MAPPING GROUNDWATER POTENTIALS OF BOSSO AND ENVIRONS, NIGER STATE, NIGERIA

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ABSTRACT

The scarcity of water in Bosso Local Government Area of Niger State warrants for a detailed investigation of the groundwater potential characteristics of the area so that an exploration guide as well as sustainable groundwater management strategy can be developed. Therefore, this study assessed groundwater potential mapping using Digital Elevation Model in Bosso Local Government Area, Niger State, Nigeria. Primary data for the study includes collection of GPS points from the field and photographs. The main data used in mapping potential groundwater in the study area was SRTM DEM of 30m spatial resolution was acquired from NASA center distributed active archives (LP DAAC). A total of thirty wells were identified with their coordinates for the groundwater potential mapping in the study area. The finding shows the elevations over the study area with the highest elevation of 452m located at the North eastern part of the study area and 71m as the lowest elevation found at the southwestern part respectively. The high elevation points have low potential of groundwater and low elevation has moderate and high groundwater potential in the study area. As revealed in the study some areas in Bosso, Tudun Fulani, Maitumbi and Chanchaga were within the range of 257 to 452m and this in turn has made the areas low or moderate groundwater potential. As revealed in the study, 48.37% of the entire study area were within moderate convergence index, 27.1% of the study area were within high convergence index and 24.62% of the study area were within low convergence index. The result shows that the Maikunkele, Beji and Garatu areas with very high groundwater potential is characterized by high rainfall, low slope and dominated with cambisols which have a relative high water holding capacity. The Bosso central,Maitumbi and Chanchaga areas with very low ground water potential is characterized by moderate slope, high

drainage density and dominated by granite which has low ground water potential. There is the need for precise estimate of the available subsurface resources for the significance of appropriate preparation to ensure the guarantee of accessibility of water.

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ABBREVIATIONS

RS: Remote Sensing

GIS: Geographic Information System

GPS: Global Positioning System

DEM: Digital Elevation Model

SRTM: Shuttle Radar Topography Mission

NDVI: Normalized Difference Vegetation Index

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Ground water is contained in underground rocks, which contain and transmit water in economical rate generally referred to as aquifers (Hussein *et al.*, 2016). Groundwater accounts for 26% of global renewable fresh water resources. Salt water (mainly in oceans) represents about 97.2% of the global water resources with only 2.8% available as fresh water. Surface water represents about 2.2% out of the 2.8% and 0.6% as groundwater. The problem is not only to locate the groundwater, as it is often imagined, but the engineer's problem usually is to find water at such a depth, in such quantities, and of such quality that can be economically utilized. Groundwater is a term used to denote all the waters found beneath the ground surface. Groundwater aquifers are not just a source of water supply, but also a vast storage facility providing great management flexibility at relatively affordable costs (Elbeih, 2015).

The amount and distribution of groundwater is a function of the amount of open space and the special extent of these rocks. The behavior of these rocks in turn is function of their formation and geological processes that shaped their status. Conventional groundwater exploration requires hydro-geologic investigation to study the lithology, stratigraphy and structural aspects of a region using geologic methods to understand the factors that regulate the amount, circulation and quality of groundwater (Elbeih, 2015). These studies deliver results of various type and quality based upon the range of the study. In recent years, relatively cheap availability of Remote Sensing data of greater spatial and spectral resolution and increasing availability image processing algorithms and GIS technology has enabled better efficiency in groundwater resource potential exploration (Mohamed, 2014).

Groundwater (hydrogeological) mapping is among the major devices for methodical as well as regulated growth and also preparation of groundwater. The result is utilized by drillers, coordinators as well as stakeholders in order to designate, establish and also take care of groundwater among a national water plan. Hydrogeological maps existing hydrogeological information in a map form. A hydrogeological map reveals circulation of aquifers, as well as their topographical, geological, hydrographical, hydrological and also hydrochemical attribute. Discussion of these information in the form of maps allows fast analysis of specific location. Appropriately, hydrogeological maps help to identifying locations requiring unique security (Dar *et al.,* 2010).

Remotely sensed signs of groundwater might offer vital data where timeless options are not readily available. For Instances of determined data consist of groundwater heads, modifications in groundwater storage, warm signatures, and also decrease data (Jasmin and Mallikarjuna, 2013). Ground-based remote sensing is typically costly than space and also airborne remote sensing however is still much precise and also less expensive than intrusive approaches (boring exploration). These indicators include vegetation surface water, water discharging to the surface carrying heat energy and runoff. Satellite technology is reviewed with respect to its ability to measure groundwater potential, storage, and fluxes. Satellite data can be used if ancillary analysis is used to infer groundwater behavior from surface expressions.

An essential to the geospatial technique of aquifer is acknowledgment superficial aquifer circulation typically force by surface compelling and also parameterized by geologic properties that can be presumed from surface data. A specifically effective application of Remote Sensing to groundwater has actually been the recognition of lineaments that are related to faults as well as fracturing in hard-rock. simple method to pair Remote Sensing with groundwater circulation forecasts, for that reason is to utilized remotely sensed imagery to specify border problems such as streams, infiltration locations, recharge region, evapotranspiration areas (Jasmin and Mallikarjuna, 2013). Therefore, this study will evaluate groundwater potential mapping using Digital Elevation Model in Bosso and its Environs.

Several research studies have disclosed that groundwater possibility is associated with several variables, such as geological features, terrain surface, hydrology attributes, etc. Digital Elevation Models (DEM) is the electronic representations of the topography, the technical developments offered by GIS and also the raising accessibility as well as high quality of DEMs have actually substantially broadened the potential of DEMs to applications in several fields (Tarun, 2014).Among those element associated with groundwater potential mapping, the majority of the details has been verified can be extracted from DEM data, as well as this made extracting pertinent features from DEM for groundwater potential mapping is viable (Tarun, 2014).

1.2 Statement of the Research Problem

Many researchers conduct studies on groundwater potential mapping utilizing use of DEM, remote sensing and geospatial technique which include Ikegwuonu (2013); Dar and Sankara (2010); Elbeih (2015); Hussein *et al. (*2016); and Mohamed (2014). There was paucity of knowledge with regard to groundwater potential mapping in Bosso and environ which has created a gap and this study intends to fill. Hence, this research aimed to assess groundwater potential mapping utilizing Digital Elevation Model in Bosso and environ, Niger State, Nigeria.

One major obstacles dealing with the sustainable growth in the study area is the demand for much better growth as well as monitoring of its minimal fresh water resources. Several of crucial groundwater issues in Bosso and its Environs are: overexploitation as well as decreasing of its levels in some areas; presence of igneous rock around aquifer which disallow groundwater recharge. Conventional groundwater exploration techniques though they provide better results of diverse range, often to be time consuming as well as costly ventures. The use of remotely sensed data as well as GIS give the opportunity to have details of substantial spatial and temporal range, evaluate, as well as handle it effectively.

Severe water scarcity has been one problem citizens of Bosso Local Government Area had to contend with. Of the 3.9 million people in Niger State, only those in Minna the state capital, could boast of access to potable water, though not all residents of the city have access to drinkable water (Ikegwuonu, 2013). Water projects constructed in the study area are no longer capable of providing enough water for the ever-growing population. This development has subjected the people of the study area to rely on other sources of water such as; rain water and groundwater which are seasonal. Hand dug wells in the area yield little water which dries up eventually due poor construction and also lack of information on groundwater potential zone before groundwater exploration, likewise the poor yields from boreholes constructed by government agencies and other private organizations (Ikegwuonu, 2013) in area of interest are few of the water challenges. Therefore, this study assessed groundwater potential mapping using Digital Elevation Model in Bosso and its Environs.

1.3 Research Questions

The research questions for this study will include the followings: -

i. Where are the drainage networks and slope in the study area?
ii. Where are the convergence index location of the study area?
iii. Where are the groundwater potential zones in the study area?

1.4 Aim and Objectives

The aim of this study is to assess groundwater potential zones in Bosso and its Environs, Niger State, Nigeria. This aim was achieved through the following Specific objectives:

i. Examine the drainage networks and slope in the study area;
ii. Identify the convergence zone location of the study area; and
iii. Map groundwater potential zones in the study area.

1.5 Justification of the Study

This study will offer empirical proof on the groundwater potentiality available in region of study, and hopefully will guide water policy makers in actions to improve quantity of water supply in area of interest and the State at large. There is need for appropriate estimate of the readily subsurface water resources for the significance of appropriate measure to guarantee the frequent accessibility of good drinking water in the study area. This study will function as direction to Government, and Non-Government Organizations and other manager involve in water exploration. Also, other water agencies in Niger State can benefit from this research.

Data on groundwater potential mapping in area of interest is inadequate for assessment of groundwater potential and there is no known study that investigated groundwater potential area of interest. This study will therefore, focus on utilizing of Geographic Information System and Remote Sensing in assessing groundwater potentiality region of interest which could serve as a guide when conducting groundwater exploration in Bosso and its Environs.

1.6 Scope and Limitation of the Study

The study area Bosso Local Government is among the largest Local Government Areas of Niger State, it comprises of three districts; Bosso, Maikunkele and Beji each districts has many villages such as Shata, Pyata, Kampala, Kodo, Gurusu, Gidan Mangoro, Garatu, Dama, Gidan Kwano, Dagah etc. This study focuses on the mapping of groundwater potential zones utilizing Remote Sensing and Geographic Information System. The Element to be considered in the study would include geology, Dem, drainage, and slope. This study is limited to Bosso Local Government area and not the entire Niger State.

1.7 The Study Area

1.7.1 Location

Bosso Local Government Area lies between longitude 6^{o} 33” E - longitude 6^{o} 37” E and latitude 9^{o} 33” N - latitude 9^{o} 38” N, (figure 1.1 and figure 1.2) on a geological base of undifferentiated base complex of mainly gneiss and magnetite situated at the base of prominent hills in an undulating plan. Bosso Local Government Area is situated on Niger valley. It is located in the south eastern part of Niger State with elevation in height between 100 feet (300 meters). The area geographically shares boundaries with Wushishi Local Government to the west, Chanchaga Local Government Area to the east, Shiroro Local Government Area to the north and Katcha Local Government Area to the south. It is characterized by having sedimentary rocks. Certain surrounded hill can be seen in some parts of the areas (Bosso Encyclopedia, 2019).

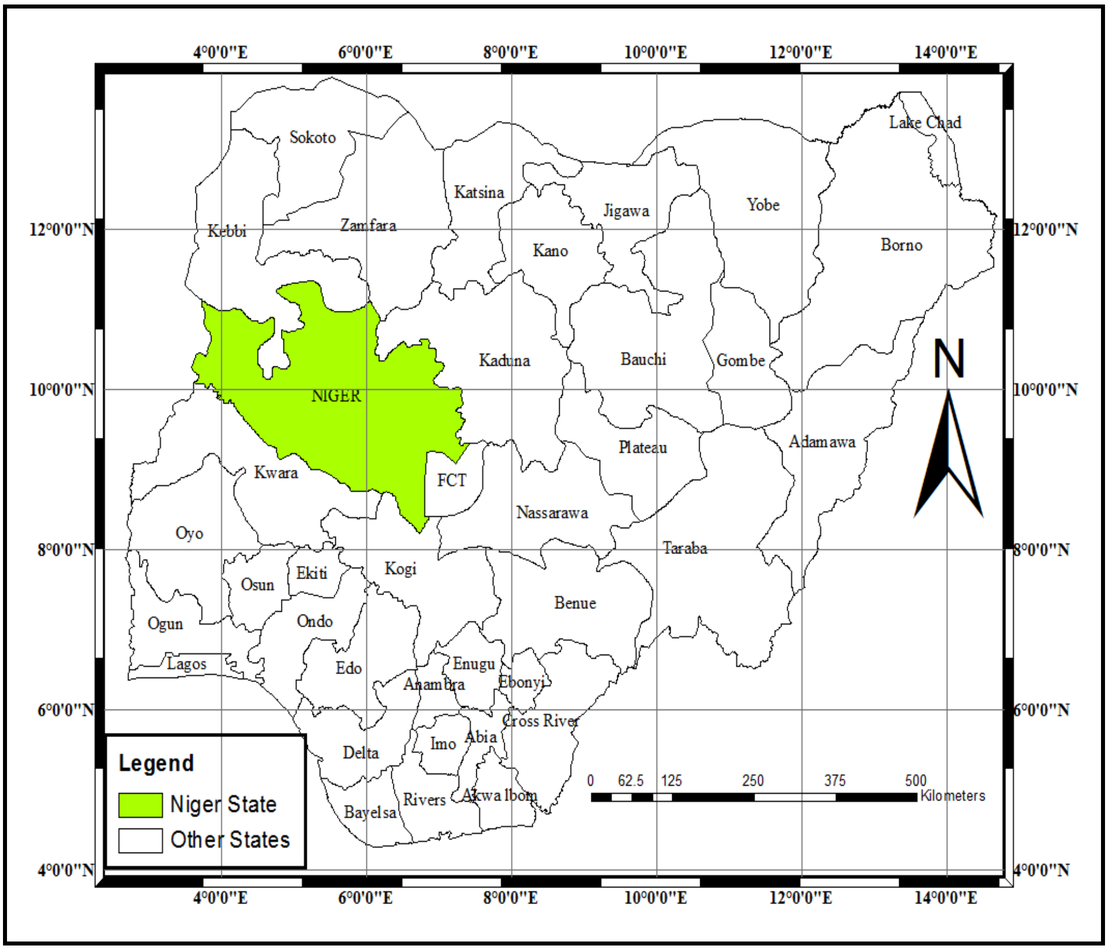

Figure 1.1: Nigeria Showing Niger State

Source: Niger State Ministry of Land and Survey (2019)

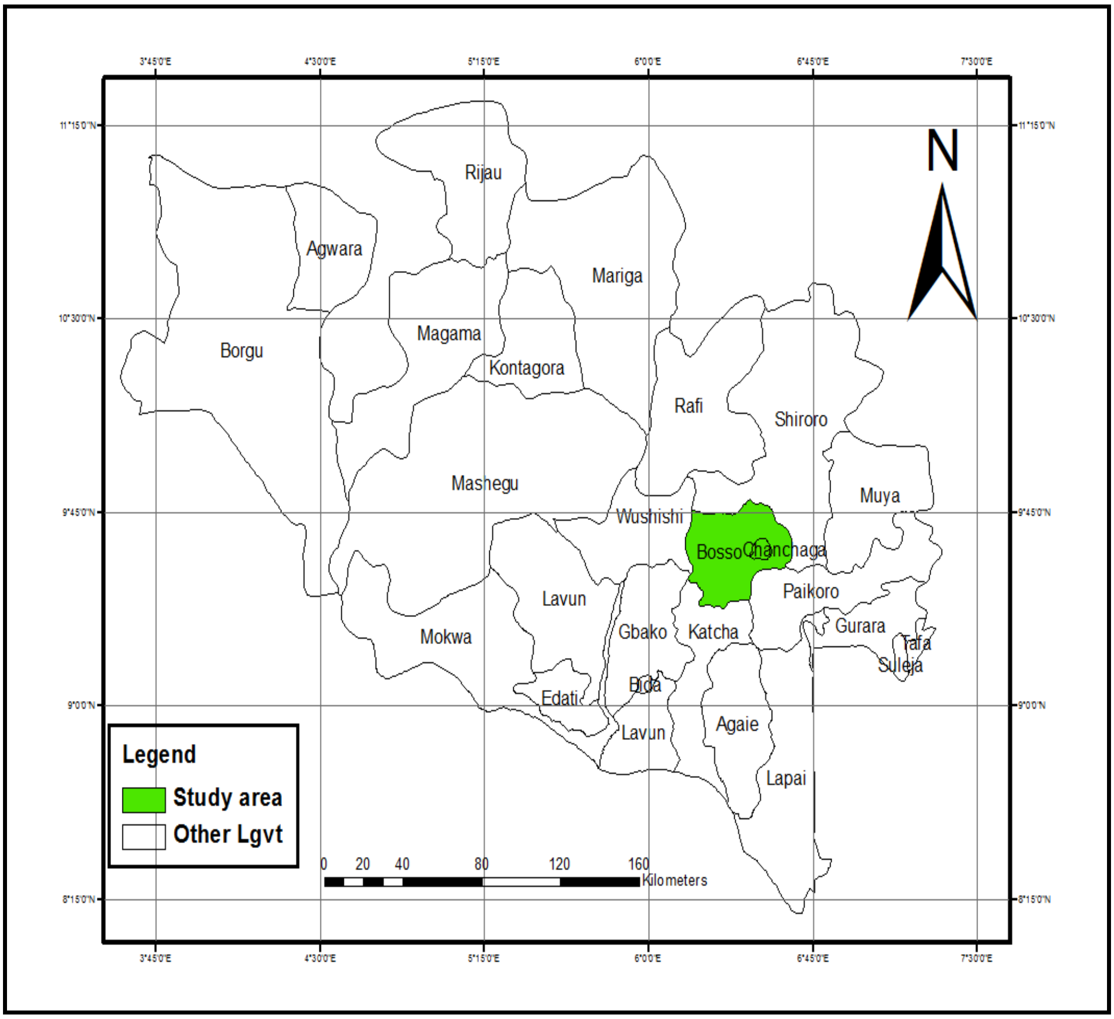

Figure 1.2: Location of Bosso Area council, Niger State, Nigeria

Source: Niger State Ministry of Land and Survey (2019)

1.7.2 Climate

The Bosso has two district weather, namely the rainy season that begins around March and runs through October and the dry season which begins from October and end in March. However, within these seasons is a brief hamattan season that is occasioned by the northeast. Weather conditions in Bosso are influenced by its location within the Niger Benue through on the windward side at the climate transition zone between the essentially humid south and the sub-humid north of the country. The climatic dictates of the Bosso essentially from the south-west to the North West due to rising elevation from the valley in the southwest the high temperatures and the relative humidity in the Niger-Benue through give Niger state a heating affect but the increasing elevation toward north. Rainfall in Minna reflects the location on the wind ward side while the monthly rainfall distribution intensified during the month of July, August and September (Oyebanji, 1993). Rainfall occurs in Nigeria along disturbance lines in places overlaid by the warm and humid maritime air mass originating over the Atlantic Ocean in the south. Because of this, the Southern parts of the country receive more rain than the northern parts. Southern coastal areas are permanently overlaid by the humid air mass. Early in the year, the air mass beings to hurried interior locations and more parts of the country fall in to an expanding rainfall belt. By the middle of September, the air mass begins a rapid recession back to its coastal, most southerly positions, thus while coastal locations are perennially humid and received substantial rainfall throughout the year interior locations experience various lengths of rainless season. The length of the rainy season therefore decreases with distance from the coast line.

1.7.3 Topography and vegetation

Nigeria is a big country, 1,045 kilometres long and wide of 1,126 kilometres, and it has various relevant rivers notably the Niger and its major tributary. Bosso, falls within the savannah zone greenery of West Africa sub-region however patches of rain forest, however. The greenery of Bosso is split in to three savannah of park or grassy that inhabit about 53 percent of the overall area and where the greenery is annually savannah wood land that happen mainly in the tough and less available parts on the Robo as well as Rubochi plains and exact ending hills (Lar, 2013).

The natural greenery of the study area is typical of the Niger State, which belongs to the Northern Guinea savannah, but most of the plants have been removed by deforestation attributed to earlier agricultural activities in the area. At present agriculture has began in some part of area of interest, vegetation of the area is mostly covered with grasses, shrubs, and little woodland which is heavily used for fuel, building construction and other purposes (Lar, 2013).

1.7.4 Soil, topography and geology

Bosso have two main types of soil, sedimentary belt in the southern and south western extremities of the area and the pre-Cambrian basement complex rock of the country which account for more than 80 percent of the area. (Figure 1.3). The sedimentary formation, being part of the Nupe land sandstones consists mainly of fine grained sandstones with inclusion of grits, siltstones and clay lines; and basement complex consists of wide variety of rock types which can be classified in to three broad groups.

Schist, including biotite/muscoriote schist, muscorite and tale schist's with quartzite intrusive account for most of the rugged landscape in the southern parts of the Minna. The igneous rocks made up mostly of biotite granite, rhyolite, and syenite. The granite account for most of the rock domes and massive hills in the north-eastern and north-western parts of Bosso.

The magnitites and gneiss complex. Which are metamorphic rocks consisting mostly of magnetite's, granite, gneiss and biota granite underline the site of the area. These are rocks of medium to high strength which were not expected to present serious engineering problems and the rocks of Bosso are generally quartz rich, acidic types which account for the generally sandy nature of the soil especially on the Robo and Rubochi Plains. The plains have the most fertile soils and the best agricultural lands of all plains of Minna while the high sand content of most soils within Minna accounts for the relatively high erosion status. There is however, one major advantage about the type of rocks and soils found in Minna because of the ability of construction materials in the form of building stones quartz and pistol tic gravel, building sands and earth for use as foundation materials.

Bosso geology consists of pre- Cambrian basement with an elevation which range between 273m to 333m in the west and 200m to 364m in the East. The landscape of the region (Bosso L.G.A) is relatively flat; this means it is located on a plain. North South direction divides the plain into two Western and Eastern part (Oyebanji, 1993). Bosso L.G.A geology can, therefore, be broad Meta-sediments occurring in more than 63.5 percent of the state Basement complex rocks occurring higher ground further away. The Niger State has proven deposits of a wide range of mineral resources including marble, tin, mica, clay, wolfromite, tantalite and talc**.**

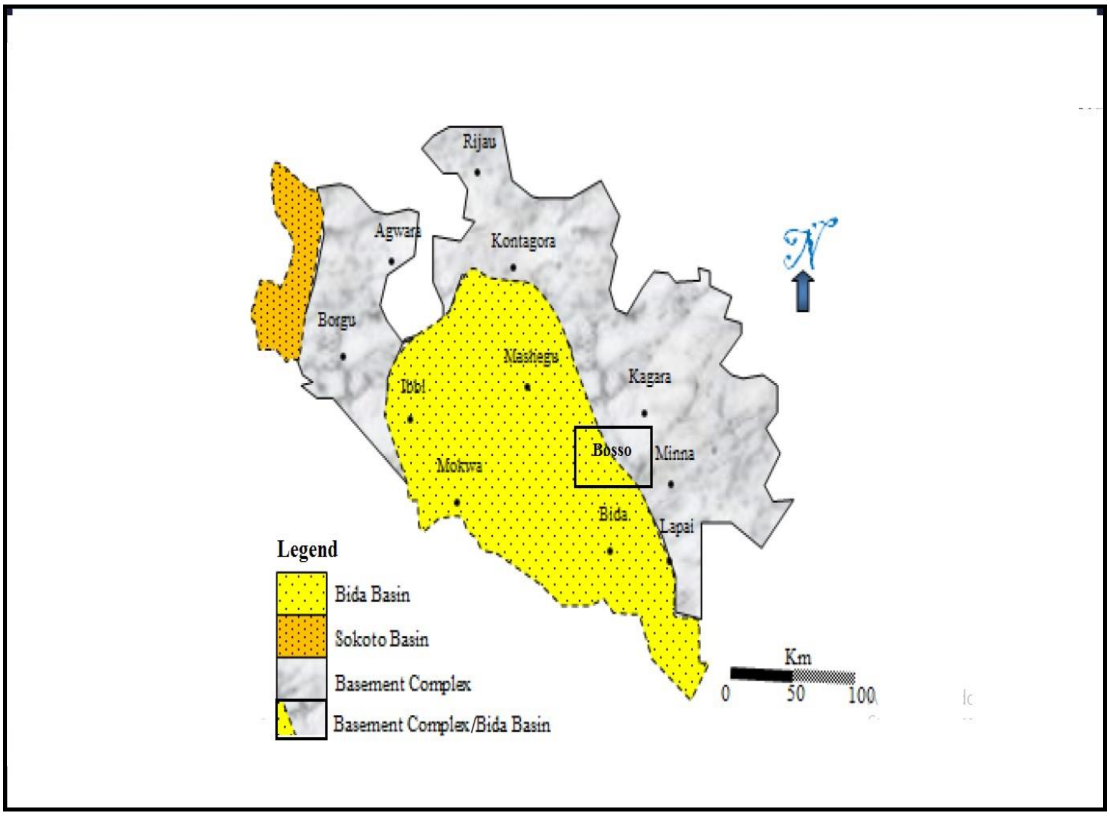

Figure 1.3: Geology of Niger State Showing the Study Area

Source: Federal Ministry of Mines and Steel (2019).

In the study area, groundwater happens within the weathered mantle and partially weathered rocks (Idris *et al.,* 2015; MacDonald and partners, 1996). Dupreez and Barker (1995) suggested that, aquifer lies in the weathered mantle and fractured rock where permeability and porosity are sufficient to permit appreciable much of water to accumulate in storage. The high groundwater return in the area is located where thick overburden overlies fractured zones. The aquifer types from the study area consist of

- Weathered layer aquifer;
- Weathered/ fractured or partially weathered aquifer; and
- Fractured aquifer.

The older granite has gone through many tectonic motions and pressure via geologic history such that they frequently have several fracture lines (Idris *et al.,* 2015).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Water

Water is an important constituent of all forms of life and is required in sufficient quantity and acceptable quality to meet the ever-increasing demand for various domestic, agricultural and industrial processing operations (Mallick *et al.,* 2015). This requirement is hardly fulfilled because 97.5 % of the world global water is saline existing in the ocean, 69.5 % of the remaining 2.5 % world global water that is fresh is locked up in glaciers while 30.1 % and 0.4 % of it represent groundwater and surface/atmospheric water respectively (Mallick *et al.,* 2015).

Water is one of the most essential commodities for mankind and the largest available source of fresh water lays underground (Mallick *et al.,* 2015). It is one of the most significant natural resources which support both human needs and economic development. The arid and semi-arid areas characterized by short periods of heavy rainfall and prolonged dry periods, the continual replenishment of groundwater storage and its sustainable utilization is indispensable to address the water needs of the community. Human activities cause changes in groundwater by change in land use/land cover, soil cover, and reduction in groundwater recharge. Although best methods to estimate aquifer thickness and preferable location of borehole are groundwater pumping test/drilling test and stratigraphy analysis, they are cost and time intensive as well as often require skilled manpower (Mukherjee *et al.,* 2012). Mallick *et al.* (2015). On the other hand, the integrated use of remote sensing, GIS, and satellite data is time and cost-effective means to assess and manage groundwater resources (Verma and Singh, 2013). This method that has a significant potential to monitor the information about various phenomenon and changes on the earth surface, such as the type of soil, geomorphology, land use / land cover, altitude, slope, etc. based on spectral reflectance on earth surface is widely accepted (Verbesselt *et al.,* 2016). Many of the scientific communities has reported the signicance of the elements of hydrogeological vary, i.e, land cover, drainage density, surface temperature, etc., which Control ground water potentiality of each location, so far which they may vary from region and space (Sener *et al*., 2015; Sreedhar *et al.,* 2014).

2.1.2 Groundwater

Ground water is contained in underground rocks, which contain and transmit water in economical rate generally referred to as aquifers (Mallick *et al.,* 2015). The amount and distribution of groundwater is a function of the amount of open space and the special extent of these rocks. The behavior of these rocks in turn is function of their formation and geological processes that shaped their status (Mallick *et al.,* 2015).
Groundwater is the largest available reservoir of fresh water, it comes from rain, snow sheet and hail that infiltrate the ground and become the groundwater responsible for the spring, wells and bore holes (Oseji *et al*., 2015).

Groundwater Potential in the region is managed by plenty variables such as geology, slope, depth of weathering, the presence of fractures, surface water bodies, canals and irrigation, among others (Jain, 1998). The slope is one of the variables which manage level of infiltration of rain water into the subsurface and therefore can be utilized as index of the groundwater potential of the land evaluation. In areas that slow runoff ramps allow more time for rainwater to sink in, while the high slope region help high runoff allows the available time is less for the relatively less rain water infiltration (Jain, 1998). Groundwater occurrence in geological formations and insight for exploitation mainly depend on porosity of the formation. Topographic depression increase infiltration. A high-density area drainage runoff also increases compared with a fair drainage density area. Surface water bodies such as rivers, ponds, etc., may act as a catchment zone (Murugesean *et al.*, 2012). Groundwater refers to all waters stored beneath the surface of the Earth (the zone of saturation) in aquifers (Dasgupta and Sikdar, 1992). Aquifers are also known as underground reservoirs otherwise called underground flood and the water that reaches this chamber is usually much cleaner than the one at the earth surface (Gustafsson, 1993).

Groundwater is a vital natural resource for the provision of consistent and economics of supply of drinking water to rural and urban environments (Mallick *et al*., 2015). With the potential to become the loudest in countries that already suffer from water scarcity. Occurrence water potential, which refers as the possibility of soil in the region (Rahmati *et al.*, 2014) became a hot research issue. The traditional approach to assessing the potential for ground water drilling, high expensive. Progress Geographic information system and Remote Sensing method has brought a more efficient way for mapping potential groundwater. Conventional groundwater exploration requires hydro-geologic investigation to study the lithology, stratigraphy and structural aspects of a region using geologic methods to understand the factors that regulate the amount, circulation and quality of groundwater.

2.1.3 Digital elevation model

Digital Elevation Model (DEM) is a representation of the topography, the technological advances offered by the GIS and the availability and quality ride Dems have significantly expanded the potential application of the Dems for several applications in various fields (Moore and Grayson, 2011). Among those variables related to groundwater mapping of potential, most of the information that has proved to be extracted from DEM data, and it makes extracting the relevant features of the DEM for potential groundwater mapping feasible. Many studies have revealed that the potential for ground water associated with many factors, such as geological features, terrain features and hydrological features. Candra *et al.* (2010) also used RS and GIS in groundwater exploration, they used DEM, slope map, soil map, hydro geomorphology map and analyse them using ARC GIS 9.3 version spatial analyst. In that research, the groundwater potentiality of the interest by way of via incorporation of a variety of groups include slope, and aquifer thickness.

2.1.4 Groundwater potential zones

Groundwater potential means having a latent possibility or likelihood of occurrence of groundwater in an area. Areas or zones of abundant groundwater available for use are referred to as areas of good groundwater potential (Mathew, 2006). Productive water bearing zones referred to as excellent groundwater potential aquifers. The search for groundwater has become quite extreme in human history. This can be achieved through groundwater potential studies. For example, Matthew (2006) pointed out that the groundwater potential of United States is divided into principal aquifers of over 300,000km^2, principal aquifers of over 20,000km^2, principal aquifers of less than

20,000km^2 and non-principal aquifers. Classification of areas into groundwater potential zones or classes is not a new issue in the field of hydrology.

Ali-elnaqa *et al.* (2009) determined groundwater potential of Wadi Arabia and classified the area into 40% of higher potential, 40% moderate potential, 17% low potential and the rest were undecided. Groundwater potential is determined utilizing RS and GIS to valuate water resource potentiality.

Evaluation for groundwater potential in Nigeria was conducted through delineation of aquifers by many researchers. Okoro *et al.* (2010) evaluated groundwater potentials in parts of escarpment areas of south-eastern Nigeria through delineation for aquifers, the groundwater potentiality area was categorized as excellent, medium, fair and poor potential zones.

2.2 Empirical Framework

Qazi *et al.* (2015) assessed groundwater potentiality areas in Allahabad region in India, utilizing RS & GIS techniques. The study was conducted to investigate potential ground water zone in Allahabad district utilizing RS data and GIS techniques. In the study, remotely sensed land use and DEM data were utilized to assess ground water potential zones. DEM (Digital Elevation Model) data used was also obtained from USGS. The presence of ground water in a given area depend on many hydro geological factors such as land use pattern and slope. The assessment of ground water potential zone was done by taking into account an impact of land use and slope on ground water after assigning ranks and weightage to these factors. Various land use classes were given weight and ranks according to their potential towards ground water. Similarly slope of the study area were weighted and ranked according to its impact on ground water potential for e.g. areas with steep slopes were weighted and ranked least because the surface water would stand long enough to get infiltrated and subsurface water in these areas will tend to less slope or to the level areas. It was found that the ground water potential zones information analyzed for Allahabad district can be used for effective utility of ground water for domestic and other purposes. It is also important to get suitable wells location for extraction of water and it’s a convenient and time saving method as compared to field methods. The ground water potentiality areas map of interest was classify in 4 groups viz. excellent, good, moderate and poor zones which gave a more realistic view to understand potential ground water areas and can be utilized for groundwater growth & monitoring.

Basavarajappa *et al.* (2014) studied mapping groundwater potentiality areas at pre-cambrian hard rock terrain in Tumakuru Region, Karnataka, India utiling geomatics application. Geomatic encompasses RS Satellite data, GIS, GPS and Survey in India (SoI) toposheets for mapping & integration of geology, drainage, lineament, soil types, slope category and other related features in assessing the groundwater resources of a region. Individual features in all thematic layers were assigned certain weights based on their relative importance in groundwater occurrences using SoItopomap (scale-1:50,000) and False Color Composite (FCC) images of IRS-1D PAN+LISS-III of 2008. The thematic layers was at last incorporated to produce a groundwater potential zones result through Erdas Imagine v2013. The final result highlights the potentiality of geomatics technique in mapping of excellent, good, moderate and poor groundwater potentiality areas in hard rock terrain of Tumakuru region, Karnataka. The study revealed that incorporation of thematic maps like, lineament, soil, provides data bank details for local group and planners in groundwater exploration and management. Weathered & fractured zones, granite, gneisses, schists and pegmatite were identified as major water bearing formations. The minimum and maximum water level observed were 14.4m and 62.5m respectively. Water table map represents main four groundwater prospect zones using the higher and lower contours based on the weightages obtained from all thematic layers. The final output implies the integration of RS, GIS, GPS and SoItopomaps with limited Ground Truth Check (GTC) in mapping groundwater prospects of area interest.

Bereket (2017) assessed potential for groundwater mapping Utilizing RS and GIS in the rift valley Lakes Basin, Weito Sub Basin, Ethiopia. Conventional ground water exploration methods, although they provide a quality result of varying range, tend to be time consuming and costly undertaking. The use of RS data and GIS opens the opportunity to utilize details from spatial and temporal scales broad, evaluate, and handle them effectively. This study also used remote sensing data shared with geological maps and distinct rainfall data to produce land map Weito prospective watershed in the rift valley lake basin (RVLB) in Ethiopia. The slope, geomorphology and drainage maps were developed from SRTM 30m digital elevation models. The results were verified through multiple field survey in the watershed. Geologic map, acquired from Ethiopian geologic survey was digitized and converted to raster format. Rainfall data from gauging station in the watershed was complemented with climate model data to develop a representative rainfall raster. PCI Geomatica software utilize for land use classification and extraction of lineament of Landsat 8 OLI / Tirs multispectral images. ArcGIS 10.0 and extensions that were utilize to produce the slopes and geomorphological map of SRTM 30m DEM and digitize the existing geological maps. Data from the database soil grids ISRIC land at 250 m resolution for the top 200cm also be utilized to produce a map of land for watershed. Weights are appointed to layers utilizing analytical hierarchy procedure (AHP) and overlay evaluation in ArchGis used to establish the ground water prospective maps. The outcome showed 1, 15 and 23 percent of the watershed is in high, moderate or low in each other, while the remaining 60 percent of the land location of potential water low soils. The resulting groundwater map conforms to initial assessment based on secondary data sources such as landform and geological information. The study concluded that the use of soil data from ISRC as opposed to large-scale shape files from FAO delivered promising results. With continuous improvement of the data set and the ease with which it can be incorporated in the analysis will make it a preferred data source for similar analysis.

Akinwumiju *et al.* (2016) analyzed the potential evaluation of integrated land-based GIS Osun drainage basin, western Nigeria. A GIS-based integrated method adopted to assess the potential for ground water of Osun Drainage Basin Basement Complex terrain constituted by Western Nigeria. 10.3 ArcGIS Spatial Analysis Module software used to generate the proximity of straightness, hydrolineament and density map of area of interest. Module vegetation index were employed to model the patterns of vegetation from Landsat imagery. Lithology and topsoil extracted from geological maps and land there. Five hundred dataset Vertical Electrical Sounding quantitative interpreted using partial matching curve engineering and computer aided 1-D forward modeling. Overburden thickness and the aquifer thickness map generated from the interpretation of VES. Eleven raster-based thematic maps (density straightness, straightness proximity, drainage density, vegetation index, slope, elevation, landscape, thickness of overburden, the thickness of the aquifer, lithology, soil) prepared from a map produced and their respective influence on groundwater systematically determined. Thematic layer was subjected Overlay Fuzzy Logic in ArcGIS environment to illustrate the basin into classified areas of ground water potentiality. The basin groundwater is described in five zones comprising potential is very excellent, good, fair and bad. Sixty-one percent of area of interest is considered very low, 16 percent rated moderate and 23 percent of the remainder was adjudged to have good potential for ground water. Seventy-six percent of the drill hole results correlated with soil water potential models with a correlation coefficient of 0.872 at $\alpha = 0.01$. The study concludes that the potential for ground water is generally low in Osun Drainage Basin.However, an isolated zone with high groundwater potential is identified in particular in the field of highland basins. A significant positive correlation was observed between the end of the ground potential maps and spatial pattern of borehole results in the study area. In this case, the environmental factors that are considered in this study is powerful enough to provide meaningful explanations of borehole results in the study area. The study concludes that the potential for ground water is generally low in Osun Drainage Basin. However, remote areas of potential groundwater real good especially in upland basin. Thus, the prospect of ground water is observed only suitable for groundwater development schemes of small scale.

Lars (2016) investigated modelling of groundwater discharge areas using only digital elevation models as input data in Lanzhou, China. Advanced geohydrological models require data on topography, soil distribution in three dimensions, vegetation, land use, bedrock fracture zones. To model present geohydrological conditions, these factors can be gathered with different techniques. The study used GIS software with four different functions using digital elevation models as input data, geomorphometrical parameters to predict landscape ridges, basin fill for predicting lakes, flow accumulations for predicting future waterways, and topographical wetness indexes for dividing in-between areas based on degree of wetness. The hydrological model (ArcGis Hydrological modelling extension) predicted lakes and waterways; these areas were classified as “probably discharge areas”. The topographic wetness index (TWI) was calculated for the entire calibration area. Statistics for the distribution of TWI areas for “most likely recharge areas” and “most likely discharge areas” were calculated. Hitherto unclassified areas with TWI values lower than the 3rd quartile for “most likely recharge area” (4.2) were classified as “probably recharge areas” and areas with higher TWI values than the 1st quartile for “most likely discharge areas” (7.9) were classified as “probably discharge areas”. The remaining areas were classified as “undefined”. The model was validated with DEM, the localities map’s wetlands and lakes (discharge areas), and soil map’s exposed bedrock exposures (recharge areas) for the area immediately to the east of the calibration area. The results showed that only 1.2% of the points were incorrectly classified, 3.4% were undefined, and 95.4% were correctly classified. Validation with exposed bedrock (recharge areas) gave lower results. 1.0% of the points were incorrectly classified, 13.8% were undefined, and 85.2% were correctly classified. The conclusion is that topography has a significant influence on the distribution of recharge and discharge areas in the landscape.

Mogaji *et al*. (2011) assessed mapping of lineaments for groundwater targeting in the basement complex region of Ondo State, Nigeria, using remote sensing and geographic information system (GIS) techniques. Sustainable groundwater supplies in the terrain underlying by crystalline basement rocks require lineament analyses for proper sitting of boreholes. This study was carried out to illustrate the application and importance of Remote Sensing and Geographic Information System (GIS) techniques for efficient groundwater resource exploration and management. The study demonstrates the use of LANDSAT 7 ETM+ imagery, ASTER digital elevations models (DEMs) and geological maps for mapping and analyses of lineaments in the Basement Complex region of Ondo State, Nigeria. Digital image processing techniques involving linear / edge enhancements and directional filtering were applied on the image to enhance the edges of the linear features using ENVI 4.7. The enhanced image, normalized difference vegetation index (NDVI) image and hill shaded relief image (processed ASTER DEM) were visually interpreted through GIS overlay operations for lineaments extraction through on-screen digitizing using ArcGIS 9.3. The extracted lineaments were statistically analyzed to determine their lengths, densities and intersections. The results obtained were used to generate lineament density, lineament intersection map and rose diagram. The lineament / fracture analyses indicated that the area has numerous long and short fractures whose structural trends are mainly in the north-south and east-west directions. The cross-cutting lineaments were relatively high in areas around the central, northeastern and south-western parts of the study area, and relatively low in the other areas. The zones of high lineament intersection density were identified as feasible zones for groundwater prospecting in the study area. The study has led to the delineation of areas where groundwater occurrences is most promising for sustainable supply and hence, further geophysical survey can be concentrated.

Impact of the surface topography of ground water potential in Kano State, Nigeria was examined by Tasi'u (2017). With the aim of identifying potential ground water zones and connect with the nature of the surface topography or the slope location. Sixteen rural location were identified from eight local government areas utilizing systematic random sampling technique. Data depth to water level and water table values acquire from wells drilled selected. DEM of the study location was produce from Shuttle Radar Topography Mission, derived thematic maps and overlays. Zone soil water potential is determined. Map contour and slope maps are created and regroup. Slope and contour values associated with zones of ground water potential. The findings suggest that the southern part of the study location were high in elevation with values relief more than 767.9m. Five ground potential areas classify as excellent, good, fair and bad. Falls excellent in Yandadi, Karfi and Shakogi depth to water level 13.29 - 14.98m, the value of the water table of 407 - 426m, 440m contour value - 566m and the slope value 0o - 2o. outcomes also showed that a bad prospective area at Riruwai was the depth to the water level of 18.31m -> 19.31m, water tables appreciate 873.69m - 874.69m, 893m contour values and slope> 18o. Hence suggested that the field values are higher contour, depth to higher water levels, the value of the water table is higher and values higher slope lower borehole ahead with a hand pump must be offer for the water supply of rural efficient and monitoring.

Obimba *et al.* (2017) evaluated the use of RS techniques, GIS for ground water potential of Ilesha region, Osun State. The land in the Basement Complex terrain Ile, southwest Nigeria control with the secondary porosity produce of weathering and fracturing of crystalline bedrocks. Research RS GIS integrated approach to assessing the potential of groundwater. Thematic maps of geology, lineament, drainage and topography ready and incorporated utilizing GIS 9.3 to generate a map of ground water potential research areas. Multi-criteria and weighted classification. were adopted which revealed that the topography of the study area ranges between 1700 m-850 m. Areas with high elevation or hilly areas (1450 m-1700 m) were observed to have lower ground water potential, this could be attributed to the fact that at high altitude water runs off and has little or no residence time to percolate into groundwater. This is because one of the driving forces for ground water flow is gravity. Water go from higher altitude to lower altitude and from higher force to lower force. Areas with topography range of 1150 m-1400 m are regarded as moderate altitude and moderate groundwater potential. Lastly areas with range of 850 m-1100 m are regarded as low altitude and high groundwater potential. Based upon water retaining capacity of the rocks in the study area (schists, gneisses and undifferentiated migmatite) the geology was grouped into excellent, good and fair groundwater potential depend on their ability to let water pass through them. Result of the study reveals that Ilesha (urban area) is seated on a moderate groundwater potential area. While other settlements like Eyinta, Ibede and Itagunmodi were situated on high groundwater potential zones. The groundwater potentiality in areas of interest is grouped in excellent, good and fair water potential region. A big side of the interest falls in the good-excellent groundwater potentiality region; in Ilesha city.

Maina and Tudunwada (2017) in the study lineament mapping exploration of groundwater in Kano, Nigeria demonstrates the ability and stressed the importance of geospatial systems RS and GIS approach to explore groundwater resources and effective monitoring. This study used a Landsat ETM +, ASTER DEM (30m) for mapping and evaluate of straightness. PCI Geomatica is used to extract and cross straightness map model. ArcGIS 10.2 is used to create the alignment density and ultimately Rockworks 17 is used for the analysis of trends to chart roses. Analysis lineaments / fractures indicate that the area has a lot of broken bones and short-term structural trends, especially in North-South direction. The Zones of high-density lineaments crossing the zone for prospecting groundwater in the study area. These findings indicate the direction of lineaments frequency is detected in the study area. It shows statistics represent a means to crack different environments, as well as the development trend of fissure in the area. Long petals represent the intensity of alignment in the area of analysis and solid countenance indicated intense fracturing rock in the area. The southern part of the country has abundant groundwater resources unlike the northern part of the country to the level of ground water in. This research reaches the shooting scene region were groundwater has the good result for the substantial exploitation of ground water. The study concluded that remote sensing technique that is able to extract lineament trends over a large area. It is therefore recommended that the high density of crossing alignment must have combined of results electrical sounding surveys for quantity outcome to ground water potentiality of research interest.

Abel and Monshood (2011) uses an incorporated technique to study the potential of groundwater in Ekiti South West Nigeria through overlay evaluation weighted where land Sat and thematic maps are incorporated and the results showed the research location is categorized into excellent, moderate and bad in terms of the potential for ground water and among the factors straightness was found to be the most influential.

The land in the Basement Complex terrain Ekiti location, southwest Nigeria managed by the secondary porosity established via weathering and fracturing of crystalline bedrocks. A typical aquifer is disconnected (localized) analysis of potential groundwater guarantor of the region. Therefore, this paper offer an incorporated method of RS and GIS potential groundwater zoning in the study location. Thematic maps of geology, geomorphology, straightness, slope, and drainage density produce and incorporated utilizing ArcGIS 9.1 environment to generate a result of ground water prospective research areas. Evaluation of potential groundwater GIS generates a map where the study location is group in high, moderate and the low. In addition, the superimposition data of soil from the area of research on ground water potential maps reveal that there are more number of wells in the zone of high-yield favorable (high and moderate enough) shown by the GIS method. The research highlights that soil water prospective maps aside from his function as exploration guides will be important for the growth of a sustainable ground water schemes in the location.

Anudu *et al.* (2011) carried out a research on the potential for ground water in Nassarawa State Nigeria Wamba. Thematic maps utilized slope, drainage density, density contour maps and straightness. Results showed that the lineament and drainage is the most vital factor of identification of land in the area. In this research, an incorporated RS and geophysical methods (aeromagnetic and geo-electric) are used to evaluate the prospective for ground water in the basement of the complex field Okene and surrounding areas, the West, Nigeria. Landsat imagery obtained over research location is refined within GIS to describe the surface lineament, drainage network and their orientation. The aeromagnetic data over the located evaluated and interpreted to better map derivatives of mapping the structure and geology below the surface; the depth of the magnetic source is identified utilizing spectral evaluation. Vertical Electrical Sounding (VES) on geo-electric approach is translated to map the geological layers below the surface. Outcomes of incorporated data that is correlated with the data from the drill hole area for efficient interpretation. Described straightness of the azimuth, the groove frequency indicates the dominant trend in the NE-SW and NNE-SSW direction. The average power range reveals the deepness of radial magnetic source between 100 and 2500 m and the data translated VES marked location into 3 and 4 layers below the surface. In associating the outcome with data from the borehole, lineament density areas with good / fair negative magnetic anomaly zone is classified as a high ground water possibility while location of low lineament density are potential ground water zones of low magnetic anomaly high positive. This research will guide the drilling program next efficiently groundwater in the study area.

Al Saud (2010) evaluated the potential for groundwater storage in Wadi Aurnah Basin, in Saudi Arabia utilizing RS and GIS approach. Satellite images with high spatial resolution are refined to acknowledge the terrain factor control the behavior of the subsurface rock. Landsat 7 ETM +, ASTER satellite imagery and SRTM are refined. The element on soil water storage and digital influence identified mapped as thematic layers. This includes rain, slope, drainage and land cover/ use. These elements are incorporated into the GIS system. A map is generated, showing the prospective location for ground water storage. The resulting map reveals that 12-15% of Wadi Aurnah Basin has the prospective for ground water storage, especially in location where there is extensive crack system.

Tesfaye (2010) studied groundwater potential of Bilate river catchment of Ethiopia through integration of lithology, geomorphology, landform, lineament density, soil and slope utilizing Saaty's analytical hierarchy process approach. Land sat ETM+ area of interest was used. Those regions were divided into very fair, fair, good and excellent in terms of groundwater potentiality.

Imran *et al*. (2010) studied the groundwater conditions in the basin Mamundiyar, Tamil Nadu which combine RS, evaluation of DEM, GIS and survey work Method. DEM is utilized for straightness and geomorphological mapping. These thematic group are incorporated and examined in GIS. The overall results indicate that the use of RS and GIS provides a strong tool for studying the groundwater resources and design best mapping guide.

Vijith *et al*. (2007) also conducted a study of identifying and describing potential areas of groundwater information on the Western Ghats, Kottayam, including watershed upstream Meenachil. Information from the lithology, geomorphology, straightness, tilt and cover land use / land produced using RS data and the Survey of India topographical sheet they are integrated with a raster-based GIS to signify potential groundwater area of interest. Hence, GIS models that take into account local conditions / variations have being created to mapping soil water potentiality. On the basis of hydrogeomorphology, three groups for ground water area are high, moderate, and bad are signify and described. It was found that high-potential zones in accordance with a broken valley, valley fills, pediments and slope deforestation that coincides with the slope of the low- and high-density location lineament.

Prabir *et al*. (2012) attempts to evaluate the potential for ground water zones in an arid area of Kutch district, Gujarat. Thematic layers have been produced utilizing additional data and digital satellite imagery. Potential zones have been acquire with a weighted overlay evaluation, the ratings provide to each specific specification of each thematic maps and weights are designated according to their impact. Convergence Index (CI) is used to distinguish the flow area of the convergent divergent regions (Kiss 2004 N. Thommeret 2009), so it could be used for potential groundwater modeling. Vanessa, (2008) presents a favorability mapping groundwater in brazil; lithology and geomorphology layer integrated in GIS environment Imran *et al*. (2010) GIS and RS to map groundwater potential zones are incorporated; GIS and the probability model utilized, the hydrological data utilized.

Vasanthavigar *et al*. (2011) map prospective areas of groundwater in the basin Thirumanimuttar with an incorporated technique to the use of RS and GIS. Landsat TM 30m resolution data and topographic maps are Utilized to get thematic maps such as geology, straightness and lineament density, and slope map of the research. Some geomorphic units such as denudation hill, Deep pediment and alluvial plains has been observed. A composite soil maps generated prospective as very excellent, good, fair and bad based on the location of ground water availability. The top, center and lower reaches of the basin has been determined as a prospective zone for ground water exploration. Straightness and intersected area proved to zone soil water potential. The resulting data were validated with field inspection and observed the same suit.

Suragit (2014) assessed the evaluation of groundwater prospective zones utilizing electrical resistivity, RS and GIS methods in a typical mine location of Odisha, India.

Regardless of adequate rainfall huge component of India experiences water deficiency. Ground water takes place in weathered or semi-weathered/fractured layers in hard-rock locations whose density differs, generally from 5m to 20m. Satellite images are commonly being utilized for groundwater exploration as a result of its capability to determine different ground attributes, which might act as a sign of groundwater's visibility, Research and also evaluation of remote sensing data is rapid and also affordable means of searching and also discovering. Existing research, for evaluation of groundwater accessibility in Tensa valley (Sunderghar Area, Odisha) reveals different groundwater prospective areas. India had actually been marked utilizing remote sensing and also GIS methods. The groundwater accessibility at the valley was approximately split into various courses i.e., Superb, excellent, moderate and also inadequate based upon its hydrogeomorphological condition. Toposheets by Study of India and also IRS-1C satellite images are utilized for preparing different thematic maps viz. geomorphology, land-use, lineament, density and also soil map, were changed to raster course data utilizing attribute to raster converter device in ArcGIS. All the raster maps were designated to a set percent of impact and also weighted their after weighted overlay device or method was utilized. For obtaining the groundwater prospective areas, each weighted thematic layer was calculated statistically. The outcomes hence acquired were later on validated with resistivity study examination data. The outcomes acquired were incorporated with the various thematic maps on GIS system which generated an excellent suit with the acquired resistivity examination outcome. Additionally, an inexpensive soil wetness meter has been developed and also established in the Department of Civil Engineering to keep track of the surface area wetness which likewise functions as sign of feasible groundwater potential sites, various plants and also plants situated in the area.

Moghaddam *et al*. (2013) produced groundwater spring prospective map utilizing a bivariate analytical model regularity proportion and also GIS in the Taleghan Watershed, Alborz District, area studies were provided for determining and also springs inventory mapping. The efficient elements on the groundwater spring such as: slope percent, slope element elevation, topographic moisture index, stream power index, slope size , strategy curvature, range from rivers, range from roadways, range from faults, lithology, land use, soil hydrology teams, and also drain density was originated from the spatial database Utilizing the above efficient elements groundwater spring prospective mapping was computed utilizing bivariate analytical model and also the outcomes were outlined in Arc GIS. The outcomes of groundwater spring prospective map might be useful for coordinators and also engineers in water resource monitoring and also planning.

Murugesean *et al.* (2012) have also conduct research in the ground water kodaikanal hill Dindigul district, a Hills region in the Western Ghats of Tamilnadu. Zone soil water potential has been limited with the help of RS and GIS approach. All thematic maps were produced using resources seating (IRS P6 LISS IV MX) Data Model and Inverse distance weight (IDW) is utilized GIS data to show potential groundwater in area of interest. For a variety of geomorphic unit, weight factor, defined by their ability to hold ground water.

Davoodi (2015) Groundwater spring prospective mapping. Several researchers have actually located that multi-criteria analysis technique is an efficient device for defining groundwater prospective resources. As stated over, all sort of thematic layers and also data was prepared for multi-criteria building and construction. this technique will certainly experience lots of problems as a result of the restricted data. Several research studies have actually disclosed that groundwater possibility is associated with several element, such as geological attributes, surface attributes, hydrology attributes. DEM is the electronic representations of the topography, the technical developments offered by GIS and also enhancing accessibility also high quality of DEMs have significantly increased the application possibility of DEMs to several applications in several areas (Moore *et al.*, 1991). Amongst those elements associated with groundwater prospective mapping, the majority of the details has actually been verified by extracted from DEM data, and also this made extracting appropriate attributes from DEM for groundwater prospective mapping is viable.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Data and Tools

This research work used both primary and secondary Sourced data.

3.1.1 Primary data source

Primary data for this study includes collection of GPS points from the field and photographs. Field surveys were undertaken to validate the dependability and constraint of the adopted technique. Thirty (30) wells were identified for potential mapping of groundwater in area of interest.

3.1.2 Secondary data source

Secondary data utilized consist geology and topography maps of the study area and this were acquired from geological survey of Nigeria 2006 at a range of 1:250000. main data utilized in mapping potential groundwater in the study area was SRTM DEM of 30m spatial resolution was acquired from NASA center distributed active archives (LP DAAC) website, journals, Books, etc.

3.3 Methods of Data Analysis

3.3.1 Examine drainage networks and slope in the study area

Several algorithms have been put forward on the DEM drainage network extraction. The D8 algorithm (deterministic eight nodes) has been widely used and applied in the ArcGIS software (Mohamed, 2014). In this study, the ArcGIS software (D8 algorithm) was adopted in accordance with Mohamed (2014) for the extraction of drainage network. Then the map drainage network was generated for the groundwater modeling. Drainage network may indicate the permeability of the area thus had a close mapping of potential ground water connection.

Digital Elevation Model (DEM) could store varying variables like elevation, slope, ground water depth etc. The accuracy and efficiency of DEM depends upon details of elevations which was digitized to find slope. The DEM map was prepared using ArcGIS 10.2. The slopes was categorized into three classes: gentle, moderate gentle and steep on the basis of level of slope. The lesser the slope, the higher is the infiltration rate resulting to good ground water potential zones (Anudu *et al.* 2011). Similarly, the higher the slope, the lesser was infiltration rate resulting in poor ground water potential zones. It means lesser opportunity time for water to infiltrate into ground. Level areas was given highest rank i.e. 3rd rank as slope classes was grouped up to three classes that's why 3rd rank was assigned to level areas, moderate level areas was given 2nd rank and steep areas was given least rank i.e. first rank depending upon infiltration rate and its impact on potential groundwater. Map was produced by creating SRTM DEM interpolation and the height of the spot and the edges in the GIS environment adopted by Goyal *et al*. (2009), Tesfaye (2010), Okoro *et al*. (2010), Anudu *et al.* (2011).

3.3.2 Determine the convergence zone location of the study area

Convergence Index (CI) to be adopted from Kiss (2004) was utilized to differentiate circulation convergent area from divergent area, thus could be utilized for groundwater potential modelling. CI was computed based on the element which can be extracted from DEM. CI was acquired by calculating the average angle between the element of adjacent cells and the direction of the central cell and then subtracts

900. Positive values stand for CI divergent zone while negative values stand for CI converging zone. Thus, a lower IC value was linked to the accumulation of groundwater and have a potential value of more groundwater. The CI Map was produced.

3.3.3 Map groundwater potential zones in the study area

A total of thirty (30) wells were identified with their coordinates for the groundwater potentiality mapping in area of interest. To generate groundwater potentiality zonation map, following methods were adopted:

a. Integrated thematic maps such as base, drainage, geology, slope overlays was prepared from Niger State Ministry of Geoinformatic, toposheets and satellite data respectively.

b. Field visits was carried out for inspecting the interpretation as well as for gathering other additional details.

c. Thematic maps was prepared using Arc GIS Software.

d. Field observations was incorporated in various thematic maps.

e. Multi-Criterion Evaluation technique was used for assigning weightages, ranks and scores to different themes and features class by assessing the relevance of it in ground water occurrence. After which ranks and scores to the themes and element were converted to raster format using ‘Spatial Analysis’, extension of ArcGIS software.

This map was reclassified into GIS home utilizing Arc GIS to demarcate different ground water potentiality areas. The generated outcome consists different classes of ground water potentiality zones namely excellent, good and fair Zones from ground water potential point of view. Score of feature class for weightages and rank. “Raster Calculator” alternative of ‘Spatial Analysist’ extension of Arc Info Arc GIS software was utilized to prepare incorporated groundwater potential zones map by adopting appropriate map algebra.

CHAPTER FOUR

3.0 RESULTS AND DISCUSSION

4.1 Examine Drainage Networks and Slope in the Study Area

The outcomes for this objective were classified into three and they include DEM, drainage network and density.

4.1.1 Digital elevation model of the study area

Figure 4.1 shows the elevations over area of interest with the highest altitude of 452m situated in the North eastern part of interest and 71m as the lowest elevation found at the southwestern part respectively. The high elevation points have low potential of groundwater and low elevation has good and excellent groundwater possibility in the study area. As revealed in the study some areas in Bosso, Tudun Fulani, Maitumbi and Chanchaga were within the range of 257 to 452m and this in turn has made the areas to have low or moderate groundwater potential.

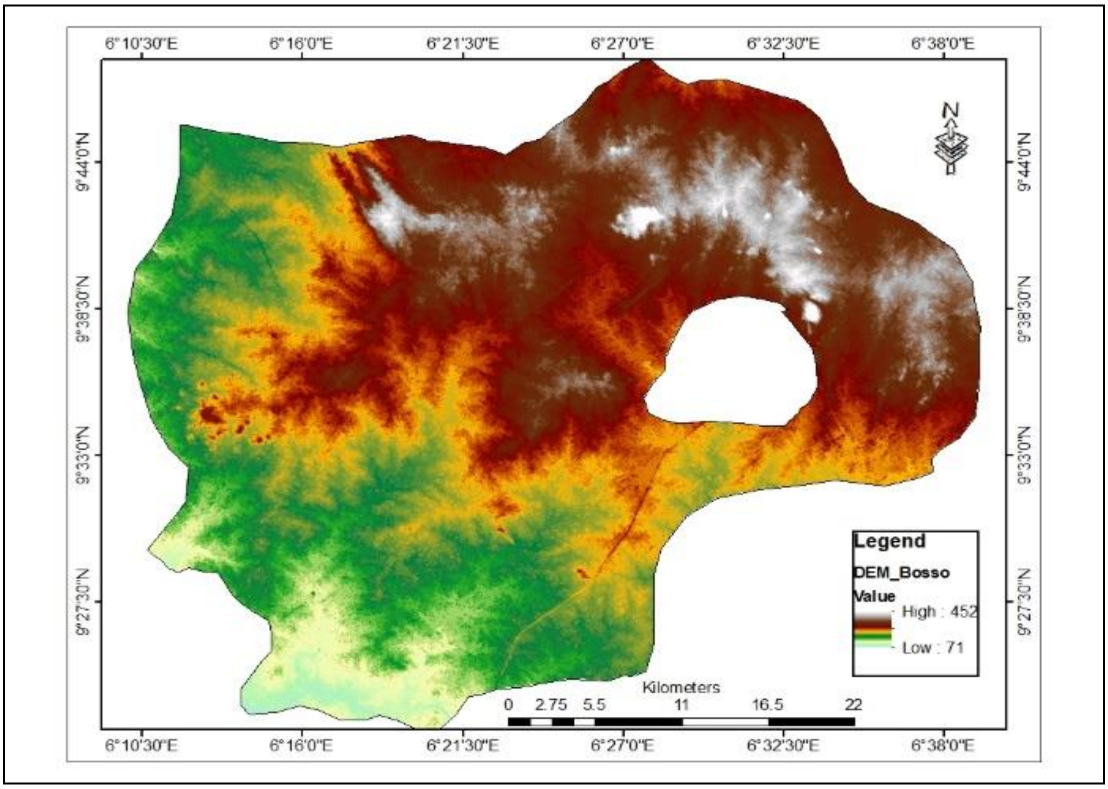

Figure 4.1: Digital Elevation Model over the Study Area

Areas with High elevations will provide the people with low groundwater and places with low elevation will give moderate or high groundwater this is because places in low altitude will offer more possibilities for the accumulation of ground water. DEM data is essential element in identifying the water level altitude (Sener, *et al.*, 2015). The combination of cracks with a low topographic land can functions as the most effective of the aquifer perspective.

4.1.2 Drainage network of the study area

This map covers bodies of water, rivers, creeks, perennial and ephemeral streams, and ponds. The research area still ranks fourth basin joining a river, a tributary drainage network based on the sequence depicted in Figure 4.2 of the study.

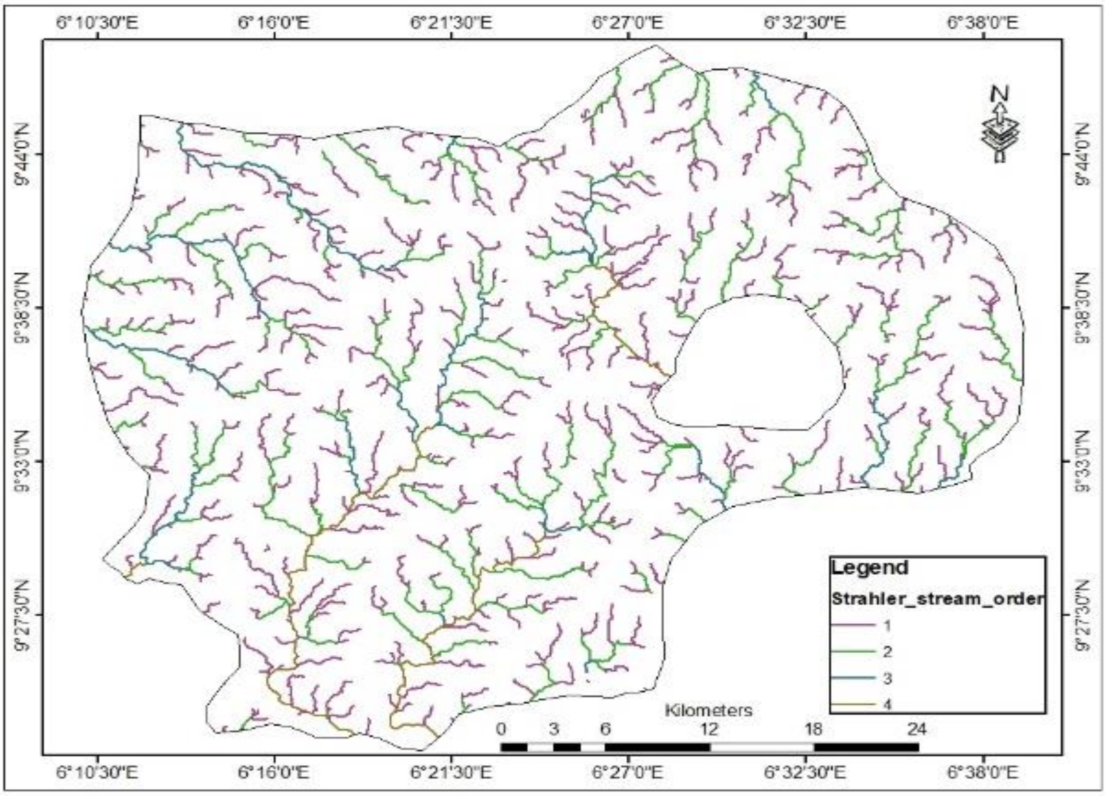

Figure 4.2: Drainage network order over study area

The North West Maikunkele, South West Beji and South Eastern Garatu areas have more drainage network ordering involving all classes which made them to be high or moderate potential groundwater areas while North East Bosso, Mitumbi, Chanchaga areas have low drainage network stream ordering which made the locations to have low groundwater potential.

4.1.3 Drainage density network

Less absorptive rock, the less the infiltration of rain, which otherwise tend to be focused in surface run-off. The area of extremely high drainage density amount more nearness drainage networks and vice versa. Figure 4.3 revealed the areas with high, moderate, and low drainage density covered 590.37km^2 (37.18%), 648.67km^2 (40.85%), and 348.83km^2 (21.97%) respectively. high drainage density is below the surface of the resultant material weak or nonporous, rarely green and hilly relief. low drainage density causes the texture of rugged drainage while a high drainage density causes the great appearance of drainage. Identify runoff drainage density in the area or in other words, the relative quantum rainwater can infiltrate. For this reason, the lower drainage density, the greater is the chance to reenergize or prospective ground water area. Drainage Density is calculated using statistics Focal spatial analyst tool in ArcGIS 10.5.

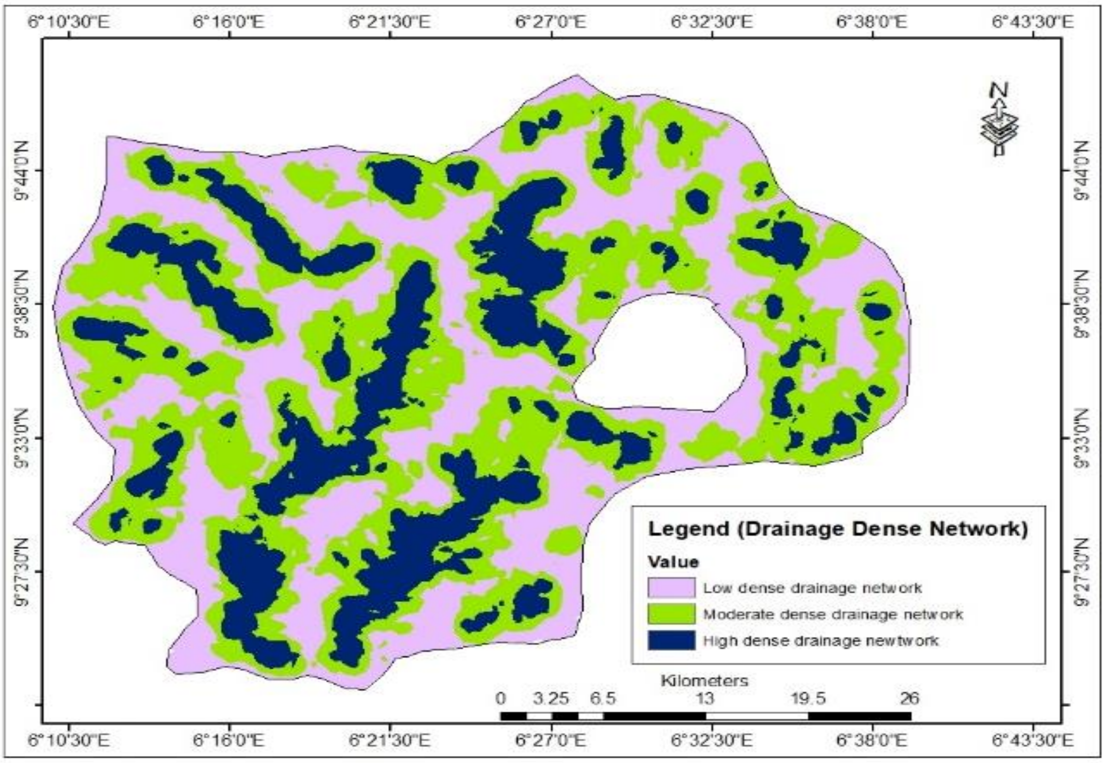

Figure 4.3: Drainage density network over the study area

The density of drainage runoff in a location identified as a relative quantity of water that is not able to pass through into the subsurface. Furthermore, the drainage density of this study do provide signs of closure or stream / river network which inturn will rely on the nature and level of weathering of surface and subsurface lithology unit. A low drainage density in this study therefore increases the possibility of recharge and contributing positively to the availability of groundwater if the various conditions of the ground water is useful.

4.1.4 Slope

Slope map was prepared with hydrological tools in the spatial analyst in ArcGIS 10.5. The study area was categorized into three groups such as 0 to 2°, 2 to 5°, and above 5° based on slope measured in degrees. It is shown in Figure 4.5 that area with low slope (0° to 2°) covered an area 390.94km^2 (24.62%) and is excellent from the point of occurrence of groundwater. While moderate and high slope area covered 428.95km^2 (27.01%) and 767.98km^2 (48.37%) respectively.

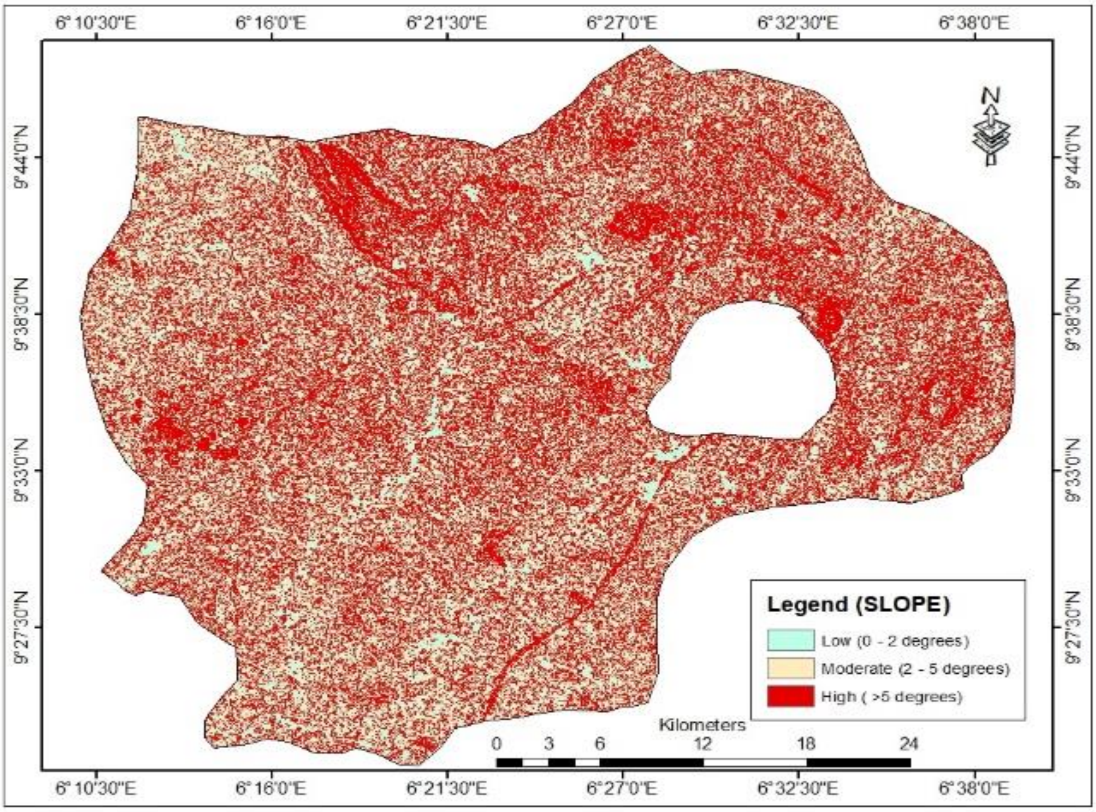

Figure 4.4: Slope over the study area.

Further analysis about the attribute of slope of the research area disclosed that the lower slopes are indicative of slow moving runoff permitting more time for rainwater infiltration which inturn leads to accumulation of ground water, while the area high slope facilitate runoff allows less time to stay for rainwater, hence, relatively less infiltration and less ground water accumulation. This agreed with study of Tasi’u (2017) and Bereket (2017).

4.2 Convergence Index Map

Figure 4.5 revealed the convergence index map over the study with most part of the area having low index. Areas with high convergence flow indicate high groundwater potential; areas with moderate convergence flow indicate average groundwater potential and areas with low convergence flow indicate low or no potential groundwater in the study area.

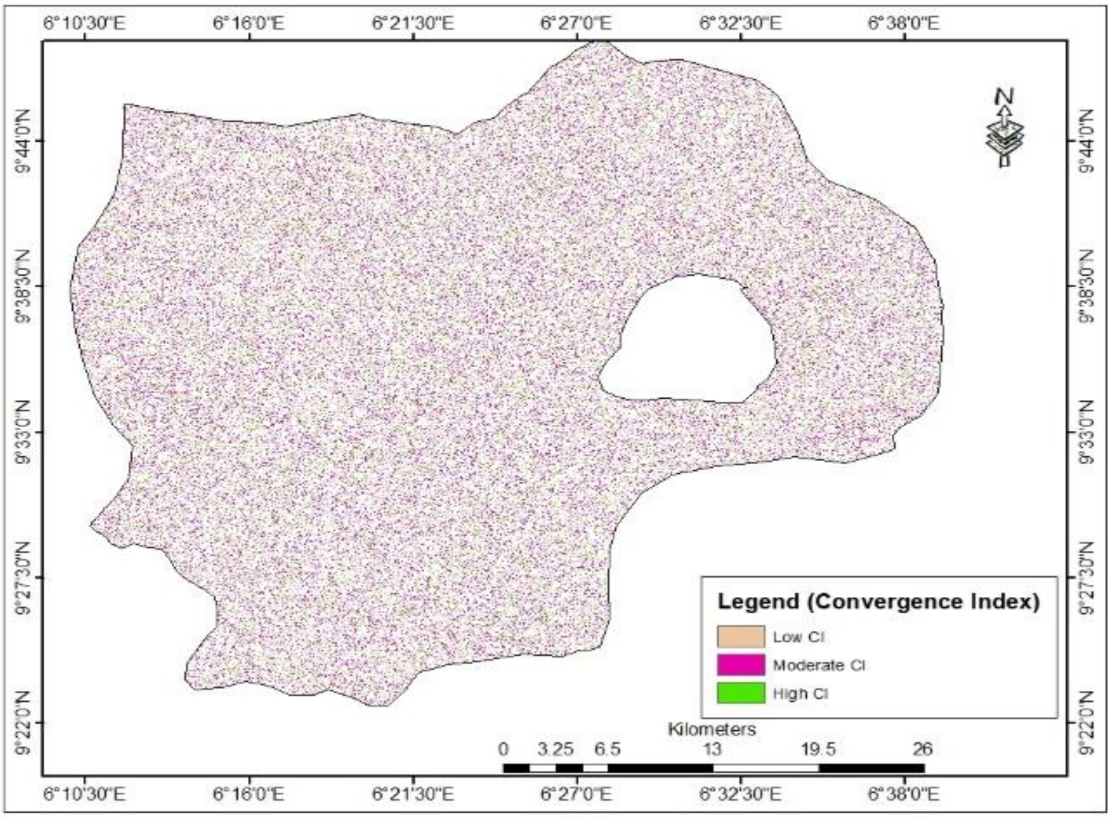

Figure 4.5: Convergence index over the study area

As revealed in the study 48.37% of entire study area were within moderate convergence index, 27.1% of the study area were within high convergence index and 24.62% of the study area were within low convergence index. Low CI stand for divergent areas while High CI stand for convergent areas. Thus, a higher CI area associated with groundwater accumulation and had a higher groundwater potential.

4.3 Groundwater Potential

Each thematic map such as drainage density, convergence index, elevation and slope gives particular hint for the event of groundwater. To get all this detail merged, it is essential to incorporate these data with appropriate element. Using weighted overlay evaluation device in ArcGIS all the thematic maps were incorporated. Weightage to the various layers have been established to consider comparable work performed by several researchers as studied in the literature. A simple arithmetic model have been adopted to incorporate a variety of thematic maps with the weightage. The final map has been classified into three groups, from groundwater potential point of view High, moderate, and low which covered 128.54km^2 (8.10%), 1315.27km^2 (82.83%), and 144.06km^2 (9.07%) respectively as shown in Figure 4.6.

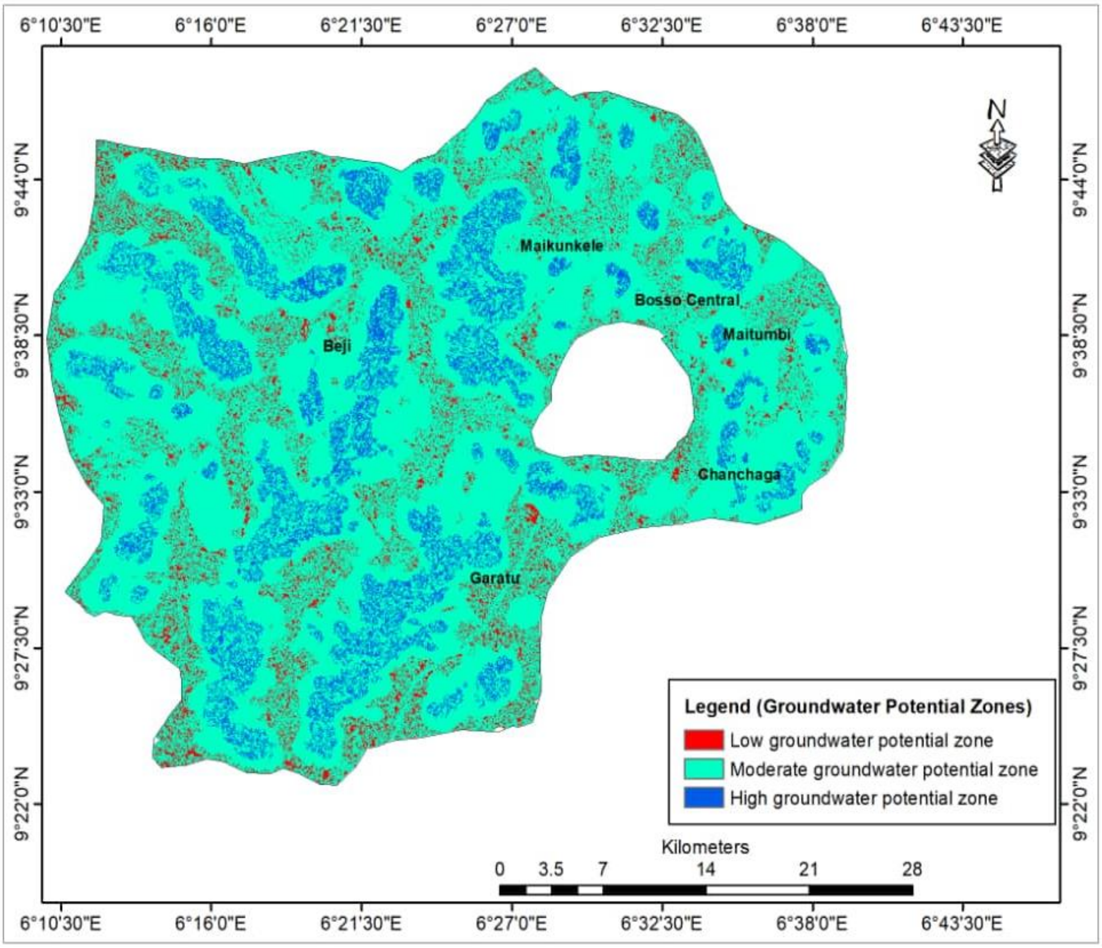

Figure 4.6: Groundwater potential groups over area of interest.

As Revealed in the study shows the three (3) different potentiality of ground water within area of study and they are classified into fair, good and excellent groundwater potentiality areas. The result shows that the Maikunkele, Beji and Garatu areas with very high groundwater potential is characterized by high rainfall, low slope and dominated with cambisols which have a relative high-water holding capacity. The

Bosso central, Chanchaga and Maitumbi areas with very low ground water potential is characterized by moderate slope, high drainage density and dominated by granite which has low ground water potential. It can be observed from the result that high rainfall and high slope as well as low drainage density are the major element contributing to ground water potential in area of interest as places with high rainfall and low slope were found to be the areas with very high groundwater potentiality. This agreed with the finding of Idris *et al.* (2015).

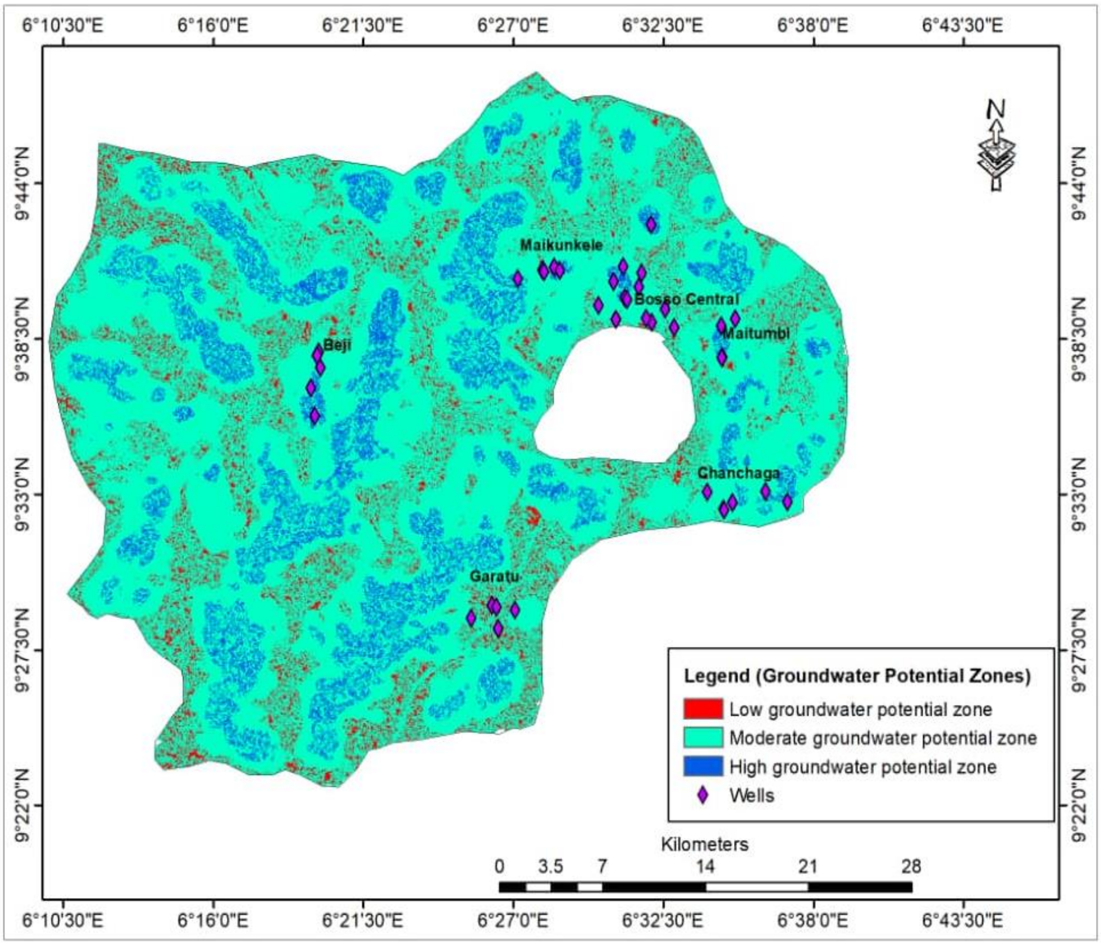

Figure 4.7: Overlay of Identified Wells on Groundwater Potential Zones.

As revealed in the study 13 sampled points were located within excellent potentiality areas; nine sample points were identified within low potentiality areas and eight were identified within moderate potential zone. Those wells identified in fair potentiality areas only have water during the rainy season; wells located in moderate potential zone have less water during the dry season when compared with the wells identified in high potential zone. This implies that the study area have more of high potential zones which inturn made the area very good groundwater potential zones.

4.4 Summary of Findings

A summary of the findings of the study consist the following:

a. The finding shows the elevations over the study area with the highest elevation of 452m situated at the North eastern part of location of interest and 71m as the lowest elevation found at the southwestern part respectively. The high elevation points have low potential of groundwater and low elevation has good and excellent groundwater potentiality in area of interest. As revealed in Figure 4.1, some areas in Bosso, Tudun Fulani, Maikunkele and Chanchaga were within the range of 257 and 452m and this in turn has made the areas low or moderate groundwater potential.
b. The result also shows that North West, South West and South Eastern areas have more drainage network ordering involving all classes which made them to be high or moderate potential groundwater areas while North East areas have low drainage network stream ordering which made the locations to have low groundwater potential.
c. Figure 4.3 revealed areas of excellent, moderate, and fair drainage density covered 590.37km^2 (37.18%), 648.67km^2 (40.85%), and 348.83km^2 (21.97%) respectively. high drainage density is below the surface of the resultant material weak or watertight, rarely green and hilly relief. Low drainage courses drainage density of coarse appearance while high drainage density

course texture good drainage. Drainage density characteristics of runoff in the location or simply put, the relative quantum rain water can be infiltrated.

d. The drainage density identifies the runoff in a location as the quantity of relative water that was not able to permeate into the subsurface. Furthermore, drainage density of this study do provide sign of closure or stream / river networks which inturn will rely on the nature and extent of weathering of surface and subsurface lithology unit. a low drainage density in this study therefore it increases the chance to recharge and contributing positively to the availability of ground water occurrence conditions more useful.

e. It is shown in Figure 4.4 that area with low slope (0° to 2°) covered an area 390.94km^2 (24.62%) and is excellent from the point of occurrence of groundwater. While moderate and high slope area covered 428.95km^2 (27.01%) and 767.98km^2 (48.37%) respectively.

f. As shown in Figure 4.5, 48.37% of the entire study area were within moderate convergence index, 27.1% of the study area were within high convergence index and 24.62% of the study area were within low convergence index. Low CI stand for divergent areas while High CI stand for convergent areas. Thus a higher CI areas associated with groundwater accumulation and had a higher groundwater potential.

g. The overall map has been classified into three groups, from groundwater potential point of view High, moderate, and low which covered 128.54km^2 (8.10%), 1315.27km^2 (82.83%), and 144.06km^2 (9.07%) respectively in 4.6.

h. Figure 4.7 shows the three (3) different potentiality of ground water within area of study and they are classified into fair, good and excellent groundwater potentiality areas. The result shows that the Maikunkele, Beji and Garatu areas with very high groundwater potential is characterized by high rainfall, low slope and dominated with cambisols which have a relative high-water holding capacity. The Bosso central, Chanchaga and Maitumbi areas with very low ground water potential is characterized by moderate slope, high drainage density and dominated by granite which has low ground water potential. It can be observed from the result that high rainfall and high slope as well as low drainage density are the major element contributing to potential ground water in area of interest as places with high rainfall and low slope were found to be the areas with very high groundwater potentiality.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the research it can be concluded that based on overlaying and analysis of thematic maps in GIS three, groundwater potential zones have been delineated i.e. High, Moderate and Low. Area covered by high groundwater potential zone is 8.10 km^2 mostly in the lower main part of the study location. Thus, integration of maps prepared from RS and GIS analytical tools proved an efficient method for delineation of groundwater potential area in the study location. This groundwater prospective details will serve for efficient recognition of appropriate areas for extraction of water. Furthermore, it is felt that the present approach can be utilized as a guideline for further research. The use of remote Sensing techniques is a very inexpensive technique in prospecting and in preliminary survey because the cost of exploration in a random means is extremely costly.

The final map of groundwater potential zones produced shows that the pattern of distribution for areas categorized as high potential zones are located within the North Western, and South Eastern areas around Garatu, Beji and Maikunkele. While areas with the low potential lie in Bosso and Maitumbi respectively. The moderate and low groundwater potential areas are scattered all over in the area of interest.

Superimpositions that the data of groundwater in the zone outlined potential over the groundwater reveal a constant high yield wells in the occurrence potential zone that maintains the favorable results incorporated GIS thematic maps. In conclusion the general assessment as provided in the highlight of this research is that the mapping of prospective ground water using the incorporated RS / GIS techniques may be an efficient way of characterization zone of occurrence groundwater potential in addition to serve as a useful device and guide in the exploration of ground water and growth in the location of interest.

5.2 Recommendations

Based on the findings, the following suggestion were made to enhance the mapping ground water potential in Bosso and Environs.

1) Mapping Groundwater potential zone need to be performed for the entire Niger State to serve as overview for water resource agencies.

2) The scarcity of water in Bosso and Environs warrants for a comprehensive evaluation of the ground water prospective qualities of the location to ensure that an exploration overview along with sustainable groundwater monitoring approach could established.

3) Remote sensing data and GIS are effective tools to enhance our understanding of groundwater systems. They offer continuous comprehensive terrain information and enable the mapping of features substantial to groundwater development therefore it is important to incorporate them in the data collection stage of groundwater exploration works.

4) There is the need for precise estimate of the available subsurface resources for the significance of appropriate preparation to ensure the guarantee of accessibility of water.

5) The results of this study work is excellent. Consequently, further studies should be carried out such as groundwater recharge, groundwater contamination in order to maintain the ground water prospective zones.

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