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Influence of Lineaments on drainage morphometry using Geoinformatics: a case study of Nethravathi Watershed

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Abstract:

An attempt has been made to study the influence of Lineaments on drainage morphometry of Nethravathi Watershed of Dakshina Kannada district. A lineament is s linear feature in a landscape which represents the underlying geological structure. Lineaments play an important role in water movement and storage. Usually drainage network follows elevation of terrain. A linear drainage network will either controlled by geological structures or steep slope. Typically it represents the fault zones, series of folds, fracture zones, shear zones and igneous intrusions like dykes. Lineaments were extracted from Bhuvan website in the form of WMS layer and processed in ArcGIS 9.3 software. Drainage networks for the sub watershed are extracted from Cartosat 1 Dem data derived from Bhuvan portal. Morphometric calculations were carried out using ArcGIS 9.3 to evaluate aerial, linear and relief features of morphometric parameters. Compare to conventional method of drainage analysis, Remote sensing and GIS can provide appropriate data with good coverage. The analysis clearly shows following successive results. IX sub-basin have high elongation ratio (Re), basin relief (Bh), Ruggedness number (Rn) and time of concentration (Tc). The erosion and peak discharges were high in these basins. It is necessary to construct the check dams and earth dams to reduce peak discharge along the main channel. The study is predominantly useful in field of watershed management and artificial recharge structure to solve the crisis on water issues.

Keywords:

Lineament; Drainage morphometry; Geographical Information System; Cartosat DEM; Watershed analysis

Introduction

Lineaments are the geological manifestations of the features on the earth's surface, which prove the groundwater and surface water occurrence. Lineaments play a very important role in storing water in subsurface. Water is the most essential element for the survival of living organisms next to air. Water is non renewable energy resource which we have to sustain for future generation by developing the harvesting structures and community awareness programs. The current study area is Nethravathi Watershed, having a drainage area of about 248.91 sq. km. Climatic conditions of the area is humid in nature and the area is suffered from water deficiency due to poor management. A possible solution for such problem is the micro level planning and use of standard methodology

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for assessing the drainage parameters (Zhong Li et al, 2014). Lineaments play a very important role in the drainage flow and recharge conditions. The surface hydrological features like topography, drainage, surface water bodies, etc. play important role in water management issues (Kamal Kumar et al, 2014). Remote sensing is an excellent tool for hydrologists in understanding the "perplexing" problems involved in water crisis and management. Satellite remote sensing provides an opportunity for better observation and more systematic analysis of various geomorphic units/landforms due to the synoptic and multi-spectral coverage of a terrain.

Study area

The Nethravathi is a major river of the Dakshina Kannada district, having a drainage area of about 248.91 sq. km. The study area lies between latitude from 12.625 to 12.375 North and longitude from 75.00 to 75.68 East. Dakshina Kannada receives an average annual rainfall of 3500-4500 mm. Nethravathi River has its origins at Gangamoola in Kudremukh in Chikkamagaluru district of Karnataka, India. This river flows through the famous pilgrimage place Dharmasthala and is considered as one of the holy rivers of India. It merges with the Kumaradhara River at Uppinangadi before flowing to the Arabian Sea, south of Mangalore city. This river is the main source of water to Bantwal and Mangalore as shown in figure 1.

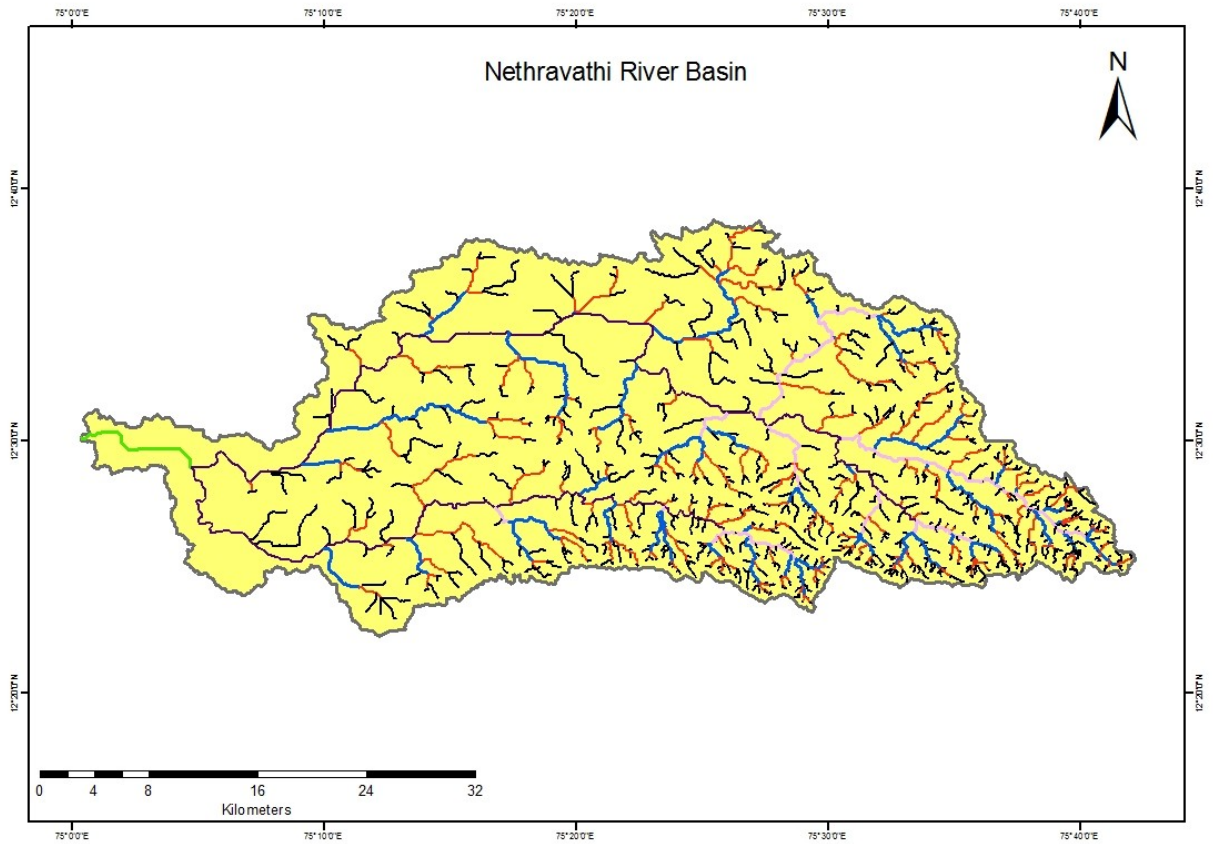

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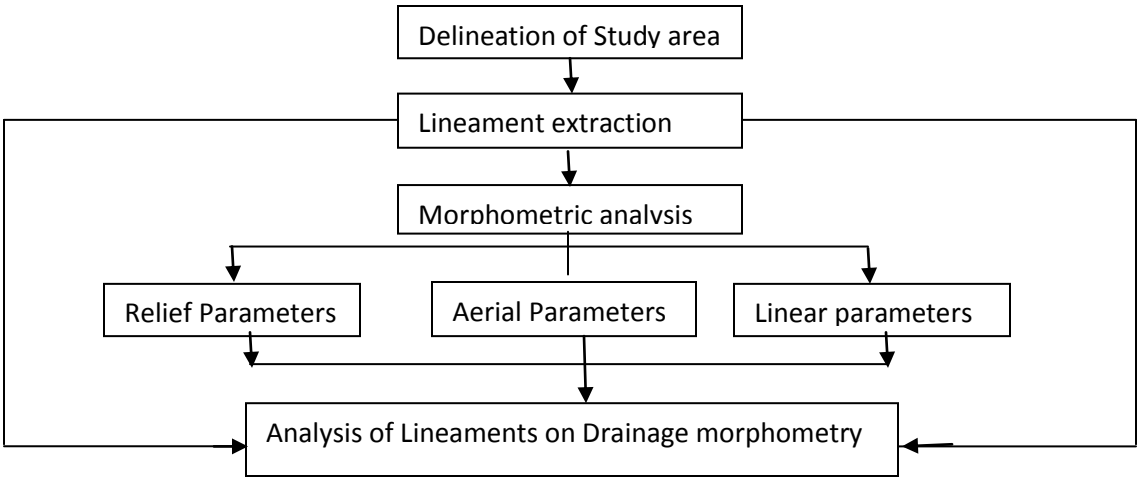
Figure 1: Study area

Methodology

The Nethravathi watershed is delineated based on the ridge-valley concept. The lineaments were extracted by Bhuvan website (http://www.bhuvan.com). The drainage morphometric analysis of the Nethravathi Watershed was prepared by using Cartosat DEM data and processed using ArcGIS tools. The basin was divided into 11 sub-basins and morphometric analysis was carried out at sub-basin level in ArcGIS. Three varieties of parameters were calculated such as linear, relief and aerial parameters. ArcGIS serves a good platform for hydrological researchers. Hydrological tools were used to derive and calculate the parameters of watershed and stream characteristics. It serves an excellent platform to maintain the database of a watershed boundary.



Flow chart indicating brief methodology

Results and discussion

The total drainage area of Nethravathi Watershed is 248.91 km^2 and it is divided into 11 sub-basins for the analysis (Fig. 3). The drainage network mainly depends on geologic features and endogenetic forces acting upon it.

Lineament map

The rectilinear aligned geological features, which represent the lineaments in the current study, were processed from Bhuvan portal. Lineaments may include series of fault, fold and joints. Area represents the lineaments are considered as the zones of having good groundwater potential. Figure 2 represent the lineament map of the study area.

Drainage parameters

Stream order number (Nu):

Stream order is a measure of relative size of streams. Total number of streams in the watershed is 1062, among which 785 streams are 1st order, 198, 54, 10, 2 and 1

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are 2nd, 3rd, 4th, 5th and 6th order streams, respectively (Table 2).

Stream length (Lu)

Stream length is one of the important parameter which states the surface runoff characteristics. Longer lengths of streams are generally indicative of flatter gradients. The number of streams of various orders in the basin is counted and their lengths from mouth to drainage divide are measured with the help of ArcGIS (Table 2).

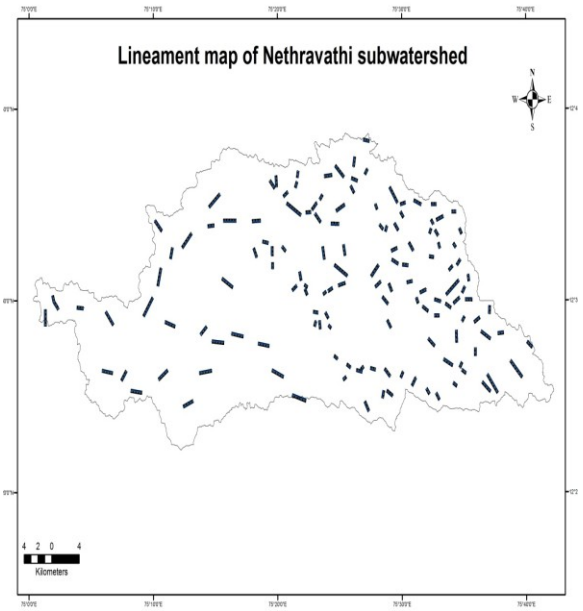

Figure 2: Lineament map of study area

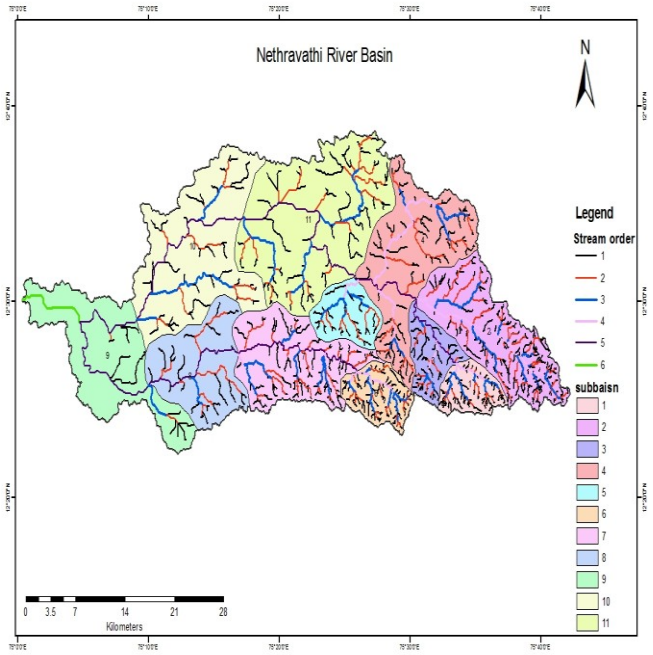

Figure 3: sub watershed distribution map

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Table 1:

Linear parameters of Nethravathi Watershed

Sub-basins	Basin Length(Lin kms)	Stream Orders(U)					Total stream no.	Stream length(Lu in kms)					Total stream length	Bifurcation ratio(Rb)			Mean Rb
		1	2	3	4	5		1	2	3	4	5		Rb1	Rb2	Rb3	
		6						6						Rb4	Rb5		
I	7.54	69	17	5	2		93	34.88	13.31	12.02	6.24		66.46	4.06	3.40	2.50	3.31
II	22.75	194	43	11	1		249	102.79	64.56	30.67	23.15	0.22	221.41	4.51	3.91	11.00	6.47
III	10.02	48	12	3	1	1	65	34.01	13.09	4.34	4.08	11.14	66.679	4.00 1.00	4.00	3.00	3.00
IV	17.02	98	22	6	3	1	130	78.98	38.16	16.64	24.02	10.50	168.32	4.45 3.00	3.67	2.00	3.28
V	7.17	32	15	7	3	1	58	25.57	16.00	11.14	3.66	0.57	56.96	2.13 3.00	2.14	2.33	2.4
VI	8.38	101	23	7	2		133	43.36	19.92	15.14	8.17		86.6	4.39	3.29	3.50	3.72
VII	19.58	102	25	6	3	1	137	75.4	39.64	23.40	2.18	21.14	161.78	4.08 3.00	4.17	2.00	3.31
VIII	14.05	26	7	1	1	1	36	36.59	24.92	3.85	0.06	16.18	81.62	3.71 1.00	7.00	1.00	3.17

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IX	26.61	12 1	3	1	2	19	27.41 9.80	2.99	4.88	27.29		72.39	4.00 2.00	3.00	2.41
X	21.62	39	10	3	1	53	55.61	25.89	22.04	22.56		126.12	3.90	3.33	3.61
XI	20.71	65	19	4	1	89	86.99	47.74	30.18	24.28		189.19	3.42	4.75	4.08
Nethravathi	76.08	785 1	198	54	10	2 1062	601.73 9.80	306.25	174.35	71.58	133.92	1297.5 29	3.96 5.00	3.66 2.00	5.4 4.00

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Table 2:

Sl.no.	Parameters	Formulae
1	Stream order (U)	Hierarchical rank
2	Stream length (Lu)	Length of the stream
3	Bifurcation ratio (Rb)	Rb=Nu/(Nu-1)
4	Drainage density (Dd)	Dd=Lu/A
5	Drainage texture (T)	T=Dd*Fd
6	Stream frequency (Fs)	Fd= SNu/A
7	Elongation ratio (Re)	Re=D/L
8	Circulatory ratio (Rc)	$Rc=4PA/P^2$
9	Form factor (Ft)	$Ft=A/L^2$
10	Constant of channel maintenance (C)	$C=km^2/km$
11	Texture ratio (Rc)	$T=N_1(1/P)$
12	Relief (R)	R=H-h
13	Basin relief (Br)	$Bh=h_{max}-h_{min}$
14	Ruggedness number (Rn)	Bh*Dd
15	Time of concentration (Tc)	$Tc=0.0078*L^{0.77}(L/H)^{0.385}$

Bifurcation ratios (Rb)

Bifurcation ratio is used to express the ratio of the number of streams of any given order to the number of the next lower order. In the study area mean Rb varies from 2.41 to6.49; the mean Rb of the entire watershed is 4.00 (Table 2). Sub-basins Rb values range from 1 to 10. The higher Rb for few sub-basins is the result of large variation in frequencies between successive orders and also indicates the mature topography.

Morphometric parameters:

Areal parameters

The total area of the basin is found to be 248.91 km2 (Table 3). The aerial aspects of the drainage basin such as drainage density (D), drainage texture (T), stream frequency (Fs), elongation ratio (Re), circularity ratio (Rc), form factor (Ff), constant of channel maintenance (C) and texture ratio (Rt) where calculated and results are given in Table 3.

Drainage density (Dd)

The Dd is the ratio of total channel segment length cumulated for all orders within a basin to the basin area. The Dd for the whole basin is 5.21 km/km^2, while those of the XI sub-basins are shown in Table 3. Dd gave an idea about the physical properties of the underlying rocks in the study area. Low Dd occurs in the regions of highly resistant and permeable sub-soil materials with dense vegetated cover and low relief; whereas high Dd is prevalent in the region of weak impermeable sub-surface materials which are sparsely vegetated and show high relief in the study area.

Drainage texture (T)

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The drainage texture (T) depends on a number of natural factors, such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. The T of the whole basin is 3.06, while those of the XI sub-basins are shown in Table 3. According to Smith classification, T of the whole basin comes under coarse texture, as the values are 3.06.

Stream frequency (Fs)

The Fs of a basin may be defined as the number of streams per unit area. The Fs of the whole basin is 4.26 km/km^2, while the Fs for XI sub-basins are shown in Table 3. Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity. It mainly depends on the lithology of the basin and reflects the texture of the drainage network.

Elongation ratio (Re)

The Re is defined as the ratio between the diameter of a circle with the same area as that of the basin (A) and maximum length (L) of the basin Schumn (1956). Elongation ratio for the basin is estimated as 0.78, and the XI sub-basins are shown in Table 3. High Re values indicate that the areas are having high infiltration capacity and low runoff. The sub-basins having low Re values are susceptible to high erosion and sedimentation load.

Circularity ratio (Rc)

Circularity ratio values approaching 1 indicates that the basin shapes are like circular and as a result, it gets scope for uniform infiltration and takes long time to reach excess water at basin outlet, which further depends on the prevalent geology, slope and land cover. The ratio is more influenced by length, frequency (Fs) and gradient of various orders rather than slope conditions and drainage pattern of the basin. The Rc of the whole basin is 0.50, while thoseof the XI sub-basins are shown in Table 3.

Form factor (Ff)

Form factor is defined as the ratio of the basin area to the square of the basin length. The Ff of the whole basin is 0.50, while the Ff of XI sub-basins is shown in Table 3. Form factor reveals that sub-basins having low Ff have less side flow for shorter duration and high main flow for longer duration and vice versa.

Constant of channel maintenance (C)

The sub-basins V and IX have low C values of 6.41 and 5.42, respectively. It indicates that these sub-basins are under the influence of low structural disturbance, moderate permeability; gentle slopes and low surface runoff shown in (Table 3).

Texture ratio (Rt)

Texture ratio is defined as the ratio between the first order streams and perimeter of the basin. Rt is an important factor in the drainage morphometric analysis which depends on the underlying geology, infiltration capacity of bedrock and relief aspects of the sub-basins. VI sub-basin contains highest Rt value in the watershed (Table 3).

Table 3: Aerial parameters of Nethravathi Watershed

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Sub-basin	Area(A)	Perimeter(P)	Drainage density(Dd) km/km2	Drainage texture(T)	Stream frequency (Fs)	Elongation ratio(Re)	Circularity ratio(Rc)	Form factor (Ff)	Constant of channel maintainance©	Texture ratio(Rt)
I	35.50	25.93	0.21	0.56	2.62	0.89	0.66	0.62	4.71	2.66
II	135.57	65.76	0.17	0.31	1.84	0.58	0.39	0.26	5.96	2.95
III	42.50	32.37	0.24	0.36	1.53	0.73	0.51	0.42	4.24	1.48
IV	158.27	72.68	0.11	0.09	0.82	0.83	0.38	0.55	9.30	1.35
V	45.96	27.55	0.16	0.20	1.26	1.07	0.76	0.89	6.41	1.16
VI	43.90	28.75	0.19	0.58	3.03	0.89	0.67	0.63	5.24	3.51
VII	126.58	60.14	0.15	0.17	1.08	0.65	0.44	0.33	6.46	1.70
VIII	110.16	49.29	0.13	0.04	0.33	0.84	0.57	0.56	7.84	0.53
IX	144.27	85.04	0.18	0.02	0.13	0.51	0.25	0.20	5.42	0.14
X	200.83	82.42	0.11	0.03	0.26	0.74	0.37	0.43	9.29	0.47
XI	248.91	77.69	0.08	0.03	0.36	0.86	0.52	0.58	12.02	0.84

Relief parameters

The DEM map of the study area revealed that the maximum height of the whole watershed is 1300 m above mean sea level (amsl). The study area is associated with dissected hills in the eastern part of the watershed and lowest minimum 10 m amsl near the confluence of the river (Fig. 5).

Basin relief (Bh)

Basin relief is defined as the maximum vertical distance between the lowest and the highest points of a sub-basin. From the analysis it is found that the sub-basins of I,II,III,V have relief more than 1000 m (Table 4). The high Bh values indicated the gravity of water flow, low infiltration and high runoff conditions.

Ruggedness number (Rn)

Ruggedness number is defined as the product of the basin relief and its drainage density. The analysis shows that the Rn value varies between 1.00 and 4.53. It is found that the Rn value is more than 4 for IX sub-basin (Table 4). The basins having high Rn values are highly susceptible to erosion. Therefore, they are susceptible to an increased peak discharge.

Time of concentration (Tc)

The time of concentration is defined as the ratio between length of main stream and basin relief. Tc values varieed from 1.19 to 1.46. (Table 4). The highest Tc value represents the greatest length in time for water to travel from the most distant point of the sub-basin to its outlet.

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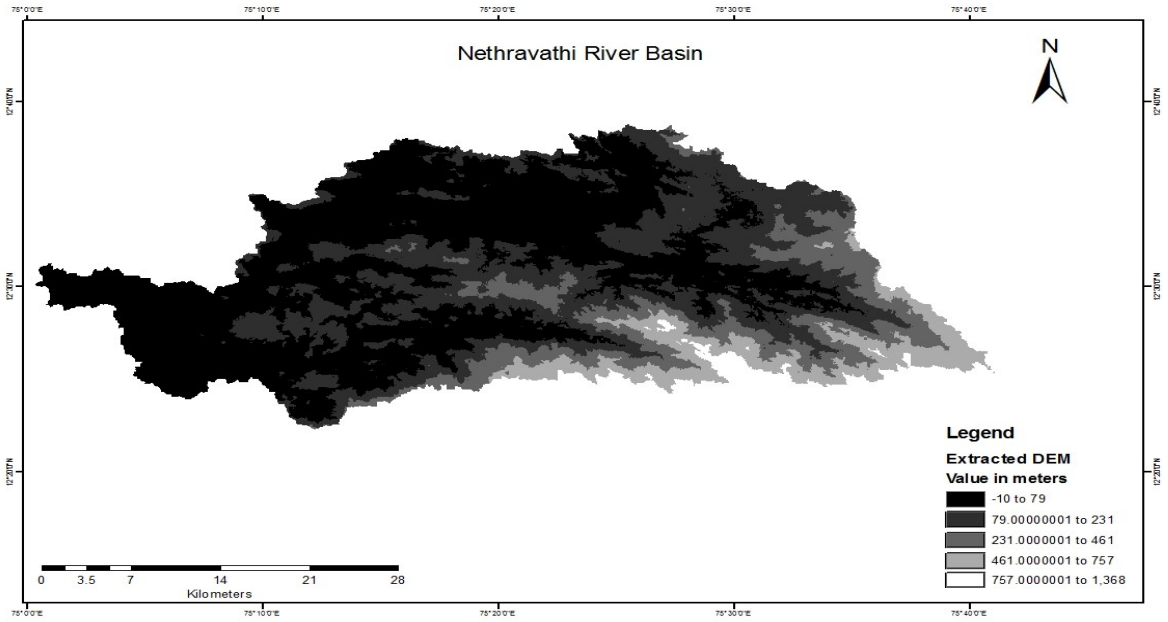

Figure 4: Cartosat DEM image of Nethravathi Watershed

Table 4:Relief parameters of Nethravathi Watershed

Sub-basins	Relief		Basin relief(Bh)	Ruggedness number(Rn)	Time of concentrations(Tc)
	Max	Min			
I	1300	140	1160	1.42	1.221260728
II	1080	30	1050	3	1.39410985
III	1190	40	1150	2.18	1.231505399
IV	1110	10	1100	1.27	1.429488644
V	870	20	850	1	1.212186268
VI	1180	170	1010	1.52	1.199082574
VII	1040	10	1130	2.39	1.377120071
VIII	390	10	380	1.63	1.26966624
IX	230	20	210	4.53	1.327592367
X	220	30	190	1.61	1.460006083
XI	280	50	230	1.29	1.408387738

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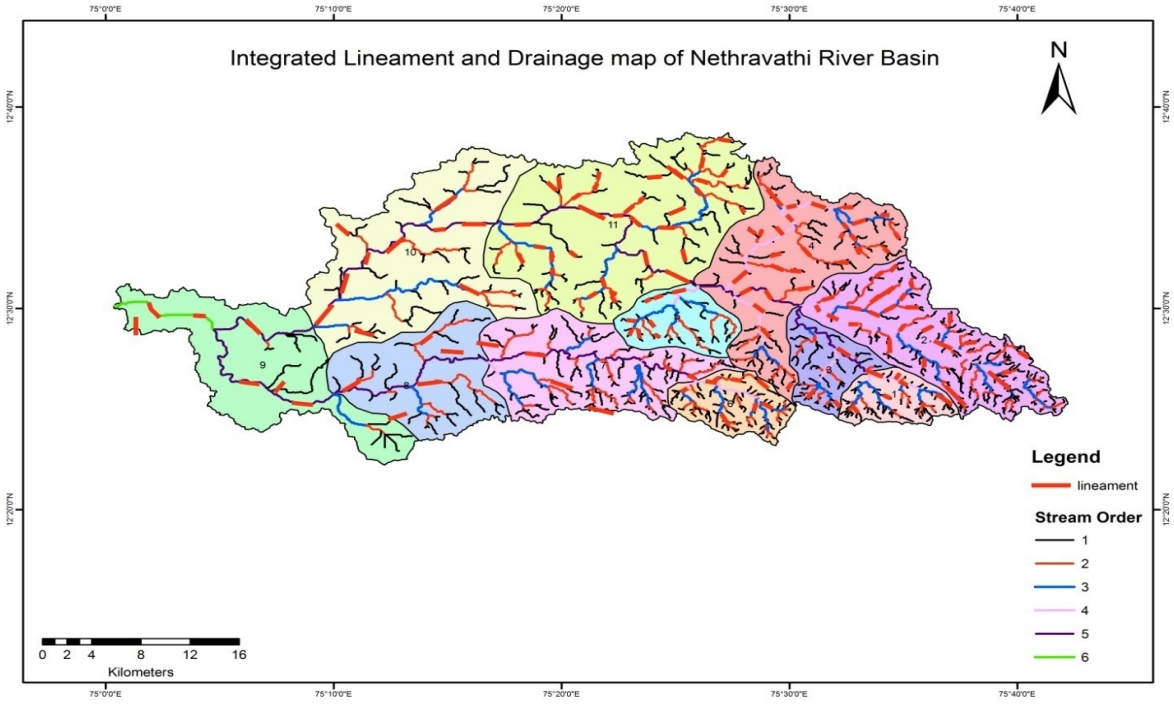

Figure 5: Integrated Lineament and Draiange map of Nethravathi watershed

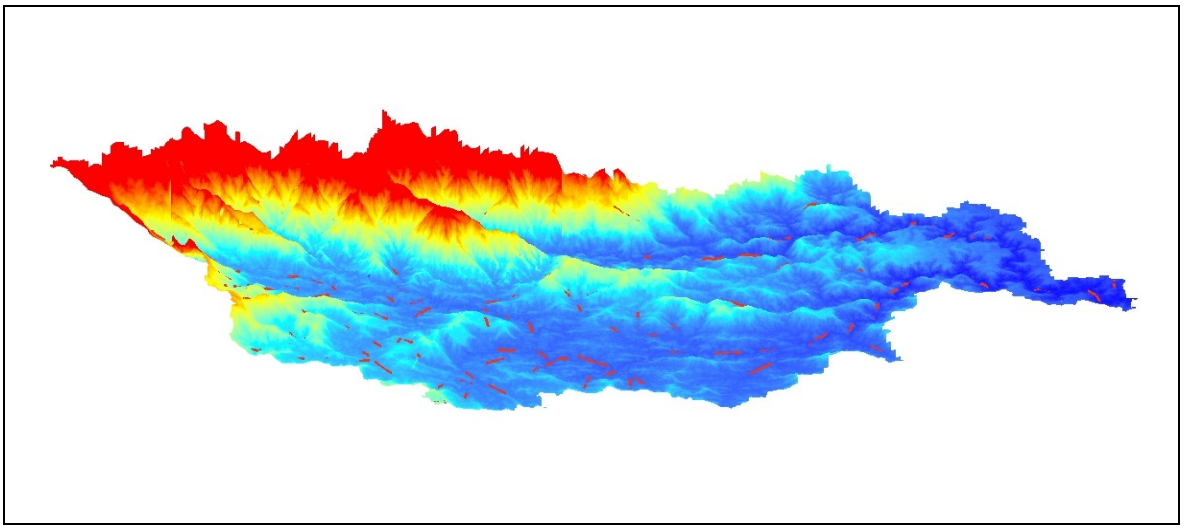

Figure 6: An integrated Arcscene 3d view of Lineaments and Nethravathi Watershed

Conclusion

The study revealed that lineaments play very important role in hydrological regime of the

Nethravathi watershed. The study demonstrates the efficiency of remote sensing data for hydrological works. The use of the Cartosat DEM and GIS-based approach can provide an effective result in analyzing the effect of Lineament on drainage characteristics. The morphometry of the watershed established the strong relation exists between the geological structures on hydrological characteristics. The relation between lineament and drainage network showed the high positive correlation. Groundwater occurrence majorly depends on the location of lineaments of this watershed. The drainage path is purely dependent on lineament and the existing geological features. The major observations obtained from this study are as follows.

- The Rc of the basin is less than 1. It indicates that the infiltration rate is varying throughout the basin.
- Sub-basins I, V, VI and X are having low Ff, it indicated that less side flow for shorter duration and high main flow for longer duration.
- Sub-basin XI was found to have highest C values; it is indicative of the very less structural disturbances and less runoff condition.
- Sub-basins I, V, VI and X are having high Bh values, which indicates that the gravity of water flow, low infiltration and high runoff conditions are prevailing in that basins.
- IX sub-basin having high Rn value indicates that it is highly susceptible to erosion and therefore susceptible to an increase peak discharge.
- Sub-basin V has high Re and Ff. It indicates that the erosion and peak discharges are high in the basins.

Therefore, the analysis helps to construct recharge structures in Lineament located areas. Lineament acts as a subsurface barrier for groundwater storage. Lineament concentration in the watershed is sparsely distributed and serves good recharge rate and storage capacity.

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