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IMPACTS OF SURFACE TOPOGRAPHY ON GROUNDWATER POTENTIAL IN PARTS OF KANO STATE, NIGERIA

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Abstract

Groundwater prospecting and exploitation is becoming difficult due to uneven topography and inadequate data on impacts of topography on groundwater. It is in line of this the study was conducted with the following objectives which are to identify groundwater potential zones and to relate them with nature of surface topography or slope of the area. Sixteen rural areas were selected from eight selected local government areas using systematic random sampling technique. Data on depth to water level and water table values were obtained from selected borehole. DEM (Digital Elevation Model) of the study area was developed from SRTM (Shuttle Radar Topographic Mission), thematic maps were obtained and overlaid. Groundwater potential zones were determined. Contour map and slope map were generated and reclassified. Slopes and contour values were related with groundwater potential zones. Findings show that Southern parts of the study area are higher in terms of elevation with relief values of more than 767.9m. Five groundwater potential zones were identified as very high, high, moderate, low and very low. Very high fall within Yandadi, Karfi and Shakogi depth to water level is 13.29 – 14.98m, water table value of 407 – 426m, contour values 440m – 566m and slope value of 0^{o} – 2^{o}. Results also shown that very low potential zone is around Riruwai where depth to water level is 18.31m - >19.31m, water table values 873.69m – 874.69m, contour values of 893m and slope of >18^{o} . It is therefore recommended that areas of higher contour values, higher depth to water level, higher water table values and higher slope values low yielding boreholes with hand pumps are to be provided for effective rural water supply and management.

KEY WORDS: Slope, Contour values, Groundwater, Potential, Kano

INTRODUCTION

Groundwater is a naturally filtered water accepted by many water users either officially or unofficially across the globe for many uses like domestic, industrial and agriculture among others. This is because it is free of contaminants requires little or no effort to treat it before drinking. Groundwater is one of the major sources of portable water supply in urban and rural areas of any region (UN/WWAP (united Nation / world water Assessment programme), (2003).

It is the water that is found beneath the earth surface in rock fractures and soil pores. Over much of Africa, groundwater is the only realistic water supply option for meeting dispersed rural demand (Macdonald, 2005). In Bangladash it was reported by Pramanik (1989), that groundwater is the main source of water supply especially in rural areas. In USA groundwater is regarded as the major source of rural water supply. Groundwater is an important resource in much of the Midwestern USA. It supplies drinking water for over 95% of the rural population and over 50% of the urban population (Bernard, 2003 in Rilwanu, 2014).

Groundwater movement is controlled by many factors of which slope or surface topography is among them. Groundwater flows from high elevation to low elevation and from high pressure to low pressure gradients in potential energy (hydraulic head) drive groundwater flow (Freeze and Cherry, 1979 in Rilwanu, 2014). Groundwater normally flows from structurally formed higher recharge zone to lower or cavern zones (Kyung-Seok *et al*, 2002). Groundwater is present in all sorts of landscapes. The interaction of groundwater with surface water depends on the physiographic and climatic setting of the landscape that is in terms of slope at different physiographic units (winter, Franke and Alley, 2016).

Remotely sensed information on topography, drainage, fracture patterns, are directly related to the presence or absence of groundwater (Thapa *et al.*, 2008). It is in this vain that various researches were conducted. Qazi, Deepak and Jafri (2015) Studied impact of land use land cover and slope on groundwater potential of Allahabad using DEM, LULC maps, slope maps which were weighted and ranked according to their impacts on groundwater. Results indicated that areas with steeper slope are having less weight in terms of groundwater potential while areas of lower slope values are having higher weights in terms of groundwater potential. Four groundwater potential zones were determined. Kyung-Seok *et al* (2002) determined factors affecting groundwater flow and transport in the vicinity of an underground LPG storage site, this was done using cross sectional analysis. The finding indicated that groundwater flow and transport occurs from structurally formed high-recharge zone to cavern seepage zone and it is concluded that it is affected by operational pressure and slope.

Peter *et al* (2011) used integrated approach to delineate groundwater recharge sites of Sadat industrial City of Egypt in which a number of factors were integrated using weighted overlay method in Arc GIS Boolean logic true or false method, slope map was developed through DEM and SRTM. Suitable and non-suitable areas were identified; flat areas are areas of good recharge because water concentrates while steep slope areas are areas of poor recharge because water drains easily. Nezar *et al* (2012) in Jordan where land- sat 7 ETM+ of 90m resolution was used to analysed factors such as lineament length density, drainage length density, geological formations, elevation and slope steepness together with bore holes data. Dem was used in generating drainage network maps. It was discovered that 7% of the study area is of higher groundwater potential, 79% is of moderate and 14% is of low potential. It was also discovered that areas of higher relief are of low potential and lower areas are of higher potential.

Anudu, Essien, Onuba and Ikpokonte (2011) 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. Abel and Moshood (2011) in Ekiti SW Nigeria also use integrated approach to study groundwater potential through weighted overlay analysis where land Sat and thematic maps were integrated and the result indicated that the study area is categorised into 4 classes and slope is considered very significant in groundwater potential studies. Most of these studies were conducted outside the study area and centred toward considering slope as one of the factors assisted in groundwater potential assessment not necessarily relating slope with groundwater potential that is why the objectives of the study are to identify groundwater potential and to relate it with nature of surface topography or slope of the area.

MATERIALS AND METHODS

The Study Area

Kano state extends from latitudes 10°3′ N to 12° 3′ N and longitude 7°35′ E to 9°20′ E (Figure: 3.1). The total land area of the state is about 20,760sq km (Research and Documentation Directorate Kano, 2009). The total population in 2006 national census is about 9,386,820 people (N. P .C report, 2009).
The areas are underlain by the Basement Complex Rocks of Precambrian era. These Basement Complex Rocks form part of the pan African mobile belt and lies between the West African
Interms of morphology Sara and Charles (1988) divided Kano state into three geomorphic units as follows:-

(a) North and Central: - which comprises of flat terrain, rare rock outcrops and few broad valleys which are well developed. Weathering profile is mature and lateritic duricrusts (hard fans) are widespread. The depth in fresh bed rock is greater than 40m

(b) Southeast:- This is an intermediate area in which weathering profile is usually not truncated by erosion, but fresh bedrock is commonly only a few meters below static water level

(c)West:-This area is drained by head waters of Major River valleys that tend be narrow and incised. Inselbergs, tors and rock paramount's are common and fresh bed rock is found near the surface.

The study area is located in the tropics, a region characterised by alternating wet and dry conditions, with annual rainfall of 850mm occurring between April/May and September/October with peak in July and August. The geology of the area composed of rocks that are hard and impervious in nature drained by rivers that flow in north-south direction (Ahmed, 2003). The vegetation of the Study area is Sudan Savanna type. Olofin (1987) observed that the natural vegetation of the study area is tropical grassland characterised by scattered trees which hardly exceed 20 metres high. The soil of the region is tropical Ferruginous rich in sand, while the zonal soils are also influenced by human manipulation to varying degrees (Olofin,1987 in Rilwanu, 2014) Areas in the extreme West or South Western parts of the study area are characterised by clayey loamy soils (Ahmed, 2003).

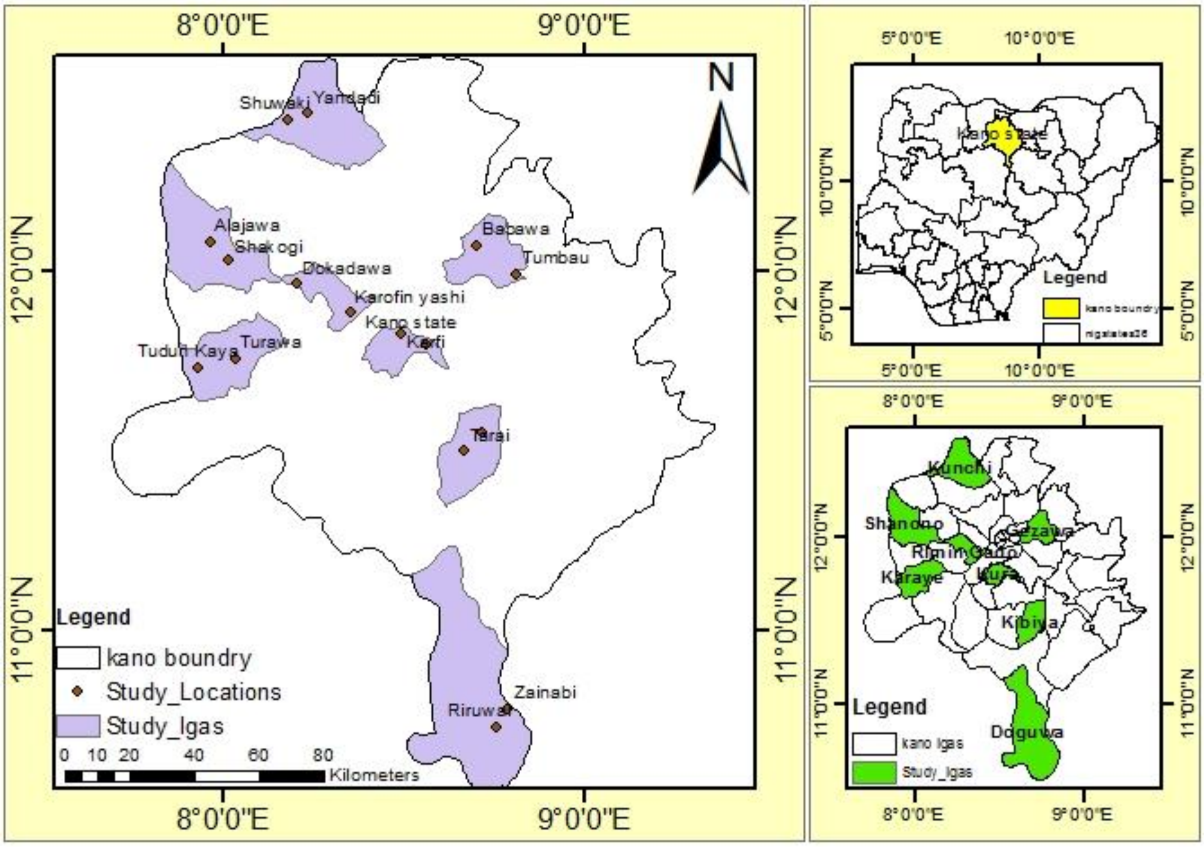

Figure 1 Map of the Study Area
Source: Department of Geography Bayero University Kano, 2013

Methods of Data Collection

For the purpose of the study one point was selected purposively from each selected locality. The selection was done based on the location of available existing borehole or hand pump in the area. Sixteen villages were selected from eight selected local government areas in each of the villages one borehole was purposively selected for determination of water level, altitude and coordinates.

The materials used in the study include DEM, SRTM, slope map, Contour map, pumping test data. ETM+ 2003 and GPS.

Slope map of the study area was prepared through the creation of DEM from SRTM and interpolation of spot height and contours in GIS environment as adopted from Anthony and Doreen (1977), Goyal *et al.,* (2009), Tesfaye (2010), Okoro *et al.,* (2010), Anudu *et al*(2011). Contour map was produced from DEM which was derived from SRTM.

Groundwater potential zones map (GPZM) was obtained through overlaying all the thematic maps. The parameters of each of the factors were given weight and related to groundwater potential. Weighted overlay method adopted from El-baz and Hamida (1995). The identified potential zones were related with slope and contour values through overlay and interpretation based on standard modified from Anthony and Doreen (1977).

Table 2.2 Classification of slope based on groundwater condition

S/N	Slope	Explanation	Relationship with groundwater
1	0^o - 2^o	Level or almost level	No much runoff, water percolates and forms groundwater
2	2^o - 3^o	Gentle	Runoff increases and groundwater reduces
3	3^o - 5^o	Moderate	Much run off Low groundwater
4	5^o - 18^o	Moderately Steep	Very much Runoff little groundwater
5	>18^o	Very Steep	Total Runoff no infiltration, insignificant groundwater

Source: Adopted from Anthony and Doreen (1977)

Data Analysis

Digitised DEM was used to generate contour map of the study area using Arc view 3.2a GIS software. Slope map was interpreted based on standards of Anthony and Doreen (1977) in Rilwanu, 2014). Ground water potential zones were categorised into very high, high, moderate, low and very low using Extension Arc view spatial analyst GIS software. AHP weighted Linear combination formulae was used as

$S = \sum_{wi} X_i X \prod_{cj}$ -- (1)

Where

S = is the composite suitability score

Wi =weighs assigned to each factor

Cj = constant (Boolean factor)

$\sum$ = sum of weighted factors

$\prod$ = product of constraints (1- suitable, 0- unsuitable)

RESULTS AND DISCUSSION

Results of the DEM in the study area is shown in Figure 2. The DEM indicates that Southern part of the study area is higher in terms of elevation with relief values of more than 767.9m and the lowest relief values of 383.3m are recorded in the northern parts. All places in the central are having moderate values of elevation. This indicates that south is the highest point which forms the watershed of the study area. North is the lowest point which form the down steam section of the study area.

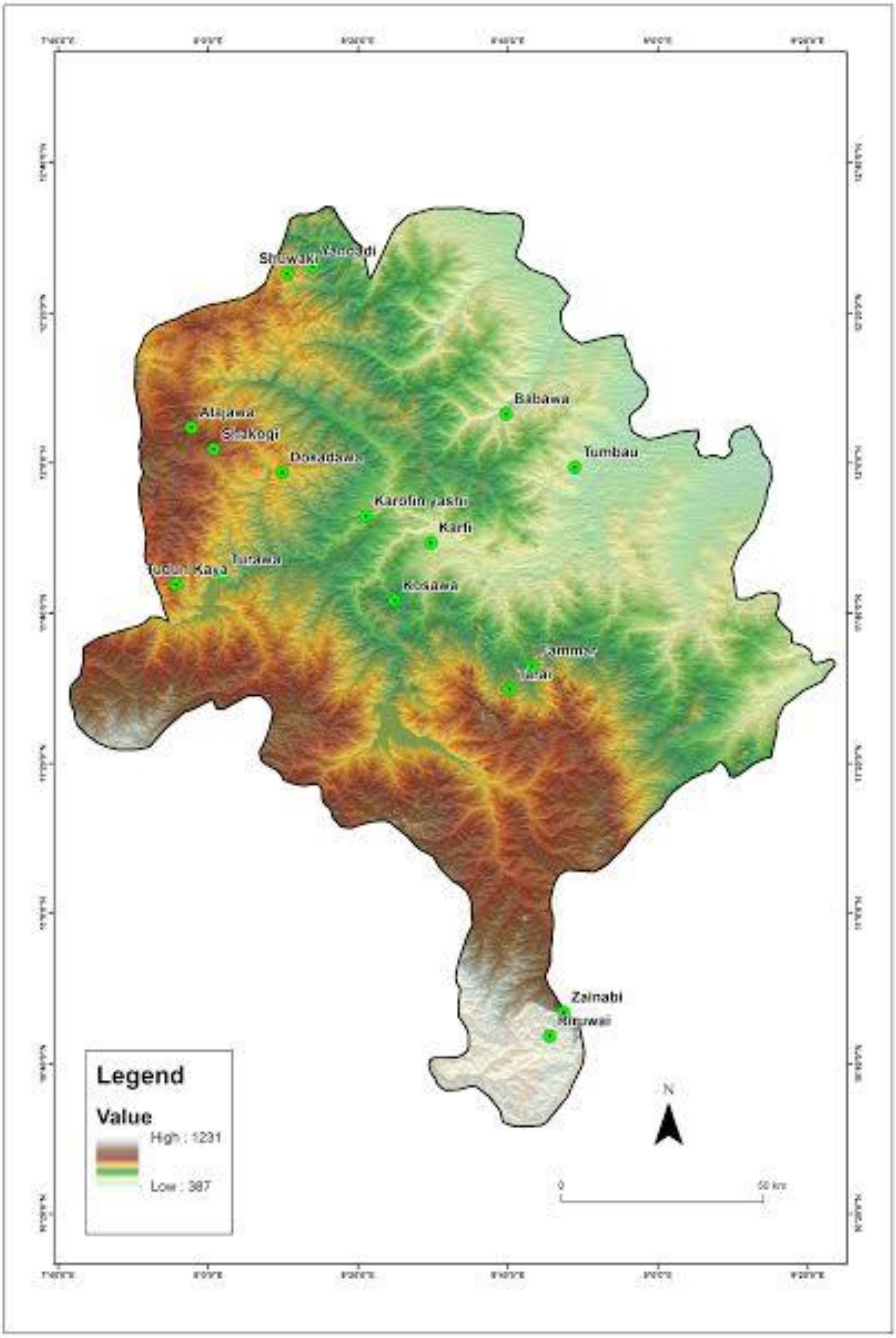

Figure 2 DEM of the rural areas
Source: Data Analysis, 2013

The results of spot heights and contour lines are presented in Table 3 and Figure 3 it is shown that the highest contour is >580m and the lowest contour is 340m. Among the rural areas studied Riruwai in Doguwa Local Government area is having contour value of >580m above mean sea level, Zainabi 570m, lowest points are recorded in Kosawa, Karofin-Yashi, Karfi, Babawa and Tumbau. The result also indicates that all areas with lowest contour values have more drainage concentration than areas with highest values. This result is substantiated by the findings of Anudu *et al* (2011) in Wamba and Abel and Moshood (2011) in Ekiti South Western Nigeria.

Result shown that the highest slope values are >9 ^{o} and the lowest slope values are from 0- 3.0^{o}. Area with highest slope value is Riruwai with slope value >9^{o}.Tarai and Zainabi, are areas with slope values of between 6.0- 9.0^{o,} areas with moderate slope values of between 3.0- 6.0^{o} are Tumbau, Tudunkaya, Turawa, Kosawa and Fammar while areas with lowest slope values of between 0- 3.0^{o} are Shuwaki, Yandadi, Dokadawa, K/yashi, Shakogi, Alajawa and Karfi (table 3 and figure 4). It is deduced that areas with slope values of between 0- 3.0^{o} and 3.0- 6.0^{o} are areas ascribed to have higher drainage concentration i.e. more rivers and dams and more groundwater. This is in line with interpretations of Anthony and Doreen (1977) and Rilwanu (2014).

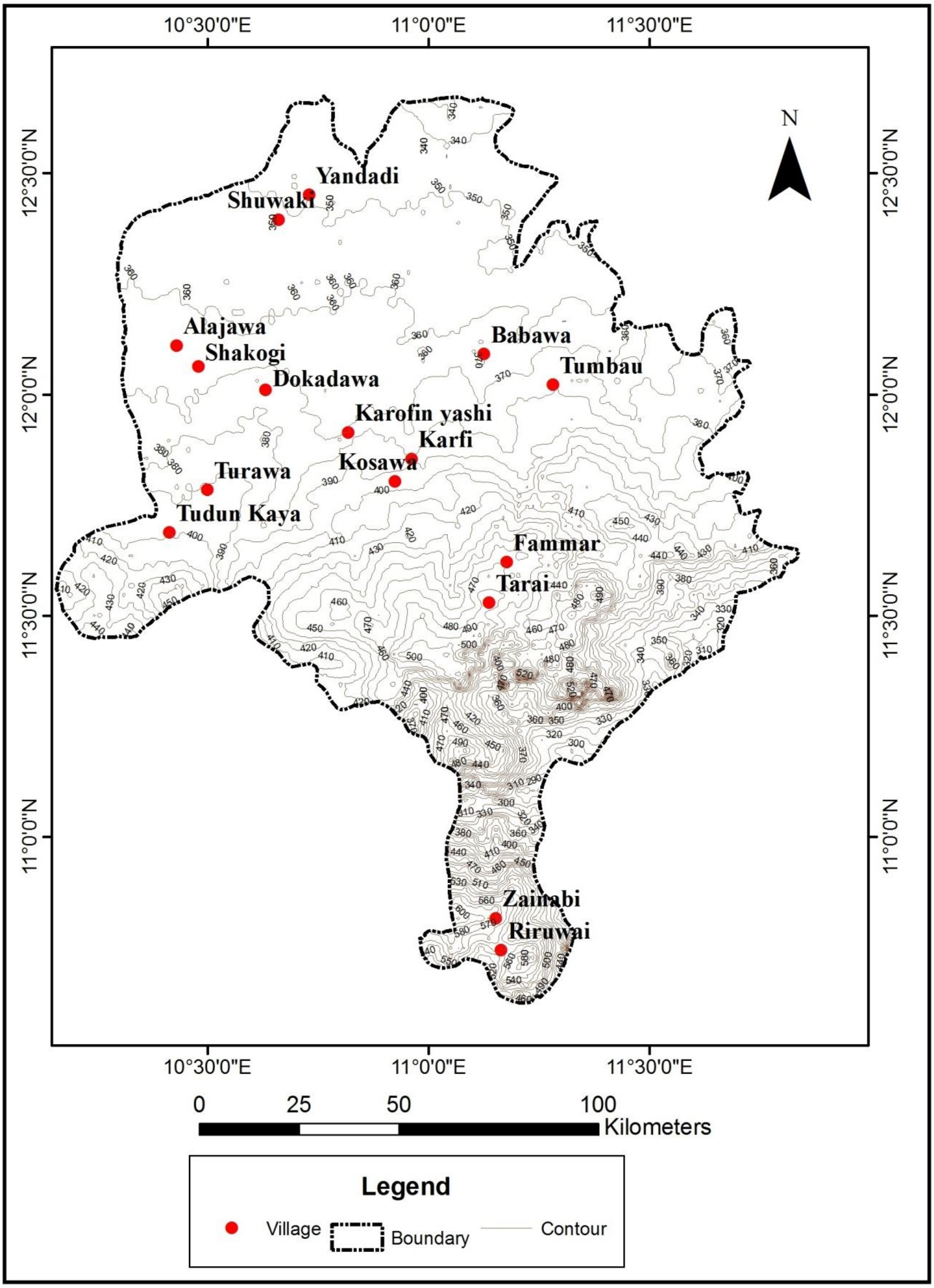

Figure 3 Contour Values of the rural areas
Source: Data Analysis, 2013

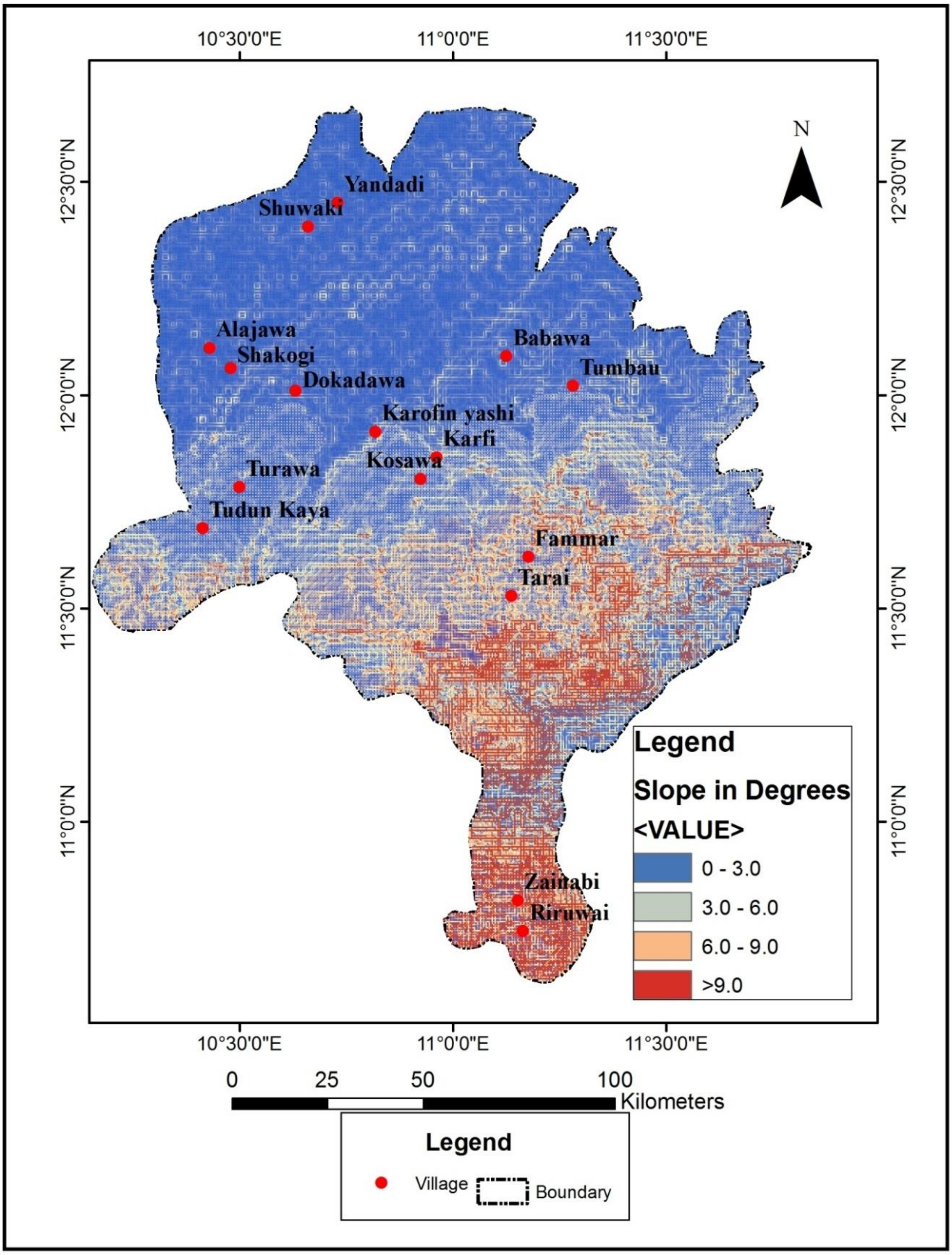

Figure 4 Slope map of the study area
Source: Data Analysis, 2013

From the result five groundwater potential zones were identified based on surface topography (relief and slope) thematic maps. These potential zones are Very high, High, Moderate, low and very low (Figure 5). Very high areas include Yandadi, Karfi and Shakogi, depth to water level in these areas ranges from 13.29 – 14.98m and water table values of 407 – 426m. High areas are areas around Kosawa, Babawa and Tarai and usually depth to water is around 14.99m – 15.12m and water table values of 435.52 – 479.8m. Areas with moderate potential are Shuwaki, K/Yashi, Turawa, Alajawa and Dokadawa in which depth to water level is 15.13m – 16.12m and water table values of 481.88 – 546.78m. Areas with low groundwater potential are around Tumbau, Fammar, Tudunkaya and Zainabi with water depth to water of 16.70 – 17.8m and water table values of 552.19 – 737.2m. Results also indicates that rural area that fall within very low groundwater potential is Riruwai depth to water level 18.31 - >19.31m and water table value of 873.69 – 874.69m and above (table 2).

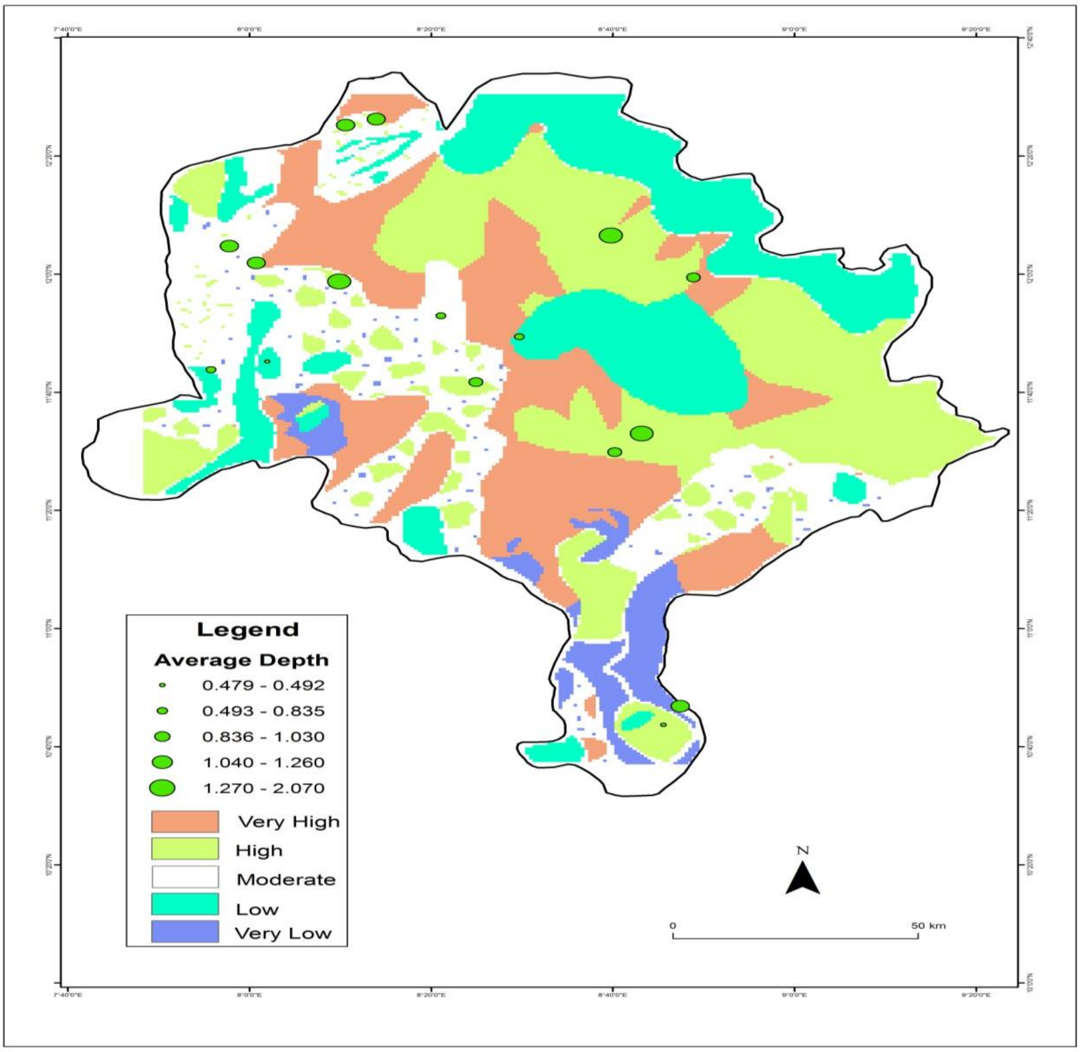

Figure 5 Groundwater Potential zones map
Source: Data Analysis, 2013

Table 2 Depth to water level, water table values and Groundwater Potential

S/N	Depth to Water Level	Water Table Values	Groundwater Potential	Villages
1	13.29 14.98m	407.3 – 426.7m	Very High	Yandadi, Karfi and Shakogi
2	14.99 – 15.12m	434.52 – 479.8m	High	Kosawa, Babawa and Tarai
3	15.13 – 16.12m	481.88 -546.78m	Moderate	Shuwaki, K/Yashi, Turawa, Alajawa and Dokadawa
4	16.70 – 17.81m	552.19 – 737.2m	Low	Tumbau, Fammar, Tudunkaya and Zainabi
5	18.31 - >19.31m	873.69 – 874.69m	Very Low	Riruwai

Source: Field Survey, 2013

Findings of the research indicated further that higher areas with higher contour and slope values are areas of low to very low groundwater potential while areas of lower contours and low relief are having more prospects in terms of groundwater potential. Areas with contour values of 440m to 546m and slope of 0°- 5° are classified as very high to moderate potential classes while areas with contour figures of 589 - >893m and slope of 5°->18° are either low or very low potential zones (table 3). This result is in line with that of Kyung-Seok *et al* (2002), Nezar *et al* (2012) that areas of higher relief are of low potential and lower areas are of higher potential

Table 3 Surface topography and groundwater Potential

S/N	Contour values	Slope(°)	Groundwater Potential	Villages
1	440 – 566m	0° - 2°	Very High	Yandadi, Karfi and Shakogi
2	447 – 493m	2° - 3°	High	Kosawa, Babawa and Tarai
3	458 – 546m	3° - 5°	Moderate	Shuwaki, K/Yashi, Turawa, Alajawa and Dokadawa
4	589 – 755m	5° - 18°	Low	Tumbau, Fammar, Tudunkaya and Zainabi
5	893m - >	>18°	Very Low	Riruwai

Source: Data Analysis, 2013

CONCLUSION AND RECOMMENDATION

Conclusion

From the study it can be deduced that the five groundwater potential zones were determined based on surface topography are very high potential, high potential, moderate potential, low and very low potential. It can be concluded that groundwater potential of the study area is controlled by surface topographical features such as contour values and slopes. From the study it was determined that areas of higher contour values and higher slopes are of low groundwater potential while areas of with lower contours and lower slope values are of very attractive potential with regards to groundwater. It can be concluded that rural areas with appreciable prospects regarding groundwater are Yandadi, Karfi, Shakogi, Kosawa, Babawa and Tarai. Areas with moderate potential are Shuwaki, K/Yashi, Turawa, Alajawa and Dokadawa. Areas with low to very low potential are Tumbau, Fammar, Tudunkaya and ZainabiRiruwai. It was established that areas with low to very low potential are situated in the south and south eastern parts of the study area while areas of good potential are in the northern, north west, central and north eastern parts of the study areas. It is also established that areas of higher groundwater prospects are having lower depth to water level and higher water table values and vice versa.

Recommendation

With particular reference to the major findings of the study it can be recommended among other issues that in areas of higher contour values, higher depth to water level, higher water table values and higher slope values low yielding boreholes with hand pumps are to be provided as the best option while in the areas with lower topographic features high yielding boreholes powered by engines or solar are the best answers to water supply problems. It is also part of the recommendation that alternative water sources should be provided to areas of poor groundwater potential.

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