Estimation of Soil Loss in Nyera Amachhu Watershed using RUSLE Model.

A PROJECT REPORT

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JIGME NAMGYEL ENGINEERING COLLEGE

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འབྲུག་རྒྱལ་འཛིན་གཙུག་ལག་སློབ་སྡེ།
འཇིགས་མེད་རྣམ་རྒྱལ་བཟོ་རིག་མཐོ་རིམ་སློབ་གྲྭ།
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Certificate

This is to certify that the project report titled ***'Estimation of Soil Loss in Nyera Amachhu Watershed using RUSLE model.'***

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In partial fulfilment of the requirements for the award of the **Diploma in Civil Engineering.**

Supervisor(s):

(**Mr. Dawa Tshering)**
Head of Department
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DECLARATION

We declare that this project titled ***'Estimation of Soil Loss in Nyera Amachhu Watershed Using RUSLE Model.'*** under the supervision of Mr. Dawa Tshering Department of Civil Engineering and Surveying is a bonfire report of work done by us. The report represents our original ideas and words including referred ideas from various sources. We declare that all the sources referred are adequately cited adhering to the academic regulation of academic dishonesty reflected in the Wheel of Academic Law (WAL), Royal University of Bhutan (RUB). The material embodied in the project report has not been submitted for any other awards.

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ABTRACT

The Soil erosion is one of the huge destructions to the soil structures. Nowadays, the environment has been threatened by soil erosion in which it declines the degree of soil fertility that can obviously give enormous affect to the agriculture land and eventually the agriculture productivity. On other hand, human settlements have also immensely affected by such problem that occurs near by the settlement that already done and started the living. Such massive problem was the obstacles that people were facing at our study area the Nyera Ama chhu watershed, due to which the necessary conservative actions has become very needed at the place. Though the erosion is very huge destruction to the environment, application of the conservative measure was not a great decision to adopt in every area but taking actions to the area of high susceptible to the erosion would be the priority. There are many factors that affects the soil erosion. Based on the easiness, accuracy and the advancement, Revised Universal Soil Loss Equation model (RUSLE) was adopted to study the area Nyera Ama chhu. This model has got various parameters which includes runoff-rainfall erosivity factor (R), soil erodibility factor (K), topographic factor (LS), cropping management factor (C), and support practice factor (P) that's contribute to the soil erosions. Those various parameters are computed and prepared from the Geographical information system (GIS) using required data source and methods. The annual average soil loss from the study watershed area was 66.411 t $ha^{-1}yr^{-1}$ and erosivity factor gives the great influence over other parameters to the soil loss in the study area. The soil loss depends upon the soil types and its structures. Clay, Loam, Sandy loam soil were present in the study area. Southern, north-western region of the area has huge loss of the soil and less in mid watershed area and north east region. RUSLE and GIS based approach provide a reliable estimation of soil loss that help in identify the priority area for effective planning and implementation of sustainable soil management practices so reduce soil erosion, particularly for sustainability of the Nyera Amachhu Watershed located in eastern region of Bhutan.

Keyword: **GIS, RUSLE, Hydrological Soil Group, LULC, Nyera Amachhu Watershed, Rainfall, Soil Erosion.**

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LIST OF ACRONYMS, KEYWORDS, SYMBOLS

BSF	Bhutan Shape File
C	Cover Management
CREAM	Chemical, Runoff, and Erosion Agriculture Managements System
DEM	Digital Elevation Model
FA	Flow Accumulation
FAO	Food and Agriculture Organization
FRMD	Forest Resource Management Division
GIS	Geographical Information System
K	Soil Erodibility
LS	Slope Length and Slope Steepness
LULC	Land Use Land Cover
MJ mm/hr/ha/yr	Mega Joule Millimeter per Hour per Hectare per Year
NCHM	National Centre for Hydrological and Meteorology
NDVI	Normalized Difference Vegetation Index
P	Support Practice Factor
R	Rainfall Erosivity
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessments Tool
t. ha.h/ha.MJ.mm	Ton Hectare Hour per Hectare Mega Joule Millimeter
US	United States Geological Survey
USLE	Universal Soil Loss Equation
SLR	Soil Loss Ratio

CHAPTER 1

INTRODUCTION

1.1 GENERALS

Soil erosion is a phenomenon that led to decrease in the amount of top soil due to rainfall activity causing top soil to wash away. It is a continuous process that occurs either slowly or at an alarming rate. It is a global threat resulting in decrease in agriculture productivity, increasing pollution, clogging waterway and etc. Generally, the soil erosion is more prone in the area where there are non- cohesive soils with little or no resistance to erosion such as silt and sandy soil and steepness of the place causes soil to erode easily. It is also more likely to occur in places that has been disturbed by agriculture, grazing animals, logging, mining, construction and recreational activities. The agents of soil erosion are water, ice, wind and gravity. Soil erosion is of many types such as gullies, sheet, rill and splash.

As a 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 (Prasannakumar et al., 2012). Bhutan as a mountainous area which has the physical geography consisting mostly of steep and high mountains crisscrossed by a network of swift rivers, which form deep valleys before draining into the Indian plains. The land rises from 200 meters above sea level in the southern foothills to 7000 meters high northern mountains. About 72.5% of the area is under forests, and it is constitutional mandate to mountain 60% forests cover for all the times to come (*ROYAL SOCIETY FOR PROTECTION OF NATURE – Royal Society for Protection of Nature*, n.d.). The predominantly steep slopes make land degradation a more serious threat in Bhutan than in most other places. As per the study conducted by NSSC across the country, annually, about 3 to 21 t ha^{-1} of fertile topsoil is lost due to soil erosion, which is a serious problem as mountain soils are generally defined as poorly developed, shallow, acidic and relatively infertile. Loss of top soil significantly reduces the inherent soil fertility resulting in poor land productivity and crop yield (Journal, 2020). The method adopted to estimate the soil erosions is Revised Universal Soil Loss Equation coupled with GIS and Remote sensing data.

The Revised Universal Soil Loss Equation (RUSLE) can be used for evaluating and quantifying soil erosion in view of its universal adaptation, it is an empirical and spatialized model. The RUSLE model takes into account for five factors to evaluate soil loss which are: rainfall erosivity, soil erodibility, steepness and length of the slope, vegetation cover and the conservation support practices (Bouhadeb et al., 2018).

We are using remote sensing mainly for the area where the human accessibility less for assessment of resources management. It will be very handy technique for the study of soil erosion, groundwater recharge, groundwater potential and rainfall-runoff modeling in large area. The remote sensing data like digital elevation model (DEM) is freely available for study of slope characteristic (Kadam et al., 2018).In recent years, Geographical Information System (GIS) and Remote Sensing (RS) have become useful tools for natural resources management and disaster research. This research requires much spatial data, which GIS is capable of handling easily and efficiently. For this reason, many researchers use GIS as main approach to estimate soil erosion at all scales (Gia et al., 2018). Therefore, we are going to conduct study in the Nyera Amachhu watershed with the aims to (1) utilize the RUSLE model and ArcGIS to determine the soil erosion rates and (2) produce the base map of soil loss for particular watershed (3) To the best of our knowledge, yet no studies have carried out the study of soil erosion estimation in Nyera Amochhu watershed area. This study will provide the future researcher a little knowledge of particular area as well as it will provide information for development of soil erosion strategies that will be useful for policy maker and planner in effectively managing soil erosion in the study area. Arable land in Bhutan is under serious threats of land degradation. Proper land management approach is also needed to control soil erosion problems (Yeshey et al., 2017). Land management such as reforestation, mix cropping, terracing and etc are suggested as a control measure.

1.2 PROBLEM STATEMENT

Soil erosion affects the land and its inhabitants in both off-site and onsite effects. Off-site effect, movement of sediments and agricultural pollutants into watercourses are the major problem, leading to sedimentation in rivers and disruption of ecosystems. While in, on-site effect is directly created through the loss of soil nutrients. This effect is particularly crucial on agricultural land because it involves the loss of soil stability, soil quality, and disruption to adjacent area.

The rate of soil erosion increases the rate of soil formation over wide areas resulting in the depletion of soil. Rate of soil loss can be determined by measuring the annual precipitation, elevation, crop cover and practiced erosion control factors. Using RUSLE model, the rate of annual soil loss (A) can be predicted based on parameters such as; annual rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cropping factor (C), practice and erosion control (P) factors.

Extensive studies have been done to estimate soil erosion using different methods but very few investigations were done on the integration of RUSLE and GIS based application. Further, the investigation at the Nyera Amachhu have to do as no severity base map for the area was produced as such. Therefore, there is a need to study soil loss estimation by integrating RUSLE and GIS based applications.

1.3 AIMS AND 0BJECTIVES

1.3.1 Aims

To estimate annual soil loss in Nyera Amochu Watershed using RUSLE method.

1.3.2 Objective

- To estimate the annual soil loss in Nyera Amachu watershed.
- To determine the parameter that contribute in causing erosion.
- To produce the severity base map for Nyera Amachu watershed using Remote sending data and Arc GIS.
- To suggest some control measures for prevention of soil erosion and protect adjacent area.

1.4 SCOPE

This study was carried out at Nyera Amachhu watershed area. RUSLE model was used to determine the annual soil loss of the watershed. Activities involved collecting rainfall data, land used land cover data and soil data which were processed in Arc GIS to prepared the base map of all the factors which contributes in soil erosion.

1.5 STUDY AREA

Nyera Amachhu watershed is located from 26°48’45.5’’ to 27°20’48’’ N latitude and 91°49’08” to 91°42’22’’E longitude and covers the area of 1109.547 km^2 (figure. 1). The region is highly undulating with the highest elevation of 4493 metre about mean sea level and the lowest elevation of 148 meter above mean sea level. Daily rainfall data of six stations (Deothang, Kanglung, Pemagatshel, Khaling, Thrimshing and Wamrong) from 2005 to 2021 years were gathered from the National Central of Hydrology and Meteorological Agency and used to extract rainfall factor maps. Average annual rainfall data were generated from the monthly rainfall data of 16 years and well adapted for the analysis. The mean annual rainfall of the Nyera Amachhu watershed was found out to be 2281.55 mm and exhibits a wet climatic condition. Almost 80% of the area is occupied by thick evergreen forests, followed by shrubs land, forest plantations and cultivated land.

The main soil type of study area is sandy and clay soil. The main source of irrigation for growing crops is rainfall. Formations of rills and gully erosion are common in the watershed due humid subtropical monsoon climate which leads to high rainfall events and bad topographical surface.

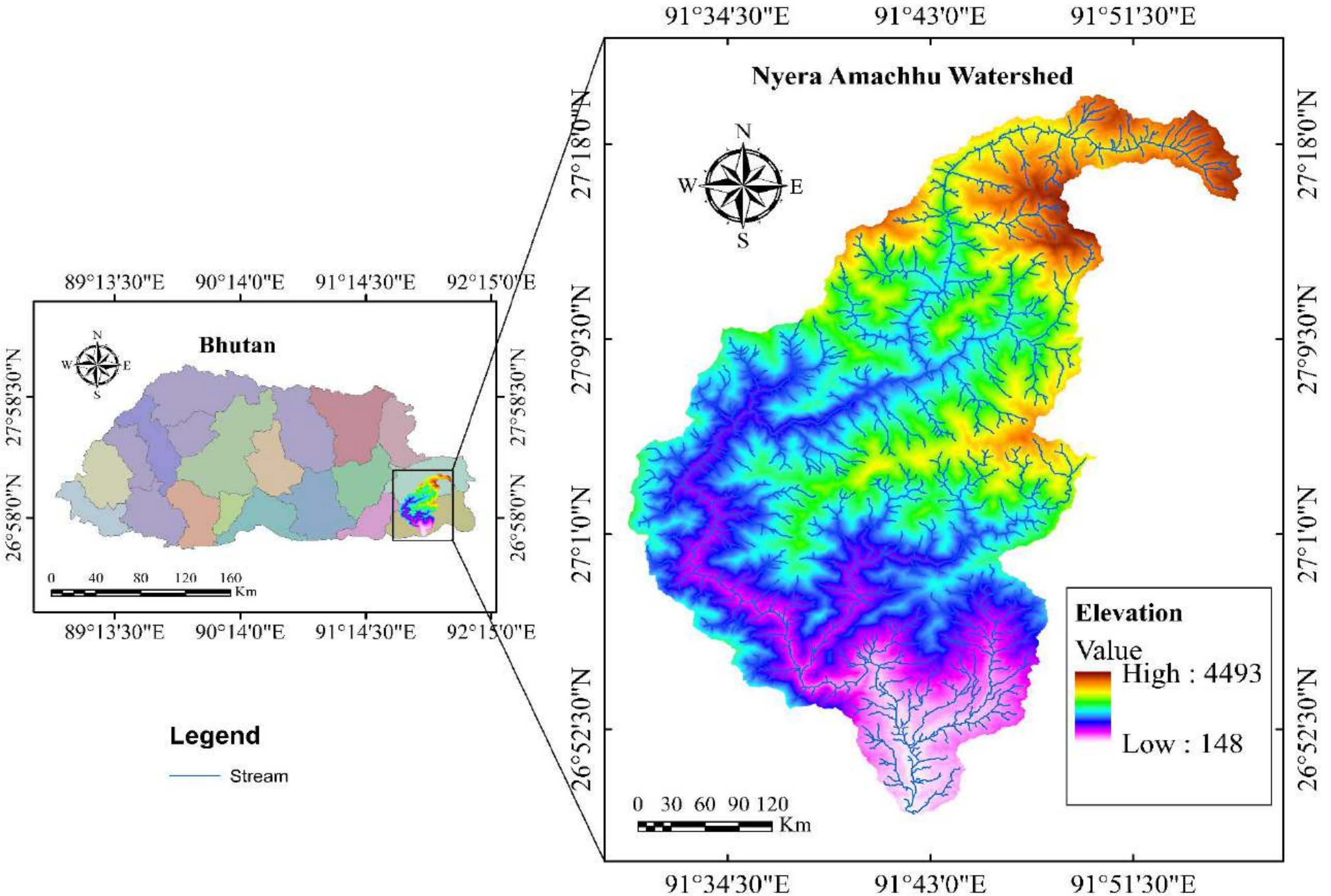

Figure 1.5.1Study area of Nyera Amachhu

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

A literature review is an overview of the previously published works on a specific topic. It is done to understand the current research in a particular field before carrying out a new investigation and it should help us to find out what research has already been done and identify what is unknown within topic we are going to conduct.

2.2 RUSLE

Revised Universal Soil Loss Equation model (RUSLE) estimates long term annual soil loss due to erosion across different land uses and land management activities. It was developed from the Universal Soil Loss Equation (USLE) developed in the U.S. Department of Agriculture and has other similar variants such as the Modified USLE (MUSLE). As all these models use similar algorithms and produce comparable result, we focus on RUSLE here and estimates average annual soil erosion by:

A = R*K*LS*C*P

RUSLE was adopted since this method is universally recognized as a standard method for soil loss monitoring. It is relevant for ecosystem services related to soil erosion and protection.

Thomas et al. (2017) has carried out the assessment of soil loss vulnerability of an agricultural mountainous watershed in Maharashtra, India; using the techniques of Revised Universal Soil Loss Equation (RUSLE) with the integration of remote sensing (RS) and geographical information system (GIS). The results revealed that the combination of RUSLE and GIS could be helpful for the management of groundwater potential and runoff modeling in a larger area. It was concluded that RUSLE model helps for mapping susceptibility zones for precipitation intensity and soil textures.

Thapa (2020) has conducted the research on spatial estimation of soil in Dolakha district, Nepal. The study area is the Dolakha District, Nepal, situated in the northeast part of Kathmandu. RUSLE method is widely used to estimate soil erosion loss and risk, which provides a guideline for the development of conservation plans and controlling erosion under different land-cover conditions, such as croplands, rangelands, and disturbed forest lands. As a result, he classified the area of Dolakha into six classes according to erosion severity and even produces a spatial distribution of soil erosion over Dolakha. And such studies suggested for conservation and refining the model in the future.

Dahal (2020) has done the study on soil erosion estimation in Kathmandu district, Nepal. Kathmandu is the largest city of Nepal, which is very densely populated and situated at average elevation 1,400 meters above sea level. RUSLE is applied to evaluate the risk of erosion in Kathmandu district with the help of GIS and RS despite its limitation. As a finding they classified the Kathmandu Districts into six varies classes based on rate of erosion that is found in specific location and provides a projection of erosion mapping base on using remotely sensed data and GIS platform with outcome of vulnerable zone.

Chen et al. (2017) has carried out the work on assessment of soil loss in Karst Basin in southwest, China. Mawoshan Karst Basin with a surface area of 16.29 km^2 and a depositional area of 0.74 km^2, is situated at Weining County located in Wumeng Mountains between eastern Yunnan and northwestern Guizhou provinces, China. The RUSLE model of the six factors that are associated with climate, soil, topography vegetation and management was considered to determined soil loss with the help of GIS and RS. They found out that the average annual soil loss rate of the simulation was 30.24 Mg $ha^{-1}yr^{-1}$ and also found out that DEM resolution is sensitive to result of the RULSE.

Bouhadeb et al. (2018) has asses the soil loss, and to highlight the areas subject to the risk of water erosion in the Bou Namoussa watershed having area of 575 km^2 and a perimeter of 176 km. The model they used to estimate the soil loss in Bou Namousa watershed is Revised Universal Soil Loss Equation (RUSLE) with the help of GIS and land used land covered map. The study indicated that the watershed loses an average of 7.8 t $ha^{-1}\cdot y^{-1}$and it is more than half of watershed area that is prone to erosion due maximum rainfall, poor soil erodibility, predominance of slope length and slope steepness and due to less erosion control measures.

Henry and Elias (2020) has studied on effect of land use land cover changes on the rate of soil erosion in the Upper Eyiohia river catchment of Afikpo North Area, the catchment occupies an area of 54,200 hectares. They have used the Revised Universal Soil loss equation (RUSLE) with combination of Geometric information system (GIS) and satellite remote sensing. The factor contributing in getting the required values are rainfall erosivity, soil erodibility, slope length and slope steepness, cover management factor and support practice factor. The study has concluded that the soil erosion rate has drastically increased due to demand in more cultivatable land, grazing land and settlement.

RUSLE as an empirically based model was used to predict the long-term average annual rate of soil erosion using data on rainfall pattern, soil type, topography, crop system and management practice. Assessment of spatial availability in the rainfall and rainfall erosivity was carried out at Pamba basin, India by applying the spatial interpolation technique available in the Arc GIS software which was used along with rainfall data of far rain gauge stations. As a conclusion they have mapped the susceptibility zones for precipitation intensity (Obiahu & Elias, 2020)

Fayas et al. (2019) has Soil loss estimation in KELANI river basin at Sri Lanka located in northern latitudes from 6°47′–7°05′ and eastern longitudes from 79°52–80°13′ using RUSLE model to prioritize erosion control. The RUSLE model was due to its flexible in modeling soil erosion in terms its ability to change conditions and parameters and easy to integrate with a GIS for spatial analysis. Their project indicates the Soil erosion severity map can be computed using six RUSLE parameters which was helpful in the management and control of erosion in the Kelani River basin.

The present study by Kayet et al. (2018) uses RUSLE and SCS-CN (Soil Conservation Service - Curve Number) process to estimate in Kiruburu and Meghahatuburu mining sites areas. The site of the study area is at latitude 22° 2′ 20.03″ 22°10' 32.71' N and longitude 85° 8′ 13.6″ 85°20'17.34″ E. The RUSLE model adopted for estimating the yearly average soil erosion in the koina and karo River watershed provided satisfactory results and can be used for estimating soil loss in additional similar micro watersheds. The average yearly soil erosion in the koina and karo river basin using the RUSLE method was found to be up to approx 40 t/ha^{-1} yr^{-1}.

The RUSLE model integrated with GIS technique was used to simulate regional evolution scenarios and plan erosion action in Buguergouh, Morocco. RUSLE offers an excellent solution to estimate annual soil erosion based on different data, such as soil parameter, topography, vegetation covers and climate. With the aid of RUSLE model, the erosion risk in the region was determined and also identified the area that could benefit from meaningful intervention strategies. RUSLE model proved that slope and rainfall are the most critical factors influencing soil erosion as research done by (Aouichaty et al., 2022).

RUSLE coupled with GIS was used to assess and quantify the annual soil erosion rate of the Jamuna basin of north central part of Bangladesh by the declination of the special distribution of the soil erosion through the identification of the factors associated with localized differences for management strategies in the basin. RUSLE model was found to be an effective tool in determining Sustainable land management and the implementation of the best and long-term soil conservation strategies for minimizing soil loss and soil related hazards as work done according to (Saha et al., 2022).

Ganasri and Ramesh, (2015) has done the Assessment of soil erosion by RUSLE model using remote sensing and GIS. The Nethravathi Basin is around 3128.72 km^2 area and located in the middle region of Western Ghats, western India where rainfall from three seasons respectively contributes about 4, 90 and 6% of the total annual rainfall. The analysis and results conclude that the annual average soil loss estimated using RUSLE model is about 473,339 t/yr and it was also observed that the quantity of erosion varies mainly on topography and land use-land cover. By analyzing the impact of increase in agricultural area on soil erosion concluded that as the agricultural area increases, erosion risk also increases due to the agricultural practices.

Jsidre et al. (2016) has done the comparison of predicted and measured soil Loss in mountain watershed of Kawamukai which is located at 34º 56' 41.4"N Latitude and 135^0 57'41.5"E Longitude on the south side of Lake Biwa in Shiga Prefecture, Japan using RUSLE model. It was observed that the increasing soil loss was caused by concentrated heavy rainfall in the rainy season (June to July) or the typhoon season (Sept. to Oct.) in Kawamukai watershed during 1993 to 1998. As a finding, they have found the average values of annual predicted and measured soil loss for the watershed with a difference of 4% which concluded that

RUSLE model can predict reasonable soil loss in Kawamukai watershed.

Soil erosion has become the main threat in Syria having 85% of agriculture land exposed to erosion. With the help of RUSLE model and GIS they outline the situation of the soil water erosion in southern region of Syria. The ranges for different parameter were calculated and as a result they have provided with immediate conservation plan and water conservation point of view. Through that simple and scientific way, they calculated the annual soil loss ranges between 1.26 to 350.5 t ha. They recommended the practice such as Buffer strips, Agri-spillways and conservation tillage to the area in high risks as drawn research by (Mohammed et al., 2020).

Muche and Fekadu (2019) has done the study on soil erosion risk assessment and mapping using GIS in Angacha watershed, North Gonder, Ethiopia. The project area is located in Amhara region, North Gonder, Gonder Zuria Woreda with the area of 2000 hectares. GIS model using RUSLE method was applied to analyze the amount of soil loss. This study identified the prone areas and mapped for planning of soil and water conservation measures based on slope classes of watershed.

A comprehensive methodology that combines Revised Universal Soil Loss Equation (RUSLE), Remote Sensing data and Geographic Information System (GIS) techniques was used to determine the soil loss vulnerability of an agriculture mountainous watershed in Maharashtra, India was done. The mean annual soil loss was 1.26 t/ha/yr and it was concluded that the parts with natural forest cover in the periphery regions have least rate of soil loss, whereas areas with human intrusion have high rate of soil erosion (Kadam et al., 2018).

The erosion risk analysis of Harebakayış sub-watershed of Elazig, Turkey was evaluated using RUSLE model based on GIS. Harabekayış sub-watershed is 5616 hectares. The results indicated that the erosion risk was high in 43.2% of the sub-watershed whereas it was lower and normal in 56.8% of the watershed. Regions with high erosion risk was found in western part which was due to the land's steepness and lack of vegetation (Gürtekin & Gökçe, 2021).

Ban et al. (2016) estimate the soil erosion rate of Kulekhani reservoir catchment area, Nepal applying RUSLE, adopting remote sensing data and geographic information system (GIS) techniques. The catchment area is about 124.75 km^2. The geology of area is fragile which experiences intense rainfall events throughout monsoon season. It was concluded that soil erosion rate of comparatively 41% area was tolerable but has no distinct zone and approximately 58% area of catchment was on the verge of high to very severe intensity classes. The research demonstrates that they use of remote sensing data and GIS has an abundant advantage in predicting soil erosion rate for the sustainable land use and ecological management planning of Himalayan region of Nepal.

Estimating the soil erosion cover-management factor at the European scale was conducted by Panagos et al. (2015). Among the different soil erosion risk factors, the cover-management factor (C-factor) is the one that policy makers and farmers can most readily influence in order to help reduce soil loss rates. The C- value lies between 0 and 1, the bare plot (no vegetation) with till up and down the slope is taken as a reference condition, with a C-factor value of 1. The LANDUM model has been developed at the European scale in order to estimate the C-factor for all land uses. The LANDUM model for C-factor estimation is differentiated between (a) arable lands and (b) all other land uses (non-arable).

The study was carried out by K et al. (2021) to estimate the average annual soil erosion and risk area in the (George K et al., 2021) State of Indian Himalayan region using various high-resolution geospatial data layers such as Global rainfall erosivity database, SOILGRIDS, Carto DEM as well LULC data by employing Revised universal soil loss equation (RUSLE) model in GIS environment. The average annual soil erosion rate was estimated as 27.45 t ha^{-1} yr^{-1}, totaling to an amount of 119 Mt yr^{-1} as potential soil loss from state. Among the various physiographic regions, total soil loss amounts were estimated to be 2.94, 5.08, 5.35, 7.48, 15.55 and 82.88 Mt yr-1 from Tarai, Trans Himalaya, Bhabhar (foothills), Shivalik, Greater Himalaya and Middle Himalaya respectively.

Moisa et al. (2022) Studied Anger Rier Basin using Rusle and geographical information system. The study area covers 2613.4km^2 the average annual soil loss was 83.7t/ha/year in the Anger River basin. The steepness of the area and clearance of the natural vegetation for agricultural activities was the key factors that influence the amount of soil loss. The study area was categorized as very sever.

Palanisamy (2020) RUSLE method has been accepted to estimate soil erosion in the Kummattipatti Nadi watershed part of the Coimbatore district of Tamil Nadu, India. It is located in the South Coimbatore this extends between the latitudes 10° 47′22″ and 10°57′45″ East and the longitude of 76°45′10″ and 77°1′40″ north and covers an area of 264.39 Sq. km. The results of the study show that the annual average soil loss within the watershed is about 6 t/ha/yr. Higher soil erosion is observed in the land use classes of gullied wasteland, open scrub forest and degraded plantation. The soil erosion risk is extremely higher on the steep slopes and adjoining foothills. The proper conservation and management strategies has to be implemented in this watershed for the development.

Njoku and Amangabara (2017) has done a study on temporal assessment of soil loss using the RUSLE model and Geospatial techniques. The study area has grown into major transit town for the southeast sub regions. The area lies in the rain forest belt of south eastern Nigeria characterized by hills and lowlands. The datasets such as Digital Elevation Model, average annual rainfall data, satellite images and soil type map were used to predict the rate of soil loss using RUSLE model in Okigwe between 1985-2015. All in all, the study found out that the northeastern part of their study area, where the topography is hilly appears to have high risk of soil loss.

2.3 SUMMERY OF WORK CARRIED OUT BY DIFFERENT RESEARCHERS

Table 2.3.1 Summery of work carried out by different researchers

Author	Work Done	Watershed Area	Parameter or Studied Methodology	Findings
(Thomas et al., 2017)	Assessment of Soil Loss and evaluate the yearly soil loss rate and to map potentials of soil losses in a hilly sub-watershed in the Shivganga river basin.	The areal extent of Shivganga watershed is 173.93 km^2 which is a part of Pune district, Maharashtra, India.	Asses soil loss rate in India by using GIS and RUSLE methodology and used remote sensing for satellite information such as study of cropping pattern.	It was concluded that RUSLE model helps for mapping susceptibility zones for precipitation intensity and soil textures and results revealed that the combination of RUSLE and GIS could be helpful for the management of groundwater potential and runoff modeling in a larger area.

(Thapa, 2020)	Spatial estimation of soil erosion using in Dolokha district, Nepal.	The study area is the Dolakha District, Nepal, situated in the northeast part of Kathmandu	With the help of remote sensing, GIS and RUSLE provide a potential to estimate soil erosion loss on a cell-by-cell basis.	As a result, he classified the area of Dolakha into six classes according to erosion severity and even produces a spatial distribution of soil erosion over Dolakha. And such studies suggested for conservation and refining the model in the future.
(Dahal, 2020)	Soil erosion estimation in Kathmandu District, Nepal	Kathmandu which is densely populated and situated at 1400m above sea level.	RUSLE is applied to evaluate the risk of erosion in Kathmandu district with the help of GIS and RS despite its limitation.	As a finding they classified the Kathmandu Districts into six varies classes based on rate of erosion that is found in specific location and provides a projection of erosion mapping base on using remotely sensed data and GIS platform with outcome of vulnerable zone.
(Chen et al., 2017)	Evaluation for soil loss in Karst Basin of Southwest China.	16.29 square km	The model of RUSLE was applied for stimulating the soil erosion rate in Karst catchment.	RUSLE along with GIS and RS, depicts the spatial distribution of soil erosion rates as well as qualify erosion amount during 1980s-2000s in a typical ungagged Karst basin of Guizhou Province, China.
(Bouhadeb et al.,2018)	Asses the soil loss, and to highlight the areas subject to the risk of water erosion	Bou Namoussa watershed having area of 575 km^2 and a perimeter of 176 km.	Revised Universal Soil Loss Equation (RUSLE) with the help of GIS and land used land covered map. The combination of RUSLE model with GIS producing a soil loss map which depicts different degrees	The study indicated that the watershed loses an average of 7.8 t $ha^{-1} \cdot y^{-1}$and it is more than half of watershed area that is prone to erosion due maximum rainfall, poor soil erodibility, predominance of slope length and

	in the Bou Namoussa.		of vulnerability of soil to erosion.	slope steepness and due to less erosion control measures.
`	Investigated the spatial pattern of soil erosion risk and map the annual soil loss rate.	The watershed covers a total area of 3,539.6 km^2.	The Revised Universal Soil Loss Equation (RUSLE) model, coupled with geographical information system (GIS) techniques was highly used to investigate the spatial pattern of soil erosion risk and map the annual soil loss rate in the Upper Beles watershed of the Blue Nile Basin, Ethiopia.	Results indicate that soil erosion in the watershed is primarily induced by human activities such as deforestation and land conservation Negligence and they have done effective planning of sustainable land management based on erosion severity classes.
Henry & Elias, (2020)	Has studied on effect of land use land cover changes on the rate of soil erosion in the Upper Eyiohia	The catchment occupies an area of 54,200 hectares.	They have used the Revised Universal Soil loss equation (RUSLE) with combination of Geometric information system (GIS) and satellite remote sensing to get accurate data.	Application of RUSLE model integrating with climatic, soil, topo-graphic and remotely sensed data within a GIS environment was found very helpful in quantifying the past and present LULC change and soil erosion rates from which an appropriate management planning and land prioritization could be made for the future.
Obiahu & Elias, (2020)	Estimated soil erosion and developed optimal soil erosion management plans in Pamba Basin, India.	167.83 km^2	Implementation of RUSLE equation in a raster GIS environment for the calculation of factors and annual soil loss.	Mapped the susceptibility zones for precipitation intensity.

Fayas et al. (2019)	Soil loss estimation in KELANI river basin at Sri Lanka located in northern.	Keleni River basin above elevation was 0 to 2345m above the sea level	The RUSLE model was selected for this study due to its demonstrated effectiveness with compared to the USLE model.	The Kelani River basin was divided into five severity categories based on their value.
Kayet et al. (2018)	Valuation of soil loss estimation using the RUSLE model and SCS-CN method in hillslope mining area	Study area is at latitude 22° 2′ 20.03″ 22°10' 32.71' N and longitude 85° 8′ 13.6″ 85°20'17.34″ E.	The RUSLE model adopted for estimating the yearly average soil erosion in the koina and karo River watershed provided satisfactory results and can be used for estimating soil loss in additional similar micro watersheds.	The average yearly soil erosion in the koina and karo river basin using the RUSLE method was found to be up to approx 40 t/ha^{-1} yr^{-1}.
(Kayet et al., 2018)	valuation of soil loss estimation using the RUSLE model and SCS-CN method in hillslope mining area	The site of the study area is at latitude 22° 2′ 20.03″ 22°10' 32.71' N and longitude 85° 8′ 13.6″ 85°20'17.34″ E with the altitude of 850 m above the MSL.	Different types of GIS application set and RUSLE are used for the estimation of soil erosion within the area.	The RUSLE model adopted for estimating the yearly average soil erosion in the Koina and Karo River watershed provided satisfactory results and can be used for estimating soil loss in additional similar micro watersheds.
(Systems & Chadli, 2019)	Estimation of soil loss in Sebou watershed	Nearly 40000 square km	To assess the risk of water erosion in the Sebou watershed (Morocco), RUSLE is implemented. Also, (Arc GIS 10.2) was used for	The raster map of the resulting soil erosion was obtained.

	(Morocco)		calculation of erosion which requires a huge amount of information and data from various sources available in different format and scales.	
(Sajjad et al., 2022)	Analyzed the relationship between drought and soil erosion using Vegetation Health Index (VHI) and RUSLE models in Godavari middle sub-basin, India.	400000 square km	The intensity of drought was quantified by integrating TCI and VCI maps. Soil erosion was estimated using site-specific factors in the RUSLE model.	Relation between drought and soil erosion was examine using Pearson correlation.
Mohammed et al., (2020).	They have done the Estimation of soil erosion risk in southern part of Syria by using RUSLE integrating geo informatics approach.	Area between 32◦28′15″N, 36◦24′18″E and 32◦46′44″N, 36◦45′15″E.	Using RUSLE model with the help of GIS they found out the soil loss.	As a result, they have provided with immediate conservation plan and water conservation point of view.
(Mangan & Kathiresan, 2018)	Since the conventional	1000 sq.km	Preparation of various thematic maps using Arc GIS 10.4.1 and	By using Rational method, peak discharge(Q) is identified which helps

	techniques of runoff measurement are expensive, time consuming, and difficult, they have used rainfall-runoff models to compute runoff.		ERDAS image are contour map, drainage map, DEM, slope map and land use/ land cover map.	to conclude the runoff estimation. Higher runoff leads to flooding and lower runoff leads to more infiltration thereby increasing the water table. Kul Nadi watershed has classified to five classes, very high risk, moderate risk, low risk, high risk, moderate risk, low risk and very low risk.
(Jsidre et al., 2016)	Comparison of predicted and measured Soil loss in mountain watershed using RUSLE model.	2.61 ha	The RUSLE model is used to estimate the soil loss for sustainable management of a watershed and the soil loss due to erosion needs to be kept within acceptable limits by adopting appropriate land management measures.	The average values of annual soil loss measured and predicted for the watershed are 27.7 kg ha^{-1} y^{-1} and 28.9 kg ha^{-1} y^{-1} respectively. The difference between them is only 4 percent and thus, it is concluded that the RUSLE model can predict reasonable soil loss in Kawamukai watershed.
Njoku and Amangabara (2017)	Determined the soil loss vulnerability of an agriculture mountainous watershed in Maharashtra, India.	173.93 km2	A comprehensive methodology that combines Revised Universal Soil Loss Equation (RUSLE), Remote Sensing data and Geographic Information System (GIS) techniques was used.	The spatial soil loss maps prepared.

Moisa et al. (2022)	Erosion risk analysis of Harebakayış sub-watershed of Elazig	5616 hectares	Erosion risk analysis was evaluated using RUSLE model based on GIS. In order to make calculations in the RUSLE model, data obtained from soil maps, meteorology station and satellite images were used. The maps of the factors in the RUSLE were integrated in ArcGIS 10.4.1 and soil erosion rate was calculated.	High erosion risk was estimated as 68%, 70% in grasslands, sparse forest, respectively. Erosion risk was high in 43.2% of the sub-watershed, in the section of 56.8% was normal and lower.
(K et al., 2021a)	To estimate the average annual soil erosion and risk area in the Uttarakhand State of Indian Himalayan region	The state is located in the North western Himalayan region covering a total geographic area of 53,483 km2 and lies between 28°43‟ to 31°28‟ N latitudes and 77°34‟ to 81°03‟ E longitudes	Used various high-resolution geospatial data layers such as Global rainfall erosivity database, SOILGRIDS, CartoDEM as well LULC data by employing Revised universal soil loss equation (RUSLE) model in a GIS environment.	The average annual soil erosion rate was estimated as 27.45 t ha-1 yr-1, totaling to an amount of 119Mt yr-1 as potential soil loss from the state.

CHAPTER 3

METHODOLOGY

This methodology is a flow chart of how we computed end result using rainfall data, soil data and land use land cover data by applying RUSLE model integrated in GIS interference.

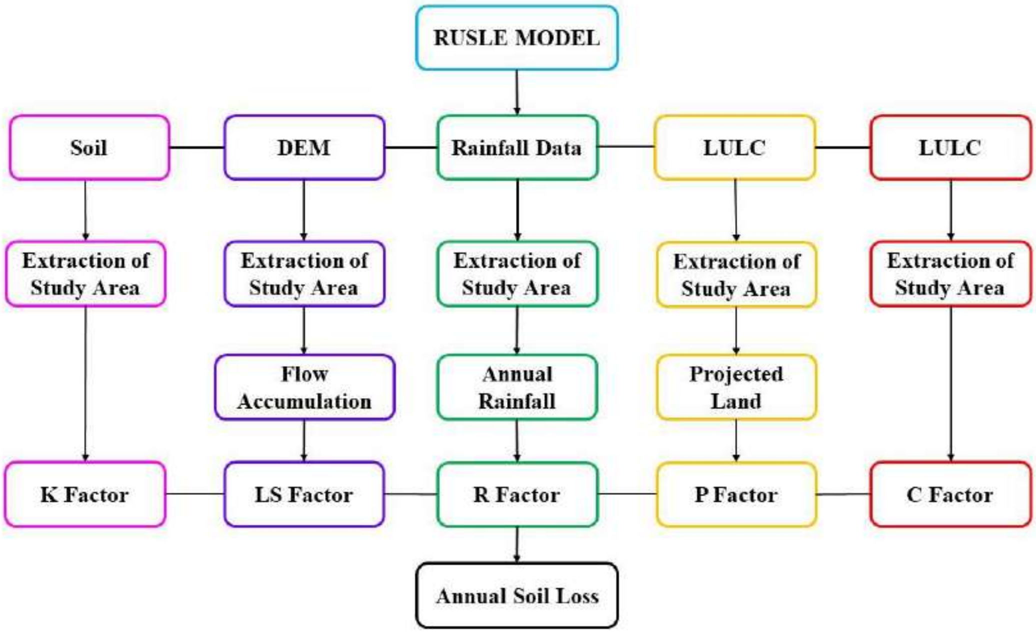

Figure 2.3.1 Methodology Flow Chart

3.1 METHOD

Many accurate soil erosion models were developed over the last four decades to assess soil erosion risk at different levels. Among these, the Universal Soil Loss Equation (USLE), the Soil and Water Assessment Tool (SWAT), and the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS). The USLE model has been widely used worldwide over the last 40 years to estimate soil erosion risk (Farhan et al., 2013). The Universal Soil Loss Equation was developed initially as a tool to assist soil conservationist in farm planning. It was widely used model in predicting soil erosion loss on specific slopes in specific fields. The USLE was extensively applied all over the world at many scales mainly due to the simplicity of the model formulation and easy availability of the data set. The Revised Universal Soil Loss Equation (RUSLE) was developed with the basic structure of the USLE with several improvements (Journal, 2020).

The Revised Universal Soil Loss Equation model was developed as an empirical model and we adopted this model which is revised form of universal soil loss equation (USLE) mainly because;

- It is easy to implement and understand from a functional perspective.
- Is compatible with GIS
- The data required to implement the model are not too complex or unattainable.
- It is a revised form.

The RUSLE model is an equation representing the main factors controlling soil erosion, namely climate, soil characteristics, topography, and land cover management. The equation is expressed as:

$$A = R\ K\ LS\ C\ P$$

where, A = computed annual soil loss per unit area.
R = runoff erosivity factor
K = soil erodibility factor
LS = slope length factor and slope steepness
C = cover management
P = support practice Factor

3.2 INFORMATION ON RAINFALL, SOIL, LAND COVER AND DEM

For the Nyera Amachhu catchment, the annual soil loss rate was computed based on the RUSLE model in Geographic Information System (GIS) using Arc GIS and its associated GIS packages. Annual soil loss is defined as the amount of soil lost in a specified time period over an area of land which has experienced net soil loss. The rainfall dataset from 2005 to 2021 was obtained from National Center for Hydrology and Meteorology (herein refer as NCHM), Ministry of Economic Affairs, Bhutan to compute the rainfall erosivity using the equation developed by Arnoldus (1980).

The global soil dataset was downloaded from global Food and Agriculture Organization (FAO) website and the soil texture was extracted (proportion of clay, silt, sand and loamy) along with the relevant intrinsic parameter course – sand contents, clay – silt content, organic carbon content and high sand content for deriving the K values of respective soil texture.

The national scale digital LULC 2016 map was requested from Forest Resource Management Division (FRMD) for study of the land used and land coverage in Nyera Amachhu Wateshed. To extract the study area or to proceed with this research we downloaded the Digital Elevation Model (DEM) having 30m spatial resolution from United State Geographical Survey (USGS) earth explorer.

3.3 INPUT PARAMETER USED FOR RUSLE

3.3.1 Rainfall Erosivity

The rainfall factor is a measure of the erosive force of a specific rainfall (Prasannakumar et al., 2012). It quantitatively reflects the impact of rainfall on the topsoil (Sajjad et al., 2022). It 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. The greater the intensity and duration of the rain storm, the higher the erosion potential. Raindrop/splash erosion is the dominant type of erosion in barren soil surface (CHEN et al., 2017).

Among the factors used within RUSLE, rainfall erosivity is of high importance as precipitation is the driving force of erosion and has a direct impact on the detachment of soil particles, the breakdown of aggregates and the transport of eroded particles via runoff. A precise assessment of rainfall erosivity requires recordings of precipitation at short time intervals (1 – 60 minutes) for a period of at least several years. (*Rainfall Erosivity in Europe - ESDAC - European Commission*, n.d.)

Our study area experiences a wide difference in precipitation intensity. Records of daily rainfall data from six rainfall stations (Dewathang, Khaling, Pemagatshel, Wamrong, Thrimshing and Kanglung) was used to calculate the R factor. Rainfall data of 16 years' (2005 to 2021) average were used to calculate R values based on the formula proposed by **Arnoldus (1980)**

$$P = 0.5P - 8.12$$

Where,

R = Rainfall erosivity factor (MJ mm h^{-1} ha^{-1} $year^{-1}$)

P = Mean annual precipitation in mm

The spatial interpolation techniques available in ArcGIS software were used along with rainfall data of all rain gauge stations for assessing the spatial variability in the rainfall and rainfall erosivity in the watershed.

3.3.2 Soil Erodibility

The K factor represents the susceptibility of soil particles to detachment and movement by water, a which depends on the physical, chemical and pedologic characteristics of soil (Eddine et al., 2018). The K factor is a numerical value that varies from 0 to 1 in which soil erodibility values closer to 0 are less prone to soil erosion (Atoma et al., 2020). Where 0 refers to soils with least susceptibility to erosion and 1refers to soils which are highly susceptible to erosion by water. Generally, soils become of low erodibility if the silt content is low, regardless of corresponding high content in the sand and clay fractions (Farhan et al., 2013)

Table 3.3.1 Erodibility Values

Table Soil Erodibility Soil type	Erodibility	K value ranges
Fine-textured; high in clay	low	0.05-0.15
Course textured; sandy	low	0.05-0.20
Medium textured; loams	moderate	0.25-0.45
High silt content	high	0.45-0.65

Organic matter reduces erodibility because it reduces the susceptibility of the soil to detachment, and it increases infiltration, which reduce runoff and thus erosion. Addition or accumulation of increased organic matter through management such as incorporation of manure is represented in the C factor rather than the K Factor. Extrapolation of the K factor nomograph beyond an organic matter of 4% is not recommended or allowed in RUSLE. In RUSLE, factor K considers the whole soil and factor Kf considers only the fine-earth fraction, the material of <2.00mm equivalent diameter. For most soils, Kf = K. Soil structures affects both susceptibility to detachment and infiltration. Permeability of the soil profile affects K because it affects runoff.

Although a K factor was selected to represent a soil in its natural condition, past management or misuse of a soil by intensive cropping can increase a soil's erodibility. The K factor may need to be increased if the subsoil is exposed or where the organic matter has been depleted, the soil's structure destroyed or soil compaction has reduced permeability. A qualified soil scientist can assist in making this interpretation. (*RUSLE - an Online Soil Erosion Assessment Tool*, n.d.)

We adopted the formula of Gyeltshen et al. (2021) has adopted the following relations to calculate the soil erodibility,

$$\mathbf{K} = \boldsymbol{f}_{\boldsymbol{co-sand}} \times \boldsymbol{f}_{\boldsymbol{cl-si}} \times \boldsymbol{f}_{\boldsymbol{org}} \times \boldsymbol{f}_{\boldsymbol{hi-sand}}$$

Where; *K* is erodibility factor,

$f_{co-sand}$ = coarse – sand contents

f_{cl-si} = clay – silt content

f_{org}= organic carbon content and

$f_{hi-sand}$ =high sand content

$$f_{co-sand} = \left(0.2 + 0.3^{\left[-0.256 \times m_s \times \left(1 - \frac{m_{si}}{100}\right)\right]}\right)$$

$$f_{cl-si} = \left(\frac{m_{si}}{m_{c+m_{si}}}\right)^{0.3}$$

$$f_{org} = \left(1 - \frac{0.256 \times orgC}{orgC + 1^{[3.72 - 2.97 \times orgC]}}\right)$$

$$f_{hi-sand} = 1 - \frac{0.7\left(1 - \frac{\mathrm{m_s}}{100}\right)}{\left(1 - \frac{\mathrm{m_s}}{100}\right) + 1\left[-5.51 + 22.9\left(1 - \frac{\mathrm{m_s}}{100}\right)\right]}$$

Where; m_s = sand fraction content (%)

m_{si} = silt fraction content (%)

m_c = clay fraction content (%)

orgC = soil organic carbon content (%)

3.3.3 Slope Length and Slope Steepness

Length Factor (L) is the slope length factor, representing the effect of slope length on erosion. S is the slope steepness and it represents the effect of slope steepness on erosion. Soil loss increases more rapidly with slope steepness than it does with slope length.(*RUSLE - an Online Soil Erosion Assessment Tool*, n.d.). Topography is considered as the most important factor determining the rate of erosion, especially in case of hilly and mountainous terrains. The influence of topography is characterized in the form of slope length (L) and slope steepness (S) factors, as erosion is not only governed by uninterrupted length of slope but also by its steepness(George K et al., 2021).Topographic factor –Slope Length and Steepness (LS) is a combination of slope gradient factor (S) and a slope-length factor (L), which are determined from the DEM (Dahal, 2020). The combined LS-factor was computed for the watershed by ArcGIS spatial analyst extension using the following equation,

$$LS= \{FA\times (\frac{CELL\ SIZE}{22.13})\}^{0.4} \times (\frac{Sin\ slope}{0.0896})^{1.3}$$

Where; LS= Slope length and steepness factor

FA= Flow accumulation and cell size is size of grid cell (30 m for this study) and sin slope is slope degree value in sin (Atoma et al., 2020).

The LS-factor was calculated from the DEM data using resolution of 30m by the means of ArcGIS spatial analysis tool (CHEN et al., 2017). As stated by (Farhan et al., 2013), the spatial analyst toolkit of the GIS software was used to generate raster layers of slope gradient (degrees), and from the hydrology toolkit the flow direction and then the flow accumulation were calculated. The slope length can be regarded as the distance along the flow path from the point of origin of overland flow where initial deposition occurs (on concave slopes) or to a concentrated flow channel (Abdulkareem et al., 2019).

The slope-length and gradient parameter is crucial in the soil erosion modeling for calculating overland flow (surface runoff). The L and S represent the effect of slope length and steepness respectively on erosion, also when it increases soil loss per unit area rises (Thapa, 2020). The LS factor represents erodibility due to combinations of slope length and steepness relative to a standard unit plot. An increase in hill slope length and steepness results in an increase in the LS factor (Koirala et al., 2019). Also, length and steepness of a slope affects the total sediment yield from the area and is accounted by the LS-factor in RUSLE model. (Atoma et al., 2020)

3.3.4 Cover Management (C)

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 (Prasannakumar et al., 2012)

Besides vegetation cover, several other land use and management factors affect soil loss, such as type of crop, tillage practice and etc. The influence of land use and management is often parameterized in the cover-management factor (C-factor). The C-factor is among the five factors that are used to estimate the risk of soil erosion within the Universal Soil Loss Equation (USLE) and its revised version, the RUSLE. The C-factor is perhaps the most important factor with regard to policy and land use decisions, as it represents conditions that can be most easily managed to reduce erosion. C-factor accounts for how land cover, crops and crop management cause soil loss to vary from those losses occurring in bare fallow areas (*Cover Management Factor - ESDAC - European Commission*, n.d.).The bare plot (no vegetation) with till up and down the slope is taken as a reference condition, with a C-factor value of 1.

The soil loss from different land-cover types is compared to the loss from the reference plot and the results are given as a ratio. The C-factor value for a particular land-cover type is the weighted average of those Soil Loss Ratios (SLRs), and ranges between 0 and 1.

C-factor ranges from 0 to approximate 1, where higher values specify no cover effect and soil loss is higher in this area where vegetation coverage is low, while C value of 0 means a strong cover effect resulting in no erosion. Impact of C-factor on soil erosion is not so much significant when the land use of the area is comprised of high grassland, plantation area (Dahal, 2020).

3.3.5 Support Practice Factor (P)

The support practice factor P represents the effects of those practices such as contouring, strip cropping and terracing that help prevent soil from eroding by reducing the rate of water runoff (Journal, 2020). The support practice factor indicates the rate of soil loss according to agricultural practice (Thapa, 2020). P factor which represents the anthropogenic effects on soil erosion varied from 0 to 1.The highest values were assigned to LULC classes where no support practices are followed or adopted, lower values were assigned to built-up land, and different cropland classes, where different support practices such as bunding, terracing etc. were adopted (K et al., 2021b).As with the other factors, the P-factor differentiates between cropland and the rangeland/permanent-pasture option contains an "other mechanical disturbance" routine rangeland or permanent pasture. Both options allow for terracing or contouring, but the cropland option contains a strip-cropping routine (university, n.d.). The RUSLE P-factor **reflects the impact of support practices and the average annual erosion rate**. The values of the support practices depend on types of conservation actions practiced in a given area (Getachew et al., 2021). To get practice factor value we adopted the most reliable value for each land use type.

CHAPTER 4

RESULT AND DISCUSSION

4.1 SOIL EROSIVITY

The spatial distribution of rainfall erosivity shows that the values of R factor vary from 648 MJ mm h^{-1} ha^{-1} $year^{-1}$ (Thrimshing station) to 2171.6 MJ mm h^{-1} ha^{-1} $year^{-1}$ (Dewathang station) a function of rainfall characteristics. The lowest R values were recorded in the central-west part of the watershed and the highest were recorded in the south and some in central-west. The northern and central east part has a moderate erosivity value. According to the Figure 4.14.1.1, only small part of our study area is subjected to high rainfall erosivity and these areas received maximum rainfall. Areas that received more rainfall are found more prone to erosivity than areas that received lesser rainfall.

Table 4.1.1 Rainfall Erosivity (R) values

Stations	Latitude	Longitude	Mean rainfall (mm)	R factor (MJ mm h^{-1} ha^{-1} $year^{-1}$)
Dewathang	26.85411	91.45797	3892.4	2171.6
Kanglung	27.28299	91.52105	1193.9	660.4
Pemagatshel	27.04009	91.40241	1796.5	997.9
Khaling	27.2086	91.59597	2502.7	1393.4
Thrimshing	27.122	91.609	1171.6	648
Wamrong	27.138	91.57	3132.2	1745.9

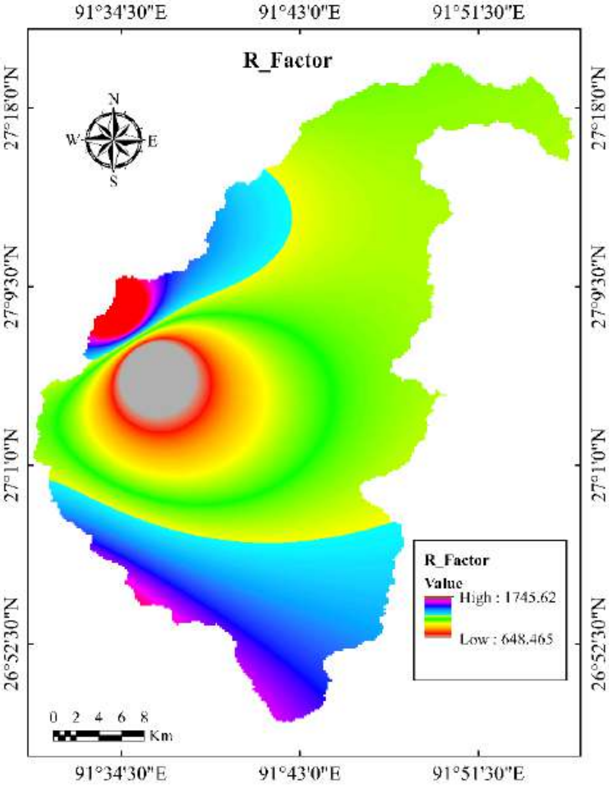

Figure 4.1.1 R factor Map

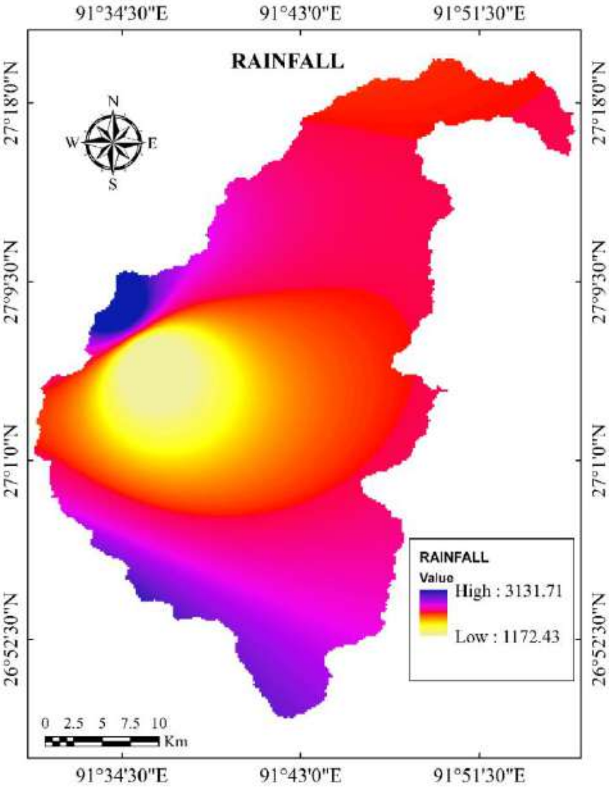

Figure 4.1.2 Rainfall Map

4.2 SOIL ERODIBILITY

The study area's soil unit map was extracted from Nyera Amachhu Watershed in which four main soil units were identified and delineated in shapefile of the study area. The k factor ranges from 0.1022 to 0.1632 as shown in table below.

Table 4.2.1 Soil Erodibility Factor (K factor)

Soil unit symbol	sand % topsoil	silt % topsoil	clay % topsoil	OC % topsoil	fcsand	fcl_si	forg	fhi sand	K factor
AO	53.6	15.8	30.6	2.25	0.200003	0.723839	0.750007	0.941788	0.1022
ND	38.9	17.6	43.6	1.57	0.200082	0.688063	0.796178	0.952963	0.1044
RD	82.1	6.7	11.3	0.27	0.2	0.743431	0.996338	1.101713	0.1632

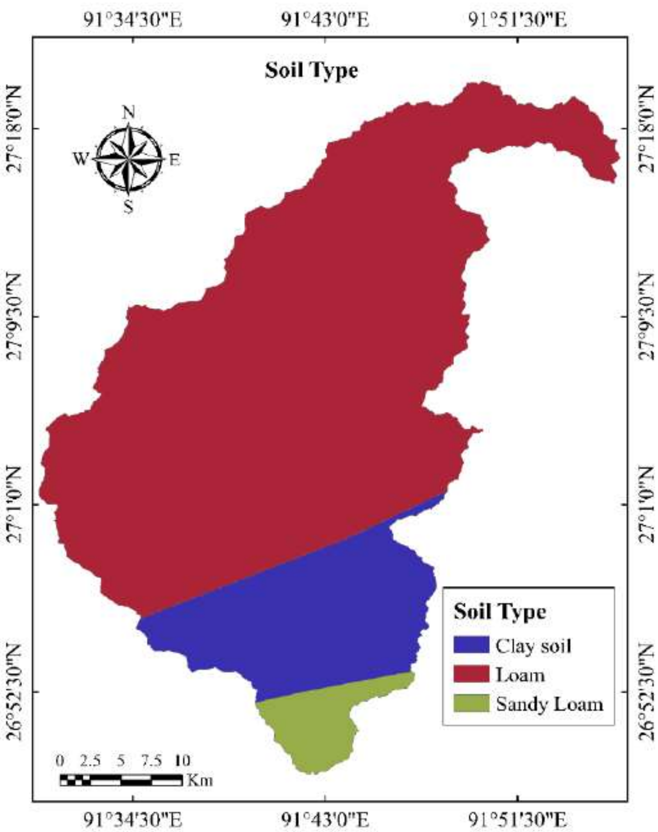

Figure 4.2.1 Soil Type

According to the World soil data, three types of soil were found in Nyera Amachhu Watershed. Maximum area of the watershed was found to be having a Loam soil with the erodibility value of 0.102-ton ha hr $MJ^{-1}\ ha^{-1}mm^{-1}$. In the southern part of watershed area were found to be having a clay and sandy loam soil coverage with the erodibility value of 0.104 ha hr $MJ^{-1}\ ha^{-1}mm^{-1}$ and 0.163 ha hr $MJ^{-1}\ ha^{-1}mm^{-1}$ respectively.

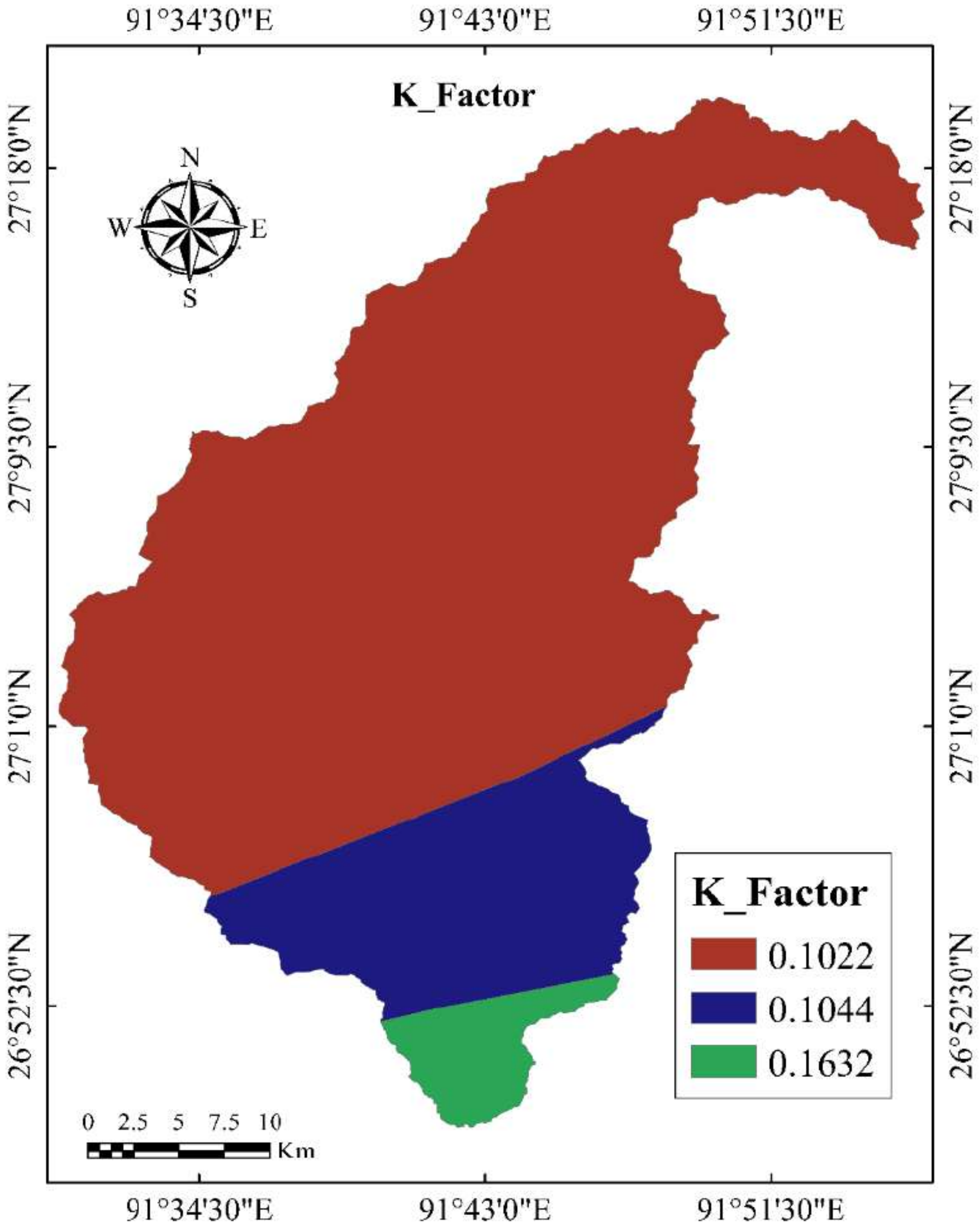

Figure 4.2.2 K Factor value

4.3 SLOPE LENGTH AND SLOPE STEEPNESS

An analysis was made in between the LS and slope which found to be directly proportional to each other. The effect of topography on soil loss is represented by L and S factors where, S factor reflects the change in potential erosion with change in slope, and L factor reflects increasing potential erosion due to surface runoff (Planning & Catchment, 2017). The upslope Nyera Amachhu catchment area for each cell in a DEM was computed with number of steps.
An increase in LS factor, increase in steepness of the slope was detected. Similarly, the slope of the upper part of our catchment area is found to be step which is prone to erosion but lower part of the catchment area is found to be gentle in slope and less prone to erosion.

The performed steps and spatial distribution of LS factor is as shown in Figure 4.3.1. LS-factor values in the study catchment varies from 0 to 1. Soil erosion is naturally more common in step land due to increase in amount of soil that is carried out with water and similarly soil erosion is directly proportional to the increase in slope length that plays an important role in collecting surface.

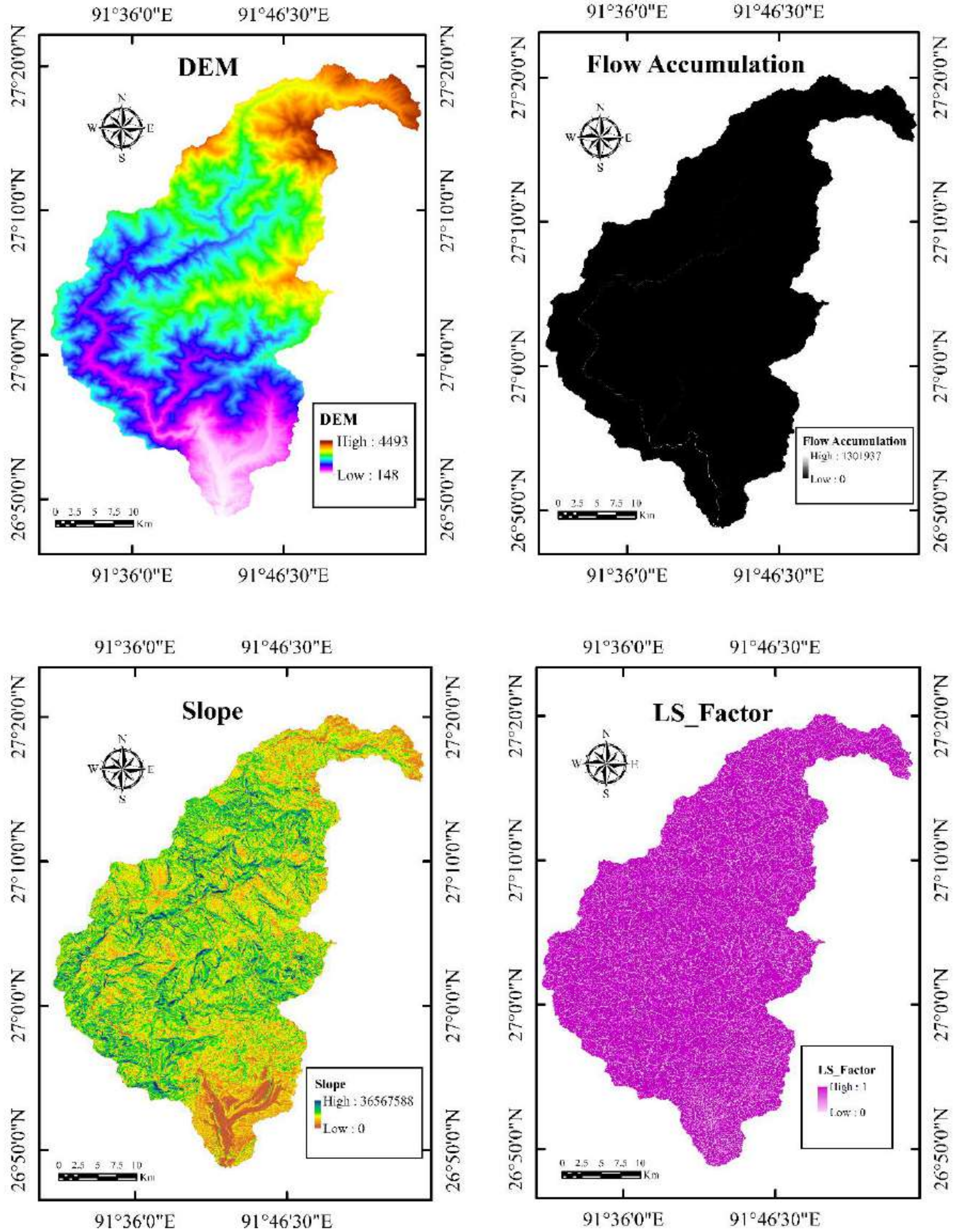

Figure 4.3.1 Slope Length and Slope Steepness.

4.4 COVER MANAGEMENT

The following C value for various classes are used to produce the C-factor map of Nyera Amachhu Warersehed.

Table 4.4.1 Cover Management adopted value.

Class	C -factor	Source
Shrubs	0.014	(Wischmeier and smith, 1978)
Meadows	0.3	(Chuenchum et al. 2020)
Forests	0.01	(Hurni, 1985)
Cultivated Agricultural	0.15	(Hurni (1985))
Landslide	0.6	(Haregeweyn et al, 2007)
Water Bodies	0	(Erdogan et al .2007)
Built up	0.1	(Chuenchum et al. 2020)
Rocky Outcrops	0.05	(Hurni (1985))
Alpine scrubs	0.05	(Bakker et al (2008))
Snow and Glacier	0	(Haregeweyn et al, 2007)

The C-factor ranges from 0 to approximate 1, where higher values specify no cover effect and soil loss is higher in this area where vegetation coverage is low, while C value of 0 means a strong cover effect resulting in no erosion. Impact of C-factor on soil erosion is not so much significant when the land use of the area is comprised of high grassland, plantation area. From the above C factor table landslides has highest value of C factor which indicates zero vegetation cover and more erosion takes place at that part whereas water bodies and snow glacier has 0 C- factor value and erosion does not happen at that place. Since, most of the C factor values in Nyera Amachhu Watershed area lies between 0 and 0.6, its indicates more vegetation cover and less erosion.

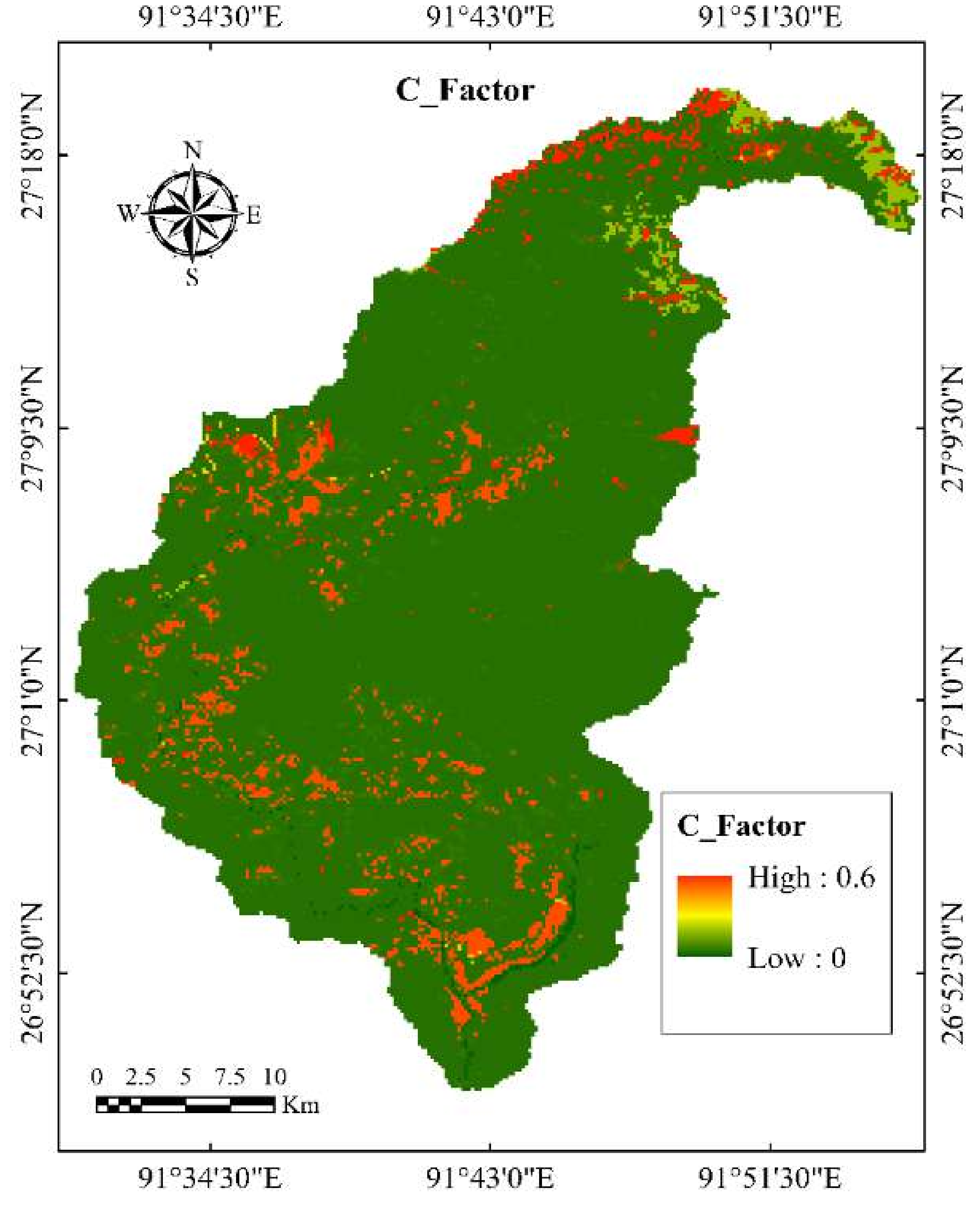

Figure 4.4.1 C factor map

4.5 SUPPORT PRACTICE FACTOR

The adopted standard value of practice factor is;

Table 4.5.1 Standard P factor value

Land used/Land cover	Value adopted	Area in (hac)	Places	Author
shrubs	1	14.359801	Lauri	(Gyeltshen et al., 2021)
Meadow	1	2.930034	Lauri	C.M Fayas et. al (2021)
Forests	0.3	17.958275	Lauri	C.M Fayas et. Al (2021)
Cultivated agriculture	0.5	2.930035	Nanong	Mausinghe et.al (2001)
landslides	1	1.955827	Nanong	(Gyeltshen et al., 2021)
Water bodies	1	1.228725	Gomdar	(Gyeltshen et al., 2021)
Built up	0	0.18934	Gomdar	(Gyeltshen et al., 2021)
Rocky outcrops	0	1.795827	Martshala	C.M Fayas et. al (2021)
Alpine shrubs	0.8	1.323242	Merak	Mausinghe et.al (2001)
Snow and glacier	1	1.228725	Merak	(Gyeltshen et al., 2021)

The P factor map was prepared from the spatial analysis program in GIS based on Table 4.5.1. Considering the LULC, majority of area in Nyera Amachu Watershed is under largely covered by forest and shrubs without any control practices area assigned with P factor of 0.3 and 1 respectively, while the conservation practice factor for agricultural land and built-up category under land use pattern are assigned with 0 and lower value which signify low susceptibility toward soil erosion.

The plantation protects soil losses and avoids erosion dependent on the soil and land use types dependent on the soil and land use types. For each land use pattern having land use practice that affects the P-value. The values of P factor of Nyera Amachhu watershed ranges from 0 to 1 with mean value of 0.66. Maximum part of Nyera Amachhu catchment area is of no conservation practices (forest and natural vegetation) followed by minimal coverage of built-up area. So, it was concluded that Nyera Amachhu catchment area is less susceptible to erosion as maximum part of area is covered by natural vegetation where no support practices are given.

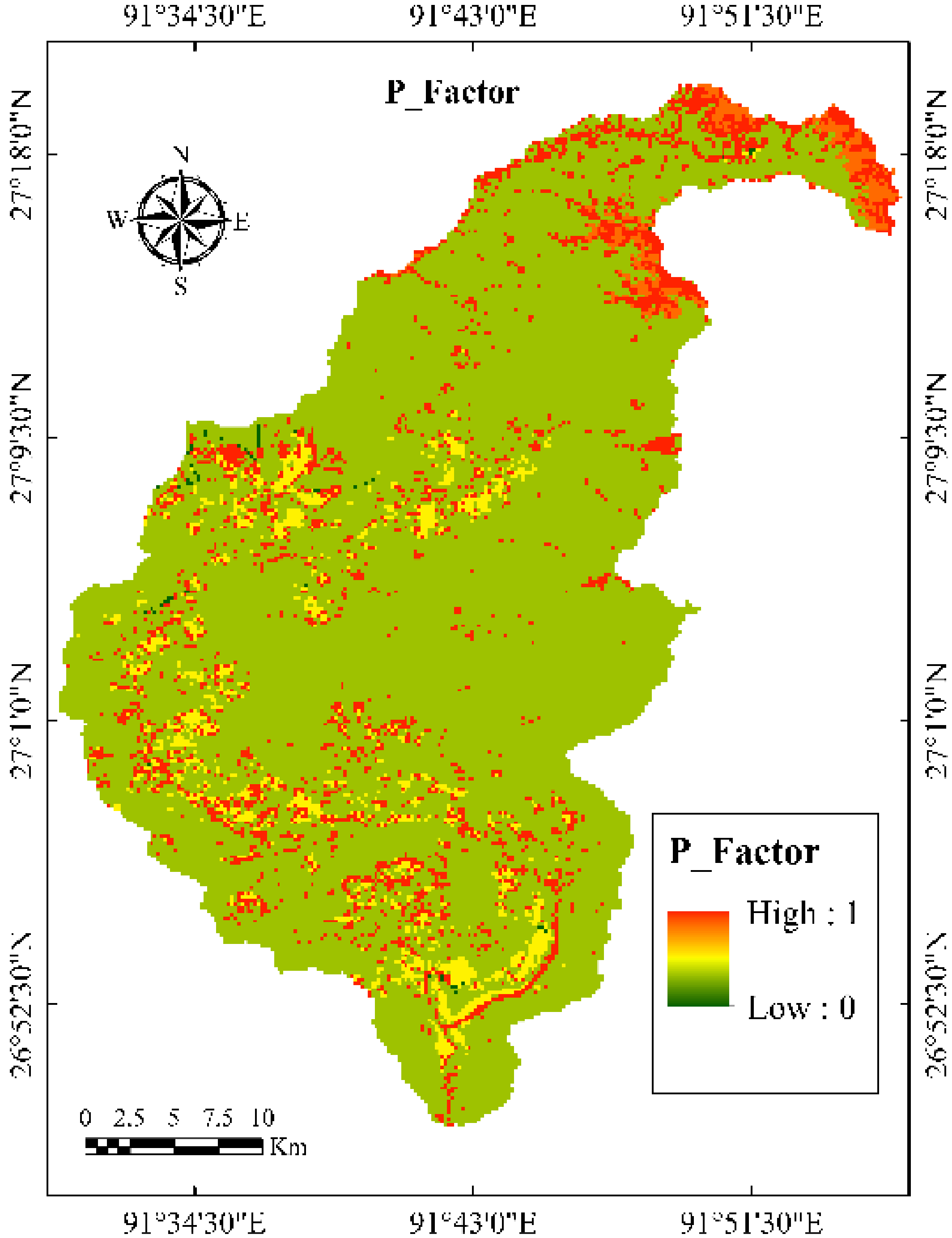

Figure 4.5.1 P factor map

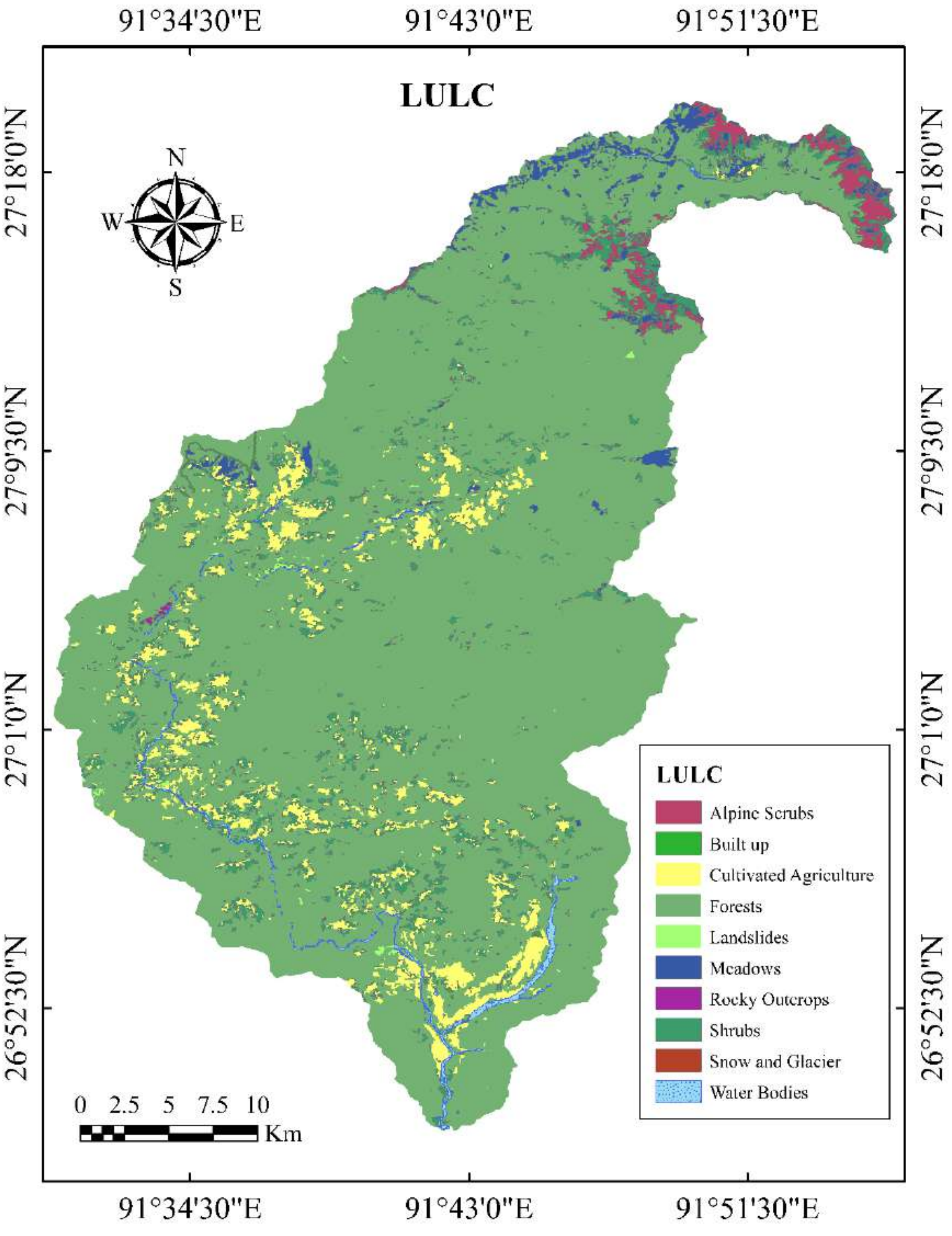

Figure 4.5.2 LULC map

4.6 SOIL EROSION ESTIMATION

The extimated total soil loss from the whole watershed was about 7368668.059 t y^{-1} with the mean soil erosion rate of 66.411 t $ha^{-1}y^{-1}$. Based on the spatial location of soil erosion, the present study found that the potential soil loss is greater in steep slope, stream bank and hilly cultivated lands. The north west down hill of Radi, steep slope of Wamrong and Riserbo and alluvial plain area of Samdrup Choling were affected by severe soil erosion. The other part of watershed in the middle west part of watershed, and near Merak experienced moderate soil erosion. Intensive rainfall also appeared in the southern part of the watershed which could be the cause of severe soil erosion in the same area.

The seven severity classes ranging from low erosion to severe erosion class was created to generated the severity map for the watershed. About 88% of the water shed was found in less prone area to soil erosion and the rest 12% of the area was found to be more than the high risk category which means it need attention and immediate conservation action should be implemented. The watershed area consisted of loam soil, clay and sandy loam soil. Loam soils have high amount of silts and fine sands, and they have moderate to low erodibility concluding watershed area as less prone to soil erosion. The huge vegetation covers protect the land from eroding.

Table 4.6.1 Standard Severity Class (Gyeltshen et al., 2021*)*

Erosion Severity	Soil loss (t/yr)
low	0-200
low	200-400
moderate	400-600
high	600-800
Very high	>800

Table 4.6.2 Severity classes obtained.

Soil loss (t/yr)	Severity class	Area coverage in percentage (%)
0-60.45	low	55.6
60.4532-324.56	low	23.6
324.563-566.2	moderate	12.9
566.234-789.43	high	4.7
>789.43	Very high	3.2

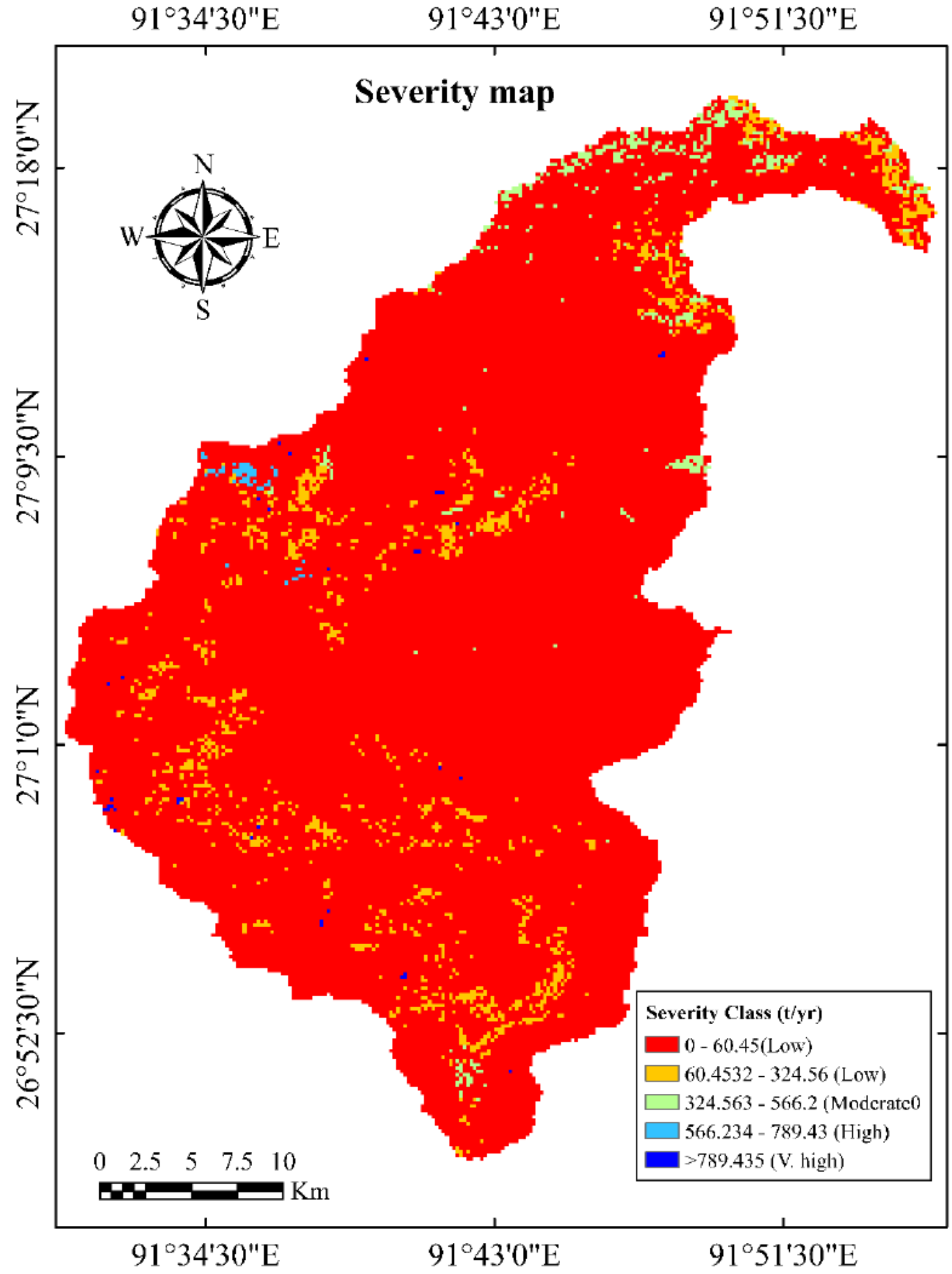

Figure 4.6.1 Severity Map

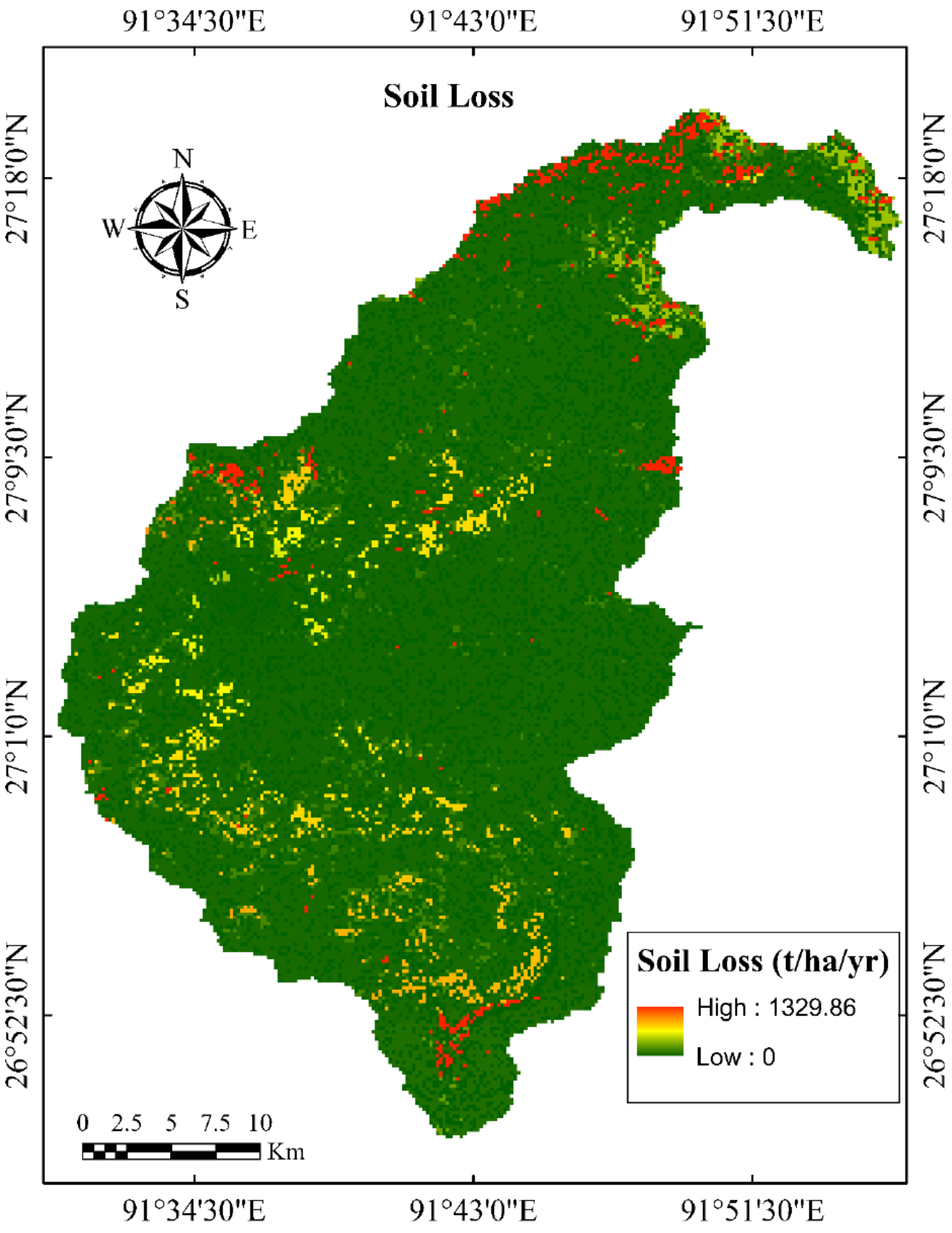

Figure 4.6.2 Annual soil loss map

CONCLUSION

Annual soil loss in Nyera Amachhu watershed = 0.01 t/ha/year. As a conclusion we have drawn that a quantitive soil erosion had been conducted in the Nyera Amachhu watershed using RUSLE model in the Arc GIS interface to quantify the mean annual soil loss and to identify erosion hotspot. A specific severity map was created for watershed as low erosion severity (0-200 t yr^{-1}) , low erosion severity (200-400 t yr^{-1}), moderate erosion severity (400-600t yr^{-1}),high erosion severity (600-800 t yr^{-1}), very high sevrity (>800 t yr^{-1}). The RUSLE model estimated the mean annual soil erosion of the watershed as 66.411 t ha^{-1} yr^{-1}. In nut shell we conclude that;

- The spatial distribution of soil erosion was more severe in the southern and northwestern parts of the watershed due to the up and down topography, poor conservation measures, intensive rainfall.
- Erosivity factor gives the great influence over other parameters to the soil loss in the study area.
- The study recommends using the developed severity map as a guide to introduce targeted conservation measures such as terracing trenches, and expanding biological measures depending on the provided priority classes.
- RUSLE and GIS-based approach applied in this study offer potentially useful approaches to identify those areas likely to be the most susceptible to soil erosion, and prioritize the areas for effective planning of sustainable land management based on erosion severity classes.

RECOMMENDATION

After doing this project we came to learn many things that are related to GIS and different models of soil erosions estimations. After so much of hardships and difficulties we have successfully completed this project up to our knowledge and with available information. There is some important information that our team would like to recommend to future researchers and learner:

- The results obtained in this research can be used as a reference for future researchers to validate their results.

- RUSLE has more flexibility in modelling erosion in mountainous and steepness slope like Bhutan. In addition to this, many parameters such as slope, aspect, etc. derived from DEM and LULC (land use land cover) from satellite images can be easily integrated with RUSLE.

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APPENDIX A

Table A.1 Data source

Data	Data source
SRTM DEM (30*30) m Resolution	https//eartheplorer.usgs.gov//
FAO soil map	https://www.fao.org
Land use land cover	Forest Resources Management Division
Meteorological data	National center for Hydrology and Meteorology.
Bhutan shape file	**http://gis.Washington.edu/area/** Bhutan/

1.Formula to Calculate the Missing Value of Rainfall

- Arithmetic Mean Method

$$Px = \frac{1}{n}\sum_{i=1}^{i=n} Pi$$

Where 'n' is the number of nearby stations, 'Pi' is precipitation at ith station and 'Px' is missing precipitation.

- In case of three stations 1, 2 and 3,
- Px = (P1 + P2 + P3)/3
- Naming stations as A, B and C instead of 1, 2 and 3
- Px = (Pa + Pb + Pc)/3
- Where Pa, Pb and Pc are defined above

- Normal Ratio method:

$$Pm = \frac{1}{n}\sum_{ni=1}^{n}\left(\frac{Nm}{ni} Pi\right)$$

Normal ratio method (NRM) is used when the normal annual precipitation at any of the index station differs from that of the interpolation station by more than 10%. In this method, the precipitation amounts at the index stations are weighted by the ratios of their normal annual precipitation data in a relationship of the form:

Where, Pm = precipitation at the missing location,

Pi = precipitation at index station,

Nm = average annual rain at ‘missing data’ gauge,

Ni = average annual rain at gauge
N = number of rain gauges.

2.Annual rainfall data of different station

Table A.2 Annual Rainfall

Annual Rainfall (mm)						
YEAR	**Deothang**	**Kanglung**	**Pemagatshel**	**Khaling**	**Thrimshing**	**Wamrong**
2005	4699.1	1319.4	2176.9	1794.7	1445.4	2162.8
2006	2692.8	1017.8	1345.4	1662.5	1197.5	1748.6
2007	4192.2	1379.6	2294.8	1714.6	2094.2	2048.3
2008	3463.1	1172.1	1795.3	1066	1475.2	2442
2009	3302.5	1091.8	1712.1	595.2	1345.5	2385.6
2010	3237.2	1065.4	1661.8	798	1560.5	1804
2011	2423.9	1016.8	1001	696.6	754.4	2305.7
2012	4177.3	1076.2	1881.1	4801.2	982.8	1856.4
2013	2856.7	1370	1465.7	6306.4	1033	2462
2014	3742.4	898.8	1437.6	6729.8	755.5	3742.65
2015	3825.2	1059.3	1748.6	7020.5	1025.1307	623.7
2016	2964.5	1033.8	1652.7	1039.7	943.3	2999.7
2017	3276.4	854.4	1135.9	1068.1	677.3	4416.1
2018	3481.7	1122.4	1612	1293.7	835.7	5168.6
2019	5107	1220.3	1978.4	1270.3	791.05281	5106
2020	5390.95	1348.4	2347.6	1203.1	968.29718	5390.95
2021	3445.3	1055.3	1497.1	982.85	861.06364	3451.9

APPENDIX B

Table B.1 World Soil Data

Soil unit symbol	sand % topsoil	silt % topsoil	clay % topsoil	OC % topsoil
A	53.3	17.2	29.5	1.74
AF	61.7	14.4	23.9	0.91
AF 1	81.1	8.7	10.2	0.35
AF 2	61.7	14.3	24	1.05
AF 3	21.3	25.7	52.9	1.85
AG	40.9	27.2	32.1	2.26
AG 1	89.3	7.2	3.5	0.5
AG 2	9.6	75.2	15.3	3.07
AG 3	35.2	17.9	47.2	1.99
AH	31.3	24.8	43.8	3.34
AH 1	72.8	14.6	12.6	1.58
AH 2	52.4	27.9	19.6	4.46
AH 3	9.2	26.1	64.8	2.88
AO	53.6	15.8	30.6	2.25
AO 1	82.3	8.6	9.2	0.3
AO 2	51	21.6	27.4	1.73
AO 3	33	14.2	52.9	1.84
AP	57	15.6	27.1	1.09
AP 1	80	12	7.8	0.69
AP 2	58.7	16.3	25	0.87
AP 3	10.4	22.7	66.7	2.91
B	60.4	17	22.5	1.17
BC	40.1	21.5	38.4	1.44
BC 1	80	10	10	1
BC 2	56.7	23.6	19.8	1.22
BC 3	15.3	18.5	66.3	1.77
BD	32.7	30.3	37.1	3.28
BD 1	70	20	10	3
BD 2	39.9	34.1	26	4.26
BD 3	27.8	27.8	44.4	2.62
BE	36.4	37.2	26.4	1.07
BE 1	84.5	6.1	10.4	0.2
BE 2	36.4	41.1	22.5	1.26
BE 3	18.8	35.7	45.4	0.68
BF	34.2	15.5	50.2	2.76
BF 1	82.2	10	8	2
BF 2	60	12	28	2.5
BF 3	22.3	16.9	60.7	3.22
BG	34.2	20.4	45.4	1.82
BG 1	78.9	8.2	12.4	0.9
BG 2	71.3	3.7	25	0.18
BG 3	6.9	30	63.1	2.68
BH	55.2	21	23.8	3.86
BH 1	82.5	6.1	11.6	0.95

BH 2	54.2	25.7	20.1	5.11
BH 3	35	35	30	3.45
BK	81.6	6.8	11.7	0.44
BK 1	88.2	4.2	7.7	0.26
BK 2	59.5	15.1	25.5	0.77
BK 3	10.3	40	49.7	0.84
BV	23.3	26	50.7	1.1
BV 1	35	25	40	1
BV 2	25	30	45	1.5
BV 3	23.3	26	50.7	1.1
BX	42.4	31.2	26.4	1.48
BX 1	75	20.6	4.5	1
BX 2	50	30	20	1.2
BX 3	26.2	36.5	37.4	1.48
C	42.9	27.6	29.5	1.52
CG	32	45	23	3.6
CG 1	80	10	10	3
CG 2	30	50	20	3.6
CG 3	42	22	36	3.6
CH	32.2	44.1	23.7	3.04
CH 1	80	10	10	2
CH 2	27.3	55.1	17.6	2.44
CH 3	42	22	36	2.89
CK	41.6	26.6	31.8	1.32
CK 1	80.5	8.6	11	1.01
CK 2	41.4	31.7	26.8	1.47
CK 3	16.1	26.8	57.1	1.17
CL	46.3	24.9	28.8	1.27
CL 1	79.7	4.4	16	0.72
CL 2	41.2	33.8	25	1.47
CL 3	39.9	17.3	42.9	1.22
D	40.2	50.3	9.6	1.09
DD	3	87.8	9.2	1.14
DD 1	70	18	12	1
DD 2	3	87.8	9.2	1.14
DD 3	45	15	40	1.5
DE	71.1	17.8	11.1	1.47
DE 1	71.1	17.8	11.1	1.47
DE 2	50	40	10	2
DE 3	45	15	40	2.2
DG	46.4	45.2	8.4	0.65
DG 1	70	20	10	2
DG 2	46.4	45.2	8.4	0.65
DG 3	50	15	35	2
E	48.5	30.8	20.7	1.74
E 1	70	10	20	0.9
E 2	50	25	25	1.96
E 3	30	35	30	2
F	35.7	16.3	48	1.93

FA	23.5	27.4	49.1	2.63
FA 1	83	5.3	11.7	0.62
FA 2	55	9	36	2
FA 3	13.6	31.1	55.3	3.03
FH	12.8	21.6	65.5	3.49
FH 1	80	6	14	3
FH 2	45	25	30	3.5
FH 3	13	20.9	66	3.64
FO	28.7	18.4	52.9	1.92
FO 1	79.1	7	13.9	0.65
FO 2	45.7	30.1	24.2	1.53
FO 3	15.7	16.5	67.8	2.21
FP	44.7	20.6	34.8	1.36
FP 1	80	6	14	1
FP 2	42	42	16	1.04
FP 3	57.7	5.8	36.5	1.69
FR	40.4	14.8	44.6	1.52
FR 1	80.7	4.1	14.6	0.65
FR 2	69.8	7.7	22.5	0.81
FR 3	23.9	18.9	57.2	1.84
FX	52.6	7.8	39.5	1.23
FX 1	79	5.8	14.8	0.81
FX 2	72.9	5.9	21.3	0.91
FX 3	8.6	8.9	82.4	1.73
G	32.9	23.7	43.4	2.02
GD	18.9	21.8	59.3	2.92
GD 1	80	5	15	2.3
GD 2	51.3	28.1	20.7	2.59
GD 3	11.8	20.5	67.7	2.96
GE	42.8	20.4	36.8	1.3
GE 1	82.1	6.5	11.4	0.81
GE 2	51	24.2	28.2	1.41
GE 3	25.5	23.1	51.3	1.35
GH	40.5	30.3	29.2	6.56
GH 1	80	5	15	5
GH 2	55.8	31.7	12.6	7.2
GH 3	25.2	29	45.9	5.27
GK	31.8	18	50.2	0.98
GK 1	80	5	15	1
GK 2	63.6	7.7	28.7	0.72
GK 3	25.6	21	53.4	1.04
GM	26.4	25.9	47.7	2.44
GM 1	81.5	8.2	10.4	0.77
GM 2	41.4	38.4	26.6	2.57
GM 3	20.5	25	54.5	2.54
GP	17.9	51.9	30.1	2.73
GP 1	40	50	10	2
GP 2	24.1	57.1	18.8	1.3
GP 3	8.6	44.1	47	4.88

GX	50	30	20	4.23
GX 1	80	5	15	2
GX 2	55	30	15	4
GX 3	25	30	45	4
H	37.3	25.7	37	1.57
HC	40.8	22.5	36.8	2.17
HC 1	75	15	10	2
HC 2	56.9	23	20.2	1.59
HC 3	8.5	21.5	70	3.33
HG	34.6	22.2	43.3	1.82
HG 1	83	6.6	10.3	0.7
HG 2	64.1	11.7	24.2	0.52
HG 3	13	29.5	57.6	2.72
HH	37.2	31.2	31.6	1.09
HH 1	75	20	5	1.5
HH 2	45.5	30.9	23.6	1.02
HH 3	20.7	31.9	47.5	1.28
HL	39.1	26.5	34.6	1.46
HL 1	75	15	10	1.5
HL 2	43.5	31.2	25.5	1.23
HL 3	33.2	20.2	46.6	1.8
I	58.9	16.2	24.9	0.97
I 1	75	15	10	0.31
I 2	65	15	20	1
I 3	55	15	30	2.3
J	55.8	22.2	22	1.32
JC	39.6	39.9	20.6	0.65
JC 1	68.9	16.7	14.4	0.28
JC 2	20.9	54	25.2	0.84
JC 3	10	50	40	0.9
JD	35.9	39.4	24.8	2.16
JD 1	79.5	13.5	7	1.31
JD 2	32.5	44.1	23.5	1.68
JD 3	2.3	51.3	46.5	4.47
JE	70.8	12.8	16.5	1.15
JE 1	80.1	8.6	11.4	0.76
JE 2	56.2	19.1	24.7	0.93
JE 3	21	36.9	42.2	2.61
JT	11.7	36.8	51.5	2.57
JT 1	50	30	20	2
JT 2	30	36.7	33.3	3
JT 3	5.8	34	60.2	2.57
K	39.1	37	23.9	1.93
KH	54.5	27.3	18.2	2.16
KH 1	80	10	10	1.2
KH 2	54.5	27.3	18.2	2.16
KH 3	40	20	40	2
KK	16.5	48.9	34.4	1.5
KK 1	80	15	5	1.5

KK 2	18.5	54.9	26.7	1.48
KK 3	12.5	37	50	1.55
KL	36.7	40.3	23.1	2
KL 1	80	5	15	1.6
KL 2	35.1	45.8	19	1.83
KL 3	41.4	23.5	35.2	1.73
L	70.4	10.3	19.3	0.51
LA	87.5	6.2	6.4	0.47
LA 1	90.1	4.5	5.3	0.28
LA 2	47.8	30.3	21.9	3.2
LA 3	50	25	25	1.5
LC	64.3	12.2	23.5	0.63
LC 1	80.2	7.7	12.1	0.3
LC 2	57.6	16.4	26.1	0.64
LC 3	29.2	13.6	57.3	1.51
LF	74.6	9.6	15.9	0.39
LF 1	82.2	7.3	10.5	0.37
LF 2	64.4	13.5	22.1	0.39
LF 3	26.9	19.1	54.1	0.54
LG	59.9	13.4	26.7	0.73
LG 1	81.7	6	12.3	0.45
LG 2	55.4	18.3	26.3	0.83
LG 3	42.4	12.7	44.9	0.85
LK	75.4	7.4	17.2	0.34
LK 1	84.3	5.1	10.6	0.26
LK 2	64	10.9	25.2	0.44
LK 3	46.7	14.8	38.6	0.49
LO	76	9.9	14.1	0.41
LO 1	87.1	4.2	8.7	0.33
LO 2	53.7	23.3	23	0.57
LO 3	43.5	13.4	43.1	0.66
LP	69.9	10.5	19.5	0.73
LP 1	74.8	11	14.2	0.55
LP 2	65.1	10.1	24.9	0.92
LP 3	45	10	45	1
LV	26.1	27.3	46.7	1.86
LV 1	55	20	25	1
LV 2	48.4	28.3	23.3	0.49
LV 3	23.8	28	48.4	2.55
M	37.9	35	27.1	3.23
MG	30	50	20	4
MG 1	75	15	10	3
MG 2	30	50	20	4
MG 3	40	20	40	4.5
MO	33.3	46.4	20.4	3.65
MO 1	75	15	10	3
MO 2	33.3	46.4	20.4	3.65
MO 3	40	20	40	4
N	57.9	13.3	28.9	1.12

ND	38.9	17.6	43.6	1.57
ND 1	85.1	7.3	7.7	1.04
ND 2	55	20	25	1.5
ND 3	15.8	22.7	61.6	1.64
NE	68.4	10.5	21.2	0.6
NE 1	81.8	5.9	12.3	0.34
NE 2	57.1	18.1	24.8	0.89
NE 3	22.8	21.2	55.9	1.33
NH	6.4	29.8	63.9	4.04
NH 1	80	8	12	2
NH 2	55	20	25	3
NH 3	6.4	29.8	63.9	4.01
O	35	40	25	46.33
OD	35	40	25	47.3
OD 1	70	20	10	50
OD 2	35	40	25	50
OD 3	10	45	45	50
OE	35	40	25	41.46
OE 1	70	20	10	40
OE 2	35	40	25	40
OE 3	10	45	45	40
OX	35	40	25	56.1
OX 1	70	20	10	55
OX 2	35	40	25	55
OX 3	10	45	45	55
P	69.5	23.9	6.7	3.86
PF	64.9	26.3	8.5	1.25
PF 1	94	3.3	2	0.6
PF 2	35.7	49.3	15	1.9
PF 3	43	40	17	2
PG	87.3	9.6	3.2	3.36
PG 1	87.3	12.3	3.2	3.36
PG 2	60	30	10	3.4
PG 3	43	40	17	3.4
PH	80.8	16.5	2.8	3.18
PH 1	96	3	1.1	1.11
PH 2	50.4	43.4	6.3	7.33
PH 3	43	40	17	5
PL	51.3	40.1	8.7	4.52
PL 1	90	9	1	3
PL 2	51.3	40.1	8.7	4.52
PL 3	43	40	17	3
PO	67.9	28.7	3.6	1.65
PO 1	91.4	8.2	0.8	0.44
PO 2	49	44	7	2.47
PO 3	43	40	17	2.5
PP	56.5	28.3	15.2	8.62
PP 1	98.6	1.1	0.3	0.94
PP 2	56.7	32.5	10.8	15.82

PP 3	22	38	40	1.88
Q	91.9	3.2	5	0.23
QA	92.6	3.6	3.7	0.87
QA 1	92.6	3.6	5.5	0.87
QA 2	93	3	4	1
QA 3	89	5	6	1.2
QB	92	3.1	4.9	0.21
QB 1	92	3.2	4.8	0.21
QB 2	89	3	8	1
QB 3	48.5	16	35.6	0.4
QF	91.7	3.3	5.1	0.27
QF 1	92	3	5	0.27
QF 2	90	3	7	0.5
QF 3	85	5	10	0.8
QL	92.8	2.7	4.7	0.2
QL 1	92.6	2.7	4.8	0.2
QL 2	87	3	10	0.8
QL 3	83	5	12	0.8
R	70.6	14.1	15.4	0.57
RC	63.5	19.2	17.3	0.76
RC 1	82.2	6.9	10.9	0.33
RC 2	38.7	35.5	25.8	0.58
RC 3	30	40	30	0.8
RD	82.1	6.7	11.3	0.27
RD 1	83	6.5	10.5	0.27
RD 2	40	37	23	0.5
RD 3	30	40	30	0.7
RE	68.3	15.1	16.6	0.5
RE 1	82.8	7.5	9.7	0.29
RE 2	38.7	36.9	24.6	0.82
RE 3	30	40	30	0.99
RX	82.5	9.9	7.7	1.7
RX 1	82.5	9.9	7.7	1.7
RX 2	40	37	23	2
RX 3	30	40	30	2.2
S	55.4	20.4	24.2	0.65
SG	53.9	25.5	20.6	0.67
SG 1	79.7	8.9	11.5	0.26
SG 2	35.4	44.9	19.5	0.5
SG 3	39.3	19.7	41	1.82
SM	51.7	31.9	16.4	1.14
SM 1	80	10	10	1.2
SM 2	55.4	25	19.6	1.14
SM 3	40	20	40	1.5
SO	57.6	13.5	29	0.39
SO 1	86.6	9.6	3.7	0.44
SO 2	59.5	16.4	24.4	0.4
SO 3	40.4	11.2	48.5	0.37
T	42.1	38.1	19.8	5.23

TH	41	41.3	17.7	7.03
TH 1	72.8	19.3	8	9.57
TH 2	34.3	49.5	16.2	6.97
TH 3	7.6	40.8	51.7	9.65
TM	31.2	39.6	29.2	3.95
TM 1	70	20	10	3.5
TM 2	38.5	44.5	17	4.35
TM 3	9.3	24.9	66	2.36
TO	38.2	36.6	25.2	3.02
TO 1	45	50	5	2.5
TO 2	43.5	41.1	15.5	3.31
TO 3	12	14	74	1.57
TV	64.5	26.2	9.3	1.4
TV 1	75.5	19.5	5	0.87
TV 2	42.5	39.7	18	2.3
TV 3	40	35	25	3
U	50.8	16.8	32.3	2.38
U 1	70	10	20	2
U 2	50.8	16.8	32.3	2.38
U 3	30	30	40	3
V	24.6	14.4	61	0.68
VC	22.4	24.5	53	0.69
VC 1	44	30	26	1
VC 2	43.7	28.6	27.3	1.43
VC 3	20.2	23.9	55.8	0.61
VP	25.1	12.2	62.7	0.68
VP 1	55	15	30	1
VP 2	53.2	15.9	31.1	0.76
VP 3	24.4	11.5	64.2	0.67
W	61.4	21.9	16.7	1.25
WD	19.8	55.2	24.8	4.27
WD 1	90	5	5	1.2
WD 2	28.5	61.5	9.8	1.5
WD 3	11.1	49	39.9	4.63
WE	76.6	10.3	13.1	0.46
WE 1	88.9	4.6	6.6	0.23
WE 2	52.1	24.4	23.5	1.06
WE 3	40.2	19.7	40.2	0.53
WH	60	10	30	2
WH 1	85	5	10	1.5
WH 2	65	10	25	2
WH 3	40	15	40	2.2
WM	21.1	56.8	22.2	2.02
WM 1	85	5	10	1.5
WM 2	21.1	56.8	22.2	2.02
WM 3	40	15	40	2.2
WS	69.1	16.7	14.3	0.72
WS 1	78.2	13	8.9	0.65
WS 2	50.3	25.3	24.4	0.87

WS 3	40	20	40	0.9
WX	65	10	25	2
WX 1	85	5	10	2
WX 2	65	10	25	2
WX 3	40	15	40	2
X	72.8	10.5	16.8	0.36
XH	54.8	20.6	24.9	0.53
XH 1	75.9	12.5	11.7	0.65
XH 2	55	21	24	0.5
XH 3	33.8	28.8	38.2	0.44
XK	48.7	29.9	21.6	0.64
XK 1	85.8	3.8	10.3	0.5
XK 2	20.5	57.9	21.8	0.67
XK 3	47.5	12.9	39.6	0.83
XL	76	8	16.1	0.32
XL 1	83.3	6.5	10.3	0.22
XL 2	66.7	10.8	22.7	0.39
XL 3	38.2	12.7	49.2	0.58
XY	64.6	21.1	14.4	0.38
XY 1	96.7	1.3	2	0.23
XY 2	32.4	40.9	26.7	0.52
XY 3	40	22	38	0.5
Y	49.2	26	24.8	0.33
YH	50.4	29	20.6	0.3
YH 1	75	12	13	0.3
YH 2	50.4	29	20.6	0.4
YH 3	35	27	38	0.4
YK	63.5	17.9	18.7	0.26
YK 1	82.4	10.4	7.6	0.12
YK 2	57.7	25.7	16.6	0.3
YK 3	31.4	25	43	0.5
YL	69.8	5.7	24.4	0.4
YL 1	80	6	14	0.35
YL 2	69.8	5.7	24.4	0.4
YL 3	35	12	53	0.4
YT	10	40	50	0.41
YT 1	50	25	25	0.3
YT 2	45	28	27	0.4
YT 3	9	35	56	0.4
YY	49	10.7	40.3	0.13
YY 1	96	3	1	0.13
YY 2	35	40	25	0.15
YY 3	2	18.3	79.5	0.12
Z	39.5	23.4	37.2	0.49
ZG	47.8	8.5	43.8	0.38
ZG 1	78.1	8.2	13.7	0.2
ZG 2	65.9	3.6	30.5	0.11
ZG 3	23.6	11	65.5	0.41
ZM	48.4	34.1	17.5	1.83

ZM 1	85	5	10	1.5
ZM 2	48.4	34.1	17.5	1.83
ZM 3	30	30	40	1.8
ZO	43.2	24.6	32.4	0.4
ZO 1	95.6	0.8	4.2	0.18
ZO 2	37.9	45.6	16.6	0.49
ZO 3	22.2	15.7	62.2	0.42
ZT	19.2	37.6	43.1	0.39
ZT 1	50	35	15	0.3
ZT 2	46.9	30.7	22.1	0.25
ZT 3	5.4	41.1	53.6	0.46