Extraction of drainage Characteristics and Morphometric analysis using GIS and SRTM Digital Elevation Model Data in Sathyavedu area, Chittoor District, Andhra Pradesh, India

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ABSTRACT

The aim of the present study is to extraction of the drainage characteristics from SRTM 30M resolution data processed in Arc GIS 10.1and develops the different maps such as Drainage fill, flow accumulation, stream link, flow direction, stream order map. The study area stream order map shows 5 orders. Most of the stream area flow in the direction of North West to south west and it determine the less porosity and permeability due to presence of the granite schist, quartzite's and laterite group of rocks and SRTM DEM with spatial resolution of 30 m.

Keywords: *SRTM Dem Map, Drainage Fill, Flow Accumulation, Stream Link, Flow Direction, Stream Order map and LISS-III Satellite map.*

1. INTRODUCTION

1.1 Digital elevation model (DEM) represents the surface of Earth and different object of the topographical and slope direction and landscape feature (**1**). Relief maps were generated from the DEM data which is often used in geographic information system (**2**).Demarcation of terrain parameters, such as slope, drainage network, watershed boundaries etc., These parameters are often required in preparation of development and conservation plan for natural resources, infrastructure development, town planning (**3**). DEM represent the three dimensional view of earth surface. Moreover, it represents the triangular irregular network (TIN) and contour maps (4).DEM play a prominent role in hydrological model lining **(5)**.

2. STUDY AREA

Sathyavedu is the one of the Mandal in chittoor district of Andhra Pradesh. The Mandal is situated on the coast of the Bay of Bengal; it is bounded by Bangarupalem, Sadhum, Appaihpalem, Nagiri. This area is included in the toposheet No's. 57 O/14, 0/15 and covers an area of 246.25 km² and is located between longitudes 79º 59'0''E and latitudes 13º 26'0''N. It has located 60 Km north of Chennai metropolitan city.

Sathyavedu town is easily accessible by road and railway transport. According to 2011 census, the Sathyavedu area has the population of 52,979. Sathyavedu vicinity has 30 settlements and it includes the small towns and villages and it's shown Figure 1.1. The majority people of the study area depend on Arani River for potable water usage.

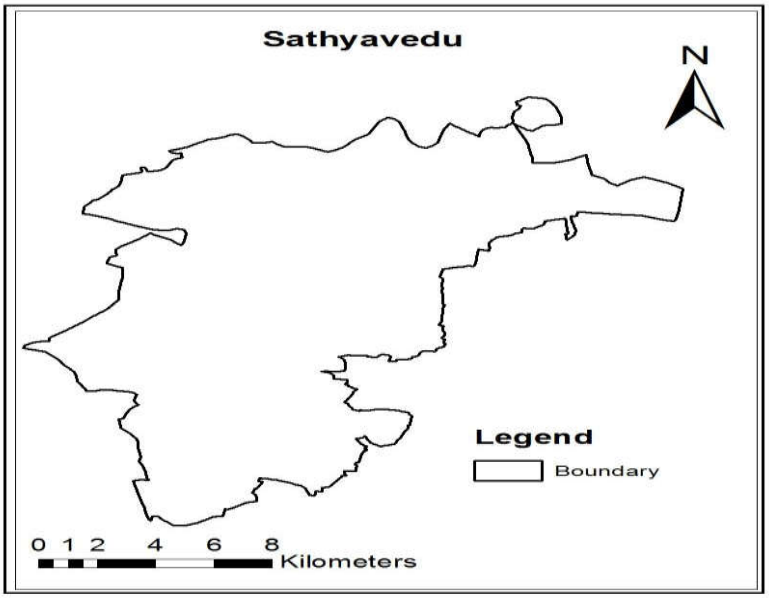

Figure 2.1 Location Map of the Study Area

3. METHODOLOGY

The freely available SRTM 30 m resolution data of one arc-second (arcsec) grid was downloaded from USGS earth explorer with a GeoTIFF format and geographic coordinates. The radars used during the SRTM mission were actually developed and flown on two Endeavour missions in 1994. The C-band Space borne Imaging Radar and the X-Band Synthetic Aperture Radar (X-SAR) hardware were used on board the space shuttle in April and October 1994 to gather data about Earth's environment. This mission used single-pass interferometer, which acquired two signals at the same time by using two different radar antennas. With reference to GDEM1, the improvements in GDEM2 include increased horizontal and vertical accuracy, as compared to both GPS benchmarks and standard DEMs, and improved horizontal accuracy and resolution. Downloaded SRTM GDEM 30 m data was reprojected to Universal Transverse Mercator (UTM) projection the extent of the study area to extract various drainage properties.

3.1 Extraction of automated drainage pattern

Digital elevation models are created by collecting elevations and referencing them to corresponding points in the mapped area.

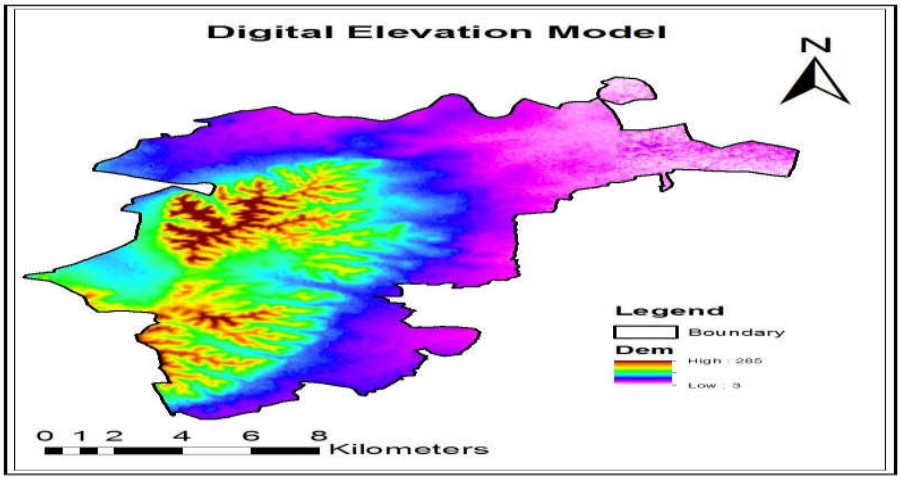

Figure 3.1 Shows Digital Elevation Model

The elevations add a z value to the ground's x and y horizontal coordinates. The DEM of the study area is created in the 3D Analyst extension of Arc GIS 10.1 software. This extension has the capability of three dimensional (3D) visualization and analysis. To get the realistic view of the region, the RESOURCESAT- 1 satellite imagery is draped over the DTM (**6**). The elevation map that shows the elevation from the mean sea level in meters is derived from the DTM and shown in the Figure 3.1 and satellite map 3.2

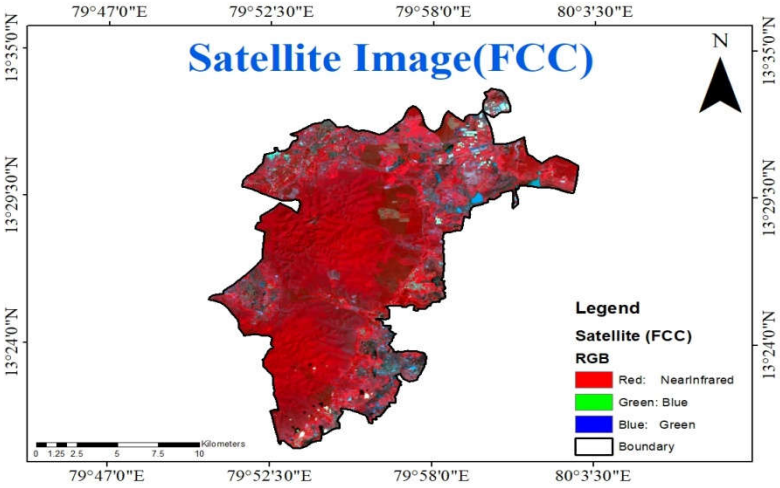

Figure 3.2 Satellite Map of the Study Area

3.2 Drainage fill

A filled digital elevation is a depression of void. A depression is a cell's in an elevation raster that are surrounded by higher elevation values and thus represents an area of internal drainage. Fill map is shown in Figure 3.3

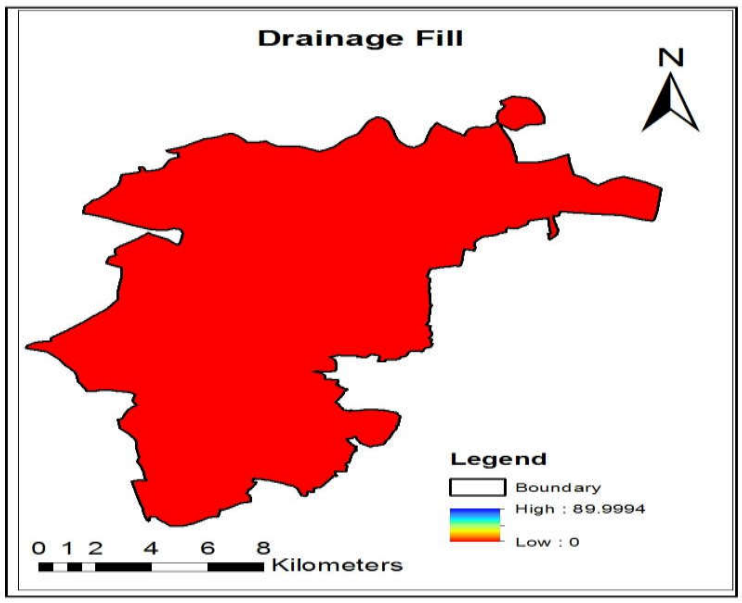

Figure 3.3 Drainage Fill Map of Study Area

3.3 Flow accumulation

A flow accumulations raster tabulates for each cell, the number of cells that will flow to it. The tabulation is based on the flow direction raster with the appearance of a spanning tree a flow accumulation raster records how many upstream cells will contribute drainage to each cell. It is shown in Figure 3.4.

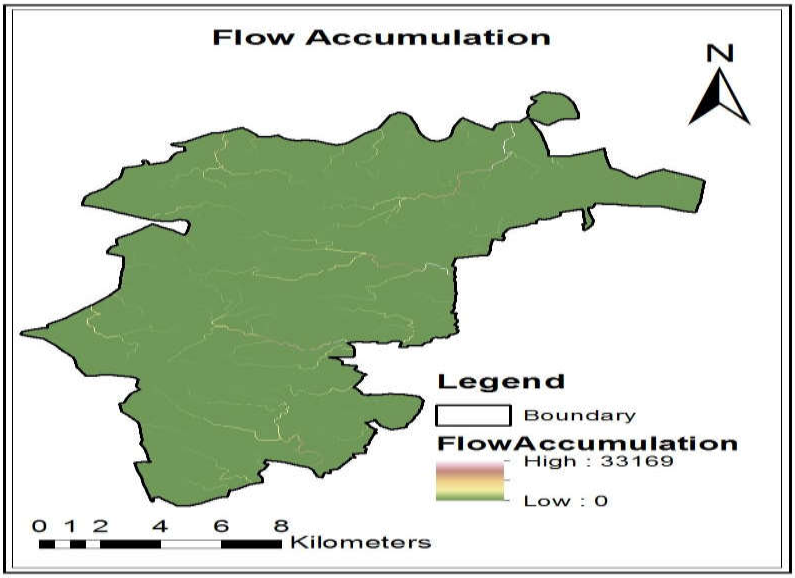

Figure 3.4 Flow Accumulation Map of Study Area

3.4 Flow direction

A flow direction raster shows the direction water will flow out each cell of a filled elevation raster. A widely used method for deriving flow direction is the D8 method. Used by Arc GIS. The d8 method assigns a cell's flow direction to the one of its eight surrounding cells that has the steepest distance-weighted gradient. It is shown in Figure 3.5.

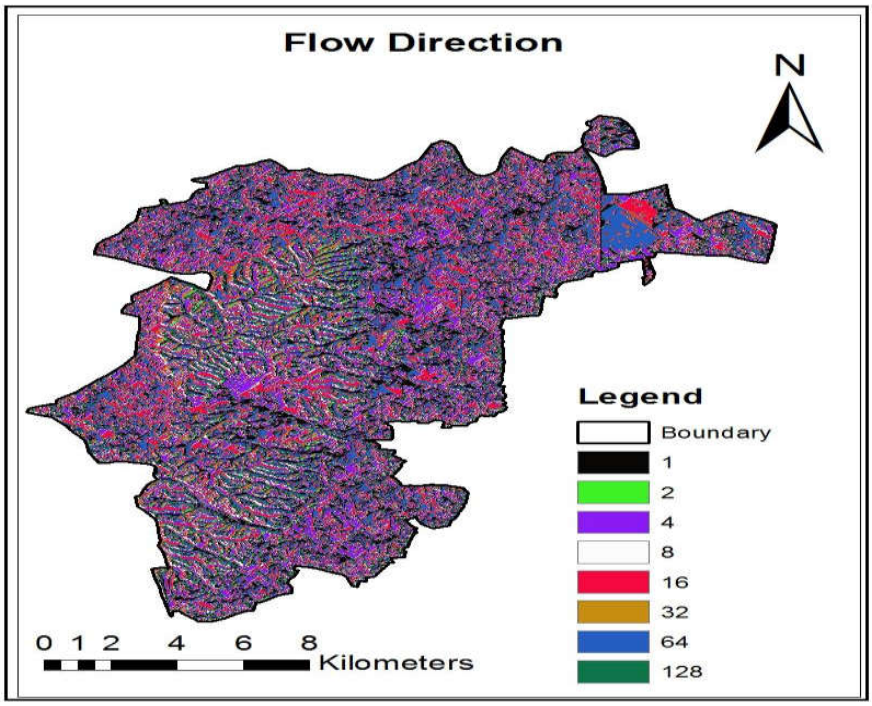

Figure 3.5 Shows Flow Direction of Study Area

3.5 Stream link

A stream network is derived from a flow accumulation raster, each section of the stream raster line is assigned a unique value and is associated with a flow direction. A stream link raster therefore resembles a topology-based stream layer and the intersections are like nodes shown in Figure 3.6.

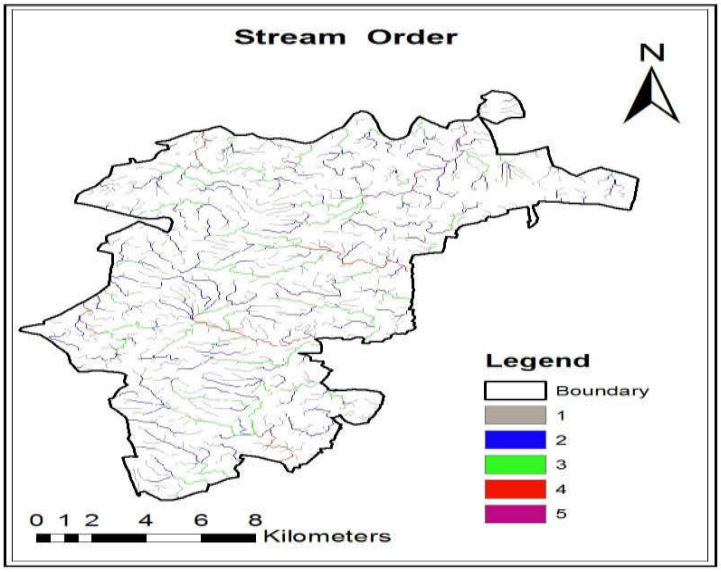

Figure 3.6 Stream Link Map of Study Area

4. MORPHOMETRIC ANALYSIS

The aim of morph-metric indices evaluate quantitative morphmetric analysis of the study area using IRS-R2 LISS-III satellite image with reference to SOI toposheet and SRTM-30 resolution (shuttle radar topographic mission) data in the GIS Environment.

Table: 4.1 Morphometric parameters of the area calculated using Arc GIS package software

S. no.	Parameter	Formula	References	Values
1	Stream order (U)	Hierarchical rank	Strahler (1964)	5^{th}
2	Stream length (Lu)	Length of the stream	Horton (1945)	116.29
3	Mean stream length (Lsm)	Lsm = Lu/Nu	Strahler (1964)	1
4	Stream length ratio (RL)	RL = Lu/(Lu − 1)	Horton (1945)	1.237676475
5	Bifurcation ratio (Rb)	Rb = Nu/Nu + 1	Schumm (1956)	0.838901956
6	Drainage density (Dd)	Dd = Lu/A	Horton (1945)	0.021146802
7	Drainage texture (T)	T = Dd × Fs	Smith (1950)	0.000447187
8	Stream frequency (Fs)	Fs = Nu/A	Horton (1945)	0.021146802
9	Elongation ratio (Re)	Re = D/L = 1.128√A/L	Schumm (1956)	3.399197
10	Circulatory ratio	Rc = 4πA/P2	Strahler (1964)	0.228824
11	Form factor (Ff)	Ff = A/L2	Horton (1945)	9.081014

12	Length of overland flow (Lg)	Lg = 1/D × 2	Horton (1945)	27.82332
13	Relief	R = H − h	Hadley and Schumm (1961)	54.76

Drainage networks extracted from sources i.e., SRTM DEM data From SRTM data, a series of geoprocessing tools are used for getting drainage network of the study area and the derived toposheet drainage network has been updated to LISS III satellite image. Evaluation of drainage analysis necessitates drainage parameter i.e. order of the stream, preparation of slope, hill shade and aspect maps, drainage texture, drainage texture ratio, drainage density, elongation ratio, form factor, stream frequency, circularity ratio and infiltration number. And finally, the relief aspects enclose of ruggedness number total relief or relative relief and relief ratio, relative relief.The Drainage system of the area was analyzed as per Horton's (1945) low and the stream order turned into made after Strahler (1964).

4.1 Basin

The total area of Sathyavedu is 246.25 km^2.The area value was measured from the using the calculate geometry tool in Arc GIS 10.1.

4.2 Basin length (L)

The area length corresponds to the maximum length of the area and sub-areas measured parallel to the main drainage line. The area length is 116.km.It is concluded that the shape of the area indicates the flow rate of water.

4.3 Stream order

Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries. The streams of the Sathyavedu area have been ranked according to the Strahler's (1964) stream order system and the number of stream of each segment (Nu) of the order (U).From the stream order analysis, it is noticed, fifth order streams generated in the study area.

4.4 Stream length (Lu)

The stream length, Mean stream length and stream length ratio were calculated using Geometry tools in Arc GIS10.1, based on the law proposed by Horton (1945). In general, the total length of stream segments decreases as the stream order increases. Plot of the logarithm of stream length versus stream order showed the linear pattern which indicates the homogenous rock material subjected to weathering erosion characteristics of the area. Deviation from its general behaviour indicates that the terrain is characterized by variation in lithology and topography (7)

4.5 Mean stream length (LSM)

Mean stream length is characteristic property related to components of a drainage network and it's contributing area surfaces (**17**). It is obtained by dividing the total length of the stream of an order by a total number of segments. The values are directly proportional to the size and topography of the area. The Mean stream length of the study area is 5.204.

4.6 Stream length ratio (Rl)

Horton (1945) states that the length ratio is the ratio of the mean (Lu) of segments of order(So) to mean length of segments of the next lower order (Lu-1), which tends to be constant throughout the successive orders of a area. Stream length ratio is a very important parameter to scan the hydrological characteristics of the area, because of permeability of the rock formations in area. It also indicates if there is a major change in the hydrological characteristics of the underlying rock surfaces with the area (**10**). RL between successive streams order varies due to differences in slope and topographic conditions (**9**).

4.7 Bifurcation ratio (Rb)

The ratio of the number of streams of any given order will be the number in the next lower order. The mean bifurcation ratio (Rbm) characteristically ranges between 3.0 and 5.0 for an area whereas the influence of geological.

Structures on the drainage network are negligible. In the study area bifurcation value should be 0.9. It shows that geologically no distortion occurred.

4.8 Drainage density (Dd)

According to Horton (1945), Drainage density is defined as the ratio between the total stream lengths of all orders to the area. As per Smith (1950) classification, Dd has classified into five different textures as <2 (Very coarse), 2-4 (Coarse), 4-6(Moderate), 6-8(Fine) and >8(Very fine). In the study area drainage density should be in <2, it indicates the low drainage density, denotes permeable sub-surface strata and has a characteristic feature of very coarse drainage.

4.9 Drainage texture (T)

Drainage Texture (T) is the product of Drainage density (Dd) and stream frequency (Fs). The total area is 0.0004; Drainage Texture of the whole area comes under coarse texture, as the values are less than 4.0. 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 (16).The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate (17).

4.10 Stream frequency (Fs)

According to Horton (1945), the stream frequency (Fs) or a channel frequency of a area may be defined as the ratio between the total number of segments cumulated for all orders within a area

$$Fs = \sum Nu/A$$

Where, Fs=Stream Frequency

$\sum Nu$ = Total number of stream segments of all orders

A = Total area of the area.

Stream frequency values indicate a positive correlation with the drainage density of the area suggesting that raise in stream population occurs with respect to increasing in drainage density (15). The Fs of the whole area is 0.02.

4.11 Form factor (Ff)

It is an important parameter to know the outline of the drainage area and also predict the flow intensity. According to Horton (1932), the Form factor maybe defined as the ratio of area (A) and square length of area (L2). The form factor (Ff) of the entire area is 9.08 and high value indicates that the area is more elongated and high peaks and short duration.

4.12 Circularity ratio (Rc)

According, Strahler (1964) definition, Circularity ratio (Rc) is the ratio of area (Au) and the area of a circle (Ac) having the same perimeter as the area. Rc has been influenced by the length and frequency of streams, geological structures, climate, relief, slope and land use/land cover, of the area. The Rc values of the Sathyavedu area are 0.22. The Sathyavedu area has an Rc values less than 0.50, which indicates that the area lie strongly elongated and impermeable homogeneous geologic materials, high discharge and more runoff.

4.13 Elongation ratio (Re)

Elongation ratio (Re) is defined as the ratio between the diameter (D) of the circle and the maximum length (L) of the area (14). According to Strahler (1964), the values of Re usually differ from 0.6 to 1 for various climatic and geologic conditions. Values close to 1 are distinctive of regions of very low relief, whereas values in the range 0.6–0.8 are generally associated with high relief and steep ground slope. These values are divided into three categories that is (i) circular (>0.9), (ii) Oval (0.9–0.8), (iii) Elongated (<0.7). The elongation ratio (Re) of the Sathyavedu area is 0.6818 it means that it shows the study area is elongated.

4.14 Total relief (R)

Relief is defined as the maximum vertical distance between the lowest and the highest points of a area; based on that understanding the denudation characteristics of the study area. The DEM map shows that the maximum height of the entire area is 285m and the lowest is 3m.Therefore, the total average relief of the study area is 282 m. The high relief

rate is observed in the north western part of the study area, which indicates the gravity of water flow, high runoff, and low infiltration conditions.

4.15 Relief ratio

As for Schumm (1963), the relief ratio is the dimensionless height-length ratio equal to the tangent of the angle formed by two planes intersecting at the mouth of the area, one representing the horizontal, the other passing through the highest point of the area. The relief ratio of the Sathyavedu area is 54.76.

5. Conclusion

An attempt of Arc GIS 10.1 the SRTM Dem data processed, in different stages were generated different maps such as basin fill, flow accumulation, stream direction, stream link and stream order map. These maps are shown drainage flow in North West to south west direction with a gentle to moderate slope. Moreover, morphometric analysis of various parameters likes linear, aerial, relief aspects. The area extent about 246.25 km2, length116 km, which the study area shape indicates the flow rate of water and fifth order drainage patterns were appeared. It is contains the area must be the hard rock characteristic. The mean bifurcation ration is >9.0, which indicates the geologically no disturbance occurred. The drainage density value is 0.2 which it indicates the very coarse in nature, The form factor (Ff) of the entire area is 9.08 and high value indicates that the area is more elongated and high peaks and short duration, The Sathyavedu area has an Rc values less than 0.50, which indicates that the area lie strongly elongated and impermeable homogeneous geologic materials, high discharge and more runoff, The elongation ratio (Re) of the area is 0.6818 and the study area is elongated. The high relief rate is observed in the north western part of the study area, which indicates the gravity of water flow, high runoff, and low infiltration conditions. The present study evaluates the nature of rock, infiltration capacity, runoff and different geological formations. Moreover, studies of the drainage patterns and landform were helpful better understanding and implementation of planning and management activities in the area.

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