

# **CATCHMENT AREA MANAGEMENT PLAN FOR MIMBUNG VILLAGE**



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## **Chapter 1**

### **Introduction**

Utilization of available natural resources is a major concern for all the stake holders. Soil and water are the two major natural resources which directly or indirectly affect the livelihood of the people. Planning and management of these two natural resources is need of the hour which is mostly affected by the growing population, industrialization deforestation, etc.

watershed is an ideal unit for sustainable management of natural resources i.e land and water to mitigate the adverse effect of exploitation. Quality and quantity of immense data base are required for management of any watershed or drainage. Land, water and vegetation are the most precious especially for mountainous region, where the economy is predominately agriculture and forest based. The unscientific agricultural practices and resources exploitation has caused soil erosion, landslides, siltation of river and flash flood in different part of North Eastern Region.

Soil degradation in India is estimated to be occurring on 147 million hectares (Mha) of land, including 94 Mha from acidification, 14 Mha from flooding, 9 Mha from wind erosion, 6 Mha from salinity, and 7 Mha from combination factors (Bhattacharyya et al. 2015). ICAR-NE has reported that the watersheds of northern states can be sustained with an average annual soil loss 46t/ha/y.

Soil erosion has increased throughout the 20<sup>th</sup> century (Angima et al., 2003), and is becoming an extremely serious environmental problem, if not a crisis (Stanley and Pierre, 2000).

Soil erosion and degradation of land resources are significant problems in a large number of countries. A quantitative assessment is needed to infer on the extent and magnitude of soil erosion problems so that sound management strategies can be developed on a regional basis. Field measurements are required for such an assessment. In addition, simulation models for soil erosion can be used to evaluate alternative land management scenarios in both the gauged and the ungauged areas (De Roo, 1996)

Soil erosion and related degradation of land resources are highly significant spatio-temporal phenomena in many countries (Fistikoglu and Harmancioglu, 2002; Hoyos, 2005; Pandey et al., 2009). Soil erosion, generally associated with agricultural practices

in tropical and semi-arid countries, leads to decline in soil fertility, brings on a series of negative impacts of environmental problems, and has become a threat to sustainable agricultural production and water quality in the region.

It has been estimated that in India about 5334 m-tonnes of soil are being removed annually due to various reasons (Narayan and Babu, 1983; Pandey et al., 2007). In recent years, as part of environment and land degradation assessment policy for sustainable agriculture and development, soil erosion is increasingly being recognized as a hazard which is more serious in mountain areas (Millward and Mersey, 1999; Angima et al., 2003; Jasrotia and Singh, 2006; Dabral et al., 2008; Sharma, 2010).

In many regions, unchecked soil erosion and associated land degradation have made vast areas economically unproductive. Often, a quantitative assessment is needed to infer the extent and magnitude of soil erosion problems so that effective management strategies can be resorted to. But, the complexity of the variables makes precise estimation or prediction of erosion difficult. The latest advances in spatial information technology have augmented the existing methods and have provided efficient methods of monitoring, analysis and management of earth resources.

Digital elevation model (DEM) along with remote sensing data and GIS can be successfully used to enable rapid as well as detailed assessment of erosion hazards (Jain et al., 2001; Srinivas et al., 2002; Kouli et al., 2009).

Spatial and quantitative information on soil erosion on a subwatershed scale contributes significantly to the planning for soil conservation, erosion control, and

management of the watershed environment. The results of estimation of soil loss in the subwatersheds

were carried out on an experiment basis in many tropical regions using different prediction techniques (Shrestha,1997; Douglas, 2006; Van De et al., 2008).

However, soil erosion management strategies in the North eastern regions are constrained by dearth of such data, because actual measurements of soil loss from crop fields and mountainous regions are uncommon in the country.

Hence, the present study was carried out with an objective to assess the annual soil erosion rate and develop a soil erosion intensity map for a mountainous watershed of river Tulia and Tuivai river using RUSLE and GIS techniques.

### **1.1 Objectives of the study**

- Delineation of catchment area and its micro watersheds.
- To assess the annual soil erosion rate and develop a soil erosion intensity map for study area using RUSLE and GIS techniques.
- Preparation of management plan in priority areas

## **Chapter 2**

### **Materials and methods**

In the present paper, an attempt has been made to delineate and estimate the soil loss from the study area by preparing management plan in priority micro watersheds. General description of the area, geographical setting of the study i.e., climate, relief, geology, natural vegetation and land use as well as analytical and spatial methods adopted by using GIS and Remote Sensing data.

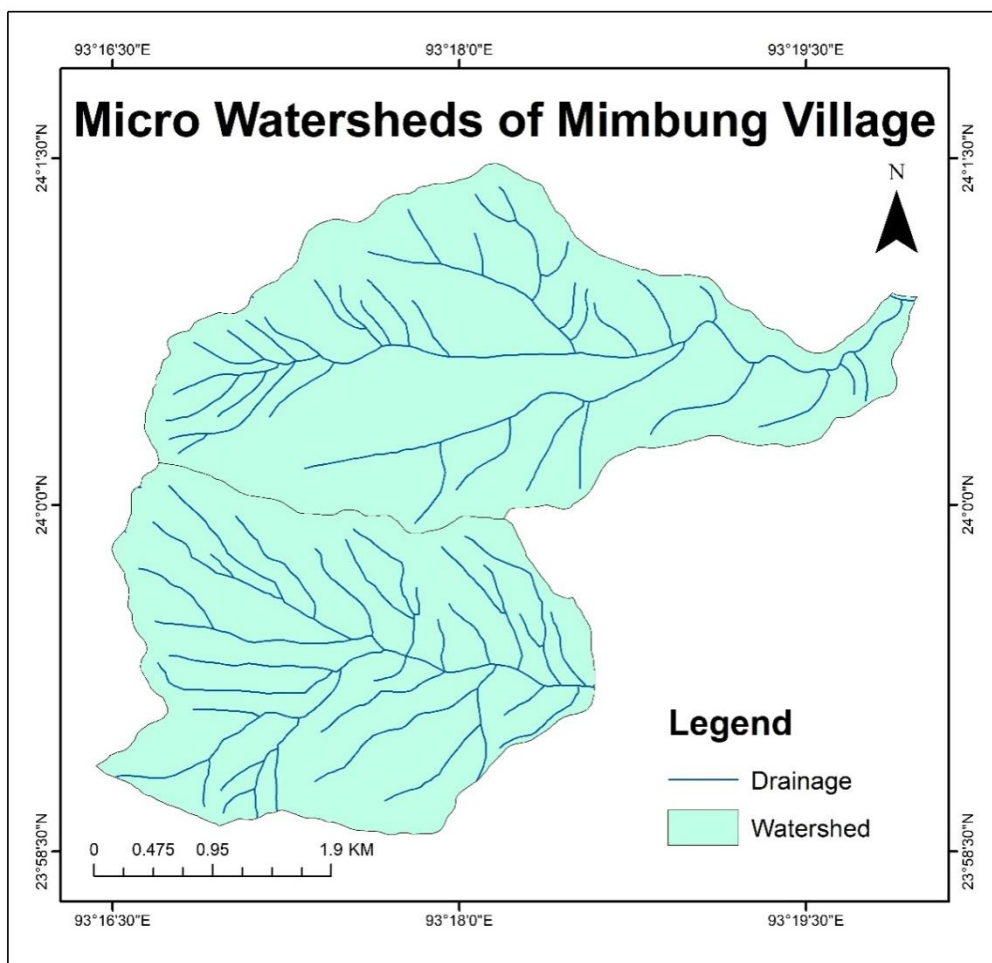
The different thematic maps such as digital elevation models, flow direction, flow accumulation, slope , topographic factor and drainage has been prepared through DEM data of 30 metre resolution from bhuvan and USGS Landsat 8 “LC08\_ L1TP”

image is used for LULC. GIS software like ArcGIS 10.3 and ERDAS has been used for computation and output generation purpose.

## 2.1 Study area

The study area is Mimbung village situated in the northeastern part of Mizoram of Champai district that lies in between latitude 23.9996°N to 93.2854°E covering an area of 16.862 square kilometres. It is the border of Champai district & Aizawl district. There are two micro watersheds from tulia and tuivai river.

The region has a moderate climate and classified as warm temperate climate, where summers are much rainier than the winters with an annual temperature of 18.6°C. It is having an average annual rainfall of 2062mm. The least amount of rainfall occurs in



**Fig 2.1** micro-watersheds of Mimbung

January. The greatest amount of precipitation occurs in June, with an average of 416 mm. The region is highly undulating and exhibits typical highland topography.

The relief is normally a moderate steeply sloping where drainage condition varies from well drain in upland areas and in low lying areas. Almost 80% of the area is occupied by thick evergreen forests, followed by scrubland, forest plantations and degraded forests. Almost all other parts of the catchment are highly inaccessible due to dense forest cover and rugged terrain. Geomorphologically, the sub watershed are characterised by steep structural hills, denudational hills, narrow gorges, intermontane valleys and precipitous escarpments with thick vegetation.

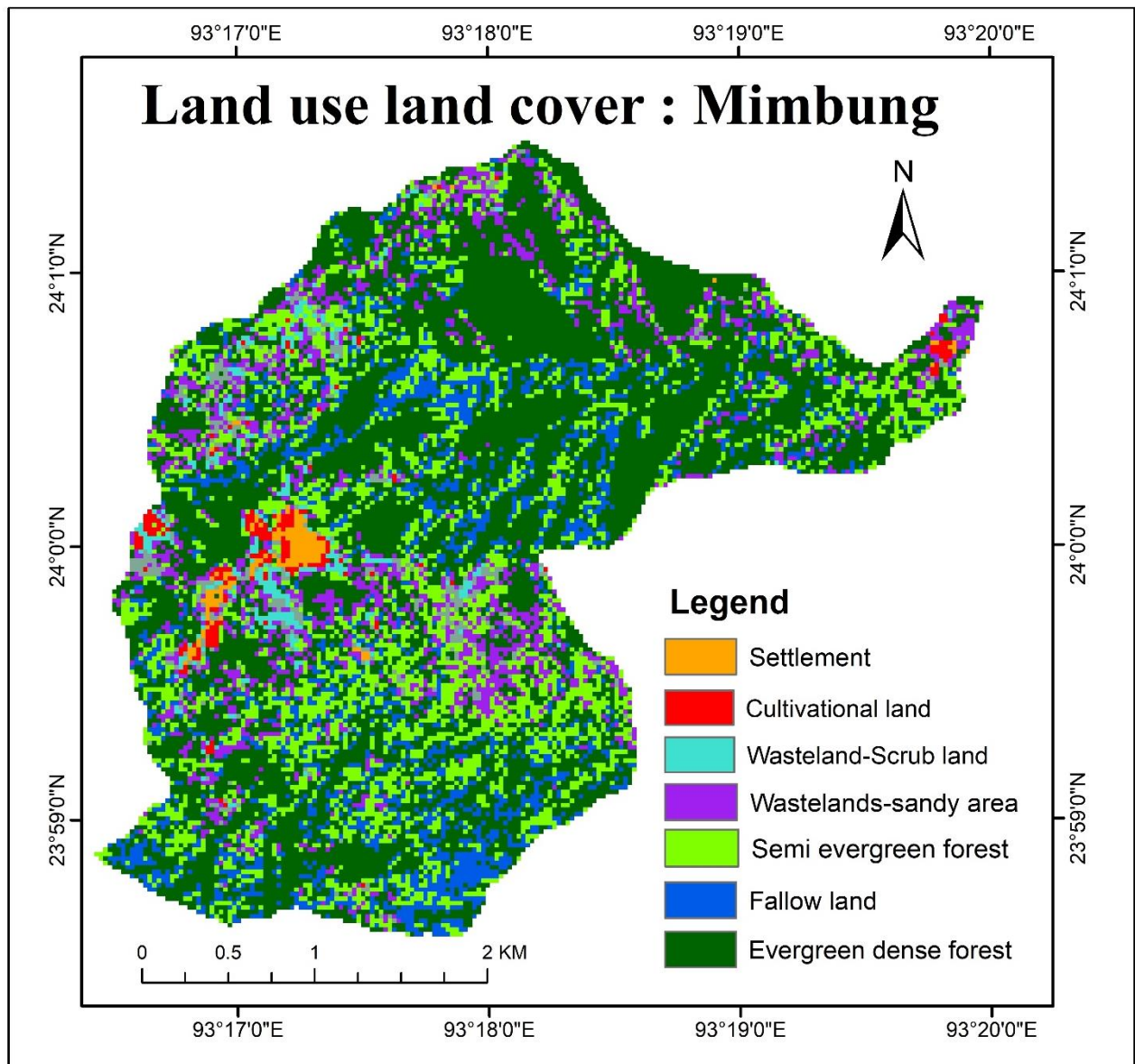
The soil texture is gravelly clay followed by coarse loam, fine loam and loamy skeletal which is well drained with moderate permeability. The region consist of various soil series like Tawizo, Buarpu, Bunghmun, Chhingchhip, Kawlkuh, Khawhai, Khawzawl, Lawngtlai, Lunglei, Lungsen-III, Phairuankai, Saitual, Zawlpui.

Tawizo soil are very deep, dark brown (10YR 3/3) to yellowish red (7.5YR 5/6), clay loam to clay, very strongly acid, well drained on hill side slopes with severe to moderate erosion, patchy thin cutans are formed.

Tawizo belongs to the subgroup Humic owing to the presence of Umbric epipedon. Saitual soils have very deep, dark brown to strong brown, sandy clay loam to clay loam, strongly acidic, moderately well drained with moderate erosion.



The series Saitual belongs to subgroup FluventicUmbric by having darker epipedons than the Typic. The economy of the area revolves around agriculture and livestock. Paddy, French-bean, carrot, tomato, potato, cabbage, cauliflower, ginger, turmeric, pea, black papper, bettal nut, beetal leaf, broomstick, bamboo are commonly grown.



**Fig 2.2 Land use land cover**

## 2.2 Annual soil loss estimation method

The emergence of soil erosion models has enabled the study of soil erosion, especially for conservation purposes, in effective and acceptable level of accuracy. To estimate

soil erosion and to develop optimal soil erosion management plans, many erosion models, such as Universal Soil Loss Equation/Revised Universal Soil Loss Equation (USLE/RUSLE), Water Erosion Prediction Project (WEPP), Soil Erosion Model for Mediterranean Regions (SEMMED), Areal Non-point Source Watershed Environment

Response Simulation (ANSWERS), Limburg Soil Erosion Model (LISEM), European Soil Erosion Model (EUROSEM), Soil and Water Assessment Tool (SWAT), Simulator for Water Resources in Rural Basins (SWRRB), Agricultural Non-point Source pollution model (AGNPS), etc. were used in regional scale assessment. Each model has its own characteristics and application scopes (Boggs et al., 2001; Lu et al., 2004; Dabral et al., 2008; Tian et al., 2009).

The dominant model applied worldwide to soil loss prediction is USLE/RUSLE, because of its convenience in application and compatibility with GIS (Millward and Mersey, 1999; Jain et al., 2001; Lu et al., 2004; Jasrotia and Singh, 2006; Dabral et al., 2008; Kouli et al., 2009; Pandey et al., 2009; Bonilla et al., 2010).

Although it is an empirical model, it not only predicts erosion rates of ungauged watersheds using knowledge of the watershed characteristics and local hydroclimatic conditions, but also presents the spatial heterogeneity of soil erosion that is too feasible with reasonable costs and better accuracy in larger areas (Angima et al., 2003).

### **2.3 RUSLE Method**

The RUSLE has been widely used for both agricultural and forest watersheds to predict the average annual soil loss by introducing improved means of computing the soil erosion factors (Wischmeier and Smith, 1978; Renard et al., 1997).

RUSLE is the method, most widely used around the world to predict long-term rates of inter-rill and rill erosion from field or farm size units subject to different management practices.

The RUSLE model can predict erosion potential on a cell-by-cell basis, which is effective when attempting to identify the spatial pattern of soil loss present within a large region. This equation is a function of five input factors in raster data format: rainfall erosivity; soil erodability; slope length and steepness; cover management; and support practice.

These factors vary over space and time and depend on other input variables.

Therefore, soil erosion within each pixel was estimated with the RUSLE.

The RUSLE method is expressed as:

$$A=R*K *LS*C*P \quad (1)$$

where A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t ha<sub>-1</sub> y<sub>-1</sub>)

R is the rainfall-runoff erosivity factor (MJ mm ha<sub>-1</sub> h<sub>-1</sub> y<sub>-1</sub>)

K is the soil erodability factor (t ha h ha<sub>-1</sub> MJ<sub>-1</sub> mm<sub>-1</sub>)

LS is the slope lengthsteepness factor (dimensionless)

C is the cover management factor (dimensionless, ranging between 0 and 1.5)

P is the erosion control (conservation support) practices factor (dimensionless, ranging between 0 and 1).

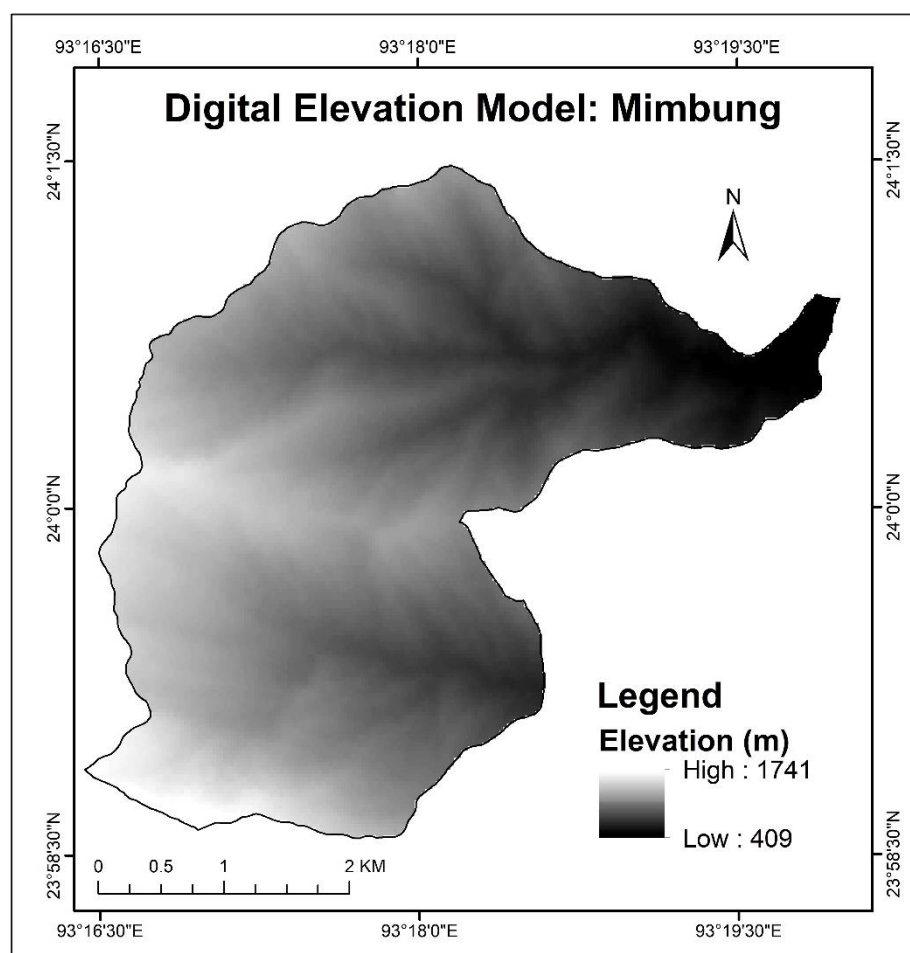
## 2.4 Morphometric analysis of watershed

Morphometric analysis of watershed is the best method to identify the relationship of various aspects in the area. It's a comparative evaluation of different watersheds in various geomorphological and topographical conditions. Watershed is a natural hydrological entity from which surface runoff flows to a defined drain, channel, stream or river at a particular point. Drainage basin/watershed analysis based on morphometric parameters is very important for watershed planning since it gives an idea about the basin characteristics regarding slope, topography, soil condition, runoff characteristics, surface water potential, etc. The morphometric analysis of watershed aids to know the aspects of linear, areal, and relief parameters.

It is the quantitative description and analysis of landforms as practiced in geomorphology that may be applied to a particular kind of landform or to drainage basins and large regions. Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds.

### 2.4.1 Digital Elevation Model

DEM is representation of the elevation of earth s' surface above a certain datum (eg mean sea level) in digital form this is achieved taking elevation measurement at regular or irregular spaced points.

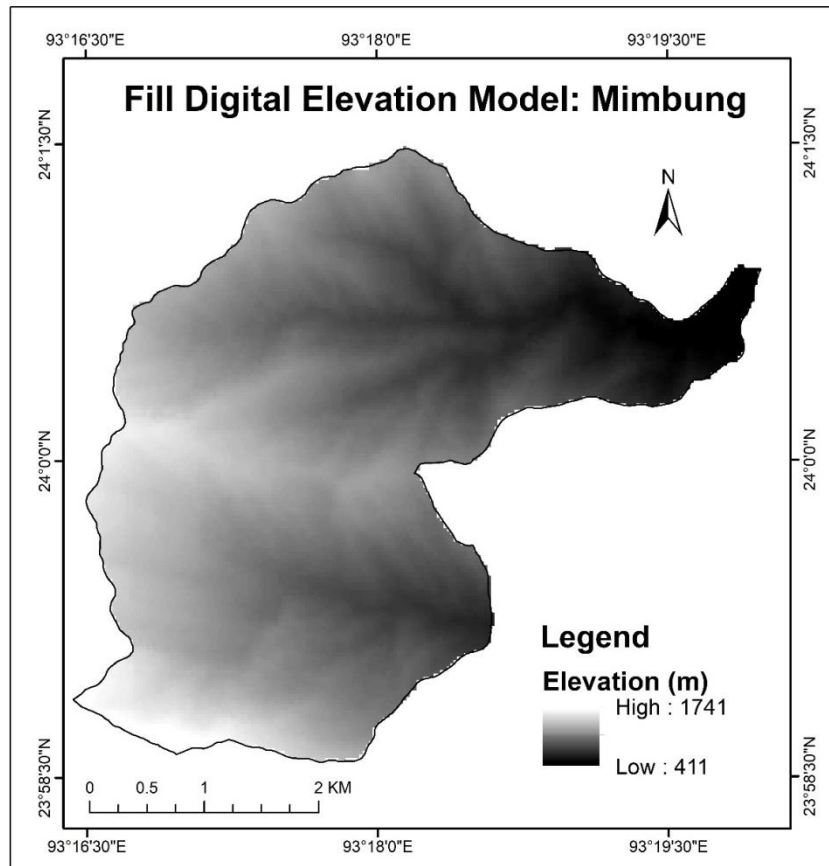


**Fig 2.3 Digital Elevation Model**

It consists of data files that contain the elevation of the terrain over a specified area usually at a fixed grid interval over the “Bare Earth”.

Fills sinks in a surface raster to remove small imperfections in the data. Fill can also be used to remove peaks. A peak is a cell where no adjacent cells are higher.

A DEM that has been processed to remove all sinks and peaks is called a depression less DEM .To create an accurate representation of flow direction and, therefore, accumulated flow, it is best to use a dataset that is free of sinks or peaks.



**Fig 2.4 Fill digital elevation model**

Sink is an area surrounded by higher elevation values and is also referred to as a depression.

A sink is a cell with an undefined drainage direction; no cells surrounding it are lower. The pour point is the boundary cell with the lowest elevation for the contributing area of a sink. If the sink were filled with water, this is the point where water would pour out. Sinks and peaks are often errors due to the resolution of the data or rounding of elevations to the nearest integer value.

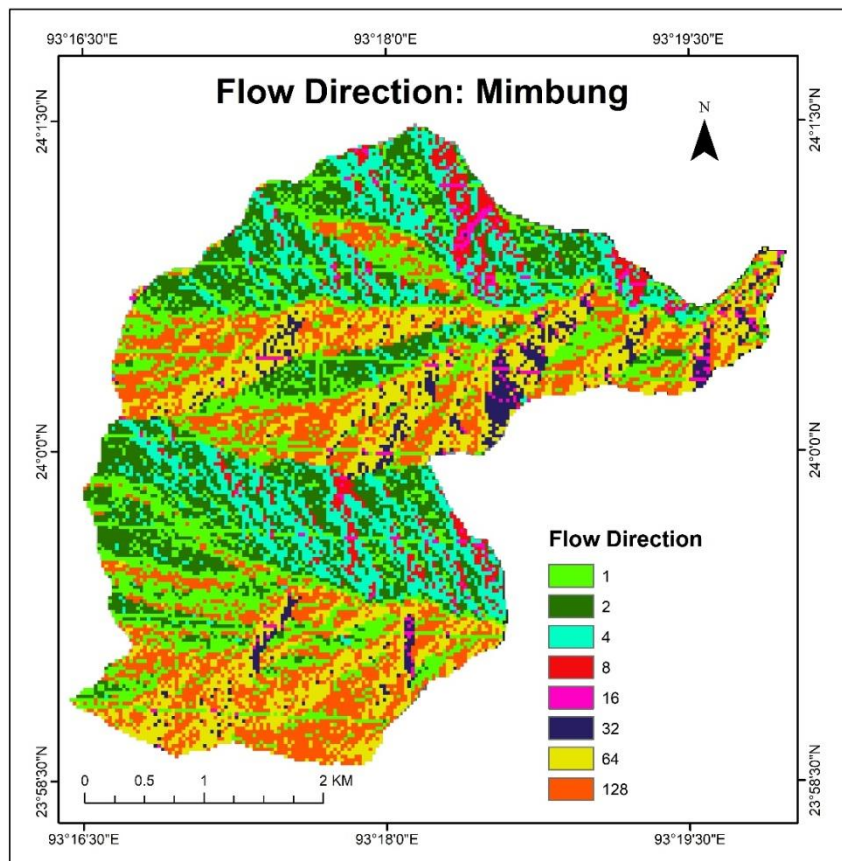
Sinks should be filled to ensure proper delineation of basins and streams. If the sinks are not filled, a derived drainage network may be discontinuous.

### 2.4.2 Flow Direction:

It creates a raster of flow direction from each cell to its steepest downslope neighbor.. Flow direction indicates the direction of flow from every cell in the raster representing the landscape. It is important to know in hydrologic modelling the direction in which a landscape drains

It was prepared using “Flow Direction” function of ArcGIS Spatial Analysis hydrology tool.

The result of flow direction is in 1,2,4,8,16,32,64,128. These number represents the direction of Flow i.e East, South East, South, South West, West, North West, North and North East respectively.



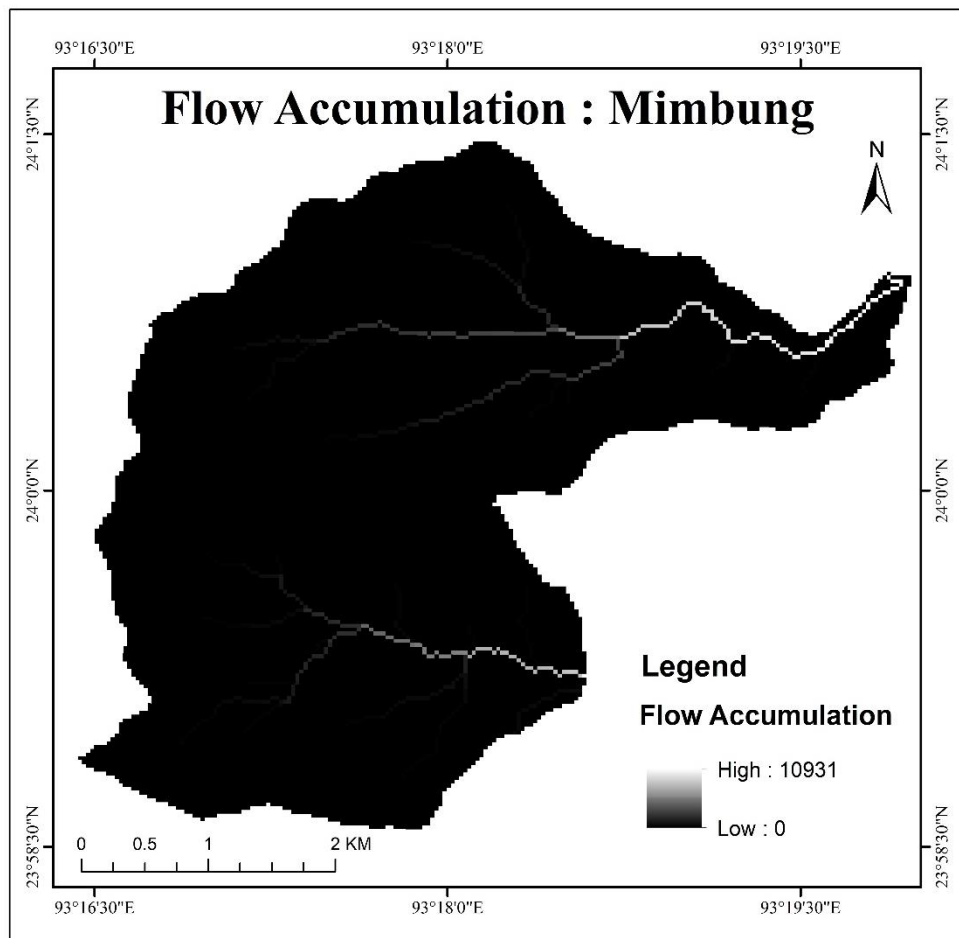
**Fig 2.5 Flow direction**

In this map the light green colour represents East direction, green, blue colour represents South, East, Red colour represent South direction. Dark blue represent south west

direction, Green colour represent west direction, Pink colour represent north west direction, Brown colour represent north direction, Yellow colour represent north east direction .We prepared layout for the result.

### 2.4.3 Flow accumulation:

Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied. It computes accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster.



**Fig 2.6 flow accumulation**

If no weight raster is provided, a weight of one is applied to each cell, and the value of cells in the output raster will be the number of cells that flow into each cell. The flow accumulation raster has a value for each cell. The value represents the number of cells upstream from that cell. Cells with higher values will tend to be located in drainage channels rather than on hillsides or ridges. Flow accumulations are important because



they allow us to locate cells with high cumulative flow. It was prepared using “Flow Accumulation” function of Arc toolbox→ Spatial Analysis → hydrology tool.

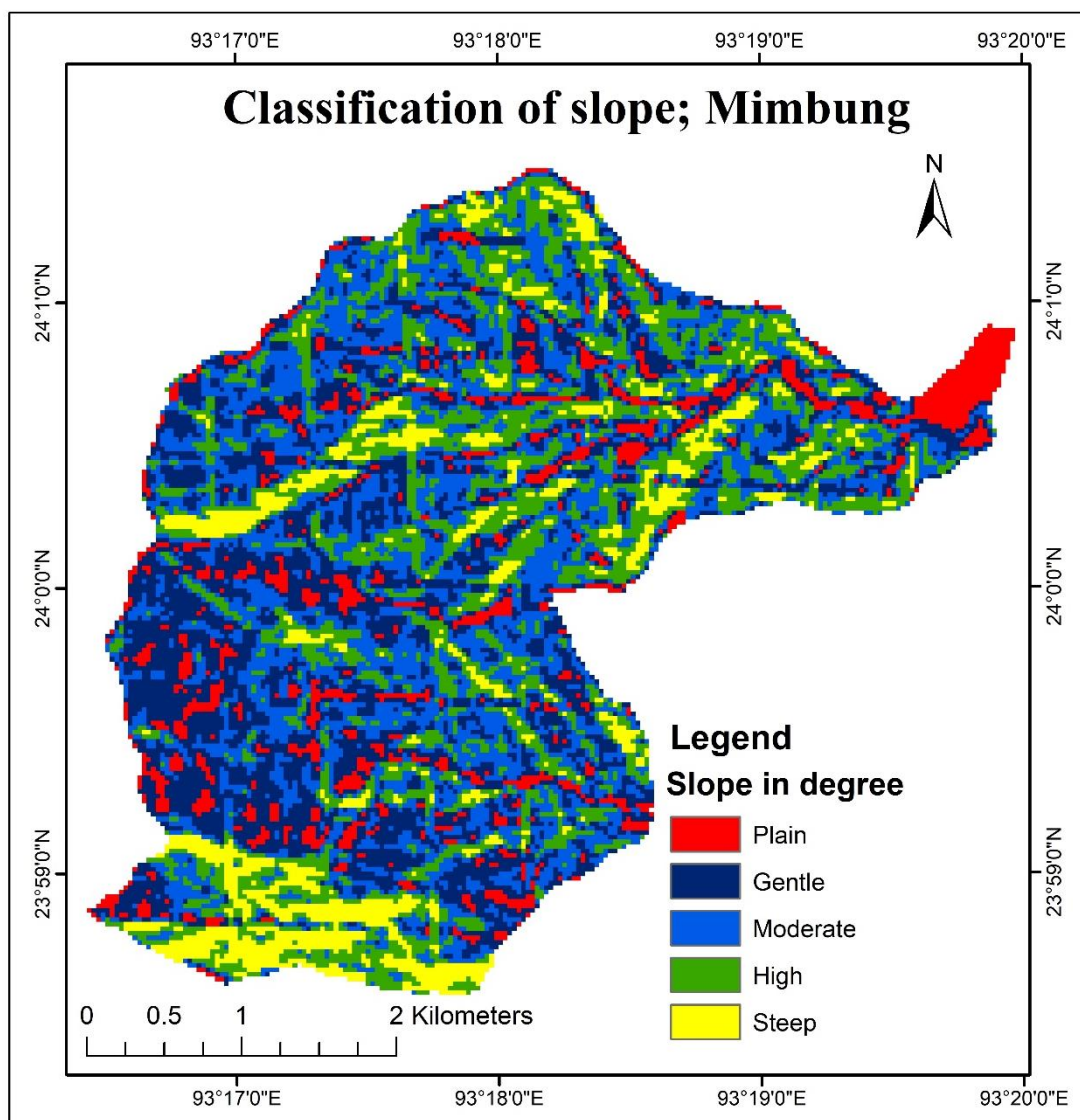
#### 2.4.4 Slope

The slope layer was prepared from the filled digital elevation model.

Slope can be created from

Arc toolbox → 3D Analyst tool→ Raster surface → Slope. We used input feature as a DEM. The slope varies in Mimbung village. Mostly moderate slope is found in the region.

Fig 2.7 Slope





## **2.5 Data processing and RUSLE factors generation**

The RUSLE model has been widely used for both agricultural and forest watersheds to predict the average annual soil loss. It is a non data-demanding and less expensive erosion model; therefore it can be fed by data usually available in institutional databases, such as low or medium spatial resolution satellite images and limited rainfall data etc. The methodology used in the present work was the implementation of RUSLE equation in a raster GIS environment for the calculation of specific factors and annual soil loss of the area under investigation. The climatic and terrain factors which are used in the equation were derived from rainfall data collected from Indian Meteorological Department (IMD), satellite image, The cell size of all the data generated was kept in to 30 m ×30 m, in order to make uniform spatial analysis environment in the GIS.

### **2.5.1 Rainfall erosivity (R)**

The rainfall factor, an index unit, is a measure of the erosive force of a specific rainfall. This is determined as a function of the volume, intensity and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period. Raindrop/splash erosion is the dominant type of erosion in barren soil surfaces.

The soil loss is closely related to rainfall partly through the detaching power of raindrop striking the soil surface and partly through the contribution of rain to runoff. R value is low in the areas of low degree of slope which imply that flat areas would increase the water pounding on the surface, thus protecting soil particles from being eroded by rain drops

There are several equations for calculation of rainfall erosivity like

Slno.	Applicable Area	Rainfall-Erosivity Factor Equation	Authors
1	Ethiopia, Egypt	$R=0.55*MAP-24.7$	Hurni H, 1985
2	Entire India	$R=79+0.363*MAP$	G. Singh et al, 1981
		$R=50+0.389*MSP,$ $R=0.1059abc+52$	R Singh, 2006
3	Dehradun, India	$R=22.8+0.6400*MAP$	Rambabu et al.,1979
4	Jharkhand, India	$R=81.5+0.375*MAP$	R.Babu et al.,2004
5	Ivory Coast and Burkina Faso	$R=P*0.5$	Roose in Morgan and Davidson, 1991
6	Northern Jordan	$R=23.61*\text{exponent}(0.0048*MAP)$	Eltaif et al.,2010
7	Kenya	$R=117.6*(1.00105^{MAP})$ for<2000mm	Kassam et al., 1992
8	Thailand	$R=38.5+0.35*(MAP)$	Harper,1987
9	Indonesia	$R=2.5P/100(0.073P+0.73$	Bols,1978

**Table 2.1 Rainfall erosivity equations**

Where

MSP= Mean Seasonal Precipitation in mm

P=Annual Rainfall(mm)

R= Rainfall Erosive Factor,

MAP= Mean Annual Precipitation (mm)

### **2.5.2 Soil Erodibility Factor (K)**

Different soil types are naturally resistant and susceptible to more erosion than other soils and are function of grain size, drainage potential, structural integrity, organic content and cohesiveness. Erodability of soil is its resistance to both detachment and transport. Because of thick forested nature of the watershed, detailed field surveys of soils in the area were not possible. So a generalized soil texture map collected from the North Eastern Space Application Centre was used for the preparation of K factormap.

The soil erodibility factor (K-factor) is a quantitative description of the inherent erodibility of a particular soil; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. For a particular soil, the soil erodibility factor is the rate of erosion per unit erosion index from a standard plot.

The factor reflects the fact that different soils erode at different rates when the other factors that affect erosion (e.g., infiltration rate, permeability, total water capacity, dispersion, rain splash, and abrasion) are the same.

Texture is the principal factor affecting K Factor, but structure, organic matter, and permeability also contribute. The soil erodibility factor ranges in value from 0.02 to 0.69 (Goldman et al. 1986; Mitchell and Bubenzer 1980).

Goldman et al. (1986) note that several methods can be used to estimate the K-factor. The most frequently used are 1) SCS County Soil Survey reports compiled for many counties in the United States and 2) nomographs relating K-factors to topsoil conditions.

The SCS county soil surveys contain soil maps superimposed on aerial photographs. The maps permit easy location of sites and tentative determination of soil series. Recent surveys list K-factors for the soil series in the table outlining the soil's physical and chemical properties.

Goldman et al. (1986) note that this method of determining K-factors should only be used if minimal soil disturbance at the site is anticipated and a site analysis is unavailable.

The preferred method, according to Goldman et al. (1986), for determining K-factors is the nomograph method based on the work by Wischmeier et al. (1971).

$$K_{\text{fac}}=(1.292)[2.1 \times 10^{-6} f_p^{1.14}(12-P_{\text{om}})+0.00325(S_{\text{struc}}-2)+0.025(f_{\text{perm}}-3)] \quad (2)$$

in which

$$f_p=P_{\text{silt}}(100-P_{\text{clay}})$$

where

$f_p$  is the particle size parameter (unitless)

$P_{\text{om}}$  is the percent organic matter (unitless)

$S_{\text{struc}}$  is the soil structure index (unitless)

$f_{\text{perm}}$  is the profile-permeability class factor (unitless)

$P_{\text{clay}}$  is the percent clay (unitless).

In Equation 2 the factor (1.292) is needed to convert  $K_{\text{fact}}$  from the English units used in Goldman et al. (1986) to the metric units used in this report.

The soil structure index,  $S_{\text{struc}}$ , is equal to: 1 for very fine granular soil;

2 for fine granular soil;

3 for medium or coarse granular soil;

4 for blocky, platy, or massive soil.

The profile-permeability class factor,  $f_{\text{perm}}$ , is equal to: 1 for very slow infiltration;

2 for slow infiltration;

3 for slow to moderate infiltration;

4 for moderate infiltration;

5 for moderate to rapid infiltration;

6 for rapid infiltration.

Erickson (1977), as reported by Goldman et al. (1986), used the information from the nomograph and superimposed K-factors for 2% organic matter on a U.S. Department of Agriculture (USDA) soil textural classification triangle.

Goldman et al. (1986) also presents tables to modify the results to account for

- soils with greater than 15% very fine sand
- soils with organic matter content different from that of 2%
- soils with rock (i.e., soil particle size greater than 2 mm) content greater than 14% by volume
- permeability
- structure.

Stewart et al. (1975), as reported by Mills et al. (1985), Mitchell and Bubenzer (1980), and Novotny and Chesters (1981), also developed a table indicating the general magnitude of the K-factor as a function of organic matter content and soil textural class. Their results are presented in Table 2.2

Goldman et al. (1986) note that if site inspection or data analyses indicate significant variations in the soil erodibility, different K-factors can be assigned to different areas of the site.

They also note that a simpler and more conservative approach is to use the highest value obtained for all parts of the site, because it may not be possible to know exactly what soils will be exposed or how varied the soils are.

The values shown are estimated averages of broad ranges of specific soil values.

When a texture is near the border line of two texture classes, use the average of the two  $K_{\text{fact}}$  values. In addition, the values shown are commensurate with the English units used in the cited reference (and as used in the source-term module input files).

To obtain analogous values in the metric units used in this report, the above values should be multiplied by 1.292.

In the study area Wischmeier et al. 1971 method has been used where soil texture, soil permeability and organic carbon have been used to calculate the K factor.

**Table 2.2 Soil Erodibility Factor  $K_{fact}$  (after Stewart et al. 1975)<sup>(a)</sup>**

Textural Class	$P_{om}(\%)$		
	<0.5	2	4
Sand	0.05	0.03	0.02
Fine Sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.2	

The K factor is calculated using following equation:

$$K=27.66 \times m^{1.14} \times 10^{-8} \times (12-a) + 0.0043 \times (b-2) + 0.0033 \times (c-3) \quad (3)$$

Where,

$m = \text{silt}(\%) + \text{very fine sand}(\%) \times (100 - \text{clay}\%)$

$a = \text{organic matter}(\%)$

$b = \text{structure code}$

$c = \text{Profile permeability}$

### 2.5.3 Slope length and steepness factor (LS)

Length and steepness of a slope affects the total sediment yield from the site and is accounted by the LS-factor in RUSLE model.

In addition to steepness and length, the other factors such as compaction, consolidation and disturbance of the soil were also considered while generating the LS-factor. Erosion increases with slope steepness but, in contrast to the L-factor representing the effects of slope length, the RUSLE makes no differentiation between rill and inter-rill erosion in the S-factor that computes the effect of slope steepness on soil loss (Renard et al., 1997; Lu et al., 2004; Krishna Bahadur, 2009)

The flow accumulation and slope steepness were computed from the DEM using ArcGIS Spatial analyst plus and arc hydro extension.

$$LS=(\text{Flow accumulation}*\text{Cell size}/22:13)^{0.4*} \sin \text{slope}/0:0896)^{1:4} *1.4(4)$$

where flow accumulation denotes the accumulated upslope contributing area for a given cell, LS=combined slope length and slope steepness factor, cell size=size of grid cell (for this study 30 m) and sin slope=slope degree value in sin.

### 2.5.4 Crop Management factor

The C-factor represents the effect of soil-disturbing activities, plants, crop sequence and productivity level, soil cover and subsurface bio-mass on soil erosion. It is defined as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean-tilled, continuous fallow (Wischmeier and Smith, 1978).

Currently, due to the variety of land cover patterns with spatial and temporal variations, satellite remote sensing data sets were used for the assessment of C-factor (Karydas et al., 2009; Tian et al., 2009).

The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigor and health is used to generate the C-factor value image for the study area (Zhou et al., 2008; Kouli et al., 2009).

$$C=\exp[\alpha(\text{NDVI}/\beta-\text{NDVI})](5)$$

where  $\alpha$  and  $\beta$  are unitless parameters that determine the shape of the curve relating to NDVI and the C-factor. Van der Knijff et al.(2000) found that this scaling approach gave better results than assuming a linear relationship and the values of 2 and 1 were selected for the parameters a and b, respectively.

This equation was successfully applied for assessing the C-factor of areas with similar terrain and climatic conditions (Prasannakumar et al.,2011a,b). The C-factor in the present case ranges between 0.3

and 1.

Normalized Difference Vegetation Index(NDVI) was calculating in ArcGIS environment by using following formula:

$$NDVI=(NIR-Red)/(NIR+Red)(6)$$

Where,

NIR=Near Infraed band

Red=Red band

The value NDVI is ranges from 0 to 1. High vegetation indicate more vegetation and zero indicate no vegetation in the area.

In the present study area Landsat 8 image of resolution of 20 m is used.

### **2.5.5 Conservation Practice Factor**

The P factor accounts for erosion control effectiveness of support practices which reflect the effects of practices that will reduce the amount and rate of the runoff water by modifying the flow pattern, grade, or direction of surface runoff and thus reduce the amount of erosion.

Generally, a support practice is most effective when it causes eroded sediments to be deposited far unslope, very close to their source. Deposition close to the end of the slope is of less benefit from a conservation planning perspective.

The most commonly used supporting cropland practice are:

Cross slope cultivation, Contour farming , Stripcropping, Terracing.



Variables that affect the P factor-

### **Cross slope farming (P range 0.75-1.0)**

Cultivation and planting is done across slope which has function like tillage, crop rows create ridges which act as small dams across slope - ridges redirect runoff, modify downslope flow pattern, reduce erosive capacity of runoff.

Erosion reduction goes up to 25%

almost complete protection from storms of low to moderate intensity

- Little or no protection against severe storms (extensive runoff breakovers of ridges, rows)
- Effectiveness influenced by slope length, soil properties, crop management, tillage type, rainfall, snowmelt
  - stabilized (grass) waterways required to carry accumulated excess runoff from depressional areas downslope without causing rill or gully erosion
  - Grass strips do not reduce upslope erosion but are effective in reducing or even preventing sediments from entering a drainage system
  - Compatible with almost any type of cropping system
  - Waterways diffuse or spread flow of water, which reduces runoff velocity, decreases erosive capability of runoff and allows sediment deposition within strip

### **Management implications**

Up and down slope tillage, planting promotes runoff, rill and gully development, erosion

- Cross slope tillage provides runoff barriers, increases infiltration, decreases runoff and erosion
- Rougher soil surfaces (e.g. ridged) provide better protection than smooth surfaces (soil loss decreases as ridge height increases)
  - Closely grown stems of stiff vegetation (e.g. forages, grain) act like ridges Examples of ridge heights: HIGH - left by twisted shoven chisel plough, ridge tillage LOW - left after small grain drilling

### **Contour farming (P range 0.50-0.90)**

Cultivation and planting is done on topographic contours of slope which has functions likeridges created along contour have a zero gradient and water flows uniformly over ridges along entire length.

Erosion reduction 10 to 50 %

- almost complete protection from storms of low to moderate intensity, more effective than cross slope farming - little or no protection against severe storms (extensive runoff breakovers of ridges, rows)
- Most effective on slopes 3 to 8%
- Most effective on ridges >15 cm
- If ridges are not level water will flow along ridge to lowest point, and can create rills or gullies at this point
- Requires stablized waterways (e.g. per-manent grass) on slopes greater than 8 %
- Combination of P practices required, or change in C

### **Strip cropping ( P range 0.25 - 0.90)**

In these range crops grown in systematic arrangement of strips or bands (across slope or on contour) that has alternating strips of close growing vegetation (grass or forage) with row crops either across slope or along contour and crops rotated between strips in systematic order, grass or legume covers a portion of slope year round.

It has functions like runoff diffused and reduced, infiltration increased at grass strip

- Soil eroded from annually cultivated crop strip filtered out within first several metres of adjacent downslope grass strip

Erosion reduction - 10 to 75 %

- Reduces erosion in the grass, legume strips
- Deposition occurs at upper edge of grass strips (infiltration increases, transport capacity decreases)
- More effective than contouring alone
- Strip cropping factor accounts for soil movement leaving the field, but not for all movement and redistribution within

### **Management implications**

- Strips of economically higher return row or cereal crops in combination with erosion resistant grasses, legumes can limit soil movement
- Strip width depends on: slope steepness and length, infiltration capacity and other properties of soil, crop management, precipitation characteristics
- Longer, steeper slopes should incorporate wider forage bands, narrower row crop bands

### **Terracing (P range 0.10-0.90)**

These range has large soil ridges constructed across slope at regular intervals and have function like-

- Divides slope into shorter lengths
- Runoff intercepted, collected, conveyed off field at nonerosive velocities
- Sediment trapped, deposited within field or in sediment traps

Erosion reduction - 10 to 90 %

- Reduces sheet, rill erosion on the terrace interval
- Causes deposition on the terrace channel if gradient is less than 1 %
- Soil losses from uniform grade vary exponentially with grade (soil loss increases as grade increases)
- P factor considers both the benefit of localized deposition (i.e. close to source) and amount of soil deposited

### **Management implications**

- Relatively expensive, permanent changes made to microtopography of slope

Factor P is, by definition, the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope cultivation and planting (Wischmeier and Smith, 1978). In the absence of any support practice, P assumes unity and equals 1 in the USLE

Table contains generalized P value information on basic support practices. The lower the P value, the more effectively the practice helps to cause deposition to occur close to the source. For example, cross slope farming can limit soil loss to 75% of soil loss

without the practice. Conversely, strip cropping on the contour reduces erosion by 75% ( $P = .25$ ).

**Table 2.3 Support Practice**

Support Practice	P-value
No support practice	1.00
Cross slope farming	0.75
Contour farming (3-8% slopes)	0.50
Strip cropping , cross slope (3-8% slope)	0.38
Strip cropping, on contour (3-8% slope)	0.25

## Chapter 3

### Result and Discussions

RUSLE is a straightforward and empirically based model that has the ability to predict long term average annual rate of soil erosion on slopes using data on rainfall pattern, soil type, topography, crop system and management practices.

In the present research, annual soil erosion rate map was generated for Mimbung watershed, a mountainous area, which represents most of the terrain characteristics of Western Ghats. Several data sources were used for the generation of RUSLE model input factors and are stored as raster GIS layers in the ArcInfo ArcGIS software. Potential annual soil loss is estimated from the product of factors (R, K, LS, C and P) which represents geo-environmental scenario of the study area in spatial analyst extension of ArcGIS software.

#### 3.1 Determination of Rainfall Erosivity(R)

is a measure of the total annual erosive rainfall for a specific location, as well as the distribution of erosive rainfall throughout the year; • is affected by storm energy and intensity, the amount of rainfall, snowfall and runoff that occurs during different seasons of the year, and snowmelt on top of frozen or partially frozen soil.

The rainfall data from 3 station viz. Champhai, Aizawl and churachandpur which is collected from AWS (Automatic Weather Station) and used for calculation of point R value.

For the present analysis, R-factor for the Mimbung watershed was computed from available rain gauge data, because the watershed has no record of daily rainfall intensity. The spatial interpolation techniques available in the ArcGIS software were used along with rainfall data of far away rain gauge stations for assessing the spatial variability in the rainfall and rainfall erosivity in the study area. Here Kriging has been used as a interpolation techniques for collection of rainfall data using the known data.

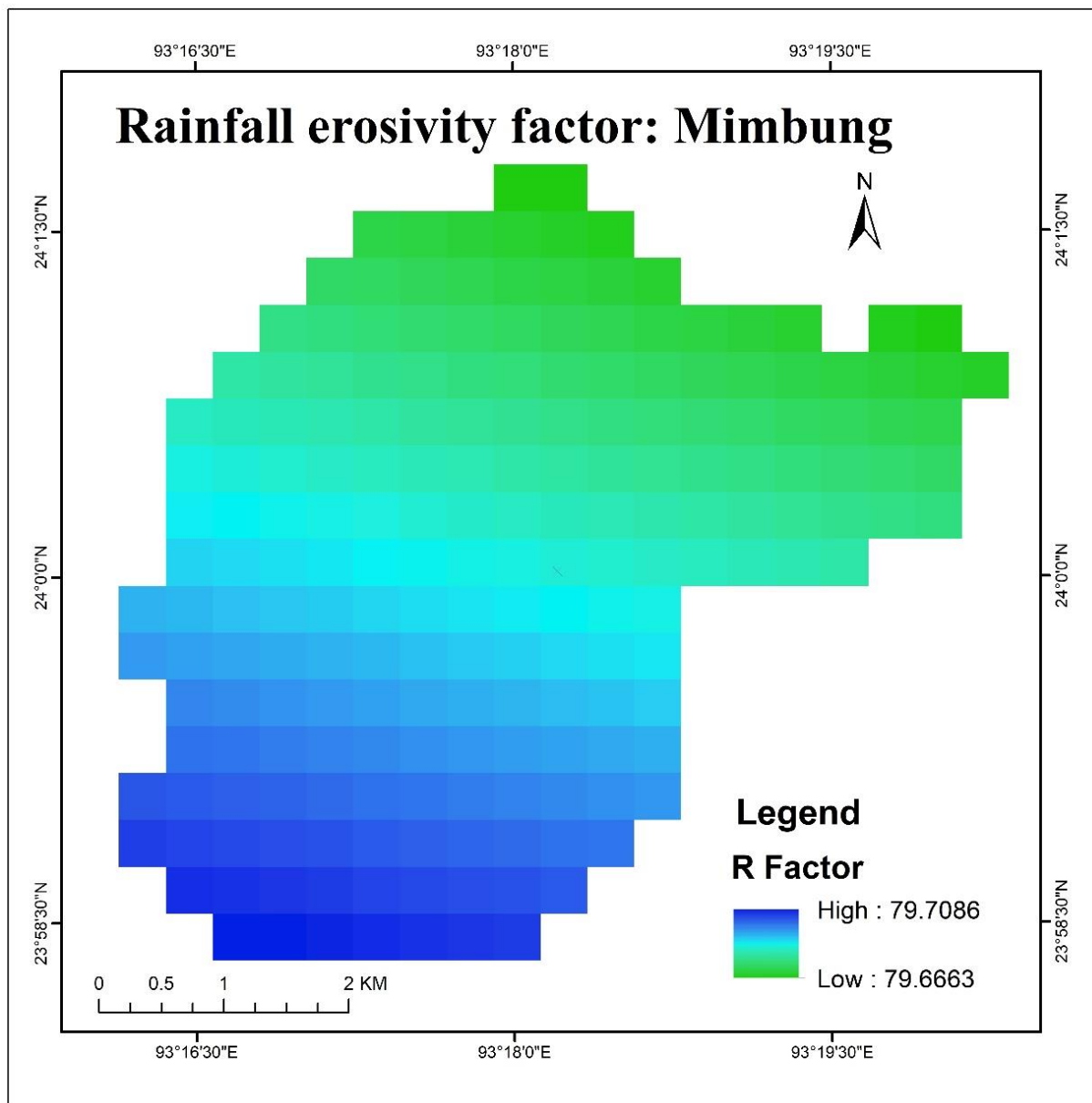
For calculation of Rainfall ErosivityFactor following equation has been used (G. Singh et al, 1981)

$$R = 79 + 0.363 * MAP \quad (7)$$

Where,

R= Rainfall Erosive Factor,

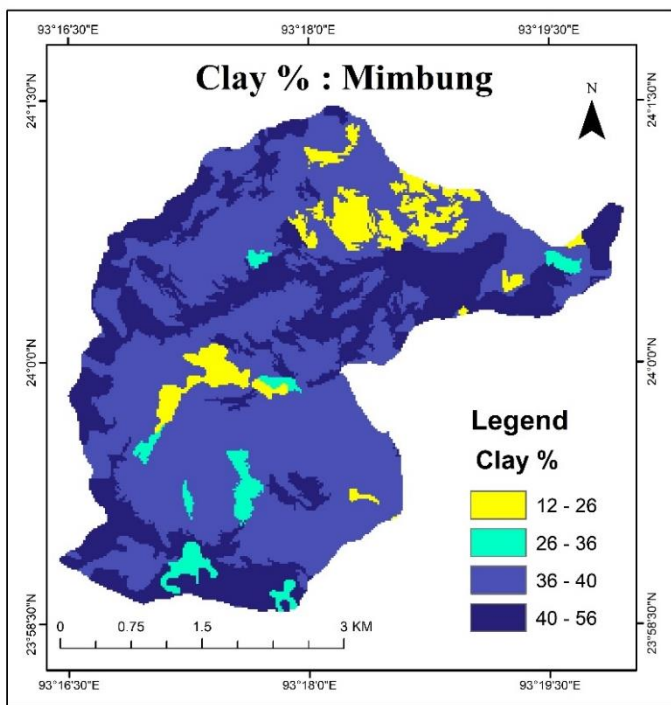
MAP= Mean Annual Precipitation (mm)



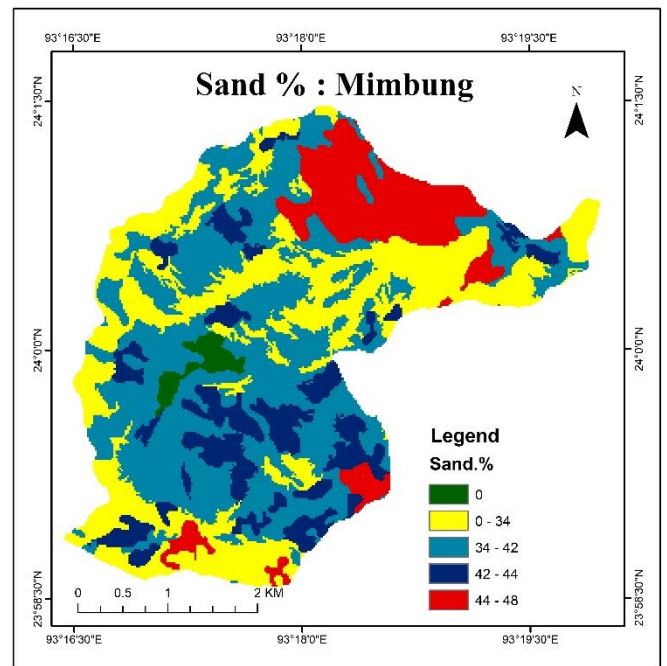
**Fig 3.1 Rainfall erosivitiy**

### 3.2 Determination of Soil Erodibility

K factor is a quantitative measure of a soil's inherent susceptibility/resistance to erosion and the soil's influence on runoff amount and rate; • is affected by soil texture and structure, organic matter content, permeability, and season of the year; • soils tend to be most susceptible in spring, especially during thaw conditions and least erodible in fall when the soil is dry and consolidated after the growing season which depends on the soil or geological characteristics, such as parent material, texture, structure, organic matter content, porosity, catena and many more. Generally, soils become of low erodibility if the silt content is low, regardless of corresponding high content in the sand and clay fractions (Mhangara et.al, 2012).



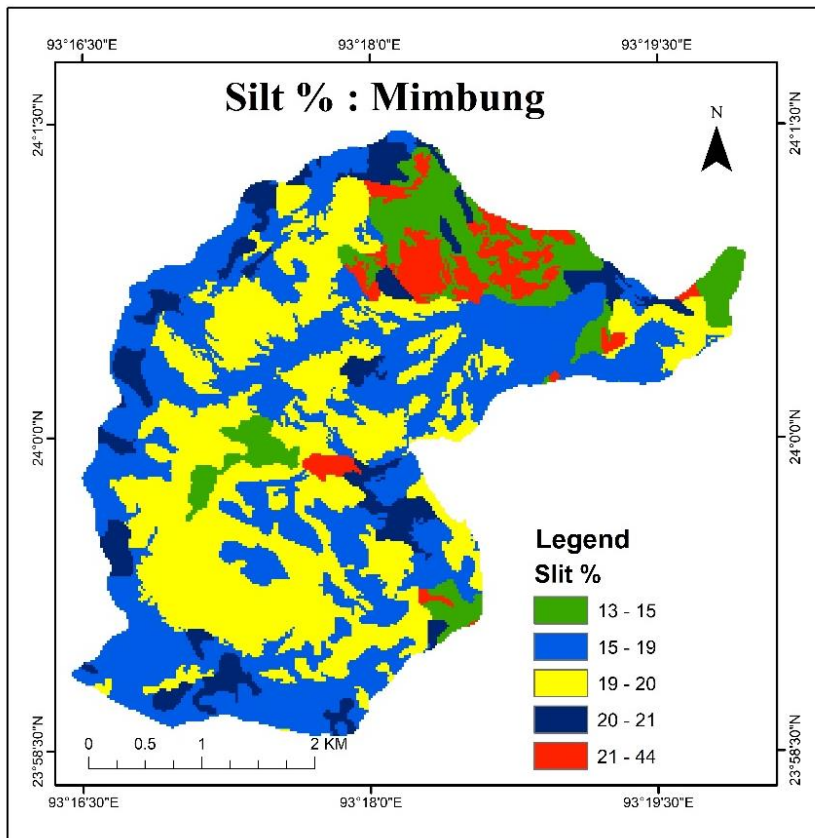
**Fig 3.3 Clay %**



**Fig 3.2 Sand %**

High content of sand % are mainly concentrated in north eastern part and in some parts of southeastern region of Mimbang ranging from 44-48 which is shown in red colour. Sand content is low in most of the region.

The % of clay is high in most part of region ranging from 36 to 56 whereas clay% is low in northeastern and some fragments near the settlement area.



Silt is granular of a size between sand and clay, whose mineral origin is quartz and feldspar. Silt may occur as a soil (often mixed with sand or clay) or as sediment mixed in suspension with water (also known as suspended load) and soil in a body of water such as a river. The silt % in Mimbung ranges from 13 to 44.

The arrangement of soil particles and their aggregate into certain defined patterns is called structure. It describes the arrangement of the solid parts of the soil and of the pore space located between them. It is determined by how individual soil granules clump, bind together, and aggregate, resulting in the arrangement of soil pores between them.

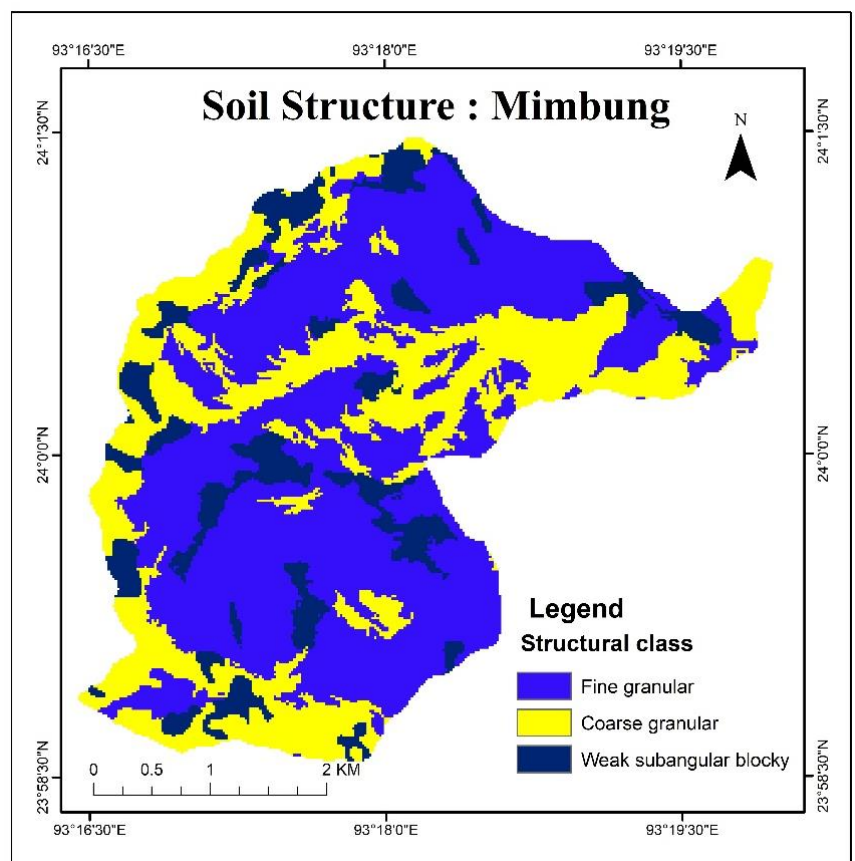
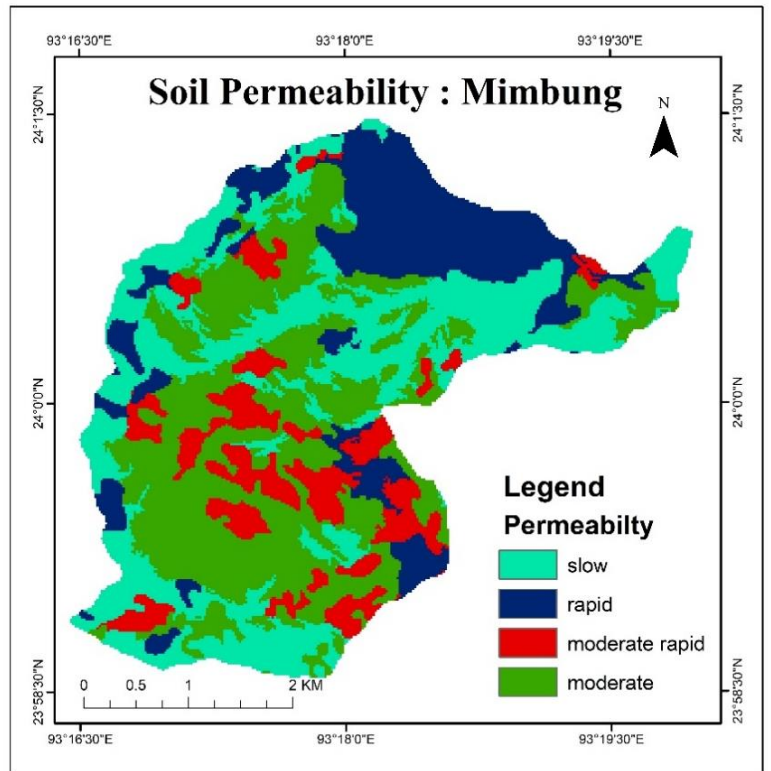


Fig 3.5 Soil Structure

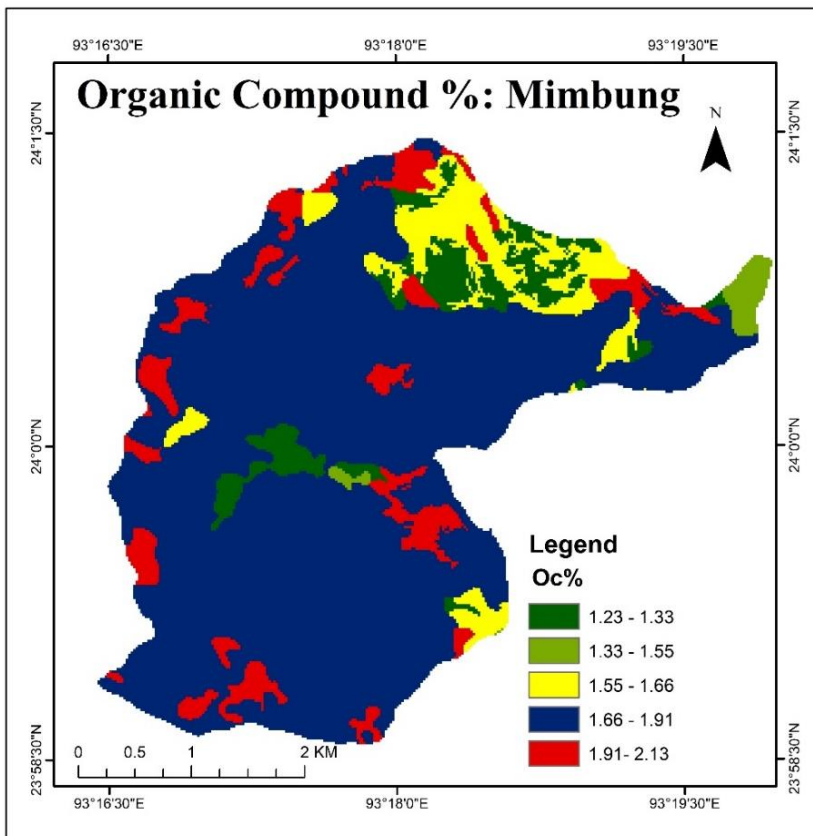


Most of the soil structure of Mimbang consists of fine granular to weak subangular blocky structure soil permeability is the property of the soil to transmit water and air and is one of the most important qualities to consider for fish culture. A number of factors affect the permeability of the soil, from particle size, impurities in the water, void ratio, the degree of saturation, and absorbed water, to entrapped air and organic material. Mimbang region has mostly moderate permeability.



**Fig 3.6 Soil permeability**

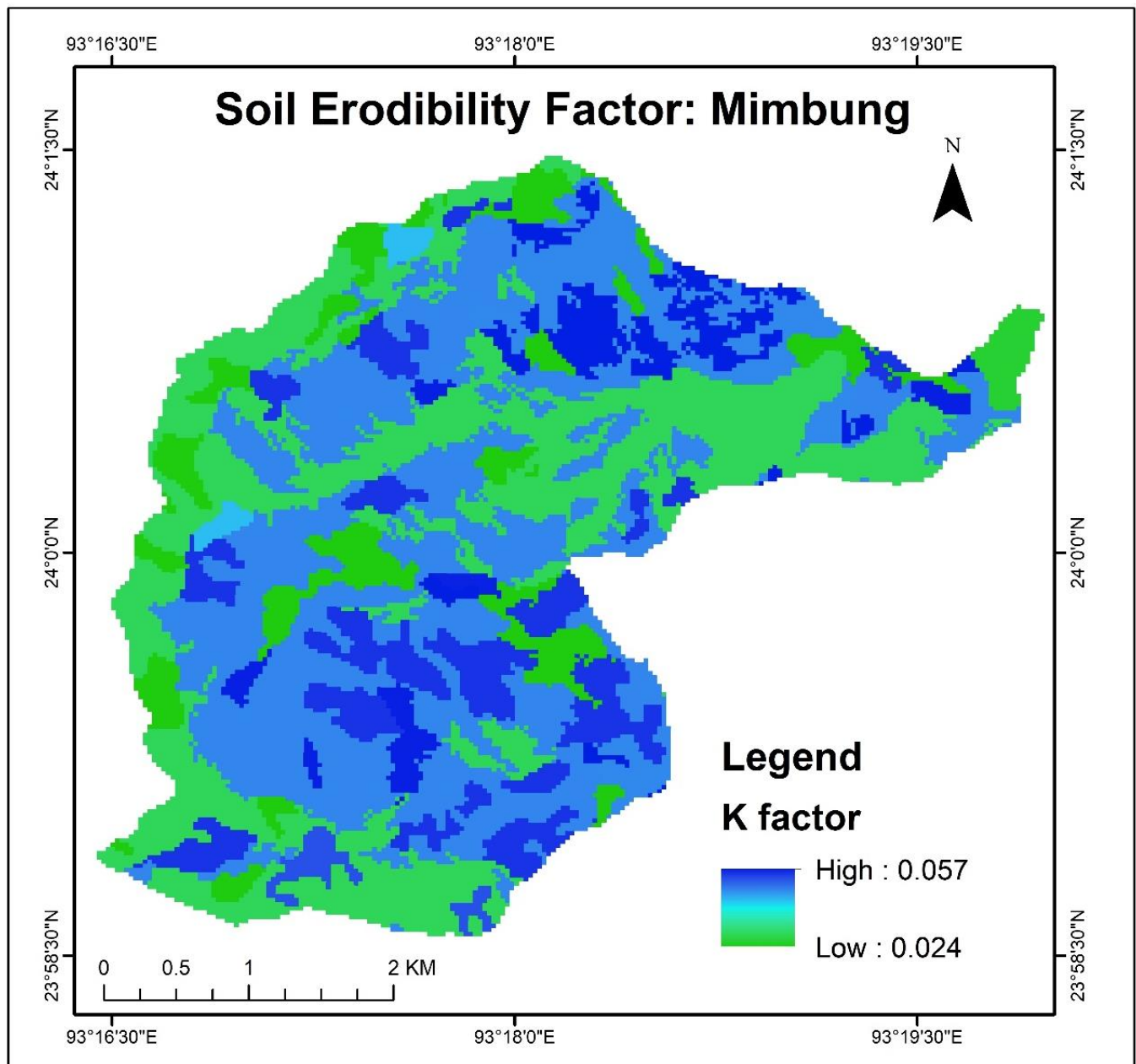
**Fig 3.7 Organic Compound**



Soil organic matter is the organic matter component of soil, consisting of plant and animal residues at various stage of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. The organic compound % in Mimbang ranges from 1.23 to 2.13%.

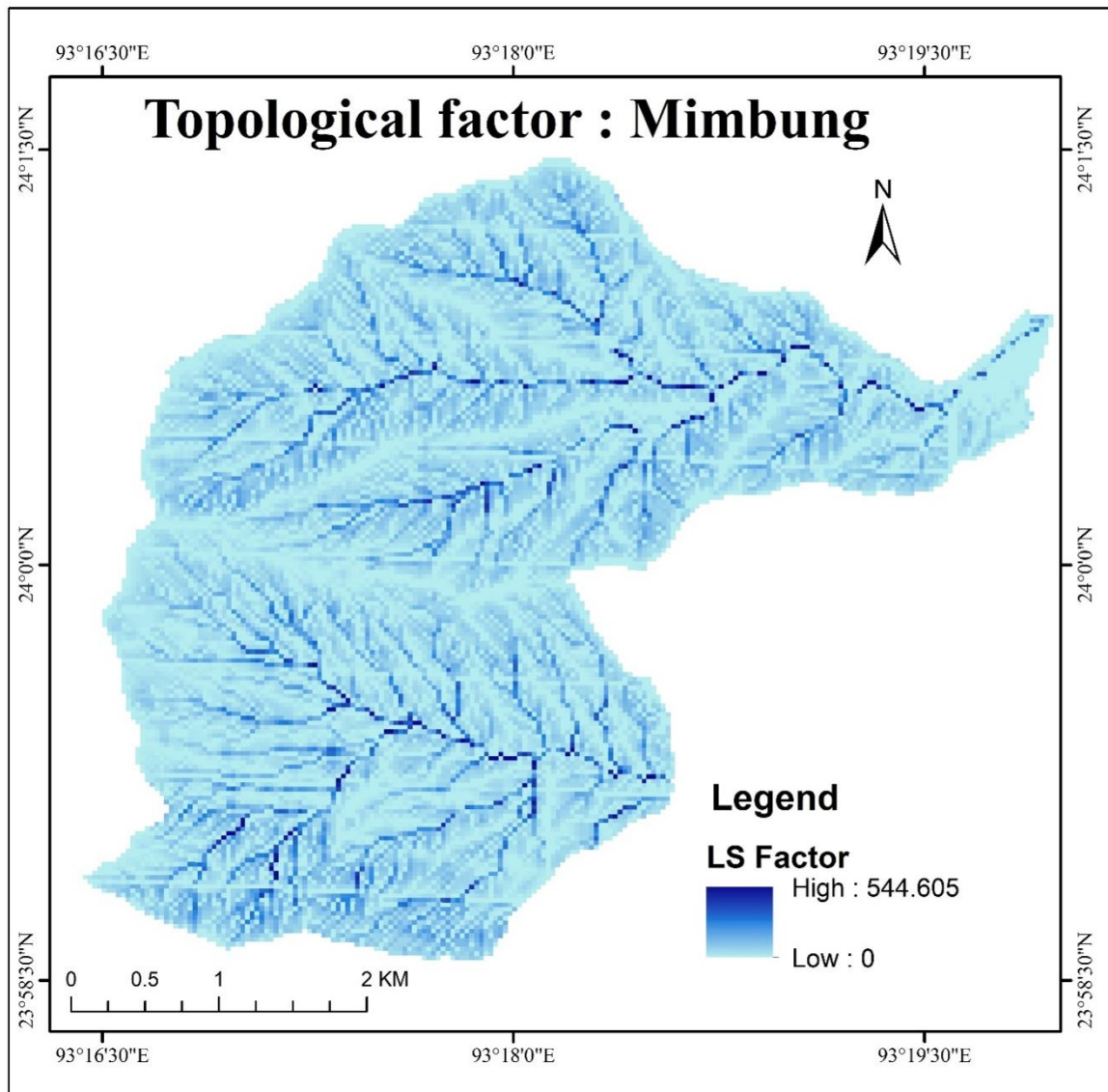
Higher the K-factor, higher erodibility, here physical property of soil viz. soil texture, soil structure. In the present study, the K factor was ranging from 0.024 to 0.057 which indicates the soil of the study area is having less soil erodibility.

**Fig 3.8 Soil Erodibility**



### 3.3 Determination of Slope length and steepness factor (LS)

LS factor is a measure of the effects of slope angle, length and complexity on erosion. The LS factor expresses the effect of local topography on soil erosion rate, combining effects of slope length(L) and slope steepness (S). The longer the slopelength , greater the amount of cumulative runoff and steeper the slope of the landhigher the velocities of the runoff which contribute to erosion.



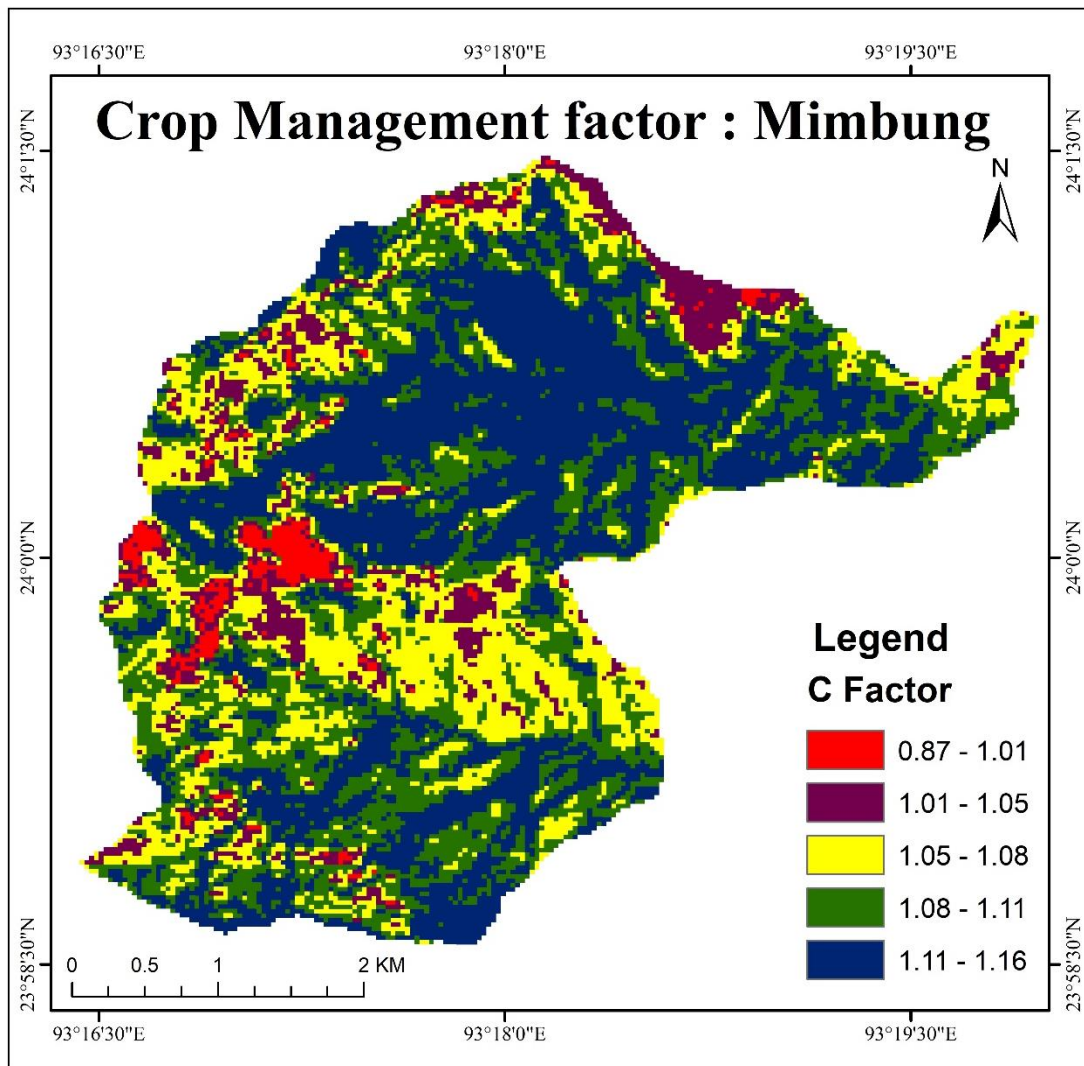
**Fig 3.9 Topological factor**

The combined LS-factor was computed for the watershed by means of ArcInfo ArcGIS Spatial analyst extension using the DEM following the equation (eq. 3), as proposed by Moore and Burch (1986a,b). The computation of LS requires factors such as flow accumulation and slope steepness.

The LS factor value in the study area varies from 0 to 544.60.

### 3.4 Determination of C -factor

It is a measure of the relative effectiveness of soil and crop management systems in preventing or reducing soil loss which is affected by: crop canopy (leaves and branches of the crop, which intercept the raindrops and dissipate some of their erosive force),



**Fig 3.10 Crop management factor**

surface cover like crop residues and live vegetation on the soil surface, soil biomass (all vegetative matter within the soil; residue helps to improve the flow of water into the soil and the soil water-holding capacity), tillage (type, timing and frequency of tillage operations; has an effect on soil porosity, surface roughness and compaction), previous year's crop, distribution of erosive rainfall over the growing season.



Larger C Factor values indicate that the corresponding land cover type results in more soil erosion, as they are considered to be unprotected barren land.

In the study area c factor is from 0.87 to 1.16, where dense forest and open forest areas having highest c value ranging from 1.08 to 1.16. The scrubland and agricultural area having the c value ranging 1.08 to 1.01. Settlement area shows the lowest c value 0.87 to 1.01.

### 3.5 Determination of soil conservation practice(P)

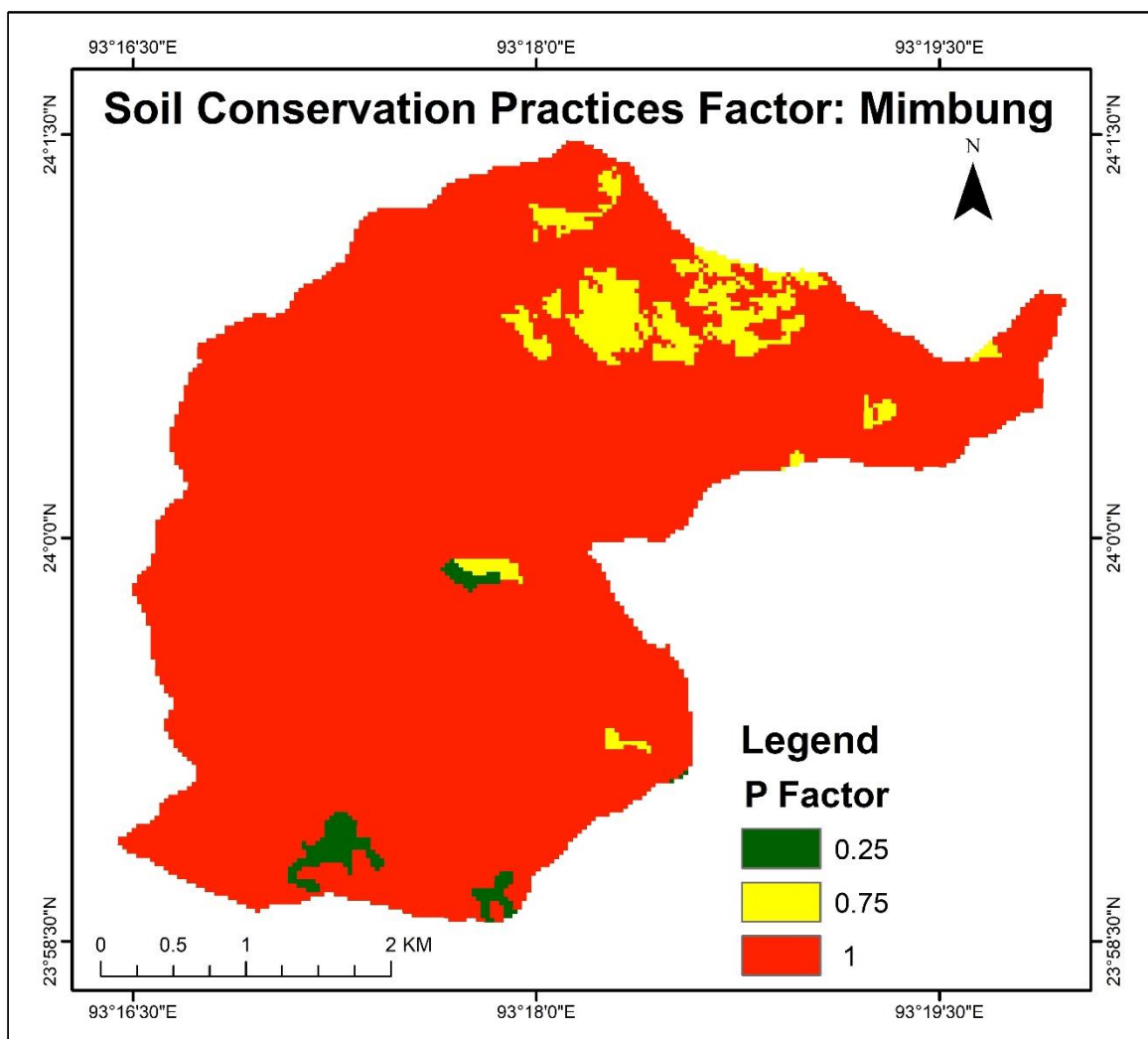


Fig 3.11 P factor

The support practice factor (P-factor) is the soil-loss ratio with a specific support practice to the corresponding soil loss with up and down slope tillage (Renard et al., 1997). In the present study the P-factor map was derived from the land use/land cover and support factors. The values of P-factor range from 0 to 1, in which the highest

value is assigned to areas with no conservation practices (deciduous forest); the minimum values correspond to built-up-land and plantation area with strip and contour cropping. The lower the P value, the more effective the conservation practices. In the study area, the conservation practices are very less, only in some places the bunding and terracing are situated. The P value is 0.25 in contour bunding and 0.50 in terrace farming areas, rest are 1.

### 3.6 Annual soil loss

The average soil erosion rate estimated for the upland sub-watershed ranges from 0 to 209.67. Soil erosion rate calculated in these studies are found to be appropriate and matching. The results were also compared with the studies carried out in areas having similar geo-environmental and rainfall characteristics.

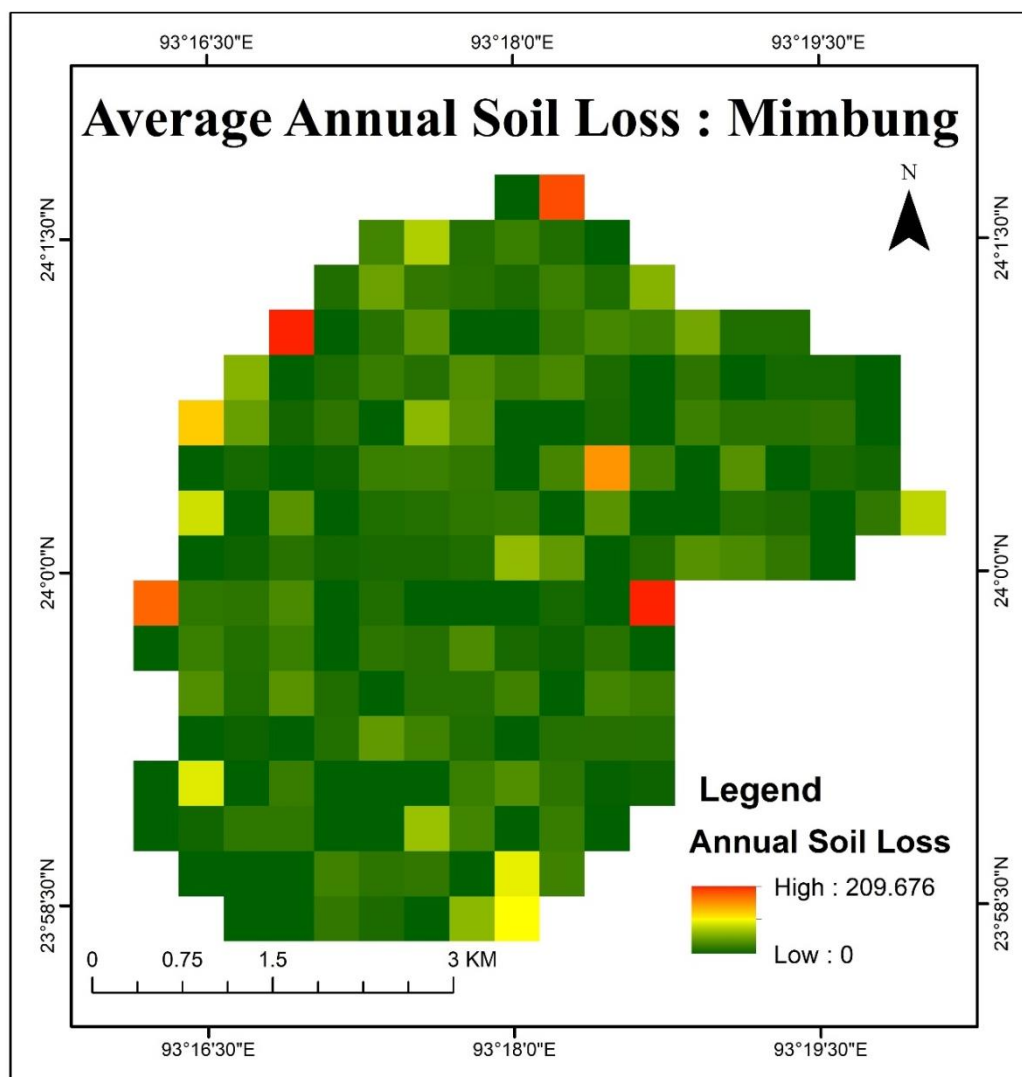
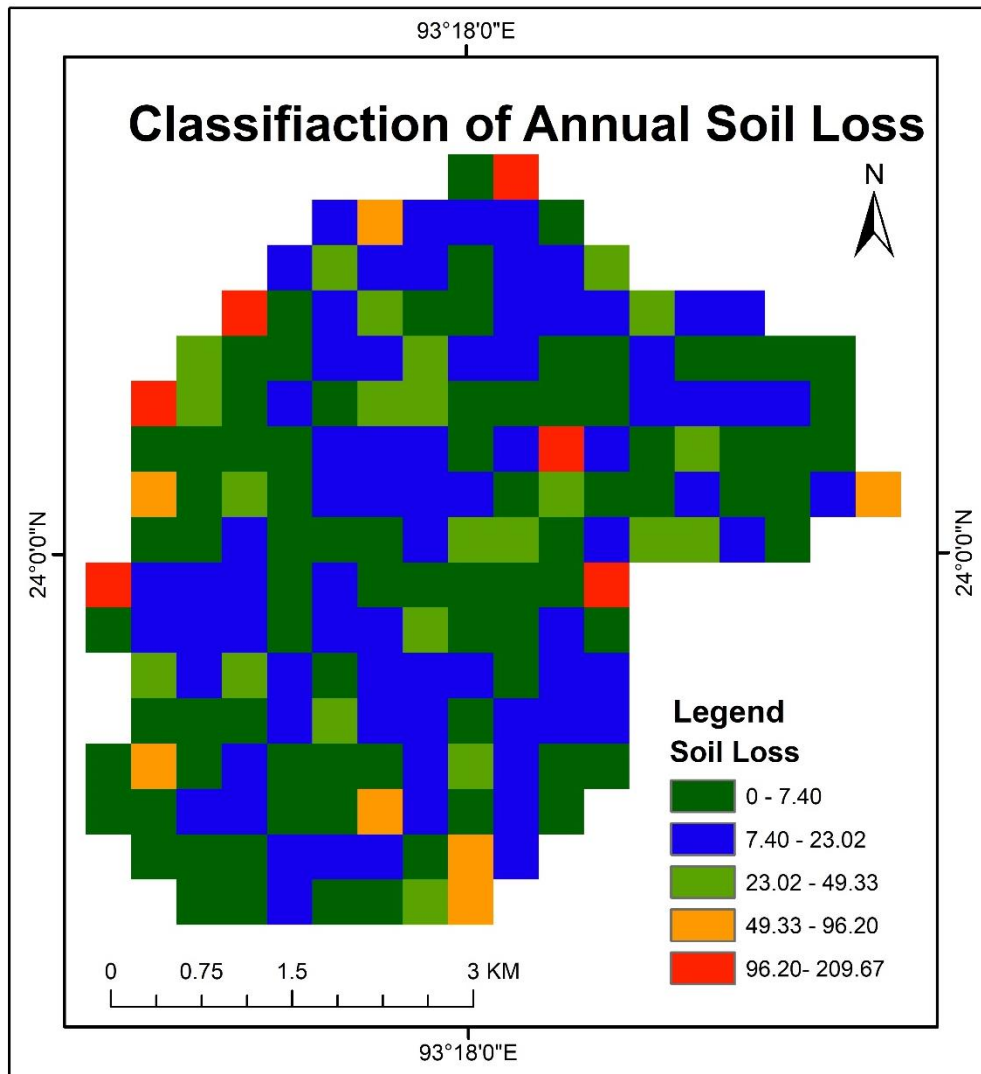


Fig 3.12 Average annual soil loss

The assessed average annual soil loss of Mimbung watershed was grouped into different classes based on the minimum and maximum values and the spatial distribution of each class is presented in Fig. 3.13



**Fig 3.13 Classification of annual soil**

The results shows that about 92% of the study area is classified as low potential erosion risk), while rest of the area is under moderate to high erosion risk. The spatial pattern of classified soil erosion risk zones indicates that the areas with high and severe erosion risk are located in the west, northwest and southern regions of the study area, while the areas with low erosion risk are in the northern eastern and central parts of the study area. In order to assess the role of human intervention in the soil erosion risk in

the sub-watershed, land use/land cover map (Fig. 3) of the area was overlaid with classified soil erosion risk zone map.

With the spatial pattern, the severe and high levels of soil erosion risk zones are distributed on the scrubland, degraded plantation, and deciduous forest areas. The area with the larger gradient is mostly covered by high fraction vegetation, and is on lower level of soil erosion risk than that with little gradient. At the same time the spatial pattern of annual average soil erosion risk map shows high spatial correlation with movement in a watershed. Therefore, the areas with high LS-factor and degraded/deciduous forest/scrublands need immediate attention in soil conservation point of view.

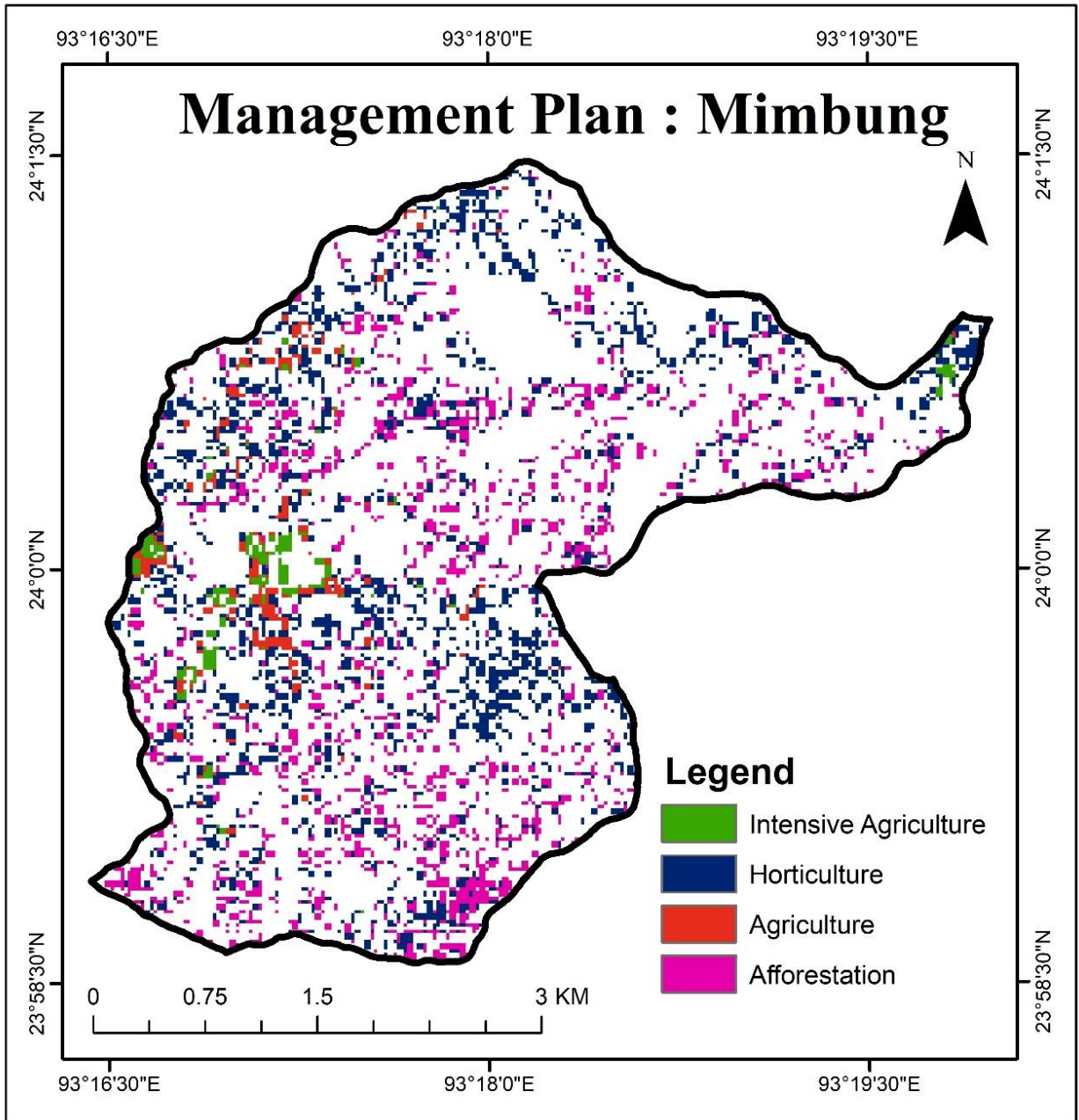
### 3.7 Management Plan

The management plan for Mimbang watershed was prepared on the basis of present LULC, slope and soil loss of the prioritize watersheds.

Management plan for Mimbang watersheds are shown in fig 3.14

Present LULC	Recommended	Slope in °
Waste land scrubland (dense)	Agriculture	14.14-30
Agriculture	Intensive agriculture	14.14-25
Waste land scrubland (open)	Afforestation	0.34-45
Fallow land sandy area	Horticulture	14-30





**Fig 3.14 Management plan**

### **3.8 Conclusion and suggestion.**

A quantitative assessment of average annual soil loss for Mimbung watershed is made with GIS based well-known RUSLE equation considering rainfall, soil, land use and topographic datasets. In the watershed the land use pattern in areas prone to soil erosion indicates that areas with natural forest cover in the head water regions have minimum rate of soil erosion while areas with human intervention have high rate of soil erosion.

Terrain alterations along with high LS-factor and rainfall prompt these areas to be more susceptible to soil erosion. The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the watershed. The areas with high and severe soil erosion warrant special priority for the implementation of control measures. While the present analytical model helps mapping of vulnerability zones, micro-scale data on rainfall intensity, soil texture and field measurements can augment the prediction capability and accuracy of remote sensing and GIS based analysis.

Remote sensing and GIS has proved to be efficient tool in drainage delineation and estimation of soil erosion model in the present study of the Mimbung watershed. The study comes across the conclusion that the soil erosion model for watershed especially for those which are exposed to high erodibility has a boost impact for management plan. The result derived and the conclusion drawn in this paper are suggested to develop better management plan for better application of the watershed.

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