Sub watershed delineation, prioritization and preparation of sub watershed management plan of Lamjung District of Gandaki Province, Nepal

Submitted to:

Soil and Watershed Management Office, Tanahun

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July 2020

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FOREWORD

Soil, water and forests are principal natural resources of Nepal. Appropriate management of these resources can contribute in the overall development of the nation. Despite the paramount importance of such resources in the socio-economic development of the country, deterioration of the resources is omnipresent. Hence, management of these resources has been a major challenge in our Nepalese context.

Soil conservation and watershed management is one of the major program components of the Ministry of Forest and Environment(former Ministry of Forests and Soil Conservation). Before federal system, the Department of Soil Conservation and Watershed Management (DSCWM) was the mandated government agency under the ministry to carry out Soil Conservation and Watershed Management (SCWM) program and district level Soil Conservation Office was the implementing agency of SCWM activities in the district level. Now in the changing federal system of Nepal, the DSCWM and Department of Forests combined together and the named as Department of Forests and Soil Conservation. In provincial level, the implementing agency of SCWM program is Soil and Watershed Management Office(SWMO).

In order to meet the objectives of the SCWM program, the government has adopted policies and strategies in different periods. For the purpose, sub watershed area has been considered as planning and management unit for implementing integrated watershed management package programs that include vegetative, agronomic and water management measures.

Working areas of SWMO Tanahun are 6 districts {(Kaski, Tanahun, Lamjung, Manang, Gorkha and Nawalparasi (Bardaghat Susta Purba)} of Gandaki Province. The working districts fall mainly in High Himalayas to middle mountain areas and vulnerable Terai physiographic zone of the country where watershed condition is at marginal condition. Soil erosion and landslides are common problems in up-stream areas and floods with riverside cutting problems in down-stream area. Loss of human lives and properties has been very serious problem and big challenges. To address such problems, SWMO Tanahun has planned to focus its program at vulnerable sub watershed areas of the working districts. To implement the approved SCWM programs, the prioritization of sub watersheds of each individual district is must in this context. Sub watershed management planning is another very important part for effective implementation of approved SCWM program.

With the advent of modern technologies such as Geographic Information System and Remote Sensing, the prioritization of sub watersheds of Nawalparasi (Bardaghat Susta Purba) District has been carried out and management plan of the prioritized sub watershed areas have been prepared by using these tools. I would like to express my thanks to the consulting team of SMART Pvt. Ltd.

I also express my thanks to office staff particularly Soil Conservation Officer Bidurnath Sapkota, Chandra Prakash Sedai, Watershed Management Officer Shyamsundar Adhikari, Soil Conservation Assistant Umanga Baral, Administration Officer Shreekant Neupane, Accountant Kamal Bhattarai and all other staff of SWMO Tanahun for their help in the course of prioritization of sub watersheds and preparing the management plan of Bungadi_Dungre Sub Watershed of this district.

My sincere thanks goes to Honorable Minister Bikas Lamsal and Secretary Dr. Deepak Kumar Kharal for encouraging us to conduct this study with budgetary support. I would like to thank to Officer Tenth Narayan Acharya, Officer Eighth Shiva Pariyar and Officer Seventh Saroj Panthi of Planning Division of Ministry of Industry, Tourism, Forest and Environment (MOITFE) for planning and budgeting to conduct this study. Last but not the least, I would like to thank Province Forest Director Kedarnath Paudel and undersecretary Indra Prasad Adhikari for their generous support in preparing this plan.

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Date: 2077/3/25 **Soil and Watershed Management Office, Tanahun**

Abstract

Sub-watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken up for development. The watersheds need to be prioritized for taking up the developmental activity, based on the severity of the problems in the watershed. The study is conducted to prioritize the sub watersheds of Lamjung District ofGandaki Province, Nepal, to map the hazards of the district and to prepare the sub watershed management plan of most vulnerable sub watershed. The criteria for prioritizing the sub watershed is based on its biophysical and anthropogenic value. Biophysical value provides 60% weight and anthropogenic value provides 40% weight for the study. A total of 14 sub watershed are delineated in this district. Finally, sub watershed management plan of ChepeKhola 2 Sub Watershed was prepared. This sub watershed covers the 57 km^2 area of Rainas Municipalityof Lamjung District. Total NRs is 102750000 proposed for proper management of Chepe Khola Sub Watershed for five years.This sub watershed may be taken up with development and management plans to conserve natural resources on a sustainable basis with immediate effect, which will ultimately lead to soil and water conservation for benefit of people.

Keywords: Anthropogenic value,ArcGIS, bio-physical value, prioritization, management plan, sub watershed

1. INTRODUCTION

1.1. Background

A watershed is an area with a fixed drainage (water) divide as a boundary and drained through a common outlet of river/ creek or stream drained to a common place, such as lake or outlet. The term ' drainage basin' is commonly used in American literature to mean the watershed, but its British equivalent is 'catchment'. Watershed, catchment area, drainage area, river basin and drainage basin are terms that are generally used interchangeably and are defined as above. Although the difference between these words is probably not defined the first three terms – watershed, catchment area and drainage area - should be used comparatively for the small streams and rivers, whereas river basin or drainage basin is the aggregation of several watersheds, catchment area or drainage area (Sthapit, 1998). Watershed of small streams or small segment of the river is sub watershed. The area of sub watershed is varied according to the area of management units (countries, districts and so on).

Land, water and forest make major natural resources within a watershed. There are strong linkages between these natural resources. The use of one resource will have effects on another. Also, the peoples and their socio-economic and cultural behavior, external interests on the watershed resources, and policies on the use of these resources will have effects on these resources. Therefore, interactions among different factors such as population dynamics, livelihood systems, external interests, policies, norms and laws have to be considered in watershed management (FAO, 2006).

Soil conservation and watershed management activities have been widely acknowledged at field level but necessary data, technology, planning, and budget are felt insufficient. Moreover, the implementation part has been a challenge for the different political units in different aspects like lack of coordination, consideration of upstream-downstream linkages, partial and incomplete solutions of problems on the same river system and other socio-cultural issues at the field level. As water runs across different political boundaries, the best way to manage is to address the natural and hydrological units of the river basin by bringing together all the interests of upstream and downstream. However, previously implementation of soil and watershed conservation programs had been implemented within

the political units (districts) as working boundaries. That approach makes life difficult for the natural resource manager to bring coordination, cooperation and synergy of the conservation efforts among the upstream and downstream stakeholders.

Nepal is situated in the central part of the Himalaya (26022' - 30027' N, 80004' - 88012' E), covering an area of 1,47,181 km^2 and an elevation ranges from 67 m to 8848 m. Nepal has diverse climates due to the large variation in elevation. The climate varies from a humid tropical type in the tropical lowlands in the south to alpine cold semi-desert type in the trans-Himalayan zone (Ohsawa et al., 1986). Nepal's forest ecosystems can be categorized into 10 major groups based on climatic conditions: (1) tropical, (2) subtropical broad-leaved, (3) subtropical conifer, (4) lower temperate broad-leaved, (5) lower temperate mixed broad-leaved, (6) upper temperate broadleaved, (7) upper temperate mixed broadleaved, (8) temperate coniferous, (9) subalpine, and (10) alpine scrub (Stainton, 1972). The average annual rainfall is around 1000 – 2000 mm, but sometimes it exceeds 3000 mm in some lower parts of the country (Ichiyanagi et al., 2007). Nepal has a diverse geography that ranges from permanent snow and ice-covered very rugged Himalayan Mountains in the north to the tropical alluvial plains in the south. Due to variations in climate and topography, Nepal is classified into five physiographic zones (i.e., Terai, Siwalik, Middle Mountain, High Mountain and Himalaya) (BarnekowLillesø et al., 2005; Shrestha et al., 2010).

Gandaki is one province out of seven provinces of Nepal. This province is situated in the center part of Nepal by covering the 11 districts: Nawalpur, Tanahun, Gorkha, Lamjung, Kaski, Syanjya, Parbat, Baglung, Myagdi, Manang, and Mustang. Similarly, there are 85 local administrative bodies, Nepal's biggest Pokhara Metropolitan City, 26 Municipalities and 58 Rural Municipalities. There is a constitutional provision of 60 members including proportional to the state assembly (MoITFE, 2018). In the north-central part of Nepal, the Gandaki Province is spreading from Himal to Terai from north to south. Near the border of India, the lowest part near the Gandak canal of Narayani River is at the height of 93 meters above sea level. This height went up gradually to Dhaulagiri is a huge iceberg with 8,167 meters, Manasalu 8,163 meters, and Annapurna first 8,091 meters. In this state, only the high Himalayan mountain range has fallen to the middle of the country. The valley is situated in the upper part of Manang, Mustang,and Lamjung. Apart from this, the vast majority of natural areas like mountainous, wind, soil, environment, biological diversity, is in this province (MoITFE, 2018). This

province consists of five distinct geographical regions: Himalaya, High Mountains, Middle Mountains, Shiwaliks and Terai or Inner Madhes.

Around 37.1% area of the province is covered by forest. Major trees species of the province are *Shorearobusta, Dalbergiasissoo, Acacia catechu, Pinusroxburghii, Schimawallichii,* and *Castenopsisindica.* The major forest management models exercised in the provinces are community forest management, collaborative forest management, and block forest management. The scientific forest management program was launched in all these forests throughout the province. Chiraito, kutki, panchaule, lokta, ban lasun, satuwa, atis, nirmansi are major NTFPs of the province (MoITFE, 2018).

Gandaki Province is rich in protected areas. Around 45.68 % area of the Gandaki Province is covered by protected areas. Annapurna Conservation Area, Manaslu Conservation Area, some parts of Dhorpatan Hunting Reserve and Chitwan National Park are situated in this province. Annapurna Conservation area is famous for mountain trekking and unique landscape, Dhorpatan Hunting Reserve is popular for trophy hunting of blue sheep and Himalayan tahr. Similarly, Chitwan National Park is famous for rhino and tiger, and the Manaslu conservation area is famous for trekking, unique landscape, and mountain biodiversity (DNPWC, 2017; MoITFE, 2018).

Nepal is soil erosion vulnerable country due to its fragile topography and irregular rainfall pattern. The surface erosion rate on laterite slopes varied from 0.03 to 1.53 cm y−1 depending on land cover and slope gradient in the Mid Hill region of Nepal (Higaki et al., 2005). A recent study shows that soil erosion rates ranging from 0.03 to 100.33 t/ha/year in the hilly watershed of western Nepal. Abandoned terraces and degraded forests are major consequences of landslides (Gerrard and Gardner, 2002). In Nepal, intense rainfall and conventional tillage practices coupled with poor soil structure and steep slopes are the main drivers of soil erosion (Chalise et al., 2019). After the enforcement of the new constitution of Nepal in 2072, the responsibility for watershed management has been shared among local government, the provincial government and federal government and four basin management centers have been established by the federal government. Basin Management Centre, Gandaki is one among them; Then the Department of Soil Conservation and Watershed Management (now merged as Department of Forests and Soil Conservation) implemented various projects, programs and regular programs on watershed approach. The climate is dominated by the Indian summer monsoon system; about 80% of the precipitation falls between June and September (Panthi et al. 2015). During this season, heavy rainfall commonly leads to water-related disasters such as landslides in the hills, flash

floods in the Siwaliks, and riverine floods in the plains. The spatial distribution of precipitation varies across the zones creating microclimates that affect annual water availability. In the hills, springs are a major source of water and depend on annual rainfall to recharge the aquifers that feed them. The river discharge varies throughout the year influenced by both snowmelt and precipitation. The hydrograph of the Devghat stations in Chitwan District (below the confluence of the Kali Gandaki and Trishuli rivers) showed a seasonal variation in average monthly discharge in the period 1963–2010 ranging from 277 m^3/sec in March to 4,634 m^3/sec in August. The maximum daily discharge recorded was 14,100 m^3/sec on 05 August 1974. The daily values show a rise in discharge from May contributed by snow and glacier melt, followed by a further increase resulting from rainfall run-off from June onwards. Manandhar et al. (2012) observed a (statistically insignificant) increasing trend in the pre-monsoon and post-monsoon discharges and a decreasing trend in annual minimum discharge at Kotagaon station over the period 1964–2006.

Gandaki Province is vulnerable to soil erosion due to its sloppy topography and high rainfall around Pokhara Valley. Landslides, flash floods, river cuttings and gully erosion are major causes of human casualties and properties loss in this province. Due to the presence of bare and no vegetation land Mustang and Manang Districts are vulnerable to wind erosion. Apart from this haphazard rural road construction practices in rural and local areas increase soil and landslide in upstream areas and flash floods at downstream areas. It has been very big challenges and issues in natural disasters in these days in Nepal. To address these issues and challenges of soil erosion, landslides and floods, the sub watershed prioritization is a scientific way of selecting the most vulnerable among all watersheds of the district. Due to limited resources for conservation and management, prioritization should be conducted to identify the most vulnerable sub watershed. The managers should allocate more resources for these prioritized subs watersheds.

Delineation of sub watersheds within a large drainage basin and their prioritization is required for proper planning and management of available resources for sustainable development. Delineation of potential zones for implementation of conservation measures above the entire watershed at similar occurrence is inaccessible as well as uneconomical; therefore it is a prerequisite to apply the appropriate technique for prioritization of sub watersheds. Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management when managers have limited resources. Quantifying soil erosion hazard and spatial prioritization of

sub watersheds would aid in better watershed management planningand implementation of soil conservation and watershed management activity in the prioritized sub watershed.

1.2. Objective

The general objective of the study is to prioritize the subwatershed for management and conservation purpose. Specific objectives are as follows

- To identify the all subwatershed within the study area
- To find out the most vulnerable sub watershed and prioritize for the conservation and intensive management
- To map the water induced hazards in the LamjungDistrict

1.3. Rational

Increasing population has created intense pressure on agriculture and in turn our subsistence agriculture system is widely claiming the forest land. Quantitative and qualitative degradation of resources is due to our primitive farming system which practices unscientific land use and over exploitation. Here is an immediate need to plan an integrated approach so as to manage natural resources more scientific in a sustainable way. Scientific management tools with respect to certain bio-physical and socio-economic condition of any area is most needed to have an effective outcome of the applied economic and human resources. Hence the sub watershed prioritization and sub watershed management plan is hoped to be a key for the proper planning, management and utilization of the available natural resources towards a prosperous socio-economic as well as ecological condition of the selected sub watershed.

Bottom up approach in the development planning is adopted to make this sub watershed management plan. The available natural resources, socio-economic condition of the local people residing within the sub watershed area and other bio physical condition has been assessed by the study team. Local governments also demands the similar type of work in this site as this is very important to conserve this area. People ofRainas Municipality are dependent in resources of this sub watershed. However,

day by day the water sources are being degraded and getting polluted. The sub watershed area is exploiting in the name of development. After effective implementation of the plan, there will be easy supply of water and other natural resources to the surrounding area.

1.4. Scope and limitations

This study is conducted by the by SWMO, Tanahun (by the help of SMART Pvt. Ltd.) more focused on the problems related to water source degradation and their possible treatments within the ChepKhola 2 Sub Watershed area. This gives detail about the bio physical and socio-economic information of sub watershed area and recommends the scientific land use and watershed management activities according to its situation analysis. Intended output at the end year of the program implementation will be the sufficient and sustainable drinking water supply and the socio-economic condition of the local people will be uplifted and also their knowledge and attachment with natural resources conservation and management issues.

Biophysical and socioeconomic analysis of this study were based on secondary data generated by different organizations thus results may vary from the current situation as coverage of different land use has changed in recent time. Due to the limited financial resources, detail field verification was not possible which may have overshadowed few critical issues. However field issues and problems had been tried to address properly so that they can be incorporated in activities. More importantly this study has sufficient room to incorporate any advices and suggestions in coming days to make it more practical and creditable.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted in Lamjung District of Gandaki Province (**Figure 1**). The district covers an area of 1,692 km^2 and geographically located at 28°14′N latitude and 82°25′E longitude. Lamjung lies in the mid-hills of Nepal spanning tropical to trans-Himalayan geo-ecological belts, including the

geographical midpoint of the country. Gorkha District is in the east, Kaski is in the west, Manang District is in the North and Tanahun is in the south of Lamjung District. The district is full of rivers such as Marshyangdi, Chepe River along with other rivulets. Lamjung District consists of 7 climatic zones; upper tropical (300m to 1000m), subtropical (1000m to 2000m), temperate (2000m to 3000m), subalpine (3000m to 4000m), alpine (4000, to 5000m), Nival (above 5000m) and Trans-Himalayan (3000m to 6400m). The district consists of 8 Municipalities, out of which four are urban municipality and four are rural municipalities. Niramasi, Paakhanved, Panchaule, Chiraito, Jatamasi, Sarpagandha, Yarshagumba, Kutki, Sughandhawal are the most useful and valuable NTFPs.

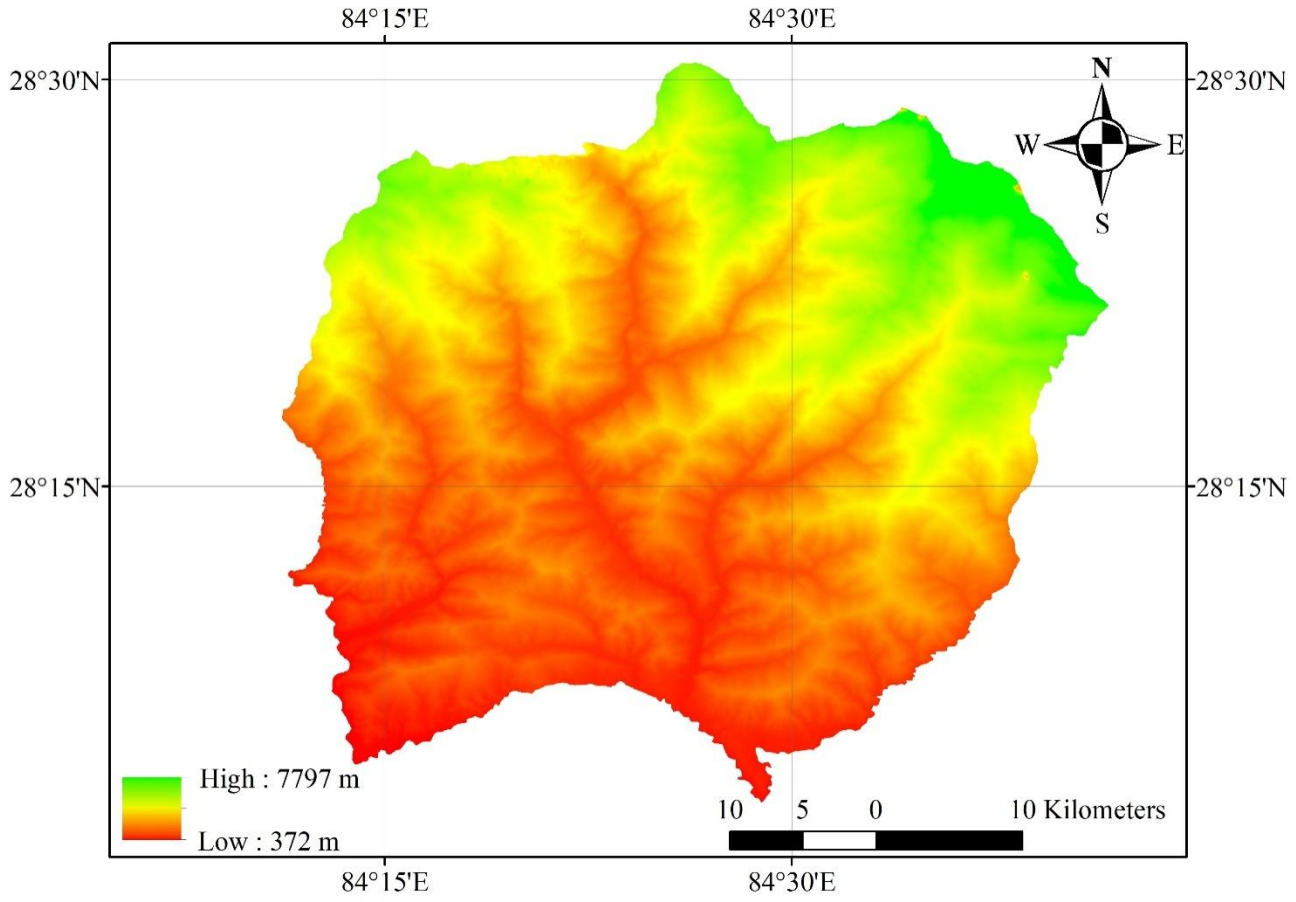

Figure 1: Study area with digital elevation model

2.2. Sub basin delineation

Subbasinswere delineated by the help of ArcGIS (ESRI, 2017). First of all, Digital Elevation Model (DEM) having 30 m spatial resolution was downloaded from USGS website (https://earthexplorer.usgs.gov/) (USGS/EarthExplorer, 2017). Subbasins were calculated by using

basin tool of ArcGIS (ESRI, 2017). Sub basin raster file was converted to the polygons and final subbasins were mapped.

2.3. Sub watershed delineation

Similar to the basin and sub basin delineation, sub watersheds were delineated using ArcGIS (ESRI, 2017). DEM file of district was refined by fill tool; then flow direction tool was used to prepare flow direction raster; flow accumulation tool was used to prepare the flow accumulation raster; raster calculator was used ("flow_accumulation_raster>5000") and give name "flow_accumulation_raster5000.tif to extract the streams where water come from more than 5000 pixels. After that, point shapefiles of pour point were created at outlet of the watershed; watershed tool of ArcGIS was used (use flow direction raster as input raster) to prepare the raster file of sub watershed. Finally, raster files were converted to polygons using raster to polygon tool. For large streams, segments of stream were delineated as sub watersheds. At the time of segmentation, areas of sub watersheds were balanced (try to make equal sizes of watershed within the district) and considered the local level (try to segment based on the boundary of the local level). Delineation process tried to inbound the watershed in a single local level (Metropolitan City, Municipality and Rural Municipality).

2.4. Sub watershed prioritization

Sub watersheds are prioritizing based on the morphometric characteristics of the sub watersheds (Abdul Rahaman et al., 2015; Arulbalaji and Padmalal, 2020), sediment yield (Adhami and Sadeghi, 2016), climatic, vegetation related, topographical and socio-economic data (Vittala et al., 2008). This study has followed the methodology suggested by Sthapit (1998) for sub watershed prioritization which includes the biophysical and anthropogenic characteristics. The study provided 60 % weight for the biophysical and 40 % weight for the anthropogenic characteristics. These two important characteristics are combined into comprehensive sub watershed priority values. Spatial analysis of prioritization was conducted in ArcGIS (ESRI, 2017). The steps involved are described below.

2.4.1. Bio-physical characteristics

Biophysical characteristics are the major characteristics that play a major role in soil erosion. The slope is a major factor to determine the severity of soil erosion. In high slope, the velocity of runoff and erosivity of water is also high. Similarly, the vegetation cover is also a key factor to determine the erosion potentiality of the area. High vegetation cover can reduce soil erosion than low vegetation cover.

Step I Preparation of land use erosion potential (LUEP) map

As suggested by Sthapit (1998), land use erosion potential (LUEP) map is prepared by marking high, moderate, and low erosion potential areas. The alphabetic symbols H or M or L are given to indicate high, moderate and low erosion potentials. Slope more than 30° is considered as high, slope between 5° to 30° is considered as medium and slope less than 5° is conserved as low erosion potentials. Slope map of Lamjung District is shown in **Figure 2**.

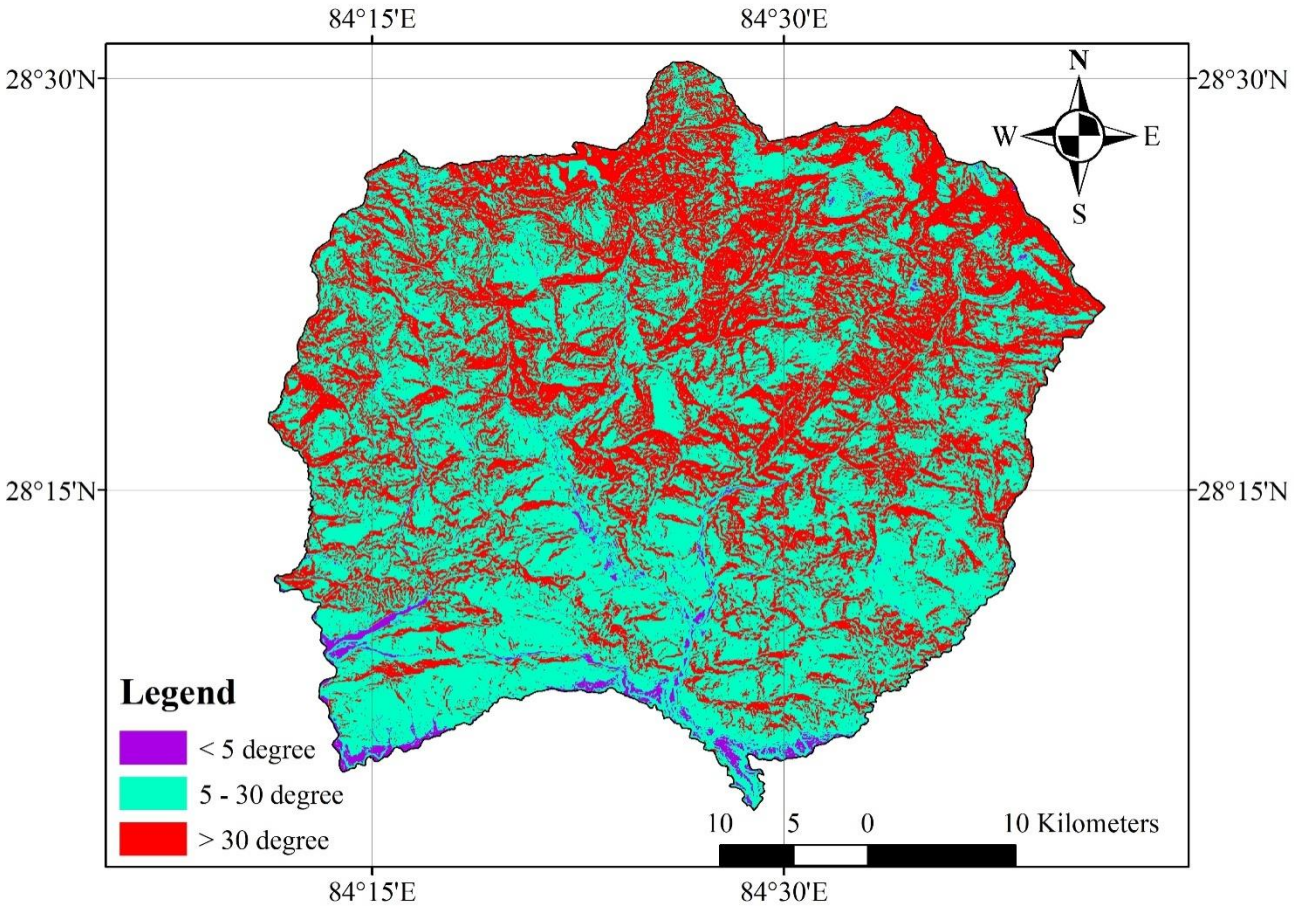

Figure 2: Slope of the Lamjung District

Step II. Preparation of land system erosion potential (LSEP)

As suggested by Sthapit (1998), land system erosion potential (LSEP) map is prepared by marking high, moderate and low erosion potential areas. The alphabetic symbol h or m or l, are given to indicate high, moderate and low erosion potentials. Agricultural land, bare land and riverside were considered as high; open forest, shrubland, grassland and lake were considered as medium and close forest, built-up area, snow and glacier were conserved as low erosion potentials. Land use / land cove maps of this district is shown in **Figure 3**.

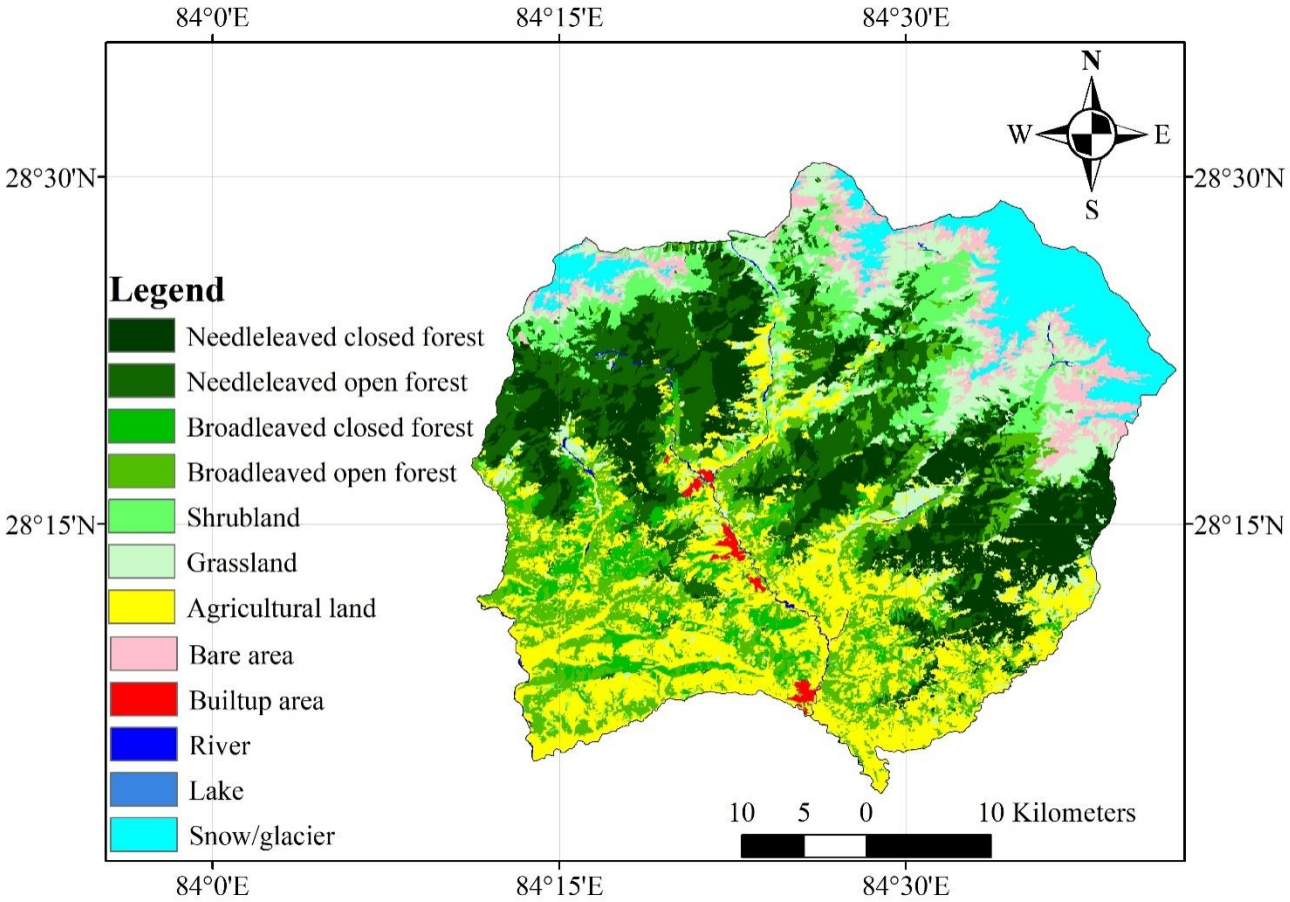

Figure 3: Land use/land cover of Lamjung District

Step III Preparation of erosion potential composite (EPC) map

An erosion potential composite (EPC) map is prepared by overlaying the land use erosion potential (LUEP) map on the land system erosion potential (LSEP) map. The common areas are overlapped by LUEP and LSEP was marked. These overlapped areas are given double letter symbols taken from LUEP and LSEP. The symbols always start from the LUEP map. For example, when LUEP is M and LSEP is l, the symbol given on the EPC map is Ml.

The double letter symbols of the composite map are converted into single letters to indicate very high, high, moderate, low and very low land use land system erosion potentials (LULSEP). The final indication of very high, high, moderate, low and very low erosion potentials are made using the following conversion table.

Single letter symbol of LULSEP	**Double letter symbol of LULSEP**
Very high (H)	Hh
High (h)	Hm, Mh
Moderate (M)	Hl, Mm, Lh
Low (L)	Lm, Ml
Very low (l)	Ll

Step V Calculation of very high, high, moderate, low, very low erosion potential areas

The composite map (explained in Step IV) and the sub watershed map (explained in Step I) are overlaid. The very high, high, moderate, low and very low LULSEP areas for each sub watershed were calculated by the help of ArcGIS (ESRI, 2017).

Step IV Estimation of land use land system erosion potential value (LULSEPV)

Very high, high, moderate, low and very low LULSEP areas are given 8,6,4,2 and 1 numerical values to enable quantitative comparison of sub watersheds. The erosion severity for each sub watershed

called the land use land system erosion potential value (LULSEPV) based on biophysical parameters is calculated in numerical terms using the following equation.

LULSEPV = {(Very high area* 8) + (high area*6) + (moderate area*4) + (low area*2) + (very low area*1)}/Total area of the sub watershed

Step V Estimation of sub watershed biophysical value (SWSBPV)

Biophysical and population parameters are combined in finalizing the sub watershed prioritization. Biophysical and population parameters are given 60% and 40% weight in the prioritization. 1 is the least possible LULSEPV reflecting null priority in adopting soil conservation and watershed management measures. Similarly, sub watershed with highest LULSEPV carries the greatest weight, i.e. 60. For prioritization of the sub watershed, the estimated LULSEPV is calibrated in a 0 to 60 scale starting from 1 as the highest value using the following equation where LULSEPV is the land use land system erosion potential value of the sub watershed derived in Step IV.

SWSBPV = (LULSEPV – 1) / (Highest LULSEPV -1)*60

2.4.2. Anthropogenic characteristics

Resource degradation caused by ecological phenomena in the Nepalese hills is thought to be beyond the control of soil conservation and watershed management measures on financial an economical grounds. Therefore, resource degradation triggered by human activities is the main concern of watershed management professionals. In the rural context, with very little off-farm economic activity, most people depend for their livelihood on existing watershed resources such as land, water, vegetation and livestock. The increasing population exerts pressure on these resources and accelerates watershed degradation. In similar watersheds, the needs of the people and their practices play a significant role in the magnitude of the degradation. Practices are governed by complicated multiple socio-economic factors that require specific study.

A simplified version of existing practices is reflected in the land utilization map that is incorporated in the LULSEPV. The population pressure, which not only plays a dominant role in human-induced watershed degradation but also causes changes in practices, requires attention in sub watershed prioritization. Two similar watersheds with different populations will naturally have different degradation rates. A heavily populated watershed will have more pressure on resources as compared to a lightly populated one. Nepalese soil conservation professionals accept this fact but so far it has

not been included in the prioritization process. The method below incorporates population density as an indication of pressure on resources into sub watershed prioritization.

Sthapit (1998) considered only population characteristics during the prioritization. Recently, rural roads are identified as major drivers of soil erosion. Similarly, livestock density is also identified as a major cause of soil erosion. Therefore, this study allocates 20 points for population density, 10 points for road density and 10 points for the livestock density during the sub watershed prioritization.

Step I Estimation of population density (PD), road network density (RD) and livestock density (LD) for each sub watershed

The population densities (latest CBS data) of the local level are used for evaluating sub watershed wise population densities. To transfer these population densities of local level on to the sub watersheds, the boundaries of the local level district sub watershed were intersected. Then the average population density of the watershed is estimated using a weighted average method.

Road networks were downloaded from the website of Geofabrik website (https://www.geofabrik.de/data/shapefiles.html). This shapefile and sub watersheds were intersected and the total length of the road was calculated. Finally, road network densities (m/km^2) of all watersheds were calculated with the help of ArcGIS (ESRI, 2017).

Raster file of livestock (cattle, goat, and sheep) density was obtained from the Center for Earth Observation and Citizen Science (see https://www.geo-wiki.org) (Robinson et al., 2014). That raster file was converted into a polygon using "rater to polygon" tool of ArcGIS (ESRI, 2017). Boundaries of sub watersheds and shapefile of livestock density were intersected. Then the average livestock density of the watershed is estimated using a weighted average method.

Step II Estimation of average population density (APD), average road network density (ARD) and average livestock density (ALD) of the district

The average population density (APD) of the district is estimated by dividing the total population by the total area of the district.

APD = Total population of the district/ Area

The average road network density (ARD) of the district is estimated by dividing the total length of road by the total area of the district.

ARD = Total length of the road of the district/ Area

The average livestock density (LPD) of the district is estimated by the help of a weighted average of livestock density of the district.

ALD = Total sum of (Livestock density X Area of that patch/Total population of the district)

Step III Estimation of sub watershed population density numerical value (SWSPDNV), sub watershed road density numerical value (SWSRDNV), and sub watershed livestock density numerical value (SWSLDNV)

In cases where the highest population density differs too much from the densities of the rest of the sub watersheds, the highest density of a more representative watershed is considered as the highest population density (HPD). The population density is very highly influenced by market places or municipal areas. This population is often not entirely dependent on the watershed resources for its livelihood.

Anthropogenic characteristics carry a 40% weight in the sub watershed prioritization. In order to simplify the calculation, the following equations are used in estimating the sub watershed population density numerical value (SWSPDNV), sub watershed road network density numerical value (SWSRDNV), sub watershed livestock density numerical value (SWSLDNV),

When the population density of the sub watershed is less than the average population density of the district,

SWSPDNV = PD/APD*10

Where PD = Population density of the sub watershed and APD = Average Population density of the district.

When the population density of the sub watershed is higher than the average population density of the district,

SWSPDNV = (PD-APD)/ (HPD-APD)*10+10

Where PD = Population density of the sub watershed, HPD = Highest population density of the sub watershed in the district and APD = Average population density of the district.

Step IV Estimation sub watershed road network density numerical value (SWSRDNV)

When the road network density of the sub watershed is less than the average road network density of the district,

SWSRDNV = RD/ARD*5

Where RD = Road network density of the sub watershed and ARD = Average road network density of the district.

When the road network density of the sub watershed is higher than the average road network density of the district,

SWSRDNV = (RD-ARD)/ (HRD-ARD)*5+5

Where RD = Road network density of the sub watershed, HRD = Highest road network density of the sub watershed in the district and ARD = Average road network density of the district.

Step V Estimation sub watershed livestock density numerical value (SWSLDNV)

When the livestock density of the sub watershed is less than the average livestock density of the district,

SWSLDNV = LD/ALD*5

Where LD = Livestock density of the sub watershed and ALD = Average livestock density of the district.

When the livestock density of the sub watershed is higher than the average livestock density of the district,

SWSLDNV = (LD-ALD)/ (HLD-ALD)*5+5

Where LD = Livestock density of the sub watershed, HLD = Highest livestock density of the sub watershed in the district and ALD = Average livestock density of the district.

Combining biophysical and anthropogenic characteristics

The biophysical and population characteristics are combined together on the same numerical scale for finalizing the priority ranking.

Step I Estimation of sub watershed priority cumulative value (SWSPCV)

The SWSBPV, SWSPDNV, SWSRDNV, SWSLDNV are added together to estimate sub watershed priority cumulative value (SWSPCV).

SWSPCV = SWSBPV + SWSPDNV + SWSRDNV + SWSLDNV

Step II Priority ranking

The sub watershed priority ranking is based on the SWSPCV. The values are arranged in descending order for prioritization ranking. Priority is given to the sub watershed with the highest SWSPCV.

2.5. Hazard mapping

Most serious climate induces hazards are flood and landslide. This study identified the flood and landslide risk zone of the district. Identified risk zones are vulnerable to the hazards. These regions are recommended for the intensive management to save lives and environment.

2.5.1. Data collection

2.5.1.1 Primary data collection

First of all, discussion with government officials and other stakeholders were conducted in all 6 districts of the study area identify the potential risk zone and locations of hazards. Then study team visited and identified locations for collection of GPS points for modeling and mapping. The team also recorded other information likes photos, type of hazards, condition of hazards, affected population, and impact of hazards, land use types and possible remedy measures.

2.5.1.2 Secondary data collection

GPS locations of floods and landslides were also collected from secondary sources such as pervious study reports, reports prepared by governments and academic institutions. Some points of floods and landslides were collected by the help of Google earth.

2.5.1.3 Environmental variables

The environmental variables were downloaded from freely available sources (**Table 1**) and pre-processed in ArcGIS (ESRI, 2017) to make appropriate format (ASCII) and same spatial resolution (30 m). Some variables with vector features (i.e. point and line) were also converted into raster format having the same resolution (30 m). The environmental variables were divided into four categories as follows.

Table 1: Environmental variables used for the study

Category	Variables	Source	Unit
Topographic	Aspect	USGS	degree
	Elevation		m
	Slope		degree
	Distance to water	Geofabrik	km
Climatic	Mean precipitation	WorldClim	cm
	Mean temperature		degree
	Mean solar radiation		
Vegetation Related	Mean EVI	MODIS	dimension less
	Forest	Global forest change	dimension less
Anthropogenic	Land use land cover	ICIMOD	type
	Distance to road	Geofabrik	km
	Distance to path		km
	Distance to settlement	Department of survey, Nepal	km

Topographical variables

Topographical variables have been widely used for species habitat modeling for 20 years (Osborne et al., 2001). These variables were also used for mapping of disasters because aspect, elevation and slope are directly related to types of disasters. For this study, Digital Elevation Model (DEM) of 30 m resolution was downloaded from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/), and aspect and slope were computed from the DEM using ArcGIS software (ESRI, 2017).

Climatic variables

Driving force of the most of hazards are climatic variables. Temperature, precipitation and solar radiation are directly related to the disasters like fire, flood and landslide. Therefore, this study use climatic variable as input of the model. Climatic variables were downloaded from the WorldClim database (http://worldclim.org/). The WorldClim database (version 2) is a set of global climate layers that derived from over 4000 weather stations between 1950 and 2000, including annual time series with annual means, seasonality, and extreme or limiting temperature and precipitation data (Hijmans et al., 2005). In this study, average of temperature, precipitation and solar radiation were used as input of the model (**Table 1**).

Vegetation-related variables

Vegetation-related variables are responsible for accelerate or mitigate the disaster. For example, vegetation may be favorable for the fire but unfavorable for the landslide. In this study, forest cover and mean of Enhanced Vegetation Index (EVI) were used as model input.

Forest cover data prepared by Hansen et al. (2013)was downloaded from the Global Forest Change (GFC) website was used as a variable. EVI time series data from 2015, 2016, and 2017 from USGS computed from images obtained by Moderate Resolution Imaging Spectroradiometer (MODIS) was smoothed by using an adaptive Savitzky-Golay filter in the TIMESAT program (Jönsson and Eklundh, 2004) to reduce the cloud effect. Finally mean EVI was calculated and used for the modeling.

Anthropogenic variables

The triggering factors of most of the natural hazards are human activities. Now a days, roads and paths are being major causes of landslide. Therefore anthropogenic variables were incorporated into the

models. Anthropogenic variables included were distance to human paths and roads, distance to settlements, and land use land cover. Location of paths and roads was obtained from shapefile available on the Geofabrik website (https://www.geofabrik.de/data/shapefiles.html). Settlement locations were obtained from the Department of Survey, Nepal. Distance raster files of paths, roads and settlements were created by using ArcGIS (ESRI, 2017). Land use land cover data were downloaded from the International Centre for Integrated Mountain Development website (ICIMOD; http://www.icimod.org) (Uddin et al., 2015) and incorporated into the model.

2.5.2. Modeling

Maximun Entropy (MaxEnt) is a software program used to model species distributions by using geo-referenced occurrence data and environmental variables to predict suitable habitat for a species (Phillips et al., 2006). This model is successfully used for disaster risk modeling also. Variables listed in **Table 1** were incorporatedinto MaxEnt (version 3.4.1) along with occurrence data of hazards to determine potential disaster risk zone. We selected ten 1000 maximum iterations and 10 replicates during modeling (Barbet-Massin et al., 2012). We used 70 percent of data to train and rest to validate the model. The maximum sum of sensitivity and specificity (MaxSSS) threshold is appropriate to convert the continuous probability map to binary map when only presence data are available from the field (Liu et al., 2013). Therefore, this threshold was used to produce the risk flood and landslide risk of the study area.

For environmental modeling, wide range of models (e.g. BIOCLIM, BRT, DOMAIN, GARP, GLM, and MaxEnt) has been developed to cover aspects as diverse as climate change, biogeography, biology, spatial ecology and habitat management. These models have been used to predict the distribution of plants, and animals (Gillespie and Walter, 2001; Guisan et al., 1998; Pearce and Ferrier, 2000; Phillips et al., 2006). These species distribution models are also using to predict the risk of landslides (Goetz et al., 2011), fires (Renard et al., 2012), accidents (Maher and Summersgill, 1996) and diseases (Murray et al., 2011). Due to the chance of not occurring the hazards due other causes like human protection and other environmental causes like protection of forests to prevent the flood and landslides, researcher's field visit, the recording of the true absence data points is a challenging task during the study. Moreover, collection of large number of data for hazards is also another challenge in research.

Therefore model which needs only presence data from the field is becoming more popular among the species distribution models. In this scenario MaxEnt needs only presence data for the modeling (Phillips et al., 2006). Therefore, this study used MaxEntsoftware to model the hazards of the district.

2.6. Preparation of management plan

2.6.1. Data collection

2.6.1.1. Primary data sources

Household survey

Socio-economic, demographic and other necessary information were collected from the household survey. Randomly selected houses within the sub watershed area were used for the purpose of data collection.

PRA and RRA

Focused group discussion was conducted to obtain information about sub watershed. PRA and RRA were done to extract important information about sub watershed, its condition and issues with local community. In addition, key informants like local leaders, elected representatives of rural municipality, teachers, and social workers were consulted for information, suggestions regarding the procedure and activity of planning and also for verification of collected data.

Field observation

During the visit to the sub watershed areas different field observations were made by the office staffs to identify the type and severity of the problems. Problems related to the water sources like construction of road, haphazard cultivation, slash burn and other forest related issues were studied, and photographed.

Local body profile survey

In order to generate information on local level institutions, status of development infrastructures and others, municipality and ward profile survey were carried out.

2.6.1.2. Secondary data sources

District profiles of district and the available profiles of rural municipality, population census reports, operational plan of community forest user group, and annual reports of SWMO were reviewed during the preparation of the plan. Both published and unpublished literatures, reports and other related documents were considered as the important tools of the information collection. The necessary digital data were used of planning. DEM was downloaded from website of USGS website (https://earthexplorer.usgs.gov/)and slope and aspect were calculated by the help of ArcGIS(ESRI, 2017).

2.6.2. Data analysis

Following steps were followed for problem identification in urban watershed.

Step 1: GISsoftware followed by Google Earth were used to delineate a sub watershed area for conservation of water sources in the long run.

Step 2: Thematic layers were gathered from ICIMOD and DEM from USGS website for slope, aspect, altitude variation, LULC.

Step 3: Problems identified from field survey was analyzed and appropriate activities was recommended to overcome the issues.

3. RESULTS AND DISCUSSION

3.1. Subbasins of Gandaki Province

This study identified and delineated four subbasins in the Gandaki Province (**Figure 4**). Largest sub basin is the KaligadakiSub Basin whereas smallest sub basin is BudhiGandakiSub Basin. Some parts of the province are not covered by these four sub basins. Area of Dhorpatan Hunting Reserve (Western part of the Province) is watershed of Karnali Basin and rest area is watershed of Gandaki Basin.

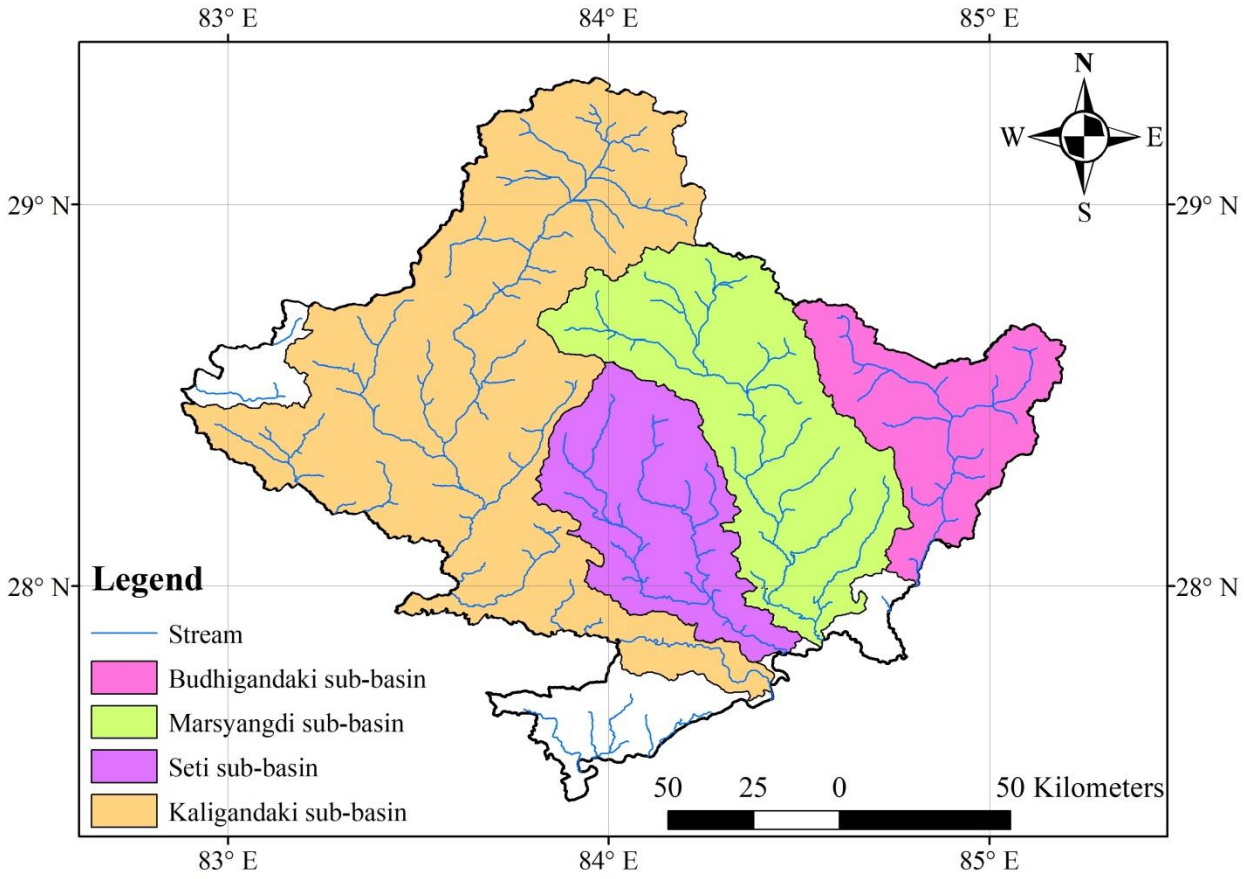

Figure 4: Sub basins of Gandaki Province

If only Lamjung District is considered as working unit, the study identified three sub basins: Chepe, Marsyangdi and Midim (**Figure 5**).

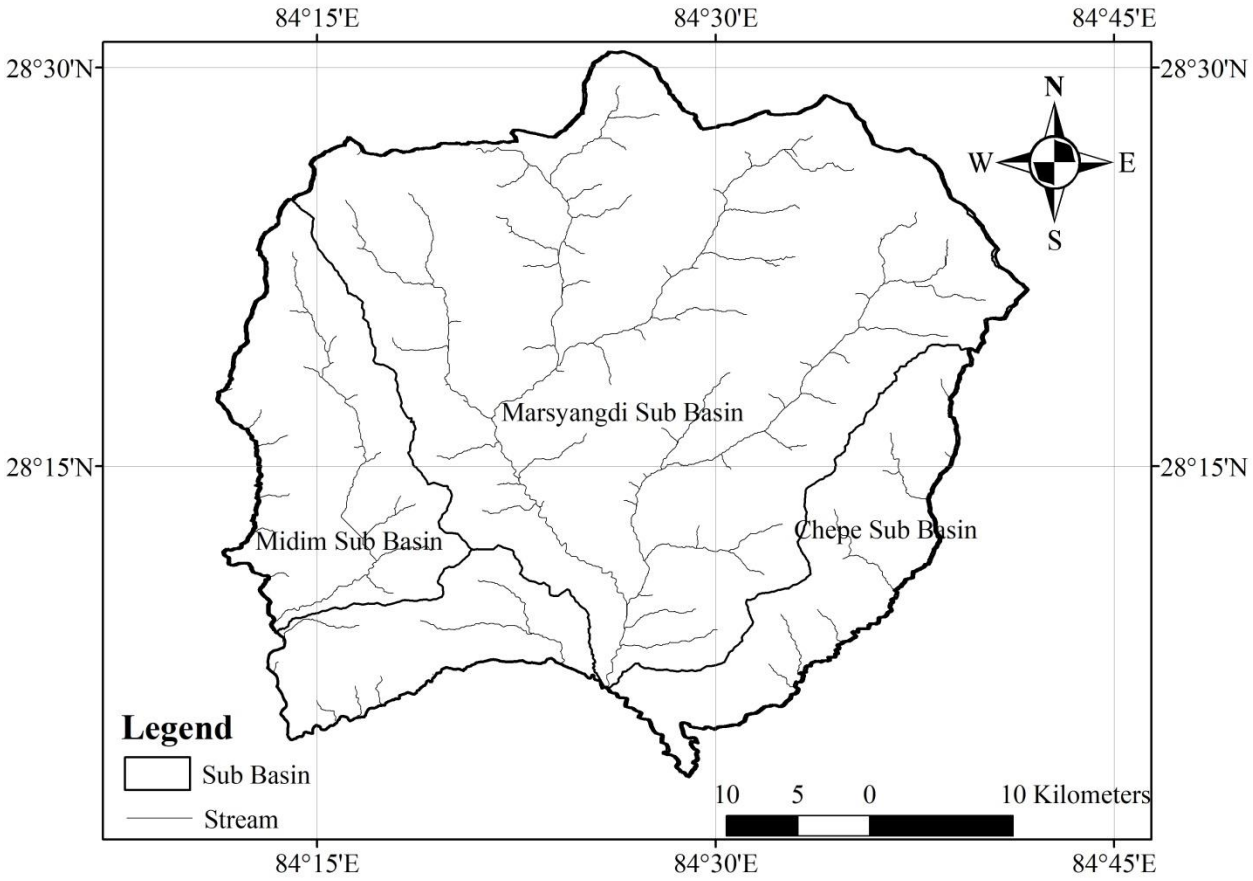

Figure 5: Sub basins of Lamjung District

3.2. Sub watersheds of district

A total of 14 sub watersheds are delineated in the Lamjung District (**Figure 6**). The range of the sub watershed is 220 km^2 to 48 km^2. The largest sub-watershed is NadiKhola and smallest is MarsyangdiNadi 2(**Table 2**).

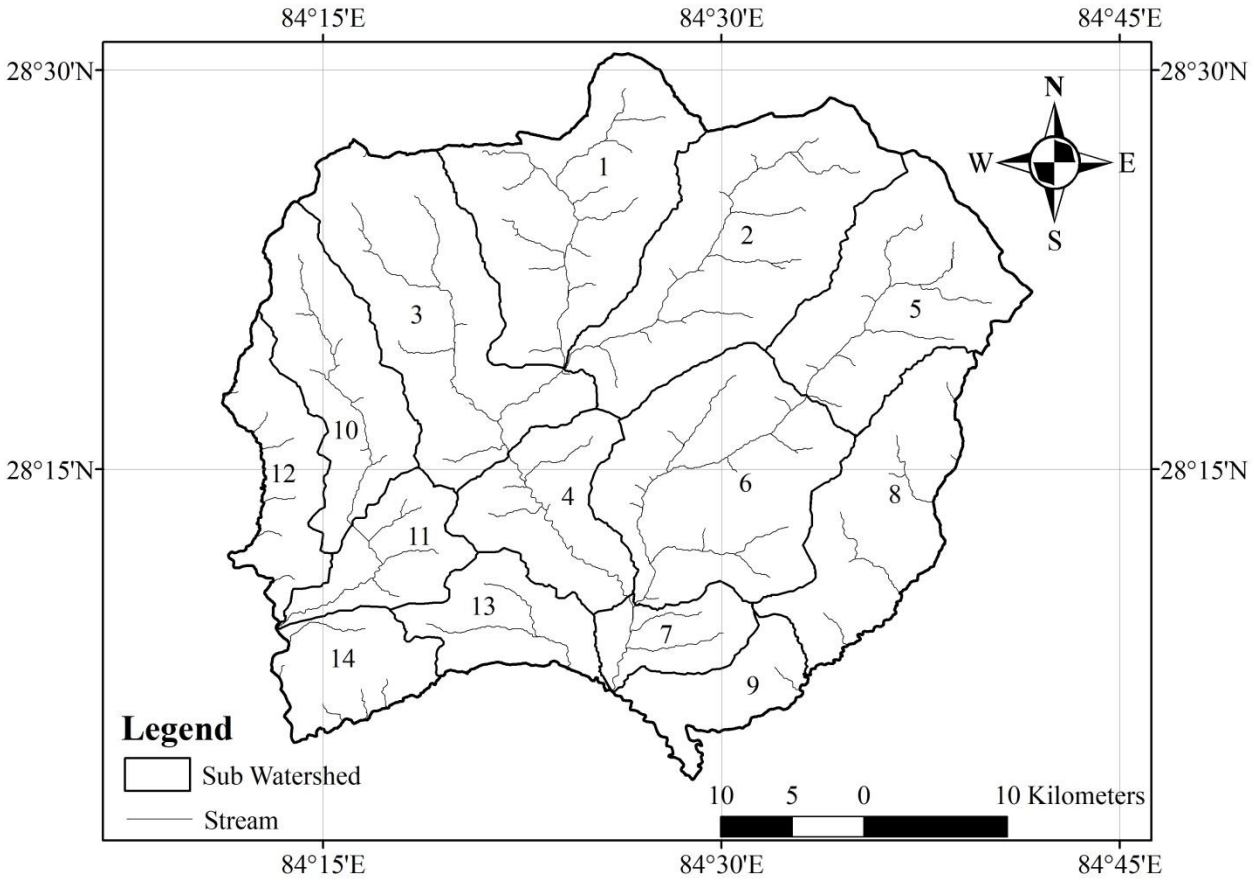

Figure 6: Sub watersheds of Lamjung District

Table 2: Sub watersheds of Lamjung

S.N.	Name of sub watershed	Area (km^2)	Corresponding local level
1	MyarsangdiNadi 1	192	Myarsangdi Rural Municipality
2	NadiKhola	220	Myarsangdi Rural Municipality
3	KhudiMarsyangdi	198	Myarsangdi Rural Municipality
4	MyarsangdiNadi 3	94	Besishahar Municipality
5	DordiKhola 1	158	Dordi Rural Municipality
6	DordiKhola 2	200	Dordi Rural Municipality

7	MyarsangdiNadi 3	48	Dordi and DudhPokhari Rural Municipality, Rainas and Sundarbazar Municipality
8	ChepeKhola 1	135	DudhPokhari Rural Municipality
9	ChepeKhola 2	57	Rainas Municipality
10	MidimKhola 1	116	Kwholasothar Rural Municipality
11	MidimKhola 2	66	Kwholasothar Rural Municipality Besishahar, Madhya Nepal and Sundarbazar Municipality
12	Rudi Khola	73	Kwholasothar Rural Municipality
13	PaudiKhola	69	Sundarbazar Municipality
14	ThudiKhola	66	Madhya Nepal Municipality

3.3. Prioritized sub watersheds

ChepeKhola 2 sub watershed is top prioritized sub watershed of the Lamjung District with an area of 57 km^2. This sub watershed located atRainas Municipality. Similarly, PaudiKholais the second prioritized sub watershed of the district and located at SundarbazarMunicipality (**Table 3**).

Table 3: Sub watershed prioritization of Lamjung

3.4. Hazards of district

3.4.1. Flood / river cutting risk

The water is an only flood causing agent. The study found that flood risk is higher near to the water resources. In favorable condition, water automatically creates the flooding. Lands within one kilometer from water body are highly susceptible to flooding. Generally, area two kilometer far from the water body is safe from flooding in normal condition. Normally the flooding occurs in flat land. This study

S.N.	Name of sub watershed	Area (km^2)	Corresponding local level	Bio Physical value {SWSBPV (LULSEPV-1)/(HighestLULSEPV-1)*60}	Anthropogenic value (Population Density+ Livestock Density +Road Network Density)	Total value	Rank
9	ChepeKhola 2	57	Rainas Municipality (ward: 1, 2, 3, 4, 5, 6, 7, 8, 10)	60.00	36.09	96.09	1
13	PaudiKhola	69	Sundarbazar Municipality	55.31	39.18	94.49	2
4	MyarsangdiNadi 3	94	Besishahar Municipality	53.68	33.10	86.78	3
14	ThudiKhola	66	Madhya Nepal Municipality	55.00	31.01	86.01	4
7	MyarsangdiNadi 3	48	Dordi and DudhPokhari Rural Municipality, Rainas and Sundarbazar Municipality	55.55	30.29	85.84	5
12	Rudi Khola	73	Kwholasothar Rural Municipality	53.59	27.01	80.60	6
11	MidimKhola 2	66	Kwholasothar Rural Municipality Besishahar, Madhya Nepal	53.82	26.34	80.16	7

			and Sundarbazar Municipality				
6	DordiKhola2	200	Dordi Rural Municipality	47.74	20.65	68.39	8
1	MyarsangdiNadi 1	192	Myarsangdi Rural Municipality	53.83	10.87	64.70	9
8	ChepeKhola 1	135	DudhPokhari Rural Municipality	42.40	21.92	64.32	10
3	KhudiMarsyangdi	198	Myarsangdi Rural Municipality	48.76	15.06	63.82	11
10	MidimKhola 1	116	Kwholasothar Rural Municipality	45.44	15.30	60.74	12
5	DordiKhola 1	158	Dordi Rural Municipality	49.13	10.00	59.14	13
2	NadiKhola	220	Myarsangdi Rural Municipality	51.20	7.93	59.13	14

also identified that flat land has risk of flood. Area having slope less than 10 degree is susceptible to high flood risk. In flat land water can't drain immediately so land can face the flooding. Lands more than 30 degree slope are safe from the flooding.

At the national level, the Department of Hydrology and Meteorology (DHM), under the Ministry of Science Technology and Environment (MoSTE), is mandated to monitor all hydrological and meteorological activities in Nepal. DHM collects hydrological, meteorological, and climate information and disseminates it to a variety of stakeholders for water resources, agriculture, energy, and other development activities (www.dhm.gov.np). In Gandaki Province, DHM has 15 existing river monitoring stations. The stations are regularly monitored and the information is collected centrally at the DHM office. Most of the hydro-meteorological stations are manually operated, while some have been upgraded to automatic stations, able to continuously monitor flood parameters such as rainfall and water level around the clock and to transmit the data in real time. A number of flood early warning

systems have also been put in place to forewarn communities of approaching flood disasters. Flood risk area of district is shown in **Figure 7**.

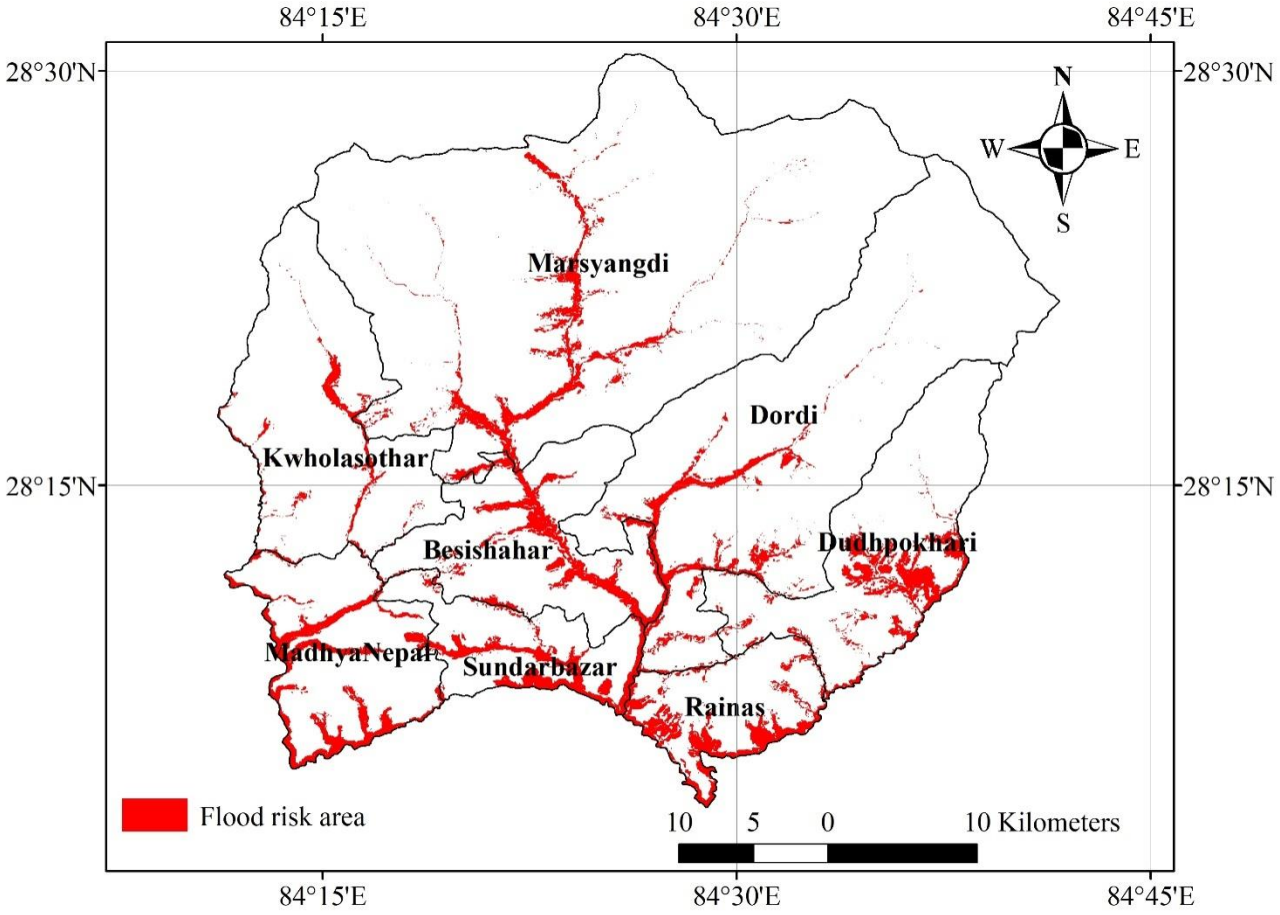

Figure 7: Flood risk in Lamjung District

Due to lots of rivers,Lamjungis flood/river cutting prone district of the Gandaki Province. Area along the Myarsangdi, Dordi, Chepe, Paudi and Midimare more flood prone area of this district (**Figure 7**). Details of flood prone area of this district is shown in **Table 4**.

Table 4: Flood risk area of Lamjung

Rural Municipality (RM)/ Municipality	Ward	Location of Flood	River/stream
Sundarbazar Municipality	4	Satrasayahal	Paudi/KilincheKhola
	5,6	Khatrithanti	Paudi/KhahareKhola
	7	Paudidhik	Marsyangdi/Paudi
Besishahar Municipality	6,7	Sahaji	Puma Khola
	11	Bazar Khutta	DhwangKhola
Dordi	3,4	Sera	Dhodi/KaisediKhola
	6	Dhodeni	DordiKhola
Marsyangdi RM	3	Khudibazar	Marsyangdi/KhudiKhola
	4	Ram Bazar	Marsyangdi/Raidu
Rainas RM	1	Seltar Bazar	Katbate /ChepeKhola
	3	Timure	Chepe/TimureKhola
	3,4	Satdobato	Attarkhola
	7	BangeChaur (Near Sara Phant), ChepeSangu	ChepeKhola
Madhya Nepal	1	Jitatar, Apchaur	Risti/KhahareKhola
	2,3	Sotipasal	Risti/GolandiKhola
	3,4	ChardiPasal	ChardiKhola
	4	SishaGhat, Dui Piple	Madi River
	7	Ram Bazar	Madi River/MidimKhola

3.4.2. Landslide risk

The major driving force of the landslide is gravity. In higher slope land mass should face the high gravity power. Therefore area having high slope is vulnerable to the landslide. The study identified that higher the slope higher is the risk of landslide. Lands having less than 10 degree slopes are nearly safe from the landslide.

Out of 11 land use land cover types, areas near to the rivers are more susceptible to the landslide. Similarly, agricultural lands and grasslands are also facing the landslide risk during the rainy season. Other land cover types such as forest and built-up area not facing landslide risk. Landslide risk area of district is shown in **Figure 8**.

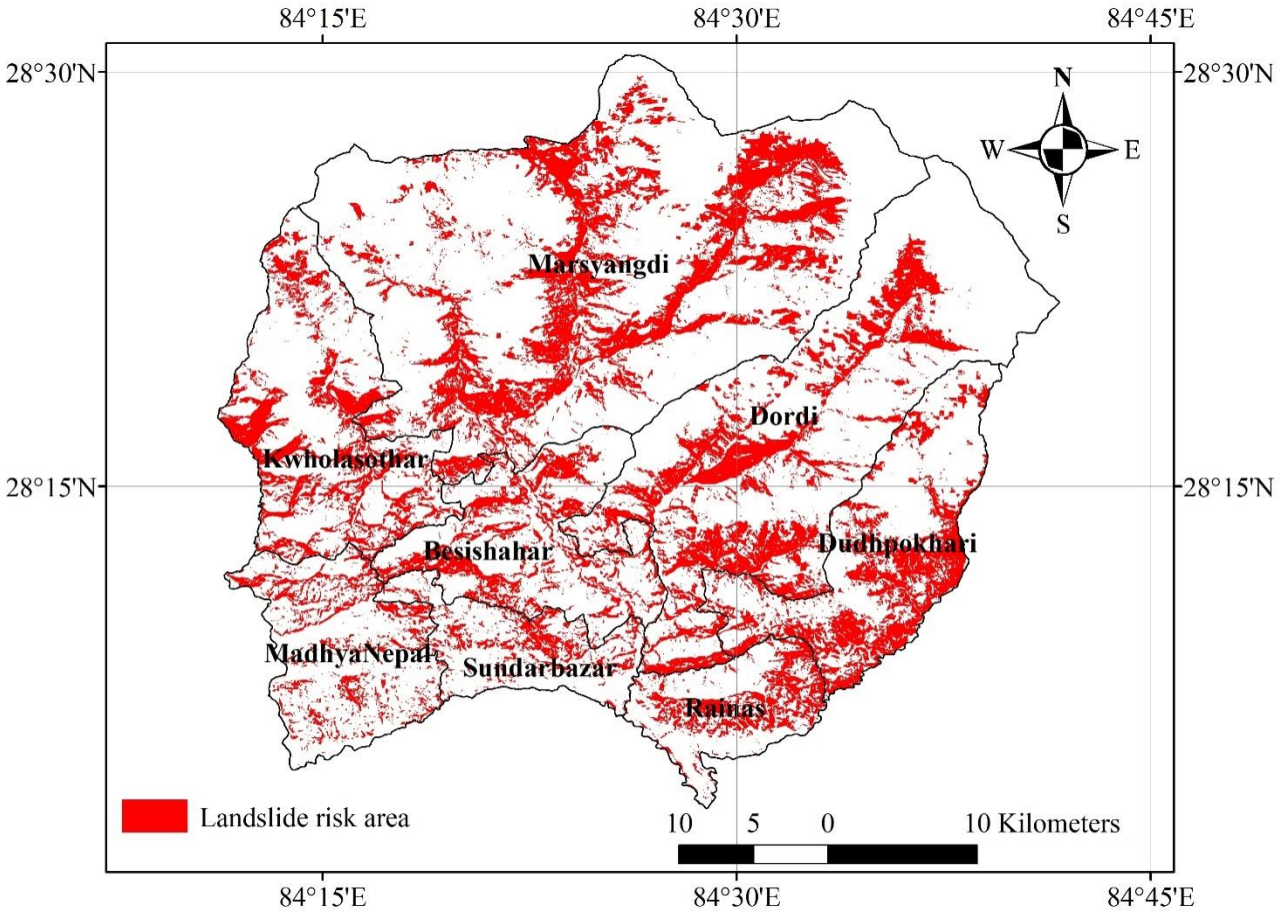

Figure 8: Landslide risk area of LamjungDistrict

Table 5: Landslide risk area of Lamjung District

Rural Municipality (RM)/ Municipality	Ward	Locations of Landslide	Potential Hazard
Sundarbazar Municipality	4	Saunipani, Simpani	Landslide
	5	Thakle, Kiting khola cutting	Landslide
	10	Baspani area	Landslide
	11	Western upper part of Bhaktichok	Landslide
Besisahar Municipality	1	Upper part of Udipur, Edge cutting of Marsyangdi River	Landslide, edge cutting

	2	Lakuriswara	Landslide
	4	Jhagrearea,Dakateri	Landslide
	5	Upper part of Fedi, Yuru, kholakhet, BakhreJagat, Lausibot,Edge cutting of Ramchekhola	Landslide, edge cutting
	6	Makaidada, Edge cutting of Marsyangdi River	Landslide, edge cutting
	7	Upper part of Mugum, Edge cutting of Marsyangdi River	Landslide, edge cutting
	8	Edge cutting of Marsyangdi River	Edge cutting
	9	Bhirmuni, Dudhe area	Landslide
	10	Bajakhet, Dejunthok, Saldada,Edge cutting of Marsyangdi River	Landslide, edge cutting
	11	Kusunde area, western part of Odare, eastern part of Sedaigaun, Edge cutting of Marsyangdi River	Landslide, edge cutting
Madhya Nepal Municipality	1	Edge cutting of Ristikhola	Landslide, edge cutting
	3	NewarHatiya	Landslide
	4	Chameriswara	Landslide
	5	Kharibari	Landslide
	6	Edge cutting of Pistikhola	edge cutting
	7	Edge cutting of Midimkhola and Sitikhola	Landslide
	8	Naglemro, Aldada area, Karapu area, Edge cutting of Midimkhola and Madi River	Landslide, edge cutting
	9	Western part of Kotgau	Landslide
	10	Simlegau area, Bardim area, Hadikholagau	Landslide
	2	Pandar area, Walmo, Sumle, Eastern part of Rajgau, Edge cutting of Midimkhola and Hadikhola	Landslide, edge cutting
	3	Kamdun and Khagum area	Landslide
	4	Sudi area, Ramje area, Kama area, Talinuarea,Syauda area, Lower part of Kholasonthar dada, Ghamrukharka	Landslide
	5	Rudi khola and Chhedewakhola area, Singdi,Sigu area	Landslide
	6	Pasgau area, Pasgaupakho	Landslide
	7	Bhonje area, Raksikhola edge cutting, talloCharagau, Sasarau	Landslide, edge cutting
	8	Tamukot,Lower part of Mapin, Edge cutting of Midimkhola,	Landslide,edge cutting

	9	Southern part of Gilun,upper part of Rudi and Pandharadovan	Landslide
Dudhpokhari RM	1	Charthar area, upalloNisimro, Chitre area, Patle area, Dadagau,kallabati, Nayagau,Kunaswara, edge cutting of Chepekhola	Landslide, edge cutting
	2	Paljearea,Kyukodada, Syalme, Baledada area, BichaurMarathagau,Edge cutting of langdikhola,	Landslide, edge cutting
	3	PhulingiriMadi, ThuloKapre,Edge cutting of langdikhola	Landslide, edge cutting
	4	Kuyale, Muge Bazar area, KeureniDigau and its upper part, Archele, Jamunedada, Swargabas, Edge cutting of Chepe and Krikhola	Landslide, edge cutting
	5	Kolki area and its eastern part, Ramche area, Bandeswara, Bansarbesi, Kotod and Northern part of Kotod Edge cutting of Chepe	Landslide, edge cutting
	6	Hau, Natheswara, Lakhjun and its southern part, eastern part of Jaubaridada	Landslide
Dordi RM	1	Sirubaribesi, sirubari, Thulaghar, Bikharka,Jhughara,Edge cutting of Tardikhola	Landslide, edge cutting
	2	Archalbot, PiparBhanjyang, Thadswara, Bhaiswara, Edge cutting of Pyardikhola	Landslide, edge cutting
	3	Karabaridada area, Gairigau, Kamrakhu	Landslide
	4	Jitaurephedi, southern part of Sikhra, Thulakhetphatarea,lamidada, northern part of Jireswara,eastern part of Jumdada,Edge cutting of Lamidadakhola and Kisedikhola	Landslide, edge cutting
	5	Arubotbesi, Wakswasra, arubot, Jamtudada, TalloPachok, Kaichi, Simrodada, Phrumche, barigau, Chhaigau, Edge cutting of Kisedikhola	Landslide, edge cutting
	6	Chhuswara, Lodokhola area, Goth kharka, Dudhkhola area	Landslide
	7	Phateni, Dailun, Phadka, Lausibot, Malagyu, Upper part of Dordikhola, Edge cutting of Dordikhola	Landslide, edge cutting
	8	Tao, Paswara, Bansar area, Edge cutting of Dordi, Pagi and Chhanoikhola	Landslide, edge cutting
Marsyangdi RM	1	Kalau area	Landslide
	2	Saituti area, Probi, Sabje, Ghimrun, Edge cutting of Khudikhola,GhimrungKhola and Thule khola	Landslide, edge cutting

	3	Topu, Khudi bazaar, Dhadu, Purangau, Dhagai, Dhagibesi, Thakan area, Sirunbeshi, Edge cutting of Khudikhola and Marsyangdi River	Landslide, edge cutting
	4	Nalukhola area, Ghoptegau, Kabre, Chhapagau, Mipra area, Syage area, PuranoJagat, Chyamche,Edge cutting of Marsyangdi River and Syagakhola	Landslide, edge cutting
	5	Badalbisauna, Khanigau, Chhichu, mathilloChipla, upper part of Koyeprdkyukhla, Sattalearea,Edge cutting of Marsyangdi River and Koyeprdkyukhola	Landslide, edge cutting
	6	Thulibesi, Sanla, Naiche, Dahare, Upper part Nadikhola, Edge cutting of Nadikhola	Landslide, edge cutting
	7	Upper part of Upallobesi,Kolkoche area, Upper part of Taban, Edge cutting of Siurikhola	Landslide, edge cutting
	8	Bandre area	Landslide
	9	Lamagau, Bhalamchaur area	Landslide
Rainas RM	1	Simlegaun, Chapswara,Damadhunga,Seltar	Landslide
	2	Tingharearea,Edge cutting of Borangkhola	Landslide
	3	Rimidada,Gaurigau, Northern upper part of Timure	Landslide
	4	Manegauda area	Landslide
	6	Manegauda area, Gaebote and northern part of Gaebote, Phulbari area	Landslide
	7	Edge cutting of Marsyangdi River	Edge cutting
	8	Neupanedada, Amledada area	Landslide
	10	Sisneri, Pyarjun dada area	Landslide

Boundary points of ChepeKhola 2

FID	X	y
1	84.48146	28.05573
2	84.48202	28.05563
3	84.48619	28.0608
4	84.48727	28.06267
5	84.48648	28.06356
6	84.48542	28.06429

7	84.48547	28.06477
8	84.48619	28.06523
9	84.48709	28.06555
10	84.48809	28.06677
11	84.48735	28.07019
12	84.48812	28.07113
13	84.48809	28.07159
14	84.48742	28.07227
15	84.48569	28.073
16	84.4853	28.07335
17	84.4843	28.07497
18	84.48395	28.07665
19	84.48451	28.0776
20	84.48483	28.07771
21	84.48528	28.07772
22	84.48697	28.07692
23	84.48778	28.07676
24	84.48747	28.07756
25	84.48742	28.07779
26	84.48691	28.07909
27	84.48658	28.0796
28	84.48592	28.08011
29	84.4843	28.08008
30	84.48297	28.07971
31	84.48121	28.07996
32	84.48046	28.08033
33	84.47864	28.0849
34	84.47782	28.0873
35	84.4779	28.08882
36	84.47862	28.08946
37	84.4801	28.08931
38	84.48183	28.08864
39	84.48238	28.08856
40	84.48342	28.087
41	84.48439	28.08648
42	84.48714	28.08637
43	84.48946	28.08596
44	84.49141	28.08549
45	84.49236	28.08577
46	84.49357	28.08671
47	84.49409	28.08675
48	84.49631	28.08611

49	84.49833	28.08534
50	84.50081	28.0865
51	84.50292	28.08697
52	84.51094	28.08816
53	84.5136	28.08796
54	84.51562	28.08954
55	84.51728	28.09037
56	84.5187	28.09396
57	84.51912	28.09435
58	84.52381	28.09538
59	84.52949	28.09903
60	84.53308	28.09975
61	84.53701	28.1004
62	84.53914	28.09944
63	84.54217	28.10069
64	84.54332	28.10218
65	84.546	28.10442
66	84.54701	28.10704
67	84.54952	28.10774
68	84.55112	28.10989
69	84.55102	28.11065
70	84.5496	28.11152
71	84.54937	28.11212
72	84.54962	28.11388
73	84.5501	28.11462
74	84.55106	28.11502
75	84.5521	28.11478
76	84.554	28.11634
77	84.55416	28.11688
78	84.55417	28.11764
79	84.55434	28.11834
80	84.55434	28.11925
81	84.55349	28.11968
82	84.55219	28.11987
83	84.55233	28.12059
84	84.55183	28.12097
85	84.55154	28.12189
86	84.55259	28.12202
87	84.55277	28.12239
88	84.55238	28.12291
89	84.55237	28.12399
90	84.55283	28.12457

91	84.55288	28.1252
92	84.55393	28.12635
93	84.5537	28.12694
94	84.55312	28.12733
95	84.55266	28.12819
96	84.55349	28.12986
97	84.55367	28.13081
98	84.55283	28.13227
99	84.55283	28.13341
100	84.55251	28.13432
101	84.55149	28.13494
102	84.55125	28.13621
103	84.55058	28.13733
104	84.55023	28.14038
105	84.54895	28.14109
106	84.5478	28.14275
107	84.54813	28.14451
108	84.54798	28.14484
109	84.54661	28.14546
110	84.54593	28.14847
111	84.5463	28.14947
112	84.54605	28.15013
113	84.54536	28.15066
114	84.54502	28.15126
115	84.54516	28.15287
116	84.54477	28.15327
117	84.54369	28.15367
118	84.54325	28.1541
119	84.54258	28.15577
120	84.5416	28.15645
121	84.54099	28.15736
122	84.53963	28.15752
123	84.53891	28.15818
124	84.53813	28.1582
125	84.53705	28.15876
126	84.53421	28.15922
127	84.53229	28.15919
128	84.5292	28.15816
129	84.52587	28.1574
130	84.52449	28.1574
131	84.52372	28.15768
132	84.52063	28.16117

133	84.52023	28.16042
134	84.52141	28.15673
135	84.52351	28.1524
136	84.51684	28.14407
137	84.51642	28.1406
138	84.51456	28.13836
139	84.51209	28.13708
140	84.51104	28.13522
141	84.50814	28.13327
142	84.50557	28.12756
143	84.49933	28.12508
144	84.4941	28.1247
145	84.491	28.1227
146	84.48739	28.12175
147	84.48544	28.12251
148	84.48301	28.1218
149	84.47854	28.12228
150	84.47735	28.12152
151	84.47173	28.12209
152	84.47045	28.12266
153	84.4624	28.12232
154	84.46164	28.12323
155	84.45526	28.12366
156	84.4525	28.12542
157	84.45208	28.12651
158	84.44965	28.12637
159	84.44389	28.12161
160	84.44137	28.12094
161	84.44123	28.11899
162	84.43889	28.11714
163	84.43918	28.11576
164	84.43794	28.11371
165	84.43528	28.11323
166	84.43513	28.11271
167	84.43275	28.11071
168	84.43183	28.11069
169	84.43183	28.11069
170	84.43349	28.10853
171	84.43449	28.1081
172	84.43681	28.10783
173	84.43727	28.10745
174	84.43805	28.10559

175	84.43991	28.10502
176	84.44274	28.10489
177	84.44357	28.10442
178	84.44277	28.1001
179	84.44313	28.09932
180	84.44694	28.09859
181	84.44853	28.09742
182	84.44983	28.0967
183	84.45155	28.09624
184	84.45238	28.09568
185	84.45245	28.09513
186	84.45122	28.09337
187	84.45152	28.09251
188	84.45742	28.09117
189	84.45786	28.09028
190	84.46044	28.08429
191	84.46179	28.08293
192	84.4644	28.08213
193	84.46574	28.08167
194	84.46597	28.08081
195	84.46572	28.0767
196	84.46874	28.07552
197	84.46966	28.07218
198	84.46893	28.07124
199	84.46815	28.07126
200	84.46703	28.07063
201	84.46735	28.06981
202	84.46969	28.0695
203	84.47406	28.06786
204	84.47628	28.06506
205	84.47613	28.06391
206	84.47525	28.06298
207	84.47472	28.06148
208	84.47761	28.05822
209	84.47874	28.05841
210	84.48003	28.05767

3.5. Sub watershed management plan

3.5.1. Chepe Khola Sub Watershed

During the study, Chepe Khola Sub Watershed of Rainas Municipality is identified as top prioritized sub watershed of this district. Due to local and managerial perspective, Soil and Watershed Management Office, Tanahun decided to prepare the management plan of Chepe Khola Sub Watershed which is second top prioritized sub watershed of the district. This sub-watershed covers the 57 km^2 area of Rainas Municipality of the Lamjung district. This sub watershed is situated in the Southeast part of the Marshyangdi River (**Figure 8**).

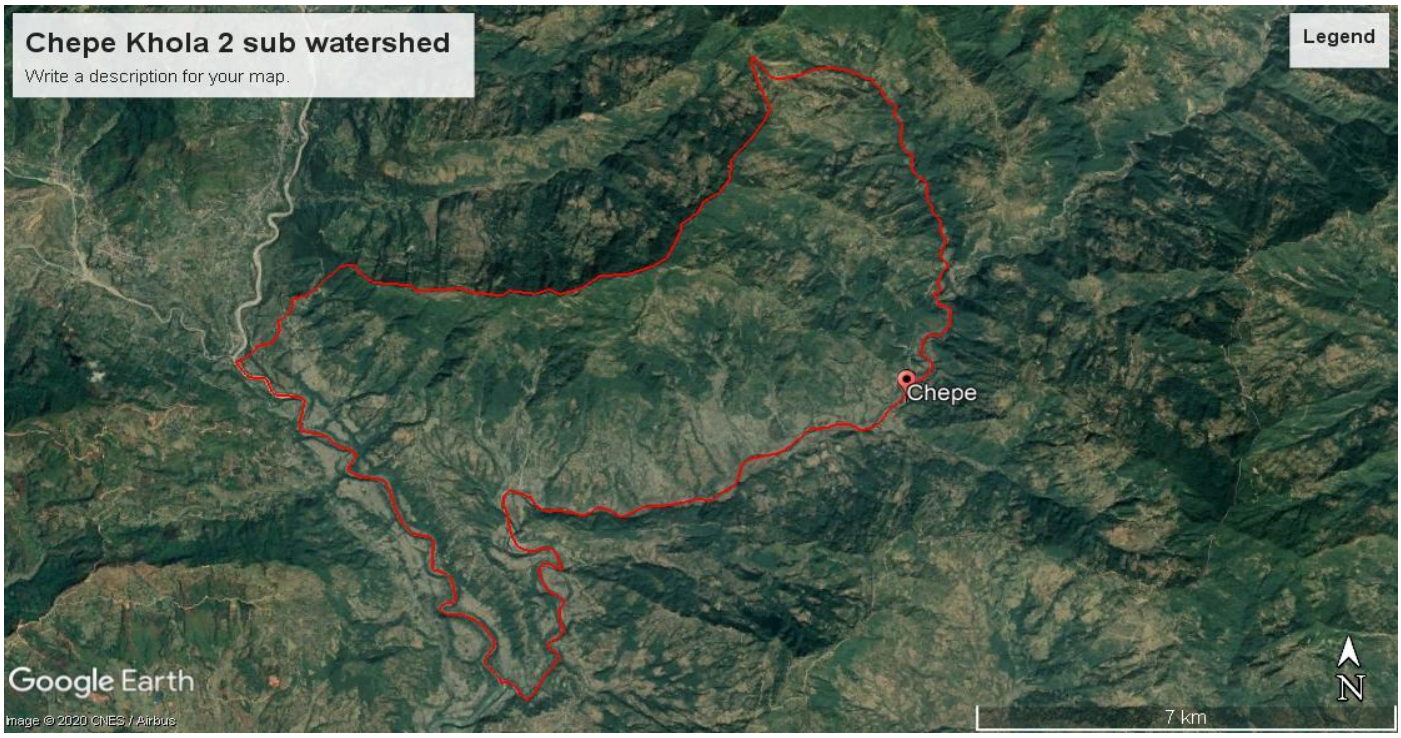

Figure 8 Chepe Khola Sub watershed boundary map

3.5.2. Location

Majority part of the Chepe Khola Sub Watershed lies in Rainas Municipality.This sub watershed totally covers 1, 2, 3, 4, 5, 6, 7 and partially covers 8 and 10 wards of Rainas Municipality. (**Figure 9**).

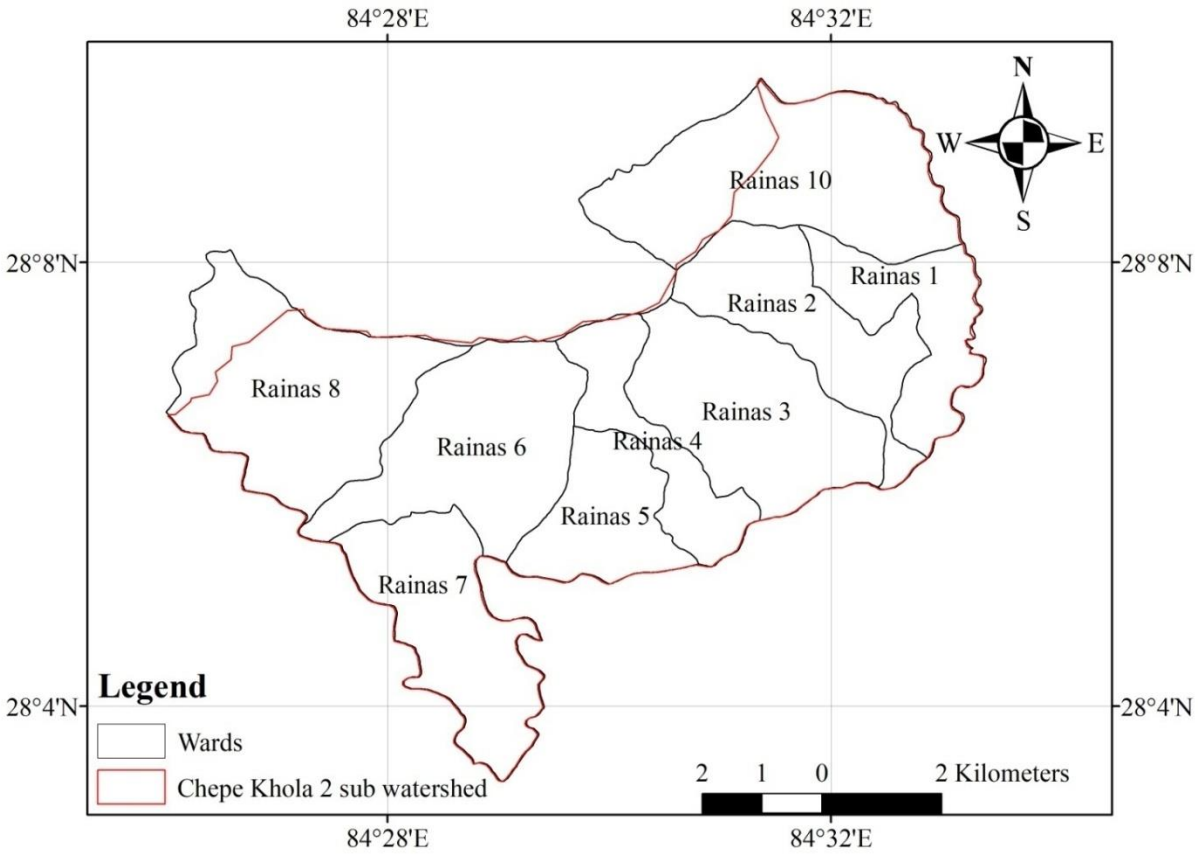

Figure 9 **Location of Chepe Khola Sub Watershed of Lamjung district**

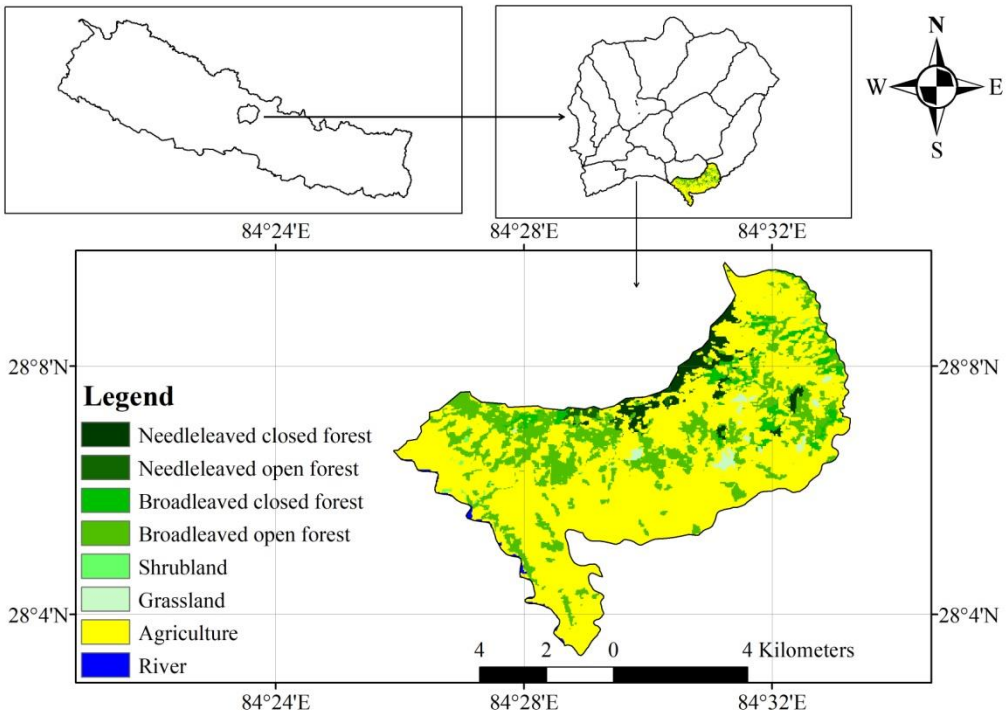

Figure 9: Land use land cover map of Chepe Khola Sub watershed

3.5.3. Slope

Land slope affects the erosion predominantly. As the slope increases, the runoff coefficient, kinetic energy and carrying capacity of surface runoff also increase while soil stability and slope stability both decrease. Thus it is very important to identify different slope in watershed. Slope map was prepared is three categories: less than 5 degree, 5 to 30 degree and more than 30 degree. Southern part of the watershed is more stepper than northern parts. In the middle part of the watershed there is medium slope. Slope analysis was carried out DEM in ArcGIS. Western part with higher elevation has greater slope and decreases to some elevation down and increases again with flat near to water source. Most of the area of this sub watershed is fall in the moderate slope. Out of 57 km^2 of sub watershed, slope less than 5 degree covers 6.19 km^2, slope between 5 and 30 degree covers 40.87 km^2 and slope more than 30 degree covers 9.94km^2.

S.N.	Slope	Area km
1	< 5 degree	6.19
2	5-30 degree	40.87
3	> 30 degree	9.94
		57.00

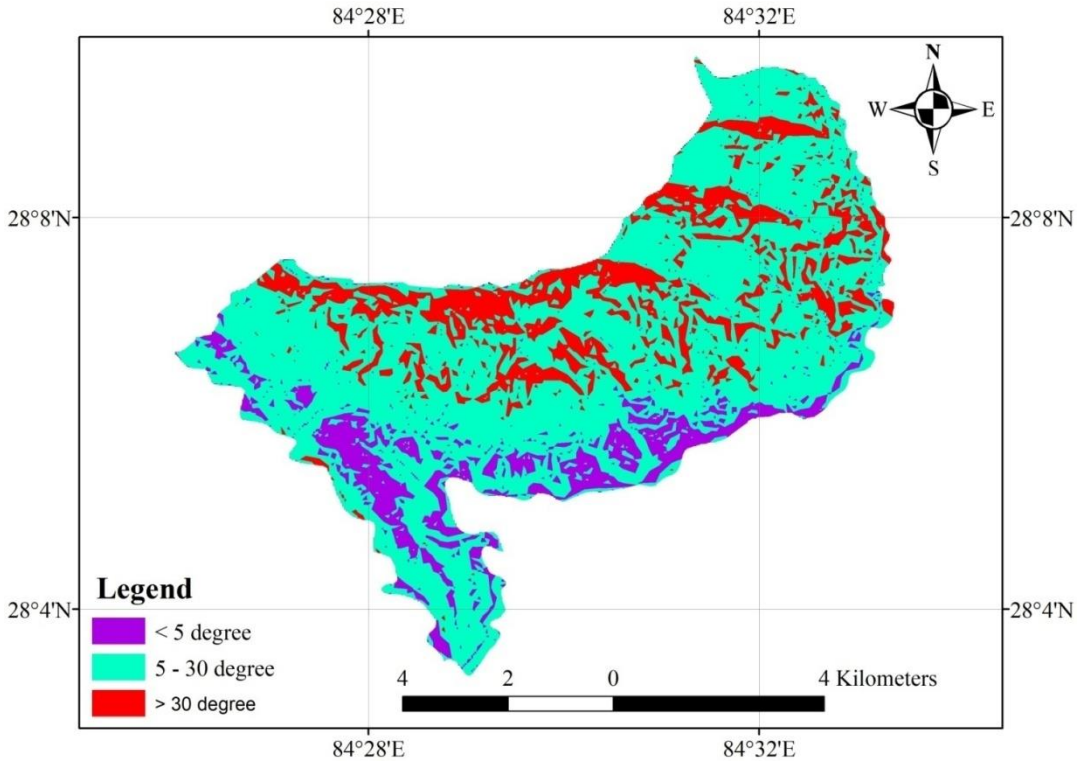

Fig 11 Slope map of Chepe Khola Sub Watershed

3.5.4. Aspect

Aspect is the compass direction where the slope faces. For example, a slope on the eastern edge of watershed is described as having an southern aspect. Southern aspect get more solar radiation than northern aspect, thus it affects the vegetation and soil moisture in the watershed. Most of the part of micro watershed is facing to South (**Figure 12**).

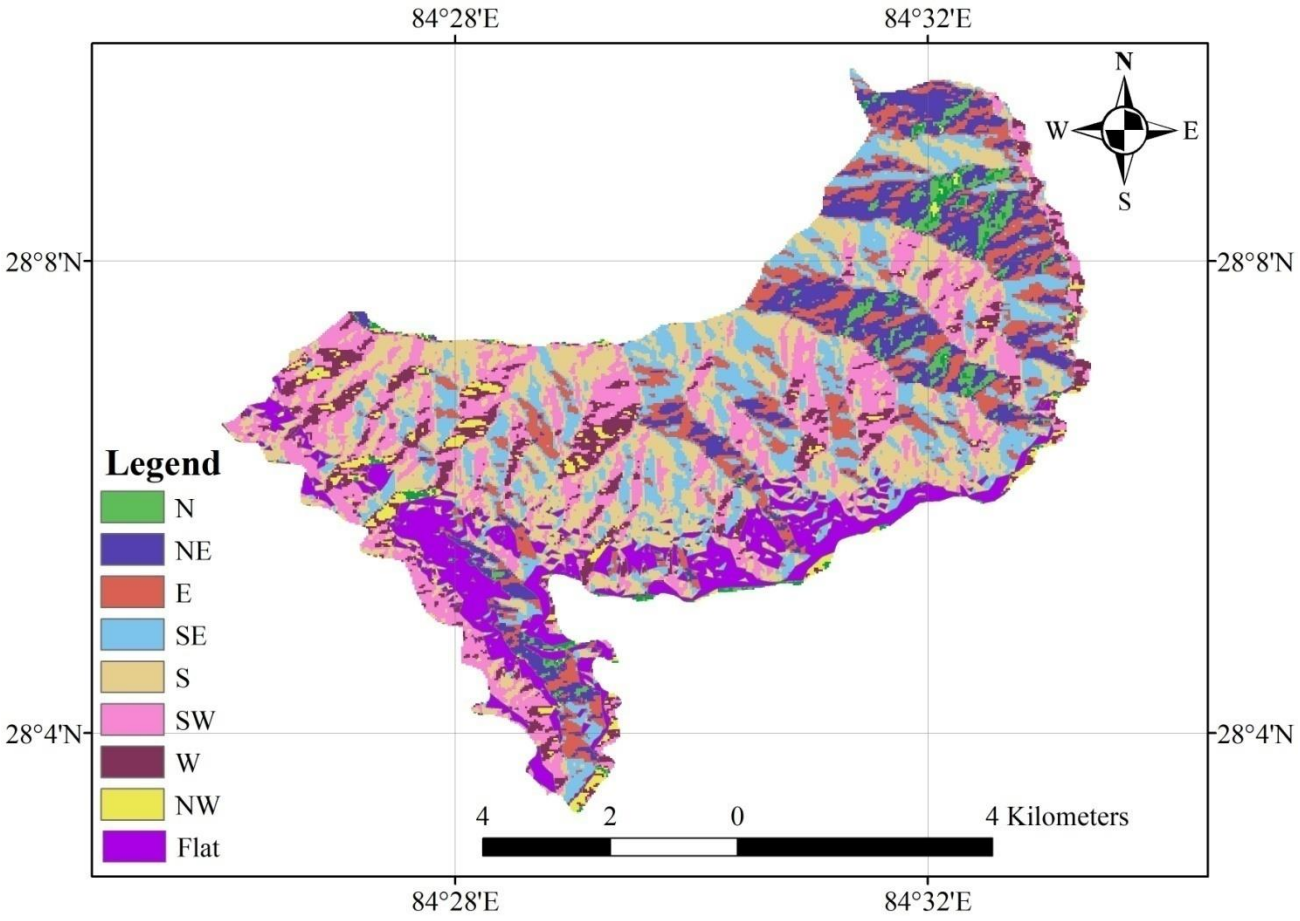

FIG 12 ASPECT OF CHEPE KHOLA SUBWATERSHED

3.5.5. Population

According to the population census of 2011, total household and total population of the Sub watershed are 4751 and 18527. Out of total population, 8099 are male and 10428 are female. The population

density of the Sub Watershed is 325/km^2. Major casts of Chepe Khola sub-watershed are Brahmin, Chhetri, Gurung , Dalits, Newar and other.

3.5.6. Agriculture and livestock

Rice, maize, millet, wheat, orange and lemon are major agricultural product of Chepe Khola sub-watershed. Agriculture of this area is facing lack of irrigation, manure, market and mechanized technology. Goat, buffalo, pig, poultry are major livestock of this area. Livestock (cattle, goat, and sheep) density with a spatial resolution of 1 km was obtained from the Center for Earth Observation and Citizen Science (see https://www.geo-wiki.org)" (Robinson et al., 2014). Livestock density of the district is 63/km^2 whereas that Fewa sub watershed.

3.5.7. Road networks

Road networks were downloaded from the Geofabrik website (http://download.geofa 750brik.de/asia/nepal.html; OpenStreetMap Contributors, 2017). Total road length of the district is km where as that of the Fewa sub-watershed is 147.357 km.

3.5.8. Forests

This sub-watershed is land of 19 community forests and 25 leasehold forests. Major forest types of this area are broadleaved close forest, broad leaved open forest and needle leaved open forest. Major species of these forests are Sal, Chilaune, Sisoo, Khayar, katus and Non Timber Forests Products (NTFPs).

3.5.9. Problems observed within sub watershed area

Watershed is an integration of land, water, forest, people and livestock within the drainage area of any water body (**Figure 14**). These five major and all other associated components within the drainage area of 68 ha of sub watershed come under the umbrella of micro watershed and are the major componentsconsidered on integrated approach of watershed management. The issues related to these components are the concern of development organization to deal with.

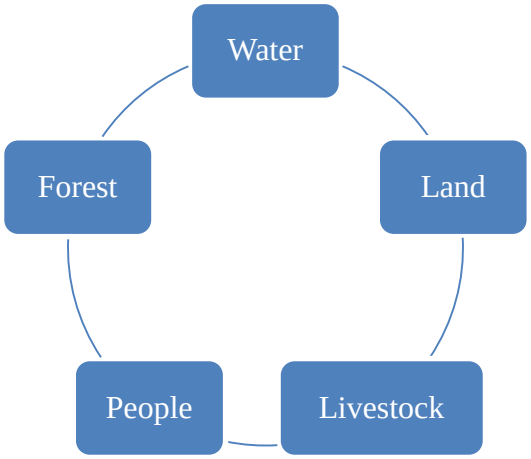

Figure 10: Major components of watershed

Problem of watershed incorporates the socio economic, environmental and different development issues connected with the components of watershed within the considered area. Hence some of such problems identified within the subwatershed area are as follows:

- The landslide both at the upstream and downstream area is causing the soil erosion in the monsoon season.
- The water resource is used without proper intake and collection tank and the series of pipes from the individual household is causing the seepage of water and it is underutilized.
- The river banks of the three different streams (Kaligandaki, Bungadi and Dungre) are degrading day by day.
- The irrigation canals of sub watershed area needs to be maintained.
- The landslide within the sub-watershed area needs to be treated.
- Increasing rural roads construction in haphazard way without any IEE/EIA and supporting structures is resulting huge soil erosion. Every year large volume of sedimentation on the River.
- Deforestation and human encroachment to the forest area.
- Unscientific agricultural practice, unplanned land use and poor land/soil quality.
- Lack of awareness of conservation of soil and water resources.
- Lack of irrigation, drinking water, education and other facilities

3.5.10. Soil conservation and watershed management planning

Approved soil conservation and watershed management programs has the overall goal to contribute to the livelihood and well-being of the people through sustainable watershed management of the sub watershed area. Its purpose has been defined as to increase the productivity and utility of land and water and to prolong the services of the development infrastructures leading towards livelihood improvement on an equitable and sustainable basis through integrated soil conservation and watershed management.

To serve for the above mentioned goal and purpose the Soil and Watershed Management Office (SWMO) is implementing number of programs. Some major activities that SWMO has been doing are below.

Table 6: Major activities that are envisaged for watershed management programs

Component	Activities	Sub activities
1. **Water and sediment yield**	1.1.Water activities 1.1.1 Water source protection 1.1.2 Wetland conservation 1.1.3 Conservation pond/runoff harvesting dam	Intake construction, fencing, Bioengineering techniques, pond/lake conservation, water harvesting/utilization structures, greenery promotion activities
	1.2. Natural hazard management 1.2.1. Landslide/gully treatment 1.2.2. Torrent/stream bank protection 1.2.3. Community based DM support 1.2.4. Sediment trap structures	Structural /bioengineering techniques, conservation plantation, awareness activities, group mobilization, Community's skill development activities, provision of emergency fund
2. **Land productivity conservation**	2.1. On/off farm conservation 2.2.Degraded land rehabilitation 2.3. Terrace improvement	SALT, bioengineering ,slope management ,seed /seeding supply, agro-forestry, soil fertility management activities
3. **Protection of infrastructure**	3.1. Roadside slope protection 3.2. Irrigation canal improvement 3.3.Siltation management 3.4. Hotspot treatment	Rural/National road side slope stabilization measures (Structural/nonstructural),national heritage and other infrastructure protection hard/soft activities

4. **Institutional development**	4.1.Partnership program 4.2. CRMP (community resource management plan) formulation 4.3. Group's tour/training 4.4. Income generation support 4.5.Group monitoring/extension	Partnership with GO/NGO/CBOs organizations, income generation support (conservation oriented), and group strengthening activities, best practice findings documentation and extension related activities.
5. **Program management**	5.1.Erosion hazard map preparation 5.2. Sub w/s management plan preparation 5.3. Nursery management 5.4.Motivator/conservation assistant 5.5.Maintenance/follow up	Hazard map preparation, sub w/s plan preparation, Nursery build up /seeding production, hiring local staff as conservation assistants, maintenance and follow up of past activities.

3.5.11. Plan of activities

Use of the land based on its capability is the main theme of rational land use. Based on proper land use and slope, which are two key parameters deciding its use, recommendations for land use and conservation measures are required. Change in land use recommended for some present use is not so easy because it depends in the willingness of the owner/farmer.

3.5.11.1. Land use planning

The first-hand information about sub watershed can be obtained through land use planning. Scientific utilization and management of watershed resources on basis of existing bio-physical and socio-economic situation analysis is planned through the sub watershed management plan, community resources management plan, watershed prioritization, forest operation plan and other related to land use development and natural resources management planning.Land use, land capability, land system and other different primary and secondary data sources are used during the planning process.

3.5.11.2. Land productivity conservation

Appropriate land uses on the basis of land capability are encouraged through different land productivity conservation activities for improved land productivity and soil depth.

On farm conservation, degraded and reclaimed land rehabilitation, fruit/fodder tree plantation, grass plantation, green belt/shelter belt construction, nursery management and seedling production are the major activities under this component. Improved productivity, increased agricultural land and greenery promotion are expected outcomes from these activities.

3.5.11.3. Need assessment for infrastructure protection and conservation works

This is most needed and equally demanded activities which cover the protection programs of development infrastructures like irrigation canals and reservoirs systems, trail roads, water supply systems, public/community buildings and others. Various conservation works like pond conservation,landslide/landslip treatments, stream bank protection are executed through the combination of civil and bio-engineering works like support walls, check dams, diversion channels, and vegetative measures jointly or individual as per the site's need. High preference is given to the bio-engineering works and greenery promotion activities along with the engineering work which expands economic service life of the development infrastructures. Information about the existing problems related to soil erosion and natural resources management was collected through structured questionnaire, open interview; check list, PRA, RRA within considered sub watershed area. Different activities required for conservation of individual component are given in following section.

a. River bank cutting stabilization and flood management

In this sub watershed four streams are cutting the land. These streams are affecting the agricultural land, forest and grazing lands (**Table 10**).

Table 7: Needs of river bank cutting stabilization

S.N.	Flood causing stream	Address (Ward no of Rainas Municipality)	Status	Affected area
1	Chepe khola	1, 2, 3,4,5,7	Active in monsoon	Agriculture land, Forest, Grazing land
2	Marshyangdi	6, 7, 8	Active in monsoon	Agriculture land, Forest, Grazing land
3	Borang khola	1	Active in monsoon	Agriculture land, Forest, Grazing land
4	Chili khola	1	Active in monsoon	Agriculture land, Forest, Grazing land

b. Irrigation canal maintenance work

Four irrigation arein this sub watershed. All of them are seeking maintenance and protection. Details of these canals are in **Table 11**.

Table 8: Needs of irrigation canal maintenance work

S.N.	Name of irrigation canal	Area of irrigation	Benefited household	Status
1	Vatkane kulo	approx. 500 Ropani	20	Need for protection
2	Setibagar kulo	30 ropani	55	Need for protection
3	Masar kulo	60 ropani	25	Need for protection
4	Thumpari kulo	80 ropani	46	Need for protection
5	Jokhet kulo	90 ropani	35	Need for protection
6	Chapaswara kulo	20 ropani	10	Need for protection
7	Tinghare Bhalayokharka kulo	90 ropani	100	Need for protection
8	Tintale Chanauta kulo	120 ropani	100	Need for protection
9	Lampata kulo	50 ropani	150	Need for protection
10	Jhakrithan kulo	60 ropani	150	Need for protection
11	Naubise kulo	100 ropani	200	Need for protection
12	Rainas sichai yojana	800 ha	2000	Need for protection
13	Lakhkedi kulo	50 ha	150	Need for protection
14	Sunmaya kulo	200 ropani	50	Need for protection

15	Pangre harrabot sichai yojana	700 ropani	700	Need for protection
16	Sindhure pani kulo	35 ropani	35	Need for protection

c. Landslide control

Landslides are major water and gravity induced hazards. In this sub watershed, four landslides are serious in terms of affected areas (**Table 12**). **Table 9: Needs of landslide treatment.**

S.N.	Name of landslide	Address	Status	Affected area	Remarks
1	Maure chilikhola	1 Maure	Active	Roads	Large
2	Devisthanko Pahiro	Borang	Active	Settlementnt, Roads	Large
3	Khuttte Pahiro	Borang	Active	Settlementnt, Roads	Large
4	Khathbote khola	2	Active	Settlementnt, Roads	Large
5	Samakhoriya	2	Active	Settlementnt, Roads	Large
6	Tinghare	2	Active	Settlementnt, Roads	Large
7	Bhedikharka	3	Active	Settlementnt, Roads	Large
8	Naubise Pahiro	3	Active	Settlementnt, Roads	Large
9	Dunikhola	4	Active	Roads	Large
10	Damaigaira	4	Active	Roads	Large
11	Thuloaagan pahiro	4	Active	Roads	Large
12	Chisopani tamang gau	4	Active	Roads	Large
13	Becharekulako pahiro	4	passive	NO	Large
14	Vane pahiro	6	Passive	Settlement	Medium
15	Viripani	6	No	Settlement	Small
16	Made dhunga	6	Active	Agriculture,Settlement	Large
17	Ratemate	6	Active	Agriculture,Settlement	Large
18	Dahal khola	6	Active	Agriculture,Settlement	Large
19	Chalese bata okhale	7	Passive	Agriculture,Settlement	Large
20	Chepsagu pul	7	Active	Agriculture,Settlement	Large
21	Nep Dham	7	Active	Agriculture,Settlement	Large
22	Kandel gau Pahiro	8	Active	Agriculture,Settlement	Large
23	Marme tole pahiro	10	Active	Agriculture,Settlement	Large
24	Sighari pahiro	10	Active	Agriculture,Settlement	Large

d. Gully control

Gully control is also major activity of sub watershed management plan. Two gullies of Jgyalbaas area are more serious gullies of this sub watershed (**Table 13**). These needs to be controlled.

Table 10: Needs of assessment of gully control

S.N.	Name of gully	Address	Status	Affected area	Remarks
1	Kamigam kholsi	1	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
2	Gairiswara kulo	1	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
3	Upallo birauto kulo	1	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
4	Tusare Kholsi	2	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
5	Birmane Kholsi	2	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
6	Thulo Kholsi	2	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
7	Adheri Kholsi	2	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
8	Borang Kholsi	2	serious	Settlement, Agricultural land, Grazing land, Forest	small
9	Tinkhutte kholsi	2	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
10	Lampata	3	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
11	Chepe khola	4	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
12	Lhose galchi	5	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
13	Dovan khola	6	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
14	Dahal khola	6	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
15	Gharti Gaun	7	Serious	Settlement, Agricultural land	small

e. Road slope stabilization

Roads are major factors of accelerating the soil erosion. Now days, roads are becoming major factors of landslides and soil loss. In this sub watershed, six feeder roads are causing the soil erosion (**Table 14**).

Table 11: Needs of Road Slope Stablization work

S.N.	Name of Road	Address (Ward Rainas)	Status of Soil Erosion	Status of Road
1	Tidupani Jaukhet sadak	1	Active	Kachhi, Hile
2	Borang khola gairi swara sadak	1	Active	Kachhi, Hile
3	Shimle gaira boring gau	1	Active	Kachhi, Hile
4	Bhangari damadung sadak	1	Active	Kachhi, Hile
5	Sahilitar panthe danda sadak	2	Active	Kachhi, Hile
6	Panthedanda shimle gaira sadak	2	Active	Kachhi, Hile
7	Naubise Baribate Gaurigaun	3	Active	Kachhi, Hile
8	Bhedikharka Gaurigaun	3	Active	Kachhi, Hile
9	Jethak Biruata Jyamire	3	Active	Kachhi, Hile
10	Beluwatar mowe chisapani	5	Active	Kachhi, Hile
11	Budichaur lisimati kungar	5	Mild	Kachhi, Hile
12	Basanta hatiya deurali	5	Mild	Kachhi, Hile
13	Ahale Chatise lose	5	Serious	Kachhi, Hile
14	Nayapauwa khed khet	6	Serious	Kachhi, Hile
15	Dhanipani Batar	6	Serious	Kachhi, Hile
16	Syauli Aapchaur bora gaun	6	Serious	Kachhi, Hile
17	Harit marga	7	Serious	Kachhi, Hile
18	Kadikhet upallo Phant	7	Serious	Kachhi, Hile
19	Kalidaha Thutabagar	7	Serious	Kachhi, Hile
20	Madhyapahadi lokmarga	4, 5, 6	Serious	Blacktopped

3.5.11.4. Plantation and income generation activity

Almost of the conservation works are carried out with active participation of the people. The required activities are planned as per the public demand. Under the community soil conservation, programs are intended to carry out in partnership with community people as well as agencies. Income generation

activities under this component are aimed to the local people's economic status so as to help decrease poverty. NTFPs cultivation, nursery operation, bee keeping, mushroom growing, vegetable farming, saving–credit supports, agro-business promotion with agro-cooperatives and other entrepreneurial initiatives as per feasibility and public demands are carried out for the income generation purpose. Small watershed demonstration site development work is another important conservation works with an objective to develop a model site with integrated activities of all conservation and watershed management works that could be instrumental to know and learn about good watershed management practices for farmers, local peoples, students, visitors and other interested.

3.5.11.5. Capacity building and technology development support program

Capacity building of natural resource users groups and people's organizations is another important aspect of the development processes as their engagement can contribute in achieving targeted goal. They have better knowledge of local context and resources. However, they need additional supports to improve knowledge, skills and organizational functions in dealing with the enormously damaged landscapes and its resources. Thus, capacity building (training, coaching and organizational supports) should be an integral part of soil conservation and watershed management. Besides, it is also recommended to promote awareness and meaningful participation people of watershed in soil conservation and watershed management.

3.5.12. Costs and funding

3.5.12.1. Estimation of costs for the 5 year planning

With respect to the requirements identified during field studies and above-mentioned in the planning of activities (need assessment), a tentative estimate of the volume of work as well as its costing has been prepared as per the current norms. This estimation (**Table 15**)of quantity and budget may get changed as per time, terms and condition.

S.N.	Activities	Quantity (unit)	Annual activities for 5 years					Total activity	Total cost (In thousands)	Remarks
			1	2	3	4	5			
1	**Natural Hazard Prevention/ Management**									
1.a	Landslide and landslip treatment	No	6	6	5	4	4	24	24000	1000/No
1.b	Gully/torrent treatment	Place	3	3	3	3	3	15	15000	1000/Place
1.c	River/stream bank protection	Km	1	1	1	1	1	5	22500	5000/Km
2	**Land productivity conservation**									
2.a	On /off farm conservation / Farmer together with soil conservation	Ha	5	5	5	5	5	25	2500	100/Ha
2.b	Degraded land rehabilitation	Ha	5	5	5	5	5	25	2500	100/Ha
2.c	Conservation plantation	Ha	5	5	5	5	5	25	2500	100/Ha
3	**Water conservation**									
3.a	Water source / wetlands protection	No	1	1	1	1	1	5	1000	200/No
3.b	Conservation pond construction/maintenance	No	1	1	1	1	1	5	1500	300/No
3.b	Run off harvesting dam construction / maintenance	No	1	1	1	1	1	5	3500	700/No
4	**Development Infrastructure**									
4.a	Rural road with soil conservation / Roadside slope stabilization	Km	4	4	4	4	4	20	20000	1000/Km

4.b	Drinking water supply and irrigation canal system improvement	No	5	5	5	3	3	21	4200	200/No
4.c	Miscellaneous development works	L.S.							1000	
5	**Program plan and management**									
5.a	Land use planning	No	1	1	1	1	1	5	250	50/No
5.b	CRMP formulation	No	1	1	1	1	1	5	250	50/No
5.c	Hazard assessment and map preparation	No	1					1	100	100/No
5.d	Nursery management	Years	1	1	1	1	1	5	250	50/Year
5.e	Income generation activities	Package	1	1	1	1	1	5	250	50/Package
6	**Institutional development**									
6.a	Users and farmers training	Times	1	1	1	1	1	5	250	50/Times
6.b	Women motivators/ youth club	No	1	1	1	1	1	5	250	50/No
6.c	Study tours and cross visits	Times	1	1	1	1	1	5	250	50/Times
6.d	Production of extension materials	L.S.	1	1	1	1	1	5	250	50/Times
6.e	School program	Times	1	1	1	1	1	5	250	50/Times
6.f	Miscellaneous (programs as per need)	L.S.							200	
Total									102750	

3.5.13. Methods of funding

Successful implementation of the watershed management plan's activities will require adequate program funding and professional supports of various sectors. There could be following funding methods. To be noted that there are a number of other supplemental sources of funding:

1. SWMO, Tanahun
2. Private land owners and other users
3. Division Forests Office, Lamjung
4. Rainas Municipality
5. International Development Agencies
6. Non-governmental organizations
7. CFUG
8. CBOs and local groups: mother groups

A blend of funding method is strongly recommended since various actors have their own areas of specialization as well as limitations.

3.5.14. Plan implementation approach

SWMO Tanahun is doing the watershed management activities in Lamjung District from few years. Besides all these efforts the outcome is not meeting the expectations and problems are not sorted out as the problems are accelerating and adding each next year. So their needs an integrated and focused approach of all line/concerned agencies to work on different components of the watershed.

3.5.15. Implementation mechanism

a. Sub watershed management committee

The first step before implementation of the planned works is to form a multi-disciplinary coordination committee lead by the SWMO and members will be the representative from identified stakeholders like from Government Offices District Agriculture, Livestock, Irrigation, Tourism, Road, Rainas Municipality, INGOs/NGOs working on the sub watershed area and at local level representative of local CBOs, political leaders and other identified.

The committee coordinated by the SWMO will be responsible for the identification of roles and responsibilities of different agencies, planning of yearly activities and budget, resource sharing, working procedures and others as per need. Since SWMO alone can't carry out all the identified need and works due to its limited financial and human resource and more of it the works are related to different offices it identifies and purpose to different line agencies for their nature of job to be carried out in the watershed area. In accordance with the available budget of different government and non-government offices a working plan will be endorsed at the commencement of the year based on this management plan.

b. Collaborative approach

The destructions in the watershed area is enormous and thus, demand huge investments in various aspects such as technical, social, economic, human and so on. Fulfillment of these investments is beyond the capacity of one organization or two. So, the collaborative approach in rehabilitation of watershed resources and livelihoods of people will strongly be established.

c. Awareness raising and capacity building

Ultimate beneficiaries of the natural resources in watershed are local community. Their livelihood is based on the local environment. In other words, they are interdependent. Over exploitation of resources not only deteriorate the environment they are living in but also degrade their livelihood. Thus, it is very important to make them understand about the sustainable use of these resources. Trainings, workshops, field visits can be means for awareness raising and capacity building of the community in watershed.

d. Participatory approach

Sense of ownership in local community is the only way for the successful watershed management. It has to be created using active participation of local community of all level equally in all activities from decision making to planning and finally implementation. SWMO has strong guidelines to work on active participation of the beneficiaries so as to make the work sustainable, to make people aware about the activities and for post work care / repair and maintenances.

3.5.16. Working modality

Almost programs will be done through Beneficiaries Group Approach. Existing users group (CFUG, women groups, saving and credit groups, youth groups and so on) working in the area and community development groups (CDGs) facilitated by GOs/NGOs will be involved directly. For group mobilization and empowerment, NGO support will be sought through contractual arrangement.

If watershed management task is conceived as per time based project on collaboration of different line agencies. The possible project implementation stages will be:

Stage I – Formation of watershed management council, working plan/strategy/schedule, monitoring mechanism and others as per required

Stage II – Village clusters, hotspots and priority areas are to be identified within the sub watersheds

Stage III – Taking into the consideration of interest and need of local inhabitants, number of interest or user groups will be formed

Stage IV – At village level, sub watershed conservation users group as an umbrella organization of small beneficiaries' level users group will be foreseen. And sub watershed level federation of watershed conservation users group, as a network of village level groups will be formed if needed

Stage V – Hiring of staffs (If required), trainings for working GOs/NGOs/CBOs staffs for their increased working capacity and empowerment / capacity building for user's group

3.5.17. Monitoring and evaluation

Monitoring and evaluation are major component of the planning. Whether or not the implemented activities have got the intended outputs or to check for the fulfillment of set objectives for any plan the designed activities and works are monitored and evaluated. In sub watershed management activities M&E is very important tool to have intermediate checks to ensure proper work in scheduled time and to make recommendation and learning from the experiences that may help in other similar works and for future planning. Proper monitoring and evaluation need to be done in participatory

approach. Progress will be monitored by setting time based targets in presence of local community and SWMO.

Financial and technical auditing is expected for the sub watershed management works by the agencies involved. On government side M&E is done by the SWMO itself and reports are sent to its higher agencies regularly. Besides Forest Directorate (FD), Ministry if Industry, Tourism, Forest and Environment (MOITFE) as well are frequently monitoring the works. Public auditing will be done at various stages of activity implementation in order to maintain transparency, accountability and reliance.

3.5.18. Log frame

Logframe is an analytical tool which helps to identify goals, purpose,outputs, means of verification and assumptions or the conditions (If any) of the planned programs/activities. Here based on the needs and activities identified and field level assessments a log frame has been prepared. Mentioned log frame (**Table 17**) is well guided for sub watershed management.

Table 12: Log frame

Components (Activities)	Indicators(Output)	Means of verifications	Important assumptions
Goal:			
Contributing positive support in livelihood of the people and to the environment through sustainable watershed management practices	District Co-ordination Committee (DCC),Rural Municipality (RM) and other institute recognizes SWMO Program's significant contribution to the overall development	Reports of DCC, RM and other agencies	
• **Purpose :**			
To increase the productivity and utility of land and water resources, decrease disaster and to prolong the services of development infrastructures leading towards better livelihood along with environmental improvement on an equitable and sustainable basis through integrated soil conservation and watershed management approach	• Reduced water induced disasters and its loss. • Decreased siltation in downstream • Availability of water from pond, stream and other water source for different purpose increased (by quantity and quality) significantly • Production per unit area of intervened watershed increased significantly	• Disaster related reports • Water use and other water related reports of different agencies • Specific production study of the concerned agency • Monitoring reports of MOITFE, FD, SWMO, DCC, RM and other concerned agencies	• Sub watershed will be given priority to work on • SWMO programs continues to be national and district priority program • Adequate human and financial resources are available for the program • Active participation of local people from planning to post work

	• Utility of development infrastructures increased significantly • The poor, women and vulnerable groups of people benefited from SWMO programs		maintenance will be available
Activities :			
1. Natural Hazard prevention			
a. Landslide/Landslip treatments	No. of landslides/landslip treated stabilized	SWMO activity profiles, MOITFE, FD, DCC, RM, report, field study monitoring report	Natural calamities will not occur.
	No. of HH benefitted Ha. of land protected		Active participation of local people on implementation and post work maintenance will be available
b. River/stream bank protection	No of hectare of land reclaimed and handed over to the user group Length of river span trained	"	"
c. Conservation ponds/Silt trapping structures	No. of ponds/dams constructed	"	"
	Area of land protected No. of HH benefitted		

2. Water Source protection			
a. Conservation ponds/lakes/waterhole protection	No. of ponds/lake/water source and wetlands protected/managed Ha (area) of agricultural land irrigated. Total no of HHs benefitted	"	"
b. Water Source protection	No. of ponds/lake/water source and wetlands protected/managed Total no of HHs benefitted	"	"
c. Wetland conservation/Management	No. of ponds/lake/water source and wetlands protected/managed Total no of HHs benefitted	"	"
3. Land Productivity enhancement/Conservation programs			
a. Agro forest friendly land conservation	Total hectares of land conserved/reclaimed Amount of income (Rs.) generated	"	People's participation and willingness Lands available for the intended purpose and people

	No. of farmers/HHs benefitted and applying proper land use practices		Favorable environmental condition
b. Degraded land reclamation	Total hectares of land conserved/reclaimed Production and income generated	"	"
	No. of farmers/HHs benefitted and applying proper land use practices		
c. River land reclaimed/handover to the local people	Total hectares of land conserved/reclaimed	"	People's participation and willingness
	No. of farmers/HHs benefitted and applying proper land use practices		Lands available for the intended purpose and people
			Natural calamities will not occur
4. Development Infrastructure protection			
a. Irrigation canal improvement	Total kilometer of irrigation canal/work over	"	"
	Total command area (ha)facilitated with irrigation		
	No. of HH benefitted		
b. Roadside slope stabilization	Slope stabilized/work over	"	"

	Total command area (ha)facilitated with irrigation		
	No. of HH benefitted		
5. Community soil conservation			
a. Partnership soil conservation program	No. of activities	"	People's participation and willingness Agencies eager to work on collaboration/partnership
	No of partner agencies and resource contribution		Concern local organization/groups continue the maintenance work
	Total no of HHs benefitted		
b. Income generation activities for pro-poor and marginalized people	No of HHs upgraded to their social and economic status	"	People's participation and willingness
	Total income generated per person/HH		
c. Integrated watershed demonstration site development	No. of demonstration site developed	"	People's participation and willingness
	Quantity and quality of different components implemented		Concern local organization/groups continue the maintenance work
	No. of HHs benefitted		
4 Extension Activities	No of trainings and tours conducted (no of people) Level of conservation awareness increased to community people	"	People's participation and willingness. Basic education and knowledge of people

4. CONCLUSIONS AND RECOMMENDATIONS

This study delineates sub-basins and sub-watersheds of the Lamjung District. Furthermore this study prioritized the identified sub watersheds and prepared the management plan of most vulnerable watershed for effective and efficient management of sub watershed. Although this district does not support any sub-basin, total 14 sub-watersheds were identified. During the study, Chepe Khola Sub Watershed of Rainas Municipality is identified as top prioritized sub watershed of this district. Due to local and managerial perspective, Soil and Watershed Management Office, Tanahun decided to prepare the management plan of Chepe Khola Sub Watershed which is top prioritized sub watershed of the district. Resources allocation to these prioritized sub-watersheds is recommended. Furthermore, effective implementation of this sub watershed management plan is recommended for benefit of environment and people.

Some important recommendations are as follows:

- Use of existing rules and regulations (Soil Conservation Act 2039 and so on) for sub watershed management.
- Establishment of coordination mechanism on comprehensive land use planning.
- Construction of terraces for hill side farming.
- Establishment of production forest in gentle slope and protection forest in steep slope.

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