© 2017 IJSRST | Volume 3 | Issue 7 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Identification of Groundwater Potential Zone in Vaippar Basin, Tamil Nadu through Remote Sensing and GIS Techniques

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ABSTRACT

The study aims to delineate the Groundwater Potential Zones (GPZ) of Vaippar Basin. Groundwater potential zone identification can be done using advanced as well as recently developed geospatial technology such as Remote Sensing and GIS. The groundwater potential zone analysis done by using spatial layers like geology, geomorphology, rainfall, lineament, land use/land cover, drainage density, soil texture, soil depth etc. Suitable weightage and ranks are assigned to these layers based on its influence on groundwater occurrence. The weighted layers are integrated in GIS Environment and which demarcates the actual zones of groundwater potential zones. These results can be helpful for identifying intensity of groundwater potential zone. Groundwater Potential Zone Index (GWPI) in this index calculated the area of all these using thematic layers. This index mentioned about the spatial layer coverage area and percentages area in sq.km of Vaippar basin. Groundwater potential zones are divided into four zones such as very high, high, low, and very low.

Keywords : Groundwater Potential Zones, Geographical Information System, Remote Sensing, Weightage and Ranking.

I. INTRODUCTION

Groundwater is important and basic need in the daily life. The groundwater resources are being utilized for drinking, irrigation and industrial purposes. Groundwater, which is in aquifers below the surface of the Earth, is one of the nation's most important natural resources. Groundwater is the source of about 33 percent of the water that country and city water departments supply to households and businesses. It provides drinking water for more than 90 percent of population. Groundwater is one of the major sources of water, which is stored beneath the ground as well as within space of the soil and rock. It is an essential and basic need for survival of every life on earth. Various uses of fresh water for drinking, cleaning, agriculture and so on. Groundwater provides fresh source of water as compared to oceans, rivers and lakes. Groundwater is also one of the dynamic sources of water than any other sources of water. Groundwater resources are an important natural resource for its use in domestic, agriculture, and industries purposes.

Identification of groundwater potential zone serves the present need in the increasing water scarcity in urban and rural regions. In the earlier stage Groundwater Potential zone is achieved by surveys. remote sensing and GIS techniques in the recent times help in precise identification of groundwater through analysing the various parameters. There has been a tremendous increase in the demand for groundwater due to increase in population, advanced irrigation practices and industrial usages (Ramamoorthy and Rammohan 2015, Ramamoorthy et al. 2015). Integration of the information on the controlling parameters has achieved through GIS, which is an effective tool for storage, management and retrieval of spatial and non-spatial data as well as for integration and analysis of this information for meaningful solutions. The techniques of integration of remote sensing and GIS have proved to be extremely useful for groundwater studies (Saraf, et al. 1998, Sankar 2002, Biswas et al 2012).

Remote Sensing and GIS techniques are useful for the actual demarcation of the groundwater potential zones. The water resources condition of a river basin depends mainly upon the physical parameters of climate, geomorphic and geological condition. (Kumaraswamy et al. 1994). Spatial analysis process helps for correlating various parameters such as geology, geomorphology, mean annual rainfall, lineament density, land use/land cover, drainage density, soil texture, soil depth etc. All these parameters are playing an important role to find out groundwater potential zones with weightage overlay analysis. To estimate the groundwater occurrence, there are different kinds of methodology in which devised, for past few decades Remote Sensing (RS) and Geographical Information Systems (GIS) can be considered as an essential tools in groundwater potential zone estimation (Balasubramani et al. 2011). Identification the groundwater potential zone in Vaippar basin, Tamil Nadu, India through the use of remote sensing and GIS techniques has been attempted in the present study.

In the past, several researchers (from India and abroad) have used remote sensing and GIS techniques for the delineation of groundwater potential zones with successful results (Karanth and Seshu Babu 1978, Saraf and Jain 1993, Chi and Lee 1994, Krishnamurthy and Srinivas 1995, Kamaraju et al. 1995, Krishnamurthy et al. 1996, Sander et al. 1996, Khan and Mohd 1997, Ravindran 1997, Edet et al. 1998, Saraf and Choudhury 1998, Kumar 1999, Krishnamurthy et al. 2000, Shahid et al. 2000, Khan and Moharana 2002, Jaiswal et al. 2003, Rao and Jugran 2003, Sikdar et al. 2004, Sener et al. 2005, Ravi Shankar and Mohan 2006, Solomon and Quiel2006, Chowdhury et al. 2009).

STUDY AREA

The Vaippar Basin is located in southern part of Tamil Nadu, India. The Vaippar basin lies (8º 58' to 9º 45' N to77º 1' to 78º 15' E) with an area 5339 sq.km. This basin has variation in the climatic as well as physiographic aspects such as soil texture, soil depth, rainfall, land use/land cover. Vaippar basin covers parts of Virudhunagar, Thoothukudi, Madurai and Tirunelveli districts of Tamil Nadu. On the basis of physiography the basin can be divided into two broad sections, namely the hilly tracks with altitude above 100 meters and the vast stretch of black cotton soil plains. The basin is located on the eastern side of the Western Ghats. Though the basin extends up to the Bay of Bengal, the direction of monsoon winds restricts the rainfall considerably. The area has been selected because of it's under developed nature and also for it's varied lithological conditions such as geomorphology, hydrological characteristics, consolidated nature of rock etc.

DATA PRODUCTS

Various types of satellite data were used for analysis purpose viz., LISS- IV, and Cartosat DEM data and SOI toposheets to create thematic maps and generating vector layer. Soil data was obtained from Tamil Nadu Agriculture University, Coimbatore. The Rainfall data was obtained from Tamil Nadu Economic and Statistical Department, Chennai. Geology map (District resource map) the Geological Survey of India. Lineament and Geomorphology layers were obtained from Bhuvan thematic services of India.

II. METHODS AND MATERIAL

The toposheets 1:50000 scale using to the Vaippar basin boundary and stream digitization. Thirty years (30) of rainfall data obtained from Tamil Nadu Economic & Statistical Department, Chennai have been used. In this calculation, mean annual rainfall is done by using Microsoft excel. For the land use and land cover classification and analysis purpose downloaded LISS-IV Image data from NRSC, Bhuvan thematic service have been downloaded, India. Geology, geomorphology land use/land cover and lineament these are thematic maps digitized in ArcGIS with the help of online source of Bhutan thematic map service.

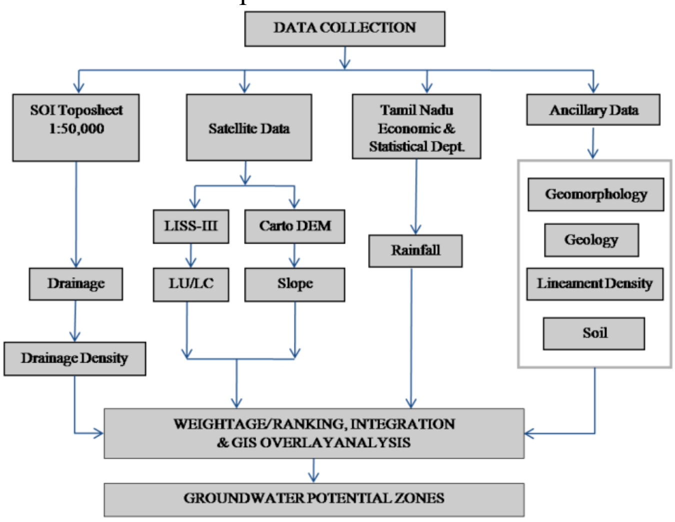

Figure 1. Methodology

After digitization given suitable weightage & ranking for correlated layers and fulfill attribute values were calculated. The lineament density map was converted from raster to vector format using raster to vector polygon tool, the lineaments were delineated from Bhuvan thematic layer service, India open data source similarly drainage density was delineated from SOI (Survey of India) toposheets (1:50000). Drainage density was converted from raster to vector. The errors in DEM were removed and corrected In ArcGIS using fill tool, as well as slope tool was used for the slope analysis in degree unit and was converted from raster to vector format. Land use land cover map was generated from LISS - IV IRS P6 satellite image. Land use land cover map was digitized in ArcGIS.

The main aim of the study is to identify groundwater potential zone of Vaippar basin. The overlay analysis technique plays a significant role in achieving the same by overlaying the thematic layers of selected spatial features, few of those layers are generated from the primary sources like satellite images, Cartosat DEM and few are from the secondary sources like geological geomorphological, soil texture, rainfall and soil depth maps of the study area

Overlay analysis is a group of methodologies applied in optimal sites selection. It is a technique for applying common scales of value to diverse and dissimilar inputs to create an integrated analysis. This technique used for identification of groundwater potential zones the best or most preferred location for a specific phenomenon.

ANALYSIS

Assignment of Weightage and Rank

Suitable weightages were assigned to the parameters and ranks for their individual classes after understanding their hydrogeological importance on groundwater occurrence in the study area. The weightages assigned from 1to100 were assigned for different parameters presented in Table .This rank from 1to5 were assigned for different classes of the individual parameters and their weightages are presented in the above Table.

Groundwater Potential Index

The weightage of different parameters were assigned on a scale of (1 to 100) based on their influence on the groundwater. Different classes of each theme were assigned rank on a scale (1 to 5) according to their relative influence on groundwater. To differentiate groundwater potential zone, all the nine thematic layers, after assigning weightages and ranks were integrated (overlaid). The total weightages and ranks, of different polygons in the integrated layer were derived from the following equation to obtain groundwater potential index.

GWPI = {[(GMw)(GMr)] + [(GGw)(GGr)] + [(SLw)(SLr)] + [(LUw)(LUr)] + [(DDw)(DDr)] + [(LDw)(LDr)] + [(RFw)(RFr)] + [(STw) (STr)]+ [(SDw)(SDr)]}………...(1)

Where,

(GWPI = Groundwater Potential Index) / (GM = Geomorphology)
(GG = Geology) / (SL = Slope) / (LU = Land use/Land Cover)
(DD = Drainage Density) / (RF = Rainfall) / (ST = Soil Texture)
(SD = Soil Depth) / (w = Weightage) / (r = Rank).

Table 1. Weightage for Various Parameters

Layers	Sub-classes	Ranking	Weightage
Geology	Silt, Clay, Sand, Laterite	5	**13**
	Charnockite	4	
	Garnet, Gneiss, Graphite	3	
	Pyroxene granulite	2	
	Pegmatite, Granite, Quartzite	1	
Geomorphology	Active flood plain	5	**20**
	Fluvial bajada	4	
	Pediplain ,Pediment	3	
	Denudational hills & valley	2	
	Structural hills & valley	1	

Drainage density (in km/sq.km)	> 4	5	**12**
	3 - 4	4	
	2 - 3	3	
	1 - 2	2	
	< 1	1	
Lineament density (in km/sq.km)	> 0.69	5	**11**
	0.45 - 0.69	4	
	0.25 - 0.45	3	
	0.10 - 0.25	2	
	< 0.10	1	
Land use/land cover	Water body	5	**8**
	Forest	4	
	Agriculture crop land	3	
	Agriculture fallow land	2	
	Built-up land	1	
Soil texture	Sandy	5	**5**
	Sandy loamy	4	
	Gravelly loamy	3	
	Loamy	2	
	Cracking clay	1	
Slope (in degree)	< 5	5	**10**
	5 - 10	4	
	10 - 15	3	
	15 - 20	2	
	> 20	1	
Annual average rainfall (in mm)	> 840	5	**6**
	780- 840	4	
	720 - 780	3	
	660 - 720	2	
	<660	1	
Soil depth (in cm)	> 20	5	**15**
	15- 20	4	
	10 - 15	3	
	10 - 5	2	
	< 5	1	

Geology

The geology is a great wall between surface water and groundwater. The rock types of the study area include granite, quartzite, calcareous gritty sand, laterite, pyroxene granitite, charnockite, genesis, graphite, calcareous granulite and limestone, Pigment, etc. The sedimentary of calcareous gritty sand, laterite, limestone are porous having good source of groundwater. The metamorphic rocks of quartzite, calc gneiss/crystalline limestone, garnet-sillimanite, biotite, cordierite, Gneiss having moderate potential. The igneous rocks of charnockite, pyroxene granitite and the acid intrusive of granites, pegmatite having low potential.

Lineament Density

Lineaments are primarily discontinuities on the earth surface caused by geological and geomorphological process. Lineaments are formed due to various geological features like faults, shear zone, dykes and veins as well as bedding planes and stratigraphic contacts. Geomorphic features, which appear as lineaments on the maps, aerial photographs and satellite images include streamline, valley sand and ridgelines. Lineaments are secondary source of water percolation for underground water occurrence. Therefore, it is very important factor in groundwater potential zone demarcation.

Based on the lineament density values the study area has been divided into five zones Lineament densities are high western part of the Vaippar basin. Very high lineament density covers an area (4.42 %) of Vaippar basin.

Geomorphology

Geomorphology is a controlling factor for the infiltration of surface water into the ground. The study area has variations in geomorphic features as well as the area. Geomorphic units are mapped for the entire basin which shows various structural, residual and denudation hills in the western part of the study area. The eastern most part of the basin is covered by young coastal plain, old coastal plain and alluvial plain. The central parts of the basin are covered by the shallow weathered pediments and moderately weathered pediments. Eroded pediplain are identified in the southern parts of the study area. Bajadas and colluvial fills are seen in the foothills of the study area i.e on the western sides of the basin. The river flows on the west to east parts of the study area, which creates various erosional and depositional landforms on both sides of the river.

For groundwater prospect geomorphology can be broadly classified into structural, denudational, fluvial and Coastal Origin Landforms. Denudational origin landform of pediments, residual hills and pediplains are moderate significant landforms and occupies major part of the study area about (84%) and the structural hill has less significance which covers 10.5% of the study area. For groundwater potential zone the active flood plain is very much suitable and it covers nearly (2.90%) of total study area.

Land Use/Land Cover

Land use/land cover plays an vital role in groundwater availability in the study area. Water body and forest are suitable for groundwater formation. Central part of the study area covered by the agricultural fallow land and it covers nearly (26.26%) of study area. Agricultural crop land covers, large area of study area nearly (51.20%) and forest covers (10.20%) very low area is covered by the built-up land of study area.

Slope

Slope is a significant factor in rainfall infiltration and groundwater storage. When the land have high slope then the land is considered as not suitable for groundwater even it has good soil depth for run-off infiltration. During rainfall, most of the water gets wasted as run-off is higher on slopes. For groundwater the land need to get absorb water and so we need a gentle slope and since the slope is an important aspect to be considered in groundwater potential studies.
The general slope of the basin is from northwest to southeast, following the general trend of most of the basins (east flowing rivers) of the Deccan. The area with 0 to 5% slope falls in the 'very high' potential category due to the nearly flat terrain and relatively high infiltration rate with little run-off. The study area is Plain region and so major part of the area (86% of the total area) falls under this category. The area with a slope of 5-10% (4.7% of the total area) causes relatively high run-off and low infiltration, and hence it is categorized as 'high'. The slope ranges from 10-15% occupies 1.5% of study area and possess moderate filtration. The fourth (15-20%) and fifth (>20%) category are considered as 'poor' due to higher slope and run-off.

Rainfall

The rainfall influence on groundwater occurrence depends on the southwest and northeast monsoon rainfall. The rainfall distribution along with the slope gradient in the upstream northwest part directly affects the infiltration rate and hence increases the possibility of groundwater potential zones in the downstream of northern part. The northwestern part of the study area receives mean annual rainfall of around >840 mm/year; the southern parts, of Vaippar basin recorded a mean annual rainfall of around 660-720 mm/year. In this study, area a high rainfall covered 637.48 sq.km area or 11.93% of total study area.

Drainage Density

The study area has a dense network of streams due to the presence of mountains on its western part. The streams observed here are seventh order. The central part of study area has good network of streams.

Drainage density of 3-4 km/sq.km is highly suitable for the groundwater formation which covers nearly 1068.9 km/sq.km area or (20.09%) of the study area.

Soil Texture

Soil texture is an important factor for delineating the groundwater potential zones. The analysis of the soil type reveals that the study area is predominantly covered by clay, loam, sandy loam, sand and sandy clay loam. Loamy soil is formed from weathered granite of Archean and quartzite of Proterozoic age. This study area is also covered by the some sub-texture types of soil texture such as sandy soil, loamy soil, gravelly loamy soil, clay soil, cracking clay soil covering a larger part of study area i.e. (80.20%) which is 4882 sq.km. The sandy soil is most suitable for the groundwater which is covered in central part of study area and it covers (33.66) sq.km area or (0.63%) of total study area.

Soil Depth

Soil depth plays a significant role in infiltration of water from surface to aquifer zones. If soil depth is higher then water infiltration rate is high. The present study area has very high variation in soil depth and it is changing from place to place and region to region. Higher than 20 cm depth soil cover is found nearly 28.13% part of Vaippar basin. Higher depth soil covers in middle part of basin as well as neighboring area of rivers and water bodies.

III. RESULTS AND DISCUSSION

The groundwater potential zones were identified by overlaying all the thematic layers using weighted and rank overlay analysis from the spatial analysis tool in ArcGIS. The groundwater potential zones were classified as very high potential, high potential, low potential, and very low potential. The groundwater potential zones were identified in the eastern part of the basin having very high potential of 4.72% of the total area. High ground water potential is found in the eastern and central part which is of about 32.37% of the total area. Low groundwater potential is found in 44.51% of the total area which is mostly the plateau region. The hilly and central regions have less groundwater potential about 8.64% of the total area. These results suggest that the high potential zones will have a key role in future expansion of drinking water and irrigation development in the study area. The results of the present study suggest the planners that more concentration should be given on low groundwater potential zone and need to take appropriate steps towards rainwater harvesting, construction of check dams on streams.

IV. CONCLUSION

GIS and Remote sensing techniques reside as the prime and easiest application in the present day to identity the groundwater potential zone. The integration of remote sensing and GIS data proved to be extremely useful in the potential mapping, which helped in defining the causative factors and the delineating the groundwater potential zone. As per the result, the groundwater potential zones in Vaippar basin are not only influenced by geomorphological conditions but also controlled by a variety of physical parameters primarily the geology, soil depth, soil texture, slope, mean annual rainfall, lineament density and drainage density. Groundwater potential zones, found through geospatial techniques, clearly indicate that it is a combination of flood plain, variation of soil depth, variation in drainage density and lineament density. These are the favorable conditions having groundwater controlling factors such as flood plain, sandy texture soil, forestland, agriculture, less degree slope, stream network, high rainfall etc. Hornblende biotite genesis (75.18%), and charnockite (19.31%) rocks are dominantly spread over the study area among which the charnockite rocks are more suitable for identification of groundwater potential zone. These results suggest that the high potential zones will have a key role in future expansion of drinking water and irrigation development in the study area. The results of the present study suggests the planners, that more concentration should be given on low groundwater potential zone and need to take appropriate steps towards rainwater harvesting, construction of check dams on streams.

V. Acknowledgement

The authors wish to thank the financial assistant provided by UGC-BSR out this research is gratefully acknowledged.

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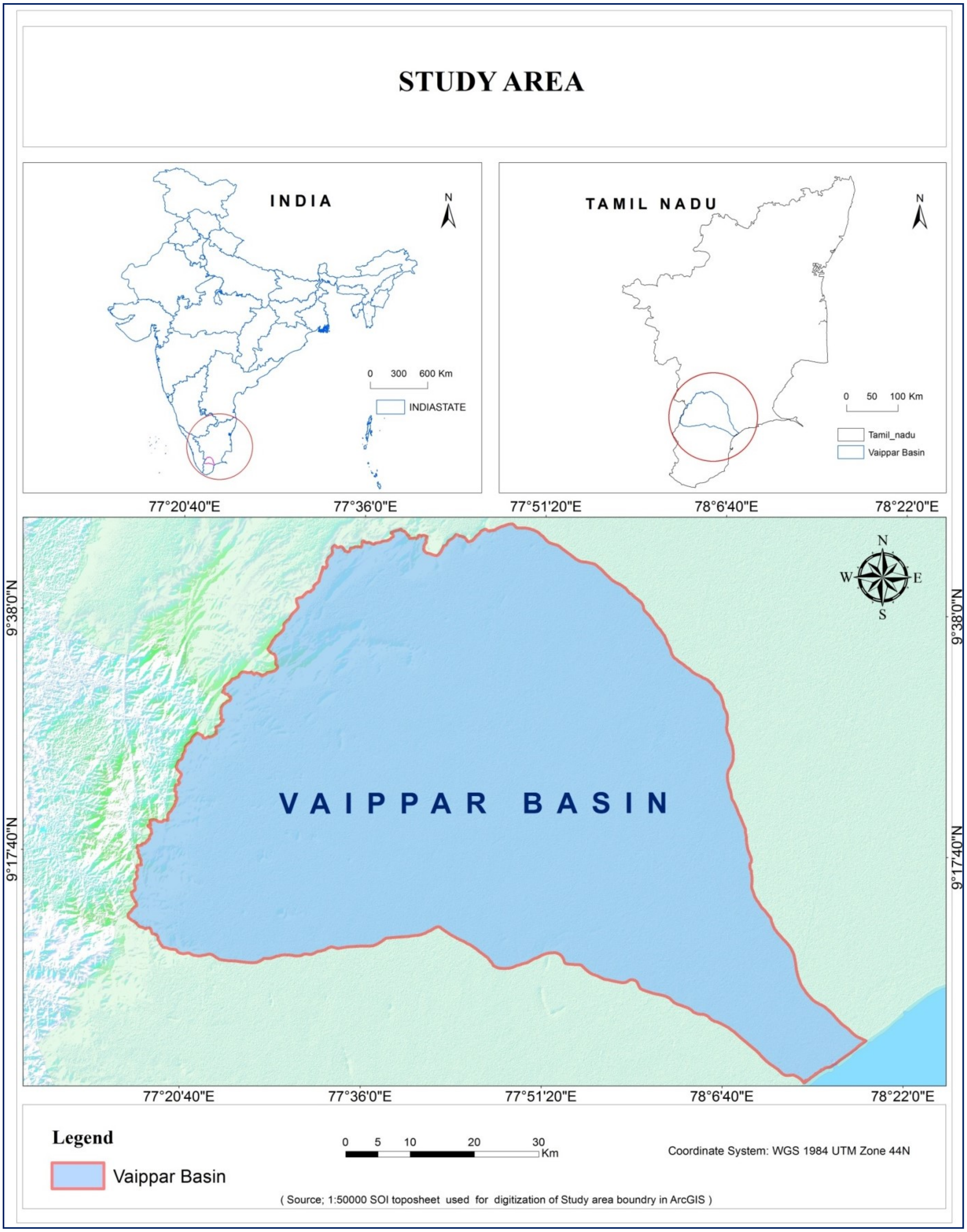

Figure.1 Location of study area

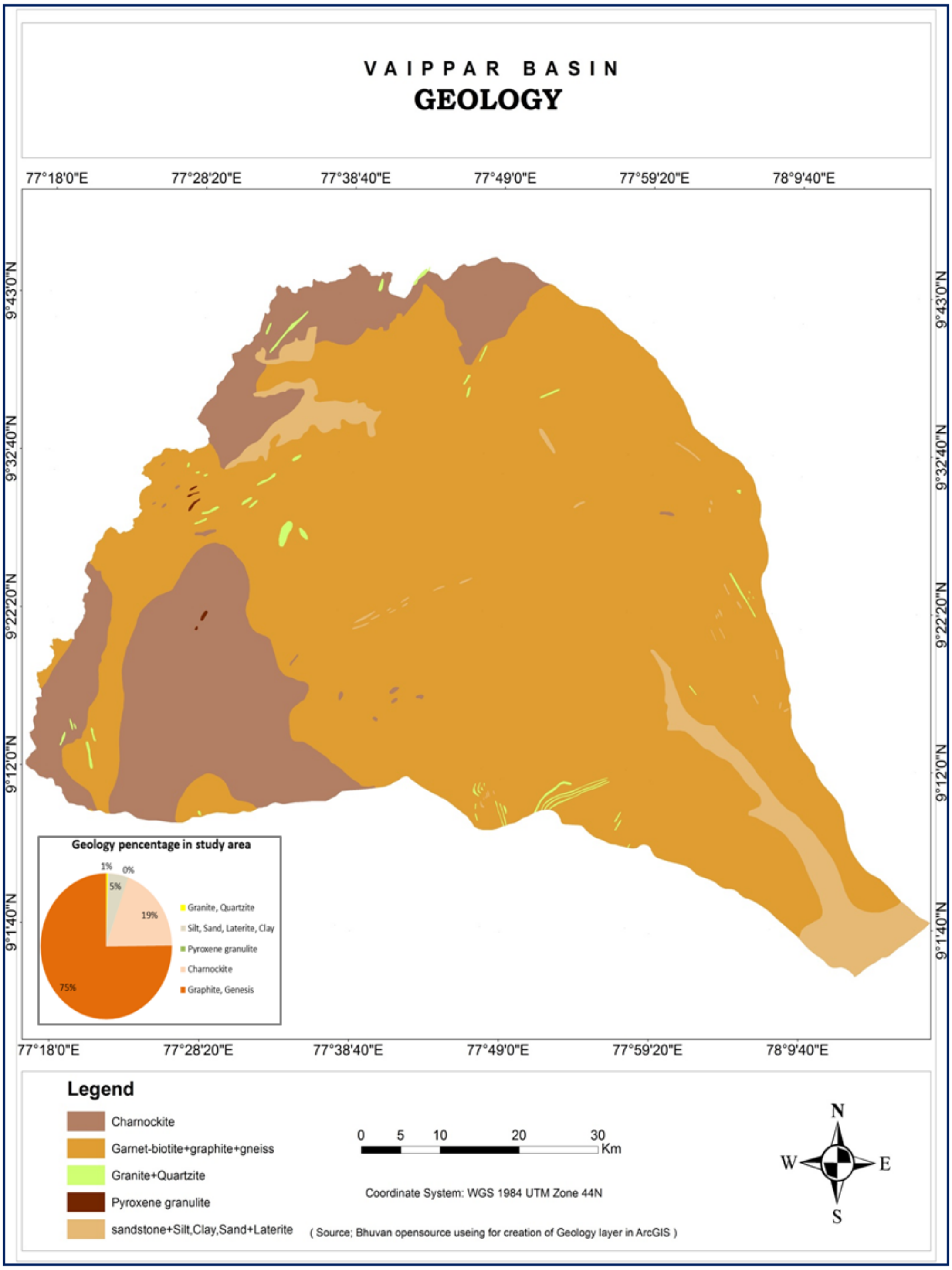

Figure.3 Geology of Vaippar Basin

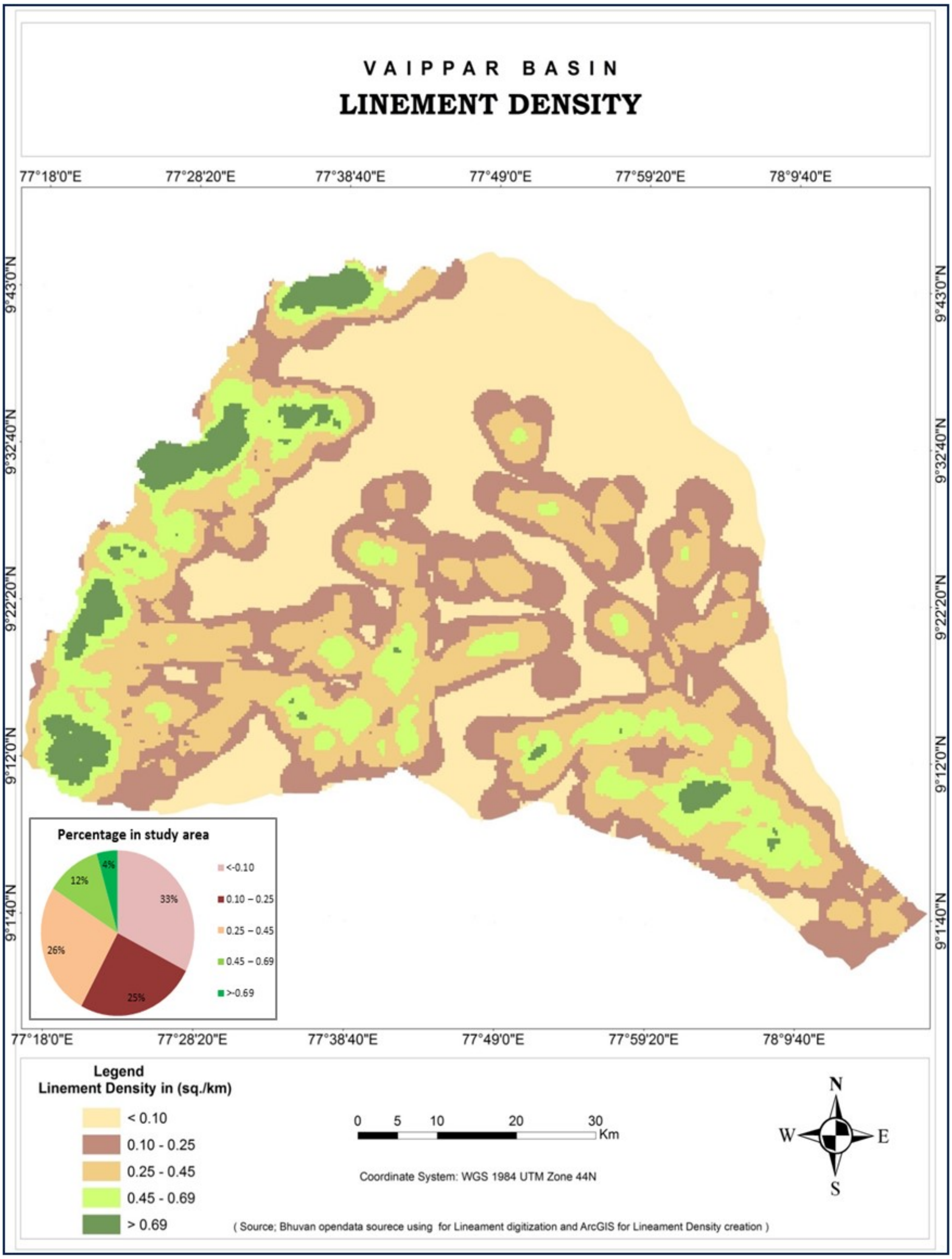

Figure.4 Lineament Density of Vaippar Basin

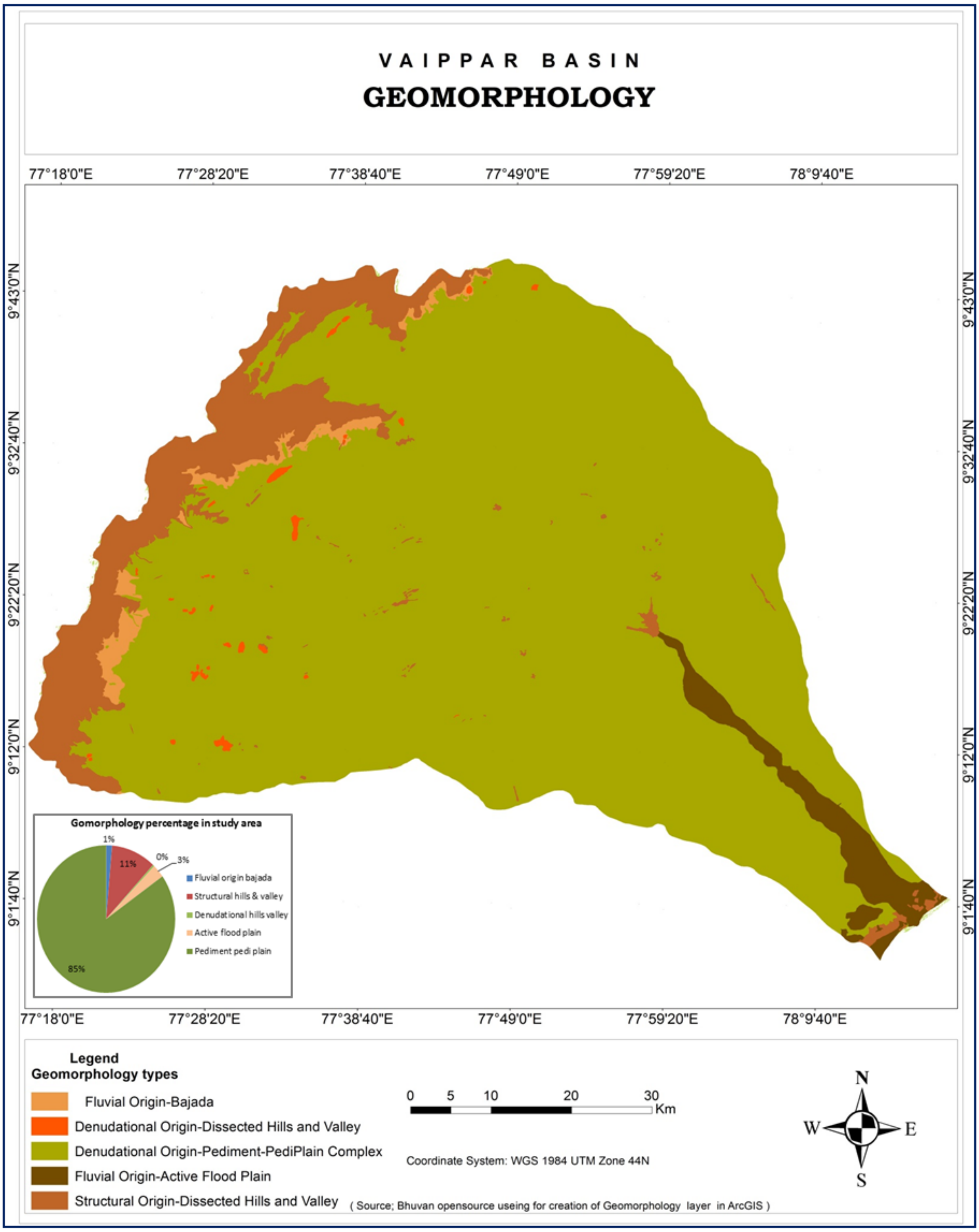

Figure 5. Geomorphology of Vaippar Basin

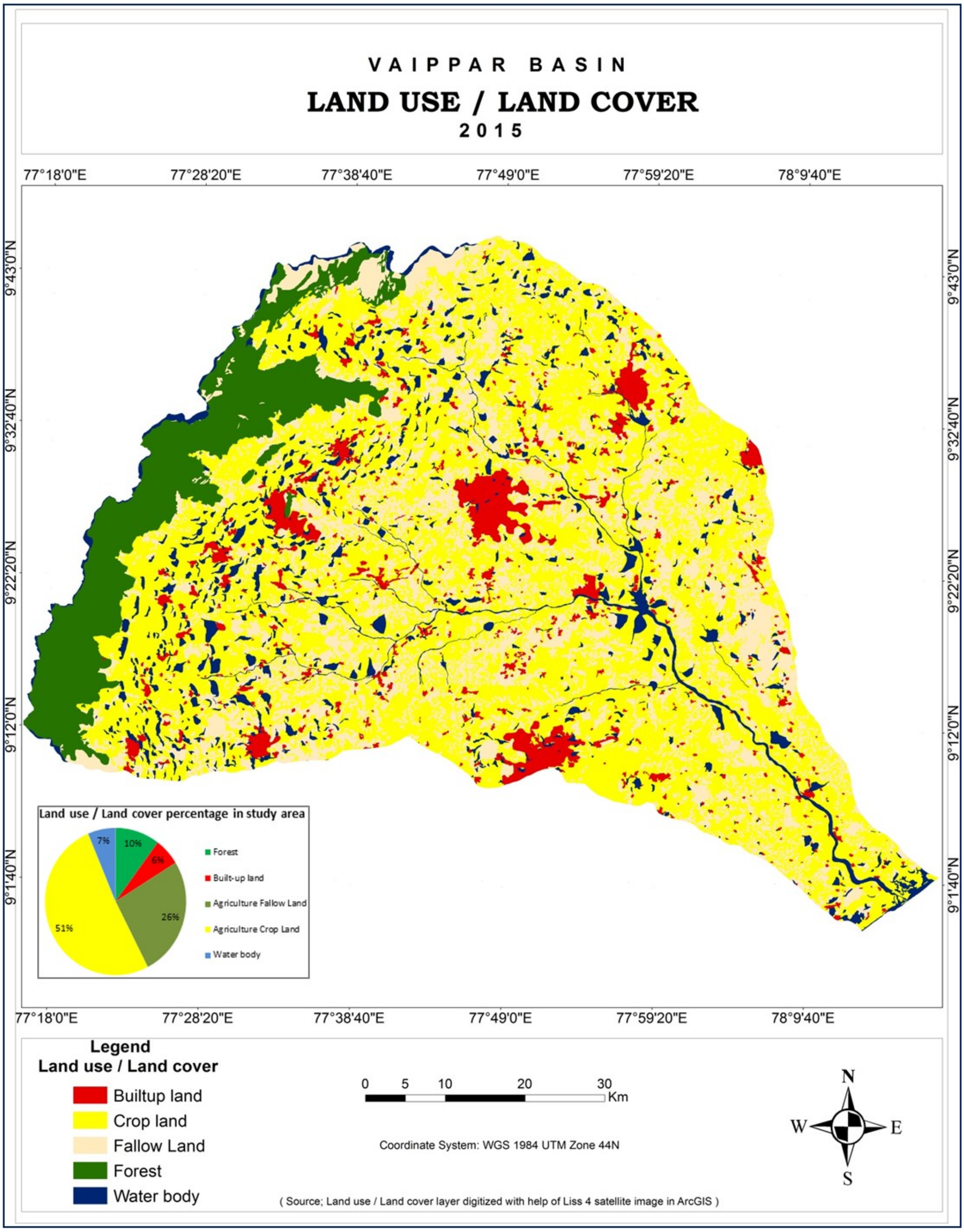

Figure. 6 Land use/Land cover of Vaippar Basin

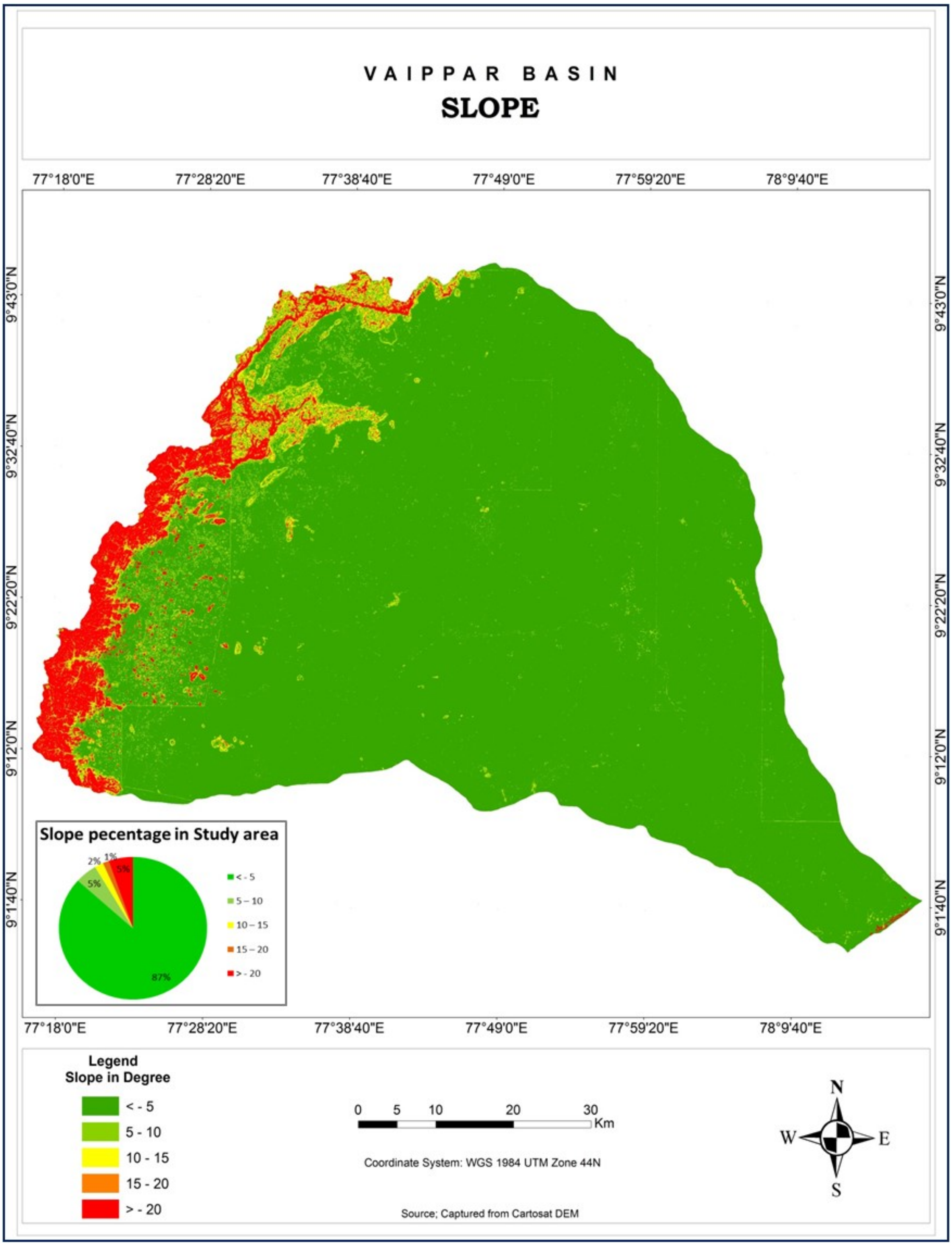

Figure.7 Slope of Vaippar Basin

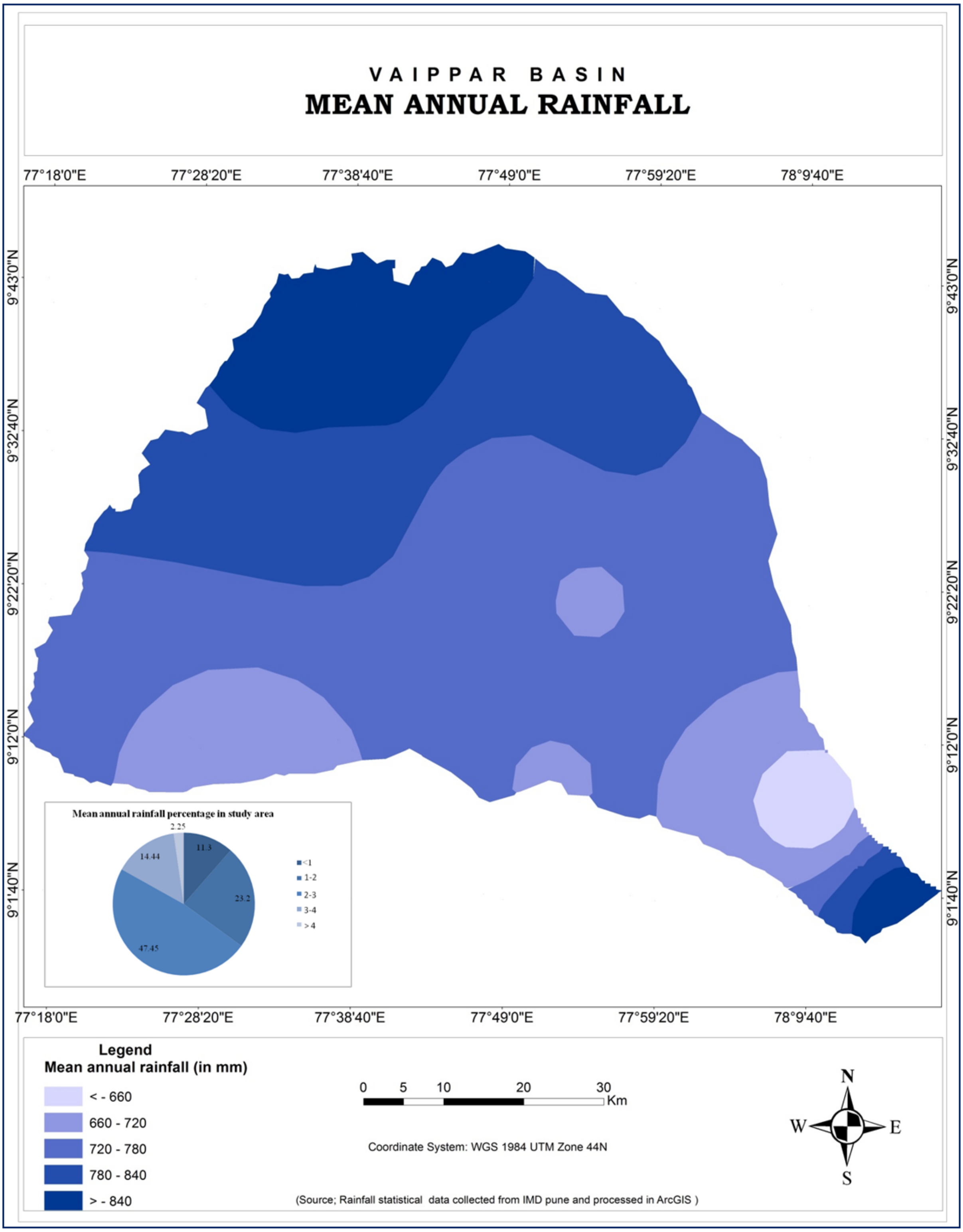

Figure .8 Mean Annual Rainfall of Vaippar Basin

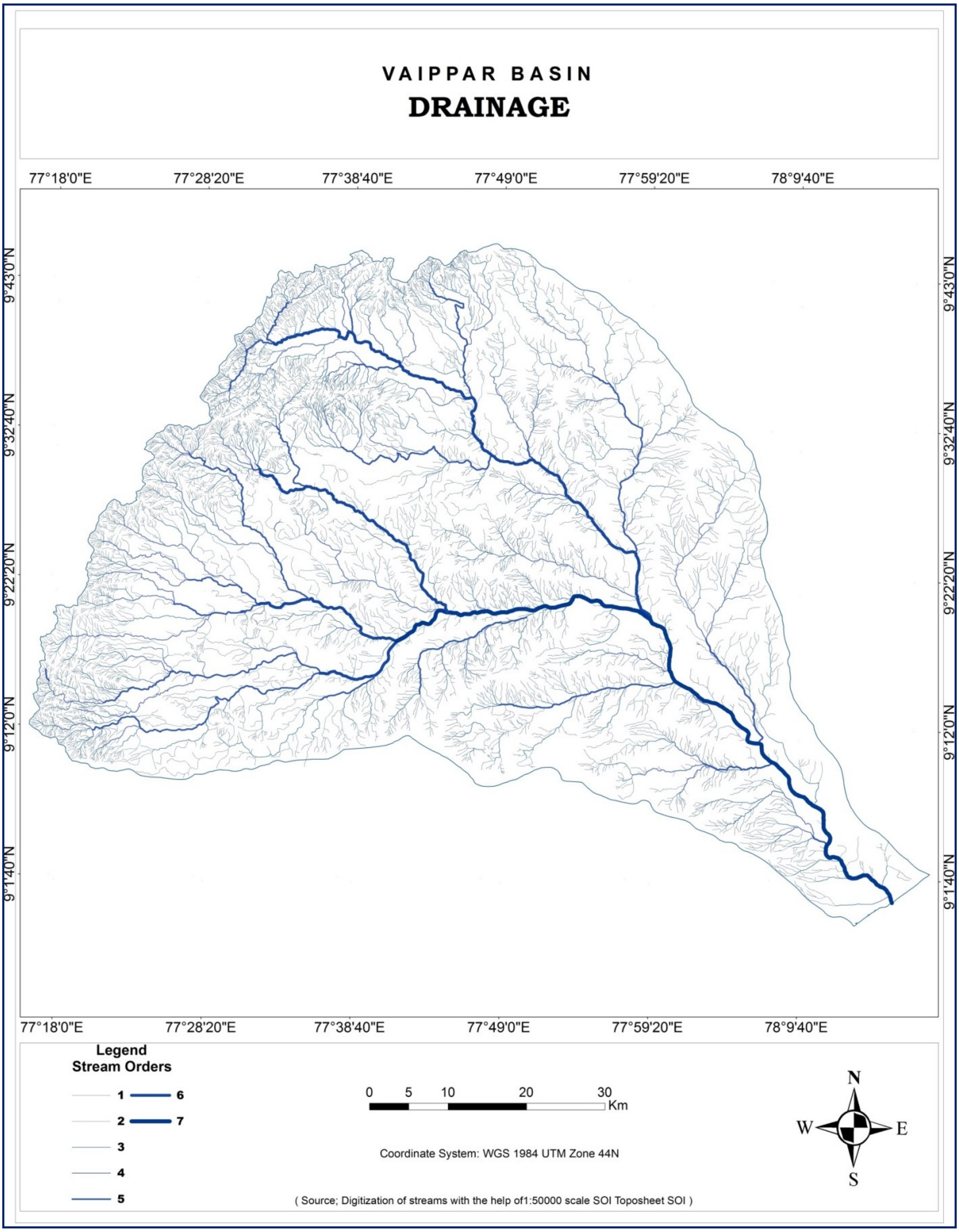

Figure.9 Drainage of Vaippar Basin

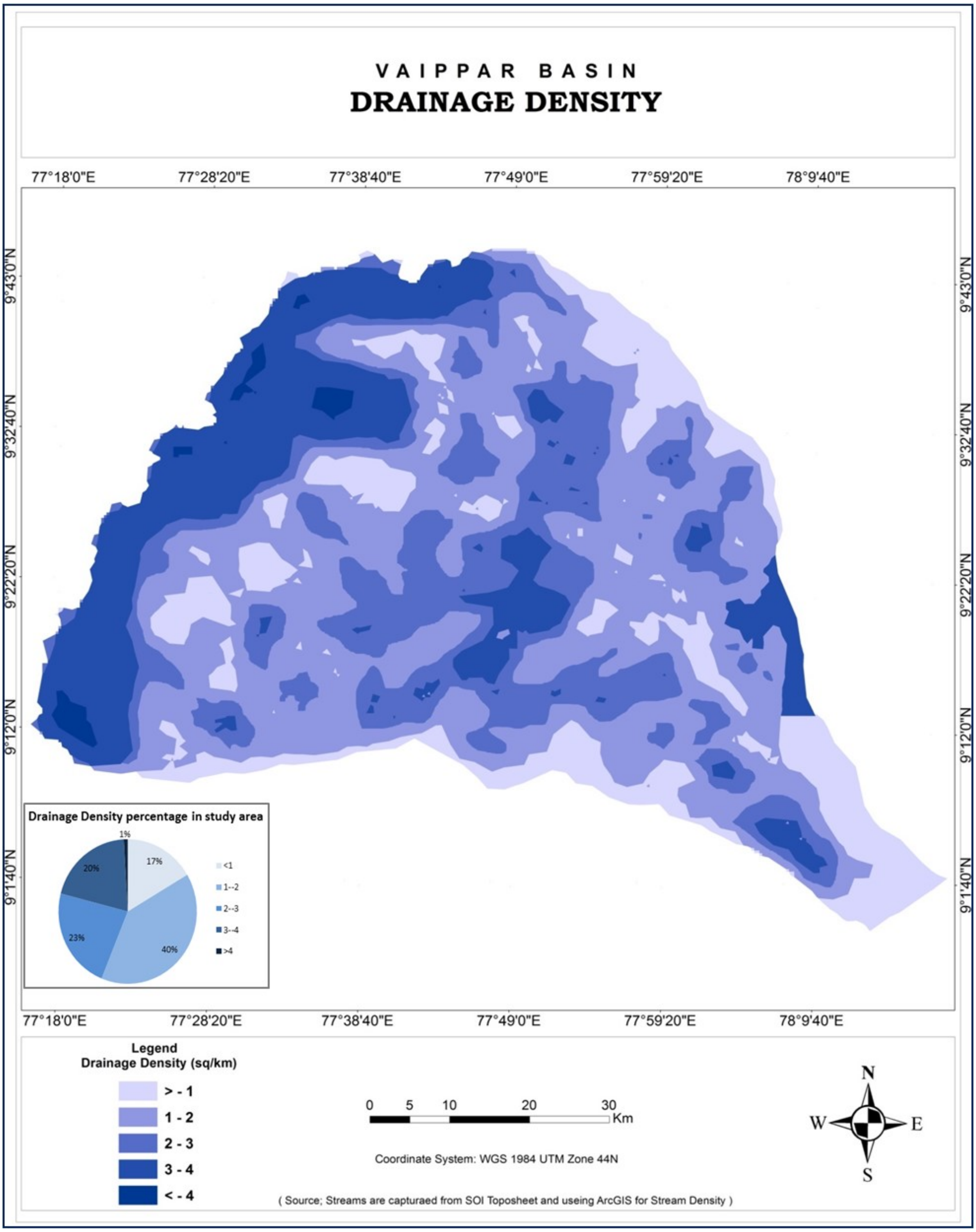

Figure.10 Drainage Density of Vaippar Basin

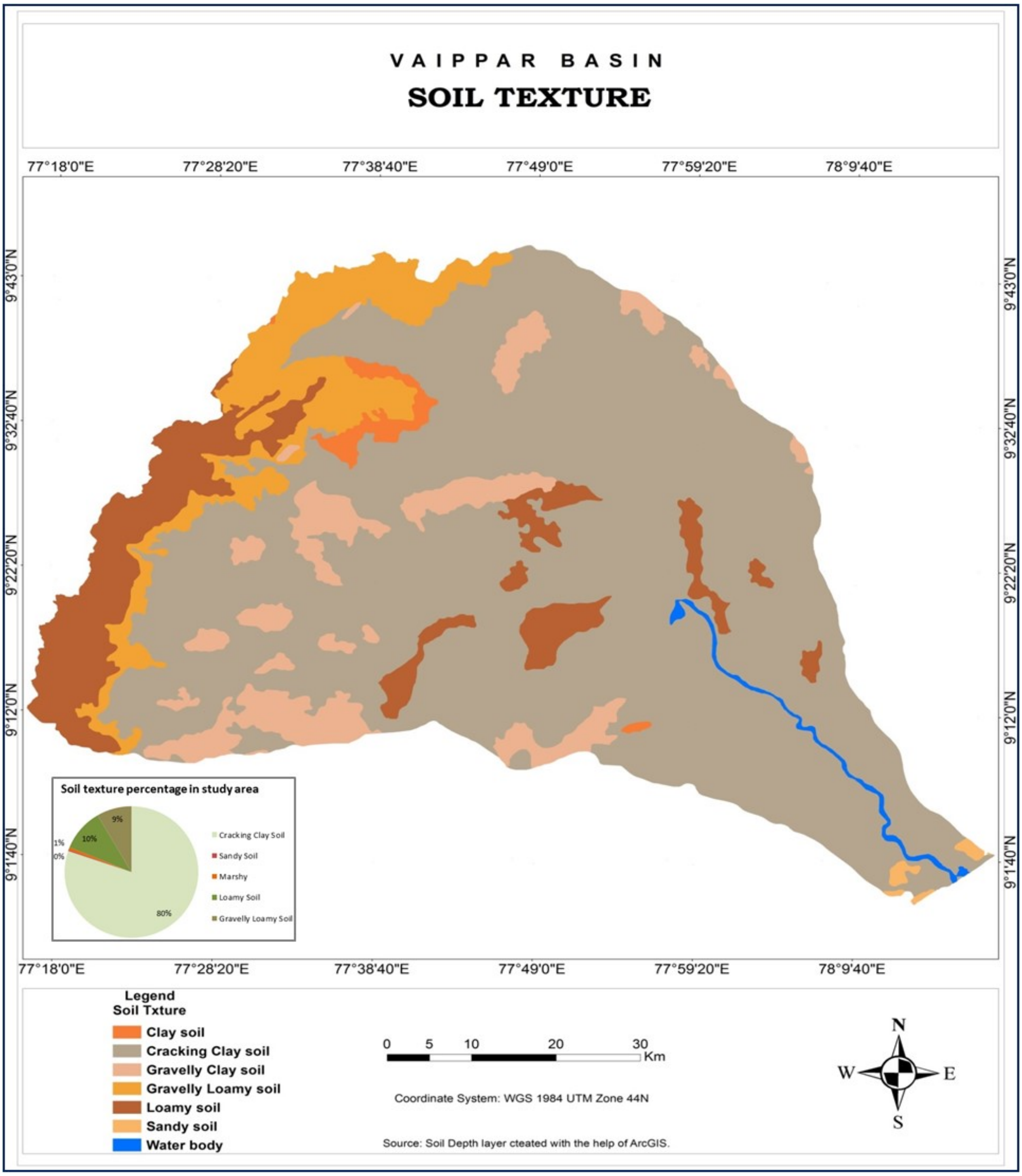

Figure.11 Soil Texture of Vaippar Basin

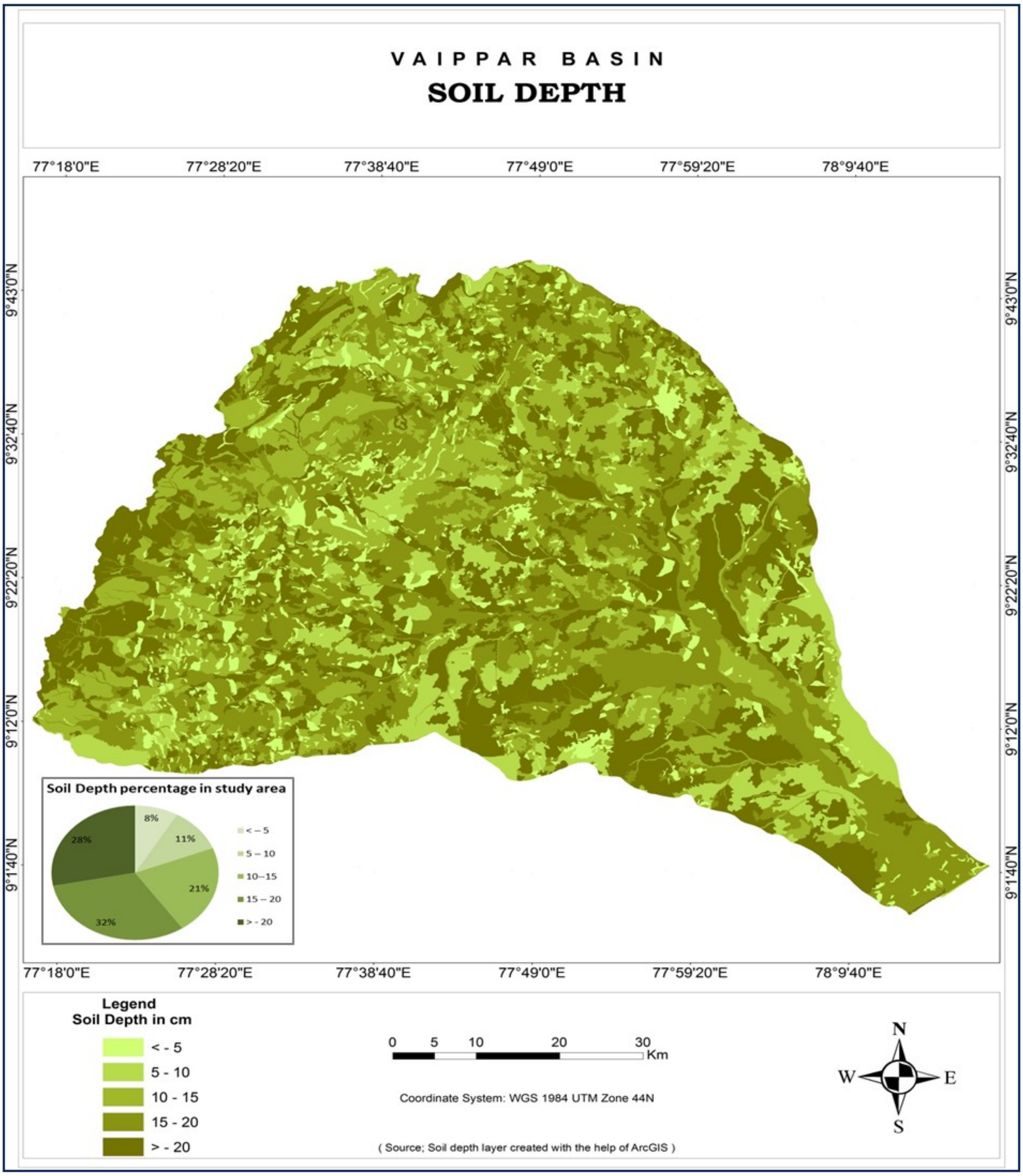

Figure.12 Soil Depth of Vaippar Basin

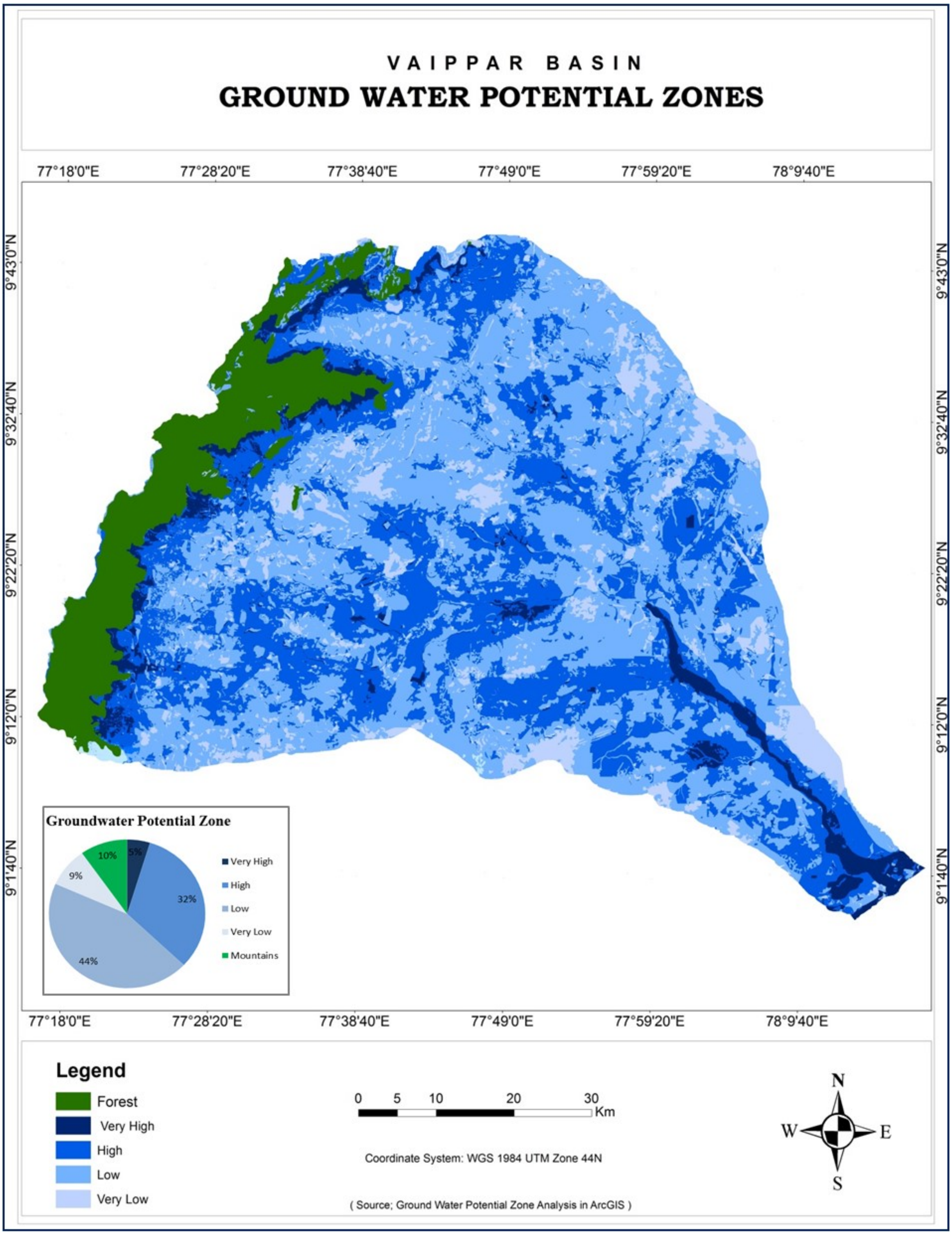

Figure.13 Groundwater Potential Zone of Vaippar Basin