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Theme:

WATER RESOURCES AND SUSTAINABLE DEVELOPMENT

Application of GIS and Remote Sensing in the Assessment of Groundwater Potential (case study of FUT Minna Gidan-Kwano Campus)

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Abstract

This paper employed the principle of GIS and Remote Sensing to evaluate zones of ground water potential for a selected part of Gidan Kwano campus in the Federal University of Technology Minna, Niger Sate, Nigeria. Multispectral image analysis and GIS were used to analyze satellite images covering Minna metropolis. Image pre-processing (image enhancement and filtering) and image classification were done to identify zones of ground water potential in the study area (Gidan Kwano Campus of FUTMinna). The zones of ground water potential were classified into four different classes (namely: excellent, good, very fair and poor) based on their capability to store water. It is found that about 6.92% of the area can be identified as excellent zones of groundwater potential while 45.99%, 43.72% and 3.38% of the remaining area fall under good, very fair and poor zones of groundwater potential respectively. Validation of result was done using the Global Positioning System (GPS) and the existing borehole(s) points in study area.

Keywords: *Groundwater potential, Remote Sensing, Land use/land cover, Satellite Images, ArcGIS.*

Introduction

The use of GIS and Remote Sensing in Hydrological Engineering has become widespread. It holds much promise in improving the location of zones of groundwater potential of a basin and thus the probability for water extraction for irrigation, domestic and industrial uses (Kumar et al, 2007). The ability of GIS to integrate advanced technologies (Murthy *et al*, 2003) such as GPS, surveillance cameras, and groundwater location devices is being applied to address hydrological systems in large and compact settlement areas. The occurrence of groundwater in basement complex terrains is localized and confined to weathered/fracture zones. Getachew (2007) employed integration of Remote Sensing and GIS for Groundwater assessment based on some factors (such as Drainage Density, Landforms/Geomorphology, Lithology/Geology [Binay and Uday, (2011)] Slope Steepness, and Land use/Land cover, Geological Structures/Lineaments) but did not take cognizance of the rainfall distribution to depth of bedrock and water table, so prospect for groundwater in such areas will be limited to these aforementioned factors and create barriers for other factors that affects the location of zones of groundwater potential. Murugesan *et al* (2012) carried out successfully groundwater study in the Dindigul district of kodaikanal hill, in the Western Ghats of Tamilnadu. All thematic maps were generated using the resource sat (IRS P6 LISS IV MX) data and Inverse distance weight (IDW) model with GIS data to identify groundwater potential of the study area. Prabir *et al* (2012) made an attempt to determine zones of groundwater potential within an arid region of Kachchh district, Gujarat. The zones of water potential were obtained by weighted overlay analysis; to this end, the ranking given for each individual parameter of the thematic map and weights were assigned according to their influence. But however, Deepesh *et al* (2010) proposed a standard methodology to delineate zones of groundwater potential using integrated Remote Sensing, GIS and multi-criteria decision making (MCDM) techniques. Here, the selected thematic maps were integrated by weighted linear combination method in a GIS environment to generate a groundwater potential map. The information on these zones of ground water potential is critical in ground water exploitation (Yeh *et al*, 2009) especially for borehole drilling.

Materials and Method

Study area

Figure 1 is a map showing Niger State in Nigeria. The project site was Part of Federal University of Technology, Gidan-kwano campus along Minna – Bida road, Bosso Local Government Area, Niger State. It is located geographically between the longitude 09° 32' 30.46"N, 06° 26' 14.37"E at the top left, 09° 31' 30.55"N, 06° 26' 08.32"E at the bottom right, 09° 32' 15.27"N, 06° 27' 33.09"E at the top right, and 09° 31' 15.84"N, 06° 27' 20.20.67"E at the bottom right of the latitude. It is also bounded in the west by Minna airport, east by Minna / Bida road (Gidan kwano village), North by Gidan-Mangaro village and in the South by Garatu village. The climate is semi-arid with high-temperature, low rain fall and high evapo-transpiration. Figure 2 shows both the digitized and Satellite Imagery of FUT Minna Gidan Kwano Campus

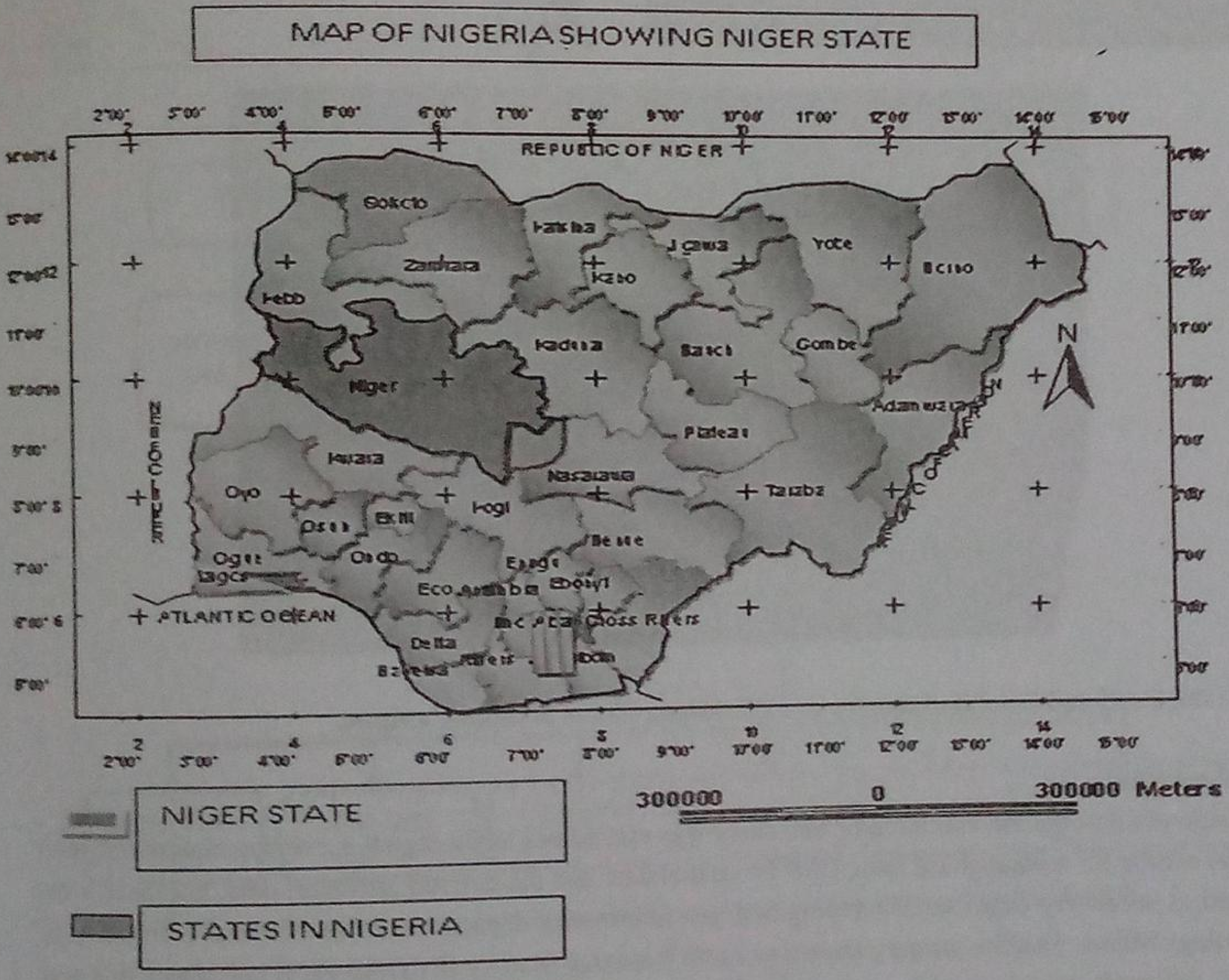


Fig. 1: Map showing Niger State in Nigeria.

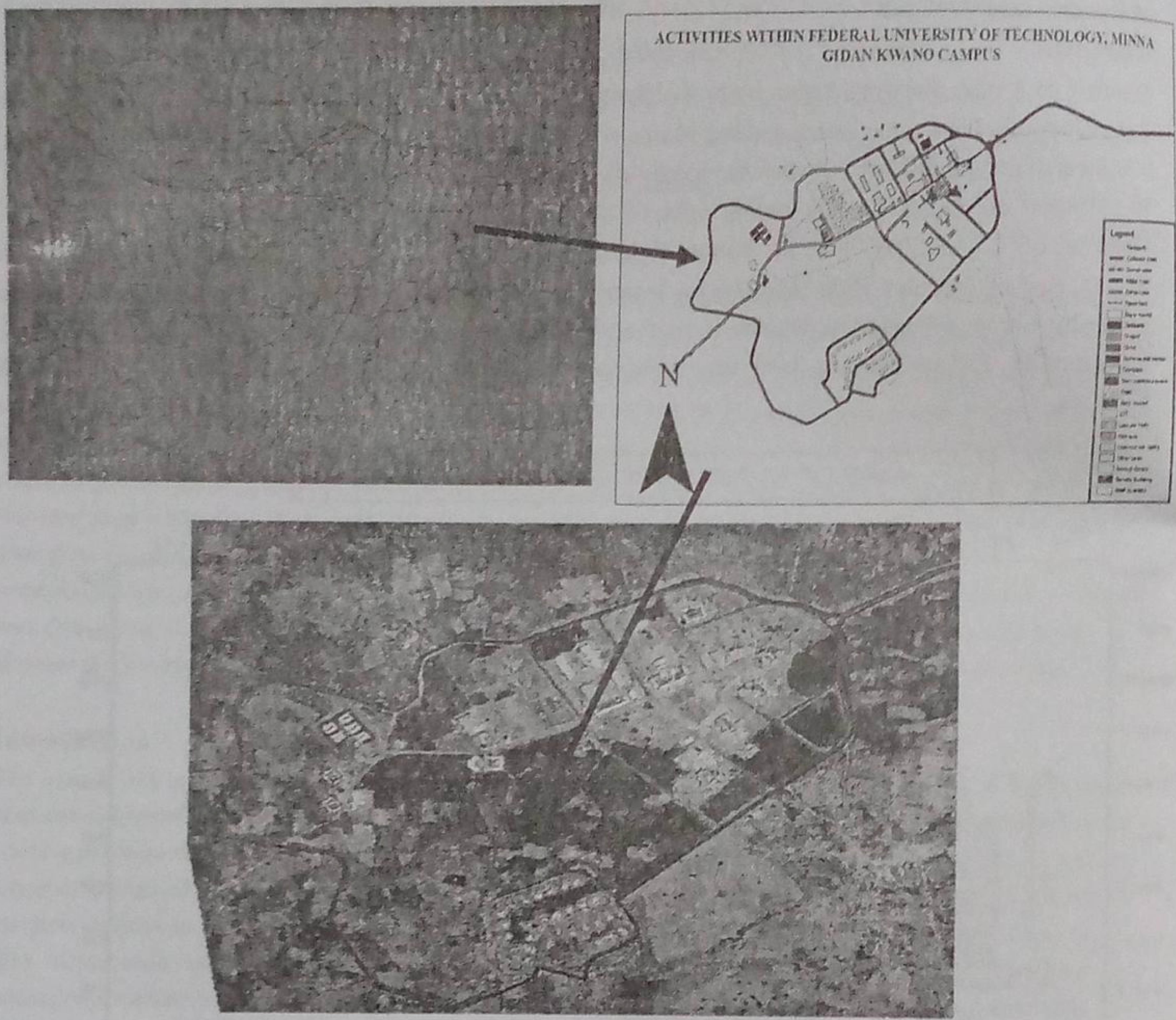


Fig. 2: Digitized and Satellite Imagery of FUT Minna Gidan Kwano Campus.

Data Acquisition

Acquisition of data for the execution of this study was carried out using digital surveying equipment such as Total-station for topographical data, GPS for spatial data and the derived attributes data, but these were obtained as secondary data from Surveying and geo-informatics department of the Federal University of Technology Minna. Satellite imagery known as Earth Resource Map by (ERDAS ECW) of Minna that was used for this study was obtained from the Surveying and Geo-informatics department of the school.

Methods

Satellite images obtained from Surveying and Geo-informatics department FUT Minna were used. Catchment delineation and drainage extraction were done using ARCMAP module. Maps are then generated using ArcGIS software. Digital image processing (image enhancement, image filtering, etc) for the extraction of linear features, land use/cover, etc was carried out which was used for extracting lineaments and for landform mapping. Field reconnaissance information at a level of accuracy were used to examine the parameters influencing zones of groundwater potential such as slope, aspect map, drainage/flow density, land use/land cover units. These are then integrated with weighted overlay in ArcGIS. Ranking and weights (Ranking and Weighting technique) are assigned for individual category of these parameters. Each unit weight factors were decided based on their capability to store groundwater.

This procedure was repeated for all the other layers. The zones of groundwater potential were classified into four classes such as Excellent, good, very fair and poor based on their capability to store water. All data were integrated in a Geographic Information System (GIS) and analyzed to assess the groundwater controlling features. Finally groundwater potential map was prepared based on GIS analysis as shown in Fig. 3.

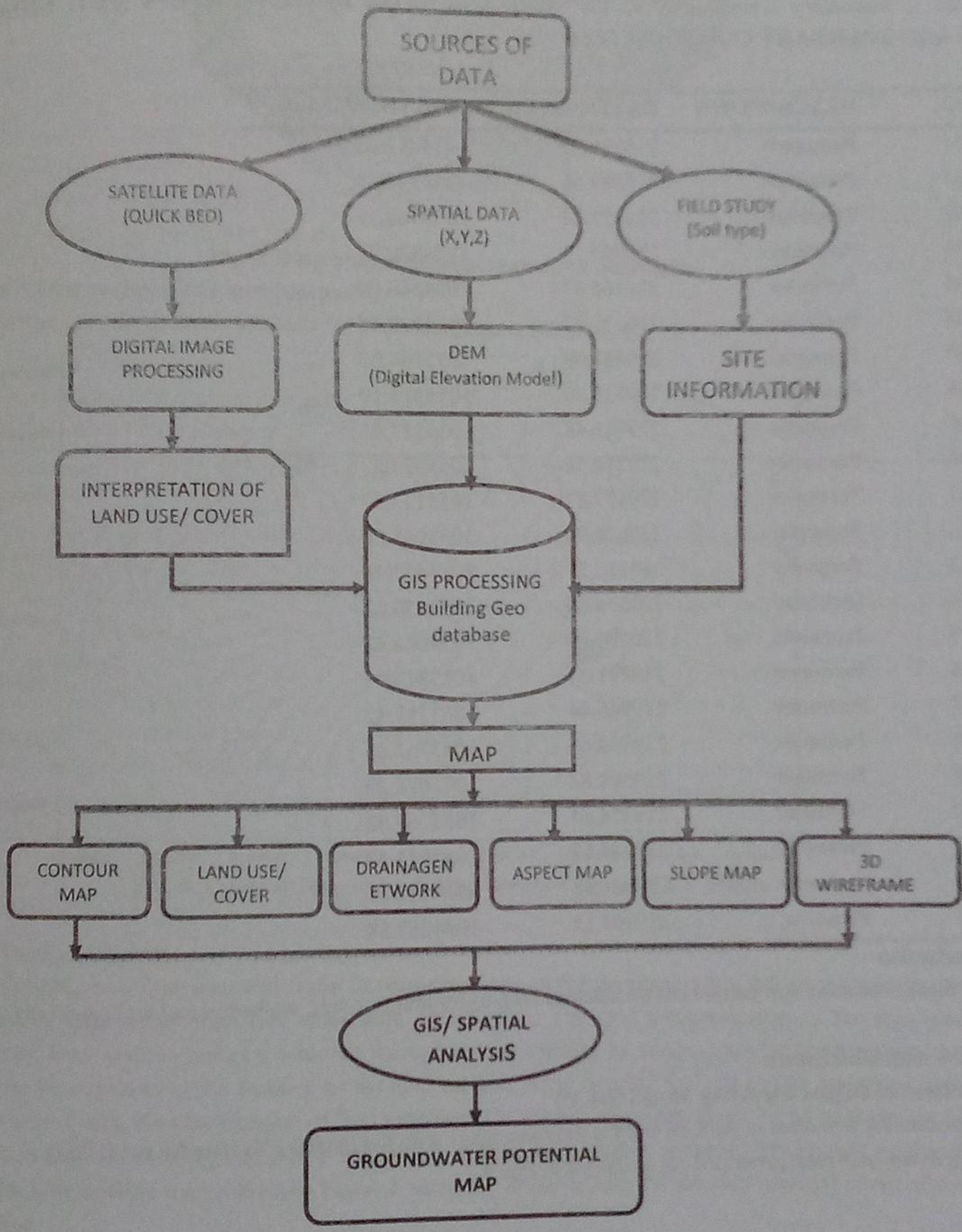


Fig. 3.0: Organo-gram of the Study

Satellite Imagery and GPS

The imagery in digital format was downloaded from Google earth pro software (2011) as recorded by the Surveying and Geo informatics department, Federal University of Technology, Minna. Hand-held GPS was used to select the waypoints; it has an accuracy of 2 m as shown in Table 1.

Table 1: Boundary Coordinates of the Study Area picked by Hand-held GPS (FUT, GIDAN KWANO BOUNDARY COORDINATES)

S/NO.	DESCRIPTION	EASTINGS (m)	NORTHINGS (m)
PG01	Perimeter	218881.89	1054312.42
PG02	Perimeter	218893.56	1054374.24
PG03	Perimeter	218992.74	1054568.56
PG04	Perimeter	219005.18	1054820.97
PG05	Perimeter	219160.434	1054860.09
PG06	Perimeter	219321.42	1054829.36
PG07	Perimeter	219437.08	1055164.05
PG08	Perimeter	219535.26	1055214.10
PG09	Perimeter	219821.48	1055217.91
PG10	Perimeter	220214.54	105552.05
PG11	Perimeter	220577.87	1055123.37
PG12	Perimeter	220676.95	1055065.86
PG13	Perimeter	220715.51	1054677.76
PG14	Perimeter	220534.86	1054350.61
PG15	Perimeter	220299.09	1054044.42
PG16	Perimeter	219991.55	1053817.95
PG17	Perimeter	219946.44	1053797.42
PG18	Perimeter	219750.6	1053762.83
PG19	Perimeter	219594.82	1053678.39
PG20	Perimeter	219374.64	1053769.62
PG21	Perimeter	219244.52	1054031.38
PG22	Perimeter	219261.98	1054212.13
PG23	Perimeter	219063.12	1054257.88

Vectorization

Vectorization process was carried out for features such as buildings, roads, walkways and drainages only.

Results and Discussion

Generation of Digital Elevation Model (DEM)

Data processing was done in ArcGIS and the thematic maps with the Digital Elevation Model (DEM) serving as the base map generated are as shown in Fig. 4.

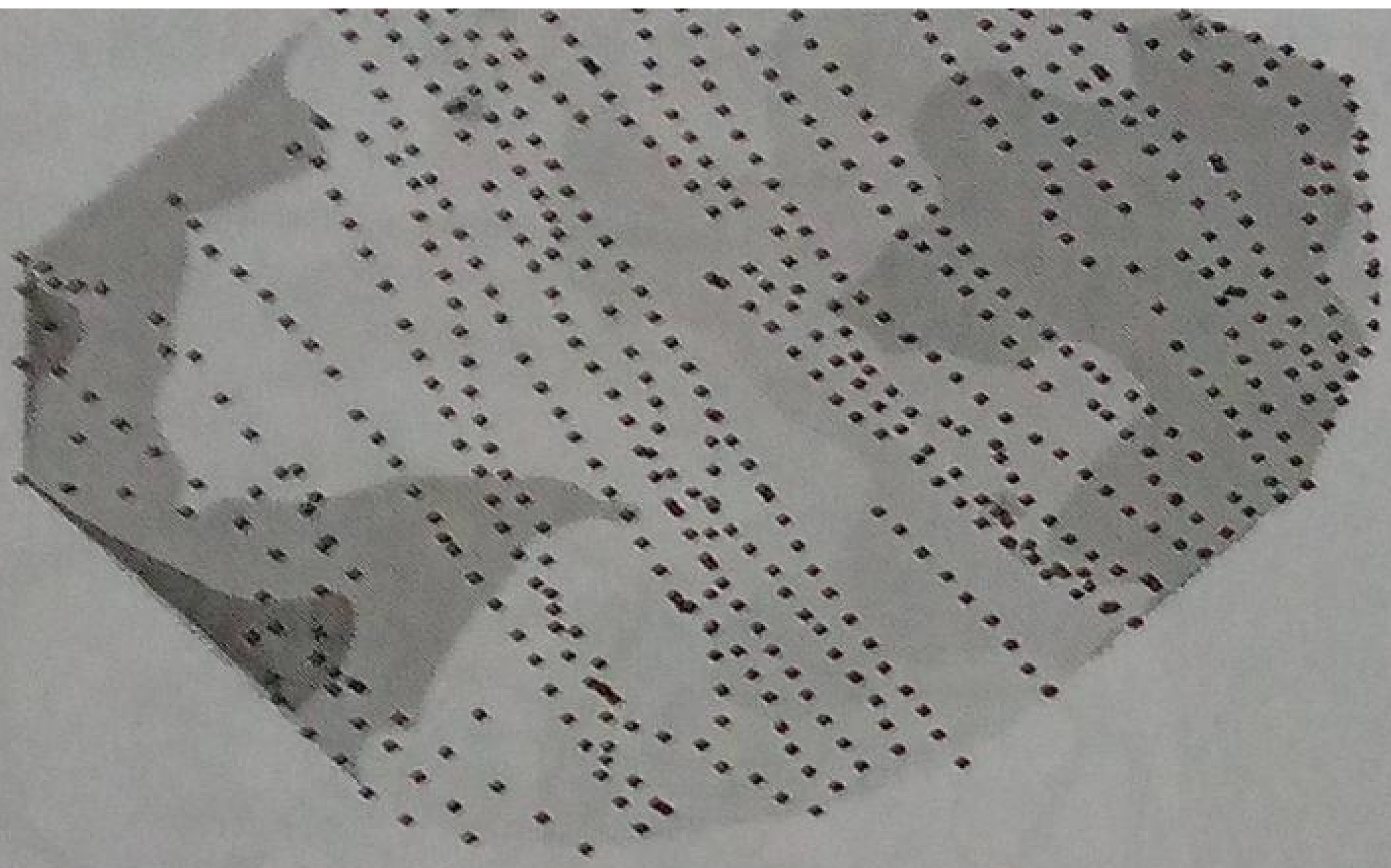


Fig 4: Base Map generated from x,y,z coordinate

Contour Line as Basis for Slope Steepness

The contour line which forms the basis for slope steepness is shown in Fig. 5.

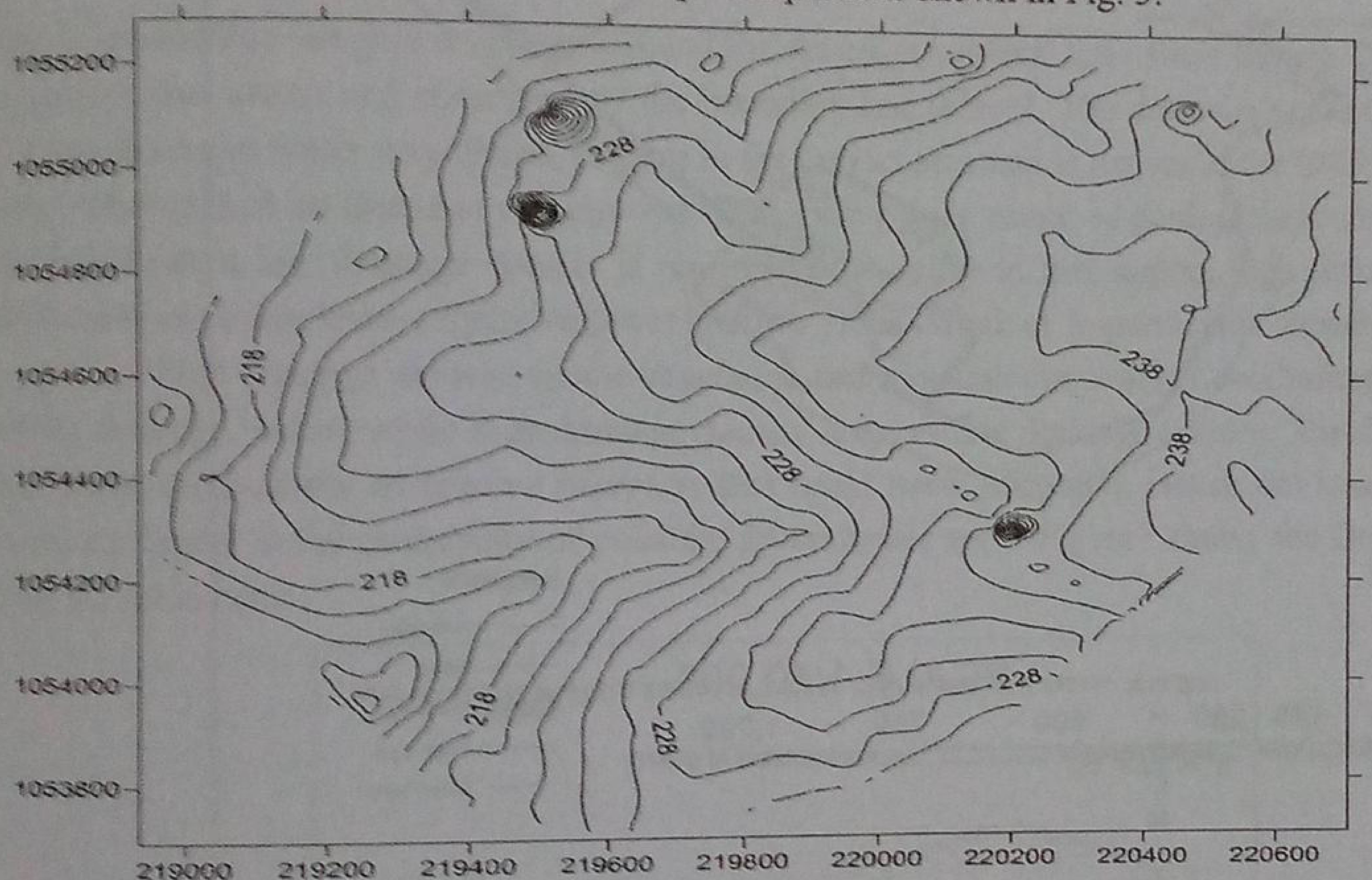
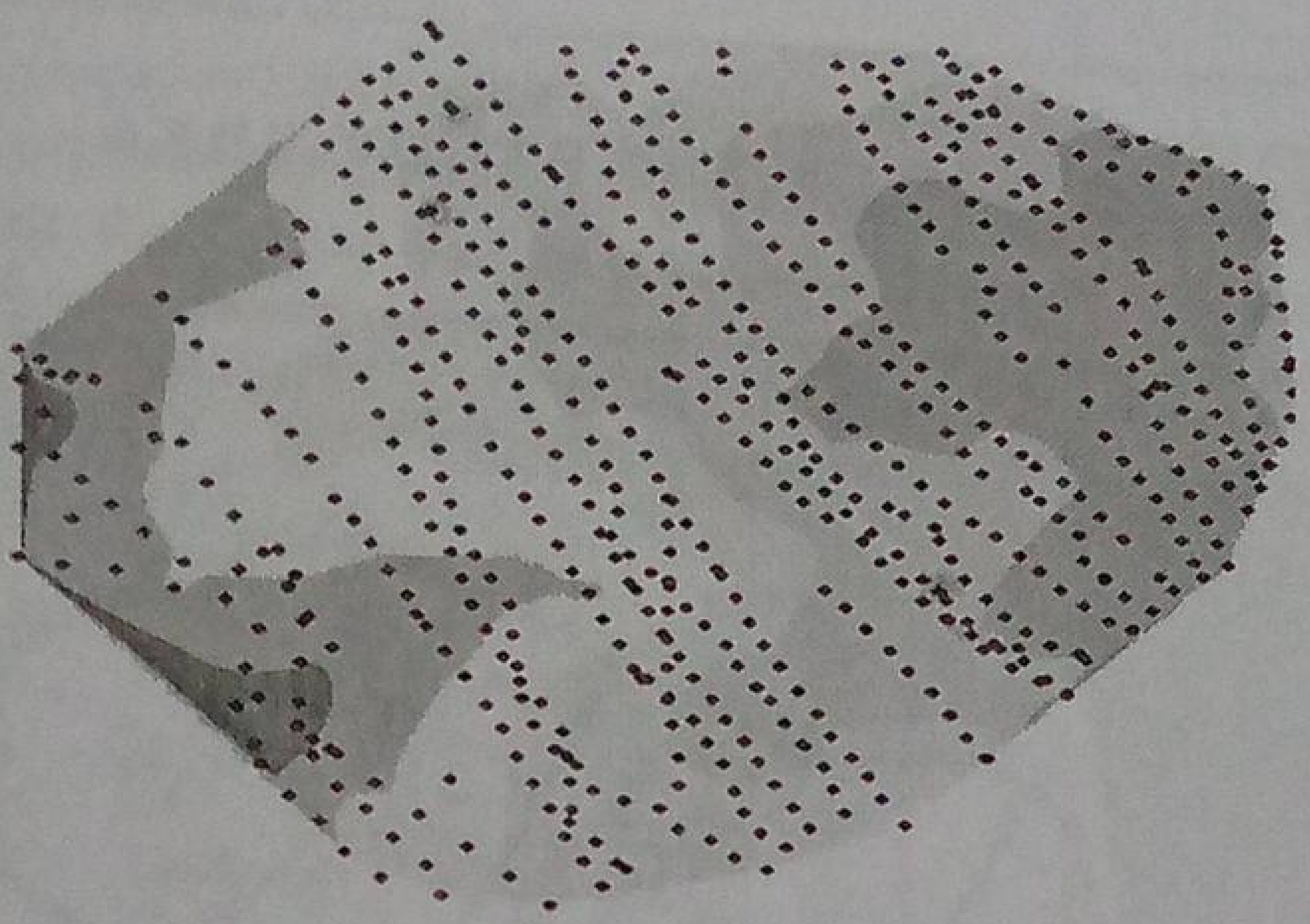


Fig. 5: Contour Map of the Gidan Kwano Campus FUT Minna

Land Use/Land Cover

Land use/land cover is an essential factor to consider as one of the parameters that influence groundwater potential of a particular zone (the study area specifically). The land use/cover map of the area was interpreted from satellite imagery achieved through remote sensing by using visual interpretation and by on-screen vectorization of the features on the land surface. After detailed analysis in GIS integrated with remote sensed data, the classification of land use/cover for analysis was carried out based on their rate of infiltration and water holding capacity. It was observed from analysis that, generally, settlements are found to be the least suitable for infiltration. Figure 6 show the detailed map for the land use/land cover of the study area.



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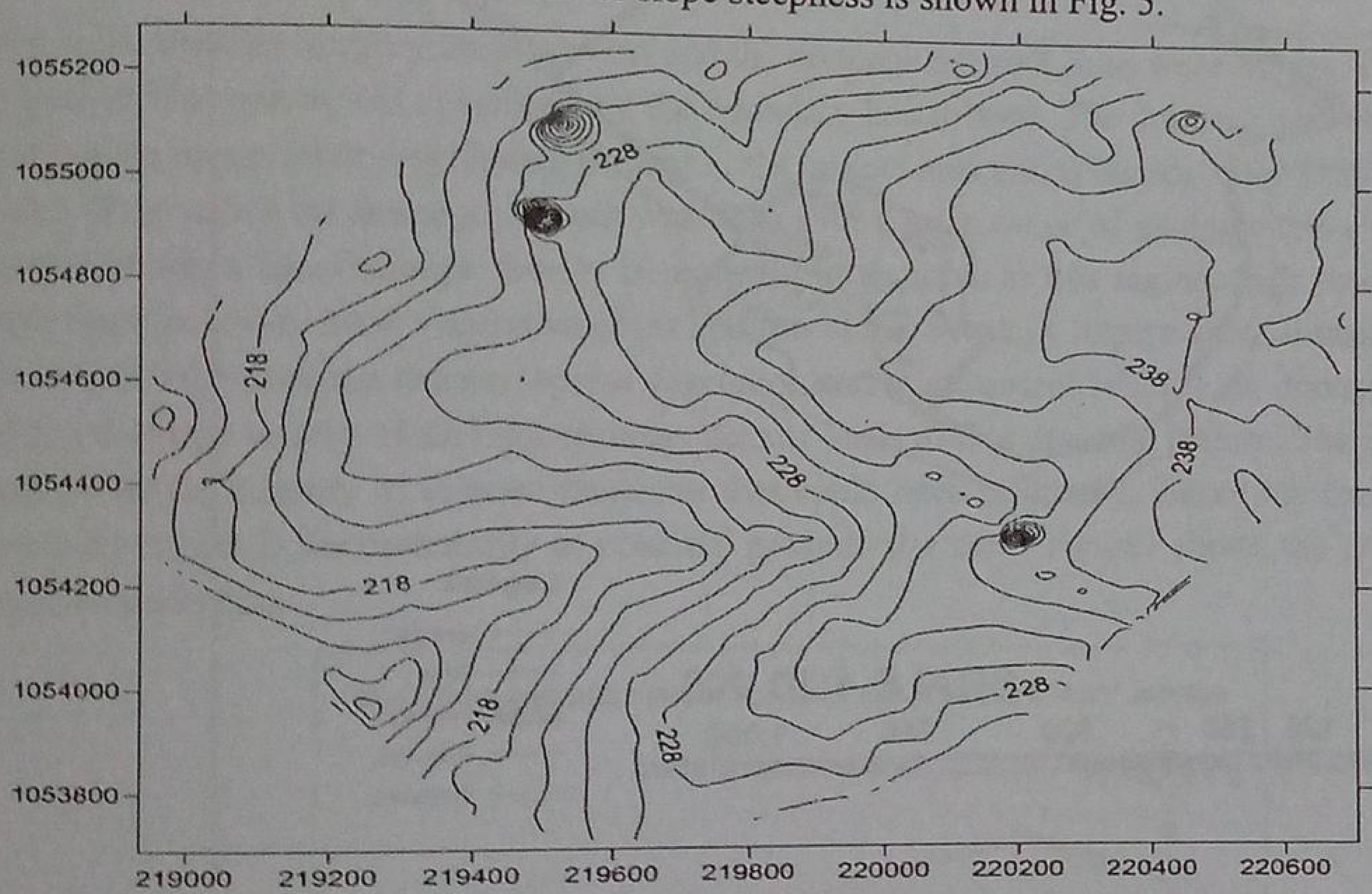

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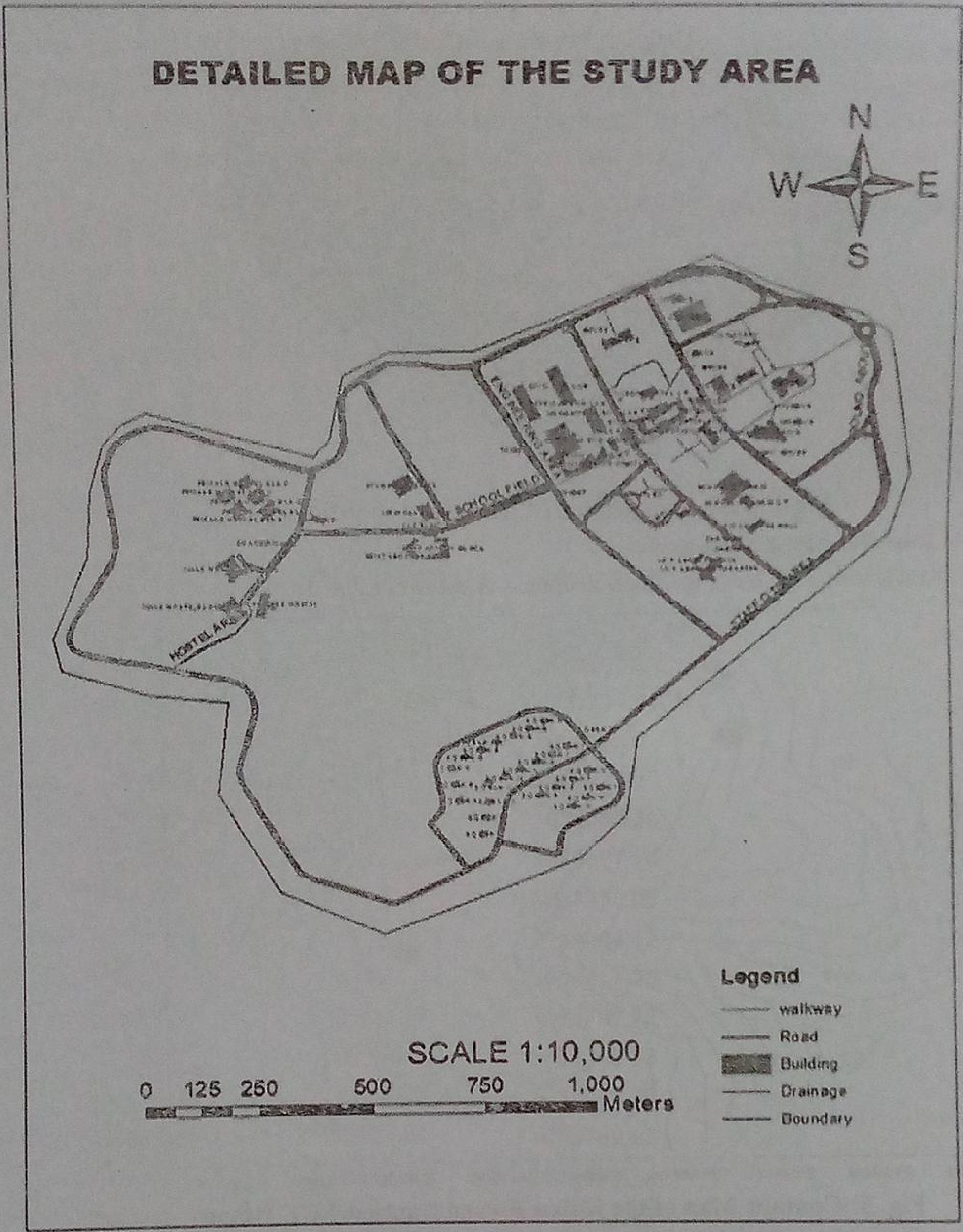

Fig. 6: Detailed Map for land use/land cover of the project site

Furthermore, the total area under study was calculated as 1,793,548.2151m^2 (179.355Hectares) and the summation of the areas that made up the land cover using ARCMAP according to their respective classes is summarized in the Table 2.

Table 2: Land use/cover area in hectare and percentages

Class	Types of LCLU	Area (ha)	Area %
1	Buildings	6.17	99.36
2	Roads	0.019	0.30
3	Walk ways	0.0049	0.08
4	Drainage	0.016	0.26

Drainage Extraction and Network

In Arcmap, On-screen vectorization from satellite imagery was performed for the extraction of drainage network which was preceded by proper site investigation to ascertain exactly where these drains were networked and concentrated. Fig. 7 shows drainage extraction and network of the study area.

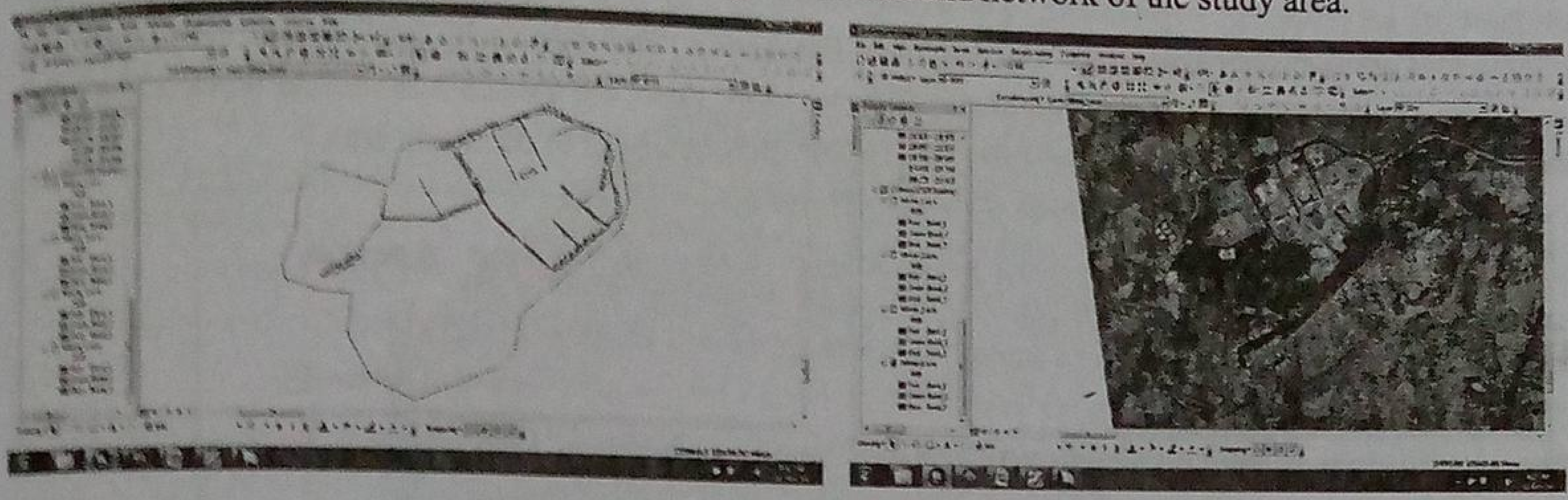

Fig. 7: The Drainage network map of the study area

In Fig. 7, the satellite imagery layer was off and the drainage network lines were shown. The network was generated in blue colour and encamped by the boundary line (black). The drainage network of the project area gives the major water way/drains, present in the project area and is denser in the hostel area and Staff Quarter. Observation on drainage amount was done over a wide range of geologic and climatic type; the findings indicate a low drainage density is more likely to occur in this region, high resistant permeable subsoil material under dense vegetative cover and low slope. Weak or impermeable subsurface material is as a result of high drainage density, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The drainage density characterizes the quantity of relative rainwater that could have infiltrated. Hence the lesser the drainage amount, the higher is the probability of potential groundwater zone. Figure7 shows the Drainage network map of the study area.

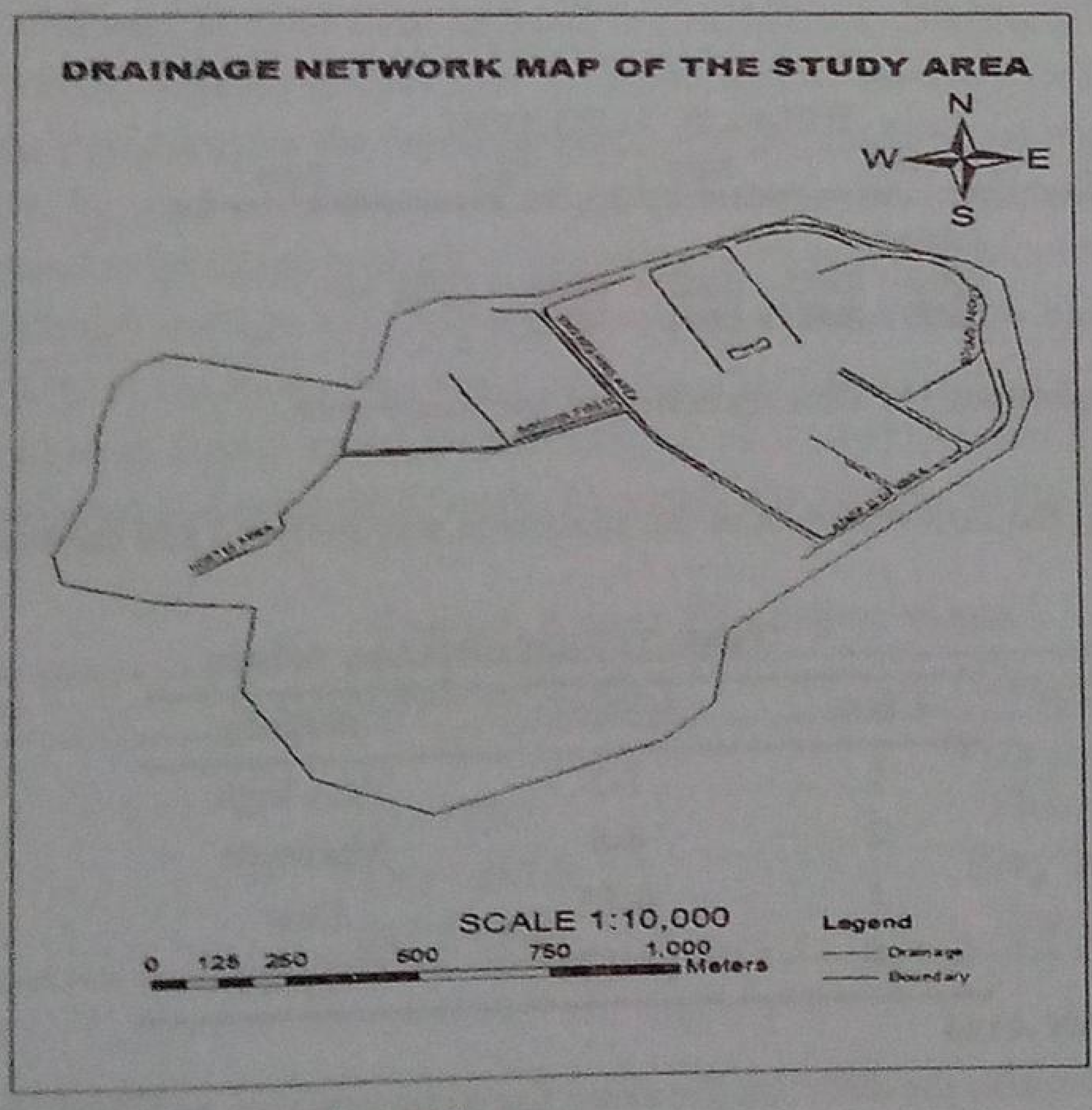

Fig.7: The Drainage network map of the study area

Flow Direction Map of the Study Area

From Fig. 8, it was observed that the colour band from band (1-8) signifies the area of land characterized by swampy class and a very low land that impounds water. Thereby cannot give a positive result for the purpose of groundwater exploration. The colour band (9-32) is a very good area which facilitates the prospect of groundwater due to its location on a flat terrain. This allows for high retention of water for good rate of infiltration that brings about rise in water table. Also, for the (64-128) colour band, it is a zone of robust groundwater potential. Fig. 8 shows the flow direction Map of the study area.

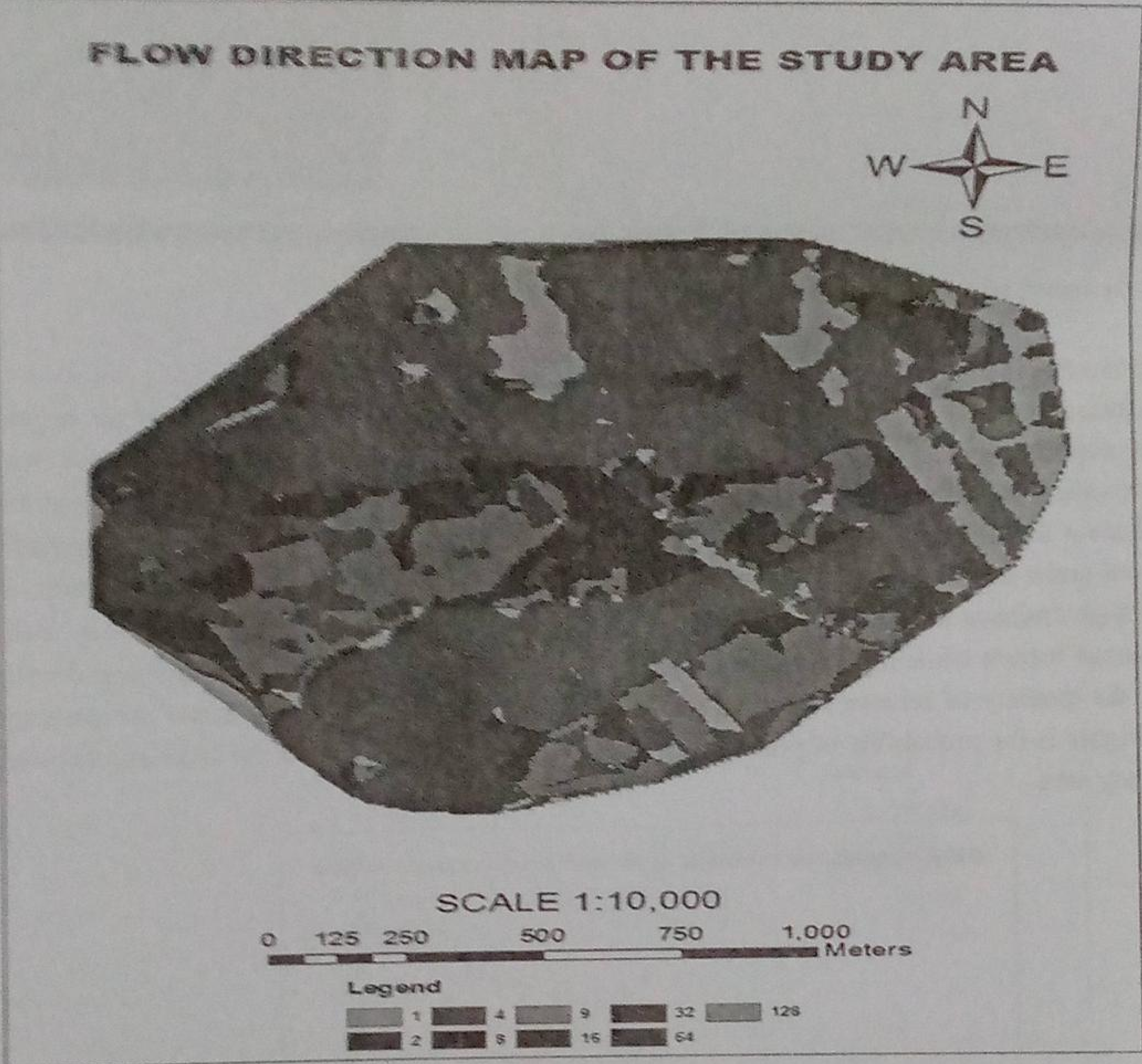

Fig. 8: Map showing the flow direction of the study area

Thematic maps showing the flow direction of the study area was analyzed and the summary is shown in Table 3.

Table 3: Flow direction values

Class	Metres	Category
1	1-2	Very high
2	4-8	Moderate
3	9-32	Low
4	64-128	Very low

Aspect Map of the Study Area

Aspect map helps to determine the direction the slope faces (surface area and direction of drainage in drainage work). After the processes performed in the ArcGIS environment, the map takes the form as shown in Fig. 10.

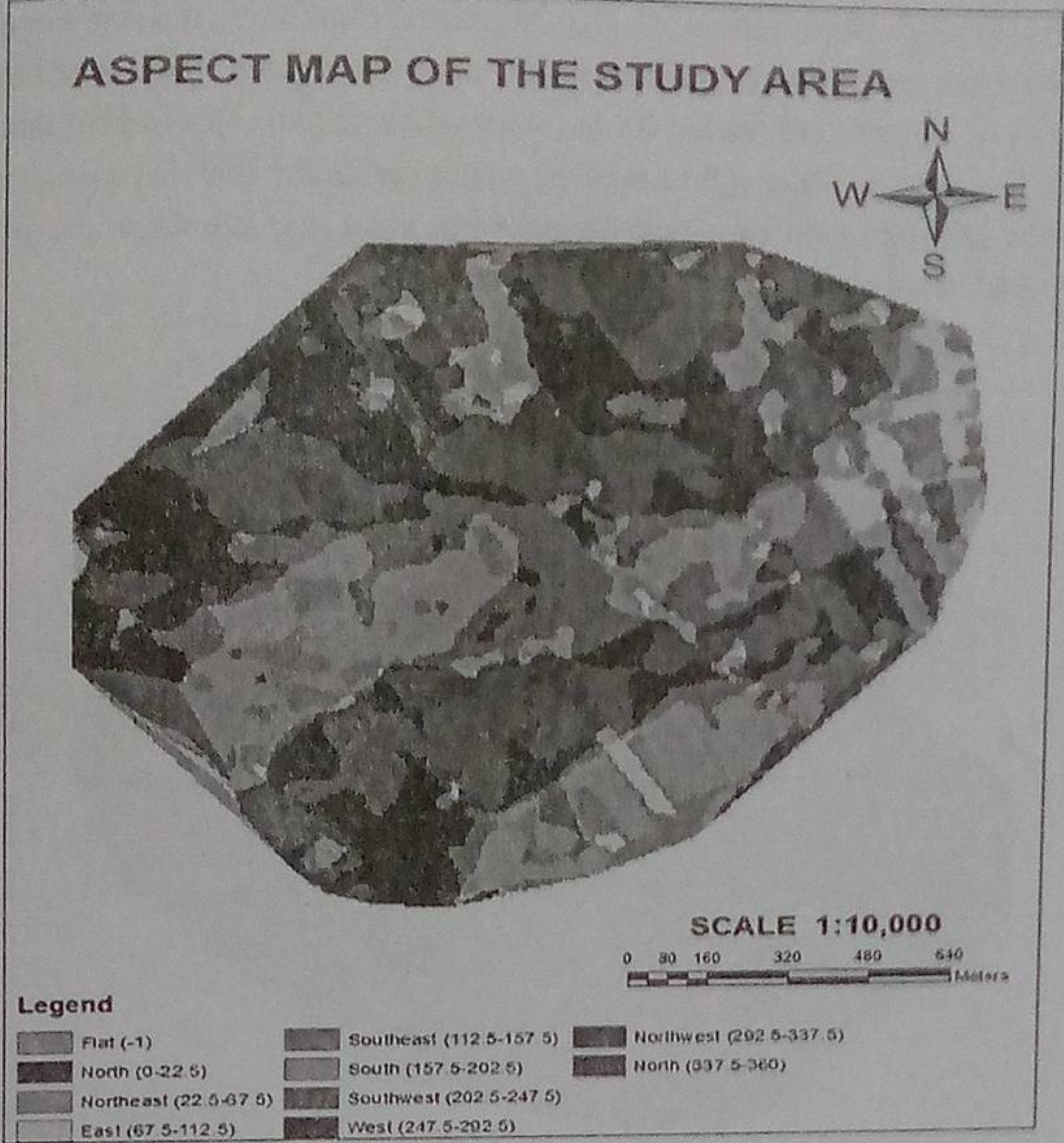

Fig. 10: Aspect Map of Gidan Kwano Campus of FUT Minna

Aspect map was derived from DEM which serves as the base map. It identifies the down slope direction of the maximum rate of change in value from each cell to its neighbour. The ash coloured surface indicate the area of flat terrain which is hardly noticed over the entire land of the study area. This is accounted for by the nature or natural topography of the land (flat slopes that had no direction and are given a value of -1). The information can be used to locate zones of groundwater potential since temperature has a greater influence on the rate of evaporation to depth of groundwater table. The rate at which the vegetation on this type of terrain will absorb sunlight will be greater. It will absolutely leads to increase in the rate of evapo-transpiration especially in the south-east, south-west and west where there is presence of colour band; i.e green, blue and light blue. Aspect map give much details about soil classification (sandy, loamy, clayey) regarding their percolation and permeability rate. All these were justified in the Table 4.

Table 4: Aspect Map degree values

Class	Degree of slope (0-360^0)	Category
1	-1	Very good
2	0 - 112.5	Good
3	112.5 - 247.5	Very fair
4	247.5 - 360	Fair

Slope Map of the Study Area

The gradient is the rate at which the steepness of a slope increases; considering this, the slope was classified into nine with low slope area being the most developed (from green colour to yellow) and high slopes depicting the areas vulnerable to erosion (from colour yellow to red). This implies that the rate of infiltration will be so low since no water will be retained on this part of the land. On a general scale, the area is characterized by low slope which are shaded green while areas of gentle slopes are in yellow with the steeper slopes shaded in red on the output map as seen in Fig. 11.

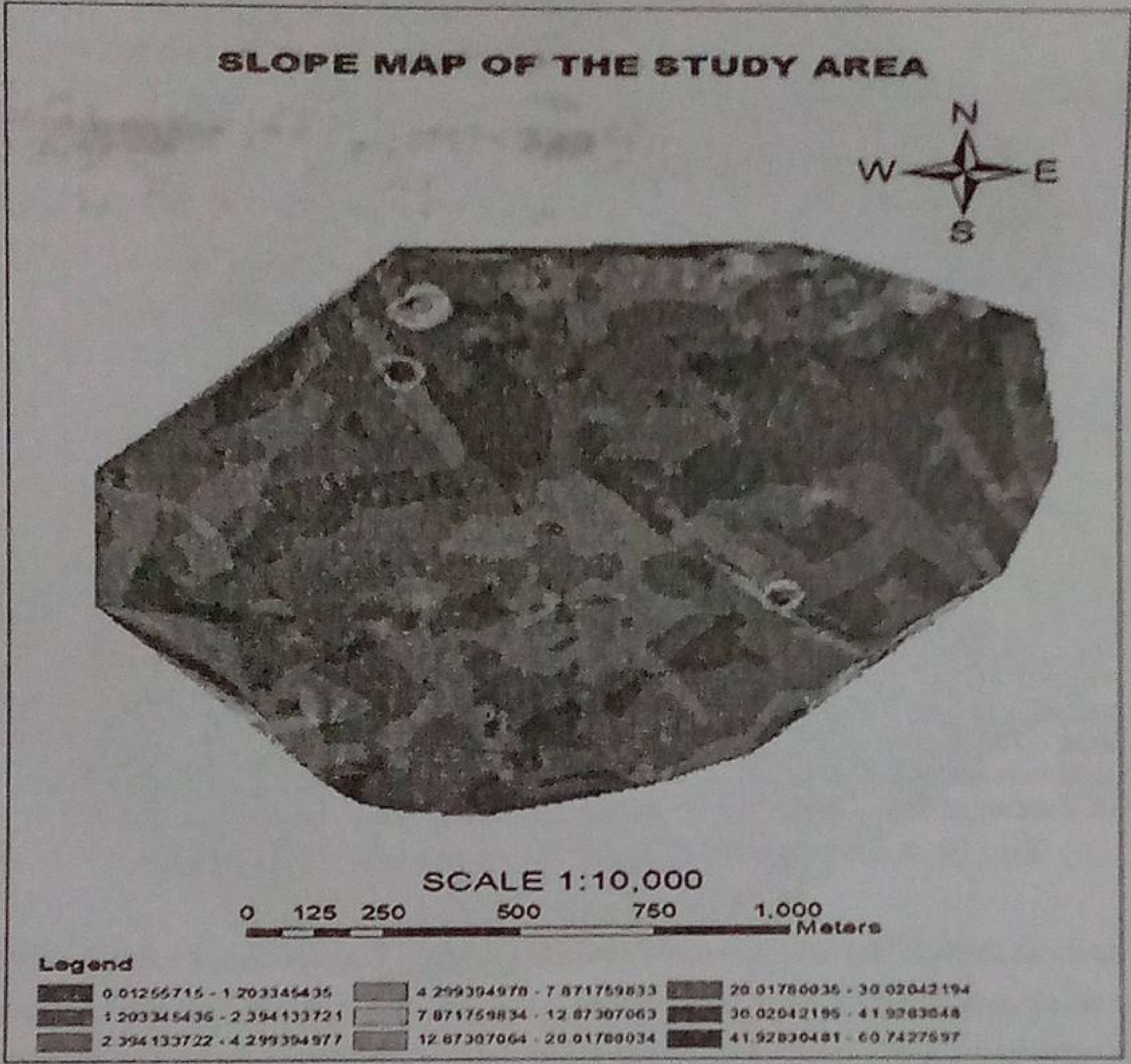

Fig. 11: Slope Map of Gidan Kwano Campus FUT Minna

The entire slope map is divided into four categories for analysis according to their level of steepness as seen in the Table 5

Table 5: Slope steepness in degrees

Class	Degree of slope	Category
1	0.013-4.21	Nearly level
2	4.21-12.87	Gently sloping
3	12.87-30.02	Moderately sloping
4	30.02-60.74	Strongly sloping

3D Wireframe Map

Figure 12 shows the true representation of the study area in 3-dimensional view. Figure 13 shows the 3D surface of the study area. The 3D surface map shown in Figures 12 and 13 used shading and colour to emphasize spatial data. From the map, the blue colour band (254-246) has the highest elevation, grey colour band (246-236) has a flat terrain and high permeability through the soil, and yellow colour band (236-220) is classified as highland which is affected by the lowland on both sides, thereby the water table is altered and the prospect for groundwater in this region depends greatly on depth of water table to bedrock. Green colour band (220-210) is classified as the lowland which is occupied by flow accumulation, it receives most of the water from the drains and this has turned the piece of land to swampy area.

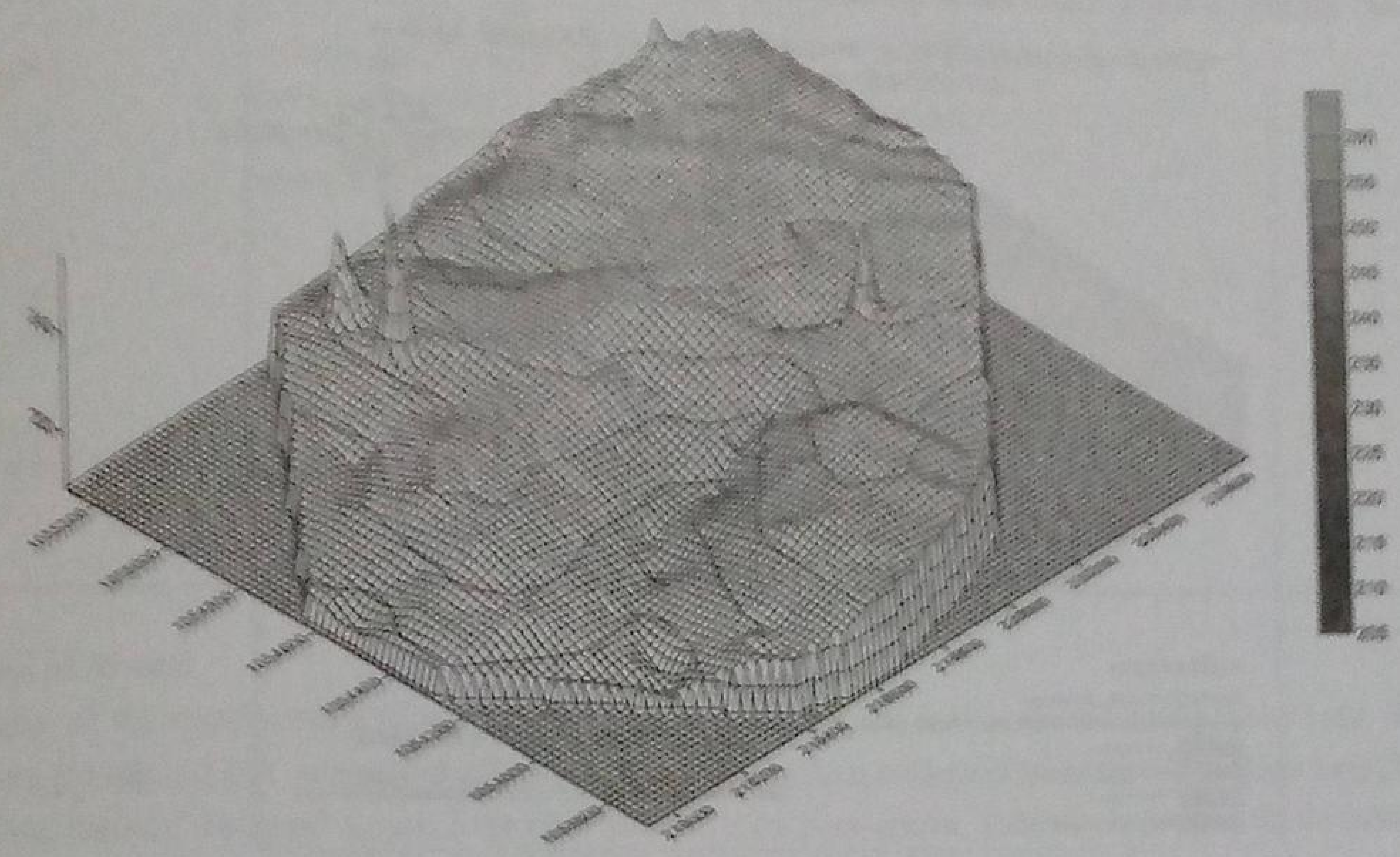

Fig. 12: The 3D wireframe of the study area

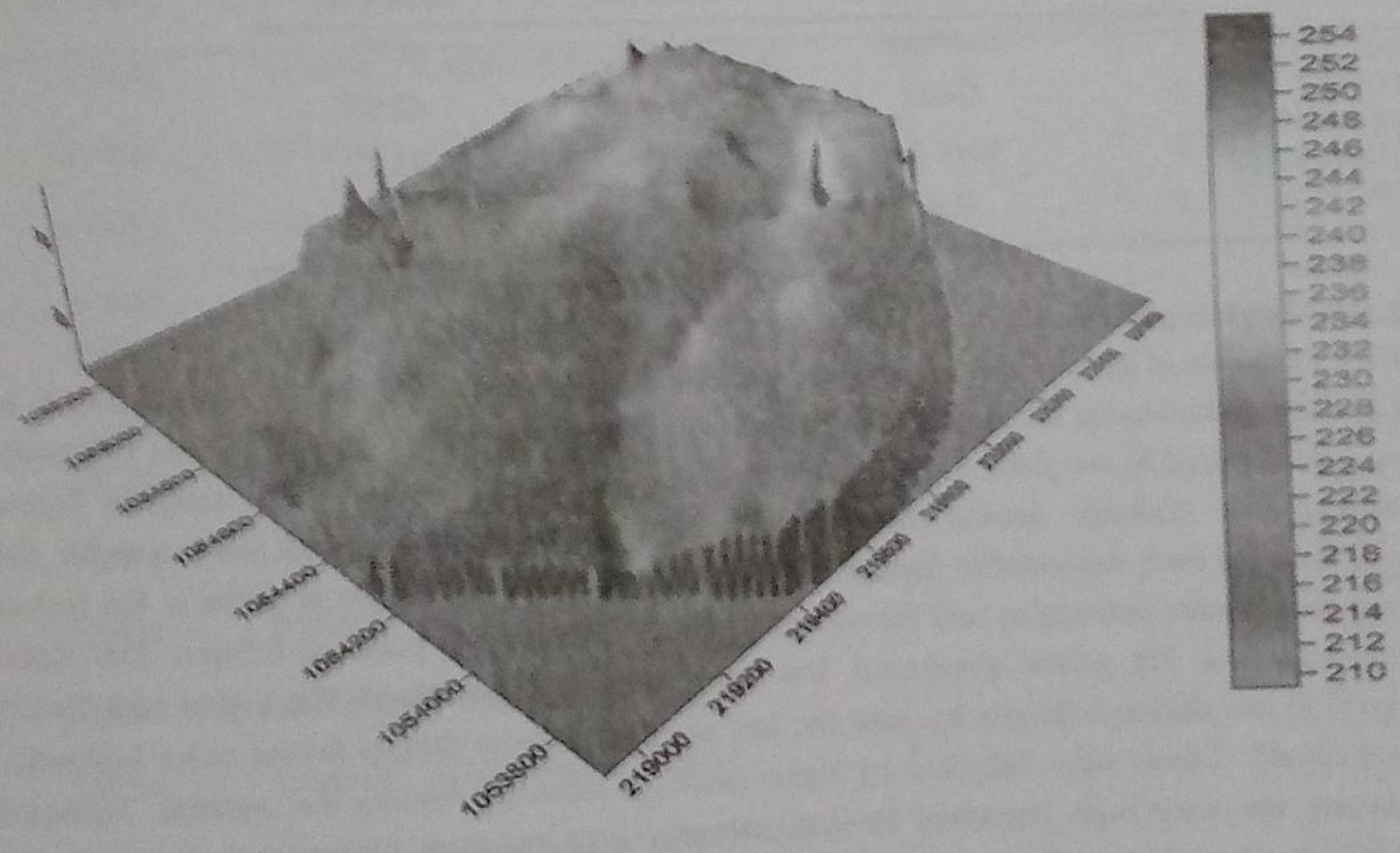

Fig. 13: The 3D surface of the study area

Map of Zones of Groundwater potential of the Study Area

The depiction of zones of groundwater potential were classified into different potential zones of four classes; Excellent, Good, Very fair and Poor was produced by utilizing the model analysis design (ARCGIS). The thematic map produced in Fig. 14 has shown that the groundwater potential of the project area is related mainly to slope, Land use/cover and drainage/flow density.

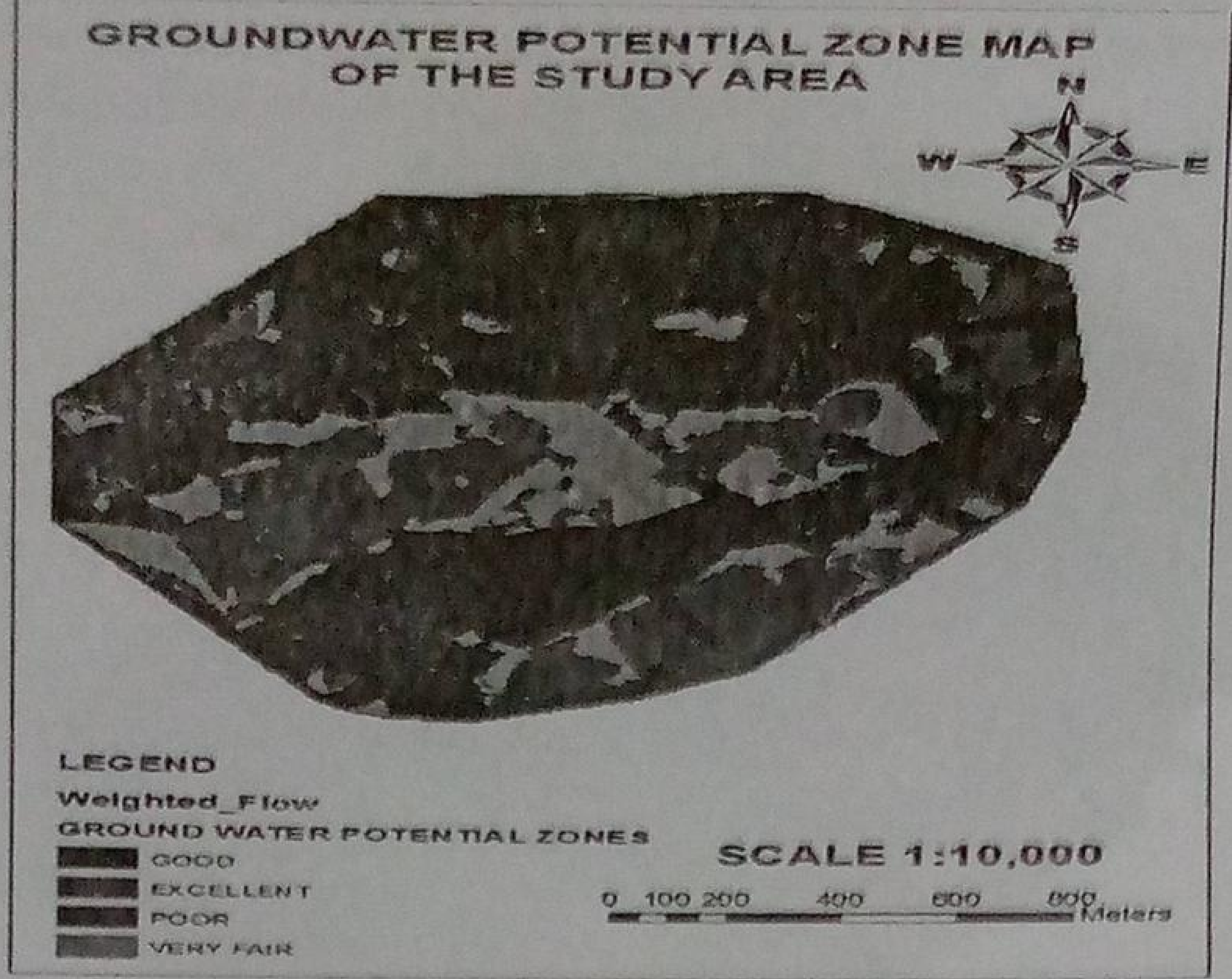

Fig. 14: The zone of groundwater potential of the study area analyzed on the bases of slope, Land use/cover, drainage/flow density and soil information.

Table 6: Zones of groundwater potential of the study area

S/No	Potential zones	Area (ha)	Area (%)
1	Excellent	6.17	6.92
2	Good	41.019	45.99
3	Very fair	39.0049	43.72
4	Poor	3.016	3.38

Ranking and Weighting Factors

In ARCGIS 10, zones of groundwater potential were derived by overlaying all the thematic maps as weighted overlay method using the spatial analysis tool. All the thematic maps were converted into raster format and superimposed by weighted overlay method. Slope and land cover/use were assigned higher weight, whereas the drainage density (flow) and climatic factor were assigned lower weight. The ranking was done for each sub-variable (Butler *et* al, 2002). The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. For slope, the highest rank was for gentle slope and low rank value to higher slope. The higher rank factors were assigned to low drainage density because the low drainage density factors favour more infiltration than surface runoff. Lower value followed by higher drainage density. Among the various lineament density classes, the very high lineament density category was assigned higher rank value as this category has greater chance for groundwater infiltration. Lower value was assigned for very low lineament density. In land use/cover, high rank was assigned to land occupied by building and low to drainage land. The overall analysis is tabulated in Table 7.

Table 7: Rank and weight for different factors of zones of groundwater potential

Factor	Classes	Groundwater potential	Weight (%)	Rank
Drainage flow (m/m^3)	1 – 2	Very poor		1
	4 – 8	Poor		2
	9 – 32	Very good	20	4
	64 – 128	Good		3
Slope classes	Nearly level (0.013^0 – 4.21^0)	Very good		4
	Gently sloping (4.21^0 – 12.87^0)	Good		3
	Moderately sloping(12.87^0 – 30.02^0)	Poor	30	3
	Strong sloping (30.02^0 – 60.74^0)	Very poor		1
Land use/ land cover (hectare)	Buildings	Very poor		4
	Roads	Poor		2
	Walk ways	Poor	30	2
	Drainage	Good		3
Aspect (Soil info)	-1	Good		3
	0 – 112.5	Very good		4
	112.5 – 247.5	Good	20	3
	247.5 – 360	Very poor		1

Validation of Result

The validity of the result obtained was tested against the borehole data collected using hand held Global Positioning System (GPS), where out of 13 (yield borehole) data collected from the study area two (2) fell on excellent zones, 7 on good zones, 3 on very fair and 2 on poor zones. Table 8 shows Borehole data from different parts of the project area. Figure 15 shows existing borehole distribution of zones of ground water potential over the entire area.

Table 8: Borehole (x, y coordinates) data from different parts of the project area

NO	EASTING	NORTHING	LOCATION	DEPTH (m)	DISTRIBUTION AREA(S)	CLASS
1	219976	1054696	ENGINEERING COMPLEX	57	4	ELECTRICALLY OPERATED
2	219651	1054652	SCHOOL CLINIC	57	2	ELECTRICALLY OPERATED
3	219981	1054877	CODEL (CIVIL LAB.)	73.77	4	ELECTRICALLY OPERATED
4	219928	1054991	CODEL 2 (CIVIL LAB.)	57	1	MANUAL
5	220250	1055046	OLD CAFETERIA	57	1	MANUAL
6	220288	1054895	ENVIRONMENTAL COMPLEX	16.77	3	ELECTRICALLY OPERATED
7	220386	1054879	FRONT OF SENATE CAR PARK	57	3	ELECTRICALLY OPERATED
8	220413	1054781	SENATE PRINCIPAL CAR PARK	57	1	ELECTRICALLY OPERATED
9	220434	1054661	FIRST BANK LT. AGRIC.	57	2	ELECTRICALLY OPERATED
10	220294	1054583	SCHOOL OF I.C.T	57	1	ELECTRICALLY OPERATED
11	220236	1054614	FUTMINNA/SNEPCO	57	1	ELECTRICALLY OPERATED
12	220139	1054639	COMMERCIAL COMPLEX	73.77	2	ELECTRICALLY OPERATED
13	219741	1054060	STAFF QUARTERS	57	1	ELECTRICALLY OPERATED

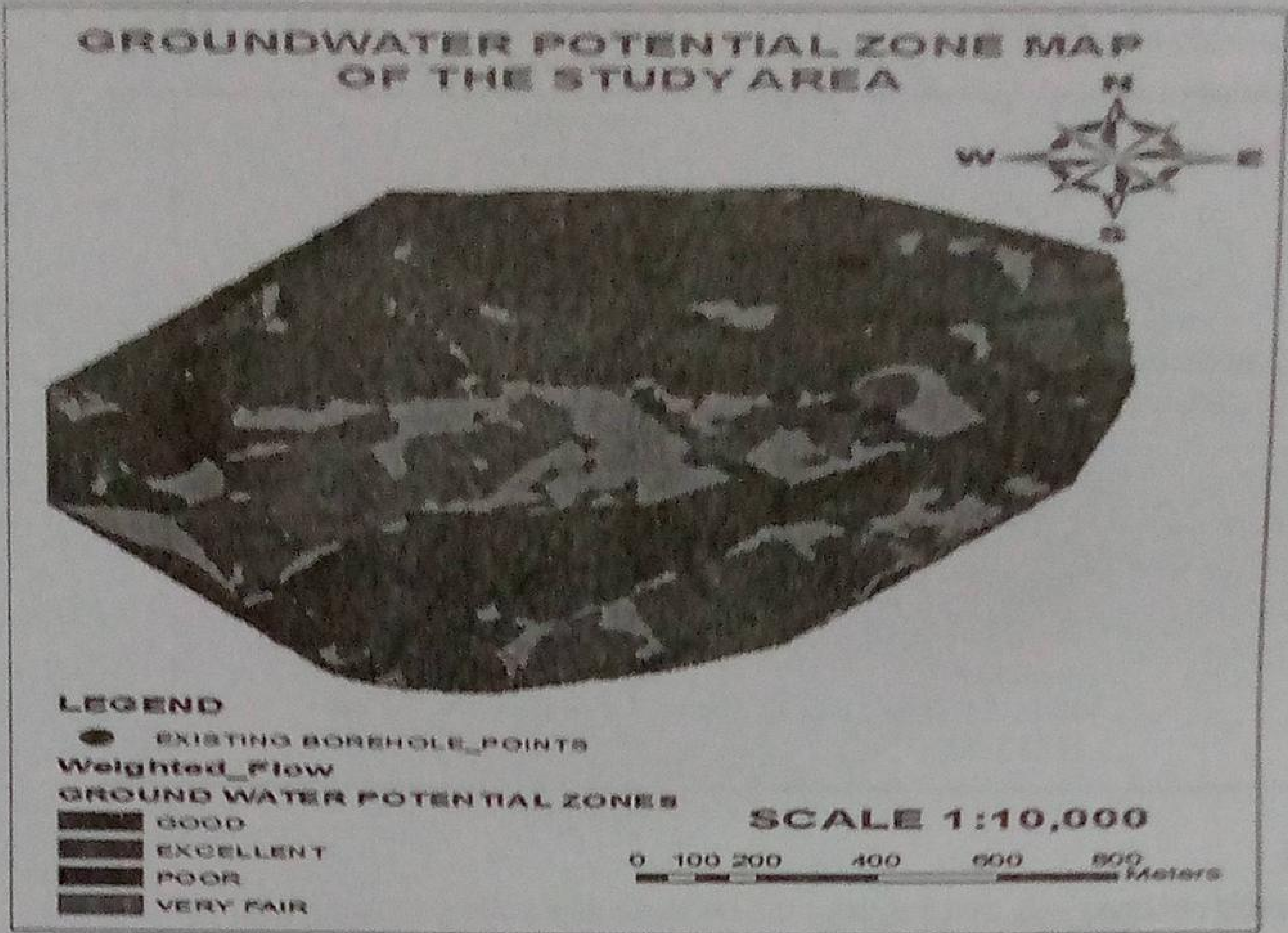

Fig. 15: Existing borehole distribution of zones of ground water potential over the entire area.

Out of 13 bore holes (with yield data); bore holes with yield between seven to nine are on the excellent and good zones which reflect the actual groundwater potential (see Fig..15).

Conclusions

Geographic Information System (GIS) and Remote Sensing technique is very constructive. All the thematic maps were converted into grid (raster format) and analyzed by weighted overlay method (rank and weighted thematic maps). From the results obtained, the zones of groundwater potential with excellence covers 6.17 ha, while good, very fair and poor zones of groundwater potential cover 41.02 ha, 39.01 ha and 3.01 ha respectively. Hence, prospective zones of groundwater were determined. Although, water exists in all zones of groundwater potential, hence, the best yielding boreholes lie in the excellent and good groundwater prospect zone. The areas with good groundwater prospects are attributed to contributions from combinations of the land use/cover, soil percolation rate, slope and landform. The low to poor categories of groundwater potential zones are spatially distributed mainly along ridges where slope class is at maximum, the lithology is massive and far from lineaments.

References

Binay K. and Uday K. (2011), Ground water recharge zonation mapping and modeling using Geomatics techniques, International Journal of Environmental Sciences, Volume 1, No 7.

Butler, M., Wallace, J., Lowe, M. (2002). Groundwater quality classification using GIS contouring methods for Cedar Valley, Iron County. Utah. In: Proceedings of Digital Mapping Techniques, Workshop, US Geological Survey Open-File Report 02–370.

Deepesh, M., Madan, K., Jha, B. C., (2011). Assessment of groundwater potential in a semi-arid region of india using Remote Sensing, GIS and MCDM techniques. Water Resource Manage 25:1359-1386.

Getachew A. (2007). Integration of Remote Sensing and GIS for Groundwater Resources Assessment in Moyale-Teltele Sub-basin, South Ethiopia.

http://www.fao.org/fileadmin/user_upload/drought/docs/Groundwater_potential_study.pdf

Kumar Dinesh P. K., Gopinath G., and Seralathan P., (2007) Application of Remote Sensing and GIS for the demarcation of groundwater potential zones of a river basin in Kerala, southwest coast of India. International Journal of Remote Sensing Vol.28Issue 24 pages 5583-5601. Taylor and Francis Inc. Bristol, PA, USA.

Murthy, K.S.R., Amminedu, E. and Venkateswara V. R., (2003) Integration of Thematic Maps Through GIS for Identification of Groundwater Potential Zones J Indian Soc Remote Sens,V.31,No.3.

Murugesan, B., Thirunavukkarasu, R., Senapathi, V., Balasubramanian, G. (2012) Application of Remote Sensing and GIS analysis for Groundwater Potential Zone in kodaikanal Taluka, South India". Earth Sci. 7(1): 65-75.

Prabir, M., Chander K. S., and Saumitra, M., (2011) Delineation of Groundwater Potential Zones in Arid Region of India, A Remote Sensing and GIS Approach". Water Resource Manage 26:2643–2672.

Principles and Application of Geographic Information Systems. 1st Series in Surveying and Geoinformatics. Soil Grouping of the Federal University of Technology, Minna, Main Campus

Yeh, H., Lee, C., and Hsu, K. (2009) GIS for the assessment of the Groundwater recharge Potential Zone. Journal of Environmental Geology Volume 58, Issue 1, pp 185–195. doi:10.1007/s00254-008-1504-9, Springer International Publishing.