"WATERSHED PRIORITIZATION OF UPPER BEAS REGION USING RS AND GIS"

A
PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

Under Supervision
of

Dr Saurav
(Assistant Professor)

by

Sahil Thakur (171635)
Saksham Kaushal (171642)
Nikhil Thakur (171658)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 1713234

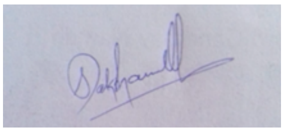
HIMACHAL PRADESH, INDIA

MAY 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"WATERSHED PRIORITIZATION USING ANALYTICHIERARCHY PROCESS (AHP) TECHNIQUE AND GIS"** submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Saurav**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Sahil Thakur
Roll No. 171635
Department of Civil Engineering
Jaypee University of Information Technology,
Waknaghat, India



Saksham Kaushal
Roll No. 171642
Department of Civil Engineering
Jaypee University of Information Technology,
Waknaghat, India

Nikhil Thakur
Roll No. 1716458
Department of Civil Engineering
Jaypee University of Information Technology,
Waknaghat, India

CERTIFICATE

This is to certify that the work which is being presented in the project report titled "**WATERSHED PRIORITIZATION USING ANALYTIC HIERARCHY PROCESS (AHP) TECHNIQUE AND GIS**" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Saksham Kaushal (171642), Sahil Thakur (171635) and Nikhil Thakur (171658)** during a period from August, 2020 to May, 2021 under the supervision of **Dr. Saurav** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. above statement made is correct to the best of our knowledge.

Date: 14-05-2021

Saurav
14/5/2021

Dr. Saurav
Assistant Professor
Department of Civil Engineering

JUIT, Waknaghat

HOD
CE DEPT

Dr. Ashok Kumar Gupta
Professor and Head of Department
Civil Engineering Department

JUIT, Waknaghat

ACKNOWLEDGEMENT

In performing my project, we had to take the help and guideline of some respected persons, who deserve my gratitude. The completion of this project report gives me much Pleasure.

We would like to show my gratitude to Asst. Prof. Dr. Saurav, for giving us a good guideline for project throughout numerous consultations. I would also like to expand our Deepest gratitude to all those who have directly and indirectly guided me in writing this report. I also thank Dr. Ashok Kumar Gupta, Professor and Head of Department, for his guidance and managing of the Civil Department during hard times. I would also like to acknowledge Floodkon Consultants LLP and Mr. Chintan Kothari (Techno- Marketing Manager, Floodkon) for their guidance during the work and being there for us whenever in need.

Many People, especially our classmate and friends, have made valuable comment suggestions on the project which gave me an inspiration to improve my project. I thank all the people for their help directly and indirectly to complete my project.

ABSTRACT

Kullu in Himachal Pradesh lies within the western part of the Indian Himalayas which is prone to natural disasters like floods, landslides, cloud bursts etc. Floods are the measure problem due to the topography of the region with the meteorological and morphological conditions. In this study the information was used to identify the causes of floods. Remote sensing data such as Cartosat Satellite data and DEMs from Bhuvan, ISRO with geological and geo-morphological data were used in geographical information system (GIS) to check the vulnerability of floods in the Beas Watershed. Morphometric analysis was used to estimate the risk level of flood in different sub-watersheds. All the sub-watersheds are assigned with a rank according to the different parameters of Linear, Areal and Relief aspects

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

CHAPTER 1
INTRODUCTION

1.1 General

Watershed prioritization means to give weightage to different watersheds of a catchment as per the sequence in which they are to be taken for different treatment measures. Morphometric parameters and analytical hierarchy process with help of land use land cover maps, drainage density map, slope map and geomorphology map of that area could be used for prioritizing the watersheds by analyzing different linear, aerial and relief aspects of the watershed. But for watershed conservation one should divide a large watershed into smaller sub-watershed for more accuracy, since it is not suitable to take the whole area at once. Thus, the whole watershed is divided into several smaller sub-watersheds [1]. Morphometric parameters will provide data required to analysis and prioritize watersheds for sedimentation susceptibility [2]. With increase in technology, it has become possible to accurately identify potential hazards economically. Since the rapid growth in population increase, settlement and land use the need for accurate information and monitoring has become essential to reduce risk and damage that can occur due to sedimentation susceptibility [3].

Analysis of watershed using morphometric parameters is the best method to establish the association of various aspects throughout the watershed. It is a comparative assessment of different sub-watersheds in various geomorphological and topographical conditions [4]. Morphological Analysis is sub divided into 3 aspects. Linear, Areal and Relief Aspects [5]. Watershed prioritization and Morphological Analysis plays a major role in sedimentation yield management and assessment parameters. Remote Sensing and GIS helps us to identify the inter relation between the morphological parameters and it also helps in assessment of sedimentation susceptibility. GIS helps in formation of database for the watershed which in terms helps to frame suitable measures for highly affected areas [6].

The analytic hierarchy process (AHP) is a procedure for decision making originally developed by Saaty [7]. It helps to provide solutions to decision makers and estimate difficulties in multivariate environments. The AHP with helps of comparison matrix establishes priority weights for alternatives by organizing objectives, criteria, and sub-criteria in a hierarchic structure. AHP technique can be used for prioritization of sub watersheds by analyzing and giving weightage to different parameters.

1.2 Study Area

Upper Beas Watershed is situated in Kullu District of Himachal Pradesh, India. It is located between Latitude 32° 6'30.32"N to 32°24'9.68"N and Longitude 77° 8'59.62"E to 77° 6'52.93"E. The geographical area of the region is of 831.942 km^2 and has parameter of 135.632 km. The region has orographic influence due to which a barrier is created by the windward slope of the Pir-Panjal for the monsoon winds giving a suitable environment for heavy rain and chances of cloudbursts [8].

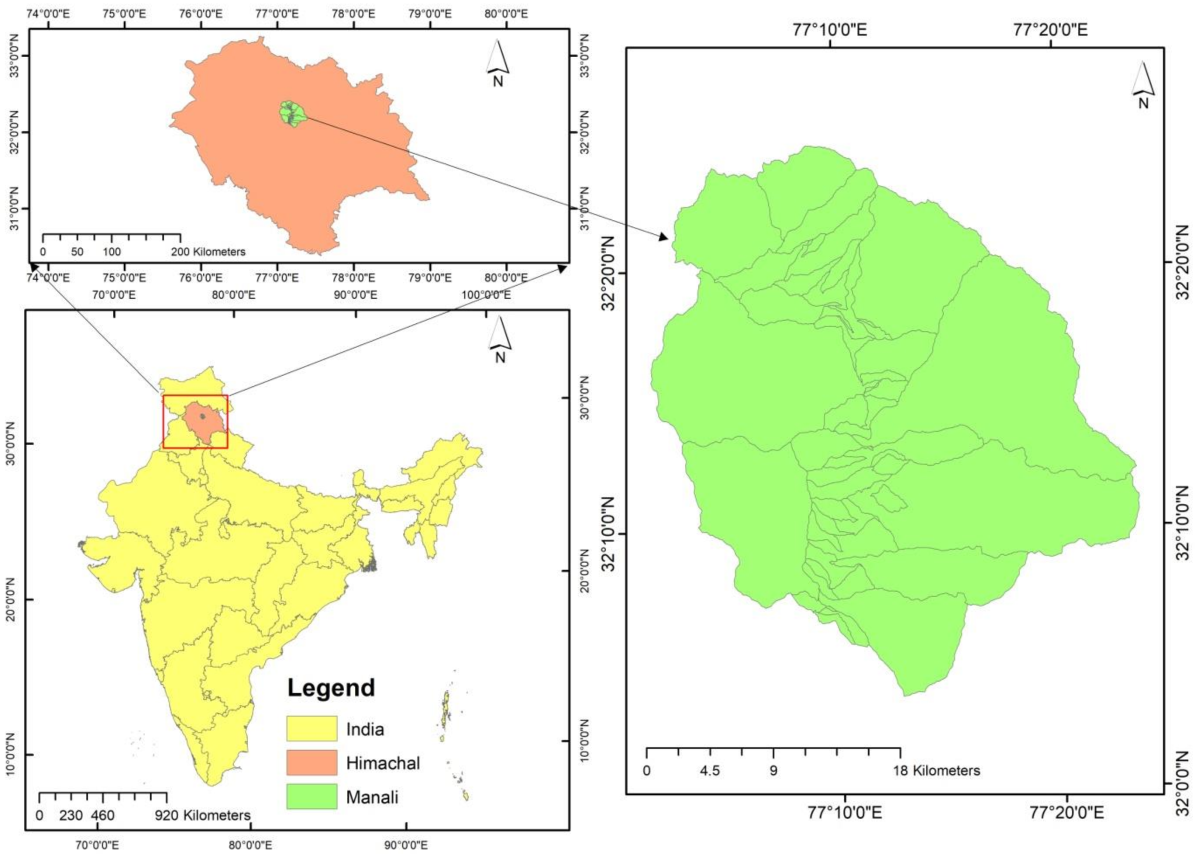


Figure 1.1: Study area of Manali, Kullu District, Himachal Pradesh

The climate of kullu valley consists of summer, monsoon and winter full of cold air masses and westerly storms which bring snowfall with it. The summer monsoon brings copious patterns in the Beas Watershed of the Kullu district. and sometimes intense rainfall Kullu experiences mild summers and harsh winters where upper regions receive snow and sleet falls. Rainfall is well distributed from January to September (confined to lower heights), with maximum downpour in the month of July. Climate in the mountainous region entirely depended on the relief, feature of the slope, altitudinal variations etc The altitude in the watershed varied from 6016 to 1084 msl. Hgher Relief area of Kullu is subject to periodic extreme snowfall throughout the year. The drainage line in the watershed showed branched pattern. These basic parameters are crucial to understand the climatic and hydrology.

1.2.1 Geomorphlogy of Study Area:

Bhukosh which is a geo-spatial platform of Geological Survey of India provided us with geomorphological map of our area with all the necessary information

As shown by the Figure 1.2, the major part of the area is occupied by structural ridges and valleys. The relief in the area varies from < 6000m to > 800m. Major landforms in the area are of structural, fluvial and glacial origin. As shown in Fig.1.2 Under structural origin three types of geomorphic units have been demarcated, viz., Highly Dissected Structural Hills and Vallys, Moderately Dissected Structural Hills and Valleys and Low Dissected Structural Hills and Valleys. Under fluvial origin, Younger Alluvial Plain and Active Flood Plain have been marked. The geomorphic units of glacial origin have been identified as Glacial Valley and Outwash Plain [38].

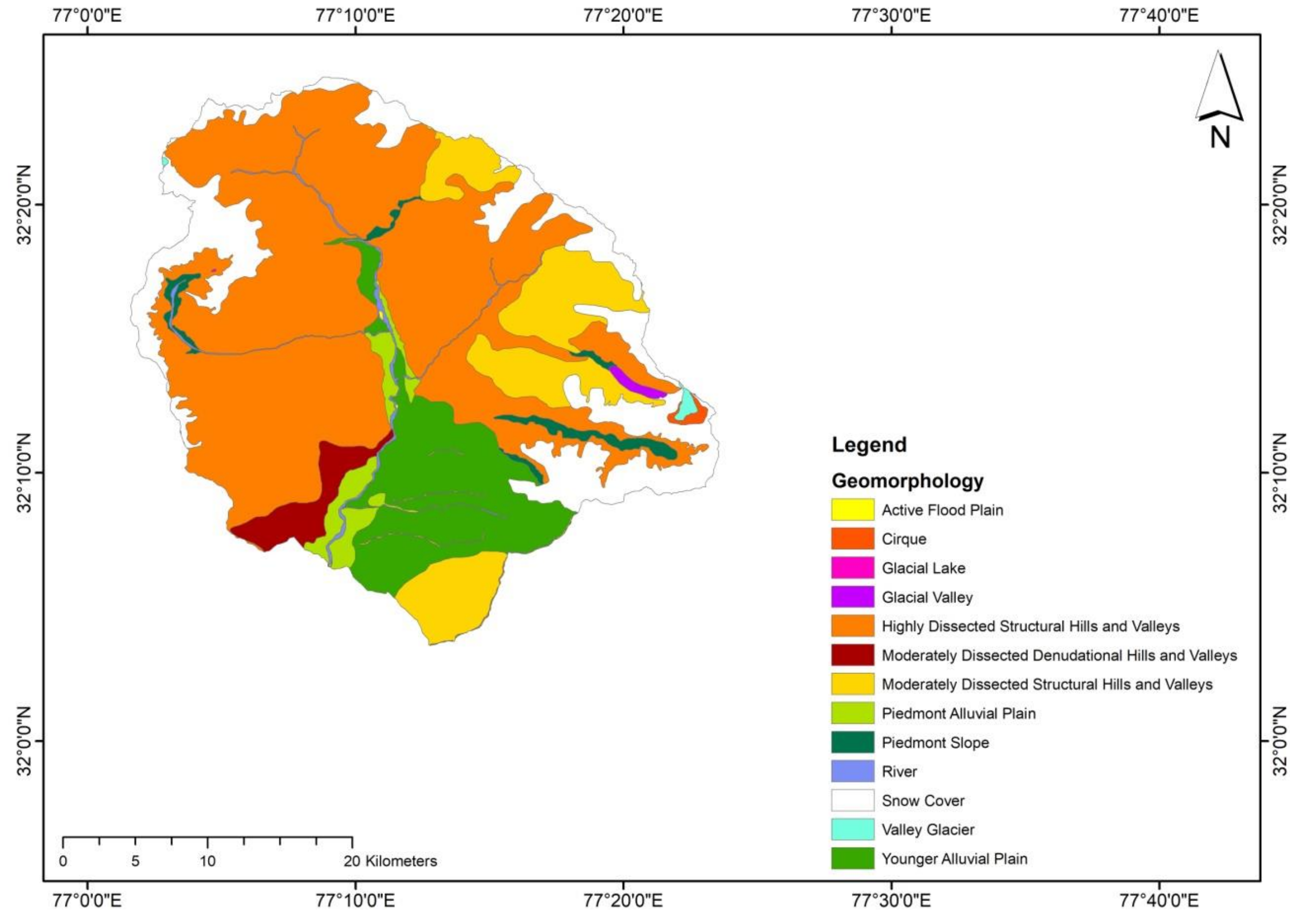


Figure 1.2: Geomorphologic Map of Study Area

1.3 Sedimentation

Due to anthropogenic activities sedimentation flow occurs in the upper Himalayan mountains of kullu district. Sedimentation bring variation to the physical, chemical, and biological components of an ecosystem, consequences of which can lead to degradation of uses such as drinking water supplies, navigation, flood control, electricity production and recreation. The consequences of deposited sediment brought from watersheds can lead to severe economic costs to the residents of downstream and may decline property values for lakefront properties and those properties near the reservoir[30,31]. Reservoir sedimentation commences with soil erosion produced due to rainfall and wind and with runoff that delivers sediment particles into streams. As per the composition, several sorts of land cover produce different runoff characteristics. [32]

1.4 Analytic Hierarchy Process :

Saaty introduced a multi-criterion for decision-making known as analytic hierarchy process for decision-makers to provide weightage to different aspects and compare the aspect on the basis of weightage provided [7].

AHP practices a multi-level hierarchical structure of criteria and sub-criteria. AHP is an effective approach to deal with many engineering applications. In AHP a pairwise comparison matrix is constructed between the parameters and ranking is provided to the parameters and on the basis of ranking weightage is given to the parameters, then the parameters are used to priorities the watershed [7]. Decision makers on the basis of prioritization can provide measure to affected area of watershed so as to reduce the damage.

The present study is being carried on the upper beas watershed to help prioritize the watershed with different parameters and help identify environmentally stressed areas which can have an effect on sedimentation yield of the watershed.

CHAPTER 2
LITERATUR REVIEW

2.1 Research work on watershed prioritization using GIS and AHP:

According to a research done by **Sapna Bisht, Smita Chaudhry, Subrat Sharma, Sandeep Soni** (2018) Himachal Pradesh which is located in the western region of the Indian Himalaya which is environmentally fragile and vulnerable to natural disasters. Hazard due to flash flood is one of the rising concerns in the state because of its diverse topography with respect to meteorological and morphological conditions. RS and GIS can be effective tools used for studies on prioritization of watersheds.

A research conducted by **Rajeev Ranjan, Garima Jhariya, R.K. Jaiswal** (2013) on Analytical Hierarchy process and in this research paper main focus was to manage soil erosion ofBina river Basin using GIS, RS and using Erosion Hazard Parameterswith AHP. It was observed that sub watersheds were prioritized form high, moderate, low to verylow. It showed that AHP is a very effective way to prioritize and analysis of a watershed.

In a study by **Dhruvesh P Patel, Prashant K Srivastava, Manika Gupta and Naresh Nandhakumar**(2015) it was observed that RS and GIS are one of the leading technology for studies on prioritization of watersheds. The Analytic Hierarchy Process (AHP) is an effective approach in dealing with multiple criteria-based decision making for prioritization of watershed as well as other industrial engineering decision making.

According to research conducted by **Avijit Mahala** (2018) it was observed that the morphometric characteristics of any area can help in effectively revealing the hydrological and morphological characteristics. Drainage Morphometry has capacity to differentiate sufficiently between morpho-climatic areas of the world by using its various values.

2.2 Objectives:

- To Delineation of watershed.
- To perform morphometric analysis on watershed.
- To perform supervised classification for land use/land cover (LULC).
- To apply analytical hierarchy process (AHP) for prioritising watershed.

CHAPTER 3
METHODOLOGY

3.1 General

A Geographic Information System (GIS) software is to be used for collecting and showing the data acquired from different satellites. And once the maps and data is ready on the software. Using different tools different parameters can be calculated. All these parameters will help us prioritize watershed based on risk factors of sedimentation.

3.2 Software Required:

3.2.1 ARC GIS:

ArcGIS is a geographic information system (GIS) database mostly used for working with maps and geographic information of a region. It also helps in creating as well as using maps, to analyze mapped information, compiling geographic data to share and discovering geographic information by using maps and geographic information by using different applications .And all the grographic information can be stored in form of database in the software.

The system helps in providing a facility and infrastructure for making maps and geographic information available to communities, organizations and individuals for research and decision making.

ArcGIS consists of the following software:

- ArcReader, it helps in viewing and query maps created using the other ArcGIS products.
- ArcGIS Desktop also referred to as "ArcMap" made up of four fundamental applications:
    - ArcMap, to view and edit spatial data in two dimensions and creating two-dimensional maps.

- ArcScene, to view and edit three-dimensional spatial data in a local projected view.
- ArcGlobe, to display large, global 3D datasets.
- ArcCatalog, used for GIS data management and manipulation the tasks performed.

- ArcGIS Pro, a new integrated GIS application, it was made tosurpass ArcMap and its companion programs.ArcGIS Pro can work in 2D and 3D for cartography and visualization, and which also includes Artificial Intelligence.

3.2.2 Google Earth pro

Google Earth is a computer program, that projects a digital 3D model of Earth using mainly satellite imagery [19].Using superimposing satellite images, aerial photography, and GIS mapping of earth can be done. And this data is then projected onto a 3D globe, that gives user ability to sight cities and landscapes from various angles. It also helps in surveying the globe by entering the address or coordinates of any area or my navigation using mouse and keyboard. The program is also available on android and iOS other than computer OS, by using a touch screen or stylus to navigate. User's own data can also be used with the help of Keyhole Markup Language and upload through forums or blogs. The program also has ability to showcase various kinds of images overlaid on the surface of the earth and is also a Web Map Service client. It cover more than 98 percent of the world, google earth has ability to captured 10 million miles of Street View imagery,[19].

3.3 Morphometry

Drainage morphometry consists of different parameters namely linear, areal and relief characteristics [9].These are the measurements of different characteristics of a river basin. Drainage morphometry was first initiated by Horton [10]. These characteristics are very crucial to grasp the type principal structure, formations of geomorphology and characteristics of hydrology of any basin [11].

3.2.1Drainage Morphometric Parameters

In order to understand hydrology and geomorphology of an area and calculate a result on the potential of hazards it is very important to know Drainage morphometric parameters. The following parameters will help us identify different features of the basin and consequence of drainage, sedimentation and erosion on the watershed. Parameters are divided into three aspects Linear, Areal and Relief Aspects.

Linear aspects of River basin morphometry

1. **Stream order (*N_u*** Based on hierarchical ranking of the streams, stream order is the first step of drainage analysis. We will be using the method invented by Strahler (1964). The smallest fingerprint tributaries numbered as 1st order, the 2nd order of stream formed when two 1st-order streams join together similarly 3rd-order stream forms when two 2nd-order streams join and so on [11]. The main channel through which maximum water is discharged is marked as highest order stream for a particular drainage basin.
2. **Stream no. (*N_u*):** All the streams having a specific stream order "u". To calculate N for each order (u) Strahler's formula is used [11].
3. **Bifurcation ratio (*R_b*):** Ratio of amount streams having a order (u) to the amount of streams having higher order (u+1) is known as bifurcation ratio (R_b) [11]. If the control over geological formation in not strong, the variation in R_b value is very minor for different areas [11]. This parameter plays an important role in identifying the water carrying capacity and related food potentiality of any basin [10]. The range of R_b lies between 2 and 5 [13]. Studies have shown that the value of R_b is higher in mountainous regions than plateau–plain regions of tropical environment because of its young morphological adjustment and higher water pressure. If the bifurcation ration is high then it signifies that huge amount of water is gathered in upper basin region. But lower R_b value with low number of streams in lower reaches it indicate increase in water pressure.
4. **Mean Bifurcation ratio (*R_{bm}*):):**To calculate R_{bm} mean of R_b of all order is taken. Similar to bifurcation ratio it helps in identifying potential of flood in the drainage basin.
5. **Stream Length (*L_u*):** Stream length L_u is the total length of streams having same order (u) [10].

6. **Mean Stream Length (*L_{um}*):** As per Strahler L_{um} is distinctive property of drainage system and surface according surrounding and associated with it[11]. It is an important measurement. To calculate the mean stream length, ratio of total length of streams of "u" order with respect to the total number of streams "N_u" of such order is calculated. Most of the times the ratio of $L_{um}$is directly proportional to order of streams [20]. Studies have indicated that low L_{um} value in mountain environment compared to plains and plateau regions morphology.
7. **Stream length ratio (R_l):** To calculate R_l mean stream length of order "u" is divided to the next stream order "u+1" [10]. In majority cases it is tends to be alike for most of different orders. The different values of R_l tells us about the region, if it is in initial phase of geomorphic development, and the regions which are vulnerable to high frequent potential change in upcoming future. This is also a proof of fluctuating hydrological behavior in the basin. If the values of R_l is high itindicates younger phase of geomorphic development.

Areal Aspects of River basin morphometry

1. **Stream frequency (S_f):** S_f is the entire number of stream segments per unit area disregarding their order [15]. It is calculated by dividing the total number of stream segment collective of all orders to the area of the basin. Stream frequency is dependent on the initial resistivity of rocks, relief, and rain fall and often times the drainage density of the watershed. S_f having low value is an indicator of poor drainage network [12]. High slope of area and heavy rainfall affects stream frequency (S_f) by increasing it in mountainous region, however if low permeability and less available surface flow is found in plateau region reduces the S_f value in environment.
2. **Drainage density (D_d):** Drainage Density express how closely the drainage channels are placed in a drainage basin. [15]. It is calculated by measuring runoff potential numerically and landscape dissection, D_d is a crucial in indicating elements of landform. D_d can be calculated by dividing total length of streams ignoring stream order to the per unit area of given basin. The value Drainage Density can be found from0.55 to 2.09 km/ km2 in humid region [12]. This parameter plays a major role in determining the travelling time of water.

3. **Texture ratio (R_t):** Texture ratio can be termed as the result of stream frequency and drainage density [10]. To calculate R_t total numbers of stream segments is divided to the perimeter of the drainage basin. As recognized by Horton, the only parameter that can influence texture ratio is Infiltration capacity. Considered a crucial parameter representing the relative spacing of drainage network of given basin. R_t is dependent on few of natural parameters like amount of rainfall, vegetation density, types of soil, geomorphic development stage, infiltration capacity and relief [14]. Drainage frequency and drainage density combined can be known drainage texture. The R_t values of less than 2 indicates very coarse, values ranging from 2 to 4indicates coarse, range 4to 6 indicates moderate, range 6 to 8 fine and greater than 8 indicates very fine drainage texture [14].
4. **Form factor (F_f):** Form factor can be calculated by dividing basin's area to the square of basin length [10]. The form factor ranges less than 0.7854 if the basin is perfectly circular in shape [16]. Similar value is recorded if basin shape is more elongated. The value '0' tells us elongated characteristics of basin and value 1represents almost circular shape and features of basin with generally high peak flow. If value of $F_f$is high, the basin is more circular in shape representing peak flow higher in shorter duration, similarly if the value of F_f is lower, shape is more elongated which represents longer duration flow with low peak flow [16]. For elongated basin flood flow management is considered easier than that of basin which is circular. Circular basin is formed by mountain–plain front river basin than plateau–plain front river basin.
5. **Elongation ratio (R_e):** It is calculated by dividing the diameter of a circle having the same area as of basin to the basin's maximum length [16]. The value of elongation ratio ranges from '0'to near '1' 0 meaning maximum elongation and 1 indicating maximum circularity. The R_e values of near '1' represents that geomorphologic control over river basin is less[11].Less elongated basin are formed in the mountain front having environment with humidity river basin with respect to plateau–plain front of sub humid environment [22]. Hydrological character can be found out using R_e of a drainage basin. Low peak discharge can be found in elongated basin.
6. **Circularity ratio (R_c):** It can be calculated by dividing the basin's area to the area of a circle having the same perimeter as of basin [11]. Range of R_c lies between '0' and '1'. Circularity being maximum towards 1 and minimum towards 0. C_r values depend

upon frequency of stream, drainage density, slope, relief, climate, geological structure of basin. During peak rainfall season basin having high circularity will have peak discharge. It is also determining the geomorphological phases of development of any basin. The high value indicating old, moderate indicating mature and low value indicating young phases of geomorphological adjustment of a river basin [11]. Often the mountain–plain front river basin incline towards forming circular basin because of its young morphological adjustment and plateau–plain front river basin forms an elongated basin due to the mature morphological characteristics of them [11].

7. **Constant of channel maintenance (CCM):** CCM can be calculated by taking drainage density's reciprocal[17]. It is minimum area required for the development and maintenance of a channel [18]. CCM is expressed in km^2 /km. Flood potentiality is high is basin having low CCM value and it indicates young geomorphological features of the river basin.CCM value of mountainous region is often low because of infiltration of bare soil is low causing high overland flow [18]. Likewise, low CCM value in plateau–plain environment because drainage density is low and infiltration is high in contrast to plateau–plain environment [18].

Relief aspects of River basin morphometry

1. **Basin relief (R, H):** Basin relief consist of absolute relief (R) and relative relief (H). Absolute relief is the highest relief value of a basin and relative relief is the maximum altitude differences[21]. Basin relief relies on the principal geology, drainage features and geomorphology of the area. Phases of erosion of drainage basin can be analyzed through basin relief. In most cases, the basin in mountainous region will have higher basin relief than that of plateau–plain front basin [12].
2. **Relief ratio (R_r)**: R_r is calculated by dividing total reliefs to the main drainage channel's length[23]. The R_r value are dependent on various parameters of areal and relief aspects of basin. Increase in the R_r value can occur due to small basin, circularity in basin shape, high basin relief and small basin area. It helps in identifying the overall steepness of the drainage basin and processes of degradation in the

geomorphology[17]. Mountainous region basin have higher $R_r$value compared plateau-plain river basin [12].

3. **Dissection index (D_i)**: Ratio of relative reliefs with respect to absolute relief is known as dissection index. It helps in identification of the vertical erosion and dissected parameters in a basin [24]. The range of D_i varies from ‘0’ to ‘1’. D_i values near to ‘0’ means absence of vertical dissection representing maximum denudation phases of geomorphology evolution likewise closer to ‘1’means vertical areas presence, and represents minimum denudation stages of geomorphic evolution. Higher D_i values are related to Mountain regions in contrast to lower D_i values representing plateau plain front [25].
4. **Ruggedness index (R_i):** The product of relative relief and drainage density is known as ruggedness ratio. R_i values are considered high if higher the value of both drainage density and relative relief [26] are. This parameter is dependent on slope, steepness, principle geology, vegetation cover, geomorphology, and so forth of study area. the area is considered to be in primary stage of geomorphic development. If values of $R_i$is high. Many Studies have shown that basin of mountain region have higher R_i compared to plateau river basins [27].
5. **Slope (ϴ)**: Slope is a morphometric parameter dependent on climatic processes and morphology characteristics of any region. Changes with varying resistance of rock surface. Slope identifies infiltration to runoff relations so it makes it crucial to grasp the nature of slope in area. Infiltration capacity and slope are related inversely to each other[27].

3.3 Digital Elevation Modeling:

Digital Elevation Model also known as DEM is a representation of elevations of ground surfaces and topography [28]. DEM is often used to denote a digital depiction of a surface map of an area. DEM can be designated as one of the simplest forms to represent a region’s topography in form of 3D imagery [28]. DEMs can be used to govern landscape characteristics such as slope, a point’s elevation and other aspects. Areas having traits of a drainage basins and channel networks can be defined in the form of DEMs. Application of DEM in hydrology include groundwater modeling, estimation of the volume of proposed reservoirs, determining landslide possibility, flood susceptible region mapping etc. [28].

Location is to be used to govern the catchment area for a region. Source for the region on which the research is to be conducted can use description such as dams and detection of the attributes of the surrounding region is necessary for that. Consecutively, flow accumulation threshold can be taken help of. When the approach is used for describing a basin, the pour point to be drawn need to be the junctions of a stream network derived using flow accumulation. This implies that flow accumulation raster need to be provided with minimum number of cells with the help of raster calculator that forms a streams.

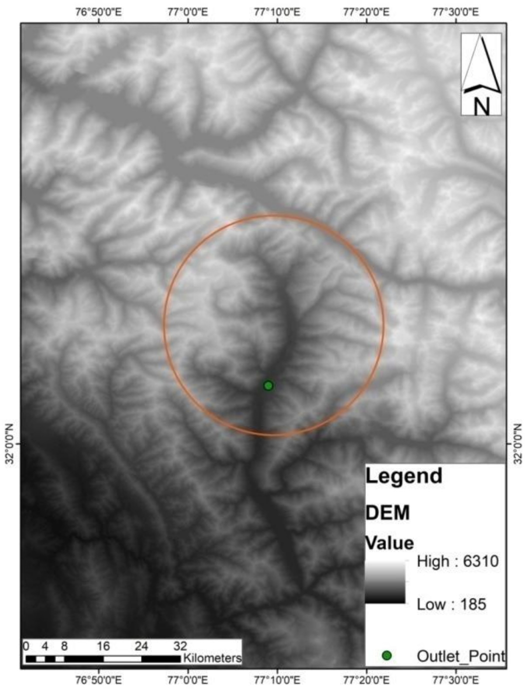


Figure 3.1 : DEM of selected area made on ArcGIS

3.3.1 Delineation of Watershed

Watershed delineation means to identify the boundary of watershed on which the research has to be done.

After creating DEM for delineation of watershed following steps are required:

Flow Direction grid is created: A flow direction grid helps in allotting value to each cell to designate the direction of flow – that is the flowing direction of the water to that particular cell with respect to the underlying topography of the region. This step is very crucial in hydrological modeling, as the direction of flow will assist us to generate the final destination of the flow of water on the surface of that area.

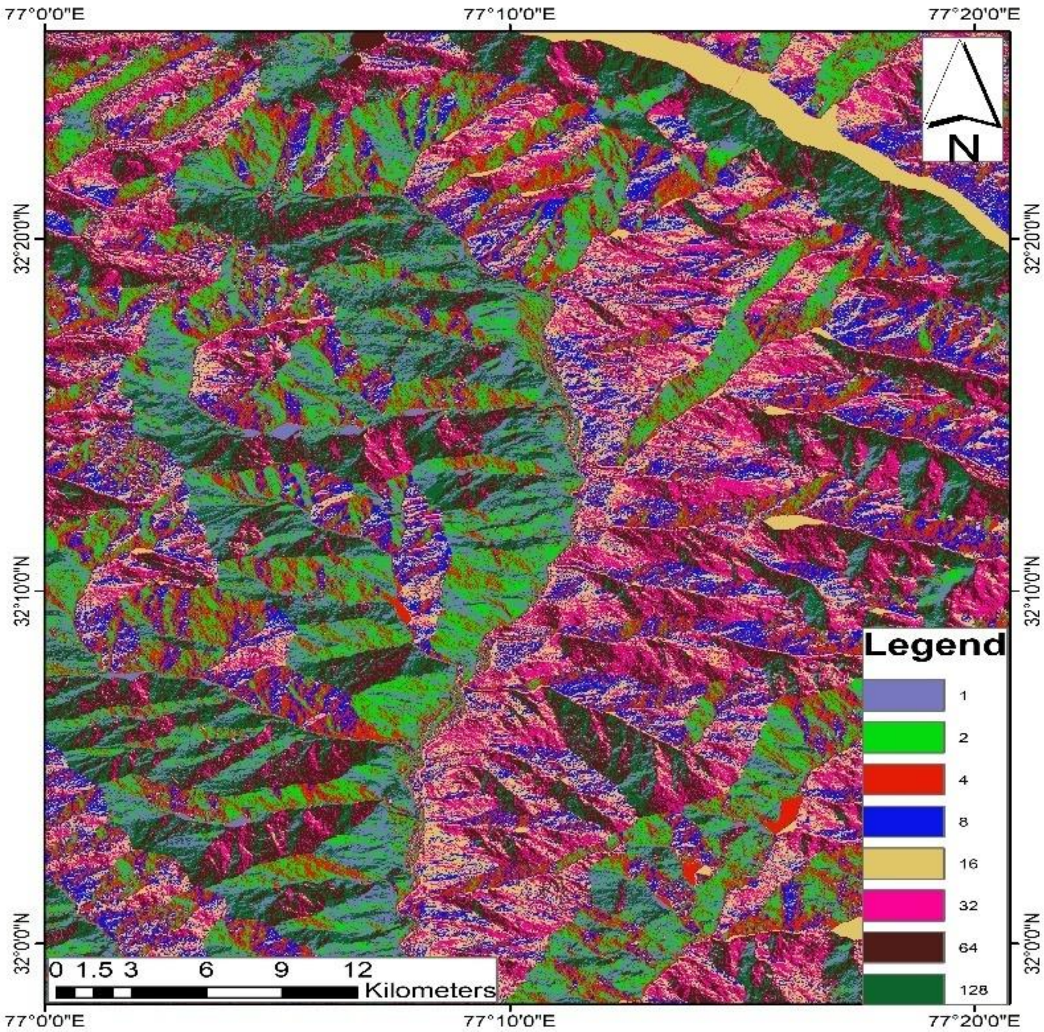


Figure 3.2 : Flow direction grid of the selected area

Flow accumulation grid is created: The Flow Accumulation tool assists in identifying the upstream cell that flow into downstream cell with that it is able to calculate flow into each cell. Hence the number of upstream cells entering the downstream cell helps in calculation of flow accumulation value.

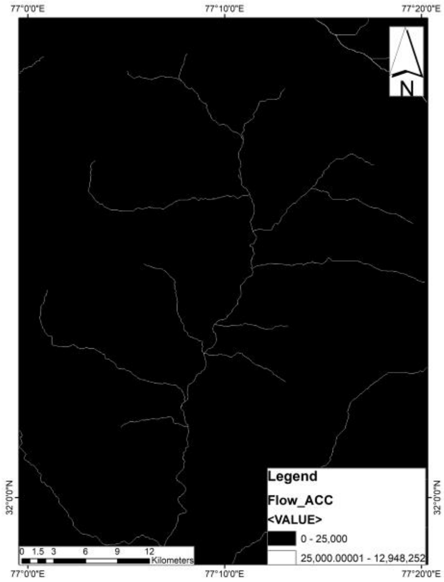


Figure 3.3 : Flow accumulation grid of the selected area

Outlet (pour) point is created:: Pour point is the outlet point of a watershed from where water from all the water bodies is discharged .The placement of an outlet point is a crucial step in the procedure of delineation of a watershed. A pour point is placed in an area consisting of high flow accumulation. it helps in calculating the overall drainage to that given point. It is preferred to create pour points manually so the boundaries of watershed can be defined by decision maker. Given as green point in Fig.3.4.

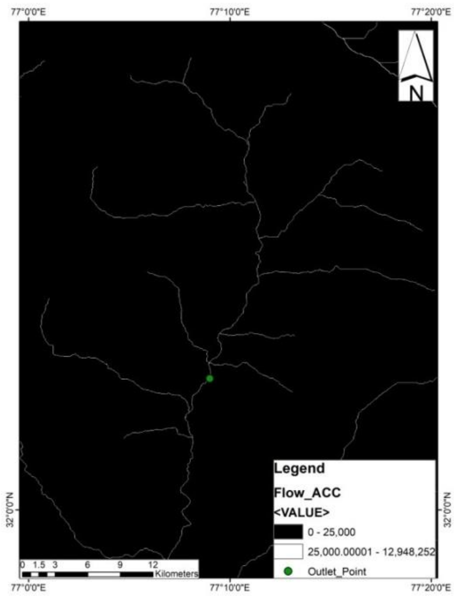


Figure 3.4 : Pour point on flow accumulation map

Delineation of Watershed is done: It is done by setting parameters such as input flow raster, feature pour point data, pour point field and new watershed raster is added to map. Then the raster is converted to polygon to get the final watershed delineation.

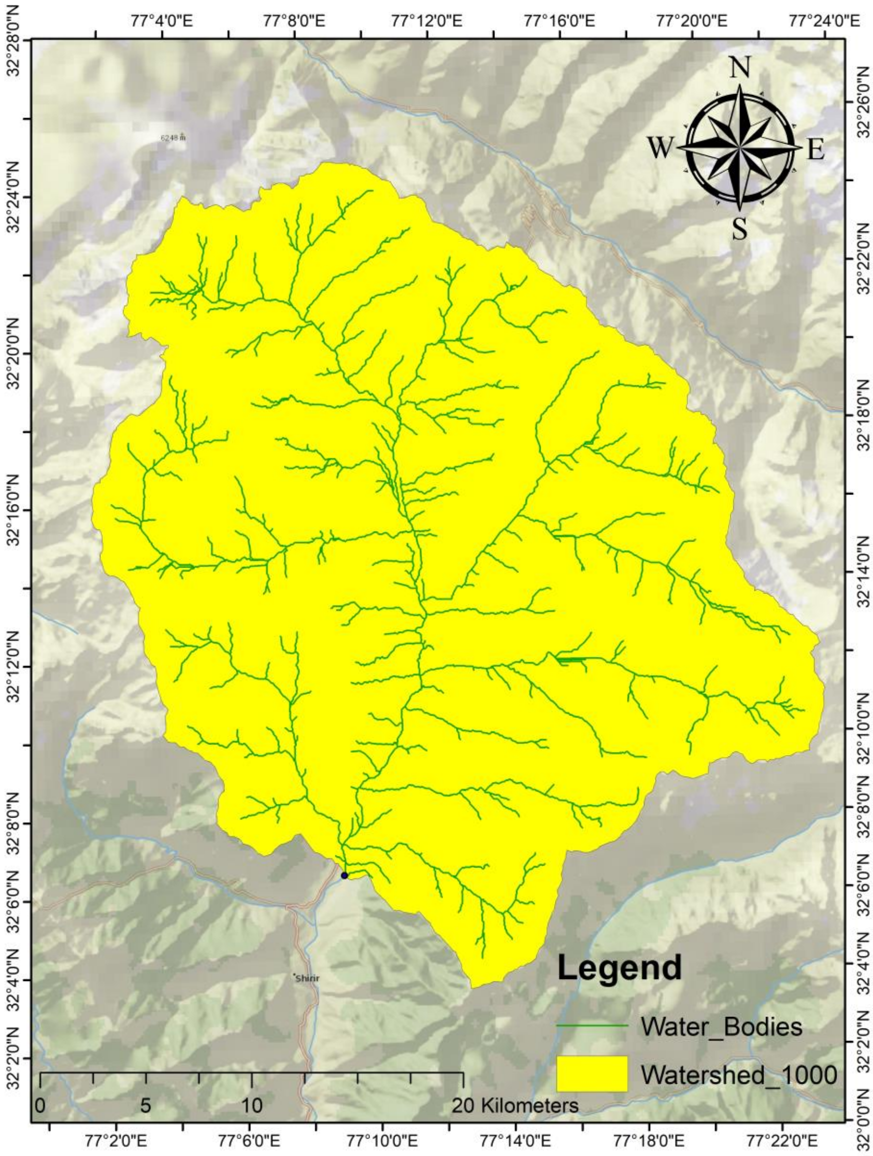


Figure 3.5 : Delineated Watershed of selected area

3.3.2 Stream Order

Stream ordering is process in which order is provided to each stream in a drainage network [29]. It is a method to recognize and categorize types of streams establish on the basis of numbers of tributaries. Some features of streams can be concluded by simply knowing their order.

The Stream Order tool in ArcGIS contains two methods that can be used to assign orders. These are the methods proposed by Strahler (1957) and Shreve (1966). Method used in this study is Strahler's.

Stream order tool under Spatial Analyst tools of Arc Toolbox feature is used for this purpose. After stream order tool stream to feature tool is used to convert the raster layer of line network to feature demonstrating line network of different orders.

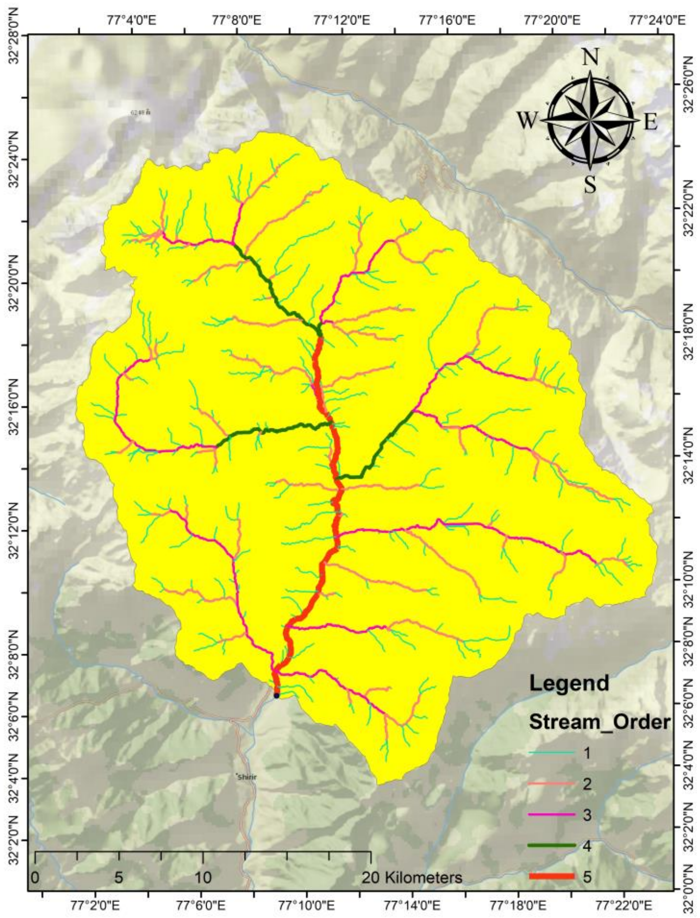


Figure 3.6 : Stream order of study area created on ArcGIS

3.3.3 Dividing Watershed to Sub Watersheds

Using catalog, a New Shapefile is created which will be our pourpoint as done for first delineation. After creating pourpoint shapefile, Start Editing and go to create features and select point construction tool and with the help of this tool all the significant pourpoints are marked around the main stream. Once all the pour points are marked the editing is saved.

Using watershed spatial analyst tool again and inputting the new pourpoint layer, the Sub Watersheds can now be delineated. There are total 61 numbers of sub watersheds on which we will be performing different analysis.

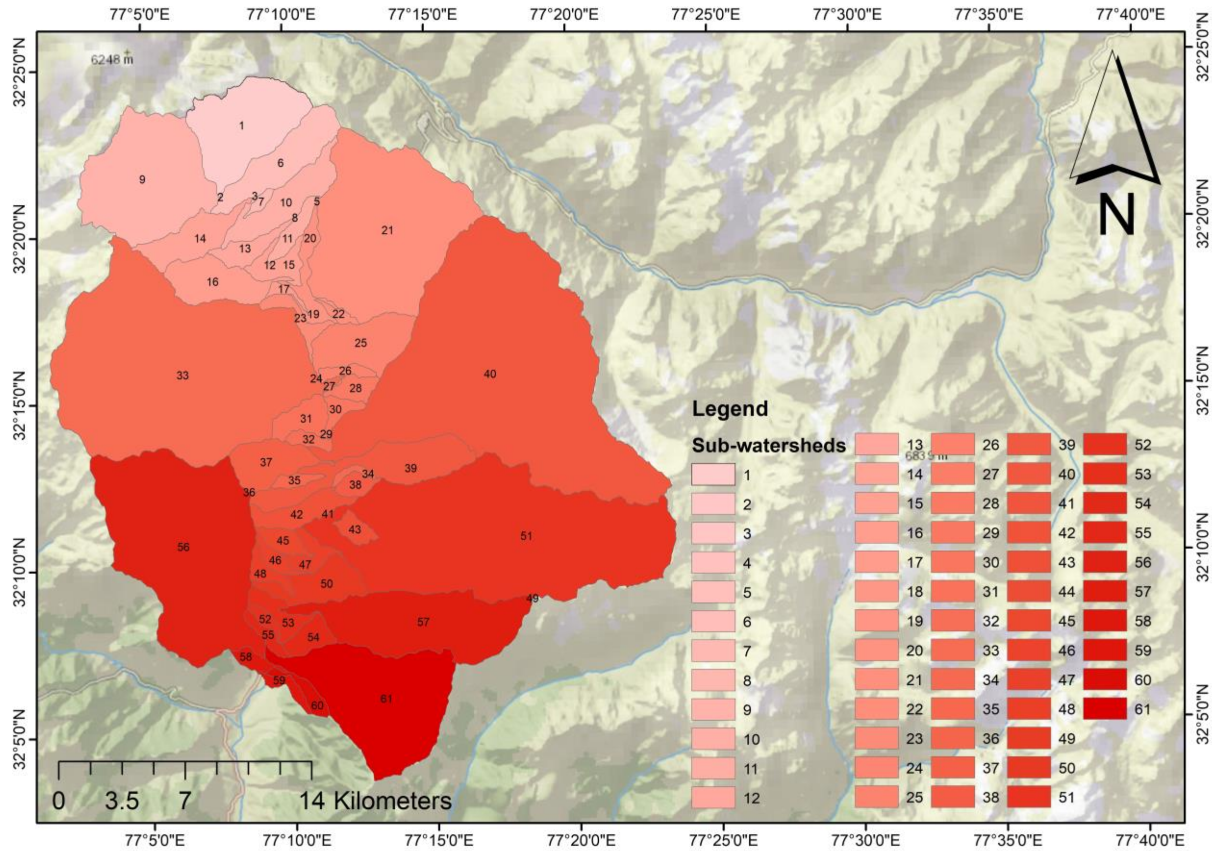


Figure 3.7 : Sub-Watersheds of Selected Study of Area

3.4 Land use land cover:

Land cover data provides information about what amount of area is covered by forests, settlement, barren land, agriculture, and other land and water. Land cover can be established by studying satellite and aerial imagery, land use of an area cannot be identified using satellite imagery [33]. Land cover maps help decision makers to analyze and understand the region's topography.

Land use and land cover (LULC) change due to significant urbanization and other natural calamities are playing major role in increasing global environment change. Land use/land cover plays an important role in development of a region. It helps to analyze socio-ecological concern of that region. Land cover is the biophysical state of the earth surface which tells us about the vegetation and other physical aspects such as built-up land etc. Land use, comprises of the ways in which the biophysical characteristics of a region are maneuvered and can also provide an idea of reason for which the land is being used.[33].

3.4.1 Supervised Image Classification

The land use land cover images were downloaded from Sentinel-2 satellite of September month 2020. Sentinel-2 provides global coverage after every five days. It is equipped with a multispectral imager (MSI) with 13 bands [41]. The bands selected for this study were 2,3,4,5,6,7,8,11,12.Using different band composition such as 4,3,2 for natural colors 8,4,3 for settlement and barren land were used. Band 11, 12 known as short wave infrared wavelength was used to differentiate snow cover from clouds.

Then AOI s extracted from the satellite image using desired band combination.

After AOI is extracted, using Image Classification tab, Training Sample window is opened ,then with the help of different band compositions different training samples are taken each for different classes such as water, snow, vegetation cover, settlement and barren land . Then using Maximum Likelihood classification tool the final classified image is extracted and ready to use.

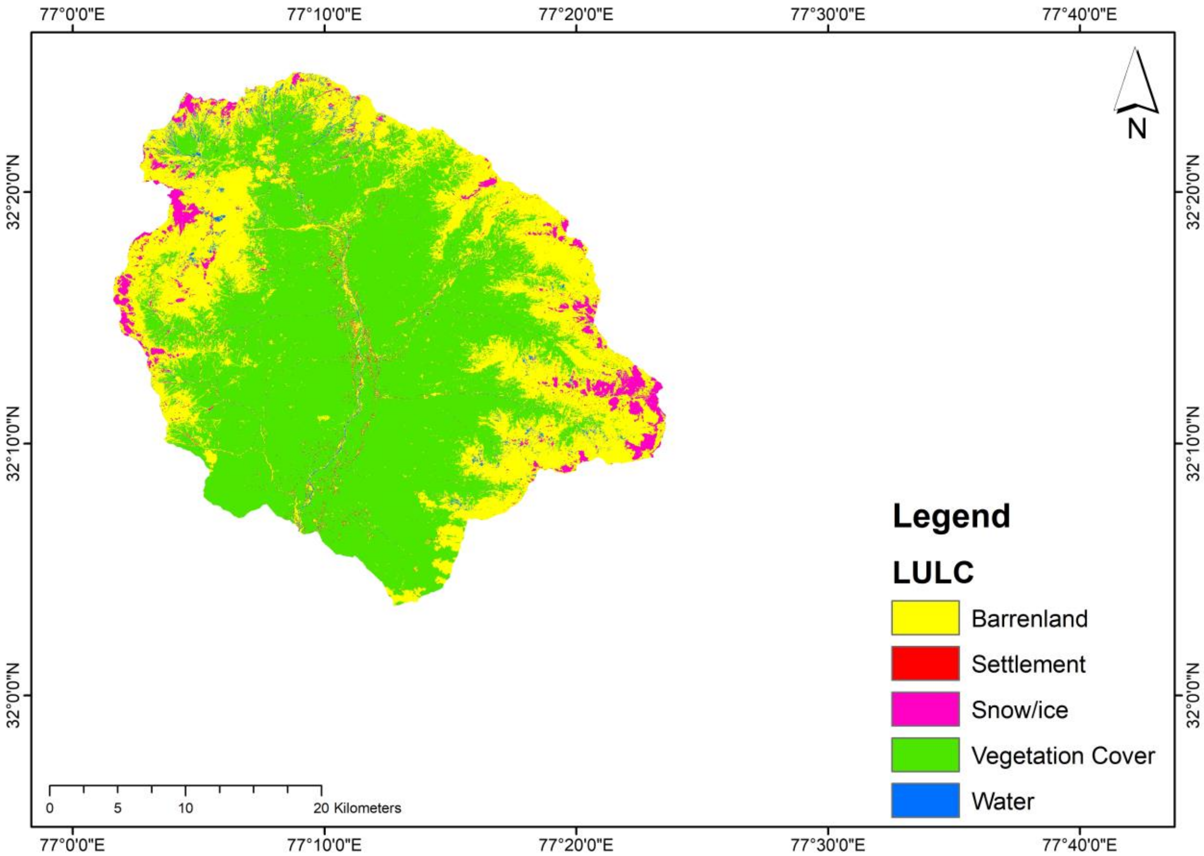


Figure 3.7: Land use land cover Map of study Area**.**

3.4.2. Accuracy Assessment

The Classified image generated is now cross referenced with the actual satellite image of the area. This is done to determine truth and false value of the classified image. So a shape file is created. And then samples are taken from different band areas in the image. Now all the sample points taken are classified into their respective representation i.e.1 for Forest, 2-Vegetation, 3- River, 4-Sandy area ,5- Agriculture land, 5- Settlement.

Cross checking on Google Earth is done now to see if the band coloured area is accurately represented if not then the value is changed according to the map of all the sample points.

To measure the accuracy in the site-specific assessment error matrix/ confusion matrix is used. Confusion matrix is obtained and positioned such that along the x-axis class membership established with the help of ground truth values are placed, and along the y-axis are the class membership which are determined through image classification [37].

Table 3.1 : Accuracy Assessment table

	Snow	Water	Rocky	Vegetation	Settlement	User
Snow	9	0	0	0	0	9
Water	3	7	0	0	0	10
Barren Land	6	0	4	0	0	10
Vegetation	0	0	2	5	0	7
Settlement	1	0	0	0	14	14
Producer	19	7	6	5	14	
Total						

Algorithms for accuracy assessment:

$$\text{Overall Accuracy} = \frac{\text{Total Number of Correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference Pixels}} * 100 \qquad [34]$$

$$\text{User Accuracy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{Total number classified pixels in that category (row total)}} * 100 \qquad [34]$$

$$\text{Producer Accuracy} = \frac{\text{Number of correctly classified ixels in each category}}{\text{Total number of classified pixels in that category (column total)}} * 100 \qquad [34]$$

Overall accuracy evaluates the percentage of cases correctly classified, so its interpretation is direct. In order to validate the result in image classification Kppa Coeffcient (K) is used. [35]

$$K = \frac{\left\{ n \sum_{i-\text{¿}1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \cdot\cdot x_{+i}) \right\}}{\left\{ n^2 - \sum_{i=1}^{r} (x_{i+} \cdot\cdot x_{+i}) \right\}} \qquad \text{(eq. 1)}$$

[36]

where:

r = number of rows in a cross-classification table;

x_{ii} = number of combinations diagonally;

x_{i} = total observations in row i;

x_{+i} = total observations in column j;

and n = total number of observations.

3.5 Slope :

The slope (S) is an important topographical factor responsible for degradation of watershed as due to the steep slopes more and more soil erosion resulting development of gullied and losing the fertility and moisture holding ability of soils. For generation of slope map slope tool in surface tools that is located in spatial analysis tool was used. Using the digital elevation model map of area and with the help of slope tool, the slope map for the region is generated in degrees as per figure 3.9.

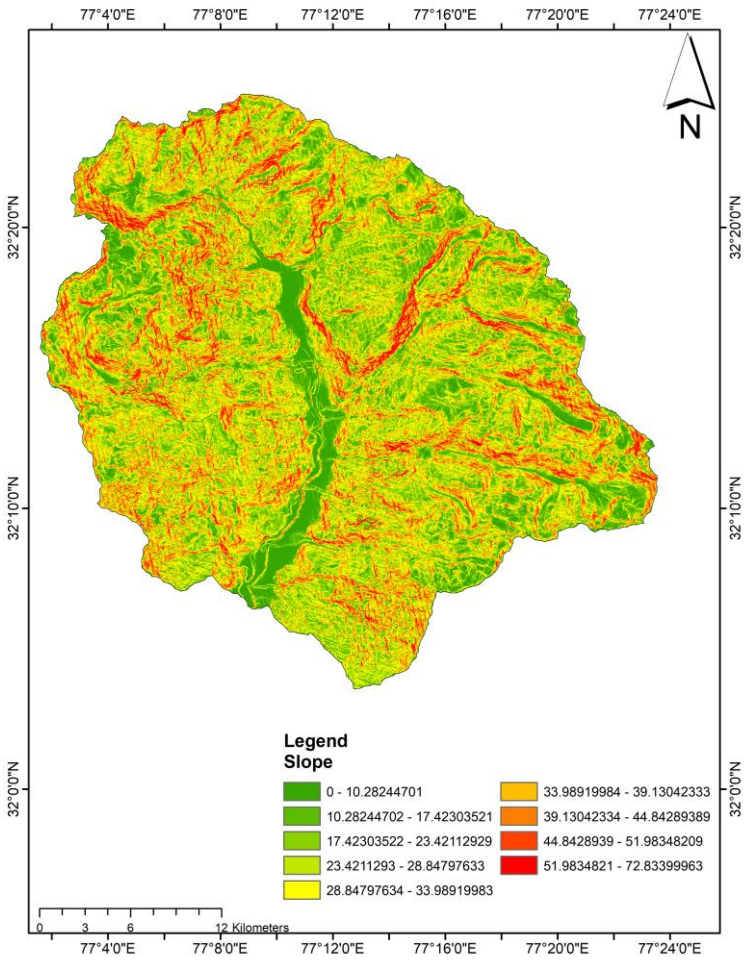


Figure 3.8 : Slope Distribution of Study Area

3.6 Watershed Prioritization

The analysis done using morphometric parameters is found to be of very useful for evaluation of drainage basin's evaluation. Thus evaluation further helps in prioritization of watersheds for taking measures against hazards like soil erosion, sedimentation. Priotritization also helps in better water resource management, water conservation and soil conservation. Morphometric analysis of a watershed gives a measureable examination of watersheds based on risk factors that can be prioritized for immediate or future risks [29].

3.6.1 Watershed Prioritization based on Morphometric Analysis:

Watershed prioritization is to be done for Sedimentation yield potential of the watershed. For this Morphometric charecterstics are taken which affects the erodibility and sedimentation in a watershed. Parameters which affects sedimentation directly are bifurcation ratio (Rb), drainage density (Dd), stream frequency (Fs), drainage texture (Dt), Length of overland flow. [39] Which means the more is the value of these parameters more are the chances of the watersheds to have sedimentation and erosion so sub watersheds with high values of these parameters will have high ranking in priority. Parameters that affects the erodibility and sedimentation inversely are elongation ratio (Re), compactness coefficient (Cc), circularity ratio (Rc), Basin Shape, and form factor (Ff). This means if the values of these parameters are more the chances of erosion and sedimentation is low in the watersheds. [40]

All the values of these parameters for all 61 sub watersheds is calculated using different spatial analyst and attribute tables in ArcGIS . And the values are written in the form of sheets. First all the directed related values are calculated together to find a computed superficial value of the risk of sedimentation. Same is done with inversely related parameters for all the sub watersheds. Once the sum of all these parameters is achieved a computation factor is calculated. Ranking of the watersheds is done based on this computation factor.

3.6.2. Watershed Prioritization for Sedimentation Susceptibility using AHP:

For AHP analysis we used 4 layers those were geomorphology layer, drainage density layer, land use land cover layer and slope layer, then ranks were provided to each layer and with the help of comparison matrix.

Once all the maps are ready weightage were given to each layer after that as per the ranking provided to the layers, then as per ranks given to classes of each layers weightages were given to the classes in which the layers were divided. After that with the help of union tool under overlay toolbox in analysis tools all layers were combined into one and overall weightage was given to that layer by adding all the weightages provided to different layers.

Analytic hierarchy process is a weighted analysis where different weight age is given to different factors and according to the weightage a raking is obtained from high to low prioritization of watersheds. For this Study weighted analysis are done for 4 Factors . : Geomorphology(GM), Land use Land cover(LULC), Drainage Density (DD) and Slope(S). Since there are 4 FACTORS so the highest weightage given will be 4 .

A matrix is made with all the Factors on vertical and horizontal sides of the matrix and actual weightage for each Factors is calculated using this matrix.

Table 3.2 Sedimentation Hazard parameters and their values.:

Factors	Geomorphology	Slope	LULC	Drainage Density	Weight
Geomorphology	4	3	2	1	0.48
Slope	2	1.5	1	0.50	0.24
LULC	1.33	1	0.67	0.33	0.16
Drainage Density	1	0.75	0.50	0.25	0.12
Total					1.00

Once this weightage of each factor is calculated, It is multiplied by the Rank given to different parameters of the factors given below:

- Geomorphology includes parameters like Active Flood Plain,Cirque, Glacial Lake, Glacial Valley, Highly Dissected Structural Hills and valleys, Moderatly Dissected denudational Hills and valleys, Moderatly Dissected Structural Hills and valleys, Piedmont Alluvial Plain, Piedmont Slope, River, Snow cover, Valley Glacier and Young Alluvial Plain.
- Drainage Density is divided into different values ranging from Very High, High, Medium, Low and Very low.

- LU/LC has been given ranking for Snow/Ice, Water, Barrenland, Vegetation and Settlement
- Slope values of Study area are divided into 5 ranges that are 0-14, 14-24,24-33, 33-43 and greater than 43. And respectively ranks are given .

CHAPTER 4
CALCULATIONS AND RESULT

4.1 Calculation of drainage morphometry:

Different drainage morphometric parameters (linear, areal and relief aspects) were extracted and calculated through a combination of geoprocessing tools available in ArcGIS.

4.1.1 Drainage Morphometry Formulae

Table 4.1 : Morphometric parameters of a river basin

Morphometric Parameters	Formulae	References
Stream Order (u)	Rank of a stream based on its origin	[11]
Stream Number (N_u)	N_u = number of streams of a particular order 'u'	[11]
Bifurcation Ratio (R_b)	$R_b = = (\frac{Nu}{Nu+1})$; where, N_u = stream number of order 'u', $N_u + 1$= Number of streams of next higher order $(u+1)$	[15]
Mean Bifurcation ratio (R_{bm})	R_{bm} = mean obifurcation ratios of all orders of stream	[15]
Stream Length (L_u)	L_u=total length of streams (km) of a particular order 'u	[15]

Mean stream length (L_{um})	$L_{um} = \left(\frac{Lu}{Nu}\right)$ where, L_u= Stream length of order (u), N_u=Stream number of irder (u)	[15]
Stream length ratio (R_l)	$R_l = \left(\frac{Lum}{Lum+1}\right)$; Where, L_{um} = mean stream length of oder (u), L_{um}+1 = mean stream length of order 'u+1'	[15]
AREAL ASPECTS		
Form Factor (F_f)	$F_f = \left(\frac{A}{L^2}\right)$; where, A = area of the drainage basin (km^2), L = length of basin (km)	[15]
Circularity Ratio (R_c)	$R_c = \left(\frac{4\pi A}{P2}\right)$; where, A = basin area (km^2), P = perimeter of a drainage basin (km)	[11]
Elongation Ratio (R_e)	$Re = \left(\frac{P}{\pi L}\right)$; P = perimeter of a drainage basin (km),	[11]

	L = basin length (km)	
Constant of Channel maintenance (CCM)	$CCM = \left(\frac{1}{Dd}\right)$; where, D_d = Drainage Density	[11]
Stream Frequency (F_s)	$F_s = \left(\frac{N}{A}\right)$; where, N = Total number of streams, A = Area of basin (km^2)	[15]
Drainage Density (D_d)	$D_d = \left(\frac{L}{A}\right)$; where, L = Length of all streams (km), A = area of the drainage basin (km^2).	[15]
Texture Ratio (R_t)	$R_{tv} = (Dd \times Fs)$, where, D_d = Drainage Density (km/km^2), F_s = Stream Frequency ($streamnumbers/km^2$)	[11]
RELIEF ASPECTS		
Relative Relief (H)	$H = (R - r)$, where, R =Highest relief, r = lowest relief value	[17]
Relief Ratio (R_r)	$Rr = \left(\frac{H}{L\ max}\right)$; where, H = Relative Relief (m), L = length of basin (m)	[17]

Dissection Index (D_i)	$D = \left(I \times \frac{H}{R}\right)$; H = relative relief (m), R = absolute relief (m)	[17]
Ruggedness Index (R_i)	$R = \left(I \times Dd \times \frac{H}{1000}\right)$; where, D_d = Drainage density, H = Relative relief	[17]

4.1.2 Drainage Morphometry Calculation:

1. Linear Aspects: For linear aspects morphometric parameters stream number, bifurcation Ratio, Mean bifurcation Ratio, Stream Length, Stream Length ratio and Mean stream length were calculated for all 61 sub-watersheds. As shown in Table 4.2 all the values were calculated saperately using the the formulas given in Table 4.1.

Table 4.2 : Linear Aspects table :

SUBWATERSHED	STREAM NUMBER					TOTAL STREAMS	BIFURCATION RATIO				MEAN BIFURCATION RATIO	STREAM LENGTH(KM)					Total length (KM)	LENGTH RATIO				Mean Strean Length (km)	MEAN STREAM LENGTH(KM)				
	1st Order	2nd Order	3rd Order	4th order	5th Order		1\2	2\3	3\4	4\5		1	2	3	4	5		2\1	3\2	4\3	5\4		1	2	3	4	5
SW1	9	2	1			12	4.5	2			1.625	9.193074	3.923284	2.825553			15.94191	0.426765	0.720201	0		3.188382	1.021453	1.961642	2.825553		
SW2			1			1		0			0						0					0			0		
SW3						0					0						0					0					
SW4						0					0						0					0					
SW5						0					0						0					0					
SW6	4	1				5	4				1	1.47946	6.90514				8.3846	4.667338	0			1.67692	0.369865	6.90514			
SW7	1					1					0	0.45201					0.45201	0				0.090402	0.45201				
SW8						0					0						0					0					
SW9	19	6	1			26	3.166667	6			2.291666667	17.5557	7.523389	5.35585			30.43494	0.428544	0.711893	0		6.086988	0.923984	1.253898	5.35585		
SW10	3	1				4	3				0.75	6.842481	0.543127				7.385608	0.079376	0			1.477122	2.280827	0.543127			
SW11	1					1					0	3.46242					3.46242	0				0.692484	3.46242				
SW12						0					0						0					0					
SW13	2	1				3	2				0.5	1.156395	0.474993				1.631388	0.410753	0			0.326278	0.578198	0.474993			
SW14	4	1				5	4				1	2.981583	4.321903				7.303486	1.449533	0			1.460697	0.745396	4.321903			
SW15				1		1			0		0				3.348194		3.348194				0	0.669639				3.348194	
SW16	4	1				5	4				1	4.140175	4.898221				9.038396	1.183095	0			1.807679	1.035044	4.898221			
SW17	1					1					0	1.0589					1.0589	0				0.21178	1.0589				
SW18						0					0						0					0					
SW19						0					0						0					0					
SW20	1			1	1	3			0	1	0.25	2.959484			0.940956	1.631557	5.531997	0			1.733935	1.106399	2.959484			0.940956	1.631557
SW21	26	5	2	1		34	5.2	2.5	2		2.425	18.36017	19.19177	8.578974	0.9376		47.06851	1.045294	0.447013	0.10929	0	9.413702	0.70616	3.838353	4.289487	0.9376	
SW22	1					1					0	0.999558					0.999558	0				0.199912	0.999558				
SW23	1	0			1	2				0	0	1.812596				2.451407	4.264003	0				0.852801	1.812596				2.451407
SW24						0					0						0					0					
SW25	6	1				7	6				1.5	6.150981	6.384854				12.53584	1.038022	0			2.507167	1.025164	6.384854			
SW26	1					1					0	0.984278					0.984278	0				0.196856	0.984278				
SW27					1	1				0	0					0.1729	0.1729					0.03458					0.1729
SW28	2				1	3				0	0	1.931628				0.275319	2.206947	0				0.441389	0.965814				0.275319
SW29						0					0						0					0					
SW30					1	1				0	0					2.691973	2.691973					0.538395					2.691973
SW31	3	1				4	3				0.75	3.502838	1.133035				4.635873	0.323462	0			0.927175	1.167613	1.133035			
SW32	1				1	2				0	0	1.168307				0.664031	1.832338	0				0.366468	1.168307				0.664031
SW33	48	9	3	1	1	62	5.333333	3	3	1	3.083333333	47.81954	16.02812	13.66213	8.177441	1.631878	87.31912	0.335179	0.852385	0.598548	0.199559	17.46382	0.99624	1.780903	4.554045	8.177441	1.631878
SW34	1				5	6				0	0	0.243094				0.121309	0.364403	0				0.072881	0.243094				0.024262
SW35	1					1					0	1.694616					1.694616	0				0.338923	1.694616				
SW36						0					0						0					0					
SW37	3	1				4	3				0.75	2.58623	4.52912				7.11535	1.751244	0			1.42307	0.862077	4.52912			
SW38	2	1				3	2				0.5	0.426678	0.364303				0.790981	0.853812	0			0.158196	0.213339	0.364303			
SW39	3	1			1	5	3			0	0.75	7.318838	5.368269			1.743148	14.43026	0.733487	0			2.886051	2.439613	5.368269			1.743148
SW40	46	6	2	1	1	56	7.666667	3	2	1	3.416666667	51.53289	19.36059	17.80885	6.996079	0.697798	96.3962	0.375694	0.919851	0.392843	0.099741	19.27924	1.12028	3.226765	8.904425	6.996079	0.697798
SW41						0					0						0					0					
SW42	1				1	2				0	0	3.81459				1.673928	5.488518	0				1.097704	3.81459				1.673928
SW43	1					1					0	1.425859					1.425859	0				0.285172	1.425859				
SW44						0					0						0					0					
SW45	1					1					0	1.982669					1.982669	0				0.396534	1.982669				
SW46	1					1					0	2.194885					2.194885	0				0.438977	2.194885				
SW47	1				1	2				0	0	0.173091				2.13664	2.309731	0				0.461946	0.173091				2.13664
SW48	1					1					0	1.983533					1.983533	0				0.396707	1.983533				
SW49						0					0						0					0					
SW50	4	1			1	6	4			0	1	1.281666	1.167298			2.171106	4.62007	0.910766	0			0.924014	0.320417	1.167298			2.171106
SW51	31	8	1		1	41	3.875	8		0	2.96875	29.49922	19.3016	18.38572		1.866955	69.05349	0.654309	0.952549	0		13.8107	0.951588	2.4127	18.38572		1.866955
SW52	1					1					0	0.796831					0.796831	0				0.159366	0.796831				
SW53	1				1	2				0	0	0.363424				2.709982	3.073406	0				0.614681	0.363424				2.709982
SW54	1					1					0	1.91275					1.91275	0				0.38255	1.91275				
SW55	1				1	2				0	0	0.920554				0.684861	1.605415	0				0.321083	0.920554				0.684861
SW56	26	6	1			33	4.333333	6			2.583333333	23.28406	12.47292	13.45289			49.20987	0.535685	1.078568	0		9.841973	0.895541	2.07882	13.45289		
SW57	8	2	1			11	4	2			1.5	12.36657	5.841675	6.743242			24.95148	0.472376	1.154334	0		4.990297	1.545821	2.920838	6.743242		
SW58	1				1	2				0	0	0.572711				0.871236	1.443947	0				0.288789	0.572711				0.871236
SW59	1				1	2				0	0	1.659278				0.573798	2.233076	0				0.446615	1.659278				0.573798
SW60	1				1	2				0	0	2.795867				0.136517	2.932384	0				0.586477	2.795867				0.136517
SW61	15	4	1		1	21	3.75	4		0	1.9375	11.32989	8.416403	8.115206		0.487362	28.34886	0.74285	0.964213	0		5.669772	0.755326	2.104101	8.115206		0.487362

2. Areal Aspects : Parameters under Areal aspects includes Area, perimeter, basin length, form factor, shape factor, compactness coefficient, elongation ratio and circulatory ratio. These parameters of all 61 sub watersheds were calculated.

Table 4.3 : Areal Aspects Calculation Table

SUB WATER SHED	AREA (km^2)	PERIMETER (km)	BASIN LENGTH (km)	FORM FACTOR (A/L^2)	SHAPE FACTOR	COMPACTNESS COEFFICIENT	ELONGATION RATIO	CIRCULATORY RATIO
1	25.5141	22.94830	20.75	0.059237176	16.88129088	1.2819337	0.35215	0.6
2	0.0008	0.11391	0.11	0.062082106	16.10770092	1.1324533	0.31847	0.8
3	0.0016	0.17553	0.18	0.052294829	19.1223497	1.233888	0.31847	0.7
4	0.0005	0.10453	0.10	0.047209721	21.18207814	1.2986389	0.31847	0.6
5	0.0016	0.17553	0.18	0.052295566	19.12208003	1.233881	0.31847	0.7
6	14.1512	21.10080	19.65	0.036636298	27.29533393	1.5827323	0.34192	0.4
7	0.9412	5.23242	5.06	0.036736841	27.22063153	1.5218211	0.32922	0.4
8	0.0008	0.11392	0.11	0.062082693	16.10754861	1.1324507	0.31847	0.8
9	40.1804	28.34020	24.67	0.066020463	15.1468189	1.2615398	0.36585	0.6
10	11.4711	24.24850	19.32	0.0307408	32.53005725	2.0201682	0.39977	0.2
11	3.2356	10.46290	10.05	0.032052052	31.19925028	1.6412591	0.33164	0.4
12	0.0006	0.10765	0.11	0.047616741	21.00101739	1.2930827	0.31847	0.6
13	4.0947	12.58420	11.60	0.030404742	32.88960673	1.754766	0.34535	0.3
14	9.5029	18.62950	16.55	0.034706635	28.81293411	1.7052081	0.35855	0.3
15	4.4147	15.39160	10.39	0.040871034	24.46720599	2.0669852	0.47164	0.2
16	11.3027	18.46740	16.53	0.041363827	24.17571247	1.5499577	0.35579	0.4
17	0.9873	6.68038	6.16	0.025977446	38.49493105	1.8971111	0.34511	0.3
18	0.0008	0.11395	0.11	0.062085309	16.10686999	1.1324261	0.31847	0.8
19	0.0079	0.43638	0.44	0.04172815	23.96463796	1.3813087	0.31847	0.5

20	5.2561	26.33520	16.36	0.019639684	50.91731656	3.2412341	0.51268	0.1
21	65.8309	36.29530	32.43	0.062601238	15.97412508	1.2622363	0.35645	0.6
22	1.1397	6.46377	6.09	0.030754959	32.51508148	1.7084245	0.33816	0.3
23	3.2691	14.68390	12.10	0.022334852	44.77307546	2.2915632	0.38653	0.2
24	0.0006	0.10768	0.11	0.047620411	20.99939885	1.2930248	0.31847	0.6
25	13.3637	17.67880	15.86	0.053118795	18.82572842	1.3645662	0.35496	0.5
26	1.7564	7.90969	7.45	0.031657099	31.58849095	1.684066	0.33819	0.4
27	0.1921	2.99351	2.82	0.02412162	41.45658605	1.9271646	0.33782	0.3
28	2.9530	8.58513	7.87	0.047632613	20.99401917	1.4096865	0.34725	0.5
29	0.0006	0.10769	0.11	0.047622473	20.99848973	1.2930083	0.31847	0.6
30	2.3133	9.42761	8.20	0.034368436	29.09646528	1.7490191	0.36597	0.3
31	4.9765	10.45770	9.55	0.054610221	18.31159047	1.3227562	0.34888	0.6
32	1.7853	6.98892	6.55	0.041664561	24.00121304	1.4759216	0.34003	0.5
33	119.67	53.04640	45.16	0.058678754	17.04194331	1.3682537	0.37409	0.5
34	1.0119	6.69661	6.03	0.027837373	35.92292954	1.8783772	0.35372	0.3
35	1.5467	6.97376	6.68	0.034708097	28.811721	1.5822487	0.3327	0.4
36	0.0008	0.11400	0.11	0.062090487	16.10552682	1.1323836	0.31847	0.8
37	9.4329	15.18310	14.04	0.04785691	20.89562391	1.3949006	0.34441	0.5
38	2.2581	6.74282	6.47	0.05401617	18.51297484	1.2661152	0.33212	0.6
39	18.1694	34.50420	27.63	0.023804226	42.00934666	2.2840565	0.39774	0.2
40	143.58	66.93240	56.40	0.045145457	22.15062308	1.5761119	0.37797	0.4
41	0.0086	0.58278	0.55	0.028307571	35.32623878	1.7722659	0.33655	0.3
42	6.3754	15.70640	13.93	0.032837758	30.4527492	1.7552006	0.35899	0.3
43	2.4936	7.32204	6.75	0.054652416	18.29745283	1.3083629	0.34522	0.6
44	0.000	0.109	0.11	0.0432	23.1326	1.3571133	0.31847	0.5

	5	35		29021	082			
45	2.9207	8.60531	8.09	0.044597333	22.42286558	1.4207797	0.33865	0.5
46	2.0730	8.83776	8.31	0.029988861	33.34571473	1.731991	0.33853	0.3
47	3.3141	12.27790	8.98	0.041125953	24.31554569	1.903048	0.43558	0.3
48	2.3979	9.30295	8.64	0.032090788	31.16159094	1.6951692	0.34274	0.3
49	0.0008	0.11404	0.11	0.062093702	16.104693	1.1323488	0.31847	0.8
50	9.0125	18.64860	14.91	0.0405142	24.68270385	1.7527855	0.3982	0.3
51	107.28	62.69610	48.01	0.046542475	21.48575019	1.707978	0.41588	0.3
52	1.2556	6.17277	5.92	0.035776737	27.95112393	1.5543825	0.33184	0.4
53	4.0620	13.61480	11.04	0.033297325	30.03244222	1.9061035	0.39257	0.3
54	3.7270	8.87164	8.42	0.0525798	19.01871065	1.2966715	0.33559	0.6
55	1.8801	8.29027	7.87	0.030366854	32.93064209	1.7060262	0.33554	0.3
56	75.5869	41.69640	36.82	0.055757009	17.93496496	1.3532576	0.36066	0.5
57	35.6781	34.99080	30.98	0.037170436	26.90310105	1.6529442	0.35968	0.4
58	1.9656	8.51521	7.39	0.035968437	27.80215353	1.7137935	0.36685	0.3
59	1.7823	9.12755	8.20	0.026497471	37.73945083	1.9291796	0.35444	0.3
60	2.4439	10.43050	9.55	0.026774733	37.3486446	1.8826649	0.3477	0.3
61	43.35	32.4777	29.83	0.048716781	20.52680763	1.3918675	0.34674	0.5

3. Relief Aspects: Under relief aspects parameters such as Highest elevation, lowest elevation, Relative relief , perimeter, relief ratio and dissection index of all 61 sub-watershed was calculated.

Table 4.4: Relief Aspects Calculation Table :

SUBWATERSHED	Highest Elevation	lowest Elevation	Relative Relief(H - L)	Perimeter(km)	Relief Ratio	Disection Index

SW1	5021	2813	2208	105.59	0.440	0.44
SW2	2782	2782	0	43.97	0.000	0.00
SW3	3427	3412	15	37.08	0.004	0.00
SW4	2278	2278	0	19.64	0.000	0.00
SW5	4025	4025	0	50.29	0.000	0.00
SW6	4911	2689	2222	73.35	0.452	0.45
SW7	3882	2630	1252	86.86	0.323	0.32
SW8	3450	3450	0	54.53	0.000	0.00
SW9	5455	2777	2678	78.87	0.491	0.49
SW10	4664	2495	2169	97.16	0.465	0.47
SW11	4158	2403	1755	52.13	0.422	0.42
SW12	2401	2400	1	30.44	0.000	0.00
SW13	4249	2436	1813	69.53	0.427	0.43
SW14	5117	2646	2471	74.69	0.483	0.48
SW15	3308	2249	1059	45.16	0.320	0.32
SW16	4972	2298	2674	55.40	0.538	0.54
SW17	2941	2147	794	44.18	0.270	0.27
SW18	2145	2145	0	76.07	0.000	0.00
SW19	2142	2116	26	76.07	0.012	0.01
SW20	3987	2078	1909	76.07	0.479	0.48
SW21	4785	2171	2614	76.07	0.546	0.55
SW22	3399	2165	1234	76.07	0.363	0.36
SW23	3203	1954	1249	76.07	0.390	0.39
SW24	1920	1919	1	76.07	0.001	0.00
SW25	4180	1922	2258	76.07	0.540	0.54
SW26	3568	1908	1660	76.07	0.465	0.47
SW27	2490	1894	596	76.07	0.239	0.24
SW28	3614	1880	1734	76.07	0.480	0.48
SW29	1804	1803	1	76.07	0.001	0.00
SW30	3069	1791	1278	76.07	0.416	0.42
SW31	3212	1805	1407	76.07	0.438	0.44
SW32	2923	1769	1154	76.07	0.395	0.39
SW33	5205	1896	3309	76.07	0.636	0.64
SW34	2672	1691	981	76.07	0.367	0.37
SW35	3410	1714	1696	76.07	0.497	0.50
SW36	3794	3794	0	76.07	0.000	0.00
SW37	3990	1739	2251	76.07	0.564	0.56
SW38	2772	1687	1085	76.07	0.391	0.39
SW39	4390	1693	2697	76.07	0.614	0.61
SW40	5727	1746	3981	76.07	0.695	0.70
SW41	1740	1651	89	76.07	0.051	0.05
SW42	3784	1651	2133	76.07	0.564	0.56
SW43	2905	1634	1271	76.07	0.438	0.44

SW44	2480	2474	6	76.07	0.002	0.00
SW45	3536	1587	1949	76.07	0.551	0.55
SW46	3469	1565	1904	76.07	0.549	0.55
SW47	2707	1561	1146	76.07	0.423	0.42
SW48	3308	1536	1772	76.07	0.536	0.54
SW49	4735	4735	0	76.07	0.000	0.00
SW50	2995	1524	1471	76.07	0.491	0.49
SW51	5721	1606	4115	76.07	0.719	0.72
SW52	2481	1472	1009	76.07	0.407	0.41
SW53	2685	1472	1213	76.07	0.452	0.45
SW54	2496	1473	1023	76.07	0.410	0.41
SW55	2426	1460	966	76.07	0.398	0.40
SW56	4866	1447	3419	76.07	0.703	0.70
SW57	4803	1510	3293	76.07	0.686	0.69
SW58	2416	1428	988	76.07	0.409	0.41
SW59	2550	1422	1128	76.07	0.442	0.44
SW60	2875	1427	1448	76.07	0.504	0.50
SW61	4361	1449	2912	76.07	0.668	0.67

4.2 Land use/Land Cover calculation

According to Confusion matrix table the Values are taken and put in the algorithm to calculate Overall Accuracy, User Accuracy, Producer Accuracy and Kappa Coefficient.

$$\text{Overall Accuracy} = \frac{\text{Total Number of Correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference Pixels}} * 100 \qquad [34]$$

$$= \frac{39}{51} \times 100$$

$$= 76.47\%$$

$$\text{User Accuracy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{Total number classified pixels in that category (row total)}} * 100 \qquad [34]$$

For, Snow $= \frac{9}{9} \times 100 = 100\%$

Water $= \frac{7}{10} \times 100 = 70\ \%$

Vegetation Cover $= \frac{5}{7} \times 100 = 71.42\ \%$

Barren land $= \frac{4}{10} \times 100 = 40\ \%$

Settlement $= \frac{14}{15} \times 100 = 93.3\ \%$

Producer Accuracy = $\frac{\text{Number of correctly classified ixels in each category}}{\text{Total number of classified pixels in that category (column total)}}$ *100 [34]

For , Snow $= \frac{9}{19} \times 100 = 47.36\%$

Water $= \frac{7}{7} \times 100 = 100\ \%$

Vegetation Cover $= \frac{5}{5} \times 100 = 100\ \%$

Barren land $= \frac{4}{6} \times 100 = 66.67\ \%$

Settlement $= \frac{14}{14} \times 100 = 100\ \%$

Kappa Coefficient (K) :

$$K = \frac{(51 \times 39) - (19 \times 9 + 10 \times 7 + 10 \times 6 + 7 \times 5 + 14 \times 15)}{51^2 - 546}$$

$$K = \frac{1443}{2055}$$

$$K = 70.22\ \%$$

4.3 AHP Calculations:

4.3.1 : AHP Calculation for Weightage value Drainage Density> G.M. > S> LULC :

Table 4.5 : AHP Calculation for ranking Dd > GM >S> LULC

Factors	DD	GM	Slope	LULC	Weight
Drainage Density	4	3	2	1	0.48
Geomorphology	2	1.5	1	0.50	0.24
Slope	1.33	1	0.67	0.33	0.16
LULC	1	0.8	0.50	0.25	0.12
Total					1.00

Factors		Rank	Overall
Drainage Density			
Very High	48	4	192
High		3	144
Medium		2	96
Low		1	48
Very Low		1	48
Geomorphology			
Active Flood Plain	24	4	96
Cirque		1	24
Glacial Lake		3	72
Glacial Valley		3	72
Highly Dissected Structural Hills and valleys		3	72
Moderatly Dissected denudational Hills and valleys		3	72
Moderatly Dissected Structural Hills and valleys		3	72
Piedmont Alluvial Plain		4	96
Piedmont Slope		4	96
River		4	96
Snow cover		1	24
Valley Glacier		2	48
Young Alluvial Plain		3	72
Slope			
0-14	16	1	16
14-24		2	32
24-33		3	48
33-43		4	64
>43		4	64
LULC			
Snow/ice	12	2	24
Water		4	48
Barrenland		3	36
Vegetation cover		2	24
Settlement		1	12

4.3.2 AHP Calculation for Weghtage value Drainage Density> S>G.M. > LULC :

Table 4.6 : AHP Calculation for ranking DD > S >GM> LULC

Factors	Drainage	Slope	Geomorphology	LULC	Weight
Drainage Density	4	3	2	1	0.48
Slope	2	1.5	1	0.50	0.24
Geomorphology	1.33	1	0.67	0.33	0.16
LULC	1	0.75	0.50	0.25	0.12
Total					1.00

Factors		Rank	Overall
Slope			
0-14	24	1	24
14-24		2	48
24-33		3	72
33-43		4	96
>43		4	96
Geomorphology			
Active Flood Plain	16	4	64
Cirque		1	16
Glacial Lake		3	48
Glacial Valley		3	48
Highly Dissected Structural Hills and valleys		3	48
Moderatly Dissected denudational Hills and valleys		3	48
Moderatly Dissected Structural Hills and valleys		3	48
Piedmont Alluvial Plain		4	64
Piedmont Slope		4	64
River		4	64
Snow cover		1	16
Valley Glacier		2	32
Young Alluvial Plain		3	48
Drainage Density			
Very High	48	4	192
High		3	144
Medium		2	96
Low		1	48
Very Low		1	48
LULC			
Snow/ice	12	2	24
Water		4	48
Barrenland		3	36
Vegetation cover		2	24
Settlement		1	12

4.3.3. AHP Calculation for Weightage value S>DD >G.M. > LULC :

Table 4.7 : AHP Calculation for ranking S > DD> GM . LULC:

Factors	GM	Slope	LULC	DD	Weight
Geomorphology	4	3	2	1	0.48
Slope	2	1.5	1	0.50	0.24
LULC	1.33	1	0.67	0.33	0.16
Drainage Density	1	0.75	0.50	0.25	0.12
Total					1.00

Geomorphology			
Active Flood Plain	48	4	192
Cirque		1	48
Glacial Lake		3	144
Glacial Valley		3	144
Highly Dissected Structural Hills and valleys		3	144
Moderatly Dissected denudational Hills and valleys		3	144
Moderatly Dissected Structural Hills and valleys		3	144
Piedmont Alluvial Plain		4	192
Piedmont Slope		4	192
River		4	192
Snow cover		1	48
Valley Glacier		2	96
Young Alluvial Plain		3	144
Slope			
0-14	24	1	24
14-24		2	48
24-33		3	72
33-43		4	96
>43		4	96
LULC			
Snow/ice	16	2	32
Water		4	64
Barrenland		3	48
Vegetation cover		2	32
Settlement		1	16
Drainage Density			
Very High	12	4	48
High		3	36
Medium		2	24
Low		1	12
Very Low		1	12

4.4 Results

Area, perimeter and basin length of 61 sub watershed were calculated and prioritization was done first on basis of Morphometric analysis. Linear, Areal and Relief Aspects were used to calculate computation factor and ranking for prioritization. Prioritization based on AHP was also done using LULC, Drainage Density, Geomorphology and Slope maps and data gathered on GIS software. All the maps and data were analysed using Saaty's AHP technique to get the ranking of medium high and low risks for erosivity and sedimentation.

4.4.1. Prioritization OF Watershed based on Morphometric Analysis:

Prioritization of the watershed was done based on the Computation Factor (CP) it was calculated using parameters and how they affected sedimentation in watershed such as factor like drainage density, stream frequency, bifurcation ratio, drainage texture and length of overland flow are directly proportional to sedimentation so sub watershed ranking was done in descending order and factors such as elongation ratio, compactness coefficient, circulatory ratio, basin shape and form factor are inversely proportional to sedimentation means higher the factor value lower is the sedimentation hence sub watershed ranking was done in ascending order, at last all factors ranking was summed up and average was taken out to calculate the compound factor.

Table 4.8 : Computation factor table :

SW	Drainage Density	stream frequency	Bifurcation Ratio	Drainage Texture	Length of over land flow	ELONGATION RATIO	COMPACTNESS COEFFCIENT	CIRCULATORY RATIO	FORM FACTOR	CP	Rank	Area
1	38	31	8	48	10	38	11	51	54	32.1	2	25.51
6	39	40	11	23	9	28	34	28	25	26.3	29	14.15
7	44	8	22	27	4	14	29	33	26	23.0	44	0.94
9	22	18	6	4	26	48	8	54	61	27.4	20	40.18
10	35	41	15	28	13	57	57	5	13	29.3	10	11.47
11	7	44	22	46	41	15	35	27	16	28.1	15	3.24
13	45	16	19	22	3	33	47	15	12	23.6	39	4.09
14	20	24	11	19	28	44	39	23	21	25.4	34	9.50

15	21	48	22	47	27	60	58	4	29	35.1	1	4.41
16	18	32	11	18	30	42	30	32	31	27.1	21	11.30
17	6	11	22	32	42	31	52	10	5	23.4	41	0.99
20	9	22	21	41	39	61	61	1	1	28.4	13	5.26
21	28	27	5	3	20	43	9	53	60	27.6	19	65.83
22	14	12	22	31	34	23	42	20	14	23.6	40	1.14
23	1	20	22	37	47	53	60	2	2	27.1	22	3.27
25	11	25	9	11	37	41	21	41	48	27.1	23	13.36
26	41	23	22	39	7	24	37	25	15	25.9	31	1.76
27	13	3	22	14	35	22	55	7	4	19.4	47	0.19
28	25	10	22	13	23	35	26	36	42	25.8	33	2.95
30	4	34	22	45	44	49	45	17	20	31.1	5	2.31
31	12	14	15	12	36	37	18	44	50	26.4	28	4.98
32	10	6	22	17	38	27	28	34	32	23.8	37	1.79
33	27	26	2	2	21	51	22	40	53	27.1	24	119.67
34	46	2	22	5	2	39	50	12	8	20.7	46	1.01
35	5	19	22	35	43	18	33	29	22	25.1	35	1.55
37	24	35	15	20	24	30	25	37	43	28.1	16	9.43
38	47	4	19	10	1	17	10	52	49	23.2	42	2.26
39	19	46	15	34	29	55	59	3	3	29.2	11	18.17
40	32	38	1	6	16	52	32	30	36	27.0	25	143.59
42	15	43	22	38	33	45	48	14	18	30.7	6	6.38
43	40	37	22	36	8	32	17	45	51	32.0	4	2.49
45	31	42	22	40	17	26	27	35	35	30.6	7	2.92
46	8	30	22	42	40	25	44	18	10	26.6	26	2.07
47	30	21	22	29	18	59	53	9	30	30.1	8	3.31
48	17	36	22	44	31	29	38	24	17	28.7	12	2.40
50	43	17	11	15	5	56	46	16	28	26.3	30	9.01
51	36	39	3	8	12	58	41	21	37	28.3	14	107.28
52	37	15	22	30	11	16	31	31	23	24.0	36	1.26
53	23	28	22	33	25	54	54	8	19	29.6	9	4.06
54	42	47	22	43	6	20	15	47	47	32.1	3	3.73
55	16	7	22	21	32	19	40	22	11	21.1	45	1.88
56	34	33	4	7	14	47	19	43	52	28.1	17	75.59
57	29	45	9	16	19	46	36	26	27	28.1	18	35.68
58	26	9	22	24	22	50	43	19	24	26.6	27	1.97
59	2	5	22	25	46	40	56	6	6	23.1	43	1.78
60	3	13	22	26	45	36	51	11	7	23.8	38	2.44
61	33	29	7	9	15	34	24	38	44	25.9	32	43.35

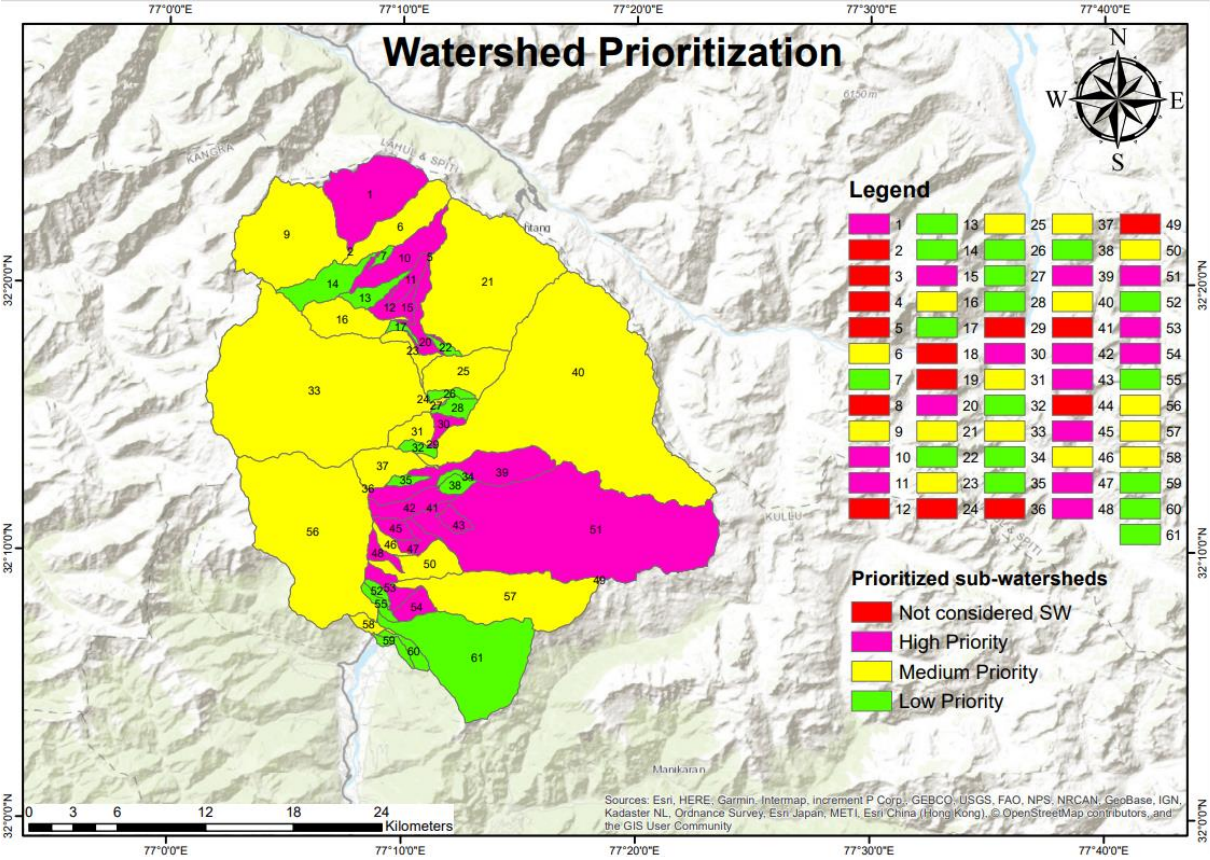


Figure 4.1 : Watershed Prioritization map

Table 4.9 : Category wise Prioritized Watershed Table

PRIORITIZATION CLASSES		
SUB-WATERSHEDS	PRIORITY TYPE	%AREA
SW15,SW1,SW54,SW43,SW30,SW42,SW45, SW47,SW53,SW10,SW39,SW48,SW20,SW51 ,SW11	HIGH	24.3954
SW37,SW56,SW57,SW21,SW9,SW16,SW23, SW25,SW33,SW40,SW46,SW58,SW31,SW6, SW50	MODERATE	66.1227
SW26,SW61,SW28,SW14,SW35,SW52,SW32 ,SW60,SW13,SW22,SW17,SW38,SW59,SW7, SW55,SW34,SW27	LOW	9.4819

High priority: Sub Watersheds SW15, SW1, SW54, SW43, SW30, SW42, SW45, SW47, SW53, SW10, SW39, SW48, SW20, SW51, SW11 are given high priority based on the risk of sedimentation in these sub watersheds which means they have the highest chances of sedimentation and require most attention among other prioritizedgroups. Measures that can reduce the risk of sedimentation are contour bunding, gully reclamation, contour vegetative barriers,

Medium priority : Sub Watersheds SW37, SW56, SW57, SW21, SW9, SW16, SW23, SW25, SW33, SW40, SW46, SW58, SW31, SW6 and SW50 aregiven medium priority because of medium drainage density and less elongation of the shapes than high priority given watersheds. Sedimentation can be treated by simple measures such as adding vegeation cover to that area such as planting trees or mulching will reduce the sedimentation yield of that area.

Low priority: Sub watersheds SW26, SW61, SW28, SW14, SW35, SW52, SW32, SW60, SW13, SW22, SW17, SW38, SW59, SW7, SW55, SW34 and SW27are given low priority. These are the watersheds that are having least importance with respect to other watersheds means they don’t require any conservation parameters to reduce sedimentation yield and if required it can simply be treated by adding vegetation cover to that area.

4.4.2 Watershed Prioritization for Sedimentation Susceptibility using AHP :

Prioritzitation based on Sedimentation factors was done by giving different weightage to different factors and then new calculated parameters values were assigned to the map to get the prioritized map from Red color representing high priority, Yellow color representing medium priority and Green color representing low priority. LULC is given lowest ranking becayse of its accuracy being 70% calculated. Prioritization is based on Pixels and each pixel show its priority with color.

1. **For Weightage ranking GM >S >DD>LULC**:

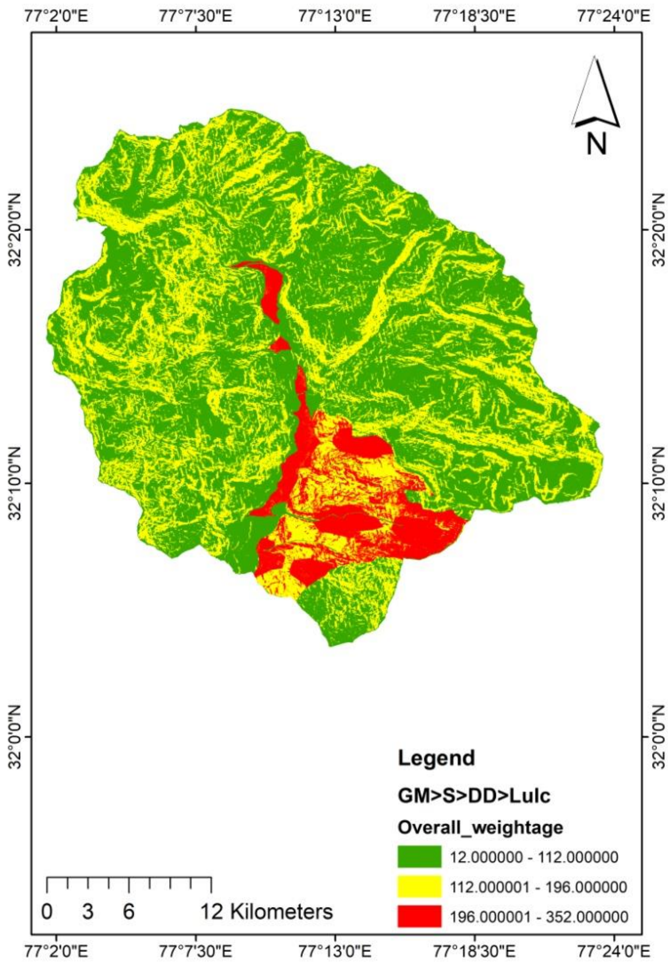


Figure 4.2 : Prioritized watershed map for rankng GM>S>DD>LULC

As the figure. 4.2 shows younger alluvial plains are given highest priority with red color. Alluvial plane with low DD is given medium prioritization meaning medium risk of sedimentation. Medium dissected denudation hills and valleys with high slope and high drainage density is given medium priority. Medium priority represented by yellow color is also given to high slope dissected structural hills and valley area with medium to high DD. Dissected hills and valley area with low drainage density is given low priority. Moderately dissected structural hills of the study area are given medium to low priority based on slope. Low priority is given to moderately denudation hills and valleys, low slope hills and valleys, low sloped moderately dissected hills and valleys with low and medium drainage density.

2. **For weightage ranking DD > GM > S > LULC :** When Drainage Desnity is given most Weightage for prioritization followed by Geomorphology, slope and Lulc following results shown in Figure 4.3 were observed . Areas with highest drainage density is shown to have highest risks for prioritization where majority of sedimentation risks are in the main stream. Places with meium to low drainage density but high slopes are given high priority too.

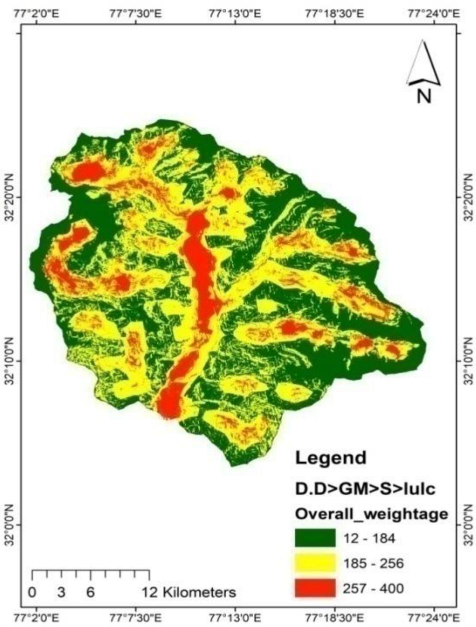


Figure 4.3: Prioritized watersheds for DD> GM > s > LULC

3. **For weightage ranking DD> S> GM >lulc :** This map shows high priority given to slopy areas consisting of highly dissected stricture and hills and valleys including rocky mountain areas it also shows high risk of sedimentation in the alluvial plains near the ,aim river stream. Areas with medium slope hills and valleys is given medium priority . Low priority is given to snow covered areas, and medium and high elevated areas with low DD are also given low priority. High drainage density areas of alluvial plain with medium slopes are also given high priority.

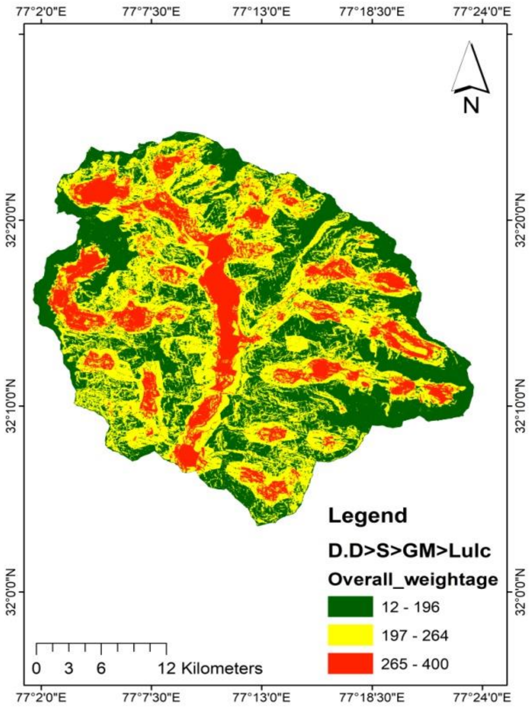


Figure 4.4 : Prioritized watershed for ranking DD>S>GM>LULC

CHAPTER 5
CONCLUSION

The changes of stream length of study area basin were found to be irregular throughout the different order ,it's a sign of the younger stage of geomorphologic development .The areal aspects characteristics of study area basin shows a large value of discharge and peak flow in comparatively less given time. All these parameters are the characteristics of younger stages of basin development geomorphic area. The relief parameters of Beas basin shows young stages of geomorphic development and rejuvenated morphological characteristics of mountainous region.

By using GIS we sub divided our watersheds into 61 sub-watersheds and performed different analyses on the watershed to obtain results for morphometric parameters. These parameters help us to indicate geomorphic evolution of our watershed. Using morphometric parameters we were able to categories are sub watershed in high, medium and low priority.

Among these 61 watersheds, SW15, SW1, SW54, SW43, SW30, SW42, SW45, SW47, SW53, SW10, SW39, SW48, SW20, SW51 and SW11 come under high priority which means these watersheds are most vulnerable to sedimentation susceptibility with respect to other watersheds. Measures that can be taken in these watersheds are flow deflection using rench, Slope Texturing, Controlling Construction Traffic, adopting suitable practices for land treatment, e.g., field bund wall, contour vegetative barriers, , contour bund wall gully reclamation. SW37, SW56, SW57, SW21, SW9, SW16, SW23, SW25, SW33, SW40, SW46, SW58, SW31, SW6 and SW50 come under medium priority hence they require less measures than high priority watershed to control sedimentation susceptibility. No immediate measures are needed but some measures that can be take are Use Existing Drainage, Design Drainage Channels Appropriately for reducing future risks of higher sedimentation yield ad erosion, SW26,SW61,SW28,SW14,SW35,SW52,SW32,SW60,SW13,SW22,SW17,SW38,SW59,SW7 ,SW55,SW34 and SW27 are the watersheds which come under low priority may not even require any measures to control sedimentation susceptibility because they have very low chances of it. With help of this data decision maker can take action beforehand to minimize the loss due to sedimentation susceptibility.

AHP analysis was also performed on the watershed and we were able to indicate areas vulnerable to sedimentation susceptibility as per weightage provided but due to limited data and time were not able to provide proper and correct weightage to the layers provided for analysis which might have caused errors in our result for AHP, none the less we were able to obtain ample of knowledge about AHP like how it is performed and how can it used for decision making.

Future Scope : AHP for this study included factors Geomorphology, Drainage density, Slope and Lulc . The results can be improved using Geology data and Soil texture. However, Detailed Geology of study area was not available and neither was soil texture data for open source . The AHP results will be made more accurate and can be used in better ways for soil conservation and sedimentation protection. Land use Land Cover study for the given area was done only using one year’s data. LULC data of multiyear can be used to find advancement and degradation data of the area to provide better results. And once AHP data are more accurate the Factors used for AHP can also be added for CP calculation to provide more accurate representation and prioritization of watersheds.

REFERENCE

1. Iqbal and Sajjad, J Geophys Remote Sens 2014, 3:1 DOI:10.4172/2169-0049.1000115
2. Youssef, A. M., Pradhan, B., & Hassan, A. M. (2011). Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery. Environmental Earth Sciences , 62(3), 611-623.
3. James S. Gardner & Eric Saczuk .Journal of Mountain Science volume 1, Article number: 115 (2004)
4. Chandrashekar H, Lokesh K V, Sameena M, Roopa J and Ranganna G 2015 Proc. Int. Conf. on Water Resources, Coastal and Ocean Engineering (Mangalore) vol 4 ed G S Dwarakish (Elsevier Procedia) 1345 – 1353
5. Abboud I A and Nofal R A 2017 J. African Earth Sci. 126 58-74
6. Thakkar A K and Dhiman S 2007 Morphometric analysis and prioritization of miniwatersheds in Mohr watershed, Gujarat using remote sensing and GIS techniques; J. Indian Soc. Remote Sens. 35 313–321.
7. Saaty T L 1980 The Analytic Hierarchy Process; McGraw Hill, New York.
8. Sah, M.P., Mazari, R.K., 2007. An overview of the geoenvironmental status of the Kullu Valley, Himachal Pradesh, India. J. Mt. Sci. 4 (1), 3–23. https://doi.org/10.1007/s11629-007-0003-x.
9. Clarke JJ (1966) Morphometry from map. Essays in geomorphology. Elsevier, New York, pp 235–274
10. Horton RE (1932) Drainage basin characteristics, 2nd edn. ransactions, American Geophysical Union, New York
11. Strahler AN (1964) Quantitative geomorphology of basins and channel networks. In: Chow VT (ed) Handbook of applied hydrology. McGraw Hill Book Company, New York
12. Thomas J, Joseph S, Thrivikramaji KP (2010) Morphometric aspects of a small tropical mountain river system, the southern Western Ghats, India. Int J Digit Earth 3(2):135–156

13. Joji VS, Nair AS, Baiju KV (2013) Drainage basin delineation and quantitative analysis of Panamaram Watershed of Kabani River Basin, Kerala using remote sensing and GIS. J Geol Soc Ind 82:368–378
14. Smith KG (1950) Standards for grading texture of erosional topography. Am J Sci 248:655–668
15. Horton RE (1945) Erosional development of streams and their drainage basins: hydro physical approach to quantitative morphology. Bull Geol Soc Am 56:275–370
16. Bali R, Agarwal KK, Ali SN, Rastogi SK, Krishna K (2011) Drainage morphometry of Himalayan Glacio-fluvial basin, India: hydrologic and neotectonic implications. Environ Earth Sci 66(4):1163–1174
17. Schumm SA (1956) The evolution of drainage system and slopes in Badlands at Perth Amboy, New Jersey. Bull Geol Soc Am 67:214–236
18. Dutta S, Roy S (2012) Determination of erosion surfaces and stages of evolution of Sangra drainage basin in Giridih district, Jharkhand, India. Int J GeomatGeosci 3(1):63–73
19. https://serc.carleton.edu/introgeo/google_earth
20. Shrestha RK, Ahlers R, Bakker M, Gupta J (2010) Institutional dysfunction and challenges in food control: a case study of the Kosi food 2008. Econ Polit Wkly 14(2):45–53
21. Raux J, Copard Y, Laignel B, Fournier M, Masseï N (2011) Classifcation of worldwide drainage basins through the multivariate analysis of variables controlling their hydro sedimentary response. Glob Planet Change 76:117–127
22. Chen NS, Hu GS, Deng W, Khanal N, Zhu YH, Han D (2013) On the water hazards in the trans-boundary Kosi River basin. Nat Hazards Earth Syst Sci 13:795–808
23. Lindsay JB, Seibert J (2013) Measuring the signifcance of a divide to local drainage patterns. Int J Geogr Inf Sci 27(7):1453–1468
24. Haghipour N, Burg JP (2014) Geomorphological analysis of the drainage system on the growing Makran accretionary wedge. Geomorphology 209:111–132
25. Waikar ML, Nilawar AP (2014) Morphometric analysis of a drainage basin using geographical information system: a case study. Int J MultidiscipCurr Res 2:179–184
26. Ansari ZR, Rao LA, Yusuf A (2012) GIS based morphometric analysis of yamuna drainage network in parts of Fatehabad area of Agra District, Uttar Pradesh. J Geol Soc India 79:505–514

27. Parveen R, Kumar U, Singh VK (2012) Geomorphometric characterization of Upper South Koel Basin, Jharkhand: a remote sensing & GIS approach. J Wat ResourProt4:1042–1050
28. A. Balasubramanian (2017) Remote Sensing and GIS applications for water resources studies, Hydrogeochemistry, Groundwater modeling, Geochemical modeling and computer applications
29. Strahler AN (1952) Hypsometric analysis (area-altitude) of erosional topography. Geol Soc Am Bull 63:117–142
30. Sharma, P. D., Goel, A. K. and Minhas, R. S., Water and sediment yields into the Satluj river from the High Himalaya. Mt. Res. Dev., 1991, 11, 87–100.
31. Rawat, J. S. and Rawat, M. S., Accelerated erosion and denudation in the Nana Kosi watershed, Central Himalayas, India, Part I: sediment load. Mt. Res. Dev., 1994, 14, 25–38.
32. Novotny and Olem, 1994. V. Novotny, H. Olem. Water Quality: Prevention and Management of Diffuse Pollution, Van Nostrand-Reinhold, New York, NY (1994).
33. urner BL II, Clark C, Kates RW, Richards JF, Mathews JT, et al. (1990) The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years. Cambridge University Press, Cambridge, UK.
34. Congalton, R. G. and K. Green. 1999. Assessing the accuracy of remotely sensed data: Principles and practices. Lewis Publishers, Boca Raton.
35. Lillesand and Kiefer, Chapter 7
36. J. Cohen, Weighted Kappa: Nominal Scale agreement with provision for scaled disagreement or partial credit. Psychological Bulletin, 70: 213–220, 1968
37. Maitima JM, Mugatha SM, Reid RS, Gachimbi LN (2009) The linkages between land use change, land degradation and biodiversity across East Africa. 3(10): 310-325.
38. Manual for National Geomorphological and Lineament Mapping on 1:50,000 scale February 2010Report number: NRSC/RS&GIS-AA/GEOM//October 2009Affiliation: Indian Space Research Organisation and Geological Surve of India Authors: Krishnamurthy Jagannathan
39. Biswas S, Sudhakar S, Desai VR (1999) Prioritization of sub-watersheds based on Morphometric Analysis of Drainage Basin, District Midnapore, West Bengal. J Indian Soc Remote Sensing 27: 155-166.

40. Ratnam NK, Srivastava YK, Rao VV, Amminedu E, Murthy KSR (2005) Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis- Remote Sensing and GIS perspective. J Indian Soc Remote Sensing 33: 25-38.

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT

PLAGIARISM VERIFICATION REPORT

Date: 15/06/21........

Type of Document (Tick): PhD Thesis | M.Tech Dissertation/ Report | B.Tech Project Report ✔ | Paper

Name: Sahil Thakur,Saksham kaushal and Nikhil Thakur **Department:** Civil **Enrolment No** 171635,171642,171658

Contact No. 8219278743,9816859752,8350935007 **E-mail.**171635@juitsolan.in,171642@juitsolan.in,171658@juitsolan.in

Name of the Supervisor: Dr. Saurav

Title of the Thesis/Dissertation/Project Report/Paper (In Capital letters): WATERSHED PRIORITIZATION OF UPPER BEAS REGION USING RS AND GIS

UNDERTAKING

I undertake that I am aware of the plagiarism related norms/ regulations, if I found guilty of any plagiarism and copyright violations in the above thesis/report even after award of degree, the University reserves the rights to withdraw/revoke my degree/report. Kindly allow me to avail Plagiarism verification report for the document mentioned above.

Complete Thesis/Report Pages Detail:

- Total No. of Pages = 67
- Total No. of Preliminary pages = 11
- Total No. of pages accommodate bibliography/references = 4

171635-
171642-
171658-

(Signature of Student)

FOR DEPARTMENT USE

We have checked the thesis/report as per norms and found **Similarity Index** at ....17........(%). Therefore, we are forwarding the complete thesis/report for final plagiarism check. The plagiarism verification report may be handed over to the candidate.

Saurav

(Signature of Guide/Supervisor)

HOD
CE DEPT

Signature of HOD

FOR LRC USE

The above document was scanned for plagiarism check. The outcome of the same is reported below:

Copy Received on	Excluded	Similarity Index (%)	Generated Plagiarism Report Details (Title, Abstract & Chapters)	
	• All Preliminary Pages • Bibliography/Images/Quotes • 14 Words String		Word Counts	
Report Generated on			Character Counts	
		Submission ID	Total Pages Scanned	
			File Size	

Checked by
Name & Signature **Librarian**

....

Please send your complete thesis/report in (PDF) with Title Page, Abstract and Chapters in (Word File) through the supervisor at plagcheck.juit@gmail.com