National Association Of Surveying And Geoinformatics Lecturers First Annual General Meeting/Conference

MINNA 2019

EXPLORING THE FRONTIERS OF SURVEYING AND GEOINFORMATICS FOR NATIONAL DEVELOPMENT

4TH -7TH FEBRUARY, 2019

School of Environmental Technology, Federal University of Technology, Minna, Niger State

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Book of Proceedings

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1st Annual General Meeting/Conference Minna 2019

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4th – 7th FEBRUARY, 2019

School of Environmental Technology

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FOREWORD

The organizing committee of the 1st National Association of Surveying and Geoinformatics Lecturers (NASGL) 1st AGM/Conference Minna 2019 is pleased to welcome you to Federal University of Technology Minna, Niger State, Nigeria.

The conference provides forum for researchers and professionals in the geospatial industry and allied professions to address fundamental problems and challenges of National Development-Exploring the Frontiers of Surveying and Geoinformatics. The conference is a platform where recognized best practices, theories and concepts are shared and discussed amongst academics, practitioners and researchers. The scope and papers are quite broad but have been organised around the sub-themes listed below:

- Education, Training and capacity Building in Surveying and Geoinformatics
- Advancement in Earth Observation and Geospatial Technologies
- Best Practice Models in Land Administration
- Spatial Data Infrastructure for National Security
- Surveillance and Security Monitoring
- Geo-Hazards Prediction and Mitigation
- Energy and Water Resources Inventory and Governance
- Food security and National Development

We hope you enjoy your time at our conference, and that you have the opportunities to exchange ideas and share knowledge, as well as participate in productive discussions with the like-minded researchers and practitioners in the geospatial environment and academia**.**

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It is the policy of the National Association of Surveying and Geoinformatics Lecturers (NASGL) AGM/Conference that for papers to be accepted for inclusion in the conference proceedings it must have undergone the blind review process and passed the academic integrity test. All papers are only published based on the recommendation of the reviewers and the scientific Committee of NASGL Conference.

Names and individual affiliation of members of Review and Scientific Committee for NASGL Conference Minna 2019 are published in the NASGL Conference Minna 2019 Conference Proceedings.

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TABLE OF CONTENTS

Cover Page iii
Title Page iv
Forward v
Copyright Statement vi
Declaration of peer review and scientific publishing policy vii
Scientific / Review Committee viii
Local Organising Committee x
NASGL National Executives xi
Table of Contents xii

SUB THEME 01: Education, Training and Capacity building in Surveying and Geoinformatics

The Dynamics of Surveying Education Curriculum in Nigeria by
Oluwadare, C. O. and Abidoye I. A. 2

Marginalization of Female Surveying and Geoinformatics Lecturers in Tertiary Institutions
Opatoyinbo, Oladunni O. 16

SUB THEME 02: Advances in Earth Observation and Geospatial Technologies

View shed Analysis of Campus Radio Fm 92.3mhz of Federal University of Technology, Minna, Niger State, Nigeria
Gbedu, A.M., Pwasa, P. B. and Mohammed, I. K. 47

The Establishment of an Electromagnetic Distance Measurement Calibration Baseline using the straight line configuration approach
Devote, B., Hart L., Ekima, R. and Okporo, U. 63

Realisation of Time-Dependent Geocentric Datum Transformation Parameters for Nigeria
Swafiudeen, B., Ojigi, L. M., Dodo, J. D. and Lawal, K. M. 75

Monitoring Atmospheric Water Vapour Variability over Nigeria from ERA-Interim and NCEP Reanalysis Data
Ojigi, M. L. 96

Land Cover Mapping using Combined Soft Classification and Geographic Object Based Image Analysis (SGOBIA) in the Niger Delta Region of Nigeria
Abdullahi, A. Kuta, Stephen Grebby and Doreen S. Boyd 114

Proliferations of Borehole Distribution Pattern in Suleja Local Government Area of Niger State, Nigeria
Areo, I.O., Arinola, F. S. and Adesina, E.A. 130

Comparison of Orthometric Heights Derived from GPS Levelling and Total Station Trigonometric Heighting
Uzodinma, V. N., Igwe, C. I. and Agba, B. B. 148

Land Use Mapping of Akure Urban for Monitoring and Control of National Development
Ogunlade, S.O. and Tukka, A. 163

Development of an Android Application for Transformation of Nigeria Projected Coordinates from Local to Universal Transverse Mercator
Odumosu, J.O., Opaluwa, Y.D. and Alade, J.A. 174

Evaluating Improved Temperature - Vegetation Dryness Index (iTVDI) for Estimating Soil moisture in Enugu State Nigeria using MODIS Satellite Data
Ndukwu, R. I., Maduako, I. N., Chiemelu, N. E and Michael, I. J. 190

Assessment of Various Ocean Tide Models on GNSS Data over Nigerian Continuously Operating Reference Stations
Opaluwa, Y. D, Aleji G. A., Ojigi, L. M. and Adeniyi, G. 214

3-D Position Determination Using Close Range Photogrammetry for 3rd Order Accuracy Positioning
Odumosu, J. O, Ajayi, O. G, Nnam, V and Ajayi, S. 232

Analysis of Telecommunication Service Mast Distribution in Minna, Niger State Using Geospatial Technique
Adesina, E. A, Uloko, U. S., Olaniyi, A. M., Mobolaji, M. K., Animashaun, A. and Abdulkareem, S. 251

A Robust Re-Definition of the Minna Datum Origin with GPS and Gravity Data
Uzodinma, V. N. 275

SUB THEME04: Spatial Data Infrastructure for National Security

Geoinformatics Based Characterization and Profiling of Solid Waste Dump Sites in Kaduna Metropolis
Lawal A. M., Sholadoye M. and Ategbe D. 294

SUB THEME 05: Surveillance and Security Monitoring

STE02: Applications of Surveying and Geoinformatics for National Security: The Nigerian Perspective
Onuigbo, I. C. 307

Surveying and Mapping: Panacea to the Challenges of Sustainable Development and National Security in Nigeria.
Adegboyega, E. R. 320

SUB THEME 06: Geo-Hazards Prediction and Mitigation

Estimation and Analysis of Dams Displacement Using Geodetic Technique
Olunlade O. A., Omogunloye O. and Olaleye J. B. 338

SUB THEME 07: Energy and Water Resources Inventory and Governance

Sediment Accumulation Study in Tagwai Dam
Oladosu, S.O., Ojigi, L. M., Aturuocha, V. E., Anekwe, C.O and Rufai, T. 363

Geospatial Assessment of Solar Energy Potential in the South-East and Parts of South-South Regions of Nigeria
Ndukwe E. Chiemelu, Francis I. Okeke and Raphael I. Ndukwu 382

Application of Geographic Information System (GIS) and Remote Sensing in Groundwater Exploration: A Case Study of Bosso Local Government Area, Minna, Nigeria
Ajayi, O. G., Nwadialor, I. J., Odumosu, J. O., Adekunle, O and Olabanji, I. 406

Evaluating Ground Water Potential Using Dar-Zarrouk Parameters at Kaduna Millenium City North-Western Nigeria
Ango, A, Abaleni, J. I and Danlami, A. 426

Spatial Point Pattern Analysis: A Case Study of Electricity distribution transformers in Doka Unit of Kaduna State
Aliyu, A.A., Muhammed, T. I., Akomolafe, E.A. and Abubakar, A. Z. 441

Single Line Diagram and GIS in Electricity Distribution Network: A Case Study of Irepo Feeder of Ilora Injection Station, Oyo state
Jeleel A. Qaadri, Solihu O. Olaosegba 466

Conventional Bathymetry Surveys and the use of Landsat 8 Satellite Imagery for Water Depth Measurements: A case study of Ajiwa Dam
Abdulkadir, I. F., Ahmed, B., Samaila-Ijah, H. A. and Bako, M. 488

Application of Geographic Information System (GIS) and Remote Sensing In Groundwater Exploration: A Case Study of Bosso Local Government Area, Minna, Nigeria

Ajayi, O. G., Nwadialor, I. J., Odumosu, J. O., Adetunji, O. O. and Abdulwasiu, I. O
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Abstract

Integrated approach of using Remote Sensing and Geographic Information System (GIS) have been of immense help to hydrogeologists and other bodies involved in management of environmental water resources to delineate the groundwater prospective zones for watershed development and management. This method is gradually providing an alternative to the expensive, time-consuming and laborious conventional approach of groundwater exploration which involves series of soil test in the laboratory. This approach is based on evaluating a set of hydrological, geological and topographical features that influence the natural occurrence of groundwater. Based on these, the mapping and identification of groundwater potential zones were carried out in Bosso Local Government Area of Minna, Niger State, Nigeria. The potential zones were classified into five categories (Very High Potential, High Potential, Moderate Potential, Low Potential and Very Low Potential zones) having analyzed four different thematic maps. About 18.65% (297km^2) of the area is classified as very high potential which spans through the western boundary of the study area, 55.05% (876km^2) was classified as high potential and is largely distributed within the central region of the Local Government, 10.35% (165km^2) of the area was classified as Moderate Potential and are distributed around the South-East and Eastern region of the study area, 11.09% (177km^2) was classified as Low Potential and are some unique areas within the High Potential class while 4.86% (77km^2) was interpreted to be of Very Low Potential area for groundwater exploration within the study area. Any groundwater management project implemented in these favourable areas will bring maximum benefit. Similar studies coupled with detailed land use and geological formation study should be considered necessary before designing a water resource development activity as it will reduce the cost on detailed field visits which are laborious and time-consuming.

Keywords: *Groundwater Potential Model, Thematic Maps, Groundwater Potential Value, GIS, Hydrogeology*

1.0 Introduction

Water is one of the mankind's most important resources. Abundant supply of water is one of the fundamentals for development and industrial growth. With increasing global change pressures coupled with existing unsustainable factors and risks characteristic in conventional urban water management, cities now experience difficulties in efficiently managing scarcer and less reliable water resources [12]. Due to population growth and increase in need for water per person, there is high need for multiple means for sourcing for water to minimize environmental hazards due to lack of water like draught [10]. Water supply is inconsistent throughout the year in Bosso Local Government area due to various reasons one of which is insufficient budgetary apportionment to Ministry of Water Resources, which has been identified as the major problem hindering water supply in Minna Metropolis [10]. Industrialization has been identified also as a global factor that adds to scarcity of water throughout the year [16].

Due to scanty surface water resource, there is need to look out for alternatives to meet up with the water requirements of irrigation, industry and domestic purposes. Groundwater is considered as the major conventional water resource to compliment the short supply from surface water [14]. Groundwater, on average, contributes to more than 45% of the total water resources in Jordan [1]. Intensive irrigation of Nalgonda district in Telangana, southern India, and major supply of water for agriculture in the area is attributed to groundwater resources [5]. Due to water scarcity in Minna, major sources of water supply for domestic usage are well water, water from vendors and boreholes which are integral part of groundwater supply [10]. Also, a study on the occurrence and chemical composition of rocks in Minna Metropolis found out that groundwater is the main source of water for shallow dug wells [11].

Although the groundwater resources are widely distributed, nature does not provide groundwater at the places of our choice. The occurrence and distribution of groundwater resources are confined to certain geological formations and structures. This implies that groundwater exploration involves an integrated work of geology, hydrogeology, hydrology and hydrochemistry studies besides some geophysical site investigation. The integrated approach to solving complicated geological, hydrological and environmental problems is one initially employed in geophysics. Studies revealed that maximum result is not obtainable without contributions from electrical techniques like conventional direct current resistivity and the more advanced electromagnetic methods and also the most recent nuclear magnetic resonance tomography [9]. Apart from the inability of this integrated approach to stand alone in groundwater exploration, it is hazardous, time consuming and costly. With the advances and availability of satellite images, it is possible to indirectly identify the ground conditions through the surface and subsurface features such as topography, land use, drainage, geology and geomorphology [16]. Visual method of interpreting various features is time-consuming, difficult and erroneous. In fact, interpretation of such features tends to impossibility in inaccessible areas. To overcome these constrains in groundwater exploration, integrating remote sensing and Geographic Information System (GIS) methods provide better accuracy and reduces the danger of error in interpretation of features [15]. GIS and Remote Sensing (RS) are modern techniques for geo-spatial study of phenomenon and nature. Therefore, RS and GIS tools are appropriate and very effective tools for detecting, interpreting features and for mapping areas with high potential for groundwater exploration ([8] and [21]). Another advantage of this integrated approach is that any form of spatial data (discrete or continuous) obtained from any kind of source (primary or secondary) can be combined, interpolated and interpreted by it [4]. This integrated approach in locating potential areas for groundwater exploration has been employed by different analysts and with recorded high level of accuracy.

Integrated approach of RS and GIS was employed in locating potential areas for groundwater exploration in Jordan. In the work, Groundwater Potential Map was produced having evaluated a set of hydrological, topographical and geological parameters which influence natural occurrence of groundwater by using GIS and RS tools [14]. RS was also employed and complimented with geo-electrical techniques to map groundwater potential zones in India [20]. GIS was also integrated with numerical modelling in mapping groundwater potential zones [6]. This integrated approach has also been employed by various researchers in locating and mapping groundwater zones in different countries ([13], [14], and [16]). Attempt has been made in this study to map the groundwater potential zones in Bosso Local Government area of Minna, Niger State, with the aid of different thematic maps produced and interpreted using the integrated approach of RS and GIS.

2.0 Study Area

Bosso Local Government Area which was adopted as the study area, is one of the 774 third tier of Nigeria Government. It is a Local Government in Niger State, Nigeria with a landmass area of about 1592 km^2 and a population of about 146,359 at the 2006 Nigeria Population Census. Its boundary lies between Latitude 9^o39'12.02''N and 9^o39'12.03''N and Longitude 6^o30'58.00''E and 6^o30'58.01''E. It is bounded to the North and East by Shiroro Local Government Area, to the South by Paikoro and Katcha Local Government Areas, and to the West by Gbako and Wushishi Local Government Areas.

The Study area (figure 1a) experiences distinct dry and wet seasons with annual rain fall varying from 1100mm and 1600mm. The maximum temperature (usually not more than 94^oC) is recorded between March and June, while the minimum is usually between December and January. The rainy seasons last for about 120 to 145days. The fertile soil and hydrology of the Local Government permits the cultivation of most staple crops and allows area suitable for grazing, fresh water fishing, etc. Most towns within the study area are plagued with restricted access to portable water [11] while water is mostly sourced from dug wells and drilled bore holes.

Geology of the Study Area

About one half of the land mass of Niger State is underlain by the basement complex rocks while the other is occupied by the Cretaceous sedimentary rocks of the Bida Basin and part of the Sokoto (Iullemeden) Basin [11]. The basement rocks consist of a suite of Precambrian gneisses, migmatites and metasedimentary schists crosscut by granitoids. The migmatite-gneiss complex includes migmatites, gneisses, mylonites and amphibolites. The mylonites are major shear zones which mark the stratigraphic breaks between the gneissic basement complex and the cover rocks of the Birnin-Gwari Schist formation [22]. Figure 1b is the generalized geological map of Niger State showing the major lithological units. The schist belts area occur as two elongated bodies separated by the older granite suite. The tips of the two formations are separated by a 40 km expanse of the older granite suite [2]. However, this study indicates a much smaller separation of less than 10 km. The Birnin-Gwari formation lies to the west of the older granite (the Minna Batholith) while the Kushaka formation lies to the East. A gravity survey model conducted over the area showed that the two formations have a maximum thickness of 11 and 6 km respectively [11].

Figure 1a: Study area.

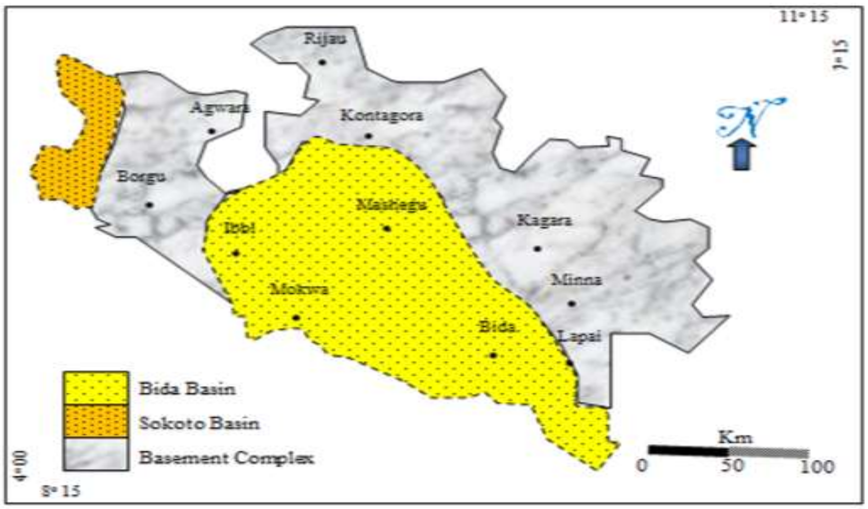


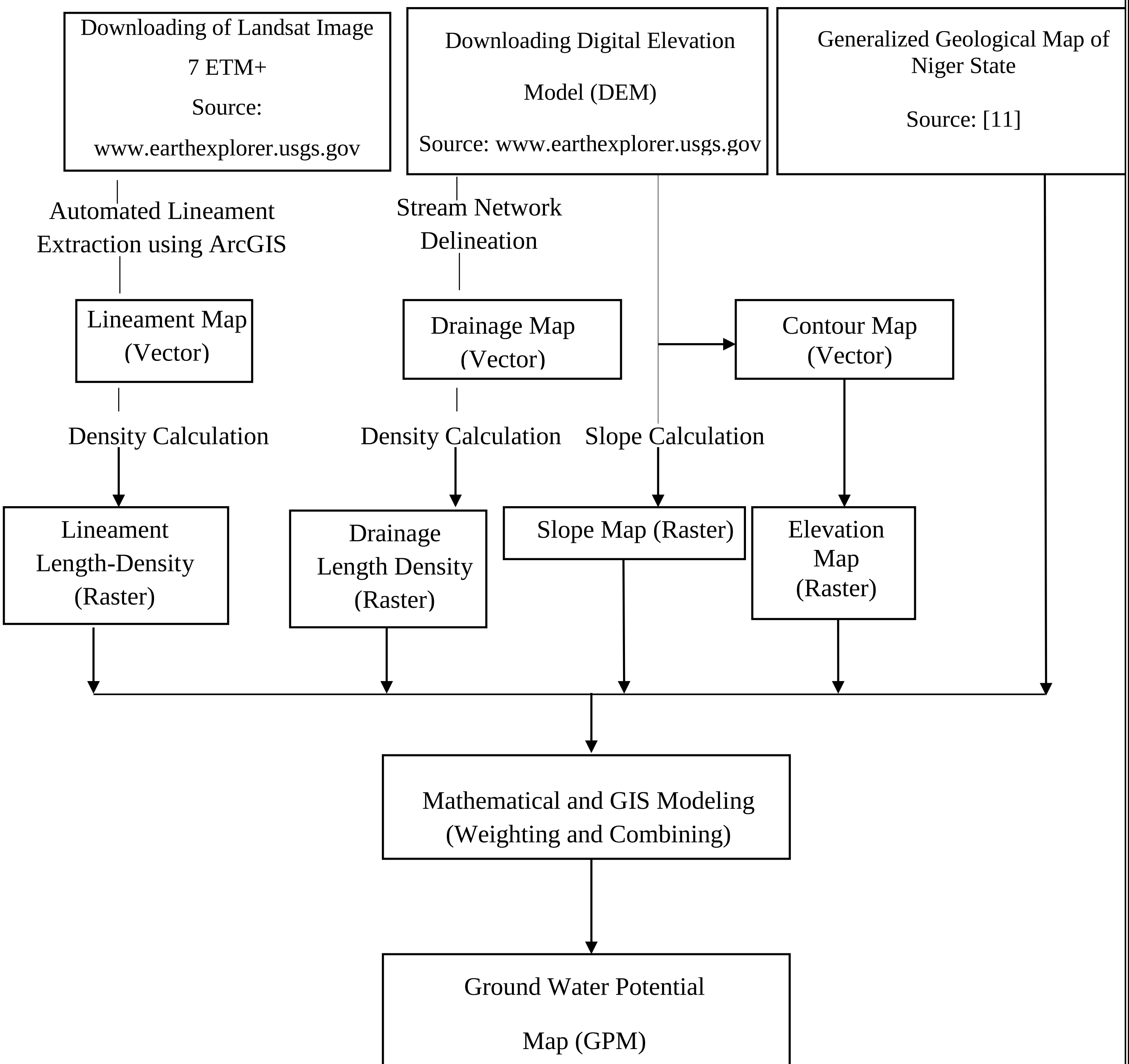
Figure 1b: Generalized Geological Map of Niger State

Source: https://www.researchgate.net/figure/Generalised-geological-map-of-Niger-State_fig1_300883625

3.0 Materials and Methods

Shape files and attribute data of towns and features in the study area, Geological map, DEM, and LandSAT 7 ETM+ imagery were used for this study. The DEM was used to map sub-watershed boundary of the study area, and slope and drainage maps were produced from the output. Geological map of the whole of Niger State was obtained from the department of Geology, Federal University of Technology, Minna, Niger State [11]. This was the basis of understanding different geological features which affect groundwater exploration within the study area. A groundwater potential model (GPM) was derived to define the scale of groundwater potentiality across the study area. It was derived based on a set of parameters that describe the natural occurrence of groundwater such as lineament length density, drainage length density, elevation, slope steepness and geological formation of the study area.

Lineament and drainage densities were extracted using the DEM and orthorectified LandSAT 7 ETM+ imagery. The DEM was obtained from the earth explorer website (www.earthexplorer.usgs.gov) and was used to delineate sub-watershed boundary of the study area, derive the slope and drainage network maps using the ArcGIS software. Based on these parameters, weighted overlay model was implemented to generate a map for groundwater potential (GPM). Results of GPM were analyzed and reclassified based on potential variability (high potential, moderate and low potential area). Figure 2 presents the schematic flow of the methods adopted in obtaining the results of this study.



Downloading of Landsat Image 7 ETM+
Source: www.earthexplorer.usgs.gov
Downloading Digital Elevation Model (DEM)
Source: www.earthexplorer.usgs.gov
Generalized Geological Map of Niger State
Source: [11]
Automated Lineament Extraction using ArcGIS
Stream Network Delineation
Lineament Map (Vector)
Drainage Map (Vector)
Contour Map (Vector)
Density Calculation
Density Calculation
Slope Calculation
Lineament Length-Density (Raster)
Drainage Length Density (Raster)
Slope Map (Raster)
Elevation Map (Raster)
Mathematical and GIS Modeling (Weighting and Combining)
Ground Water Potential Map (GPM)

4.0 Results and Discussions

Slope Map

The effect of slope has a notable impact on the infiltration of surface water from the ground. A low slope degree means that the surface water received from precipitation will take more time to remain on the ground surface and permeate into the subsurface. On the other hand, for areas with high slope degrees, the percolation is more immediate, not allowing long time retention for the water on the ground surface and hence, reduces the groundwater recharge potential. Slope solely depends on the elevation of an area, and to map this characteristic of the terrain, the DEM was processed in ArcGIS environment and the slope (in degrees) across the study area was obtained as shown in figure 3. Slope within the study area varies from 0^o to 89.99^o and large percentage of the whole area has slope range of 89.64^o to 89.99^o while the slope of the eastern part of the area ranges from 0^o to 89.64^o.

For the classification of groundwater potential zones based on this factor, the area was classified based on three ranges of slope (as in Figure 3). The range with lesser slope (0^o) was given a higher rank of 3 as it increases the infiltration rate [13] whereas the higher slope from 0^o - 89.64^o was given a lower rank of 2 and the highest slope from 89.64^o to 89.99^o was allocated the lowest rank of 1.

Drainage Density Map

Drainage in an area depends on its landscape, slope and the subsurface characteristics. Drainage density is calculated as the total length of all the streams and rivers in a basin divided by the total area of the drainage basin [16]. The higher the drainage density, the higher the run-off will be, and infiltration of water into the subsurface is affected. Drainage density calculated by Kernel density method (in ArcGIS software) to understand the potential of the watershed to favour the groundwater potential is given in Figure 4. Before this map was produced, the flow direction map was produced as a prerequisite. The drainage density of the area falls between an approximate range of 95 – $517m^{-1}$. The drainage density map was reclassified with areas having less density ($95m^{-1}$) designated with higher rank because they foster groundwater recharge [3], and areas with high density ($517m^{-1}$) were designated with lower rank as they facilitate less infiltration and recharge [19].

Lineament Density Map

Lineaments reflect a general surface manifestation of underground fractures, with inherent characteristics of porosity and permeability of the underlying materials and this is due to tectonic activities [18]. These features are the main channels for movement and storage of groundwater in impermeable rocks across the whole world [15] in the form of dykes and faults. Such lineaments are indicative of secondary porosity in the form of fractures and have the potential to supply large and reliable quantities of water if intersected by a well at depth. For this study, they were delineated from remotely-sensed imagery (satellite imagery). Lineament density map (as shown in figure 5) was prepared by using line density method (engaged in ArcGIS software). Line density in ArcMap calculates and output the density of linear features in the neighborhood of each image raster cell in the form of graph. It is calculated in units of length per unit of area. Lineament density is directly proportional to infiltration rate ([16], [17]), and this theory was employed to classify groundwater potential zones under this parameter. The lineament density map (Figure 5) shows that large percentage of the study area have an average linear density ranging between 280-365 lim^{-1} and ranked 3^{rd}.

Elevation Map

Topography is also a parameter that influences the groundwater yield rate of an area by depicting the ground configuration. At lowlands, the groundwater yield rate of an area is high and at highlands, the reverse is the case [14]. A low slope degree means that the surface water received from precipitation will take more time to remain on the ground surface and permeate into the subsurface. On the other hand, for areas with high slope degrees, the percolation is more immediate, not allowing long time retention for the water on the ground surface and hence, reduces the groundwater recharge potential. This theory was used to classify groundwater potentiality considering elevation factors across regions within the study area. The contour tool in ArcGIS was used to produce the contour map of the study area which was later rasterized to produce the elevation map of the study area. From the elevation map produced (figure 6), the elevation across the study area ranges from 100 to 450m. The North-West and South-West region of the study area has the lowest elevation ranging from 100-150m and hence rated as the lowland area with highest rank value of 5 while very small percentage of the study area scattered around the North-East region has the highest elevation value ranging from 300-450m and hence, ranked the lowest value of 1.

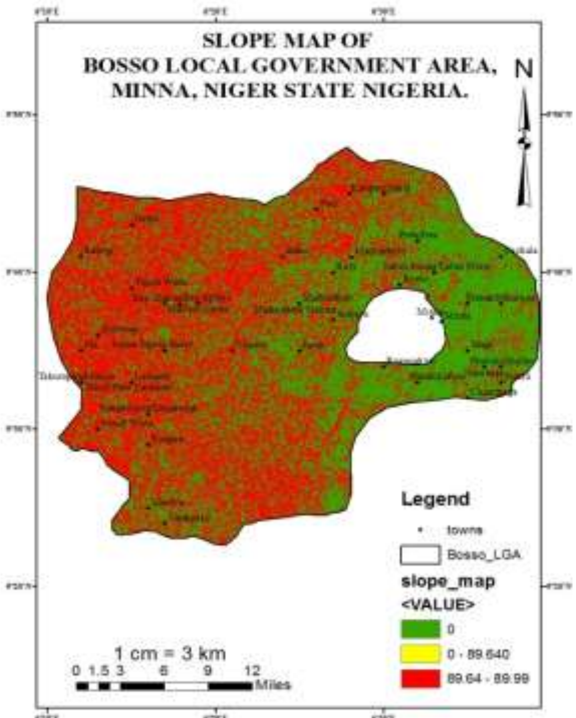


Figure 3: Slope map of study area

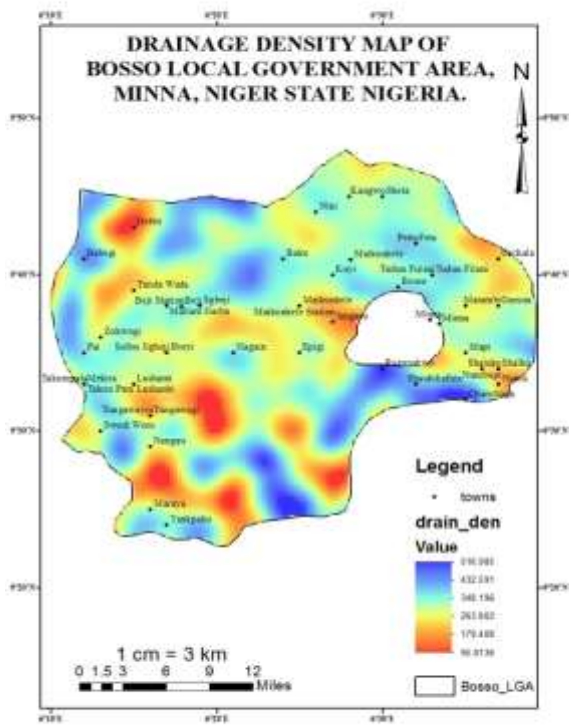


Figure 4: Drainage density map of study area

Ajayi et al: Application of GIS and RS in Ground Water Exploration . . . .

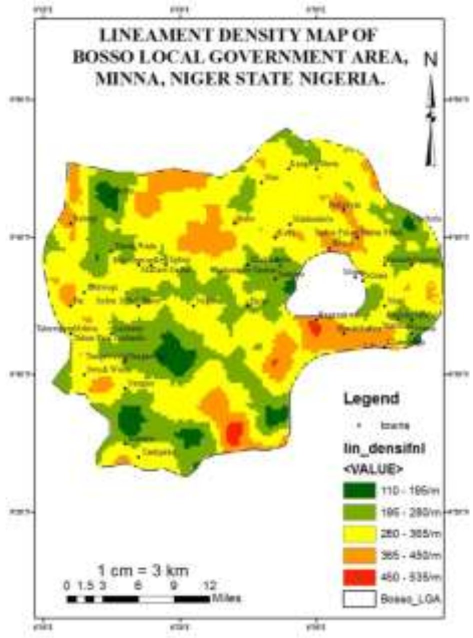


Figure 5: Lineament Density Map of the Study Area

Groundwater Potential Model

There are several approaches or features used to identify and map groundwater prospects, but this study limits itself to four features to evaluate the groundwater prospects through Remote Sensing and GIS in the study area. The various distinct characteristics and sub-features in each of these four thematic layers were reclassified by assigning ranks for computational purpose. Further, each of these thematic layers was assigned suitable weights based on several studies and deductions like the rate at which each influence groundwater recharges. Table 1 shows the ranking of the thematic maps. These features or themes were integrated to bring out a groundwater potential index value (using equation 1) so as to classify the study area based on potentials for groundwater exploration.

$$GPM = \{(Sw\ X\ Sr) + (DDw\ X\ DDr) + (LDw\ X\ LDr) + (TEw\ X\ TEr)\} = GPV \qquad (1)$$

where GPM = Groundwater Potential Model, S = Slope; DD = Drainage density; LD = Lineament density; TE = Topography/Elevation; w = feature weight; r = ranking, and GPV = Groundwater Potential Value.

Table 2 shows the computed values having integrated the thematic features and employing the Groundwater Potential Model. The five thematic maps produced were composited and the output was reclassified. The reclassified map forms the Groundwater Potential Map and classified into five different categories – Very High Potential, High Potential, Moderate Potential, Low Potential and Very Low Potential

Table 1: Ranked values (assigned to different features on each thematic map) and weights (assigned to different factors or themes influencing groundwater recharge)

Factors/Parameters	**Class**	**Ranking (r)**	**Weight (w)**
Lineament Density (m^{-1}) (LD)	450-535 365-450 280-365 195-280 110-195	5 4 3 2 1	25%
Slope (Degree) (S)	0 0-89.64 89.64-89.99	3 2 1	25%
Drainage density (DD) (m^{-1})	95.014 179.408 263.802 348.196 432.591 516.985	6 5 4 3 2 1	25%
Topographic-elevation	100-150 150-200	5 4	25%

(TE)	200-250	3	
(m)	250-300	2	
	300-450	1	

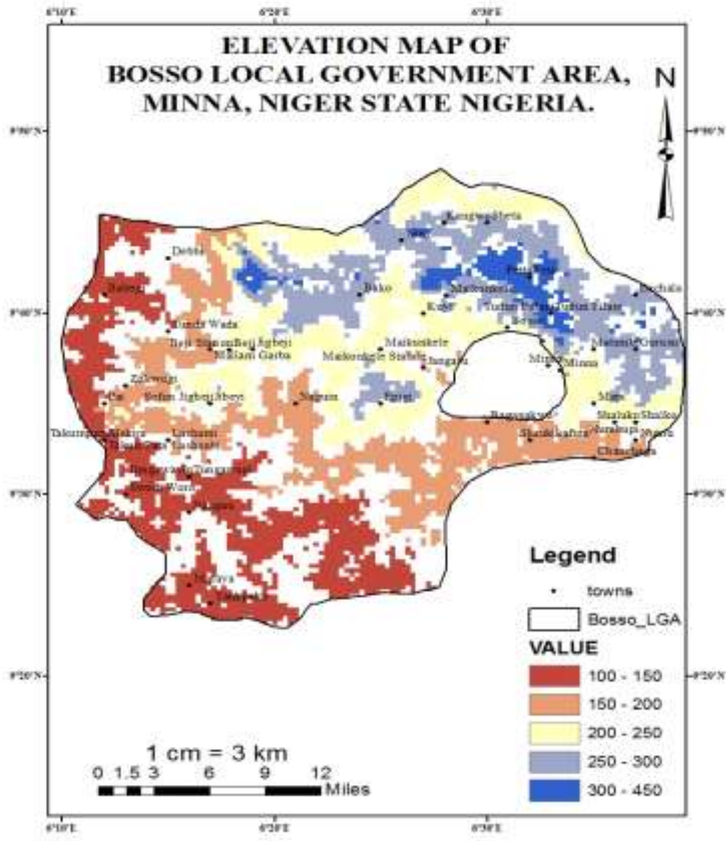


Figure 6: Topography / Elevation map of the study area

Groundwater Potential Map

This map was generated by compositing the different parameter maps produced to ensure classification of the study area in degree of groundwater potentials. In doing this, the groundwater potential model by considering the ranked values and weight (as shown in table 1) was derived. Table 2 shows the arithmetic computation of the rank of different layers on the GPM. The reclassified groundwater potential map (Figure 7) and the table 2 thus shows the classification of the study area into different level of groundwater potentiality. The reclassified groundwater potential map shows five different levels of potentiality across the study area. These levels are Very High Potential (300) which is class 1 only, High Potential (275) containing class 2, 4, 5 and 6, Moderate Potential (250) containing class 3 and 8, Low Potential (225) which contains class 7 alone and Very Low Potential (200) which contains class 9 only. About 18.65% (297km^2) of the area is classified as very high potential which spans through the western boundary of the study area, 55.05% (876km^2) was classified as high potential and is largely distributed within the central region of the Local Government, 10.35% (165km^2) of the area was classified as Moderate Potential and are distributed around the South-East and Eastern region of the study area, 11.09% (177km^2) was classified as Low Potential, part of which are within the High Potential class while 4.86% (77km^2) was interpreted to be of Very Low Potential area for groundwater exploration within the study area.

It is worth noting that low elevation, high lineament density, low drainage density and small degrees of slope are combining factors that foster groundwater recharge and hence promising for groundwater exploration.

Table 2: Arithmetic computation for ranking classification layers in the Groundwater Potential Map using the Groundwater Potential Model

LAYER	**FEATURES, WEIGHT & RANK**			**FEATURES, WEIGHT & RANK**			**FEATURES, WEIGHT & RANK**			**FEATURES, WEIGHT & RANK**			***Product Sum = GPV***
	TE	**Wt**	**Rank**	**LD**	**Wt**	**Rank**	**DD**	**Wt**	**Rank**	**Slope**	**Wt**	**Rank**	
CLASS 1	100-150	25	5	280-365	25	3	348	25	3	89.64 - 89.99	25	1	***300***
CLASS 2	150-200	25	4	280-365	25	3	348	25	3	89.64 - 89.99	25	1	***275***
CLASS 3	150-200	25	4	365-450	25	4	516	25	1	0	25	3	***250***

CLASS 4	200-250	25	3	280-365	25	3	263	25	4	89.64 - 89.99	25	1	***275***
CLASS 5	200-250	25	3	280-365	25	3	263	25	4	89.64 - 89.99	25	1	***275***
CLASS 6	200-250	25	3	110-195	25	1	95	25	6	89.64 - 89.99	25	1	***275***
CLASS 7	250-300	25	2	280-365	25	3	348	25	3	0-89.64	25	2	***225***
CLASS 8	250-300	25	2	195-280	25	2	179	25	5	0-89.64	25	2	***250***
CLASS 9	300-450	25	1	280-365	25	3	348	25	3	0-89.64	25	2	***200***

TE = Topography Elevation

Wt = Weight (Four factors were considered to map groundwater potential areas and each has an equal effect on groundwater recharges, hence, on a percentage, each assigned 25)

LD = Lineament Density

DD = Drainage Density

GPV = Groundwater Potential Value

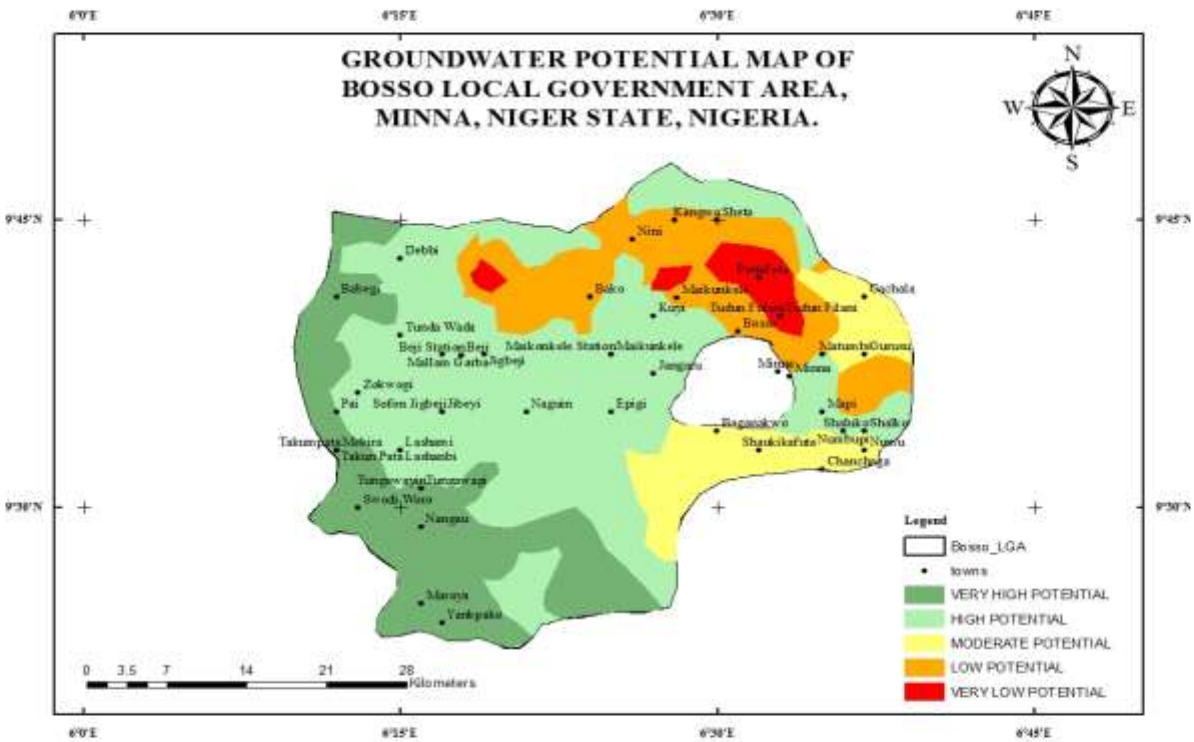


Figure 7: Groundwater Potential Map of the study area.

Table 3 shows the towns that fall within different levels of groundwater exploration potentials. This will foster decision making in minimizing or reducing scarcity of water within the Local Government across the year. It is appropriate that the towns with very low groundwater potentials during the dry season when there are little or no surface water should be catered for by distributing or channeling water from areas with very high or high groundwater potentials. While towns like Babegi, Takun, Nangau etc falls within area of very high groundwater potentials, Tudun Fulani and Petta Feta falls within the region classified as Very low potentials of ground water.

Table 3: Towns that falls within different classes of groundwater exploration potential in the study area

Nos.	Potentials	Towns
1.	Very High	Babegi, Pai, Takun, Maraya, Yankpako, Nangau
2.	High	Debbi, Tunda Wada, Beji, Mallam Garba, Jigbeji, Maikunkele, Naguan, Jangeru, Lashanbi, Zokwogi, Epigi, Kuyi
3.	Moderate	Chanchaga, Matumbi, Gurusu, Cachala, Baganakwo
4.	Low	Bosso, Tundu Fulani, Maikunkele, Nini, Kangwo, Sheta
5.	Very Low	Petta Feta, Tundu Fulani

5.0 Conclusion

Location and mapping of groundwater potential zones in an area help to plan for its exploitation, distribution and management especially in areas where surface water is not sufficient to meet up with the need and demand for water. In this study, potential areas for groundwater occurrence, storage and thus exploration were identified based on slope, drainage density, lineament density and topographic elevation of this study area. The western region of the study area which has elevation distribution range of 100-150m and an average slope were identified as the most suitable area for groundwater occurrence and exploration. Larger percentage of the study area (55.05% (876km^2)) which concentrates within the central region was identified to have 'High Potential' for groundwater exploration. Areas such as Petta Feta and Tundu Fulani are identified as regions with very low potentials of groundwater availability, Bosso, Maikunkele and Kangwo are some of the regions identified with low groundwater potentials. Chanchanga, Matumbi are some of the areas discovered to have moderate ground water potentials, while Babegi, Pai, Takun, Maraya, Yankpako, Nangau are areas identified with very high groundwater potentials. Favorable groundwater potential zones identified from this study will serve as a tool to various organizations and decision-makers in planning for groundwater resource exploration and development in this area, which will result in high yield most especially if an intensive ground truthing should be done considering the behavior of dug wells and geological sampling test across the area. Since no geophysical investigation was carried out to validate the findings of this study, the result of the study is therefore recommended for reconnaissance applications only.

Further Studies

For further research, the results obtained in this study will be validated by geophysical investigations and conventional approach of groundwater exploration.

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