AGRICULTURAL DEM GENERATION AND QUANTITATIVE MORPHOMETRIC ANALYSIS OF SAN DIEGO RIVER, CA, USA

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Abstract

Present study presenting the Digital Elevation Model generation from SPOT 5 stereoscopic pairs using ArcGIS software. DEM generation has been generated with spatial resolution 3m. After DEM generation San Diego River Basin extracted from DEM and Quantitative Morphometric Analysis has been done. The San Diego River flows from Cuyamaca Mountains range then it reaches to El Capitan Reservoir which is larges reservoir of watershed then the river runs towards west through city San Diego and finally discharges into Pacific Ocean. In this study Morphometric Analysis done on the river which lies between latitude 320 45’28” to 320 53’07”N and longitude -1170 15’09” to -1160 48’39”W i.e. the area selected from EI Capitan Reservoir to the discharging point of the river. The study area found sixth order of stream order which satisfies the (R. E. Horton 1932, 1945) theory. San Diego River Basin found less influenced by structural disturbances and having good structural control in this region. Area is having relative close to coarse drainage texture and the surface is less affected by the agents of denudation. Basin has been observed elongated in shape.

Keywords

SPOT5 DEM generation, Morphometric Analysis, Geographical Information System, San Diego River.

Introduction

Digital Elevation Model (DEM) module enables us to extract elevation data from the stereo imagery to create DEM. A DEM represents the raster grid value by that we get know the actual surface height. DEM can be prepared by number of ways like one of the technique is Interferometric synthetic aperture radar where single pass or two passes of the satellite equipped with two antennas to generate DEM with spatial resolution around ten meters; On the other way stereoscopic pairs can be used to generate DEM where two optical images are acquired with two different angles taken from the same pass by airplane or by Earth Observation Satellite (such as the HRS instrument of SPOT5). The launch date of SPOT5 satellite is May-4-2002 with altitude of 822km and the orbit period is 101minutes. The DEM could be acquired through different techniques such as Photogrammetry, lidar, IfSAR, land surveying, etc. (Li et al. 2005; Gopala et al., 2008; Babu et al., 2012). After DEM generation we can use it in different applications.

Today remote sensing, GPS and GIS technology referred as spatial information technology are the fastest emerging technology around the world and especially in India. These technologies are act as an effective tool and used to overcome most of the problems related to water and land resources planning and management (Rao et al. 2010; Feifei et al., 2013).

In this study first DEM generation has been taken place with spatial resolution obtained 3m then on the final output DEM an area extracted from ArcGIS software and Quantitative Morphometric Analysis have been performed on it. Morphometric Analysis gives the appropriate estimation of the morphometric parameters and better understanding of hydrologic system (Patel et al., 2012; Clarke et al., 1966); on the basis of these parameters we can extract the useful information that will reveal the characteristics and features of the area.

Initial Data

First data has been taken form Satellite Probatoired’ Observation de la Terre (SPOT-5), SPOT-5 is the fifth satellite in the SPOT series of CNES (Space Agency of France) and launched on May 4, 2002. The SPOT 5 satellite data used from High Resolution Geometrical (HRG) instrument sensor and the stereoscopic pairs were used with spatial resolution of 5m each and the data selected with almost 1 year difference. Following description mentioned in given below table:

Table 1 Data source description

Image pairs	Left	Right
Imaging sensor	HRG 2	HRG 2
Resolution (m)	5	5
Satellite	SPOT 5	SPOT 5
Area	USA	USA
Date of Acquisition	06-10-2002	13-11-2002

Study Area

The study area 'San Diego, CA to EI Capitan Reservoir, USA' lies between latitude 320 45'28" to 320 53'07"N and longitude -1170 15'09" to -1160 48'39"W extracted from generated SPOT 5 DEM. Figure1 showing the actual San Diego River part taken in this study which is situated in north west direction from Greenwich. San Diego River originates from Cuyamaca Mountains range then it reaches to El Capitan Reservoir which is larges reservoir of watershed then the river runs towards west through city San Diego and finally discharges into Pacific Ocean. The length of the San Diego River is about 84 Km but in this study the area selected for study is from EI Captain Reservoir to the discharging point of river Pacific Ocean (Figure 1). The average temperature in San Diego during the winter season is 57 degrees Fahrenheit and the average temperature during the summer season is 74 degrees Fahrenheit. The average rainfall in San Diego is 10.34 inches.

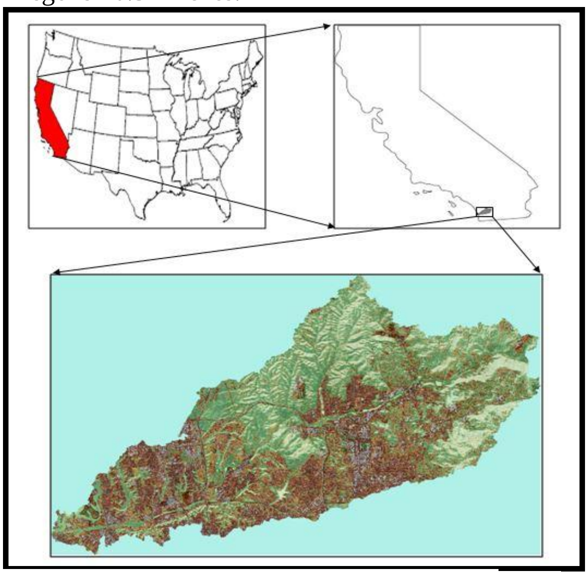

Figure 1. Study area San Diego River Basin

Methodology

Methodology for DEM generation

This section deals with the DEM generation by the process of stereography using ENVI software and final DEM has been generated with spatial resolution of 3m. After obtaining the DEM, Morphometric Analysis has been done using ArcGIS software (Figure 2). Following methodologies given below for Dem generation:

A. Input parameters such as SPOT 5 stereo pairs from SPOT series.

B. Define the GCPs and Tie points on both the stereo pairs using ENVI software.

C. Edit Tie points to minimize the Y-parallax and it should be less than 1.

D. Calculation of Epipolar geometry and specifying the parameters such as projection type, pixel size, output file name etc. for final output DEM.

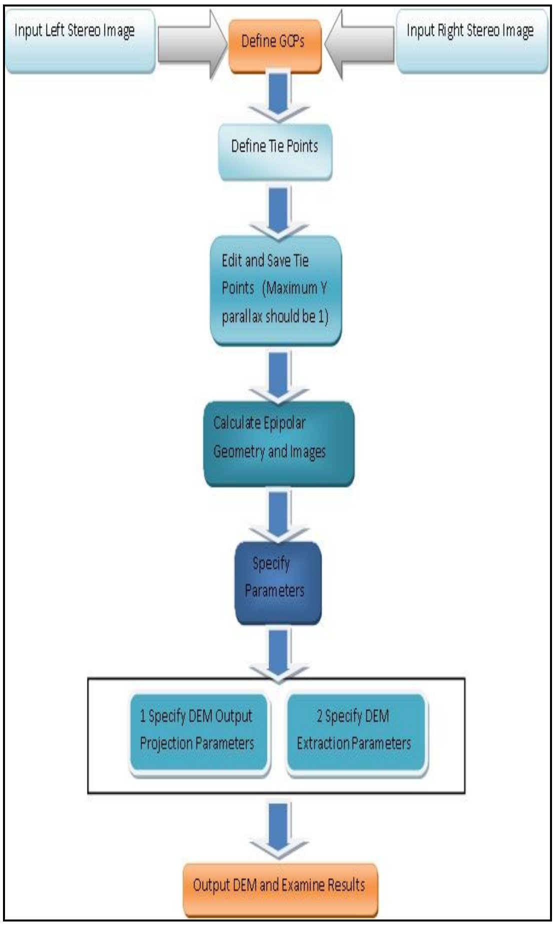

Figure 2. Methodology for DEM generation by Stereography process

Methodology for Quantitative Morphometric Analysis

Table 2. Methodology for computation of morphometric parameters

Parameters	Formulae	References
Stream order(U)	Hierarchical rank	Strahler (1964)
Stream length(Lu)	Length of the stream	Horton (1945)
Mean stream length (Lsm)	Lsm= Lu/Nu Where Nu is no. of streams	Strahler (1964)
Stream length ratio(Rl)	Rl=Lu/(Lu-1)	Horton (1945)
Bifurcation ratio(Rb)	Rb=Nu/(Nu+1)	Schumm (1956)
Mean Bifurcation ratio(Rbm)	Rbm=Average of all bifurcation ratios	Strahler (1957)
Drainage density (Dd)	Dd=Lu/A	Horton (1932)
Drainage intensity (Di)	Di= Fs/Dd	Faniran (1968)
Infiltration Number (If)	If=Fs*Dd	Faniran (1968)
Drainage texture(T)	T=Nu/P	Horton (1945)
Texture ratio	Rt=N1/P	Schumm (1965)
Stream frequency (Fs)	Fs=Nu/A	Horton (1932)
Elongation ratio(Re)	Re = (2 / Lb) * (A /π)0.5	Schumm (1956)
Circularity ratio(Rc)	Rc=4pA/ P2	Miller (1953)
Form factor(Ff)	Ff=A/Lb2	Horton (1932)
Length of overland flow(Lg)	Lg = A/(2*Lu)	Horton (1945)
Shape factor ratio(Rs)	Rs=Lb2/A	Horton (1956)
Relative perimeter (Pr)	Pr = A / P	Schumm (1956)

The methodology followed by DEM generation is for quantitative morphometric analysis and in this section analysis performed on the SPOT5 DEM with spatial resolution 3m. Earlier we use conventional methods to calculate the morphometric parameters but they are more time consuming and chances to give more errors and nowadays we have different software's to perform these analysis using spatial analyst tools. For basin analysis following procedure adopted (Table 2):.

A. SPOT 5 DEM has been used to delineate watershed.
B. Spatial Analyst Tool has been used to prepare slop map and to delineate drainage map of ArcGIS software.
C. All the parameters of linear and Areal aspects such as stream order, stream length, drainage density, drainage intensity, form factor, elongation ration etc. were calculated using ArcGIS software.

Results and Discussion

DEM generation

DEM generation has been performed in the ENVI software. (Titarov et al. 2008) suggested that in the case of single stereo pair, four well-distributed and reliable GCPs are sufficient to achieve sub-pixel orientation accuracy (Das et al., 2005; Giribabu et al., 2013; Lee et al., 2003). Two SPOT 5 stereo pairs Data set and Stereography process has been used for DEM generation. Tie points on both stereo pairs are needed to be accurate and the parallax should be less than 1. SPOT5 DEM has been obtained with spatial resolution 3m which is good enough for Quantitative Morphometric Analysis. DEM generation topic is still an active topic and we can generate more high spatial resolution DEM with help of other satellites that are providing high spatial resolution images. We can further work on it by applying multi-spectral image combination on DEM and could be extracting more information.

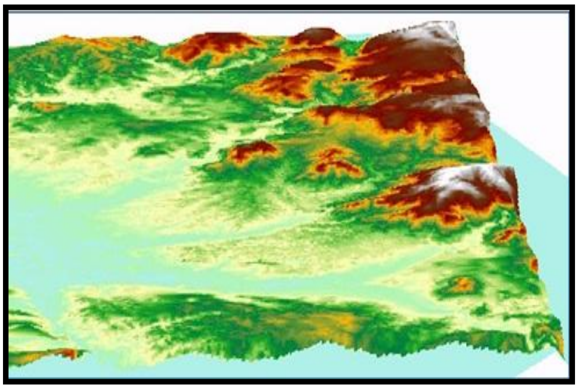

Figure 3. Final Output of SPOT5 DEM

Quantitative Morphometric Analysis

Morphometric Analysis is the term used to define the origin and behaviour of drainage basin that is very useful for water resource studies. Earlier this analysis has been done using manual operation by the help of GPS or DGPS but in current time we perform this analysis by the help of spatial analyst tools. SPOT 5 DEM has been generated with spatial resolution 3m and this DEM used in this study rigorously to calculate the morphometric parameters. Watershed and drainage network were delineated by the following methodology (Table 1).

Table 3. Linear aspect of the San Diego River Basin

Stream order	No. of streams (N_u)	Bifurcation ratio(R_b)	Mean Bifurcation ratio	Total length of streams(Km)	Mean stream length (Km)	Stream Length ratio	Mean length ratio(R_l)
I.	13507		1.9464	824.6958	0.062849		0.5794
II.	7010	1.9268		421.1039		0.5106	
III.	2759	2.5408		206.9238		0.4914	
IV.	1096	2.5173		86.9996		0.4204	
V.	798	1.3734		38.9413		0.4467	
VI.	581	1.3735		39.7513		1.0208	
Total	25751			1618.4158			

Linear Aspect of San Diego River

The linear parameters such as stream order, stream length, bifurcation ratio, total steam length were calculated using ArcGIS software. Total length of the stream found 1618.4158 km and the stream order of the basin reaches maximum sixth order to satisfy R. E. Horton's law mentioned in (Table 3). As shown in (Figure 2) the stream order increases and stream number decreasing or vice versa.

Stream Order (S_u) and Stream Number (N_u)

(Horton 1945, Strahler 1957) revealed that the stream order increases with the number of stream number decreases. In this study the relation obtained satisfies the R. E. Horton's law. The correlation between stream order and stream number gives positive result (Figure 4, Figure 6 and Table 3).

Bifurcation Ratio (R_b)

Bifurcation ratio defined in such a manner that the total number of streams in a particular order is divided by the total number of streams of next higher order i.e. $R_b = N_u/N_u+ 1$. Where R_b is the Bifurcation ratio and N_u is the number of streams in a particular order. Mean bifurcation ratio is 1.9464 and this value indicates that the basin having less influenced by structural disturbances and having good structural control in this region. The irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler 1964).

Stream Length (Lu)

By the use of spatial analyst tools of ArcGIS software stream length of study area has been delineated. Stream lengths of San Diego River Basin have various orders varies from first to sixth order distributed in whole basin. Total stream length fond 1618.4158 km as shown in (Figure 5, Table 3).

Mean stream length (L_{sm}) and Stream length ratio (R_L)

The mean stream length is the describing the characteristics of the size of channels and distribution within the basin surface (Strahler 1964). Mean stream length observed 0.062849 km. Stream length of a particular order may mismatch the length of stream due to variation in slop of area and its topographic features. There is a change from one order to another order indicating their late youth stage of geomorphic development (S. Singh et al. 1997; Subyani et al., 2010).Stream length ratio (RL) may be defined as the ratio of the mean length of the one order to the next lower order of stream segment (Table 3).

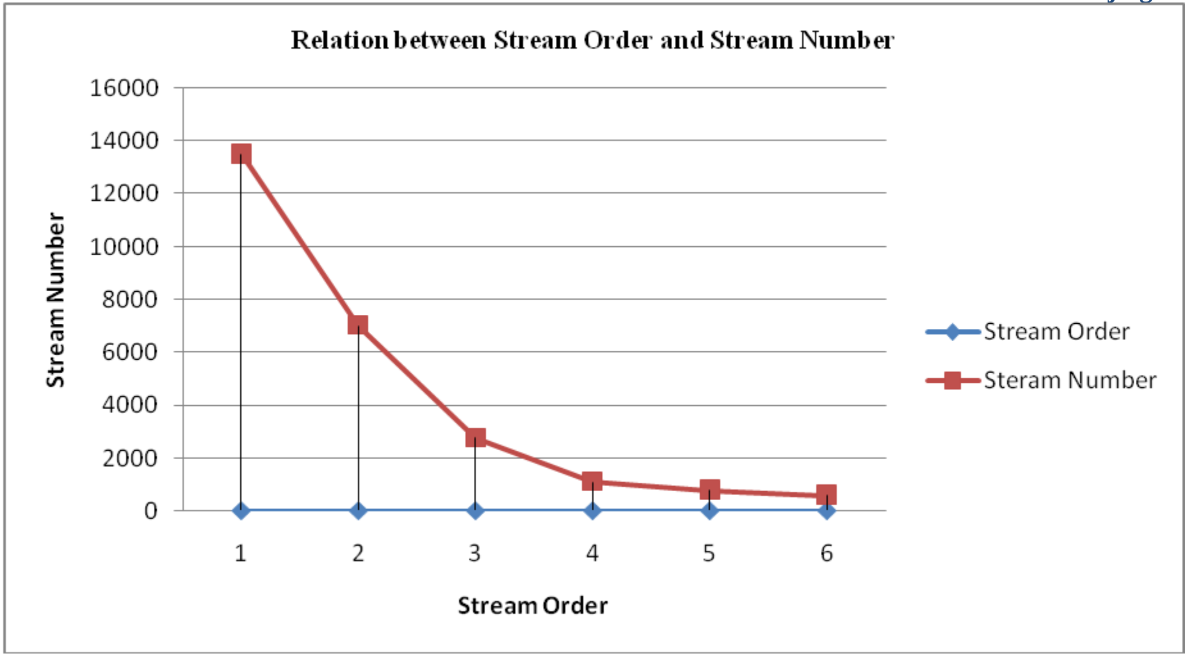

Figure 4 Relations between Stream Order and Stream Number

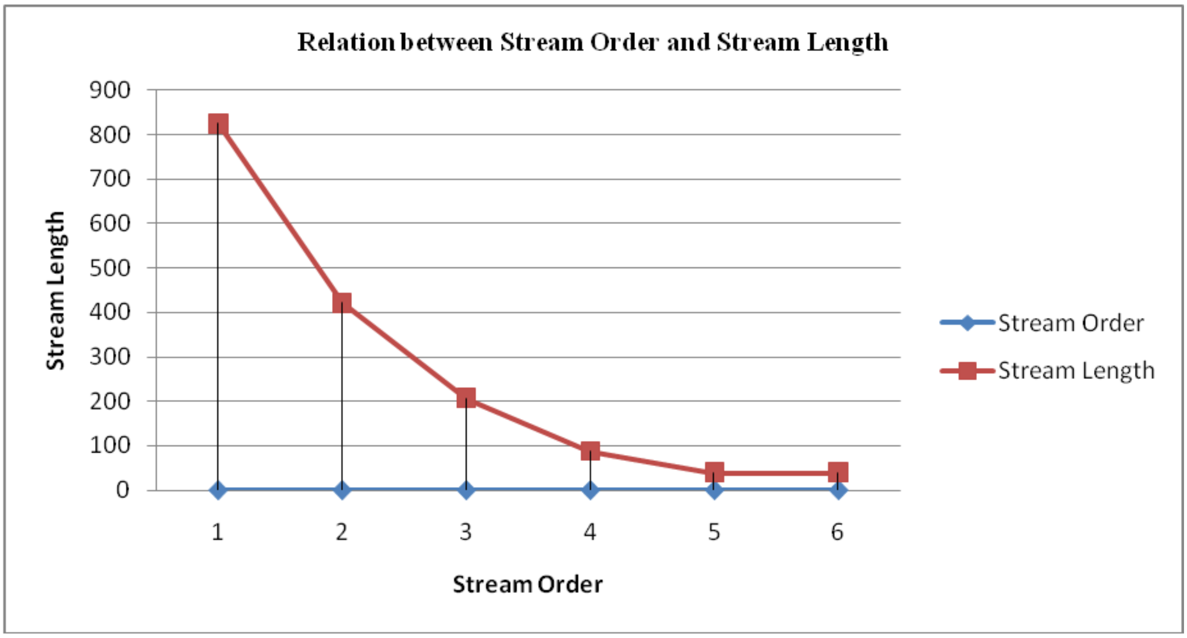

Figure 5 Relations between Stream Order and Stream length

Areal Aspect of San Diego River

Drainage Density (D_d) and Drainage texture (D_t)

Drainage density is the ratio of the total stream lengths to the total stream orders per unit area (R.E. Horton 1932). The Drainage Texture of San Diego River Basin has been divided into five major classes; Very coarse, Relative to coarse, Moderate, Fine and Very fine (Singh et al., 2013; Singh et al., 1997; Pawar et al., 2014). It indicates the part of area belonging to the region is coming under relative close to coarse category. In this study the Average Drainage Density observed 3.4071 km/km2 which indicates towards the area is having relative close to coarse drainage texture and the surface is less affected by the agents of denudation (Figure 8, Table 4).

Stream frequency (Fs)

Fs mainly depend on the lithology of the basin and the texture of the drainage network (John Wilson et al. 2013). Horton proposed that the Stream frequency (Fs) is the total number of streams segments of all orders per unit area (Horton 1932). The average stream frequency of San Diego River Basin obtained 54.2125 km/ km^2 (Table 4).

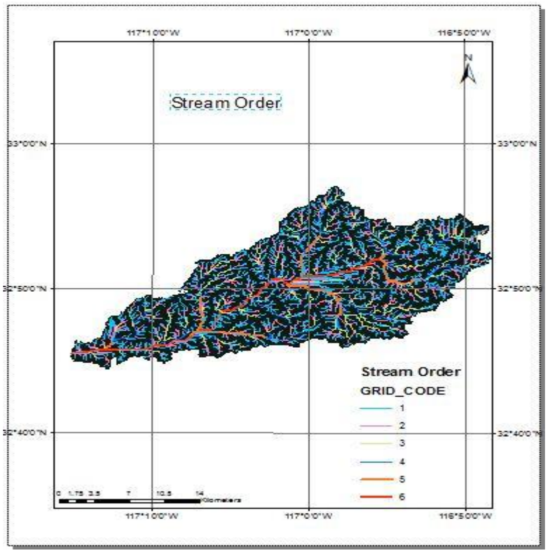

Figure 6. Stream Order of San Diego River

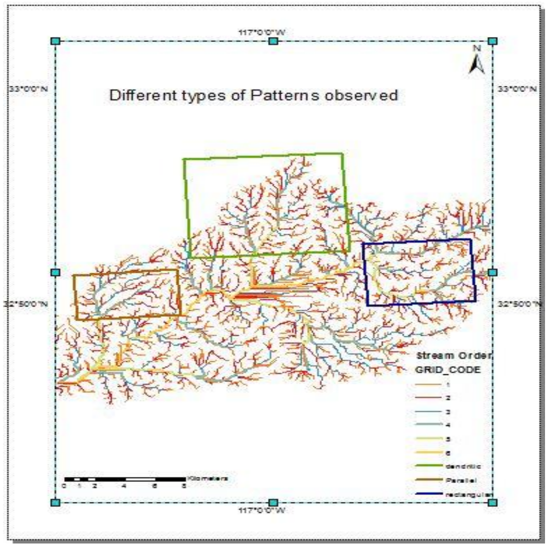

Figure 7. Different types Patterns observed

Circularity Ratio (R_c)

Circulatory Ratio of the basin is 0.2524 which indicates that the area having low discharge runoff and highly permeable soil. R_c is a circular area covers the surrounding basin perimeter environment. Factors that influence circularity ratio such as stream frequency length, geological structure, slop and topography of the area (Table 4).

Elongation ratio

(Schumm 1963) has defined the different categories of Elongation ratio; Circular, Oval, less Elongated, Elongated, More Elongated. The elongation ratio obtained after calculation is 0.5481, this reveals that the area is elongated in shape. Form factor of the basin is obtained 0.3885 and this value is also indicating towards that the area is elongated in shape because lower value of the Form factor (R.E. Horton 1932) (Table 4).

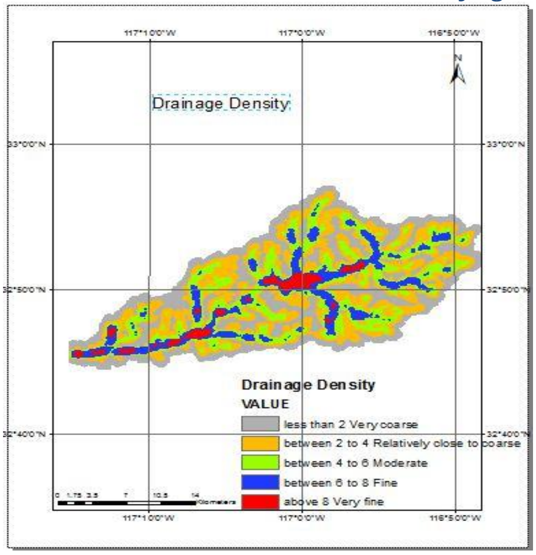

Figure 8. Drainage Density Map

Table 4 Areal aspect of the San Diego River Basin

Parameters	**Results**
Basin area(sq Km)	475.001
Perimeter (Km)	153.769
Basin Length L_b	44.868
Relative perimeter (P_r)	3.0891
Form factor	0.3885
Elongation ratio(R_e)	0.5481
Circularity ratio(R_c)	0.2524
Drainage density km^2	3.4071
Drainage intensity	15.9116
Infiltration Number I_f	184.7074
Stream frequency	54.2125
Texture ratio	87.8395
Drainage texture	167.4655
Length of overland flow	0.1467
Shape factor ratio	4.2382

Form Factor (F_f)

The ratio of the surface area of the square of the length of the drainage basin is known as Form Factor (Horton 1932). If the value of form factor is 0.754 then the basin will be perfectly circular in shape but when the value decreases the length of the basin will be increases means basin will be found elongated in shape. Form factor of the given basin is 0.3885 which indicates the basin is elongated in shape (Table 4).

Infiltration Number (I_f)

When Infiltration number is high then the infiltration is low and high runoff. In this study infiltration number calculated 184.7074 this value shows high value of infiltration number means area having low infiltration capacity and high runoff (Table 4).

Length of overland flow (L_g)

The length of overland flow defined in such a manner that the rainwater on the ground surface before falling down into a definite channel (Horton 1945). The value of length of overland flow obtained in this study is 0.1467 kms this shows that the study area is having low runoff (Table 4).

Drainage pattern (D_p)

An area drained by a single river is called its drainage basin or catchment area. Drainage system or drainage patterns defined as the patterns observed on the basin drained by a single river. Patterns are depends on the relief and property of rocks present on the surface. In the present study area three different types of drainage patterns were found such as 'Dendritic', 'Parallel' and 'Rectangular'(Figure 7).

Conclusions

San Diego River Basin, USA extracted from SPOT 5 DEM. The study area starts from EI Captain Reservoir and end to the mouth of Pacific Ocean. Study is having sixth order of stream order and a large portion area covered around 475 km^2 and Basin perimeter is 153.769 km. Due to higher value of infiltration number the area having high discharge runoff and low permeable soil. The elongation ratio obtained after calculation is 0.5481, this reveals that the area is elongated in shape. Form factor is 0.3885 and this value is also indicating towards that the area is elongated in shape because lower value of the Form factor. Average Drainage Density observed 3.4071 km/km^2 which indicates towards the area is having relative close to coarse drainage density and the surface is less affected by the agents of denudation. These factors can be used for flood mapping, determining Landslide prone area, reservoir establishment etc.

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