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GEO-HYDROLOGICAL CONDITION OF THE UPPER CATCHMENT AREA OF THE KUMARI RIVER BASIN USING GEO-SPATIAL TECHNIQUES

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ABSTRACT

The study was conducted in the upper catchment area of the Kumari river basin. Geo-hydrology elaborates the mode of occurrence of subsurface water and helps to identify the suitable sites for recharge of groundwater. The main aim of the study was to identify the geo-hydrological condition of the upper catchment area of the Kumari river basin. The integrated geospatial techniques had been formed to be very efficient tools for the appraisal of geo-hydrological aspects of the area of study. Survey of India (SOI) topographic maps, IRS P6 satellite image (LISS IV MX), ASTER DEM (Provided by Ministry of Economy, Trade and Industry of Japan & National Aeronautics and Space Administration), georeferenced Geological map, well inventory and ground truth data were used to prepare various thematic maps such as slope, DEM, drainage order and density, lineament density, land use/ land cover, hydro-geomorphologic, groundwater depth in identifying the present geo-hydrological condition. The study revealed that the integration of all attributes made known to us the present geo-hydrological condition. And after the discussion, it was revealed that the area suffered from poor geo-hydrologic situation.

KEYWORDS: Geo-hydrology, GIS, Remote Sensing, Lineament Density.

I. INTRODUCTION

Geohydrology elaborates the character, source and mode of occurrence of subsurface water [1]. It also identifies the suitable sites of recharge of groundwater [1]. Geo-hydrological studies have also been used for different purposes, e.g. regional planning and resource management [2]. Geo-hydrological setup is the knowledge about the composition of rocks system with its hydrological characteristics. The upper catchment of the Kumari river basin is belongs to the Chhatonagpur gneissic complex and the sub basin of the Kangsabati (which ultimately falls under the Gangetic system) river basin.
Remote Sensing data are being increasingly used in geo-hydrological studies [3], [4], because of their utility and less error for identifying various ground features. And sometimes these features can be identified directly and sometimes indirectly, indicating the Geo-hydrological aspect [3]. The hydrogeologist usually deduces subsurface hydrological condition through surface indicators, such as aerial geological features (lithology), geomorphic features like topography, slope, alluvial fans, pediments, old stream channels, land use/land cover and the deep-seated interconnected fractures (lineaments density) are the indicators of subsurface water accumulation [5]. In recent decades' Geospatial technology known as efficient, sophisticated, cost effective and rapid tools [3], [6] in deciphering groundwater potentials zone as well as geo hydrological condition [3], [7]. Many researchers [2], [4], [8], [9], have used integrated remote sensing and GIS techniques for different geo-hydrological studies such as groundwater exploration, groundwater recharge sites, basin analysis and also for different hydrological investigation.

Chhotanagpur region is one of the water scare regions [10] in India and affected by drought [11] also falls underneath the low groundwater production prospect zone of West Bengal [12]. The chief endeavor of this paper was to get an idea of the geo-hydrological condition of the upper catchment of the Kumari river basin with the help of Remote Sensing and Geographic Information System.

II. STUDY AREA

The upper catchment of the Kumari river basin (a sub basin of the Kangsabati river) spreading over an area 833 sq. km, in the extreme western part of West Bengal (figure 1) and northern part of the East Singhbhum District of Jhrkhand. The present investigation of the study area had been carried out in an area by longitude 86˚ 9'42.46" E to 86˚ 31' 13. 68" E and latitude 22˚ 52' 13.7" N to 23˚ 14' 7. 83"N. Administratively the study area is spreading over the part of Baghmundi Block (south eastern part of Ajodhya G. P.), part of Purulia I Block (Chakaltor Gram Panchayat (G. P.), Manara G. P.), part of Manbazar Block (Kamta Jangidiri G. P., Bamni Majhiri G. P.) and whole Balarampur Block, Barabazar Block. And part of Patamda, Boram block in East Singhbhum District. The perimeter of the upper catchment is 157 km. Kumari river originates from Ajodhya hill and going through eastward direction and gets many small tributaries like Hanumata (tributary Amruhasa Nala), Nangasai (Chota Nangasai & Bura Nangasai), Sona, Jore etc. Individually Kumari River has long 57km (up to upper catchment). Upper catchment bounded by the Ajodhya hill in the western side, Kasai River and their tributaries in northern side, lower catchment of the Kumari river in eastern side, and Dalma hill in south side. The area has been experienced by many tectonic activities and different typical geomorphic process [8], [13]. The area is a part of the southeastern flank of Chhotanagpur plateau, which is developed in the Archean age [14]. Geologically the area has been formed off Chhotanagpur Gneissic Complex in Archean age [8], [13], [14]. The area composed of igneous and metamorphic rock, namely granite, migmatite, composite gneiss [13]. And Geo-morphologically the area is an erosional landform with full of residual hills [13]. Most of the erosional landforms and undulating plain are the proof of erosional process [14]. During dry season this region suffers from acute water scarcity and there is long queue in front of every source of drinking water (figure 2).

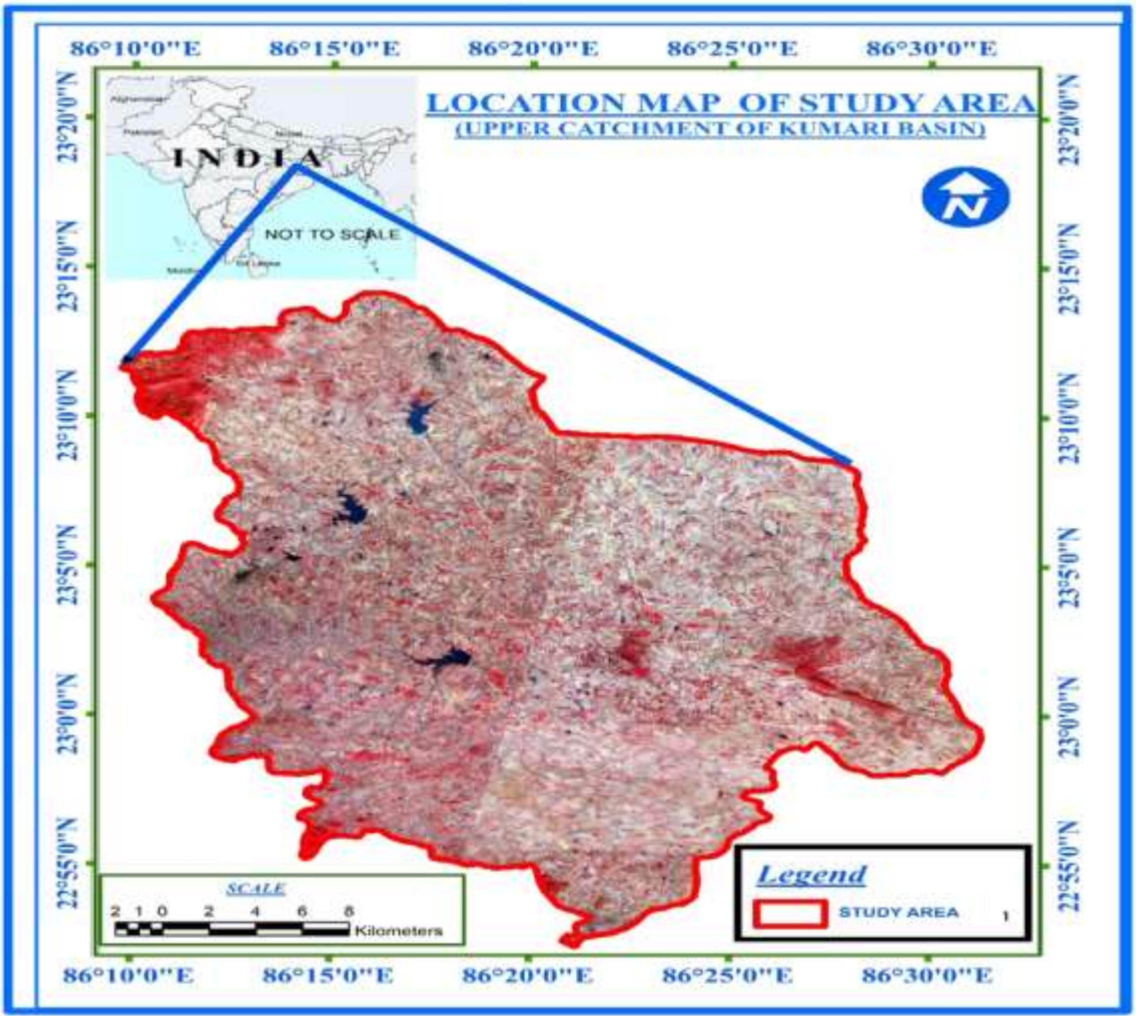

Figure 1: Map Showing the Study Area.

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Figure 2: Long queue for drinking water near Namsol, Balarampur

III. MATERIALS AND METHODS

For the fulfilment of present study, following data were used by us (Table 1):

Table 1: Data Source

Data	Source	Year
Topographical maps (Sheet no. 73 I/4, I/8, I/12 and 73 J/1, J/5, J/9) 1:50,000	Survey of India (SOI)	1977 & 2011
ASTER DEM (ASTGTM2_N23E086_dem.tif & ASTGTM2_N22E086_dem.tif)	USGS (METI & NASA)	20th JAN, 2016
Geological Map (Purulia and Singhbhum)	Geological Survey of India (GSI)	2001, 2006
Collected Data	Field Collection data at the time of study	2015-16
LISS IV MX	NRSC/ISRO	2007-08

The based map of the study area of the Kumari River Basin had been extracted from Survey of India (SOI) topographic maps based on 1:50,000 scales, georeferenced Geological map and Advance Space Thermal Emission and Radiometer (ASTER) DEM (ASTGTM2_N23E086_dem.tif & ASTGTM2_N22E086_dem.tif) used for lithological and hydrological analysis. The ASTER DEM (ASTER DEM is a product of METI and NASA) data were downloaded from the USGS's website. Other thematic map extracted from the LISS IV MX image which was provided by NRSC/ISRO. All thematic maps had been prepared in GIS environment (WGS-84, UTM zone 45N) with the help of Arc-GIS 10.2.1.

IV. RESULTS AND DISCUSSION

1. Drainage Network and Density

Analysis of drainage network and density of drainage is paramount importance for geo-hydrological studies. Drainage pattern and density of a region depend on various factors viz. climate, landforms, slopes, stages of geomorphic cycle, lithology, soil permeability, etc. Density of drainage indicates surface materials and nearness of channel. Exposed bedrock also leads to upsurge the surface runoff, therefore more frequent channel.
More drainage density indicates that low soil permeability or higher would be runoff. Drainage pattern shows the figure 3 (extracted from SOI topographical map and updated from LISS IV MX image) were dendritic and radial. Upper catchment of Kumari river has seventh order. where drainage density (figure 4) was 1.425985 km/sq. km. (calculated in GIS software) which was quiet higher and also indicated that the runoff would be higher. Top north west part of the study area had been higher density (range between from 2.718335425 km/sq. km to 4.530542374 km/sq. km). Maximum part of the study area had moderate to lower density (2.718325424 km/sq. km to 0.906108475 km/sq. km). Few parts of the study area had very low density (less than 0.906108475 km/sq. km).

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Those results were indicated poor geo-hydrological condition.

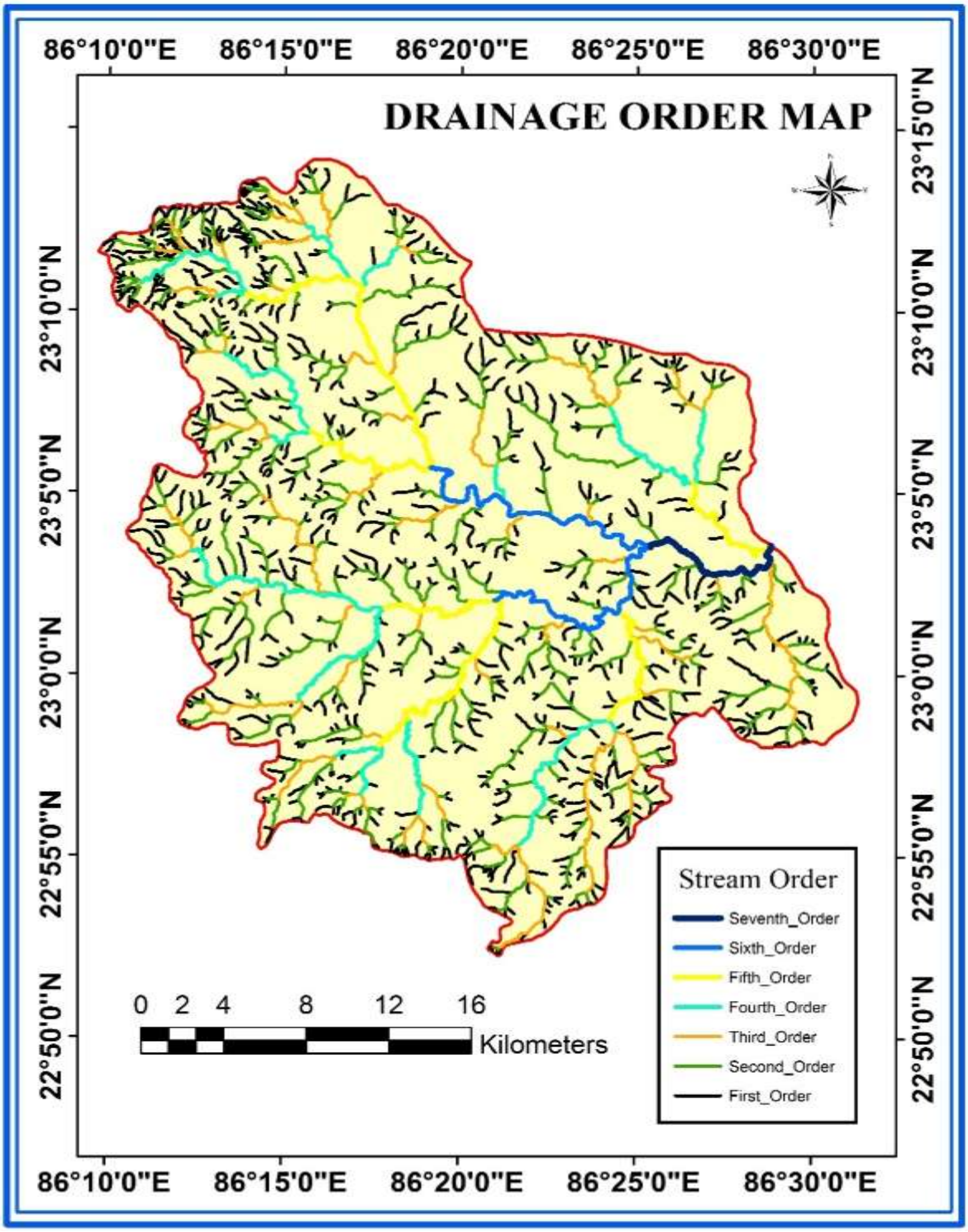

Figure 3: Stream Order Map of the study area.

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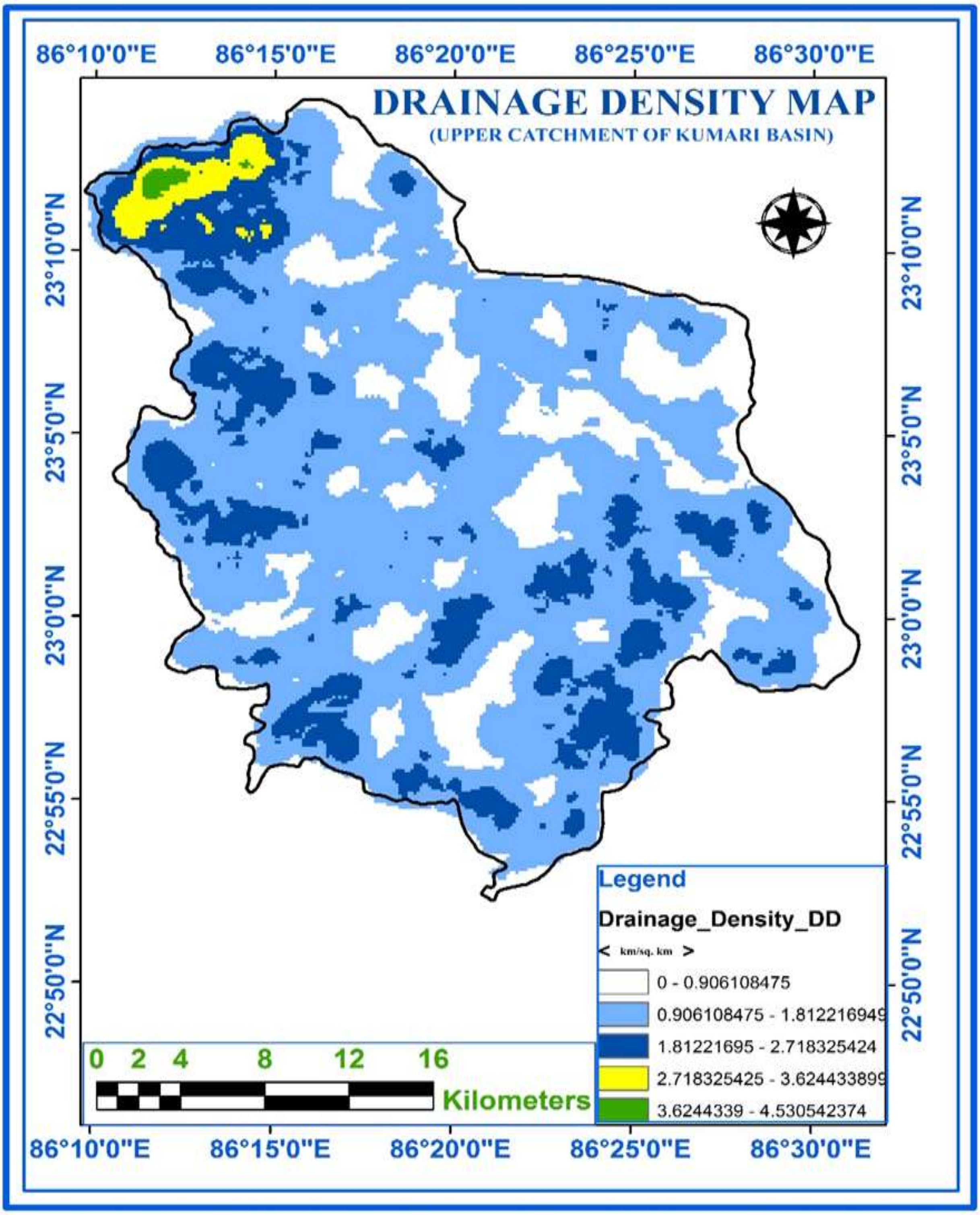

Figure 4: Drainage Density Map of the study area.

2. Slope Analysis

The slope is most significant factors for the geo-hydrological studies. It has leading influence on channel flow and recharge to groundwater, also controls spell of surface and underground flow. Equable slope has been permitted to low runoff and sufficient time for rainwater to infiltrate into the subsoil, whereas the steeper slope is provoked to high runoff, therefore less residence time for rainwater for infiltration into subsoil; for that reason, infiltration is less.

Surface slope < 2º is considered as plain area which are usually a good recharge zone because of low runoff due to the residence time of rainwater for infiltration is more [12]. In the present study we had seen that the area had less plain or equable because most of the area more than 2º and sometimes it was over the 5º slope (figure 5). In the basin area, direction of slope frequently changed due to undulating slope. For this reason, frequency of channel was huge. And overall direction of slope was to northwest to southeast (figure 6). These higher degree of slope and frequently changed their direction indicates huge frequency of channel as well as low permeability, therefore subsurface water situation was poor, which indirectly indicated bad geo-hydrological condition.

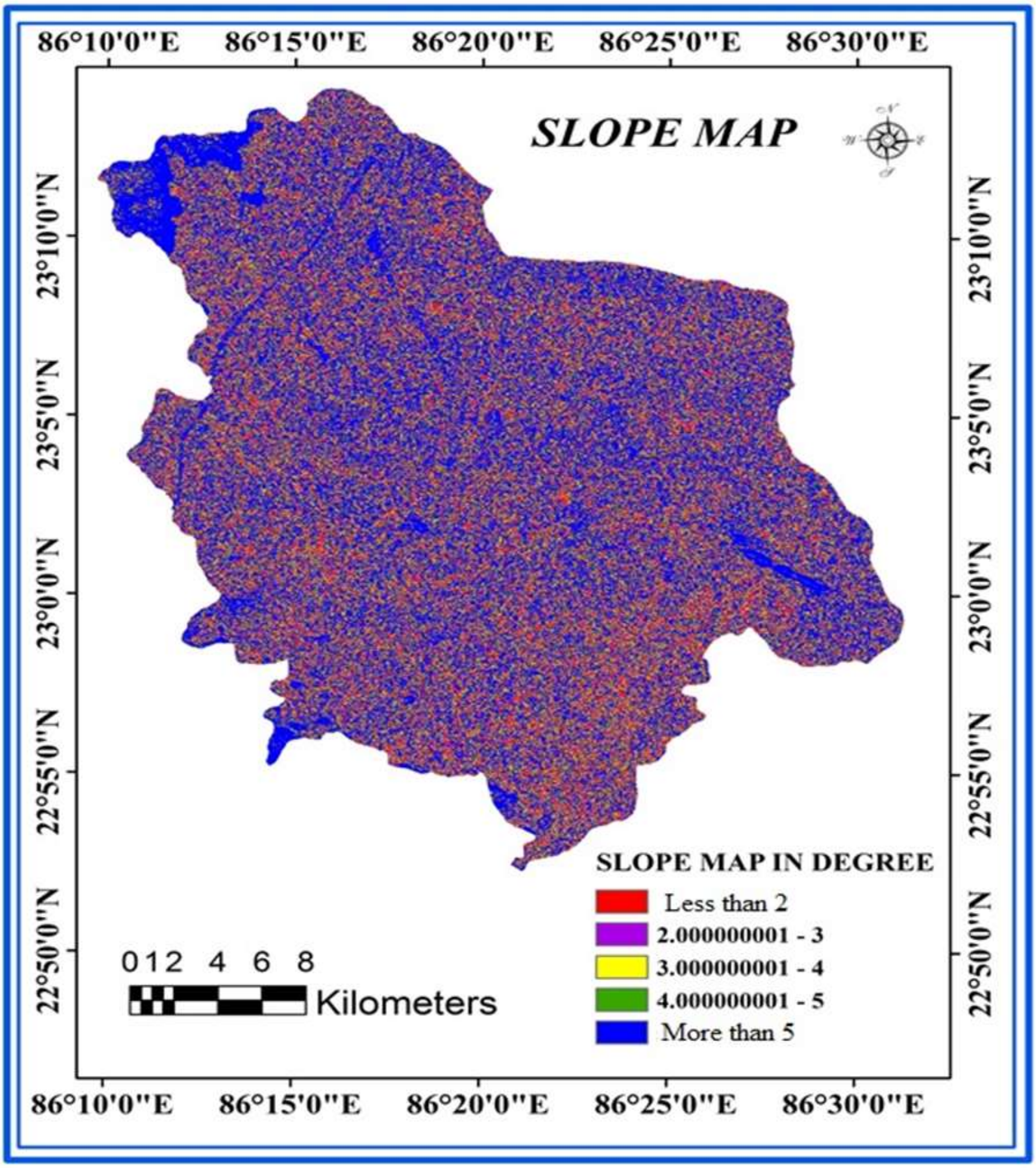

Figure 5: Slope Map of the study area.

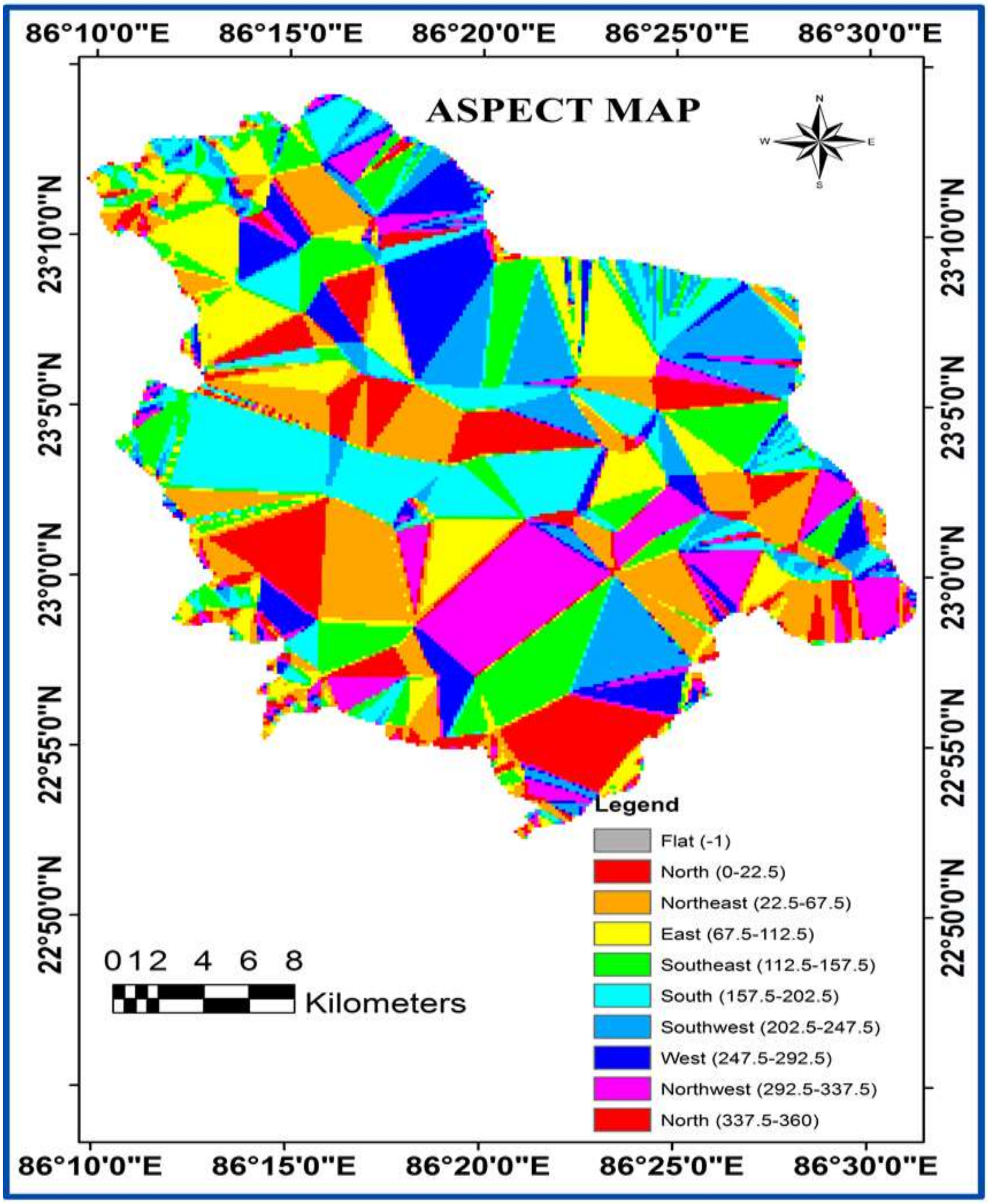

Figure 6: Aspect Map of the study area.

3. DEM

Digital elevation model (DEM) is now a reliable and day by day becoming a popular tool in hydrological analysis [15]. It has been used both in research applications and resources management [15]. DEM has been acting as relief analysis, and supporting acts as slope analysis. Here DEM had been generated from ASTER data. Elevation of the study area was roughly marked in different colors. It was noticed that the upper catchment area of the basin is highly asymmetric, because maximum elevation 655 meters was situated on the top north west side of the study area and minimum elevation less than 224 meters (figure 7). This elevated land surface was very much undulating and Kumari basin based upon the hard rock terrain, for that reason groundwater replenishment was less which indicates geo-hydrological condition not favorable.

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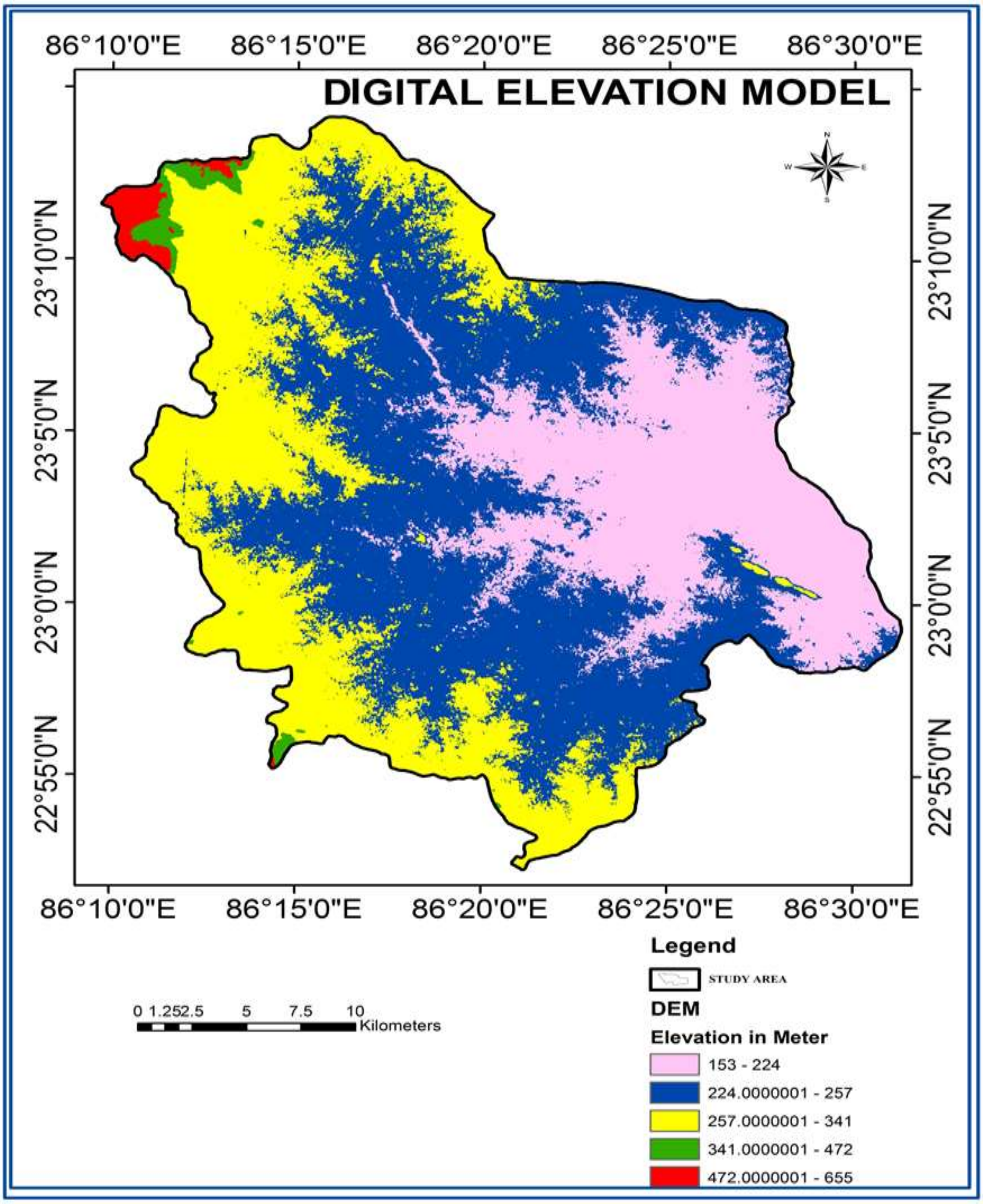

Figure 7: Digital elevation model of the study area.

4. Flow Accumulation

In the geo-hydrological studies flow accumulation has strong relation with groundwater [16]. It is closely related with slope where the bottoms of slopes have been accumulated much more moisture than ridgetops.

The flow accumulation map showed (figure 8) high value of accumulation in narrow valley which indicates most of the part of having high runoff. As the area was based on hard rock terrain and flow accumulated in a narrow valley, consequently all rainwater got washed away in a short period of time. And these circumstances indicated the deprived situation of geo-hydrology.

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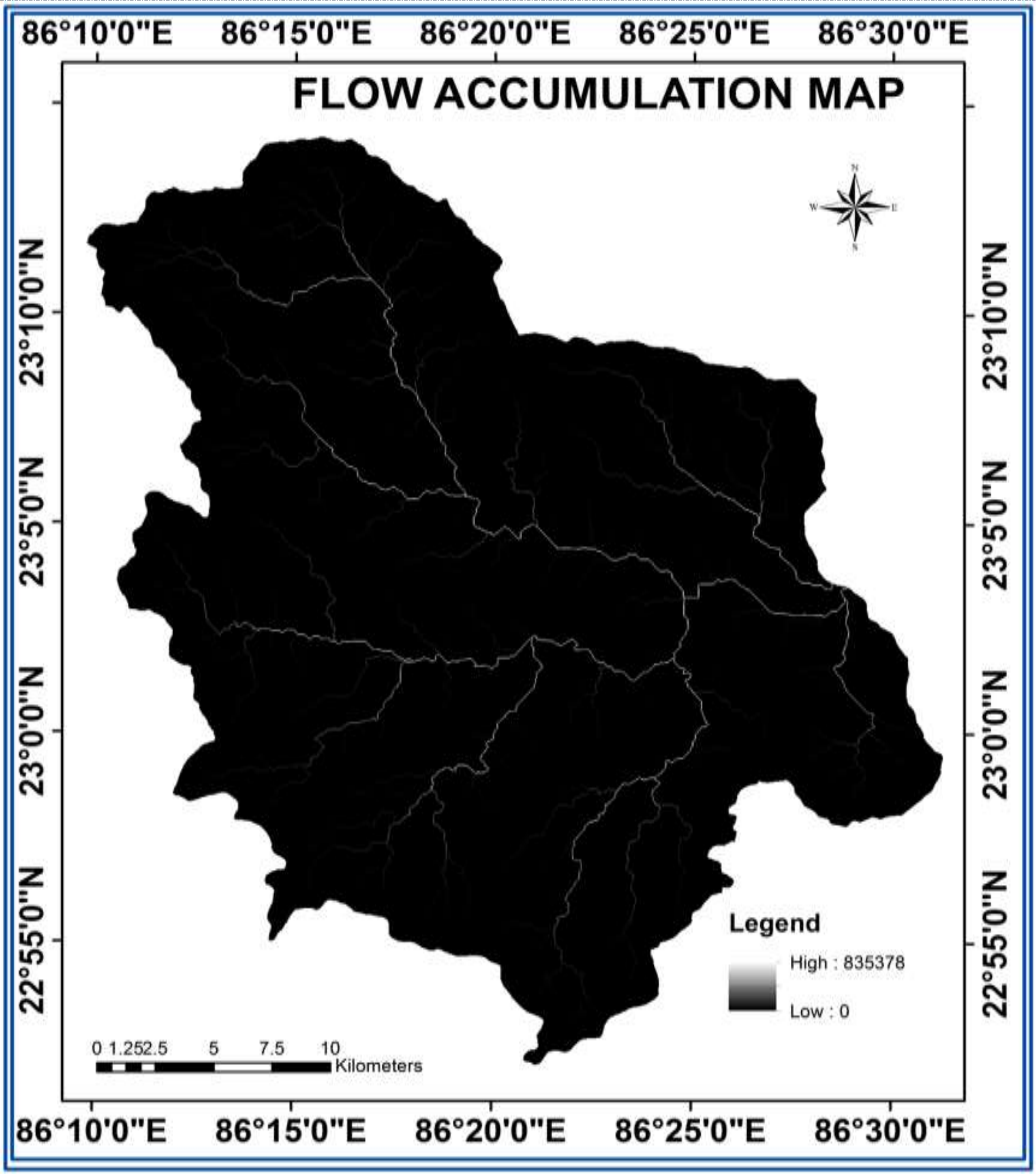

Figure 8: Flow Accumulation Map of the study area.

5. Lithology

Lithology is the most significant factor of the study of geo-hydrology. Especially lithology informs the groundwater condition (movement and storage condition) of the study area and other influencing factors such as lineament and drainage depend on it [12]. In general, lithological map had been updated with the help of the lithological map (which from GSI), IRS P6 satellite LISS-IV MX image (which from ISRO/NRSC) and ground truth observation. On the north side of study area huge exposure of Chatonagpur granite gneiss (figure 9) rock and south side of the study area was under Singhbhum group of rocks, covering with mica schist and phyllite which were Proterozoic age [13]. In the study area groundwater normally stored into weathered and fractured unweather rocks [12] zone which differed from 4 meters to 16 meters [12]. Northern part of the study area had some deposition of alluvium, for that reason lithologically that area was suitable for groundwater recharge. Sothern part of study area was mainly covered by phyllite and mica schist (figure 10). Mica schist being more week planes [12], was efficient to develop secondary porosity. These lithological situations were indicated the pitiable condition of geo-hydrology.

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The study area has less part covered by semi consolidated sediments and massive part covered by granites, gneiss, and mica schist. For that reason, aquifers are shallow, unconfined, moderate to low yielding (**table 2**) and groundwater prospects were also moderate to poor.

Figure 9: Basement of study area made up of granite and Gneiss (Field Photo-Near Balarampur)

Table 2: Stratigraphic succession and geohydrology of the study area. (adopted from: [17] Haldar and Saha, 2015)

Formation and Unit	**Age**	**Lithology**	**Geohydrology**
Alluvium	Recent	Semi consolidated sediments consisting of conglomerates, lateritic and gravel beds	Aquifer is shallow and unconfined. Yield is 5000 to 7000 lph
Quartzite and Pegmatite, Granite	Pre- Cambrian	Massive Granites and pegmatite and quartzite veins	Secondary aquifer developed at the capping and on the weathered resideum. Cracks and fissures developed in the rocks act as a minor store of groundwater. Aquifer is shallow and unconfined. Yield is 500, to 700 lph
Phyllite and Mica Schiest	Archean	Rock types belong to Chhotanagpur gneissic complex. Granite gneiss with quartz veins and pegmatite veins. Muscovite and biotiteschiest, highly foliated	Secondary aquifer developed at the capping and on the weathered resideum. Cracks and fissures developed in the rocks act as a minor store of ground water. Aquifer is shallow and unconfined. Yield is 500, to 7000 lph
Granite-gneiss			
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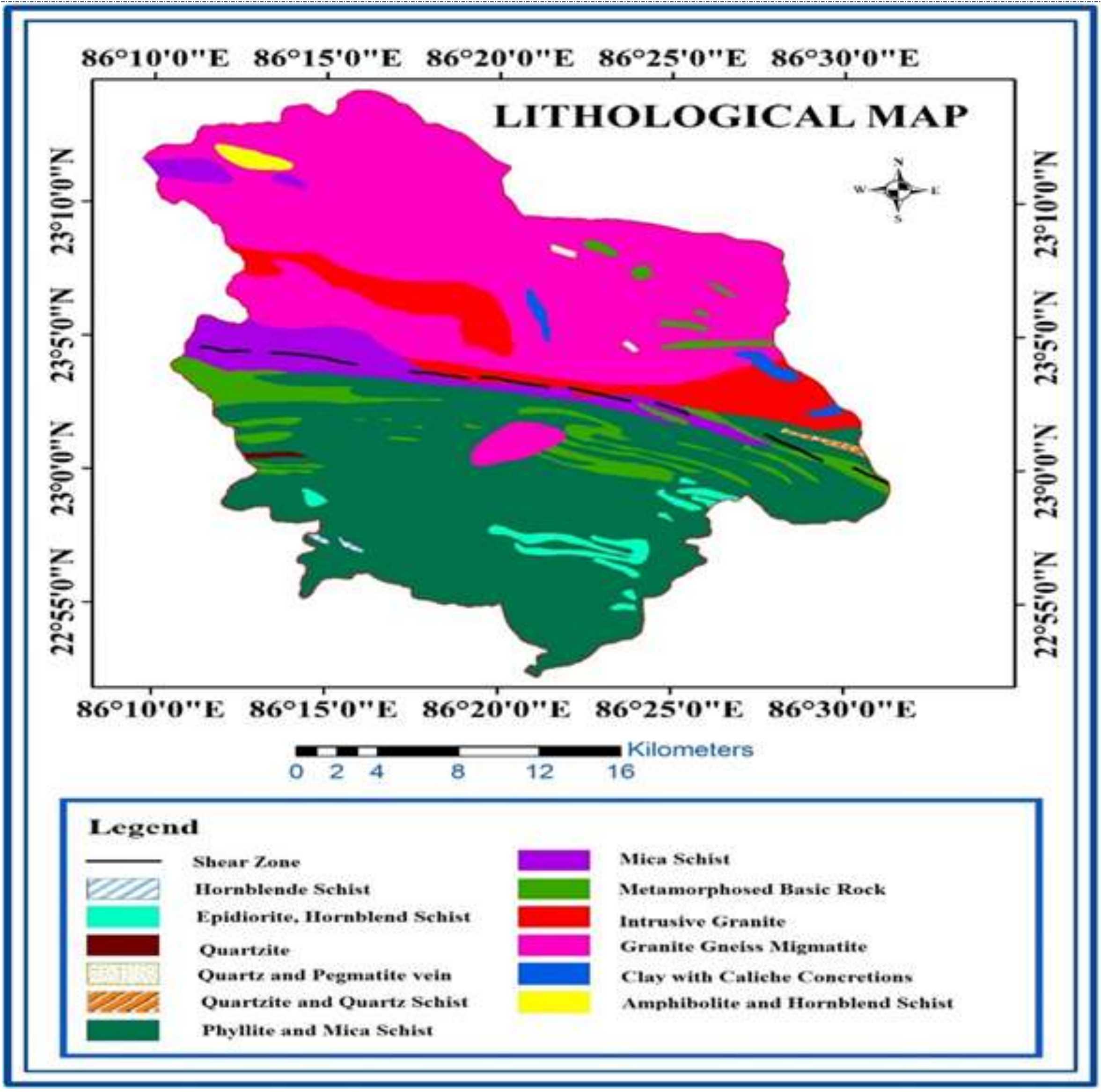

Figure 10: Lithological Map of the study area (Source: Geological Map, GSI).

6. Lineament

Lineaments are paramount importance for hydrogeological studies [12] and the identification of lineaments has gigantic importance in hard rock hydrogeology as they can detect rock fractures that localize groundwater [5]. Lineament is a linear feature, or curvilinear feature which is an expression of an underlying geological structure. Lineament denotes the zone of faulting and fracturing resulting in augmented secondary porosity and permeability [18]. Lineaments make the availability of the pathways for subsurface water movement [19] for this reason, lineament analysis is an important for geo-hydrological studies. Some researchers find out that connectivity of lineaments is only an indicative phenomenon which deals the transportation of groundwater and those connected lineaments provide an underground route for groundwater flow [20], while other researchers give importance only to the length and density of lineaments [12], [21], [22]. Here we had used second thought, because the lineament density of an area had divulged the groundwater potential, in the meantime the presence of lineament usually denoted a permeable zone [18].

Here in this study, lineaments were identified from the consultation with satellite imageries and topographical sheets by observing linear and straight alignments. Areas with high lineament concentrations were good for groundwater potential zones [18]. In the study area, it revealed that the high lineament density was observed in the western part and south western part and it was greater than 0.99 km/sq. km (figure 11). But overall analysis of lineament density revealed poor geo-hydrological condition.

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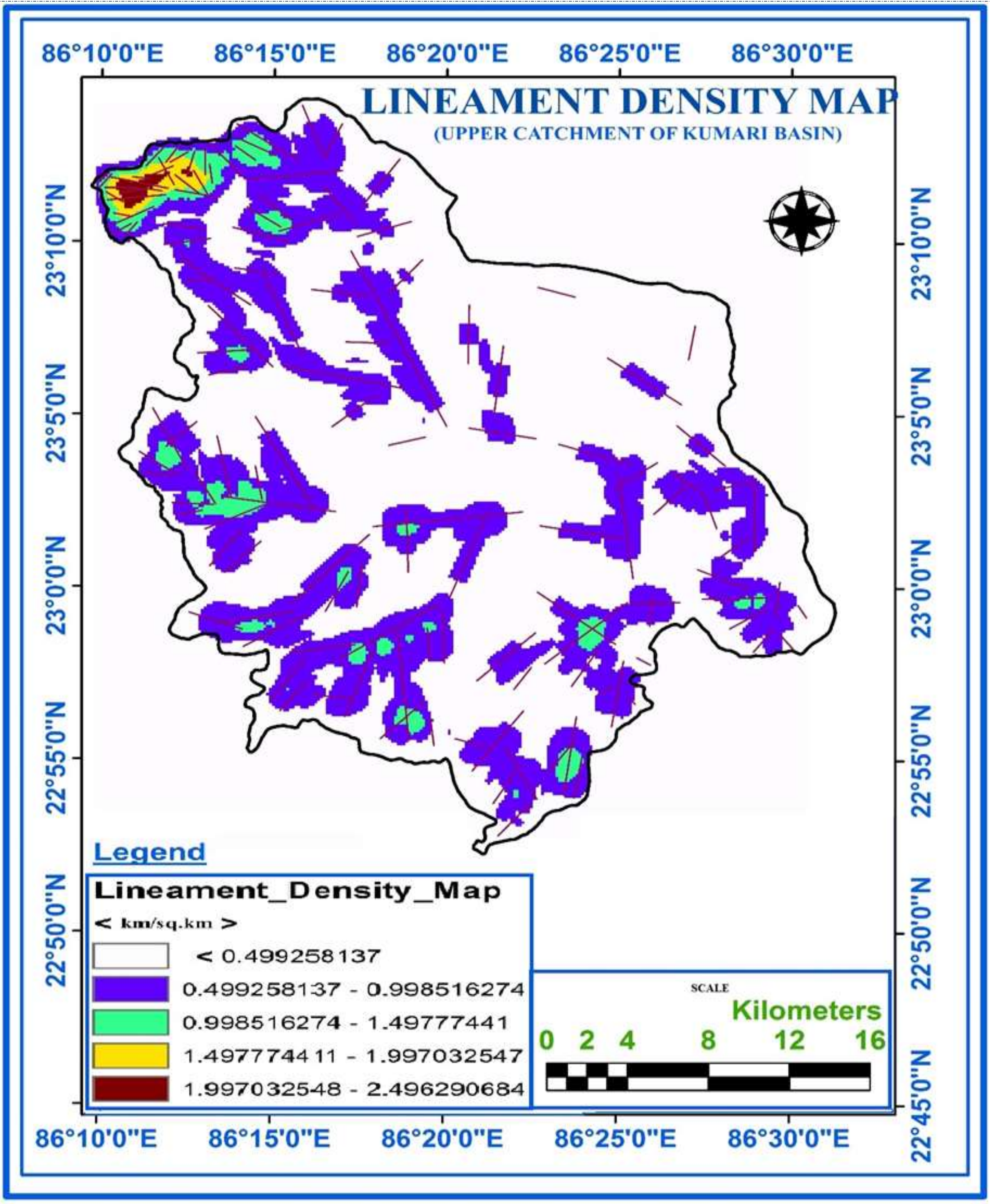

Figure 11: Lineament Density Map of the study area.

7. Hydro-geomorphology

River basin is a fundamental geomorphic unit and hydro-geomorphic character is very important for geo-hydrological studies [7]. Hydro-geomorphology of an area valuable, important parameter to evaluate groundwater potential and the prospect zone [3] and hydro-geomorphological unit provide us a general idea of the condition of geo-hydrology. Remotely sense data have been provided an opportunity to better observational and more analytic for various hydro geomorphological units and geologic parameter in this study area. These units and parameter help to preparing integrated hydro-geomorphological maps for geo-hydrological studies.

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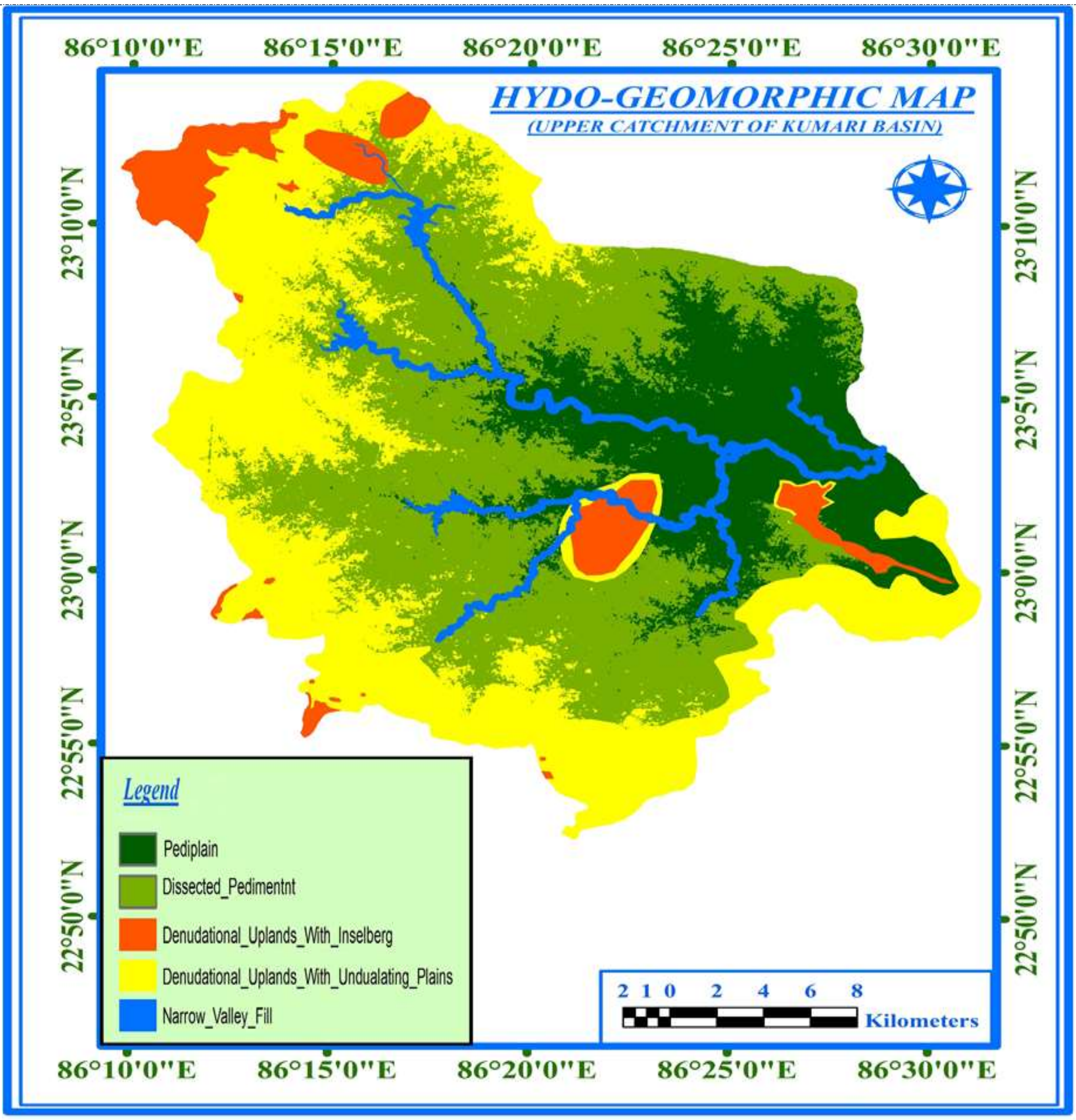

Figure 12: Hydro-Geomorphic Map of the study area.

Table 3: Hydro-geomorphic characteristics and ground water prospects.

Hydro-geomorphic units	Characteristics	Groundwater Prospects
Denudational uplands with Inselberg	Isolated hill with major uplands. Steep to moderately steep slope. Rocky surface, runoff high,	Poor
Denudation uplands with undulating plain	Undulating uplands with the little plain area. Shallow coarse textured soil and weathered rock.	Poor to Moderate
Pediments	Dissected topography, near gentle slope, loamy soil with regolith.	Poor to Moderate
Pediplain	Gentle slope nearly flat, soil moderately thick with weathered material.	Moderate
Narrow valley fills	Alluvial materials consist of pebbles, silt, gravels and sand deposited along the valley	Moderate to good

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Hydro-geomorphic units (table 3) were verified during field visit, and then the hydro-geomorphic map was prepared (figure 12). As per as the area covered by hard rock terrain was concern hydro-geomorphology was extremely influenced by lithology and structure. Justifying the all Hydro-geomorphological units we found that present geo-hydrological condition was simply bad.

8. Landuse / Landcover

In the studies of geo-hydrology, landuse /land cover is a significant parameter because landuse/ land cover mirrors of complex physical processes which are acting upon the surface of the earth [7]. Physical processes and impact of climate, lithological, topographic condition on the distribution of soil, vegetation and occurrence of water. Land use /land cover significantly affects on groundwater recharge process [20]. Remote sensing and GIS technique have been provided as dependable basic information about land use/ land cover [12].

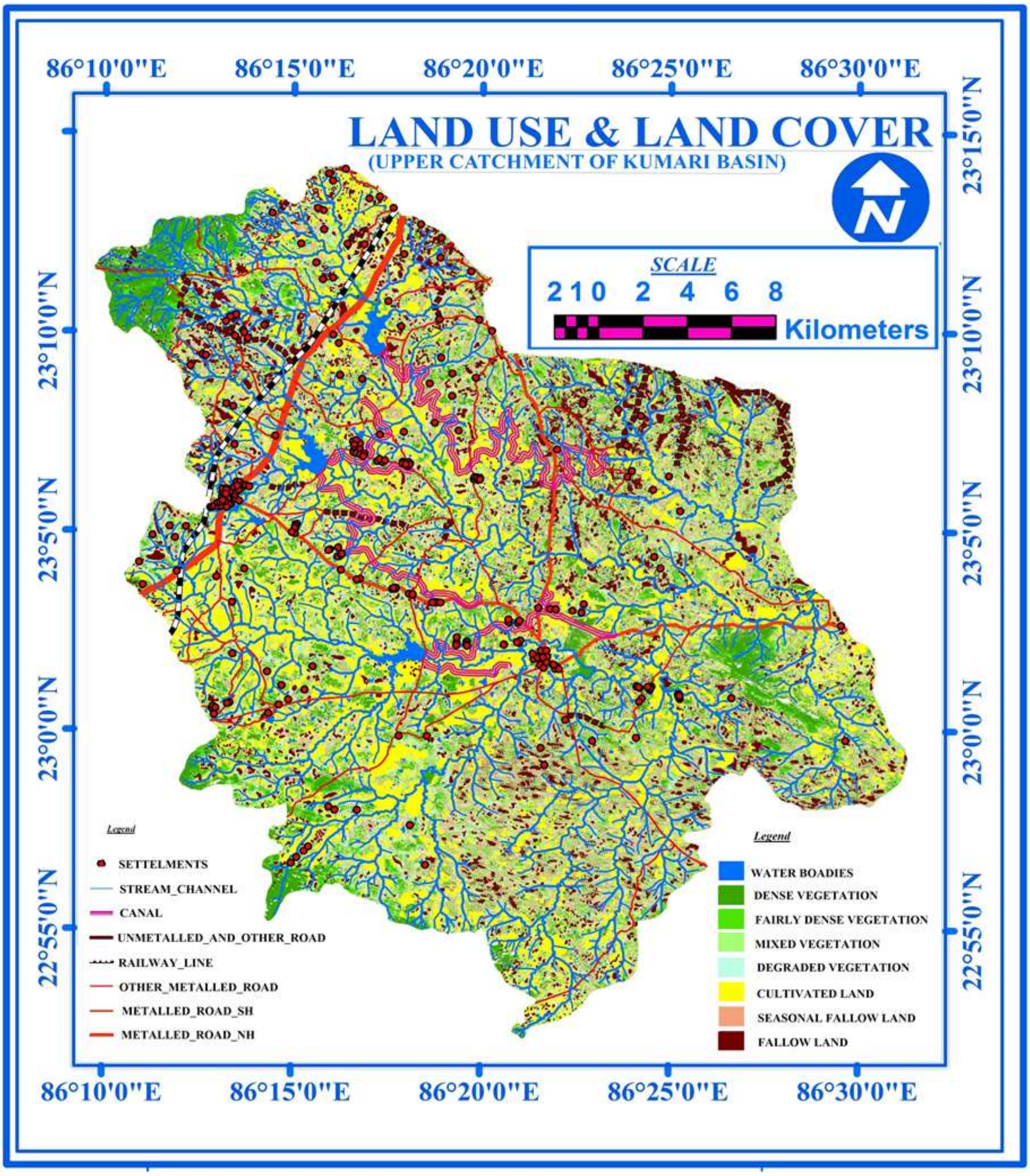

Figure 13: Land use / Land Cover Map of the study area.

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In the preparation of land use /land cover map and the generation of all set of data regarding land use/ land cover, we used IRS P6 LISS IV images followed by intense field verification. Anthropogenic construction, such as building, roads, concrete embankments etc. reduced the rate of water percolation. While, it was assumed that the vegetation cover had a significant role in the augmentation of recharge rate. Requirement of the present study, some major factors and some substandard factors were also encountered (figure 13). Some of major factors (where geo-hydrological condition is good) were water bodies, stream channel, dense vegetation, dense mixed vegetation, cultivated land and some substandard factors (where geo-hydrological condition was not good) degraded vegetation, seasonal fallow land, fallow land, national highways, state highways, other road, settlement area.

9 Groundwater Scenario

Presence and movement of groundwater depend upon various things like rock formation, topography, slope and

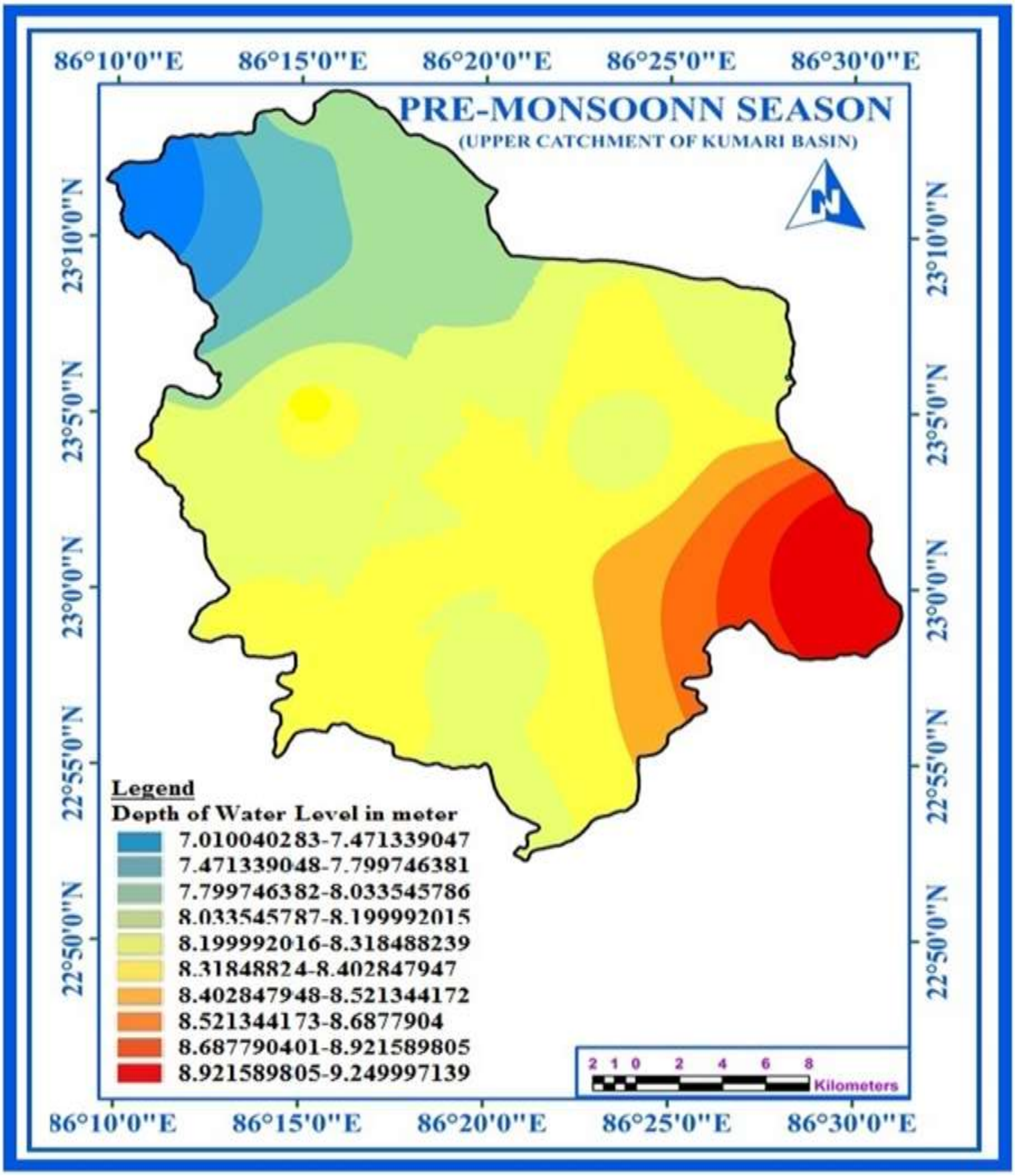

Figure 14 (a): Map showing the groundwater condition in pre monsoon season (source-field data).

also hydro-geological properties of water bearing materials [23]. Based on the field visit data on open dug well in the groundwater scenario in this study area was drastically changed from pre monsoon to post monsoon. During pre-monsoon water level depth lower in north western part where depth was less than 8 meter and high depth was found in south eastern part more than 8 meter (figure 14 a) while post monsoon groundwater depth was lower in north eastern and middle part of study area and it was 3 meter to 5 meter and south eastern and remaining eastern part was much higher and it was more than 5 meter (figure 14 b).

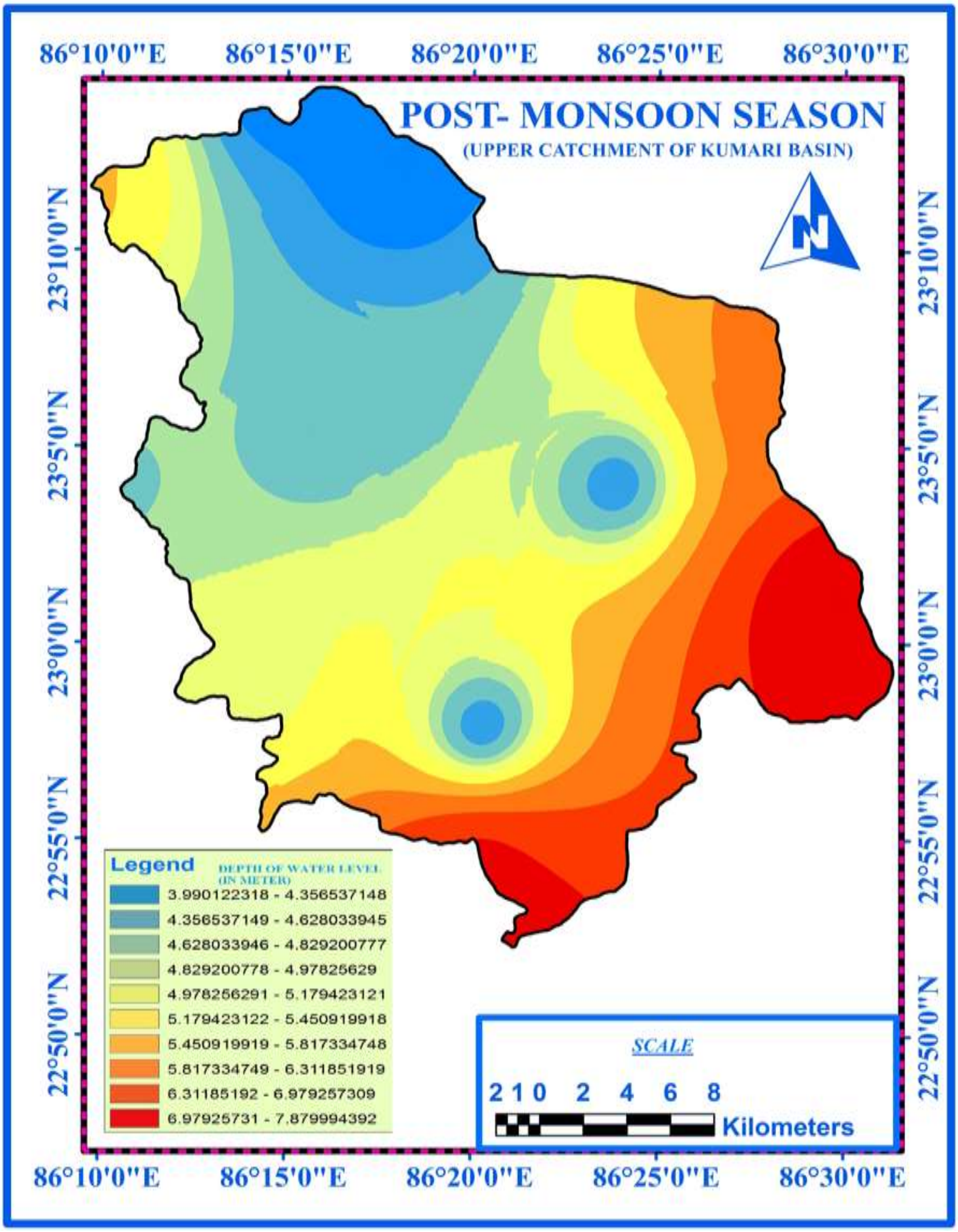

Figure 14 (b): Map showing the groundwater condition during the post monsoon season (source- field data).

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V. CONCLUSION

Remote sensing data and GIS technique have been integrated for use in creation of various thematic maps, which play a major role for the knowing of the present geo-hydrological condition. Individually all the parameters have been analysed and it reveals that present geo-hydrological condition is poor. Different thematic maps thus deciphered, could be useful for various sustainable development schemes. From above result and discussion, it is suggested that suitable rainwater harvesting as well as artificially replenishment of groundwater should be implemented for betterment of geo-hydrological condition.

VI. ACKNOWLEDGEMENTS

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