Delineation of Groundwater Potential Zones in Gwarzo Local Government Area, Kano State

Aduojo Atakpa and Tanko A. I.

Abstract

The aim of this research is to evaluate the factors influencing the natural occurrence of ground water using remote sensing and GIS to delineate groundwater potential zones in Gwarzo local government area. In order to achieve this, SPOT 5 and landsat 8 image were processed using ArcGIS and Erdas Imagine Software to delineate lineaments of the study area to understand its influence on groundwater potential. In addition, landsat 8 image was used for supervised classification to ascertain the land used and land cover of the study area. 30m resolution DEM was also analyzed for geomorphometric parameters while the aquifer thickness was determined from the geophysical data. A multicriteria evaluation method was used by combining all the influential parameters in order to generate the groundwater potential map of the study area. The overall result were classified into very high, high, moderate, low and very low groundwater potential zones. The result was validated using the measured field values of groundwater level of productive wells of the study area.

Index Terms: Geomorphometric parameters, GIS, Groundwater potential, Lineaments, multicriteria Evaluation, Remote sensing, Validation

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1.0 INTRODUCTION

Groundwater is dynamic and occurs uniquely in different natural environments. Its occurrence especially within the crystalline terrain is very complex due to lateral discontinuity of lithologies [1], [2]. Crystalline rocks have no primary porosity in their pristine state. The only conduits for groundwater are fractures, joints and other zones of weakness. Under favourable conditions, these structures can be widened by weathering and erosion to extend several hundred meters into the subsurface and provide formidable permeability [3].Groundwater exploration means searching or investigating the presence or absence of groundwater and areas or zones of abundant groundwater available for use are referred to as areas of good groundwater potential [4].

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From a research conducted by KNARDA for the former Kano state, the metamorphic rocks in Roni, Tsanyawa, Bichi, Rimin Gado, Shanono, Karaye and Gwarzo local governments were generally the poorest units for successful boreholes. In addition, the most difficult areas in the metamorphic suite are in Gwarzo, Bichi and Tsangawa local government were extensive schists are more common [5].

1.1. Background to the Study

Although much researches have not been conducted on groundwater in Gwarzo Local Government Area, in the 80' and 90's some public and private organizations such as WRECA water board and WARDROP Engineering Companies investigated the aquifers through borehole constructions in Kano State, including Gwarzo local government using vertical electrical sounding (VES). Therefore, armful data is available on groundwater characteristics in the state. One of the problems confronting the people of Gwarzo Local Government Area has to do with the issue of digital map with detailed explanations of groundwater potential zones that would enable the people to take decisions on the management of water resources of the area. There is also problem of insufficient information on geomorphometric parameters such as the slope, relief drainage density and the topographic wetness index influencing the groundwater potential of the study area. Little is also known about the lineaments which are geological structures (fractures) through which ground water flows. These key factors of groundwater potential have not been addressed in the previous researches particularly for Gwarzo local government.

1.2. Remote Sensing and GIS Applications for Groundwater Potential Assessment

Analysis of remote sensing data provides accurate information related to distinct geological formation, landforms and drainages which are essential in groundwater exploration. The concept of integrated remote sensing and GIS has proved to be an essential tool for studying hydrogeological and geological structures in order to detect groundwater potential zones. The mapping of linear features using remotely sensed data is one of the keys to understanding groundwater occurrence, especially in basement rocks. Integrating remote Sensing and GIS can provide the suitable platform for developing and testing the evaluation of the groundwater resources of any watershed.

Recent studies in Nigeria have shown the relevance of integrated approach to groundwater exploration [6] conducted research on groundwater potential in Wamba, Nassarawa State Nigeria. The thematic maps used are slope map, drainage density, contour map and lineament density. The result indicated that lineament and drainage are the most important factors of groundwater identification in the area. [7] in Ekiti SW Nigeria also use integrated approach to study groundwater potential through weighted overlay analysis where landsat and thematic maps were integrated and the result was categorised into very good, good, moderate and poor in terms of groundwater potential zones and among the factors lineament was found to be the most influential. [4] assessed groundwater potential for rural water supply in parts of Kano state, northern Nigeria. In his research, he used multicriteria based weighted overlay analysis techniques to determine the groundwater potential zones. Thus, remote sensing is useful in the search for groundwater prospect zones as it provides the current spatial disposition of basic information on geology, landforms, soils, land use and land cover, surface water bodies, quickly and reliably with less cost and manpower than conventional techniques [8].

1.3. Study Area

Gwarzo Local Government Area is located in the western part of Kano state. It has an area of 393 km² and a population of 183,624 at the 2006 census [9].The study area falls within latitudes 11°45′23.30″N and 12°5′30.30″N and longitudes 7°49′47.30″E and 8°8′36.30″E. It is bounded by Shanono to the North, Kabo in the East and Karaye in the South. It is characterised by undulating land and underlain by basement complex rock. Geologically, the study area consists of silicified sheared rocks, large quartz veins; granite gneiss, fine grained flaggy quartzite and quartzite schist; coarse porphyritic biotite and biotite hornblende granite; coarse porphyritic hornblende granite, sands and clays [10].

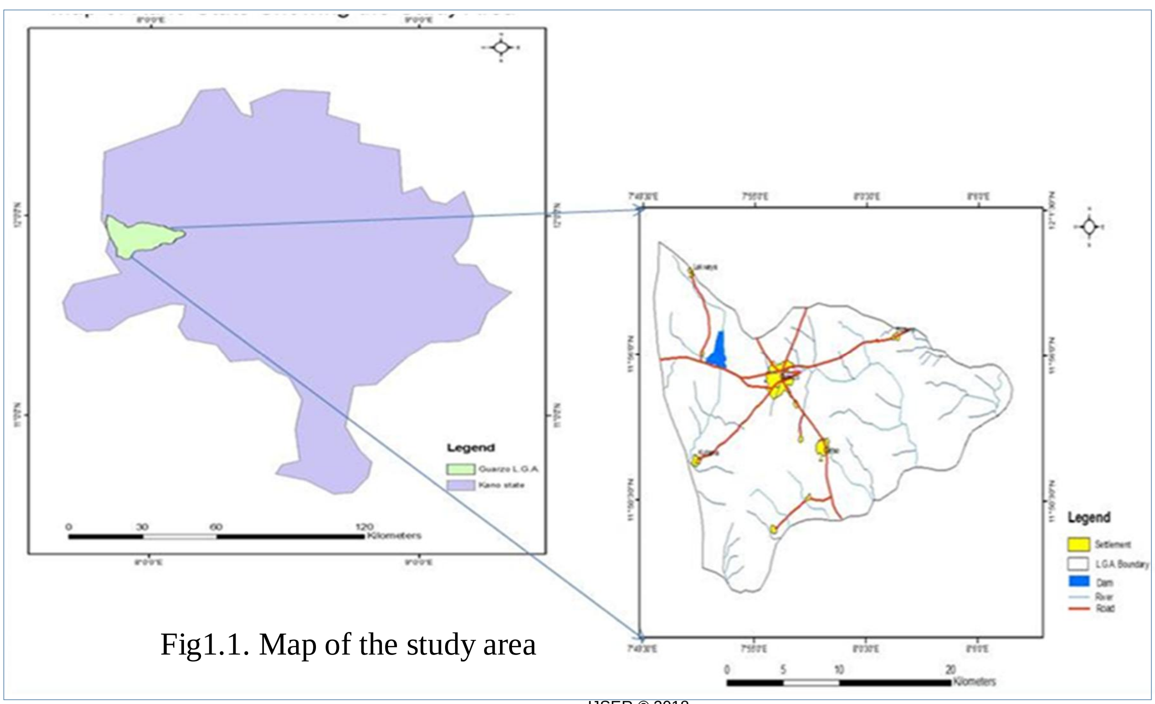


Fig1.1. Map of the study area

2.0. MATERIALS AND METHOD

Satellite data (Landsat image and SRTM) were acquired from United States Geological Survey (USGS) website, SPOT 5 was subscribed and existing geophysical data was accessed from Kano State Agricultural and Rural Development Authority (KNARDA)

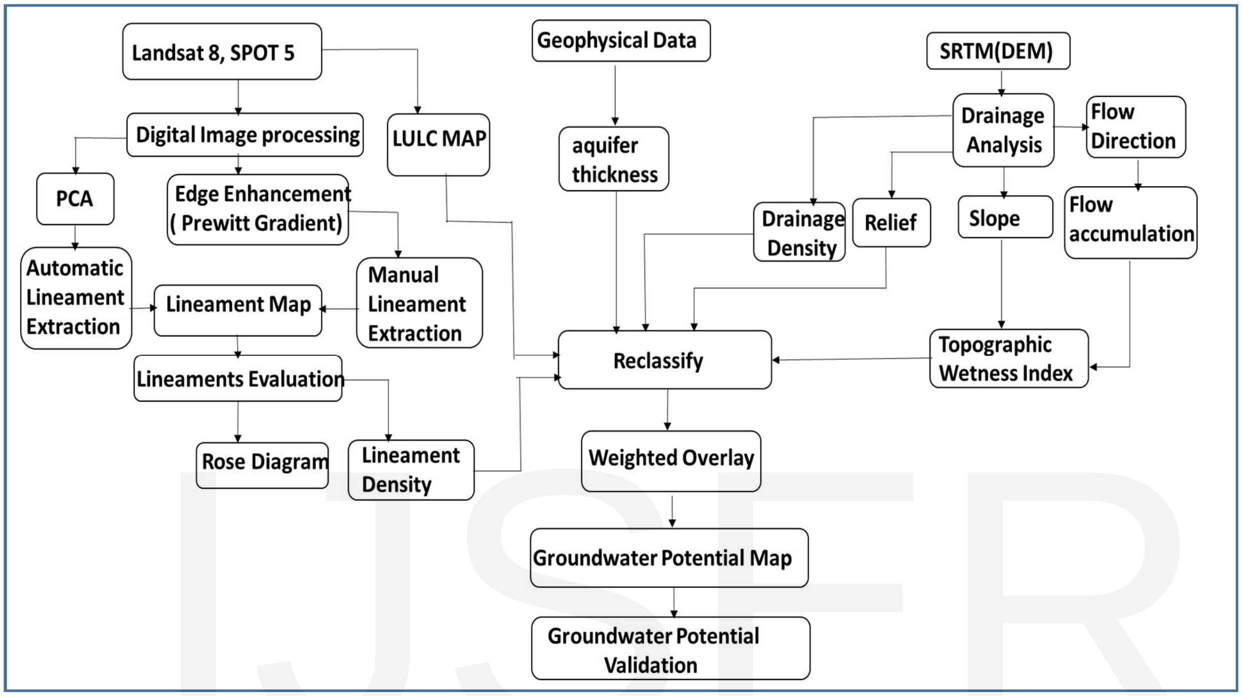


Figure1.1.1: Flow chart of the Methodology

2.1. Digital Image Processing

The acquired satellite data were processed for proper radiometric and geometric correction to minimize errors in the proceeding analysis and the layer stacking was done accordingly. The images were clipped to obtain the shapefile of the study area.

2.1.2. Lineaments Extraction

Erdas Imagine was used to conduct the Prewitt Gradient which has the capability to filter the lineaments in several directions i.e. North, N-E, N-W, South, S-E, S-W, East and West directions in order to increase frequency and contrast in the image. The operator calculates the gradient of the SPOT5image intensity at each point, giving the direction of the largest possible increase from light to dark and the rate of change in that direction.

The extracted lineaments was used to generate lineaments map for further evaluation in ArcGIS software in order to produce the lineaments densities. Kernel Density algorithm calculates the density of linear features in the neighbourhood of each output raster cell in ArcGIS. The spatial analysis tool was used to generate the lineaments intersection density with a search radius of 5km. The search radius is the distance the Kernel Density algorithm uses to search and generate contours of the density of a linear feature.

3.2 ANALYSES OF GEOMORPHOMETRIC PARAMETERS

3.2.1. Relief Analysis

The analysis of the relief was done using the spatial analyst tool of ArcGIS to reveal the difference between maximum and minimum elevations within the study area from DEM.

3.2.2. Topographic Wetness Index Analysis

The ArcGIS spatial analyst tool was used to analyze the topographic wetness index (TWI). The formula is $TWI=\ln(\alpha/\tan\beta)$. Where '$\alpha$' denotes the local upslope area draining through a certain point per unit contour length, 'β' denotes the slope angle and TWI denotes topographic wetness index.

3.2.3. Drainage Density Analysis

Drainage density is the length of streams per unit area. The formula is $Dd = LS/AS$ Where Dd is the drainage density, Ls is the total length of streams, and As is the total area of the whole basin. It is usually measured in km/km2. The DEM was used in ArcGIS hydrology to generate the drainage network as well as the drainage density.

3.3. LAND USE AND LAND COVER CLASSIFICATION

To know the Land use and land cover (LULC) of the study area, band combination (543) of landsat 8 image was done and used for supervised classification. The training sites which means sampling of pixel to represent the features were created using Erdas Imagine to identify the land cover classes. The signatures for each land cover class was created based on the training sites identified to enable the program to match the remaining unclassified (unknown) pixels to one of the (known) training class signatures and the reference points was used to determine the accuracy assessment of the analysis.

3.3.1. Accuracy Assessment of the land use land cover classification

Accuracy assessment is an important part of any classification project. This was done using Erdas Imagine software to generate random points on the pixels of landsat image based on the features observed in the field. The random points generated was compared to that of the classified image in a confusion matrix algorithm in order to obtain the accuracy level.

Land Cover Class	Producer's Accuracy (%)	User's Accuracy (%)
Settlement	83.33	100.00
Shrubland	66.67	85.71
Grassland	100.00	85.00
Bareland	87.50	87.50
Waterbody	100.00	100.00
Overall Classification Accuracy	89.13	
Overall Kappa Statistics	0.8547	

Table 1 Accuracy Assessment Result for Landsat 8(2015)

3.3.2 Aquifer thickness

The geophysical data obtained from KNARDA was used to evaluate the aquifer thickness of the study area. The thickness values were interpolated and the layer was reclassified using ArcGIS. The aquifer thickness map and its profile were generated using the geospatial analysis in ArcGIS. The profile was generated across Kutama and Mahuta town (fig. 1.3.2)

4.0. RESULTS AND DISCUSSION

4.1. Manual Lineaments Extraction

Filtering operations were used to selectively suppress image noise and detect edges of the image for proper visualization and manual extraction of the lineaments in ArcGIS. Here, directional Prewitt-Gradient filters were applied in North, N-E, N-W, South directions (Fig.1.1.2) as well as S-E, S-W, East and West directions (Fig. 1.1.3)

Table 2 Prewitt Gradient in N, N-E, N-W and South Direction

PREWITT	North			N-E			N-W			S		
	1	1	1	1	1	1	1	1	1	-1	-1	- 1
	1	-2	1	-1	-2	1	1	-2	-1	1	-2	1
	-1	-1	-1	-1	-1	1	1	-1	-1	1	1	1

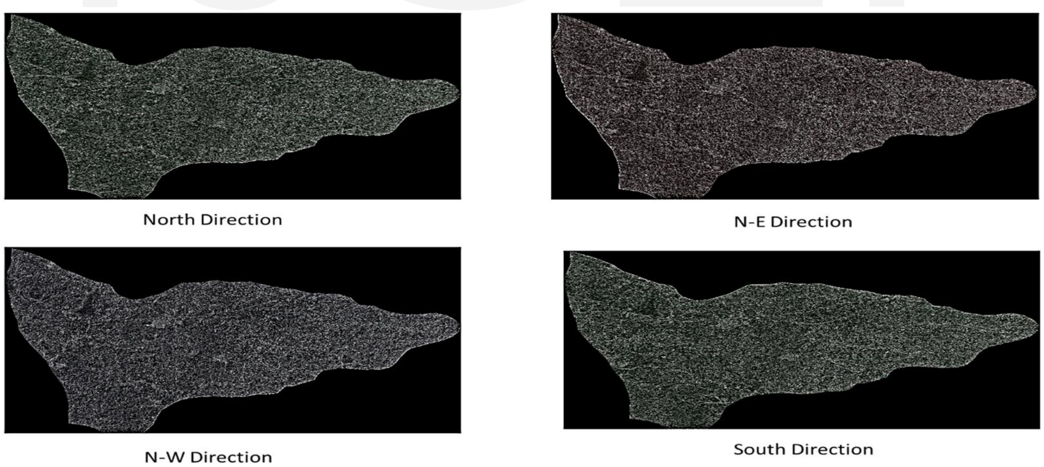


Figure1.1.2: Prewitt Gradient filtered images in North, N-E, N-W, and South Directions

Table 3: Prewitt Gradient filtered images in S-E, S-W, E and West Directions

PREWITT	S-E			S-W			E			W		
	-1	-1	1	1	-1	-1	-1	1	1	1	1	-1
	1	-2	1	-1	-2	- 1	-1	-2	1	1	-2	-1
	1	1	1	1	1	1	-1	1	1	1	1	-1

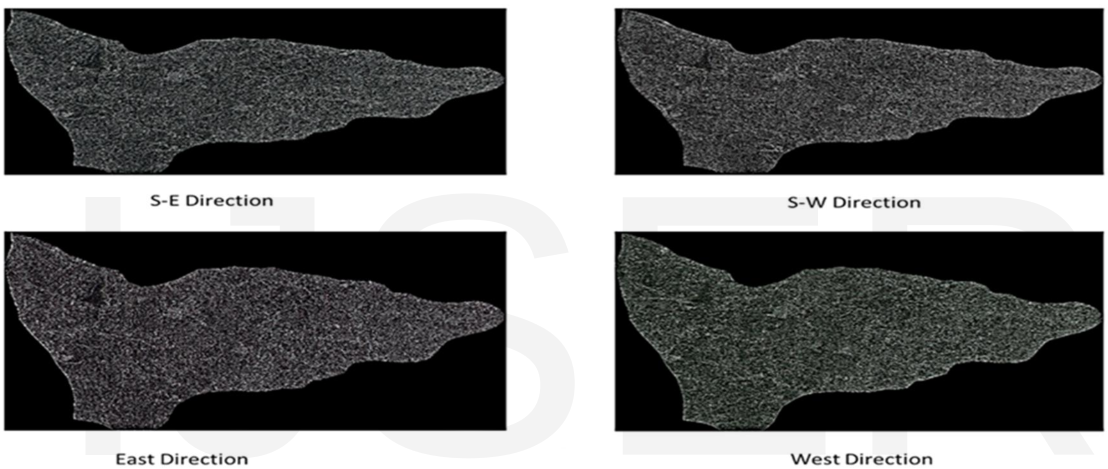


Figure 1.1.3: Prewitt Gradient filtered images in S-E, S-W, E and West Directions

4.1.2. Automatic Lineaments Extraction

Principal Component analysis is an image transformation technique based on the processing of multi-band data sets that can be used to reduce the dimensionality in the data to compress as much of the information in the original bands into fewer bands. Thus, useful information for the identification of the units that exist within the image can be compressed properly into two or three components. For the automatic lineament extraction, PCA was applied to 7 bands (1, 2, 3, 4, 5, 6 and 7) of Landsat 8 image to compress the information in three bands (Fig1.2.1). The first three components contain 99.1percent of the total variance within the whole volume data of six bands. The resultant image was exported to Geomatica software for lineament extraction (Fig. 1.2.2)

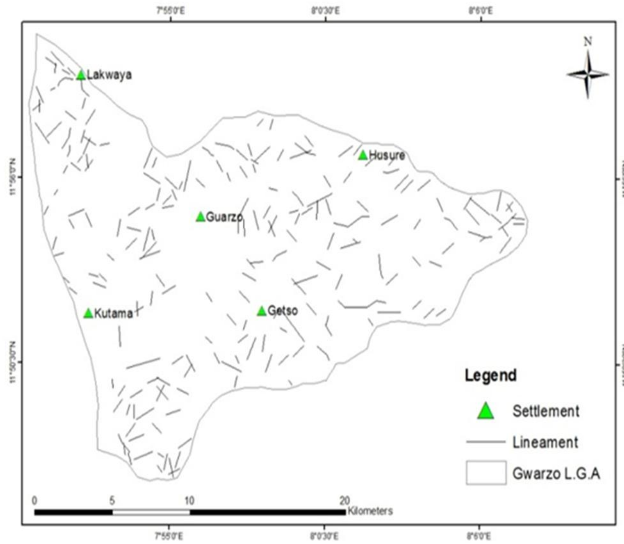


Figure 1.2.: manually extracted lineament map

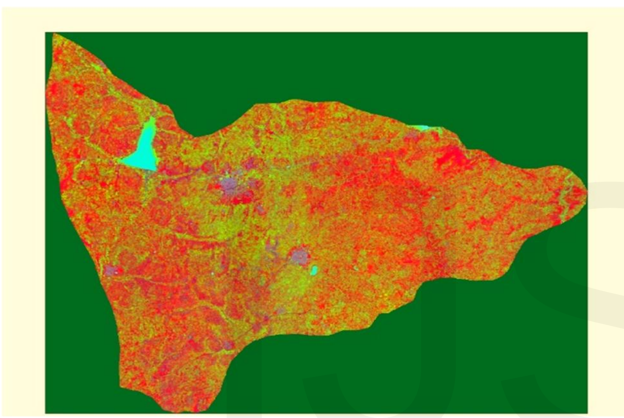


Figure 1.2.1.: Landsat 8 PCA

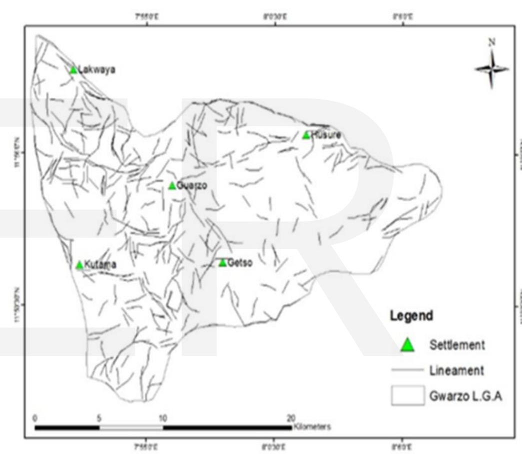


Figure1.2.2: Automatic Lineament Extraction

Table 4.Eigen Values of PCA Analysis ofthe Landsat 8 image

	Eigen Values	%Eigen Values	Cumulative Eigen Values
PCA1	16603.52154	92.6899	92.6899
PCA2	689.40887	3.8487	96.5385
PCA3	462.29245	2.5808	99.1193
PCA4	78.79213	0.4399	99.5592
PCA5	45.27861	0.2528	99.8119
PCA6	23.89237	0.1334	99.9453
PCA7	9.79396	0.0547	100.0000

4.1.3. Lineaments Density

The purpose of the lineament density analysis is to calculate frequency of the lineaments per unit area. The lineaments extracted from manual and automatic methods were combined and used to generate lineaments map for further evaluation in ArcGIS software in order to produce the lineaments densities and rose diagram. The spatial analysis tool was used to generate the lineaments intersection density

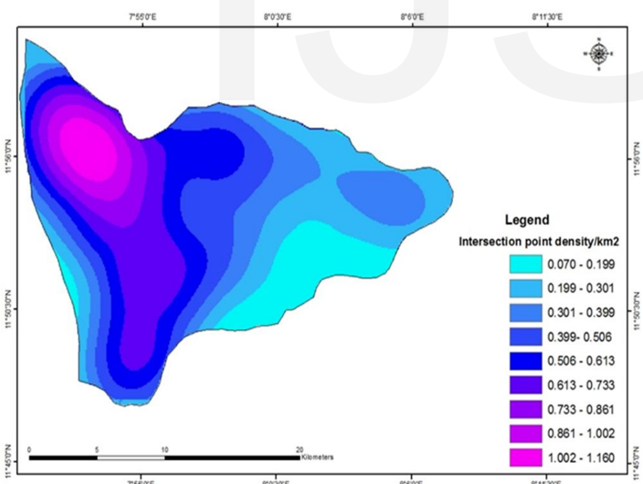


Figure 1.2.3. Lineament Density Map

(Fig. 1.2.3) with a search radius of 5km and the result indicates high groundwater potential in Lakwaya, kutama and Gwarzo but low potential in Getso and Husure. The rose diagram indicates prominent trends in the N-E and S-W directions (Fig 1.3)

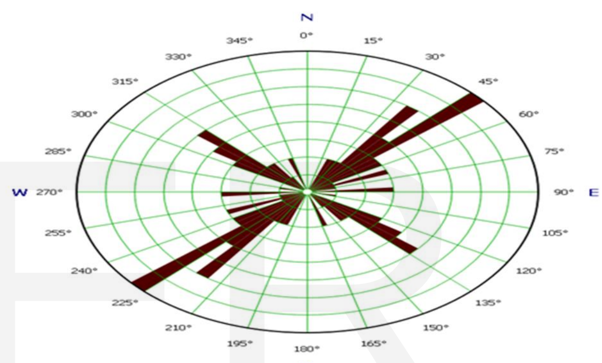
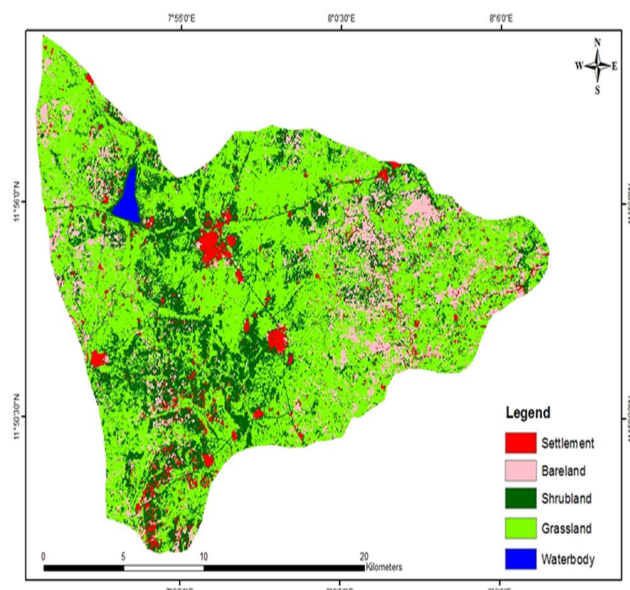


Figure 1.3. Rose Diagram



1.3.1. Land Use and Land Cover Map

4.2. LAND USE AND LAND COVER

Land use and land cover is an important factor affecting the groundwater recharge
Process. The water body recharges the groundwater but the bareland encourages erosion and excess surface water runoffs preventing percolation of water into the ground. The study of vegetation is essential because it prevents direct evaporation of water from the soil. The roots of a plant can absorb water, thus preventing water loss (Fig 1.3.1). From the result of the land use land cover, the settlement areas cover 5% of the total area. The bareland covers 12%, grassland occupies 57% and shrub land has 25% while the water body covers 1 %(Fig 1.3.2)

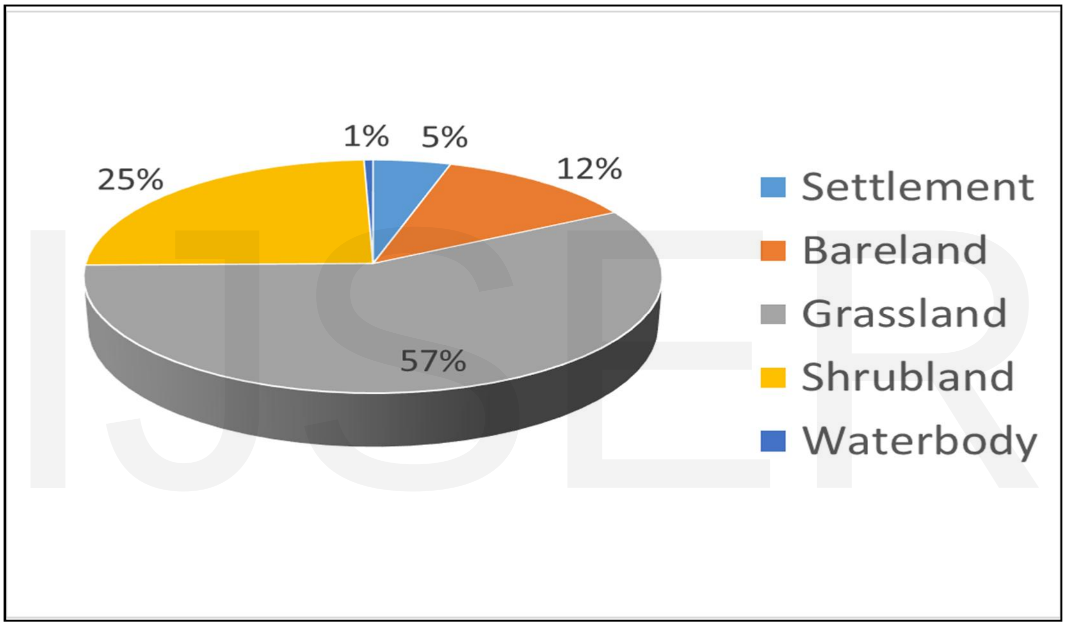


Fig. 1.3.2. Pie chart showing distribution of classified area in percentage

4.3. AQUIFER THICKNESS

The geophysical data was used to evaluate the aquifer thickness of the study area. The thickness of aquifer analysed indicates higher result in Husure, Getso and Kutama than Lakwaya and Gwarzo area (Fig. 1.3.3)

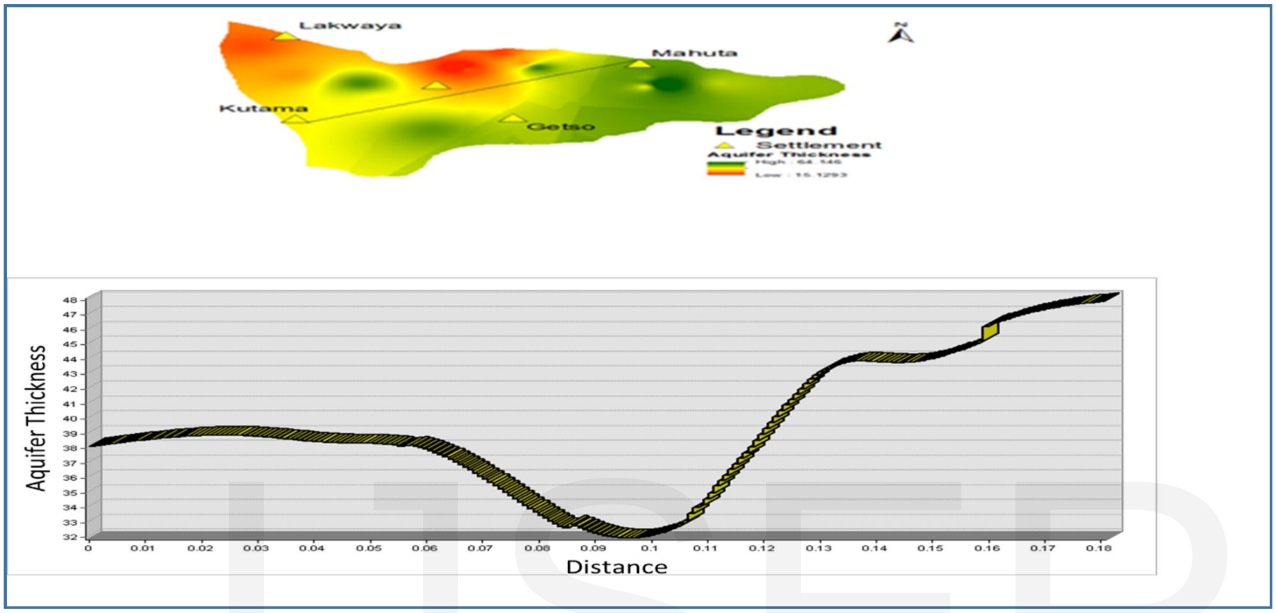


Fig 1.3.3. Aquifer Thickness Profile along Kutama and

4.4. RECLASSIFIED RASTER IMAGES

The essence of reclassifying the raster images is to exclude the missing values in the data and to attach the ranking values to the images. . The influence on the groundwater begins with rank 1 which has lowest influence and increases to 9 which is the highest rank as shown below.

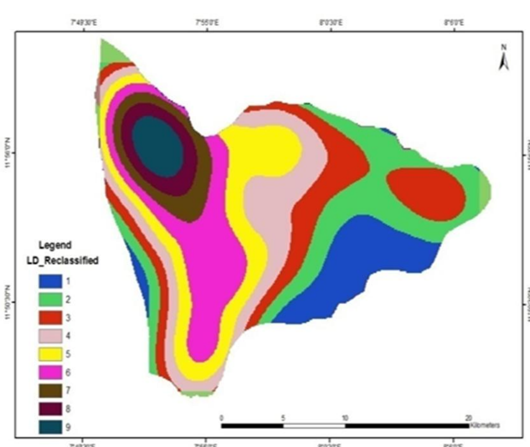


Fig1.4.Reclassified L.D

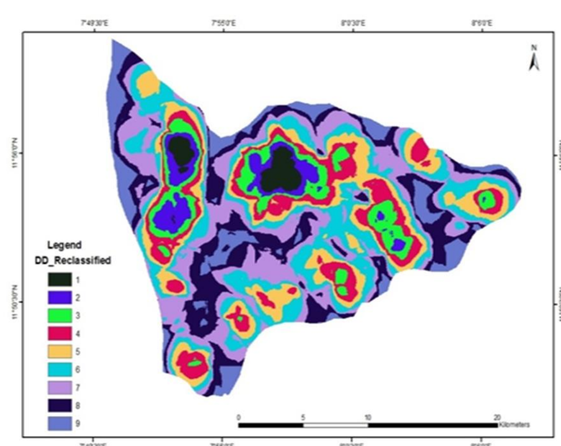


Figure 1.4.1 Reclassified D.D.

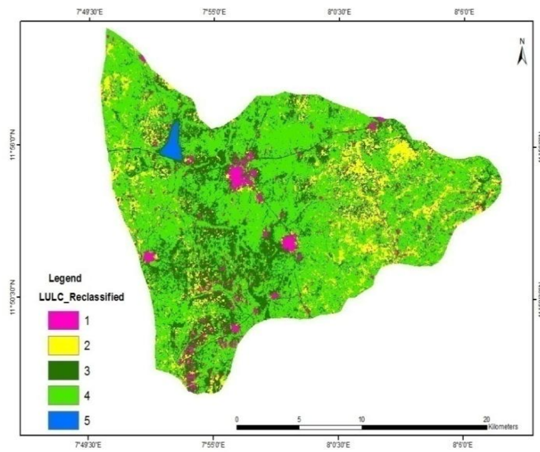


Figure 1.4.2.Reclassified LULC

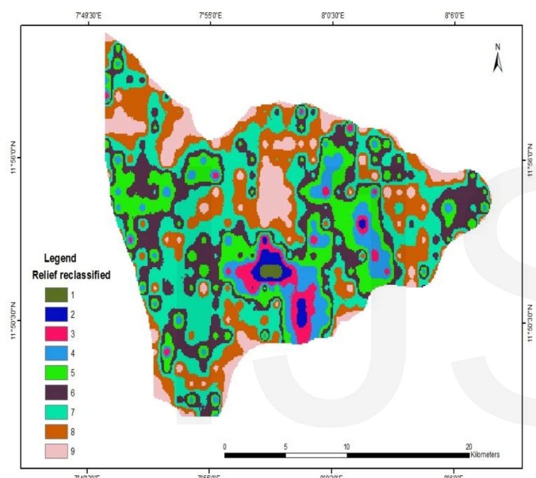


Fig 1.4.3.Reclassified Relief

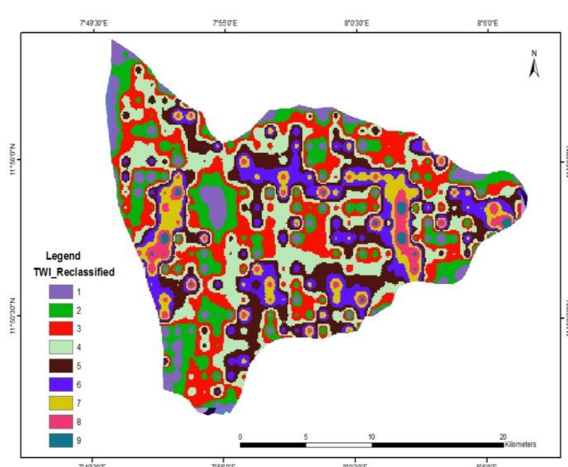


Figure 1.5. Reclassified TWI

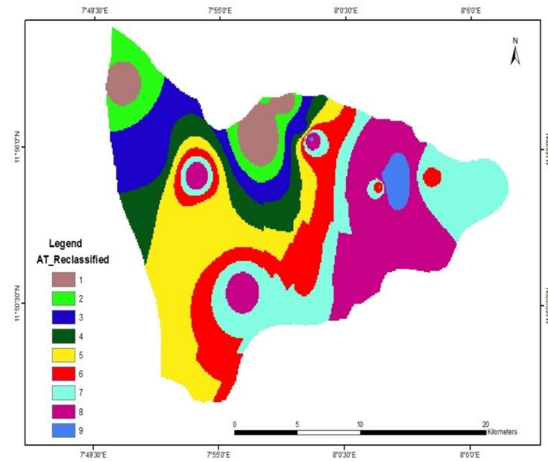


Figure 1.5.1.Reclassified Aquifer Thickness

4.5. MULTI-CRITERIA EVALUATION METHOD

4.5.1. Weight Assignment

The parameters analysed for groundwater in this research are: lineament density (L.D), topographic wetness index (TWI), relief, drainage density (DD), land use and land cover (LULC) and aquifer thickness (AT). These layers were ranked and weighted in order to generate the groundwater potential model. Cumulative Effect Matrix was used for weight assignment in this research. In this method, if one factor had effect on the other, then the two factors' conjunction point's score would be 1, otherwise the score would be 0. Each factor's cumulative effect was calculated and the weight was assigned by using each factor's cumulative effect score divide the total cumulative effect score (Table 5).These weighted parameters were used to generate the groundwater potential zones of the study area.

Table 5 Cumulative Effect Matrix

	L.D.	TWI	RELIEF	DD	LULC	A.T.	∑	WEIGHT (%)
LD	1	1	0	1	0	1	4	25
TWI	0	0	0	1	0	0	2	12.5
RELIEF	0	0	1	0	1	0	2	12.5
DD	0	0	0	1	1	0	2	12.5
LULC	0	0	0	1	1	1	3	18.75
A.T.	1	0	0	0	1	1	3	18.75

4.5.2. Groundwater Potential Model

The result of the groundwater potential model indicates five classes with number 7, 6, 5, 4, and 3 which denote very high, high, moderate, low and very low groundwater potential respectively. The results shows moderate, low and very low range of groundwater potential in Gwarzo town; moderate groundwater potential in Mahuta; moderate and low range of groundwater potential in Getso, Lakwaya and Kutama area. However, very high groundwater potential was observed from the result 7km S-E away from Kutama area (Figure 1.5.2). In addition, the result also indicates 0.08% for very high groundwater potential zone. High groundwater potential, moderate groundwater potential, low groundwater potential and very low groundwater potential have 18.66%, 59.96%, 21.17% and 0.13% respectively (Table 6)

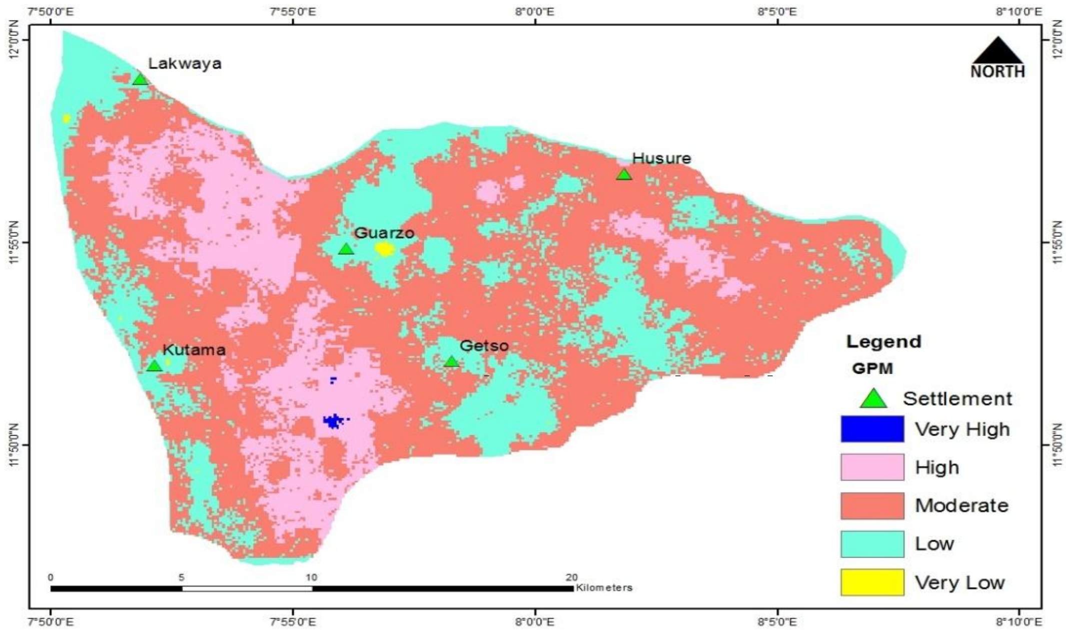


Figure1.5.2. Groundwater Potential Model

Table 6. Areal Coverage of Groundwater Potential Zone

Groundwater Potential Zone	Area(m^2)	Area (%)
Very High Groundwater Potential	293078	0.08
High Groundwater Potential	71654800	18.66
Moderate Groundwater potential	230319000	59.96
Low Groundwater Potential	81295900	21.17
Very Low Groundwater Potential	502118	0.13
TOTAL	384064896	100

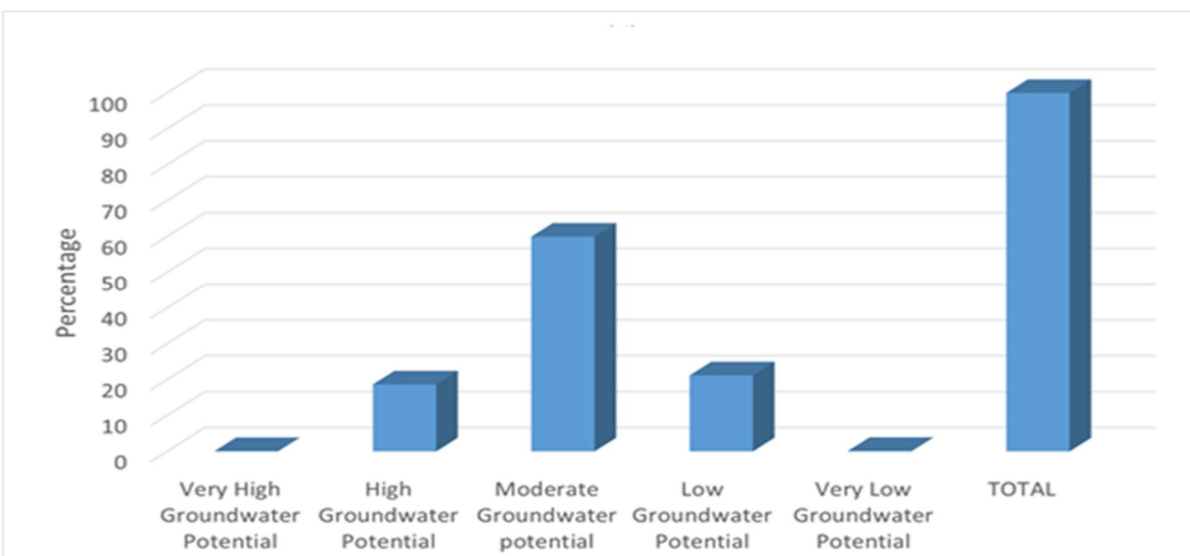


Fig 1.5.3.Percentage of Groundwater Potential Zones

4.5.3. Groundwater Potential Model Validation

The purpose of simple regression analysis is to evaluate the relative impact of a predictor variable on a particular outcome. The regression analysis conducted in this study reveals the strength of the relationship between the groundwater potential and the groundwater level of Gwarzo Local Government Area. In this study, the groundwater potential values was plotted against the groundwater level (Fig. 2.5.2.).

The results revealed coefficient of determination (R^2) of 0.644 i.e. 64% of the groundwater potential which is the fraction of the variability in Y(groundwater potential) that can be explained by the variability in the predictor X(the groundwater level) through their linear relationship.

Table 7. Groundwater level table

S/No	Well Locations	Latitude	Longitude	Groundwater Level(m)	Groundwater potential Values
1	Alha Sani Wakili	7.8644	11.9862	5.8	4
2	Mainika	7.8829	11.955	8.6	6
3	Mainika2	7.883	11.9551	9.1	6
4	Umma Gidan Mahanta	7.8689	11.868	5.1	4
5	Alha Sule Kutama	7.8686	11.8681	4.8	4
6	Rijiya Kude	7.868	11.8682	5.2	4
7	Rijiya Mallam Lukeman	7.9727	11.8736	4.7	4
8	Malla Abdullahi Dammajiri	7.9727	11.8728	4.7	4
9	Baba Dan Mommen	7.9737	11.8738	5.4	4
10	Rijiyar Cikin Kasuwa	7.9753	11.8762	8.6	5
11	Kwakwachi	7.9346	11.9209	9.3	5
12	Kofar Gidan Hakimi	7.9332	11.917	7.5	4
13	Mallami	7.9324	11.9086	6.9	4
14	Rijiyar Dangawo	7.9952	11.9376	9.8	5
15	Rijiyar Dangawo2	7.9969	11.9379	8.2	5
16	Sabon Gida Mahuta	8.0138	11.9422	6.4	4
17	Alha. Ado Abdullahi	7.9285	11.8438	18.6	7
18	Mallam Rabo	7.9309	11.842	17.9	7
19	Abdullahi Umar	7.9466	11.9161	8.2	3
20	Bakure Idris	7.9495	11.9155	7.9	3

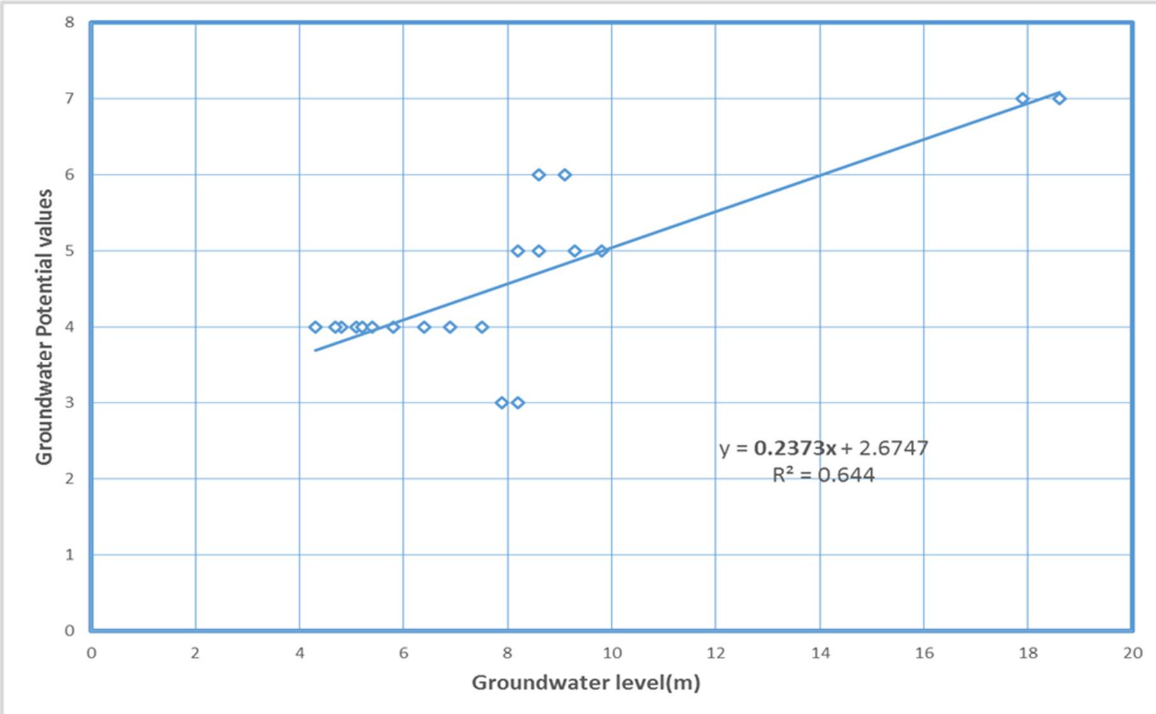


Fig 2.5.2. Groundwater level versus Groundwater Potential Values

5.1. CONCLUSION

This research has shown the significance of multicriteria evaluation of lineaments, geomorphometric and geophysical data in the assessment of groundwater in Gwarzo local government Area. This research was conducted to produce the groundwater potential map for proper management of the water resources of the study area. This is important because in the previous research conducted by Kano State Agricultural and Rural Development Authority (KNARDA) only geophysical survey was used to locate the aquifers.

In the management of groundwater especially in the basement of arid and semi region, it is important to consider the structural disposition and the geomorphological factors influencing the groundwater potential. Therefore, in this research the influential factors of groundwater were processed and analysed in order to generate the groundwater potential map of the study area. The parameters analysed to assess groundwater potential are: lineament density (L.D), topographic wetness index (TWI), relief, drainage density (DD), land use and land cover (LULC) and aquifer thickness (AT). The final groundwater potential map was divided into five categories, namely: very high, high, moderate, low and very low.

The result indicates moderate, low and very low range of Groundwater potential in Gwarzo town; moderate groundwater potential in Mahuta; moderate and low range of groundwater potential in Getso, Lakwaya and Kutama area. Furthermore, very high groundwater potential was observed from the result 7km S-E away from Kutama area. To validate the result of the analysis, groundwater level was measured from the field and used with the extracted values of the groundwater potential model to do a regression analysis. The result indicates a positive relationship between the measured values of groundwater level and the groundwater potential values with coefficient of determination (R2) of 0.644. Therefore, 64% of the groundwater potential values are predictable from the result of validation.

Studying groundwater in this manner will help in the understanding of interaction between the surface and groundwater and how they can be managed. The resultant groundwater-potential map can serve as a useful model for development and management of groundwater resources. This map can also help planners choose locations suitable for implementing further detailed explorations and siting of boreholes and wells. In addition, water extraction and distribution plants could be sited in areas with high groundwater potential to supply water to the people of the community since groundwater is their main sources of water for agricultural and domestic purposes. Exploration of groundwater in regions with meagre water resources requires the application of effective tools that save time and money. The use of remote sensing and GIS system sensing has proved to be powerful and cost effective method for determining groundwater potential in Gwarzo local government area.

5.2. ACKNOWLEDGMENT

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