APPLICATIONS OF REMOTE SENSING AND GIS IN MORPHOMETRIC ANALYSIS ON PRECAMBRIAN ROCKS, KOLLEGAL SHEAR ZONE, CHAMARAJANAGAR DISTRICT, SOUTH INDIA

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Abstract: *Morphometric studies are a tool in hydrological investigation in developing and management of drainage network. This study focuses to delineate the drainage network in Precambrian terrain around Kollegal Shear Zone (KSZ) of Chamarajanagar district which is belongs to Dharwar Craton, adjacent to high grade granulites of Biligiri-Rangan hills in Southern India. The drainage network was delivered on Geocoded FCC of IRS -1D (PAN+LISS III merged, year-2001) on SOI toposheets of 1:50,000 scales were used as a base map. The values of linear, aerial and relief variables are calculated and GIS analysis accounted using Raster calculator option of spatial analyst. The area (Au) and perimeter (P) of the drainage network has been measured with CAD-Overlay 2000 software by performing clean and build option (i.e., closed polygon, and the values are expressed in sq km). The variation in stream length ratio changes due to change in slope, lithology and topography, while the variation in the values of bifurcation ratio describes the control of lithology/structure and morphology on the development of network in the study area. The stream order varies from 1-5 with the total number of 7,167 stream orders with their total length of 5,945.56 Kms.*

Keywords: *Morphometry, Drainage network, Precambrian rocks, Kollegal Shear Zone.*

1. Introduction: The groundwater regime is a dynamic system wherein water is absorbed in the form of thin film to the underground and eventually recycled back to the surface through geological strata. Morphometric analysis provides a quantitative description of the drainage network (Strahler, 1954). Identification of fractures, joints, lineaments and sharp lithological boundaries on a satellite image is an added advantage of remote sensing in morphometric analysis of large area, calculated using GIS software (CAD-Overlay 2000, ArcInfo 8.1.2 and ArcView 3.2). Morphometric analysis requires measurement of linear drainage features, gradient of channel network and contributing ground slopes of the drainage network of the terrain (Nautiyal, 1994). The elements like relief, slope, ruggedness, depth and nature of weathering, thickness and deposited material, distribution of surface water bodies, river/stream network precipitation, canals, irrigated area, were influences the groundwater regime, besides the geological framework.

2. Study area: Kollegal Shear Zone (KSZ) demarks the boundary between low-land amphibolite mixed gneisses and high-land Biligirirangana granulites of Dharwar Craton (Basavarajappa, 1992; Srikantappa et al 1992). The charnockitic-enderbitic granulites show ductile to ductile-brittle shear deformation between amphibolite facies and banded charnockites (Basavarajappa and Srikantappa 1999) (Fig.1). The landforms of the study area represents the denudational hills, residual hills, linear ridge, pediments, inselbergs, pediplains, gullied, valley, and alluvial plains. The paleo-channels and lineaments of the area was mapped using satellite data providing additional information on water bearing zones viz, old river course, fractures and valley fills (Wadia., 1996; Basavarajappa et al., 1997; Satish, 2002; Dinakar, 2005).

***2.1 Location*:** The study area (11°45' to 12°15'N and 76°45' to 77°15'E) includes part of Yelandur, Kollegal, Chamarajanagar, Malavali, Mysore,

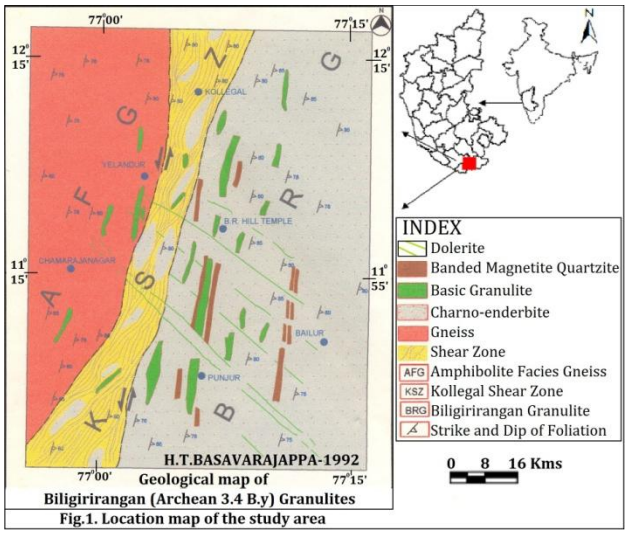


Fig.1. Location map of the study area

Gundalpet, T.Narsipur, Nanjangud Talavadi and Sathyamangalam taluks towards southern and south-eastern part with total areal extent of 3,011 Sq.km (Fig.1). Cauvery, Kabani and Suvarnavathi rivers are flowing in the study area. The trend of the Kollegal Shear Zone (KSZ) is towards N10°E to S10°W, extending about 60-65 km in length and 20-25 km width (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1998 and 2000).

2.2 Climate & Rainfall: The average annual rainfall in the study area is about 786.8mm with contribution of SW monsoon (44.45%). The annual minimum rainfall is 558.07mm while the maximum is 1455.43mm. During the period from March to April, there is a continuous rise in temperature attaining a maximum in the month of April and minimum during December. Throughout the SW monsoon period, weather is pleasant and generally, relative humidity is high and wind speed is moderate (Dinakar, and Basavarajappa, 2005).

2.3 Lithology of the study area**:** Lithological map was derived from published Geological map of 1:50,000 scale (GSI, 1996). The KSZ area consists of gneiss and charnockite, amphibolites, banded magnetite quartzites, pyroxene granulites, pink migmatites, meta ultramafites, hornblende schist and basic dykes (Fig.2) (Basavarajappa, 1992, Basavarajappa et al, 1997; Satish, 2002; Srikantappa et al, 1992, Srikantappa and Basavarajappa, 1997, Basavarajappa and Srikantappa 1998; Satish 2002; Meenakshi, 2003 and Dinakar 2005).

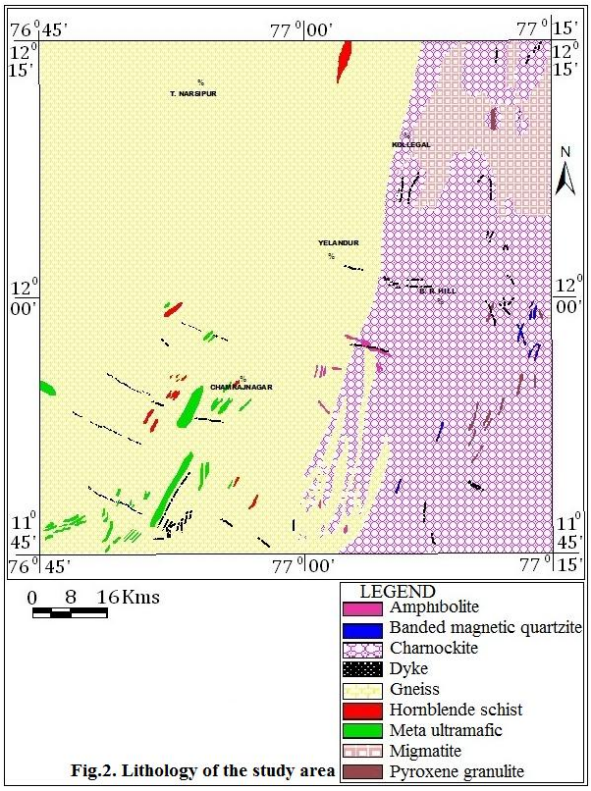


Fig.2. Lithology of the study area

3. Methods and materials: The values of linear, aerial and relief aspects are calculated separately and GIS analysis carried out using Raster calculator option of spatial analyst. The area (Au) and perimeter (P) of the drainage network has been measured with CAD-Overlay 2000 software by performing clean and build option, i.e., closed polygon, and the values are expressed in terms of sq km.The materials Re used are tabulated in table.1

Table.1. Materials used

Type of Data	**Details of Data**				**Sources of Data**
Toposheets	57D/16, 57H/4, 58A/13, 58E/1				Survey of India (SOI), Dehradun
Present work: Thematic maps of Lithology, Slope and Stream order	Scale 1:2,50,000 (Reduced to 1:25,000)				*Geological Survey of India (GSI), Calcutta. *National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Bangalore.
Remote Sensing digital data sets of IRS-1D	**LISS-III**		**PAN+LISS-III**		National Remote Sensing Agency (NRSA), Hyderabad
	Date	Resolution	Date	Resolution	
	March –2001	23.5 m	March–2001	5.8m	
	Nov-2001	23.5 m	Nov-2001	5.8m	
Rainfall data	31 year rainfall data (1970-2001)				Bureau of Economics and Statistics, Bangalore.
Groundwater data: Depth of water table and its yields.	12 years water table fluctuation. (1990-2002)				Dept of Mines and Geology, Mysore, GOK.

4. Results and Discussions

4.1 Morphometric analysis: The designation of stream order is the first step in morphometric analysis of a drainage network, based on the hierarchic making of streams proposed by Strahler, 1954. The drainage network is divided into five stream orders with codes N1 to N5, while the whole study area is belongs to fifth order of stream (Muliki and Basavarajappa 2006; Ali and Basavarajappa 2008, Pushpavathi et al, 2009).

4.2 Linear Aspects: The linear aspects of morphometric analysis of drainage network include stream length, stream order, stream length ratio, stream frequency and bifurcation ratio (Pushpavathi et al, 2009).

4.3 Stream length (Lu): The length of the streams in the KSZ is 5,945.56 Kms. The stream length decreases with higher order of streams. The mean stream length of a channel is a dimensional property and reveals the characteristic size of drainage network components and its contributing surfaces (Strahler, 1954; Muliki & Basavarajappa, 2008).

4.4 Stream order (U): The variation in the total number and total length of the streams are due of precipitation, morphology and lithology of the terrain. The terrain is characterized by flat land to steep slope and medium precipitation. The study area is a fifth order of stream with their total flow lengths are as N1-(L1), N2-(L2), N3-(L3), N4-(L4) and N5-(L5) of first, second, third, fourth and fifth order respectively (Fig.3). The total numbers of streams are 7,167 km (Dinakar et al, 2007; Basavarajappa et al, 2007; Satish, 2002).

4.5 Stream length ratio (RL): According to Horton (1945), the stream length ratio increases exponentially with increasing order. The variation in the stream length ratio (N1-N) in the drainage networks are due to change in slope and topography

$$RL = Lu/Lu\text{-}1$$

Where:

RL = Stream length ratio

Lu = Mean stream length

Lu-1 = Mean Stream length of segment of the next lower order

The mean length ratio of the study area is 1.68 km. The first and second order exhibits parallel drainage channels, tectonically controlled by parallel joints. The catchment area of all the sub-basins lies in the hilly region characterized by high precipitation during monsoon and steep scarp (Wadia, 1996; Basavarajappa et al 1996; Satish, 2002; Dinakar, 2005). This accounts for the slope initiated crowded network of channels and length ratio of first, second and third order channels. The development of fourth and fifth order channels is confined not only to scarp region, but also to the terrain characterized by low relief and moderate slope. Many channels are structurally (joints and fractures) controlled by the length ratio between the pair L4/L3 (1.992) is significantly low, due to higher cumulative length of third order channels than that of fourth order. The inconsistencies in the values of length ratio and abnormal decrease in stream length are noticed.

4.6 Stream frequency (Fs): Stream frequency is the total number of stream segments of all orders per unit area (Horton, 1932).

$$Fs = N/A$$

Where:

N=Total number of streams

A=Area of watershed

Fs values indicate positive correlation with the drainage density of all the stream orders suggesting increase in stream population with respect to increase in drainage density.

4.7 Bifurcation ratio (Rb): The bifurcation ratio of streams implies the level of branching of a fluvial system and provides an important genetic segments. Horton (1945) considered Rb as an index of reliefs and degree of dissections in an individual drainage network. Lower Rb values are the characteristics of structurally less disturbed drainage network without any distortion in drainage pattern (Nag, 1998).

$$Rb = Nu/\ Nu+1$$

Where,

Nu=Total number of stream segment

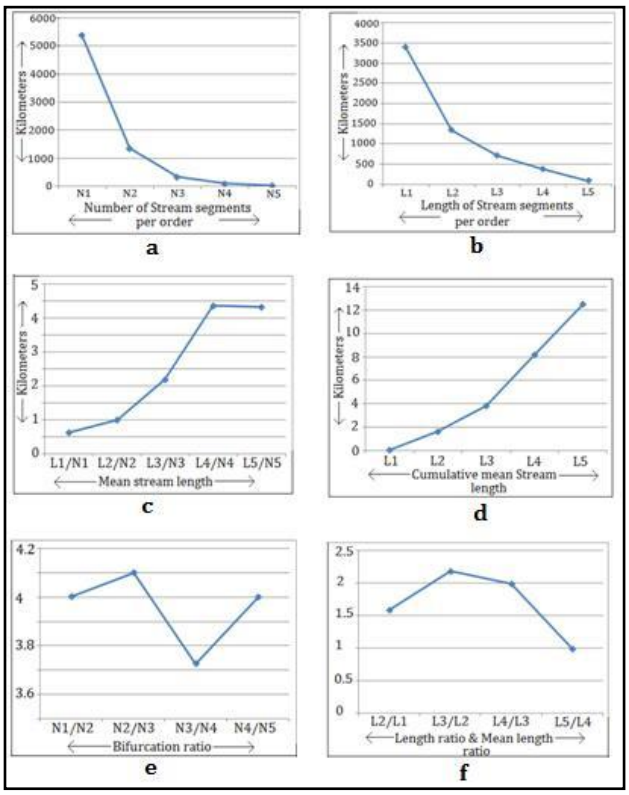
Nu+1=Number of segment of next higher order

The bifurcation ratio varies from 3.72 to 4.10 and the average bifurcation ratio of the entire drainage system of the study area is 3.85. In general, the value within the ranges of 3-5 is an accepted value for natural fluvial system (Ali and Basavarajappa, 2008).

4.8 Shape of the drainage network: The KSZ lies within the Cauvery river drainage network. About 68 sub-drainage networks have been identified. The length of the basin (Lb) is the distance between the mouth of the river and farthest length (km). The perimeter of the sub-drainage network varies from 21.86km to 49.84km (Fig.3). The variation in the area and perimeters depends on the number of segments, length and altitude. If these parameters are high, the values of area and perimeter are high. The area and perimeter values of the sub-drainage network indicate that the drainage constitute a larger or smaller drainage network. Low-land gneissic terrain and few parts at charnockite terrain show the lower perimeter with almost flat to undulating topography, where as higher perimeter is shown in the charnockite peaks of hilly terrain (Basavarajappa et al 1997; Dinakar 2005; Satish, 1992).

Table.2. Basin parameters of the drainage network in the study area

Sl no.	Basin parameter	Values
1	Maximum length of the sub-basin (km)	16.93
2	Perimeter of the sub-basin (km)	49.84
3	Cumulative stream length (km)	5945.56
4	Cumulative stream segment	7167
5	Bifurcation ratio (Mean)	3.85
6	Length ratio (Mean)	1.68
7	Stream frequency (Mean)	2.6
8	Drainage density (Mean)	2.08
9	Form factor (Mean)	0.62
10	Circularity ratio (Mean)	0.47
11	Elongation ratio (Mean)	0.84



a - Number of Stream Segments per order (km)
b - Length of Stream Segments per order (km)
c - Mean Stream length (km)
d - Cumulative main stream length (km)
e – Bifurcation ratio
f - Length ratio & Mean length ratio

Fig.4. (a - f) Morphometric attributes of the drainage network in the study area

4.9 Elongation Ratio (R): A circular type of drainage is efficient in run-off discharge than an elongated network (Singh and Singh, 1997). The elongation ratio is an indicative of the shape of the river network and expressed by the following formula,

$$Re = 2A/L$$

Where,
Re = Elongation Ratio
2 = Constant
A = Area of the drainage network
L = Maximum in the length ratio

The value of elongation ratio varies from 0.6 to 1.0 over a wide variety of the climatic and geological type. Values close to 1.0 are typically of low relief region, whereas the values ranging from 0.6 to 0.8 are associated with high relief and steep slopes (Strahler, 1964). These values can be grouped into four categories namely,

(i) Circular (>0.9)
(ii) Oval (0.8 -0.9)
(iii) Less elongated (0.7-0.8)
(vi) Elongated (<0.7)

Elongation ratio varies from 0.51 (sub-drainage network no-4) to 1.82 (sub-drainage network no-44), and average elongation ratio is 0.84. Among 68 sub-drainage networks, 24 shows elongated, 20 shows circular, 14 shows less elongated and 10 shows oval shape in the study area.

4.10 Circularity Ratio (Rc): The ratio of the circle having the same circumference as the perimeter of the circulatory ratio (Miller, 1953). It is also influenced by the length and frequency of stream, geological structures, land use/cover, climate, relief and slope of the drainage network and is expressed as:

$$Rc = 4\pi A/P^2$$

Where,
Rc = Drainage circulatory
A = Area of the drainage network
P = Perimeter of the drainage network

Among 68 sub-drainage networks, 30 shows high circularity ratio (>0.5), 38 shows low circularity ratio (<0.50) and the average is 0.47.

5. Relief properties: The drainage frequency (Df), drainage density (Du), texture (T), relative relief (Rr), relief ratio (Rh) and ruggedness number (Rn) are the variables were involved in the present study. The drainage map of the study area includes all ephemeral and perennial streams and its streams in order forming a base map for the study of relief properties. The relief ratio (Schumm, 1956) is a ratio between total relief and longest dimension of the drainage network of the study

area (Rh = RR/Lb). The relative relief (Glock, 1932) that is also known as local relief, representing the variation of altitude in a unit area with respect to its base level (Rh =Z-z).

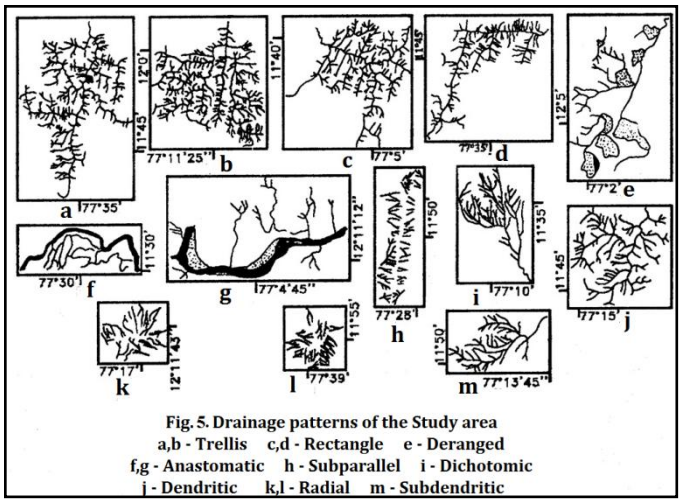


Fig. 5. Drainage patterns of the Study area
a,b - Trellis c,d - Rectangle e - Deranged
f,g - Anastomatic h - Subparallel i - Dichotomic
j - Dendritic k,l - Radial m - Subdendritic

5.1 Drainage: The drainage system belongs to the Cauvery river basin and its tributaries Suvarnavathi and Chikkahole. Drainage pattern can be defined as the design formed by the aggregate of drainage ways in an area regardless of whether they are occupied by permanent streams (Howard, 1967). Initial slope, lithology and meteorological parameters (precipitation in the form of rainfall) is distinctly assertive in the generation of a drainage pattern. The study area has varied drainage patterns viz., trellis, rectangular, deranged, anastomatic, sub-parallel, dichotomic, dendritic, radial, and sub-dendritic types (Fig.4). All these newly developed drainages are indicating the neo-tectonic responses in the study area.

5.2 Drainage frequency: The drainage frequency is the number of streams per unit area (DF =Nu/Au*)*, as defined by Horton (1945). The drainage frequency of the sub-drainage network varies from 0.36 to 7.13 and the average is 2.6. Among 68 sub-drainage networks, 8 show low (0-1) frequency, 29 show high frequency (1-2) and 31 show very high frequency (> 2).

5.3 Drainage density (Dd): The drainage density is the length of streams per unit area (Du = Lu * Au) as defined by Horton (1945). The drainage density of the sub-drainage network varies from 1.62 to 4.08. Among 68 sub-drainage networks, 3 show low (0-1), 38 show high (1-2) and 27 show very high density (2-5). In general, the low values of 'Dd' are the characteristics of regions underlain by highly permeable material with vegetative cover and low relief. Whereas, high values of 'Dd' indicate regions of weak and impermeable subsurface material, sparse vegetation and mountainous relief (Nautiyal, 1994).

$$Dd = L/A$$

where:
L=Total length of streams
A=Area of watershed

The drainage density values of sub-watersheds range from 2.50 to 3.46 indicating coarse drainage texture.

The frequency and density are high because the precipitation and high slope of the scarp, slope initiated streams are numerous, and surface runoff exceeds infiltration. All these factors favor the initiation of streams and accounts for high drainage frequency and density. Presence of varying thickness of soil cover, inhibit the initiation and development of drainage net, implies the low to moderate drainage frequency and density (Muliki and Basavarajappa et al., 2008).

5.4 Drainage texture (Rt): It is the total number of stream segments of all orders per perimeter of the area (Horton, 1945).

$$Rt = Dd \times Fs$$

Where:
Rt = Drainage texture
Dd = Drainage density
Fs = Stream frequency

Smith (1950) classified drainage density into three classes i.e.

(i) Very coarse (<2)
(ii) Coarse (2-4)
(iii) Moderate (4-6)
(iv) Fine (6-8)
(v) Very fine (>8)

Based on Singh (1967) classification, majority of the sub-drainage network (68) belongs to coarse texture due to change in the factors like climate (precipitation), lithology, structure, etc in the study area.

Table.3. Drainage Texture and Density

Sl no	Texture	Density in km/km^2	Sub-drainage network
1	Very coarse	< 1.24	6
2	Coarse	> 1.24 & < 2.49	42
3	Moderate	> 2.49 & < 3.73	18
4	Fine	> 3.73 & < 4.93	2
5	Very fine	>4.93	0

5.5 Relative Relief (Rhp): The relative relief of the sub-drainage network ranges from 10m to 920m.

$$Rhp = H\times (100) / P$$

Where,

H = Maximum drainage relief

P = Perimeter of the drainage (km)

Among 68 sub-drainage networks, 30 show low (0-100m), 15 show moderate (100-300m) and 23 sub-drainage network show high relative relief (300-920m) in the study area.

5.6 Form Factor (Rf): It is defined as the ratio of drainage network area to square of the drainage length (Horton, 1932) and expressed as:

$$Ff = A/Lp^2$$

Where:

Ff = Form factor

A = Area of the drainage network

Lp^2 = Square of drainage network length

The value of form factor would always be less than 0.7854 (for a perfectly circular drainage network). Smaller the value of form factor, more elongated will be the drainage network. The drainage network with high form factors shows high peak flows of shorter duration, whereas, elongated sub-watershed of low form factors shows lower peak flow of longer duration. In the present case sub watersheds have lower Rf value (0.26 and 0.38) indicating an elongated in shape and suggesting flatter peak flow for longer duration. Flood flows of such elongated drainage network are easier to manage than those of the circular drainage network.

5.7 Relief ratio (Rh): Schumn (1956) defined relief ratio as the ratio of maximum relief to horizontal distance along the longest dimension of the drainage network parallel to the principal drainage line.

$$Rh = H/Lb$$

Where:

Rh = Relief ratio

H = Total relief (Relative relief of drainage network in kilometers)

Lb = Length of the drainage network

Relief ratio varies from 1.29 to 216.6. Among 68 sub-drainage networks, 31 shows low (0-10), 11 moderate (10-20), 8 high (20-50) and 18 shows very high relief ratio. Maximum number of sub-drainage network shows low to very high relief ratio, low relief sub-drainage network is found in resistant basement rock like gneisses and very high relief sub-drainage network are found in charnockite rocks having high degree of slope.

5.8 Ruggedness Number (HD): The ruggedness number (dimensionless) is a product of drainage density and relative relief per km and expressed as:

$$Rn = Bh \times Dd$$

Where,

Bh =Relief of the drainage network

Dd=Drainage density

The ruggedness number ranges from 0.01 to 3.25. Among 68 sub-drainage network, 44 shows low (0-0.50), 9 shows high and 15 shows very high (>1.5) ruggedness number. Ruggedness number is low only when the relative relief is low.

6. Slope analysis: Slope map was prepared by SOI topographical map on 1:50,000 scale by adopting template method (AIS & LUS, 1990) and digitized using Cad Overlay software. Slope may define as the loss or gain in altitude per unit horizontal distance in a direction. It may be dependent on lithology, climate, meteorological parameter, runoff, vegetation, geological structure and the process of denudation & that can estimate the run-off and erosion. The maximum development of slopes is found in the hilly terrains. Several methods have been suggested to calculate the slope value (Wentworth 1930; Smith, 1935; Unwin, 1981). Slope map of an area provides information regarding the distribution of various slope classes and helps in understanding the runoff characteristics of the watershed (Basavanna, 1996). It is helpful in prioritizing areas for developmental measures and identification of suitable areas for agriculture (Sreedhara et al., 1996).

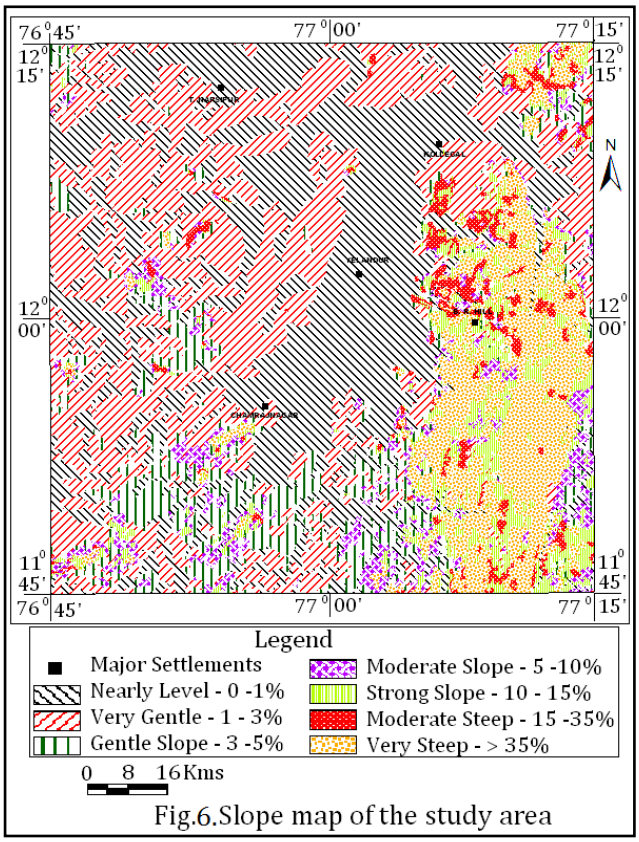


Fig.6.Slope map of the study area

6.1 Slope aspects: The SOI toposheets of 1:50,000 scale with 20m contour interval has taken to study the slope properties. The catchment characteristics (run-off and erosion) of an area are determined by the slope. Steeper the slope, higher is the run-off & erosion and lesser run-off towards gentle slope (Dinakar, 2005). A major part of the study area is dominated by nearly level slope (35%) varying from 0° to 1°. The low laying areas of gneissic terrain are noticed in the central, northwest and southwestern part. These regions mainly falls under pediplain landforms adjacent to the river Cauvery and its tributaries Kabani and Suvarnavathi. The second most significant slope category is the very gentle slope (30.6%) varying from 1° to 3°. It covers northwest and southwestern part of gneissic terrain and also some portion in northeastern part of amphibolite rocks (Satish, 2002; Dinakar, 2005). The nearly level slope and very gentle slope regions may provide good scope for infiltration of rainfall. The third most significant slope category having very steep slope (11.89%) varying >35° which are observed towards south-east part of charnockite terrain. These are hilly terrain having escarpments, parallel ridges, valleys, cliff are initiated in the slope. A stupendous rise in elevation is seen within a short distance that contribute to the rapid increase in slope as indicated by the closely spaced contour lines in the area, is dominated by charnockite terrain. The fourth most significant category is the gentle sloping (9.49%) varies 3° to 5°, occupies the southwestern parts of the study area. The pockets of varying slope within the low lying gneissic terrain is represented by residual hills, ridges, mounds, spurs and peaks. Moderately steep to steep sloping, strongly sloping, moderately sloping contributes only the small portion of 2.74%, 5.86% and 4.38%, respectively and varies from 5° to 35°. These are mainly noticed in south-eastern part of Biligirirangan hill ranges and also in south-western parts (Satish 2002, Basavarajappa et al, 1996).

Table.4. Slope categories in the study area

Sl no	Slope Category	Lower and Upper Limit of Slope Percentage	Lower and Upper Limit of Contour Spacing (cm)	Area in sq km	Percentage (%)
1	Nearly level	0 – 1	>4	1054.1	35.00
2	Very gently sloping	1 – 3	1.33 – 4	922.2	30.62
3	Gently sloping	3 – 5	0.80 – 1.33	285.9	9.49
4	Moderately sloping	5 – 10	0.40 – 0.80	131.9	4.38
5	Strongly sloping	10 – 15	0.26 – 0.40	176.4	5.86
6	Moderately steep to steep sloping	15 – 35	0.10 – 0.26	82.8	2.75
7	Very steep sloping	>35	0.11 and above	358.1	11.89

7. Conclusions:

- The terrains are geomorphologically characterized by youthful rugged high hills and are structurally controlled mountain ranges with steep slopes, scarp faces, narrow gorges and long parallel ridges. These hill slopes are having steep valleys and triangular facets.
- Pediplains are recorded near the river courses and the stream courses are structurally controlled and joined the main streams approximately at right angles. The stream courses are narrow and are controlled by lineaments. However, the topography changes wih bedrock lithology is peninsular gneiss of the shear zone.
- Circularity ratio and elongation ratio values suggest that the study area has youthful sub-drainage network. The sub-drainage networks are moderate to highly dissected and highly rugged. Majority of the sub-drainage networks are characterized by high drainage texture indicating the rocks are undergone the highly shearing effect.
- Presence of varying thickness of soil cover, inhibit the initiation and development of drainage net, implies the low to moderate drainage frequency and density. Slope is level to gently sloping. In this terrain, pediplain and pediment are characterized by the absence of any major hills and mounts. Alluvial plains, few small ridges and hills.
- The river system, drainage network, paleochannels, structural features, fracturing, shearing, weathering of high grade Precambrian rocks were highly influenced on the topography, slope, thickness of the lithounits, distribution of water bodies and ground water system of the NS Kollegal Shear Zone.

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