# Application of Remote Sensing and Gis Tools in Mountainous Region for Delineation and Prioritization of Watershed Characteristics of Balia Nala in Nainital District in Indian Himalayan Region for Water Resources Development and Management for Food Security

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**Abstract.** Availability of data for hydrological and water management analyses is a point of concern, especially in Mountainous Regions. Remote sensing is being used successfully as an alternative that provides spatially and temporally consistent information required for efficient water resources management. An effort is made to highlight remote sensing (RS) and geographic information system (GIS) and their applicability in data scarce mountainous regions for water resources development and management. The usefulness of RS and GIS for delineation and prioritization of watershed characteristics for development and management of water resources for food security. A watershed is the area of land where all of the water that falls in it and drains off of it goes into the same place or common outlet. Watershed analysis is carried out for quantitative evaluation of drainage basin and for planning and management of water resources.

## 1. Introduction

BALIA nala is a tributary of GOLA river which originates as an outlet of Nainital lake and outfalls into GOLA river near RANIBAGH in INDIAN HIMALAYAN REGION.

**2. Objective:** To delineate the watershed boundary and drains within the watershed of BALIA NALA for the study of the characteristics of watershed and to analyse the various drainage components like;

1-FORM FACTOR/FORM RATIO (FR):

2-ELONGATION RATIO (ER):

3-COMPACTION COEFFICIENT (CC):

4-CIRCULATORY RATIO (CR):

5-DRAINAGE FREQUENCY(DF):

6-DRAINAGE DENSITY (DD):

7-INFILTRATION NUMBER (IF):

8-RELIEF AND SLOPE OF BASIN:

9-RUGGEDNESS NUMBER:

10-BIFURCATION RATIO:

11-STREAM SLOPE:

12-AREA & PERIMETER:

**3. Hypothesis:** A watershed analysis is used for the management and planning of natural resources.

• To provide necessary inputs for hydrological modelling.

• Flood prediction modelling and snowmelt runoff models etc.

• Watershed analysis provides catchment boundaries but also hydrological parameters useful for management programs.

• Erosion and sedimentation control.

• Agricultural runoff control.

• Rainwater harvesting and groundwater recharging.

**4. Material and Method**

QGIS has been used in analysis the following task;
Task-1, Download the DEM of BALIANALA basin.
Task-2, Projected DEM of BALIANALA basin.

Task-3, Fill the projected DEM of BALIANALA.
Task-4, Strahler order (stream order).

Task-5, Creating channels.

Task-6, Channel network and drainage basin.
Task-7, Export basin (selected basin).

Task-8, Extracting channels within study basin.
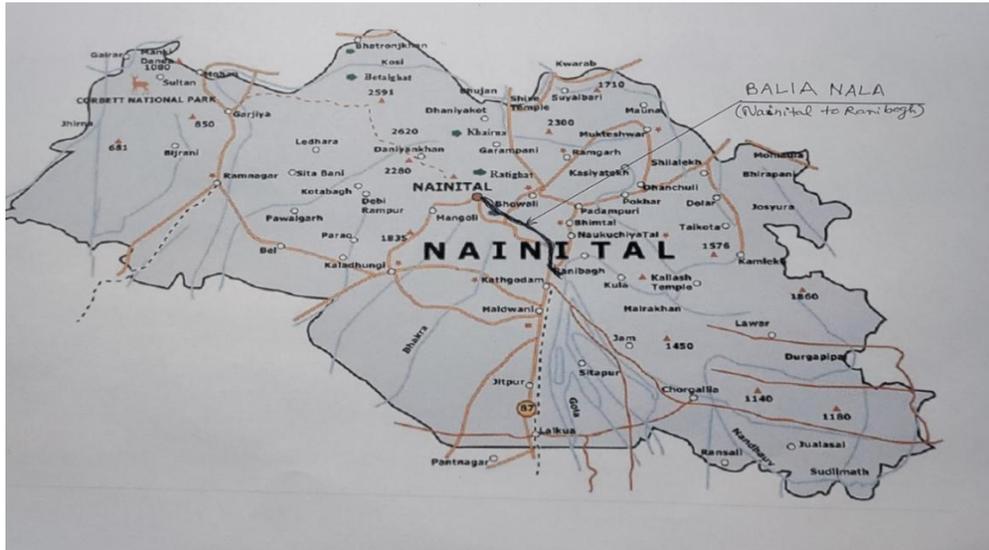Task-9, Check the area and perimeter of basin.
Task-10, Stream order and labelling.

1- Location of Nainital District:



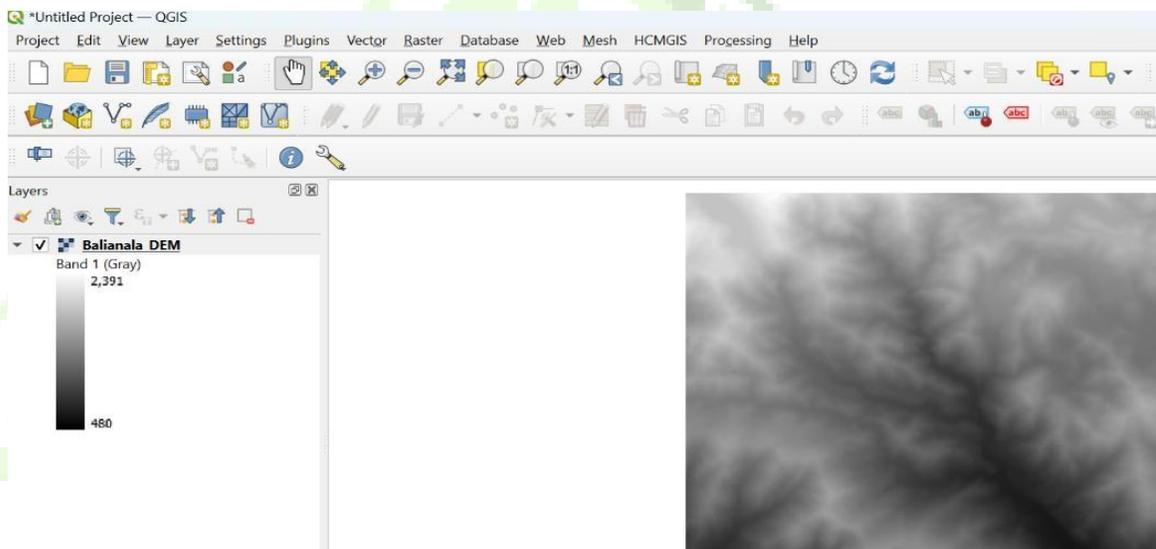Location in Uttarakhand
Coordinates: 29°20′N 79°30′E

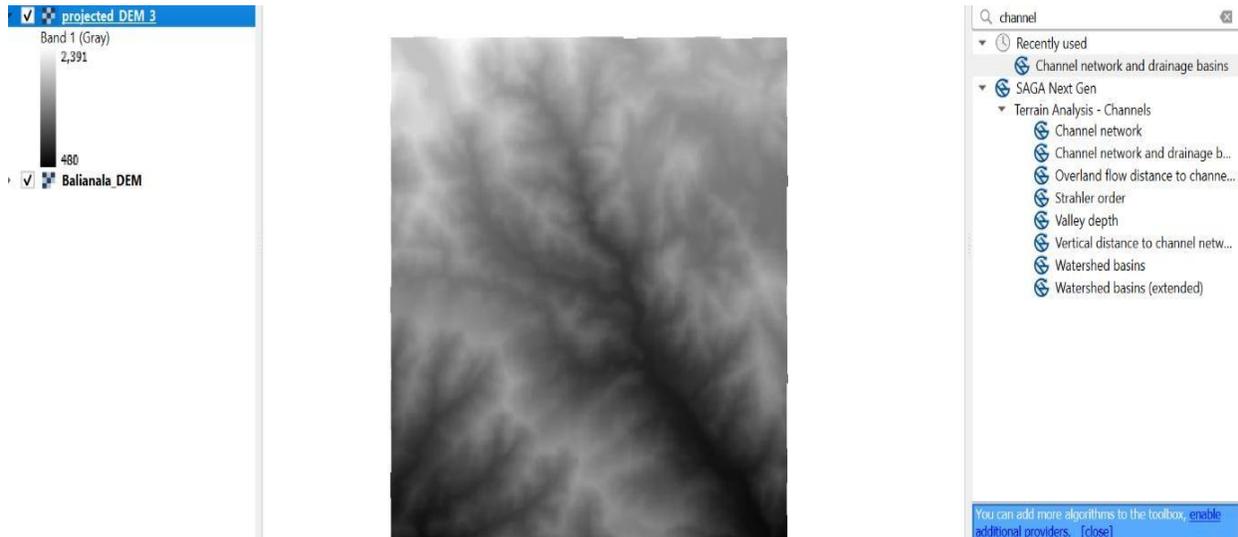2-Location of Balia Nala in Nainital District:



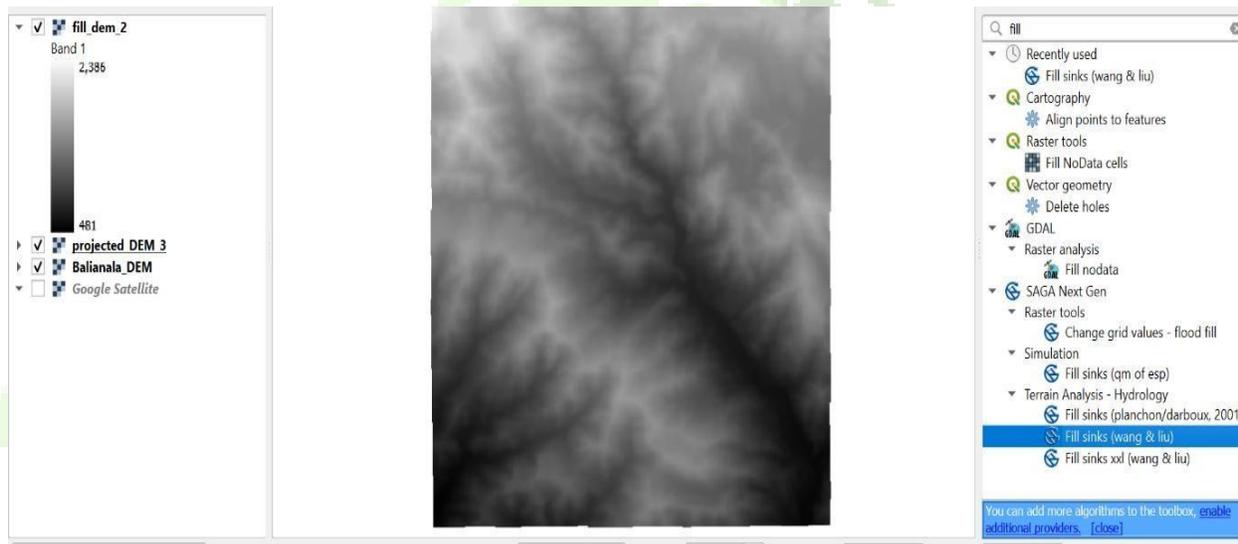3-Dem of Balia Nala Basin:
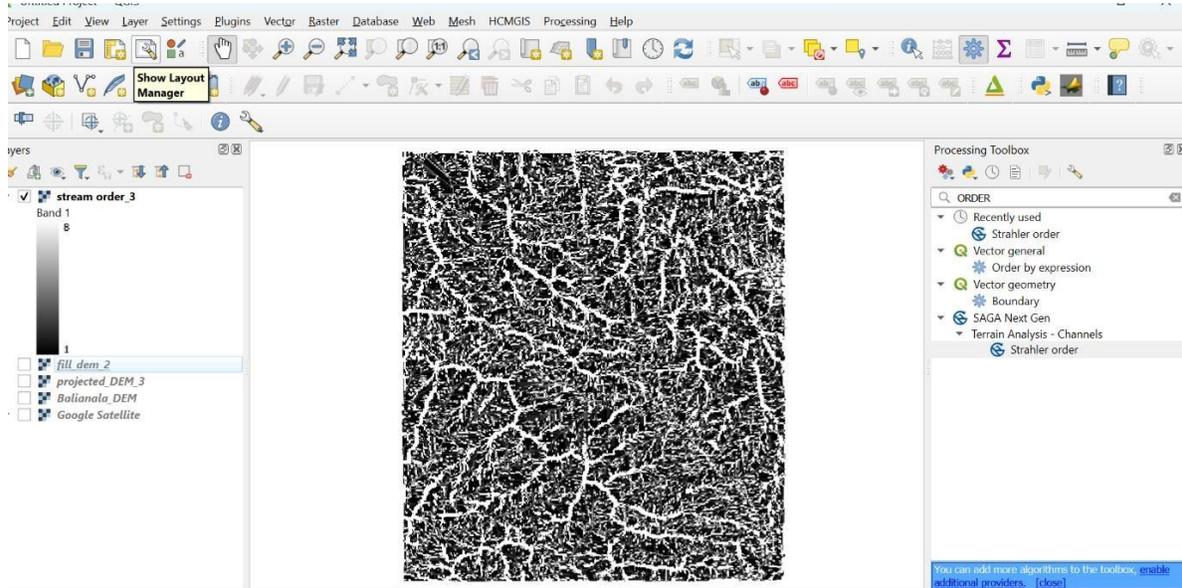
4-Projected Dem of Balia Nala Basin:
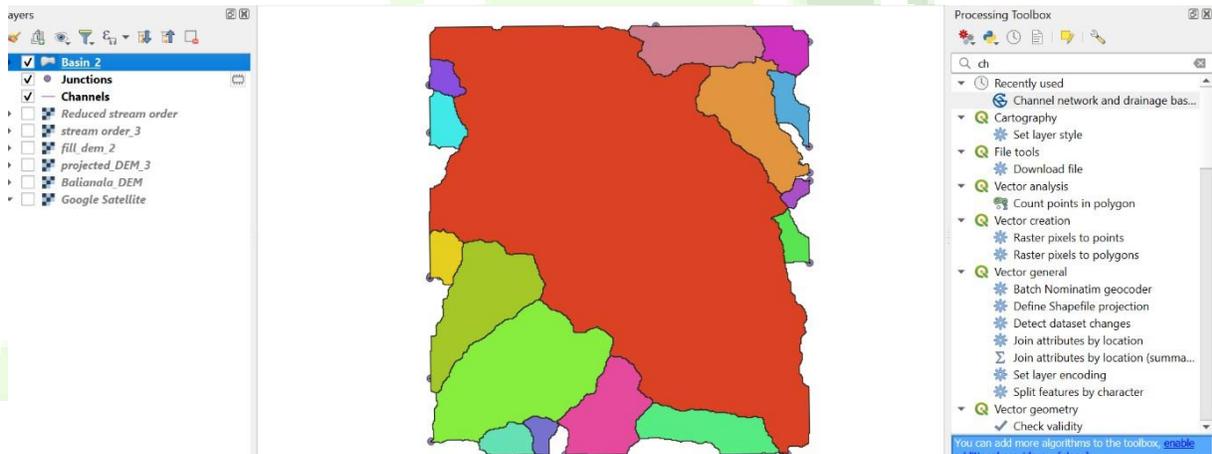


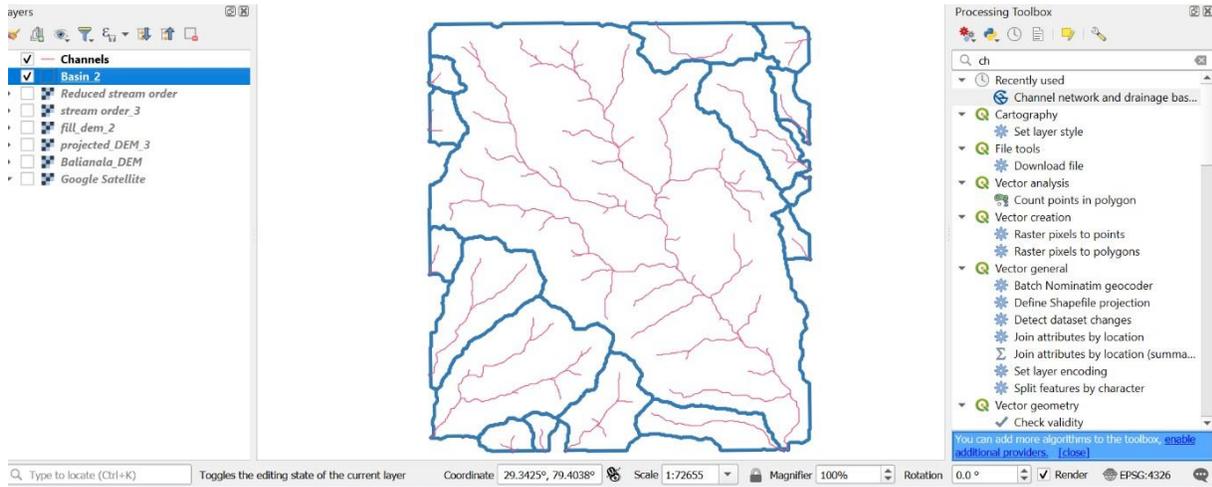5-Filled Dem of Balai Nala Basin:

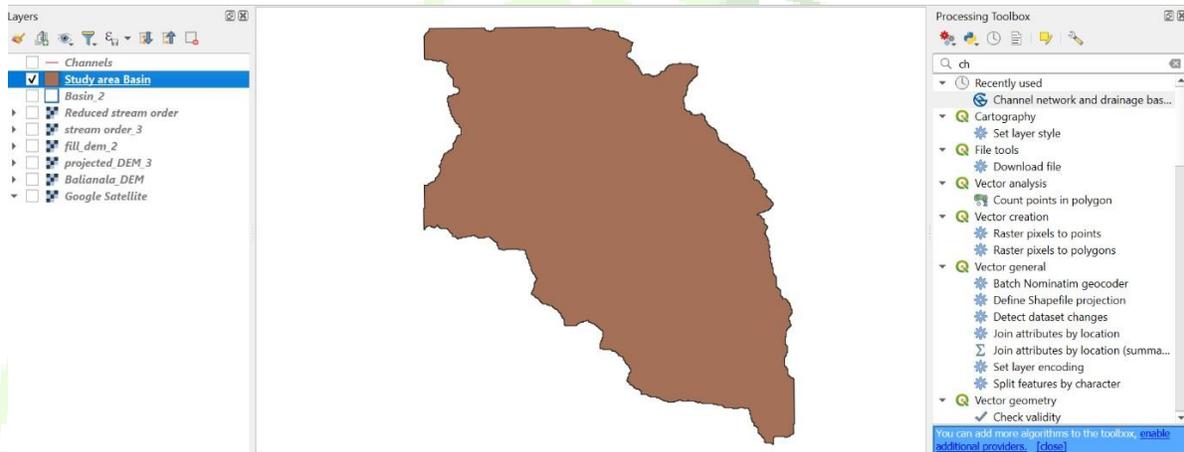6-Strahler Stream Order:



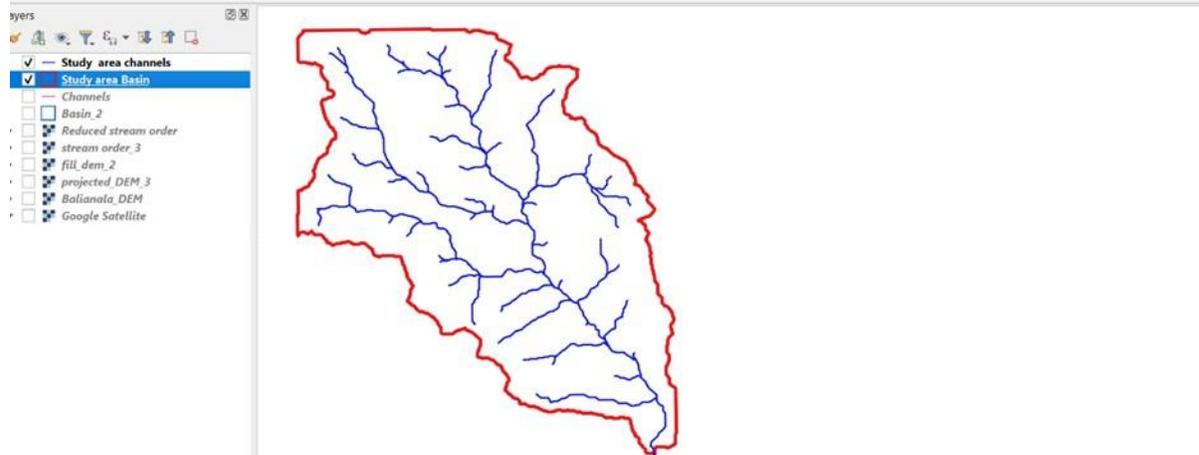7-Basins in Dem:

8-Drains Within Basins:
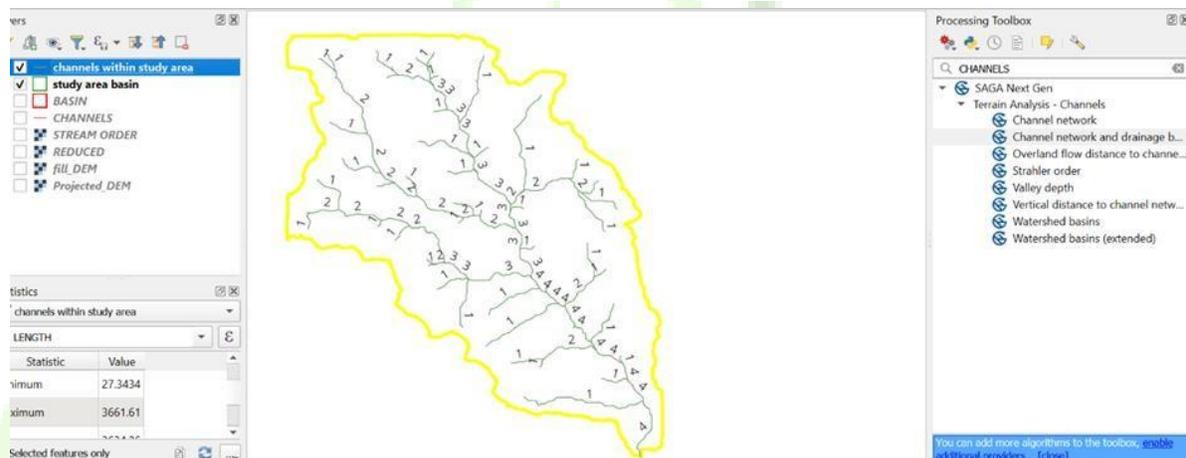


9-Study Area Basin of Balianala

10-Streams Within Study Area:



11-Stream Order of Balianala:

12-Study Area Channels Statistics:
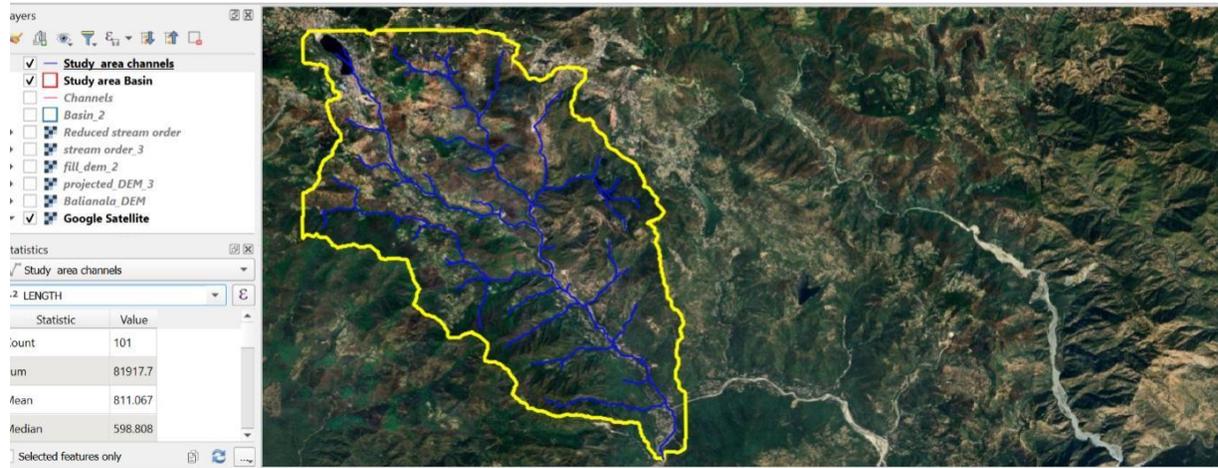


13-Area and Perimeter of Basin in Square Km:
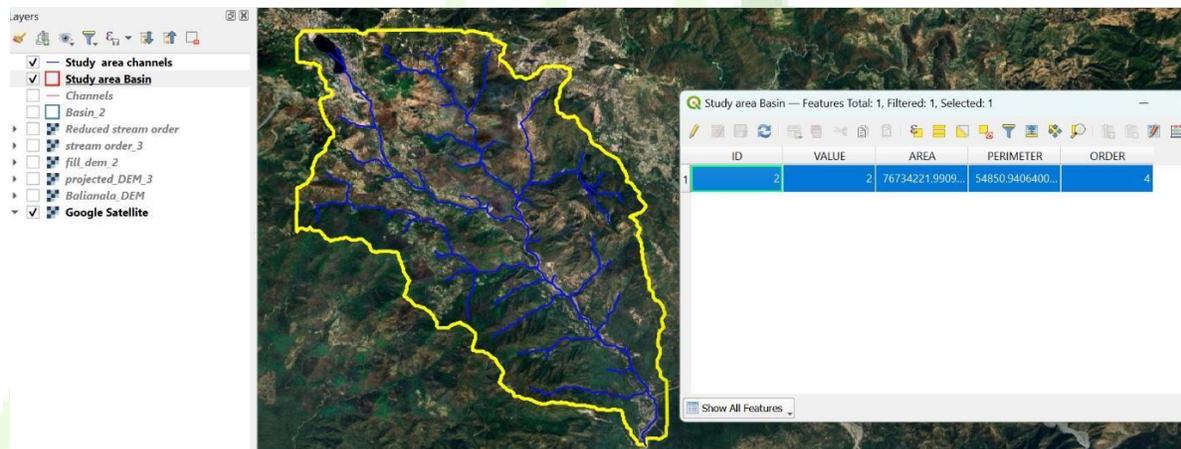
14-Basin Length in Km:
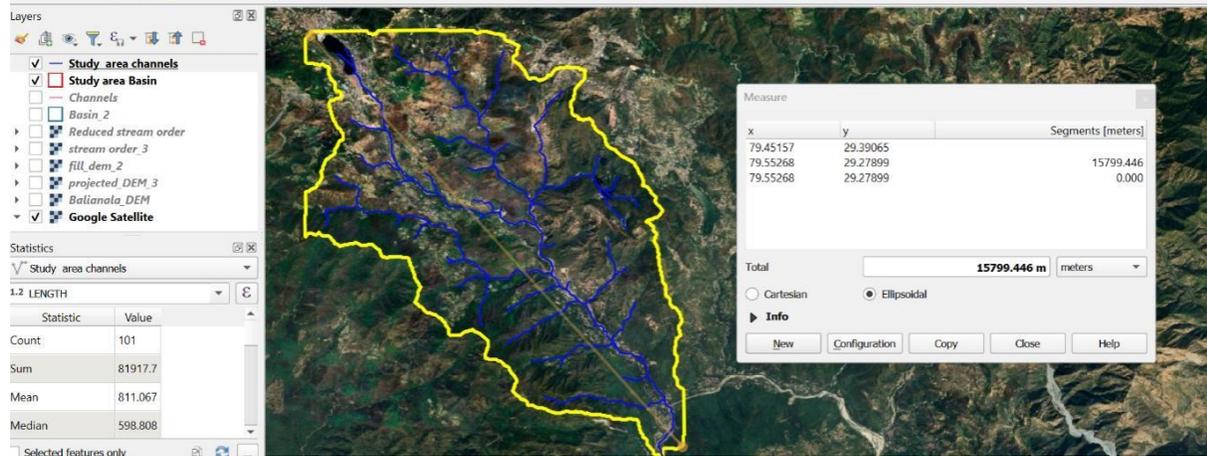


**From the above tasks of QGIS, we get the following information:**

1-Area of basin = 76.73 square km.

2-Perimeter of basin =54.85 km.

3-Maximum length of basin =15.80 km.

4-Number on streams =101 no.

5-Length of all streams =81.92 km.

6-Mean length of stream =0.81

7-Stream Order = 4

8-Drainage Pattern = Dendrite Type

**1-Form Factor: (Cheema & Bastiaanssen, 2017; Singh et al., 2023)**

FORM FACTOR= AREA OF BASIN/LENGTH SQUIRE

= A/L*L

=76.73/15.8*15.8

=76.73/249.64

=0.30

The value of FORM FACTOR is close to zero. This
indicates that basin is elongated in shape.

**2-Elongation Ratio (Er): (Cheema & Bastiaanssen, 2017; Singh et al., 2023)**

It is the ratio between the diameters of the circle of the same area as the drainage basin and the maximum length of the basin.

i- Area of basin. A = 76.73 square km.

ii- Length of basin, L=15.80 km

iii- Radius of circle, R= A/II

= 76.73/3.14

= 24.43

=4.94 km

iv- Diameter of circle=2*R

=2*4.94

=9.88 km

v- Elongation Ratio (ER) = Diameter of circle/Length of basin

=D/L

=9.88/15.80

=0.63

ER=0.63< 0.7

It indicates it is an elongated shaped basin.

**3-Compaction Coefficient (Cc): (Cheema & Bastiaanssen, 2017; Singh et al., 2023)**

Compaction Coefficient =Perimeter of basin/Circumference of circle

=P/ 2IIR

=54.85/2*3.14*4.94

=54.85/31.02

=1.76

>1.0

It is elongated shaped basin because CC is more than 1.0

**4-Circulatory Ratio (Rc): (Cheema & Bastiaanssen, 2017; Singh et al., 2023)**

It is ratio of the area of basin to the area of the circle having the same circumference as the perimeter of the basin.

I-Area of basin, A =76.73 square km.

II-Perimeter of basin, P= 54.85 km

III-P = 2 II R

IV-R=P/2II
R=54.85/2*3.14
R=54.85/6.28
R=8.73 km

V-Therefore, area of required circle as perimeter of basin= II R squire A=
3.14*8.73*8.73

=3.14*76.21

=239.299

VI-CIRCULATORY RATIO (RC)= area of basin/ area of circle

=76.73/239.299

=0.32

Low circulatory ratio is indicative of elongated shape of watersheds. This parameter is helpful in assessment of flood hazards. Low the circulatory ratio lowers the flood hazards at a peak time at the outlet point because in elongated shaped watersheds, water drains from almost all direction in different time and meet near the outlet in different intervals, as a result less water is accumulated through all the streams.

**5-Drainage Frequency (Df):** (Assessing Water Management Strategies in Data-Scarce Mountain Regions, n.d.; The Importance of Sustainable Water Management in Mountain Regions, n.d.)

Drainage Frequency = Total number of drains/basin area
=101/76.73
=1.32
It is more than 1.0
It indicates more runoff, more discharge, more floods.

**6-Drainage Density (Dd):** (Assessing Water Management Strategies in Data-Scarce Mountain Regions, n.d.; The Importance of Sustainable Water Management in Mountain Regions, n.d.)
Drainage Density = Total length of drains/basin area
=81.92/76.73
=1.07
It is more than 1.0
It indicates more drains, more runoff, less infiltration, less recharge of ground water, poor vegetation, rocky soil, steep slope.

**7-Infiltration Number (If):** (Assessing Water Management Strategies in Data-Scarce Mountain Regions, n.d.; The Importance of Sustainable Water Management in Mountain Regions, n.d.)
Infiltration Number = Drainage Density*Drainage Frequency
=1.07*1.32
=1.41
It is more than 1.0
It indicates high relief, hilly area, poor infiltration, deep water table.

**8.Relief and Slope of Basin:** (Geospatial World, n.d.; Wiley Online Library, n.d.)

1-Highest Elevation = 2391M

2-Lowest Elevation = 480M

3-Relief = (2391-480) M=1911M

4-Slope = 1911/15.8=120.95M/KM

This is a high steep slope. It indicates as a hilly terrain.

High runoff, high erosion and less infiltration.

**9-Ruggedness Number:** (Geospatial World, n.d.; Wiley Online Library, n.d.)
RUGGEDNESS NUMBER = (MAX RL – MIN RL) *Dd
= (2391-480) *1.07
=1911*1.07
=2044.77

This is high value. It indicates that it is a hilly basin.
High runoff, high erosion and less infiltration.

**10-Bifurcation Ratio:** (Geospatial World, n.d.; Wiley Online Library, n.d.)

1-no. of first order drains = 30

2-no. of second order drains = 15

3-no. of third order drains = 5

4-no. of fourth order drains = 2

Hence,
1-bifurcation ratio of first order = 30/15 =2
2-bifurcation ratio of second order = 15/5 =3
3- bifurcation ratio of third order =5/2 =2.5

Therefore,
MEAN BIFURCATION RATIO = (2+3+2.5)/3 =2.5

It indicates that large no. of drains is in basin, means, more runoff and more erosion, less infiltration.

**What Information We Get from the Watershed Characteristics of This Basin:**

1-AREA: Area is high, more runoff volume.

2-SHAPE: Shape is elongated type/ fern shaped, flood forecasting, low flood peak, flood management is easy.

3-SLOPE: Slope is steep, more runoff, more soil erosion, less infiltration, poor vegetation.

4-NO OF STREAMS: Number of streams are more, more structural disturbance, more erosion, more soil loss.

5-DRAINAGE FREQUENCY(Df): It is more than 1.0, It indicates more runoff, more discharge, more floods.

6-DRAINAGE DENSITY (Dd): It is more than 1.0, It indicates high relief, hilly area, poor infiltration, deep water table. High drainage density, more runoff, more soil erosion, poor infiltration, less recharge, deep water table, negative impact on agricultural productivity.

7-ELONGATION RATIO (ER): Its value is less than 0.7, It indicates it is an elongated shaped basin.

8-COMPACTION COEFFICIENT (CC): It is elongated shaped basin because CC is more than 1.0

9-INFILTRATION NUMBER (IF): It is more than 1.0, It indicates high relief, hilly area, poor infiltration, deep water table.

10-CIRCULATORY RATIO (CR): Low circulatory ratio is indicative of elongated shape of watersheds.

11-RELIEF AND SLOPE OF BASIN:

This is a high steep slope. It indicates as a hilly terrain.

High runoff, high erosion and less infiltration.

12-RUGGEDNESS NUMBER =2044.77

This is high value. It indicates that it is a hilly basin.
High runoff, high erosion and less infiltration.

13-BIFURCATION RATIO =2.5

It indicates that large no. of drains is in basin, means, more runoff and more erosion, less infiltration.

## 5.Conclusion

1-FORM FACTOR = 0.30, It indicates elongated shape.

2-ELONGATION RATIO (ER)= 0.63< 0.7, It indicates it is an elongated shaped basin.

3-COMPACTION COEFFICIENT (CC)=1.76 >1.0, It is elongated shaped basin (CC is more than 1.0).

4-CIRCULATORY RATIO (RC)= 0.32 Low circulatory ratio is indicative of elongated shape.

5-DRAINAGE FREQUENCY(DF)= 1.32, It is more than 1.0, It indicates more runoff, more discharge, more floods.

6-DRAINAGE DENSITY (Dd)=1.07, It is more than 1.0, It indicates more drains, more runoff, less infiltration.

7-INFILTRATION NUMBER (IF)=1.41, It is more than 1.0, It indicates high relief, hilly area, poor infiltration.

8-Relief and Slope is very high, indicates hilly terrain.

9-Ruggedness no. is also very high, indicates hilly and slopy terrain.

10-Bifurcation Ratio is high, indicates more no. of drains, means more runoff, more erosion, more slides, less infiltration.

MORE DRAINS, MORE RUNOFF, MORE DISCHARGE, MORE FLOODS, MORE EROSION, MORE LANDSLIDES,
LESS INFILTRATION, LESS GROUNDRECHARGE, LESS SOIL-MOISTURE, LESS VEGETATIONS, HILLY TERRAIN.

### Recommendations

Watershed management planning is a method of generating a plan or blueprint for protecting and improving the water quality and other natural resources in a watershed.

1-Water conservation measures are necessary to check the runoff for safety of soil erosion.
2-Check dams for water collection to increase the infiltration to recharge the ground water.
3-Forestation to check the velocity of rainfall and percolation of water to recharge the ground water by retention and detention of rainfall water.
4-Development of contour irrigation channel in the command area of BALIA NALA basin.
5-Development and Management of run off river (ROR) type micro hydro-power projects.
6-Adoptation of flood protection works in erosion and scouring areas.
7-Landslide mitigation works in debris flow and sliding zones.
8-Applying all necessary biological and engineering methods for land and water development and management of watershed area.

### References

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