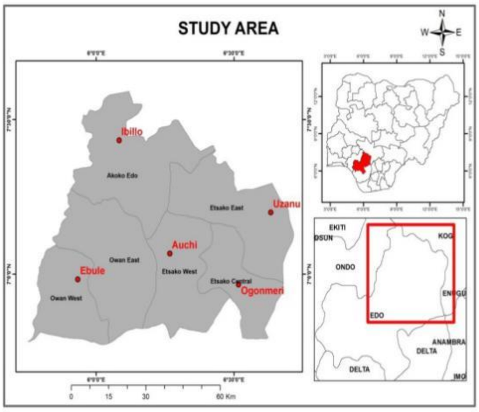

Figure 1a: Showing the Study Area

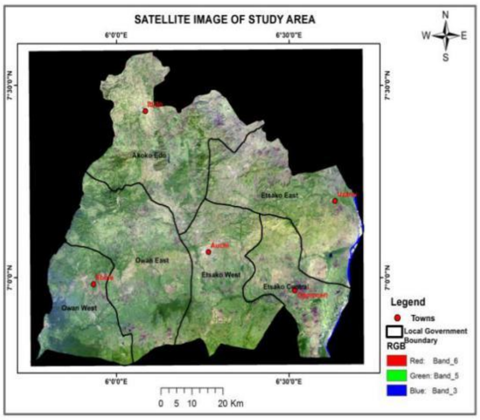

Figure 1b: Satellite image of the study area

II. METHODS AND MATERIAL

GIS techniques was employed in this study to delineate the groundwater recharge potential of the northern part of Edo state using remote sensing data and integration of multi influencing factors (MIF) of lithology, lineament density, slope, soil cover, drainage density and land use land cover.

The methodology for this study to delineate suitable sites for groundwater recharging has been illustrated in figure 2.

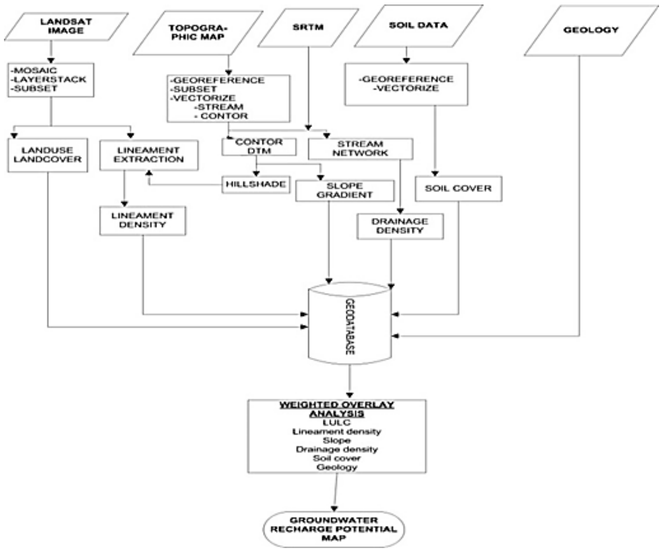

Figure 2 : Showing flow chart methodology of the research

Data acquired for the study namely geology map, from Nigerian geological survey at a scale of 1: 500,000, soil map and the topographic sheet were scanned, geo-rectified and vectorized to extract the corresponding lithology, soil cover, settlement and drainage of the area, the Landsat image of the area was pre-processed in Envi 4.7 by layerstacking, mosaicing and subsetted to enable classification of land use land cover classes using false color composite (FCC) band combination of 4,3,2 also the satellite image was used for the extraction of lineaments from band combination 7,5,3. Shuttle Radar Topographic Mission (SRTM) with a resolution of 30m was downloaded from glovis earth explorer, the SRTM data was subjected to analysis in ArcGIS 10.3 to generate hill shade of the area, the slope of the region and also the drainage.

All the MIF were then converted to raster and subsequently reclassed in order of suitability to groundwater recharge.

[31], [12], [14] employed similar method of MIF and remote sensing for groundwater studies.

III. RESULTS

Establishment of the six (6) groundwater recharge potential-related factors for the research study are discussed.

The Lithology of the study area is distinct this is due to the transition in geologic formation Figure 4, from the basement complex igneous and metamorphic rock types occurring in the northern part of the study area, underlain by coarse grained granite, meta conglomerate biotite, porphyroblastic gneiss, migmatite gneiss, schists and the unique sedimentary formation occurring in the southern part, made up of clayshale with limestone, sandstone coal , shale mustone and lignite claystone, this could be as a result of weathering of the basement rocks found on the northern hilly region and the gentle slope downward towards the south eastern and southwestern part of the area, Figure 3 showing the geomorphology

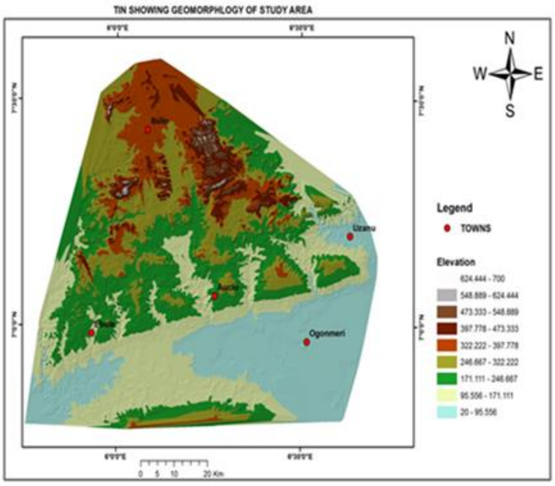

Figure 3 : Geomorphology of the area

[22] pointed out that the type of rock exposed to the surface signicantly affects groundwater recharge. Lithology affects the groundwater recharge by controlling the percolation of water [3].

Zones with less compaction, and with a higher degree of weathering and fracturing facilitate infiltration of the runoff, and hence are more suitable for groundwater recharging (Krishnamurthy et al., 2000). Hence lithology was assigned a weight and the various rock types were grouped based on similar geology and then ranked considering the permeability, porosity, textural properties, weathered/fractured zone formation and groundwater yield potential of different rock/aquifer material [6] , [1].

The lithology types was then subsequently reclassed based on potential for groundwater recharge.

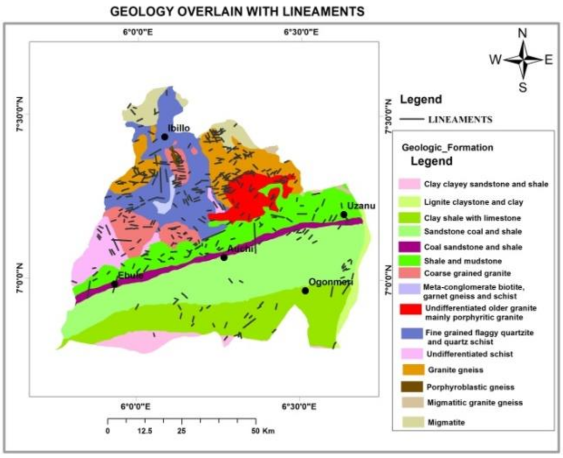

Figure 4 : Showing the Lithologic Map of Auchi and environs.

The Land use/ Land cover is an important factor in groundwater recharge. This is because the land use pattern of any terrain is a reflection of the complex physical processes acting upon the surface of the earth. The land use and land cover of the area provides important indications of the extent of groundwater requirement and utilization [17], It includes the type of Land use caused by man's physical activity, which include built up areas, bare surface, cultivated lands, etc and the natural vegetative Land cover of the area. The various classes interpreted and identified were built up, water body, cultivated land, shrub land, forest vegetation and rock outcrop Figure 5,this various land use classes were then reclassed in ArcGIS based on there characteristics to infiltrate water into the ground, generally rock outcrop are found to be least suitable for infiltration while the cultivated land, shrubland, vegetation, sand deposit were assigned reclass values based on their varying suitability to recharge and groundwater infiltration.

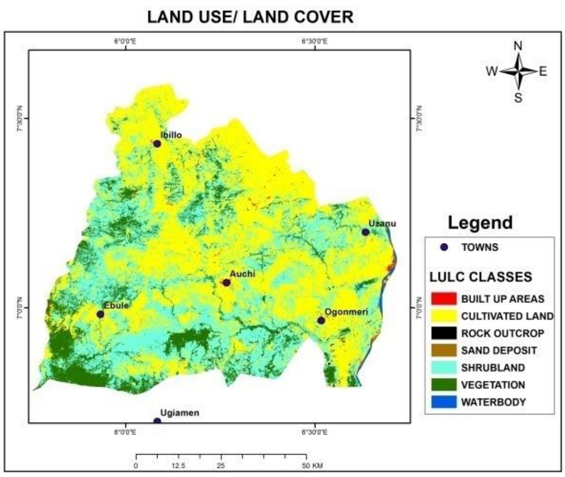

Figure 5: Land use Land cover of the area

Lineaments are structurally controlled linear or curvilinear features, which expresses the topography of underlying structural features and tonal alignments visible on satellite image due to its synoptic view. They represent fractured zones on geological structure of an area such as, fault and dykes and they can control the movement of water between surface and subsurface. Previous studies have revealed a close relationship between lineaments and groundwater flow and yield [13], [4].

Lineaments were extracted from satellite image using band combination 7,5,3 figure 6a also in order to further enhance the extraction, lineaments were also identified from hillshade generated from SRTM at an illumination angle of 45^{o} figure 6b,a total of 387 lineaments were identified.

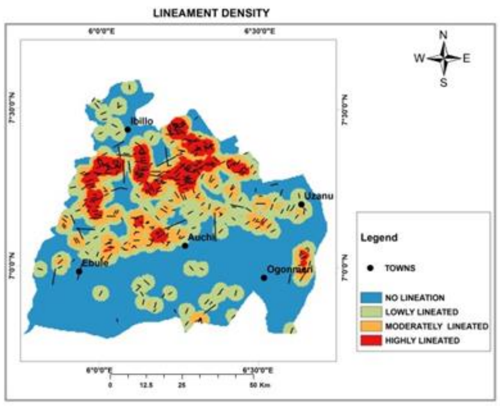

Figure 6a: Lineament density of the area

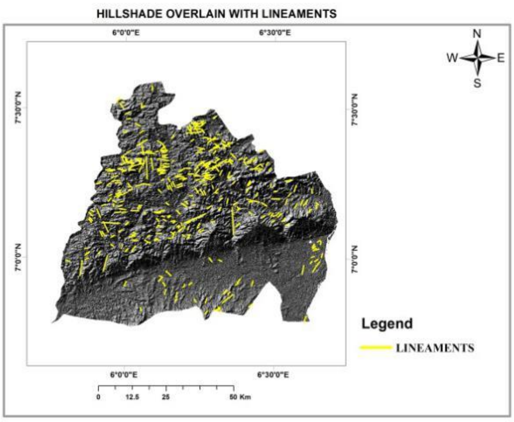

Figure 6b: Lineament overlain on Hillshade

The lineament density map was produced in ArcGIS and based on the lineament density generated, lineaments were concentrated more in the northwest of Ososo and northeastern part of Ibillo, but with little or no lineation towards the southwest and southeastern region of the study area comprising of Auchi and Ebule, this shows that the basement complex rocks experience more faulting and fracturing when compared with the sedimentary formation, and such lineated areas have high groundwater potential prospects.

The drainage density is the total length of streams divided by the total area of a basin. It is a measurement of the infiltration rate of water into watershed and deals with the relationship between surface runoff and permeability. The quality of a drainage network depends on lithology, which provides an important index of the percolation rate. Figure 7 Many studies have integrated lineaments and drainage maps to infer the groundwater recharge potential zone [2] ,[22] drainage of the study area was extracted from topographic map and SRTM image to generate drainage density thematic map which was then reclassed into 5 classes. Higher drainage density is related to increase infiltration and groundwater recharge and vice versa.

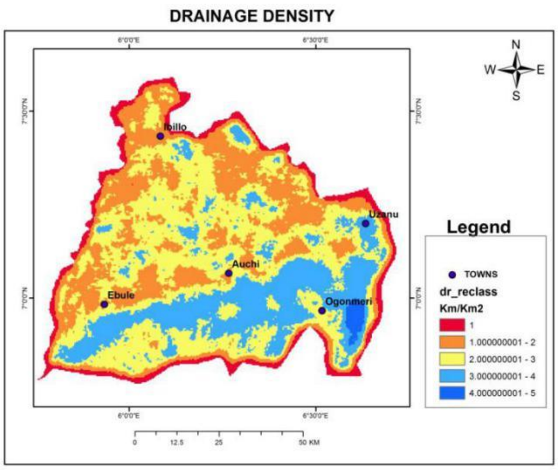

Figure 7: Drainage density of the study area

The acquired SRTM of the study area with 30m resolution was analyzed generating the slope map of the area figure 8, using the spatial analyst tool in ArcGIS 10.3, the high sloping regions of Ibillo, Igarra and Ososo, in the study area comprises of hilly terrain, which causes more run-off and less infiltration but with a gradual decrease in slope elevation towards the southern part of Auchi, Ebule and Ogonmeri which is categorized by gentle slope, leading to less run-off and increased infiltration. The wide range and distribution of the slope in the study area is an indication of varied degree in run-off and recharge which implies varied groundwater potential in the study area.

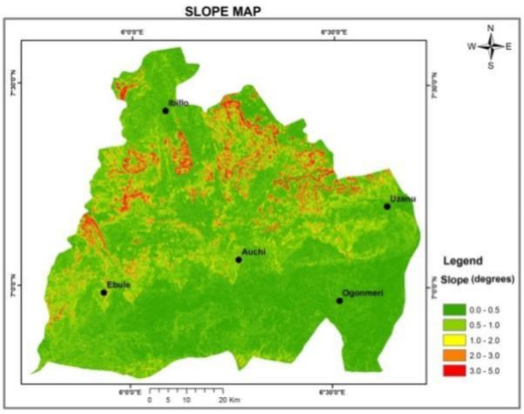

Figure 8: Slope of the study area

Soil cover is one of the significant control factors to determine the infiltration rate of an area. the various soil types of the area are the acrisols, gleysols, nitisols, and lixisols.

Based on research findings, the various soil types were categorizedbased on their parent material and their hydrological characteristics, with the lixisols and leptosols found to have poor groundwater retention capacities, while the acrisols, nitisols and gleysols soil types have moderate to suitable groundwater permeability and retention properties respectively. The various soils were then reclassed based on their influence on groundwater recharge

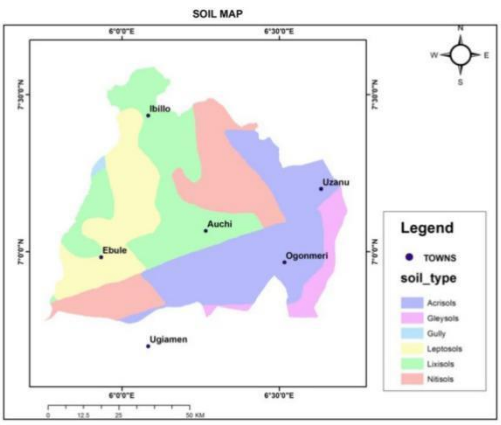

Figure 9: Soil map of the study area

IV. DISCUSSION And CONCLUSION

All the various multi influencing factors (MIF) analysed, and there thematic layers comprising of lithology, soil and Landuse land cover were categorized based on there subfactors and then reclassed and converted into raster format while the automatically generated raster based actors comprising of slope, lineament density, drainage density were also reclassed based on their influence to groundwater recharge, all in raster format.

Reclassed values ranged from 1 to 5 with 1 having the least influence on groundwater recharge and 5 with the most influence, this was done by researchers judgement and information gotten from previous research work carried out on groundwater studies.

All the 6 thematic layer were then subjected to the weighted index overlay analysis (WIOA) using multi-criteria approach, the combined reclassed thematic layers of the individual MIF was used to identify groundwater potential recharge zones of the study area. The WIOA is one of the most accepted methods for assigning weights and relative ranks based on the multi-criteria evaluation for decision making [17], [18] [16], [8], [27],[9]. It is a technique that applies a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis using multicriteria approach, this analysis according to [15] has no standard scale, but incorporates human judgment for its efficiency.

For this study each of the thematic maps was assigned a weight that represents its importance in respect groundwater recharge based on criteria of previous work [31], [12], [14]

Integrated influential factor layers using weighted overlay method on a GIS platform has been often employed in delineating artificial recharge potential zones by various researchers such as [22] , [32] and [26], [10] used weigthed aggregation method to integrate different thematic layers in order to demarcate groundwater recharge potential zones in hard rock terrain.

The resultant groundwater recaharge potential map of the study area figure 10, was generated by the integration of the result of lithology, lineament density, slope, soil cover, drainage density and land use land cover. On the basis of assigning and weighting of the individual features of the thematic layer. The groundwater recharge map produced depicts three classes of low, moderate and high groundwater recharge with majority of the area having moderate recharge rate. This research could serve as a base line study for future water management projects in the area.

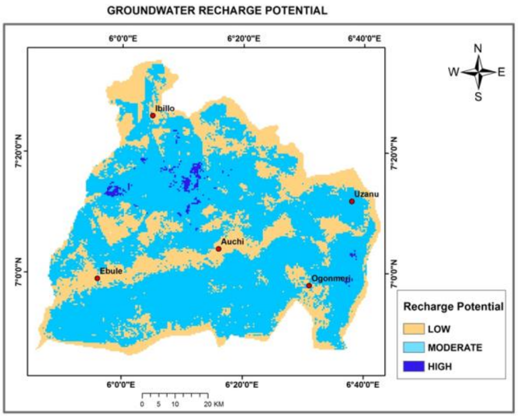

Figure 10 : Showing the groundwater recharge of the study area

V. ACKNOWLEDGEMENT

The authors are grateful for the support received for the case studies. Funding for the research was provided by the National Space Research and Development Agency (NASRDA), while the Nigerian Geological Survey, Advanced Space Application Laboratory, Glovis earth explorer is acknowledged for providing assistance with data acquisition and satellite imagery. Also Mr Kappo Ayorinde and Mr Oche Christopher for there valuable professional criticism and editing advice.

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