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

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Foreword 1

Foreword

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 Gorkha District of Gandaki 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 15 sub watershed are delineated in this district. Finally, sub watershed management plan of Daraudi Nadi 2 Sub Watershed was prepared. This sub watershed covers the 154 km^2 area of Siranchwok, Bhimsen Rural Municipality, Palungtar and Gorkha Municipality of Gorkha District. Total NRs 6,05,50,000is proposed for proper management of Daraudi Nadi 2 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 the 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) (Barnekow Lillesø 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: Gorkha, Tanahun, , 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 Gorkha. 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 *Shorea robusta, Dalbergia sissoo, Acacia catechu, Pinus roxburghii, Schima wallichii,* and *Castanopsis indica*. 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 sub-watershed for management and conservation purpose. Specific objectives are as follows

- To identify the all sub-watershed 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 Gorkha district

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 of Siranchwok and Bhimsen Rural Munucipality and Palungtar and Gorkha 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 Daraudi Nadi 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 Gorkha District of Gandaki Province (**Figure 1**). The district covers an area of 3,610 km^2 and geographically located at 28°17′24″N latitude and 84°41′23″E longitude. Four major rivers run within and along it - the Chepe, Daraudi, Marsyangdi, and Budhi Gandaki. The district consists of 11 Municipalities, out of which two are urban municipalities and nine are rural municipalities.This district consists of 8 climatic zones; low tropical (below 300m), 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).

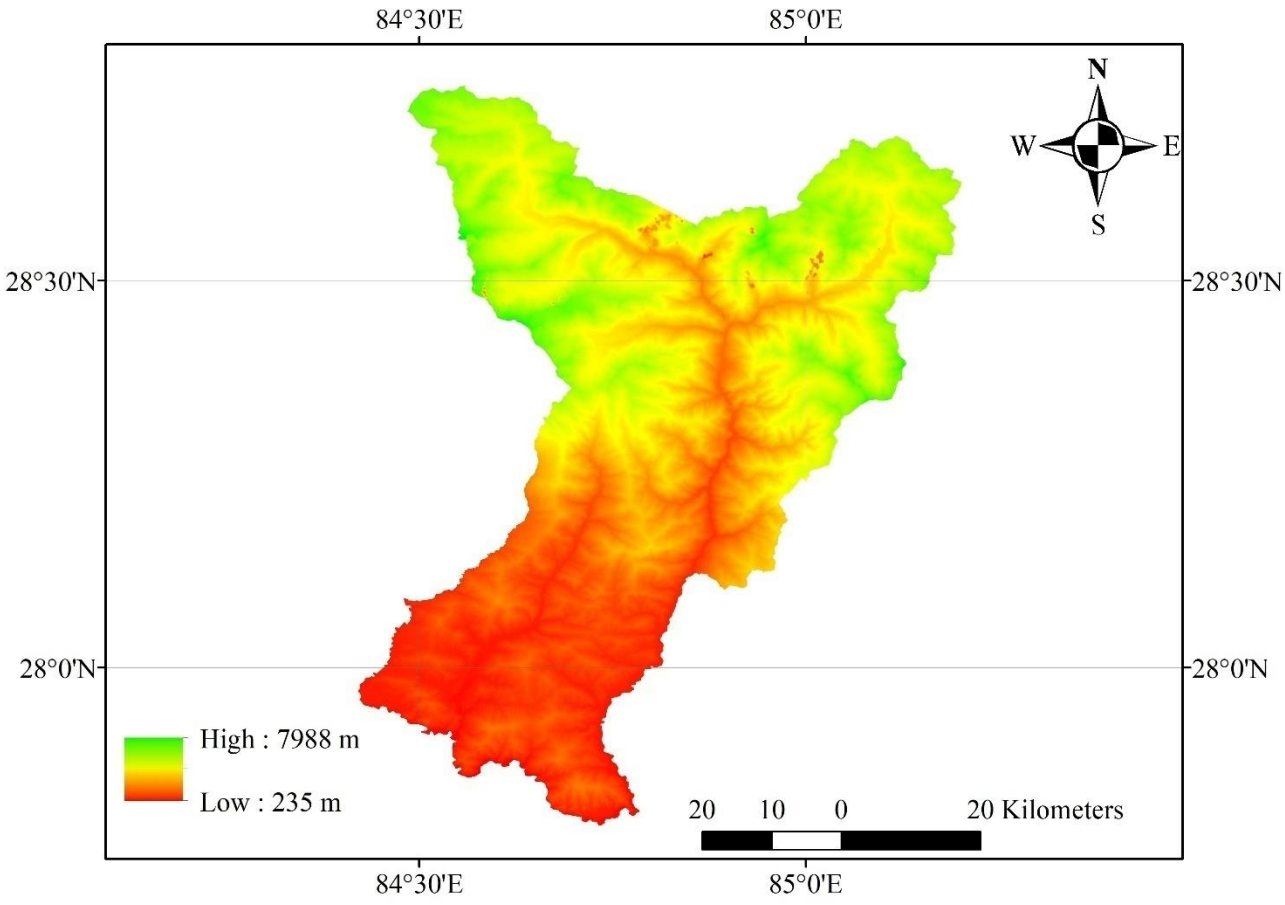

Figure 1: Study area with digital elevation model

2.2. Sub - basin delineation

Sub-basins were 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). Sub-basins were calculated by using basin tool of ArcGIS (ESRI, 2017). Sub-basin raster file was converted to the polygons and final sub-basins were mapped for 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).

2.3. Sub watershed prioritization

Sub watersheds are prioritized 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.

2.3.1. 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 Gorkha district is shown in **Figure 2**.

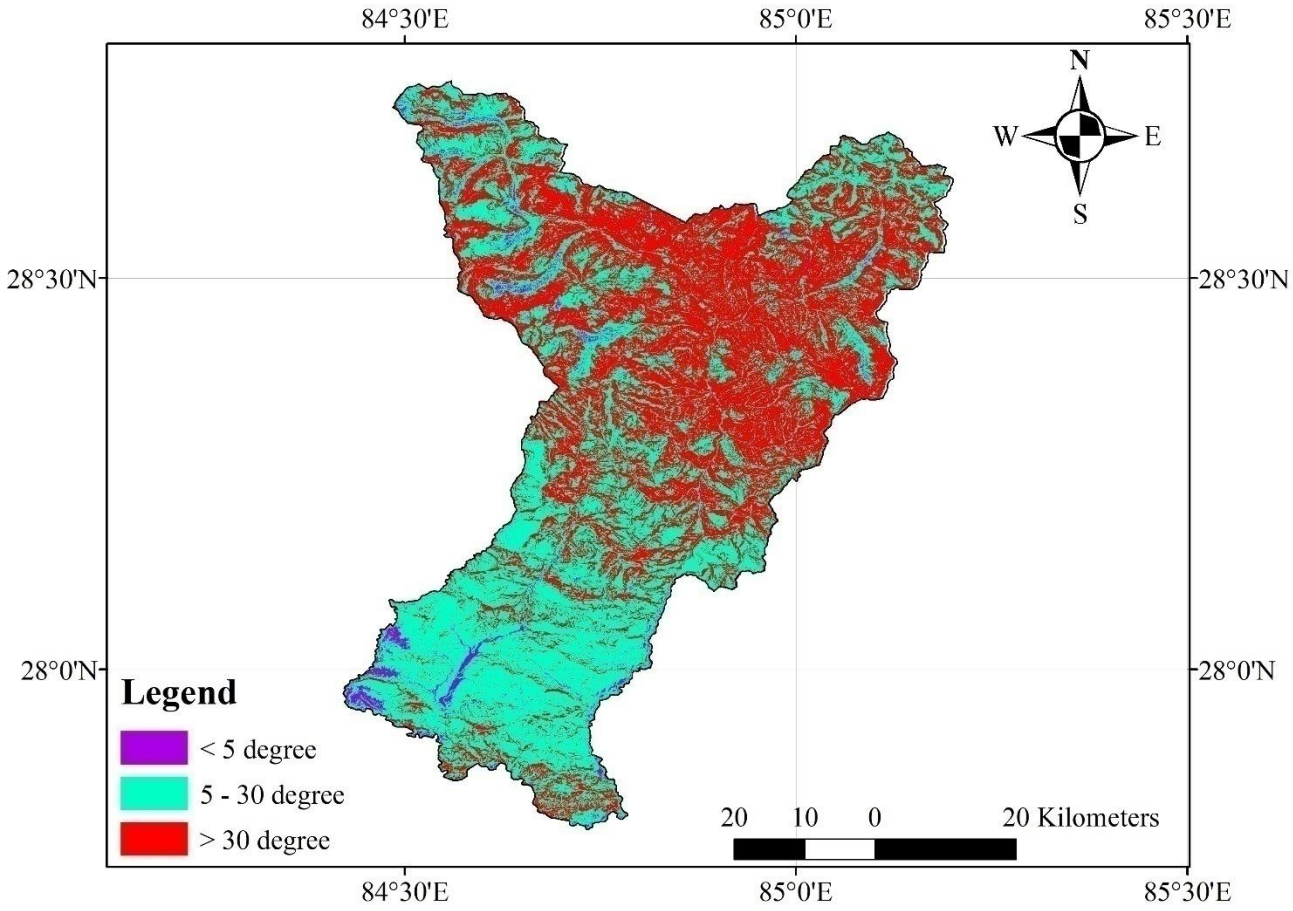

Figure 2: Slope of the Gorkha District

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**.

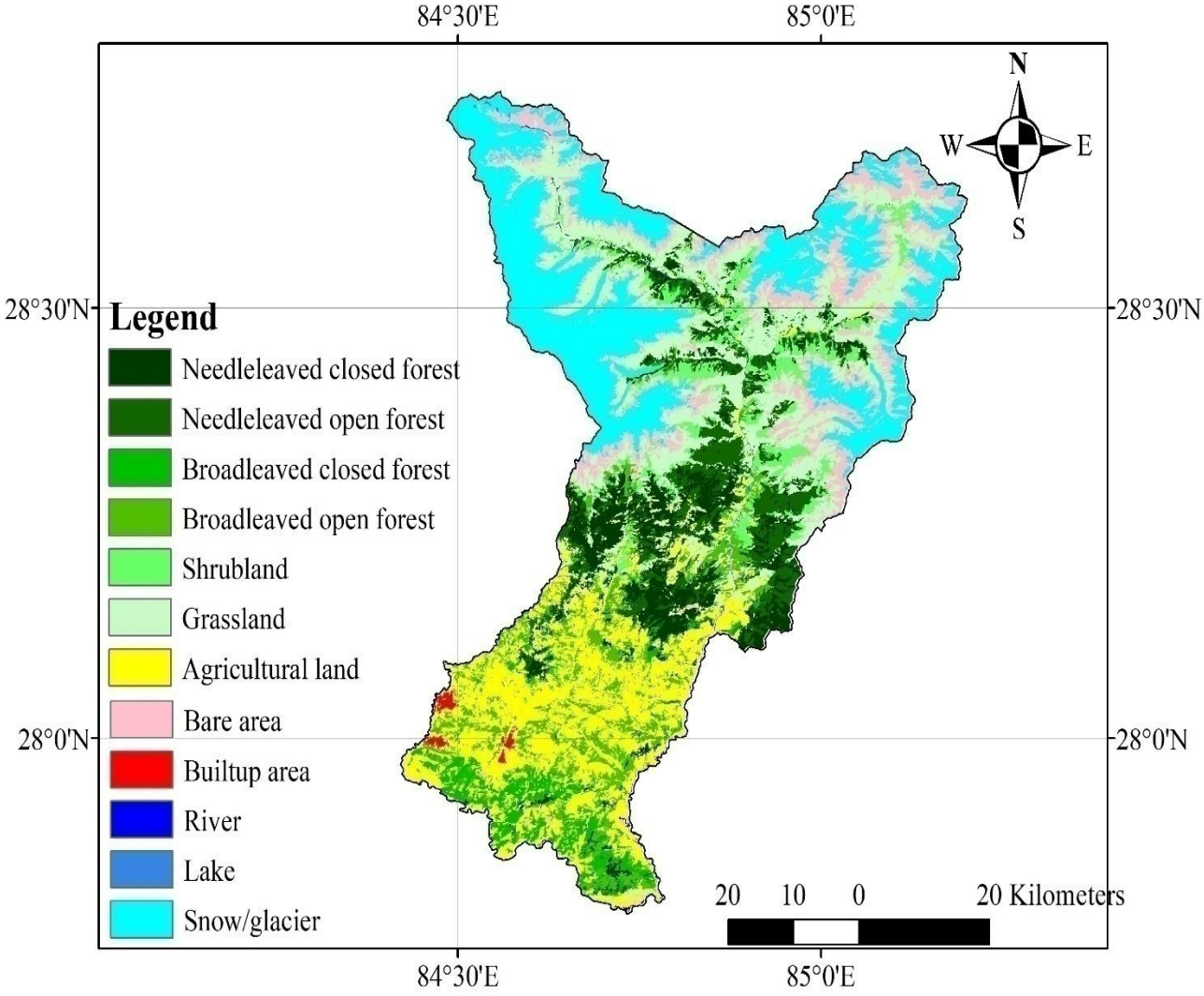

Figure 3: Land use/land cover of Gorkha District

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

2.3.2. 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.

2.4. 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.

2.4.1. 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,	km

		Nepal	

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 World Climate 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.

2.4.2. 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 MaxEnt software to model the hazards of the district.

2.5. Preparation of management plan

2.5.1. Data collection

2.5.1.1. 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.

2.5.1.2. 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).

2.5.2. 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 Kaligadaki Sub Basin whereas smallest sub basin is Budhi Gandaki Sub 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.

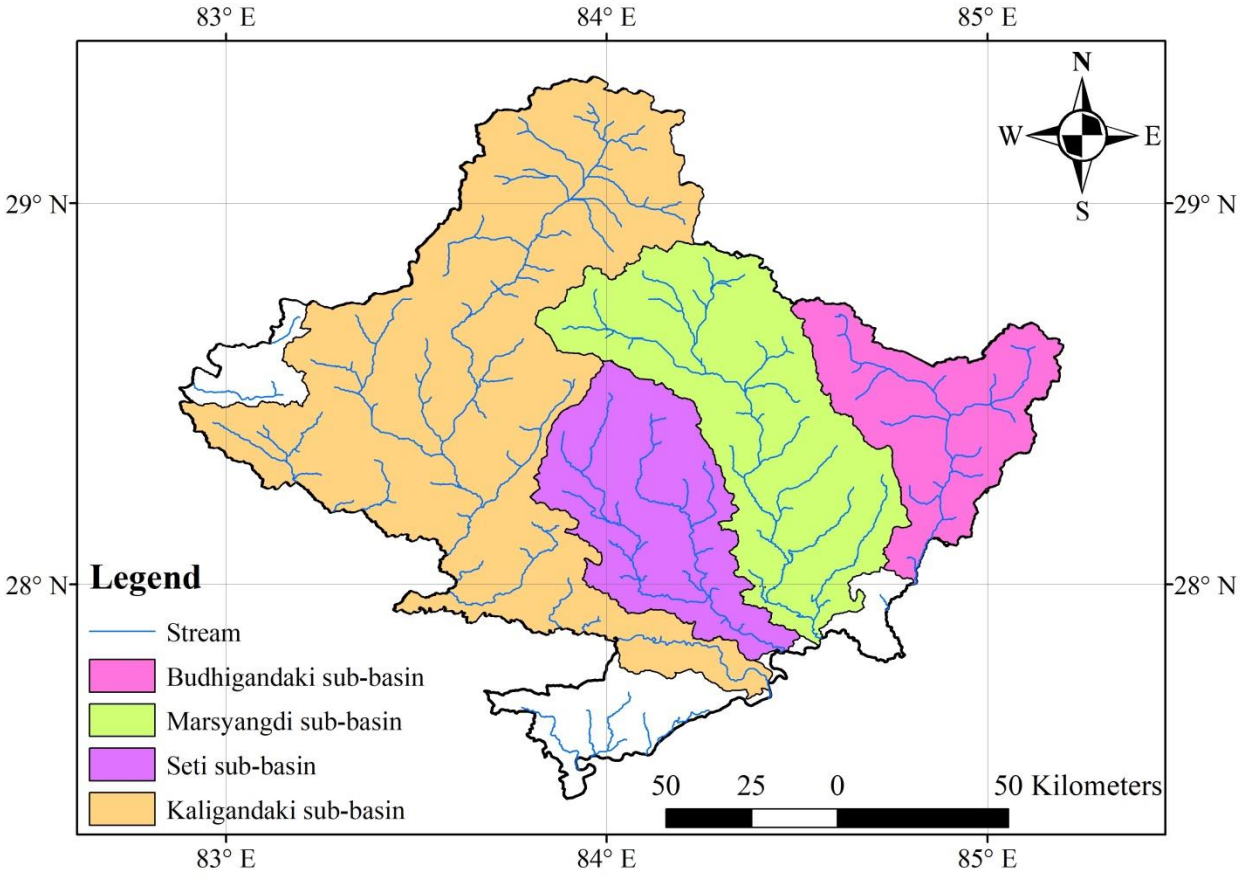

Figure 4: Sub basins of Gandaki Province

If only Gorkha district is considered as working unit, the study identified two sub basins: Budhi Gandaki and Daraudi (**Figure 5**).

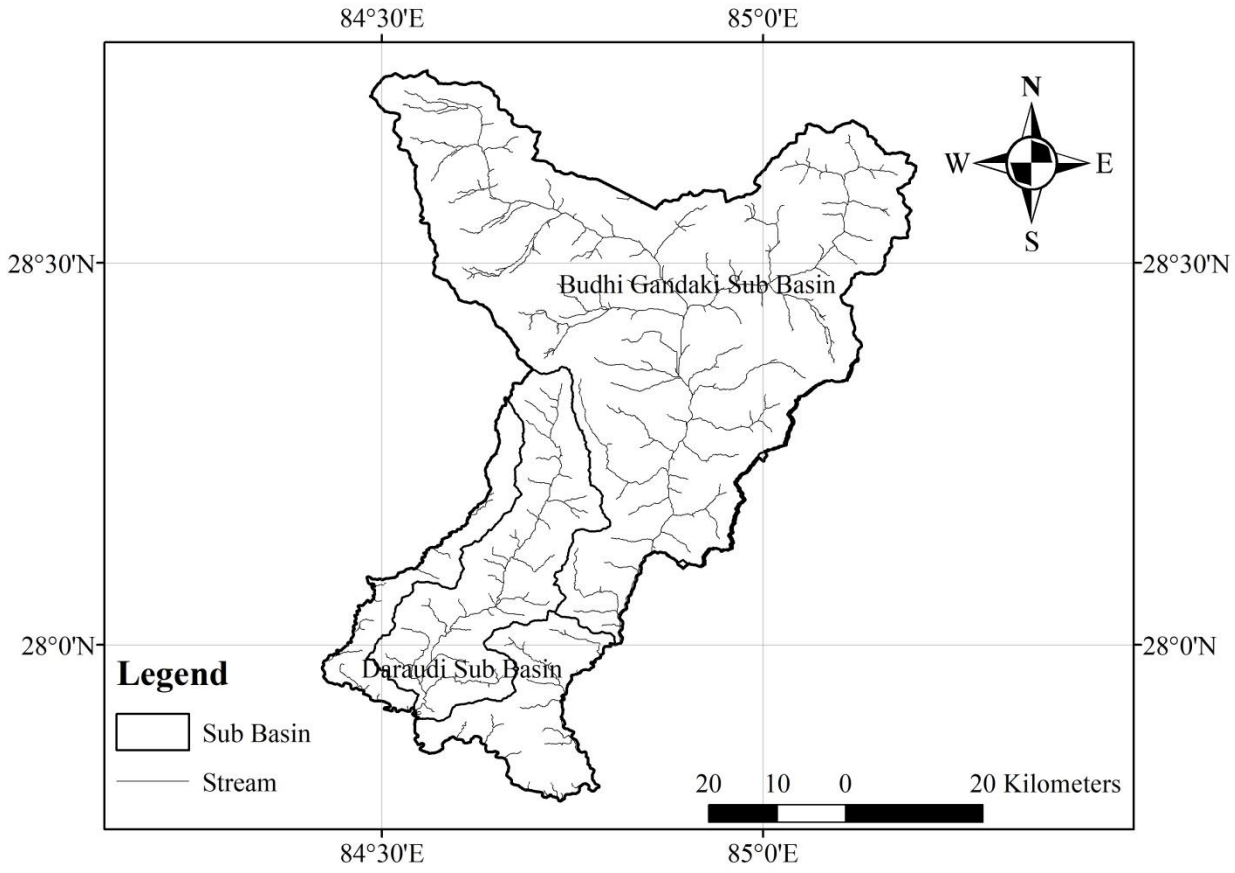

Figure 5: Sub basins of Gorkha District

3.2. Sub watersheds of districts

A total of 15 sub-watersheds are delineated in the Gorkaha District (**Figure 6**). The range of the sub-watershed is 635 km^2 to 61 km^2. The largest sub-watershed is Syar Khola and smallest is Budhi-Gandaki Nadi 6(**Table 2**).

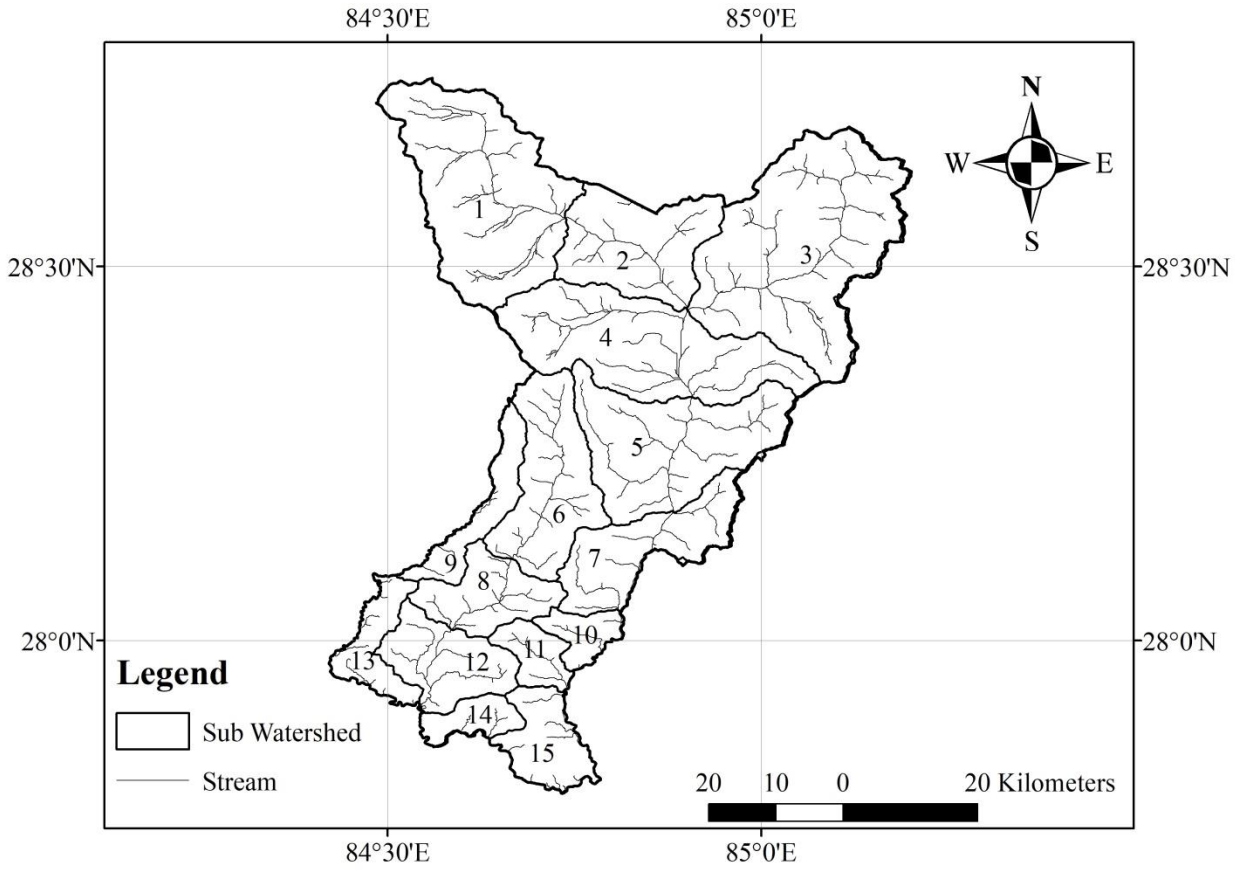

Figure 6: Sub-watersheds of Gorkha District

Table 2: Sub watersheds of Gorkha

S.N.	Name of sub watershed	Area (km^2)	Corresponding local level

1	Budhi-Gandaki Nadi 1	518	Chun Numri Rural Municipality
2	Budhi-Gandaki Nadi 2	268	Chun Numri Rural Municipality
3	Syar Khola	635	Chun Numri Rural Municipality
4	Budhi-Gandaki Nadi 3	451	Lowger Chun Numri Rural Municipality and Upper Part of Darche Rural Municipality
5	Budhi-Gandaki Nadi 4	382	Dharche Rural Municipality
6	Daraudi Nadi 1	277	Ajirkot and Sulikot Rural Municipality
7	Budhi-Gandaki Nadi 5	219	Aarughat Rural Municipality
8	Daraudi Nadi 2	154	Siranchwok, Sulikot and Bhimsen Rural Municipality and Gorkha Municipality
9	Chepe Nadi	109	Ajirkot and Siranchwok Rural Municipality
10	Budhi-Gandaki Nadi 6	61	Bhimsen Rural Municipality
11	Budhi-Gandaki Nadi 7	69	Bhimsen Rural Municipality
12	Daraudi Nadi 3	175	Gorkha and Paluntar Municipality and Sahid Lakhan Rural Municipality
13	Myarsangdi Nadi	100	Paluntar Municipality and Sahid Lakhan Rural Municipality
14	Trishuli Nadi 1	63	Sahid Lakhan Rural Municipality
15	Trishuli Nadi 2	129	Gandaki Rural Municipality

3.3. Prioritized sub-watersheds

Daraudi Nadi 2 sub-watershed is top prioritized sub-watershed of the Gorkha district with an area of 154 km^2. This sub-watershed located atSiranchwok and Bhimsen Rural Municipality and Palungtar Municipality. Similarly, Budhi-Gandaki Nadi 7is the second prioritized sub-watershed of the district and located to Bhimsen Rural Municipality (**Table 3**).

Table 3: Sub watershed prioritization of Gorkha

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
8	Daraudi Nadi 2	154	Siranchwok (ward 4,5,6,7,8) Sulikot (ward 5, 6, 8) and Bhimsen Rural Municipality (ward 1) and Gorkha (ward 2,3,5) Palungtar (ward 1, 2) Municipality	60.00	34.59	94.59	1
11	Budhi-Gandaki Nadi 7	69	Bhimsen Rural Municipality	56.08	34.15	90.24	2
10	Budhi-Gandaki Nadi 6	61	Bhimsen Rural Municipality	54.88	31.92	86.80	3
12	Daraudi Nadi 3	175	Gorkha and Paluntar Municipality and Sahid Lakhan Rural Municipality	48.75	37.05	85.80	4

13	Myarsangdi Nadi	100	Paluntar Municipality and Sahid Lakhan Rural Municipality	44.49	39.14	83.63	5
14	Trishuli Nadi 1	63	Sahid Lakhan Rural Municipality	49.32	31.65	80.97	6
15	Trishuli Nadi 2	129	Gandaki Rural Municipality	51.29	29.52	80.81	7
7	Budhi-Gandaki Nadi 5	219	Aarughat Rural Municipality	51.93	26.72	78.66	8
9	Chepe Nadi	109	Ajirkot and Siranchwok Rural Municipality	49.08	25.64	74.72	9
6	Daraudi Nadi 1	277	Ajirkot and Sulikot Rural Municipality	49.98	23.19	73.18	10
5	Budhi-Gandaki Nadi 4	382	Dharche Rural Municipality	52.87	9.52	62.40	11
2	Budhi-Gandaki Nadi 2	268	Chun Numri Rural Municipality	54.28	6.00	60.29	12
3	Syar Khola	635	Chun Numri Rural Municipality	54.51	3.42	57.93	13
4	Budhi-Gandaki Nadi 3	451	Lower Chun Numri Rural Municipality and Upper Part of Darche Rural Municipality	50.78	5.22	56.00	14
1	Budhi-Gandaki Nadi 1	518	Chun Numri Rural Municipality	37.91	2.06	39.97	15

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 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**.

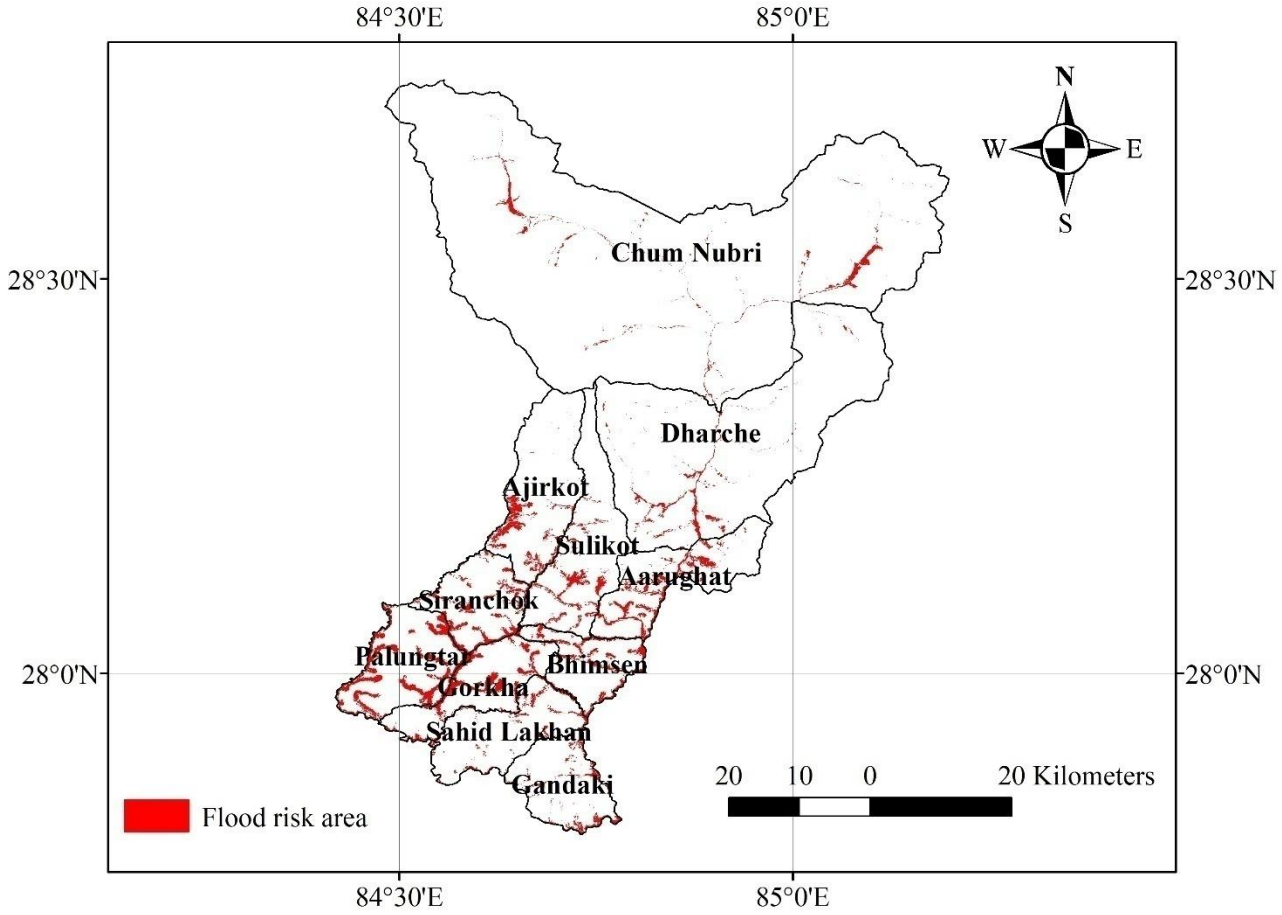

Figure 7: Flood risk in Gorkha District

Due to slope territory, the Gorkha is less flood prone district of the Gandaki Province. Gorkha and Palungtar Rural Municipality are more flood prone local levels of this district (**Figure 7**). Details of flood prone area of this district is shown in **Table 4**

Table 4: Flood risk area of Gorkha

Rural Municipality (RM)/ Municipality	Ward	Location of Flood	River/stream
Palungtar Municipality	5	Dovan	Marsyandi River/ Chepekhola
	7	Satighat	Marsyangdi River/ Pyaudikhola

Gorkha Municipality	2	Shikhar	Daraudi/Masel khola
	10	Chepetar	Daraudi/Larenkhola
	12	Deurali	Daraudi/Larenkhola
	13	Phedi Bagar	Daraudi
Sahid Lakhan RM	3	Kalleri (Lower part)	Daraudi
Gandaki RM	5	Darbun Phant	Budhigandaki/ Gamsur Khola
Bhimsen	1	Nirmal Diya	Jarang Khola, Daraudi
	3,4	Bolan, Tari Phant	Budhi Gandaki / Bhurlung Khola
Siranchok	4	Chorkate Dovan, Chamdanda	Daraudi / Budhigandaki/ Busundi
	6	Naya Sagu, Ratmate, Magar Gaun	Daraudi/Kharse, Kusunde Khola
Arughat	4	Arughat	Budhi Gandaki/Istul Khola
	3	Arkhet Bazar	Arkhet Khola
Ajirkot	1	Baluwa, Soda	Mahabhir / Daraudi / Sau Khola
	5	Chanaute	Daraudi / Syangdi
Sulikot	6	Ulte Gaun	Jarang Khola / Daraudi Khola

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**.

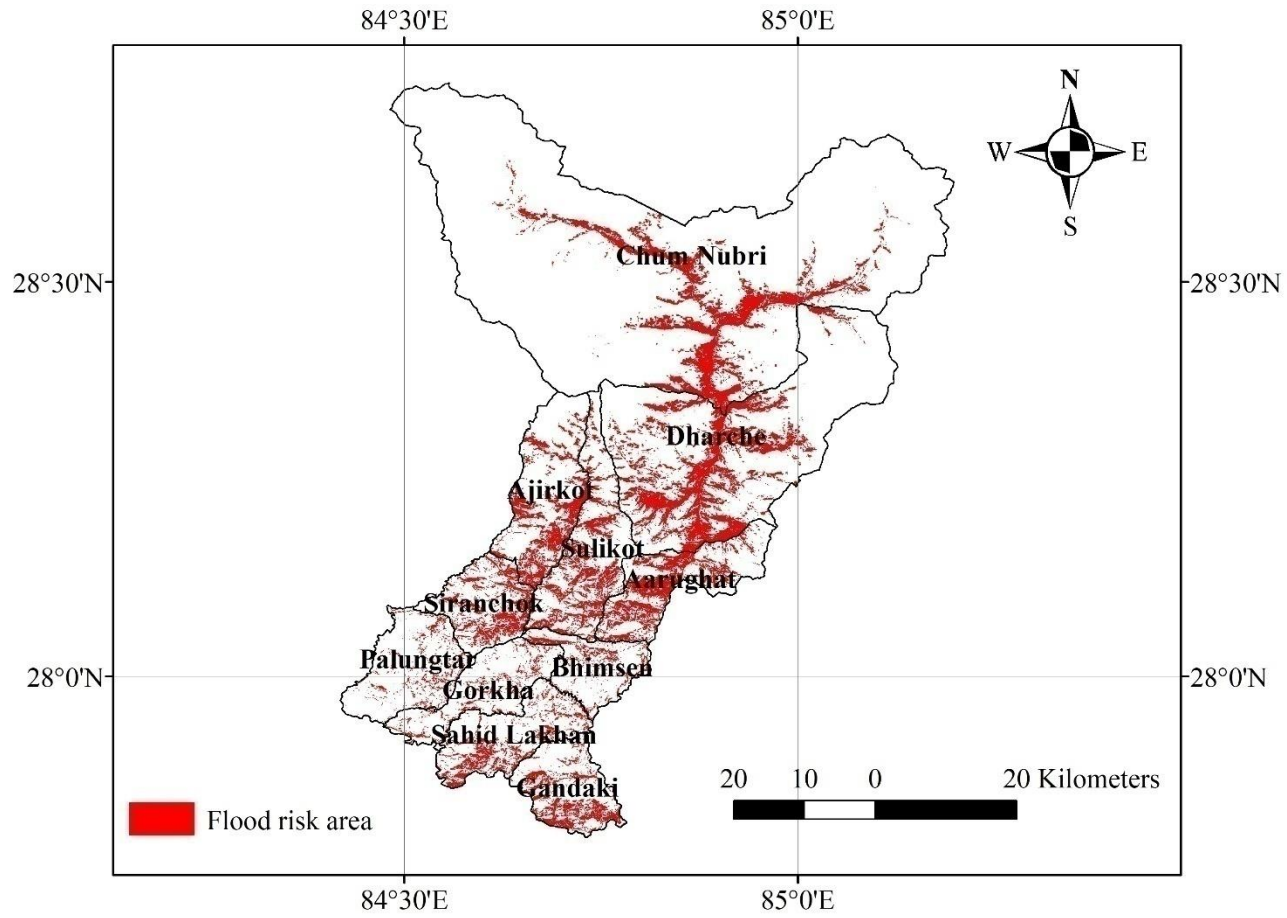

Figure 8: Landslide risk area of GorkhaDistrict

Table 5: Landslide risk area of Gorkha District

Rural Municipality (RM)/ Municipality	Ward	Locations of Landslide	Potential Hazard

Palungtar Municipality	1	Edge cutting of Daraudi River	Edge cutting
	2	Karki Gau, Simpani area	Landslide
	3	Bhandarthok	Landslide
	9	Chherak Area,	Landslide
	10	Edge cutting of Kher khola and Dhau khola	Edge cutting
Gorkha Municipality	2	Ahale Bhangjyang area	Landslide
	4	Eastern part of Toikepani area	Landslide
	6	Lower part of Gorkha Bazaar	Landslide
	7	Edge cutting of Khol khola	Edge cutting
	8	Southern part of Khalte,Khamarebesi	Landslide
	9	Southern part of Shikhar	Landslide
	10	Northern part of Ludi khola	Landslide
	11	Northern part of Ludi khola	Landslide
	12	Edge cutting of Ludi khola	
	13	Dadagaun,Edge cutting of Ludi khola	Landslide
Sahid Lakhan RM	1	Bakreswara, Galdhuk,Bakreshwari	Landslide
	2	Khaltepani area	Landslide
	3	Nibhare area,Gyajhadada area,Bhawantar, Kewarapani area, Edge cutting of Trishuli River and Marsyangdi River	Edge cutting, Landslide
	4	Dhadegau area, Edge cutting of Trishuli River and Judhi khola	Landslide, edge fall
	5	Thumsidada, edge cutting of Dovan khola	Edge cutting, Landslide
	6	Baskotgau, Southern part of Dharchegau	Landslide
	7	Basantegau area	Landslide
	8	Bahi khola edge cutting	Edge cutting
	9	Kholaparigau, Ganigau	Landslide
Gandaki RM	1	Eastern part of Dadagaun and southern part of Devisthan	Landslide
	2	Gyabintar, Bhedabari area, Edge fall of Trishuli River, edge cutting of Pashupati khola	Edge cutting, Landslide
	4	Deurali area	Landslide
	5	Northern side of Gamnsur khola (Keurani area,Darbunphat area)	Landslide
	6	Thumka, Kautikhet, northern part of Korak, Gadhaibesi, Edge fall of Trishuli River	Landslide, edge fall
	7	Badala, Darshandada, edge fall of Trishuli River	Edge fall,

			Landslide
	8	Lower part of Toriswara, Churedada, upper part of Lambu khola, Dhobadighat, upperpart oa Ghalchok, Pallotar area, Edge fall of Trishuli River and Budigandaki River	Edge cutting, Landslide
Bhimsen RM	1	Northern part of Masel khola	Landslide
	2	Khamare rea, Southren part of Okhle, Birupalo area	Landslide
	3	Chautara area, Edge cutting of Budigandaki River	Edge cutting, Landslide
	4	Baddada area, Edge cutting of Budigandaki River	Edge cutting, Landslide,
	5	Kathekholagau	Landslide
	6	Lower part of Barrabote	Landslide
	7	Edge cutting of Budigandaki River and Jyadu khola	Edge cutting
	8	Phedi khola dovan	Landslide
Siranchok RM	1	Khani khola area, easternside of Siranchaur	Landslide
	2	Ramcheamune area, northern part of Khar khola	Landslide
	3	Nawalpue area	Landslide
	4	Phirphire area	Landslide
	5	Bashetgau,Chhoprek area, Western part of Bokse khola, eastern part of Pam	Landslide
	6	Sakhu area, Mathillo gakhu area, tallo Gakhu area,Dhansadada area	Landslide
	7	Jhulungebagar, Shikhar Bhaite, Damalgau area, Sano Dhorani, Kapare area, Kapuswara, Southern part of Goredada, Edge cutting of Daraudi River and Khahare khola	Edge cutting, Landslide
	8	Northern side of Ladi khola, Kalimati area,Edge cutting of Daraudi River and ladi khola	Edge cutting, Landslide
Arughat RM	1	Chhuwardada area, Shyamchet area, Majhgau area, Dhunchet khola area,	Landslide
	2	Bharendada area, Patalekharka	Landslide
	3	Southern Part of ward 3 (Keurepani, Dharapani, Sorangau area), Northern part of ward 3 (Deurali, Shyamran, Soti, Armala, Edge cutting of Budigandaki River	Edge cutting, Landslide
	4	Dharche dada,Westrrn part of Thanti, Thumi, Kokhetar, Buddhigaira, Nebot pokhari, Gundhumu,	Edge cutting, Landslide

		Edge cutting of Budigandaki River and Arkhet khola	
	5	Northern part of samara khola	Edge cutting, Landslide
	6	Khahare khola and Andheri khola area	Landslide
	7	Kalleri, Dadapari, Istul khola area	Landslide
	8	Deurali, Lambagar	Landslide
	9	Edge cutting of Budigandaki River	Landslide
	10	Simarphat,Khatriswara,	Landslide
Ajirkot RM	1	Lower part of marsyu khola, Sadkhola Muhan area, Chisan area, Pachgau, Kharbari area, Dhansira area, Chamrau, Soda, Nilmu, Basbot, Dewalswara, Kaldunswara, Sayagau, Salghari, Edge cutting of Daraudi River, Sad khola and Mahabhir khola	Edge cutting, Landslide
	2	Pos area, Khinpu area, Chiskharka, Olan area, Bhirkuna, Gartatol, Edge cutting of Chepe khola, Syalle khola and Sadi khola	Edge cutting, Landslide
	3	Northern part of Kundung khola, Batase area	Landslide
	4	Mahabhir area, Sirandada, Patle, Harenghaderi, Sirbari area, Edge cutting of Daraudi River and Mahabhir khola	Edge cutting, Landslide
	5	Chanaute area, Manigau area, Ramche, Ghalyabari, Sotekhola area, Lambagar, Sabdirgau, Darbote, Edge cutting of Daraudi River and Syangdi khola	Edge cutting, Landslide
Sulikot RM	1	Upper part of Daraudi River, Pauko khola dovan area, Rumsalkharka area, Syamet, Birujun, Edge cutting of Daraudi River, Chhicha khola and Sherma khola	Edge cutting, Landslide
	2	Barpak area, Shan area, Chhatan area,Rangrun khola area, Pokhari, Edge cutting of Daraudi River and Rangrun khola	Edge cutting, Landslide
	3	Thulogau, upper part of Chitre, Istul khola area, Sisapani area, Thotneri area	Landslide
	4	Saurpani, Arubot, Chanaute area,Hudi khola and Apeng khola dovan area,banchok area, Tallo Simle, Chhahare khola and Adheri khola dovan area,Ranchok area	Landslide
	5	Hudipariban area, Northern part of Hudi khola area	Landslide
	6	Bhaluswara, tallo Masar, Southern part of	Edge cutting,

		Keurepani, Southern part of Manun,Edge cutting of Jarang khola	Landslide
	7	Amle area,Upper part of Khanikhola,Northern part of Daune khola	Landslide
	8	Northern part of Jarang khola,Dhawaridhan, Pandrun	Landslide
Chumnubri RM	1	Burchu and Kasupan area near Samagau,	Edge cutting, Landslide
	2	Side cutting of Budhigandaki River (Ningau, Hunbugau, Gomdan, Linlin)	Edge cutting, Landslide
	3	Side cutting of Budhigandaki River(Bansani, Philim, Nagjet, Sirdibas, Paimo, salleri, Jagat), Northern part of Chhilung khola area, Bhalu khola area and Ghatta khola area,	Edge cutting, Landslide
	4	Side cutting of Budhigandaki River (Tala,Suksam, Gap, Prok, Chhak), Tom khola area	Edge cutting, Landslide
	5	Side cutting of Budhigandaki River (Burbihi, Ranagau), Serang khola area(Krayak, Syaran),Dyang khola area, Baiahuk area,Durjunkharka	Edge cutting, Landslide
	6	Northern Part of Syar khola (Tharun, Taju,Chumlin, Kowa), Sarpukharka area, Ribukharka	Edge cutting, Landslide
	7	Chhokun,Rachen gumba, Southern part of Rachen gumba	Edge cutting, Landslide
Dharche RM	1	Southern part of Landan dada, Yaru khola area,northern part of Dovan khola,Indur area	Edge cutting, Landslide
	2	Side cutting of Budhigandaki River, Samno khola area,Rumchet khola area, Kerauja, Machhakholagau, Miujut khola area	Edge cutting, Landslide
	3	Phabang khola area,Nimrung khola area, side cutting of Budhigandaki River, Lhakpa,Maiku,Renbon,Lisyapu, Mindapuk,Khorlabeshi,Lower part of Khorla	Edge cutting, Landslide
	4	Laprak village,Northern part of laprak, Malong khola area,	Landslide
	5	Northern part of Machhakhola, Sinla, Gumda area, Sinladada area, Lapsibot area	Landslide
	6	Side cutting of Budhigandaki River, Chame khola	Edge cutting,

		cutting (Khanibesi, Chamakharka), Yarsa khola cutting, Yarsa, Yarsa dada, Phalban	Landslide
	7	Side cutting of Budhigandaki River, Khanibesi, Lapubesi, Lapu, Lidin, Bhirkuna, Potgaun	Edge cutting, Landslide

Table 6 : Boundary points of Daraudi 2 (Mid- Daraundi Sub-watershed)

FID	X	Y
0	84.63418	28.00336
1	84.63474	28.00432
2	84.63627	28.00543
3	84.63871	28.00759
4	84.64098	28.00933
5	84.64216	28.0101
6	84.64347	28.01212
7	84.64485	28.0134
8	84.64483	28.01567
9	84.64571	28.01682
10	84.64692	28.01897
11	84.64877	28.01932
12	84.64931	28.01961
13	84.65209	28.02044
14	84.65391	28.02079
15	84.65549	28.02188
16	84.65932	28.02154
17	84.66062	28.02244
18	84.66236	28.02237
19	84.66351	28.02316
20	84.66702	28.02427
21	84.66783	28.02502
22	84.66878	28.02687
23	84.66959	28.02767
24	84.67214	28.02965
25	84.67789	28.02936
26	84.68065	28.02766
27	84.68666	28.02563
28	84.68787	28.02627
29	84.69043	28.02571
30	84.69311	28.02745
31	84.69447	28.02977

32	84.69988	28.0318
33	84.71609	28.03207
34	84.71688	28.03786
35	84.71789	28.03975
36	84.718	28.0425
37	84.71761	28.04358
38	84.71947	28.04501
39	84.72352	28.04347
40	84.72655	28.0435
41	84.7275	28.04316
42	84.72849	28.0446
43	84.73001	28.04859
44	84.73157	28.05016
45	84.73148	28.05234
46	84.73347	28.05333
47	84.73559	28.05622
48	84.737	28.05689
49	84.74066	28.06028
50	84.74076	28.0626
51	84.739	28.06523
52	84.73595	28.06667
53	84.73445	28.06807
54	84.73404	28.07021
55	84.73292	28.07266
56	84.73261	28.07562
57	84.73155	28.07726
58	84.72544	28.0786
59	84.72541	28.07943
60	84.72541	28.07943
61	84.7162	28.07874
62	84.71585	28.07836
63	84.7116	28.08055
64	84.70693	28.08011
65	84.70461	28.08093
66	84.70285	28.08271
67	84.69663	28.08529
68	84.69265	28.08571
69	84.69203	28.08604
70	84.68982	28.08565
71	84.68849	28.086
72	84.68551	28.08819

73	84.68391	28.089
74	84.68151	28.08933
75	84.67823	28.09241
76	84.67706	28.0944
77	84.67716	28.09689
78	84.6768	28.09826
79	84.67599	28.09902
80	84.67552	28.10144
81	84.67348	28.10377
82	84.6723	28.1061
83	84.67076	28.10752
84	84.66821	28.10822
85	84.66593	28.1094
86	84.66329	28.10929
87	84.65896	28.11015
88	84.65724	28.10955
89	84.65376	28.1096
90	84.65134	28.11065
91	84.64799	28.11177
92	84.64414	28.11214
93	84.63997	28.11423
94	84.63782	28.11752
95	84.63606	28.11914
96	84.63196	28.12136
97	84.63151	28.12279
98	84.63157	28.12592
99	84.63238	28.12711
100	84.6298	28.12994
101	84.62768	28.13118
102	84.62736	28.13515
103	84.62679	28.13495
104	84.62484	28.13488
105	84.62274	28.13599
106	84.62126	28.13544
107	84.62079	28.13445
108	84.61931	28.1335
109	84.61793	28.13161
110	84.61592	28.13113
111	84.61408	28.13016
112	84.61126	28.12989
113	84.60821	28.12877

114	84.60743	28.1288
115	84.60317	28.12514
116	84.60566	28.12278
117	84.60622	28.12119
118	84.60516	28.11849
119	84.60331	28.11631
120	84.60431	28.11441
121	84.60431	28.11441
122	84.60211	28.11311
123	84.60204	28.11141
124	84.60404	28.10682
125	84.6046	28.10483
126	84.60622	28.10218
127	84.60752	28.09922
128	84.60607	28.09734
129	84.60538	28.09588
130	84.60388	28.09448
131	84.60349	28.09127
132	84.60255	28.08698
133	84.60044	28.08432
134	84.59794	28.07766
135	84.59683	28.07622
136	84.59683	28.07518
137	84.59459	28.07433
138	84.59374	28.07375
139	84.59264	28.07379
140	84.59023	28.07294
141	84.58653	28.07462
142	84.58279	28.07571
143	84.57904	28.07599
144	84.57515	28.07877
145	84.5725	28.08042
146	84.56918	28.08048
147	84.56726	28.07998
148	84.56516	28.081
149	84.5632	28.08127
150	84.56177	28.08237
151	84.55073	28.08172
152	84.54716	28.08293
153	84.54247	28.08093
154	84.53961	28.07855

155	84.54105	28.07666
156	84.54046	28.06935
157	84.53834	28.06795
158	84.53672	28.06575
159	84.53327	28.06406
160	84.52881	28.06243
161	84.52661	28.06208
162	84.52594	28.05772
163	84.52875	28.05603
164	84.52989	28.05107
165	84.54924	28.04057
166	84.55016	28.03609
167	84.55129	28.03446
168	84.5515	28.03077
169	84.55516	28.02837
170	84.56001	28.02765
171	84.56491	28.02378
172	84.56796	28.02519
173	84.57057	28.0252
174	84.57321	28.0235
175	84.579	28.02161
176	84.57903	28.01991
177	84.58368	28.01641
178	84.58467	28.01444
179	84.58795	28.01361
180	84.59127	28.01543
181	84.59905	28.01461
182	84.6041	28.01277
183	84.60451	28.00925
184	84.60804	28.00405
185	84.61448	28.00437
186	84.61644	28.00541
187	84.63177	28.00406

3.4.3. 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 using DEM in ArcGIS. Southern 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 are fall in the moderate slope. Out of 154 km^2 of sub watershed, slope less than 5 degree covers 4.57 km^2, slope between 5 and 30 degree covers 125.27 km^2 and slope more than 30 degree covers 24.25 km^2 .

Table 7 : **Slope table of Mid-Daraundi Sub Watershed**

S.N.	Slope	Area km	Percent
1	< 5 degree	4.57	3.0
2	5-30 degree	125.27	81
3	> 30 degree	24.25	16
	Total	154	100

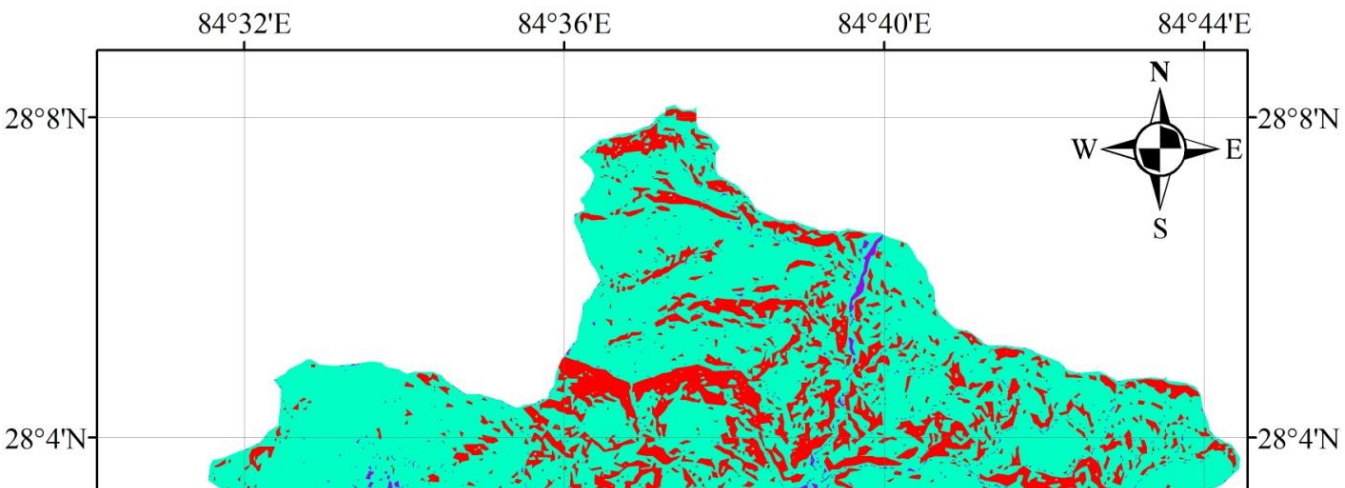

Figure 9: Slope map of Mid-Daraundi Sub Watershed

3.4.4. 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 easterly 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 north (**Figure 12**).

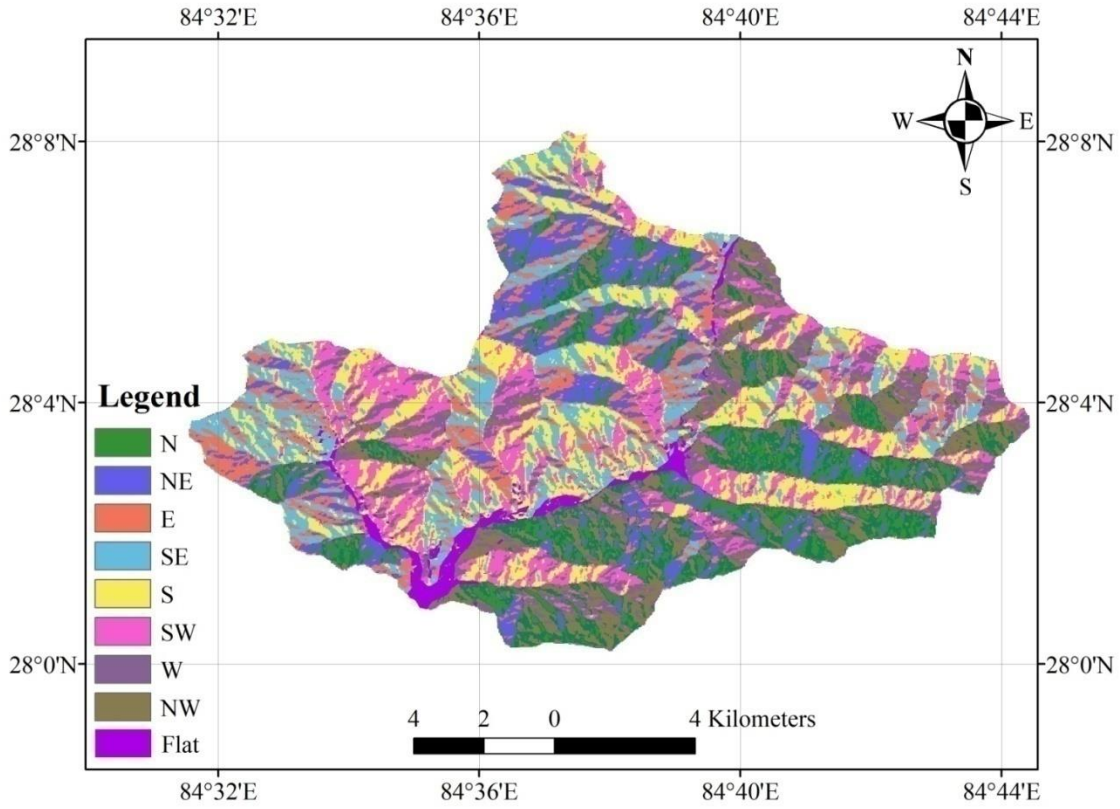

Figure 10: Aspect map of Mid- Daraundi Sub Watershed

This study categorized the eight aspect categories and flat. Four km^2 of watershed is flat area. Northern, north eastern and north western are major aspects of this sub watershed. South west aspect covers only four km^2 of watershed, which is the least area covered by the specific slope category (**Table 8**).

Table 8: Aspect of Mid Daraundi Sub Watershed of Gorkha District

S.N.	Aspect	Area (km^2)
1	North	25.07
2	North East	16.66
3	East	15.43
4	South East	19.4
5	South	24.99
6	South West	20.71
7	West	12.11
8	North West	15.06
9	Flat	4.57
	Total	154

3.4.5. Land use/land cover

The land use pattern and land management practices have great effect on the runoff yield which consequently effects on the watershed conditions. Altogether land use system of watershed is classified in 8 categories (**Figure 10**). Major LULC type of the sub watershed are Agriculture and broadleaved open forest whereas Bare land and grassland cover only few areas (**Table 8**).

Table 6 Land use land cover of Mid-Daraundi Sub Watershed of Gorkha District

S.N.	Land cover type	Area (km^2)
1	Needle leaved close forest	6.33
2	Needle leaved open forest	1.93
3	Broadleaved close forest	3.31
4	Broadleaved open forest	30.90
5	Shrubland	3.26
6	Grassland	1.51
7	Agriculture	113.08
8	Bare area	0.01
Total		154

3.4.6. Population

According to the population census of 2011, total household and total population of the subwatershed areas are 9972 and 38,937 repectively. Out of total population, 16968 are male and 21969 are female. The population density of the district is 75/km^2. Population density of the Mid-Daraundi Sub Watershed is 252/km^2. Major casts of Mid-Daraundi Sub Watershed are Gurung, Brahmin, Chhetri and Disadvantaged groups . The mother language of the most of the people is Nepalese and Gurung language. Mostly people follows Hindu and buddhist religion in the subwatershed areas.

S. N.	Location	Population			Total H.Hs
		Male	Female	Total	
1	Palungtar Municipality 1	1606	2063	3669	937
2	Palungtar Municipality 2	1682	2243	3925	1114
3	Siranchowk Rural Municipality 4	1347	1689	3036	785
4	Siranchowk Rural Municipality 5	1261	1596	2857	746
5	Siranchowk Rural Municipality 6	1348	1638	2986	694
6	Siranchowk Rural Municipality 7	1396	1751	3147	771
7	Siranchowk Rural Municipality 8	1366	1649	3015	741
8	Barpak sulikot Rural Municipality 6	1675	2204	3879	903
9	Barpak sulikot Rural Municipality 8	1102	1422	2524	664
10	Bhimsen Rural Municipality 1	1605	2234	3839	1016
11	Gorkha Municipality 2	1017	1351	2368	575
12	Gorkha Municipality 3	1563	2129	3692	1026
	Total	16968	21969	38937	9972

3.4.7. Agriculture and livestock

Rice, maize, millet and cerals are major agricultural product of Mid-Daraundi Sub Watershed. Agriculture of this area is facing lack of irrigation, manure, market and mechanized technology. Goat, buffalo, poultry and fish are major livestock of this area.

Seasonal calendar of Crop and weather

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Av. Temp (^{0}C)	16.7		20.0		24.7		28.9		30.1		30.3		29.5		29.5		28.9		26.8		22.9		18.8	
Av. Rainfall (mm)	7.3		9.6		15.1		45.6		110.8		228.4		515.6		447.1		310.0		83.3		4.9		9.8	
Crop	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Rice											←									→				
Wheat	→					→															←			
Maize (s)							←											→						
Maize (w)	→					→														←				
Legumes	→					→															←			
Vegetables	→						→													←				

3.4.8. Forests

Gorkha districts comprises of 43.06 percentage of its area as forest. This sub watershed is land of 40 community 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, Laligurans and Non Timber Forests Products (NTFPs).

3.4.9. Micro watersheds

This Mid-daraundi Sub Watershed of Gorkha District covers seven micro watersheds. The area of Mid-daraundi Sub Watershed are 154 km^2 respectively. **Figure 13** is showing two micro watersheds of this sub watersheds.

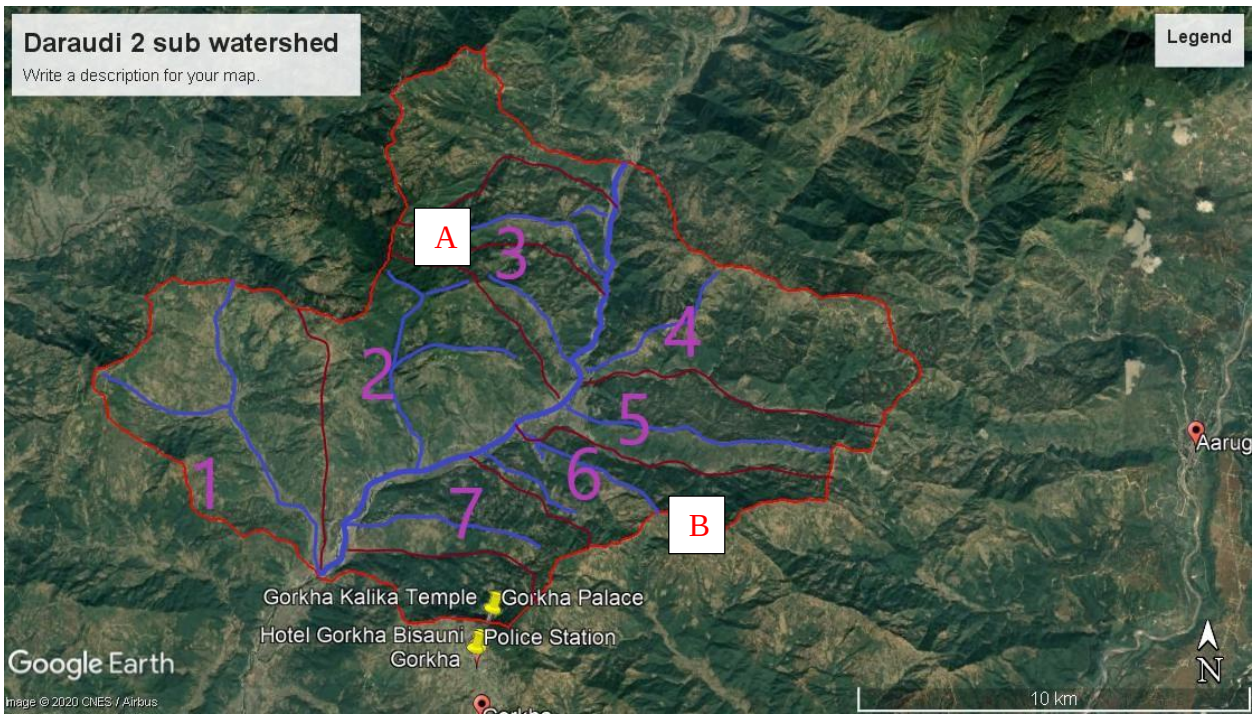

Figure 11: Mid-Daraundi Micro Watersheds

3.4.10. 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 154 $km^2$of sub watershed come under the umbrella of micro watersheds and are the major components considered on integrated approach of watershed management. The issues related to these components are the concern of development organization to deal with.

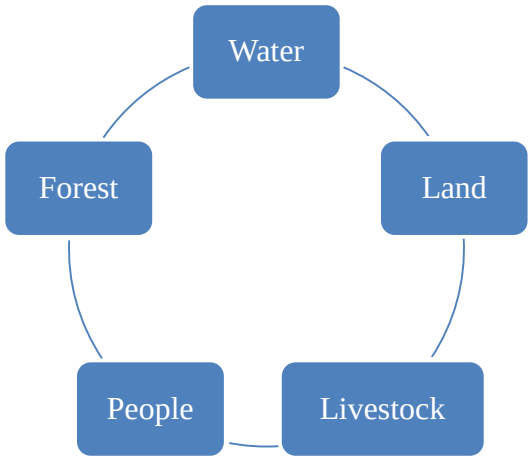

Figure 12: Major components of watershed

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 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

3.4.11. 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 7: 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, bio-engineering 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 support 1.2.4. Sediment trap structures	Structural /bio-engineering 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, bio-engineering, 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	Rural/national road side slope stabilization measures

	3.4. Hotspot treatment	(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 watershed management plan preparation 5.3. Nursery management 5.4.Motivator/conservation assistant 5.5.Maintenance/follow up	Hazard map preparation, sub watershed plan preparation, nursery build up /seeding production, hiring local staff as conservation assistants, maintenance and follow up of past activities.

3.4.12. 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.

3.4.12.1. 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.

3.4.12.2. 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.

3.4.12.3. 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 8: Needs of river bank cutting stabilization

S.N.	Flood causing stream	Municipality/ Rural municipality	Address	Status	Affected area
1	Daraundi	Siranchowk 4,5,6,7 Palungtar 1,2	near river	Active in monsoon	Agriculture land, Forest, Grazing land & village
2	Lyangdi	Siranchowk 6,7	Shrinathkot	Active in monsoon	Forest, Grazing land
3	Ludi, khahare	Siranchowk 7	Gakhu Shrinathkot	Active in monsoon	Agriculture land, Forest, Grazing land & Village
4	Syangdi	Siranchowk, 8	Jaubari	Active in monsoon	Agriculture land, Forest, Grazing land
5	Bhusunde khola, Khar khola	Palungtar 1		Active in monsoon	Agriculture land, Forest, Grazing land
6	Dhundhure khola	Palungtar 2		Active in monsoon	Agriculture land
7	Masel and Gangate	Gorkha 2	Tallo gangate, Masel Bans bote khet	Active in monsoon	Agriculture land
8	Bini Khola	Gorkha 3	Cha mure	Active in monsoon	Agriculture land
9	Ramche khola	Barpak sulikot 8		Active in monsoon	Agriculture land and forest land
10	Tal Khola	Bhimsen 1	Darang	Active in monsoon	Agriculture land and forest 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 9: Needs of irrigation canal maintenance work

S.N.	Name of irrigation canal	Municipality/ Rural municipality	Area of irrigation	Benefited household	Status
1	Macheditaar irrigational canal	Siranchowk 4,5,6,7	approx. 220 Ropani	600	Need for protection
2	Dedhgautaar irrigational canal	Siranchowk 6,7	approx. 150 Ropani	500	Need for protection
3	Raabang Tari irrigational canal	Siranchowk 7	approx. 150 Ropani	50	Need for protection
4	Gadhiya Khola, Baida irrigational canal	Siranchowk, 8	30 Ropani	15	Need for protection
5	Dudhure Belbas irrigation canal	Palungtar 1	500 Ropani	150	Need Maintenance
6	Dhundure, aagatari and Naubise irrigation canal	Palungtar 2	100 Ropani	60	Need Maintenance
7	Masel Gangate Irrigation canal	Gorkha 2	350 Ropani	125	Need Maintenance
8	Bhalamtari Junge and cha mure Irrigation canal	Gorkha 3	450 Ropani	150	Need Maintenance
10	Simle, Tari and Tinkhande daletar Irrigation canal	Barpak sulikot 8	250 Ropani	250	Need Maintenance
11	Tal khet, Nibel and Masel Khola barhabise Irrigation canal	Bhimsen 1	150 Ropani	150	Need Maintenance

c. Landslide and Gully 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 10: Needs of landslide treatment.

S.N.	Name of landslide and gully	Address	Status	Affected area	Remarks
1	Chilaune swara landslide	Siranchowk 7	Active	Residental area	Large
2	Finam landslide	Siranchowk 8	Active	Residental area	
3	Beldainda	Siranchowk 6	Active	Residental area	
4	Tinkhande	Siranchowk, 8	Active	Residental area	
5	Bandre, Sundar khola, Thapa bhanjhyang	Palungtar 1	Active	Residental area and Ag land	
6	Arubare ratdainda & himalaya pra bi	Palungtar 2	Active	Residental area and school	
7	Dharapani Masel & Jukepani	Gorkha 2	Active	Residental area	
8	Lapse & Aapchaur	Gorkha 3	Active	Residental area and school	
9	Rupseni Bhir & Jharang	Barpak sulikot 8	Active	Residental area	
10	Bhute dainda & Bagale village	Bhimsen 1	Active	Residental area	

d. Road slope stabilization

Roads are major factors of accelerating the soil erosion. Now a 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 Stabilization work

S.N.	Name of road	Address	Status of soil erosion	Status of road
1	Madhya Pahadi Lokmarga	Nayasanghu	Active	Kachhi, Hile
2	12 kilo Barpak Road	kamere	Active	Kachhi, Hile
3	Amarsingh Marga	Gauthali pata	Active	Kachhi, Hile
4	Pipletari - chapa vanjhyang & Jyoti chautara- belbas road	Palungtar 1	Active	Kachhi, Hile
5	Baddainda- budhichaur -falam khani road & katahare -Suntale chapabhanjhyang road	Palungtar 2	Active	Kachhi, Hile
6	Gorkha -Arughat road	Gorkha 2	Active	Kachhi, Hile
7	Gorkha - Nibel & Swara – ward office road	Gorkha 3	Active	Kachhi, Hile
9	Rupseni – tinkhande Road	Barpak sulikot 8	Active	Kachhi, Hile
10	Ghyampesal road	Bhimsen 1	Active	Kachhi, Hile

e. Water Source Conservation Program

Roads are major factors of accelerating the soil erosion. Now a 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 12: Needs of Water source conservation work

S.N.	Name of water source	Address	Status	Conservation measures
1	Dhakal swar, Jhithane pani, Mahagau thumki drinking water source Kahare khola to chopprak water source Kapre Swara water source Charchare, maidan water source Sakai khola Ballahari water source	Siranchowk 5	Need to be conserved	Construction Maintenance work needed
2	Balekhu, Chipleti , Magar gau , Langdi Besi , Kalimati & Finam water source	Siranchowk, 8	Need to be conserved	Construction Maintenance work needed
3	Lakhuri fed, Pangre & Junge kholsi	Palungtar 2	Need to be conserved	Construction Maintenance work needed
4	Dharapani, Kal thumka, Dhar garha, Khapte gaira, Devisthan & Bohoragaun Water source	Gorkha 2	Need to be conserved	Construction Maintenance work needed
5	Mulpani water source	Gorkha 3	Need to be conserved	Construction Maintenance work needed
6	Bokhala water source	Barpak sulikot 7	Need to be conserved	Construction Maintenance work needed
7	Khanaya chaur & Tinkhande Water source	Barpak sulikot 8	Need to be conserved	Construction Maintenance work needed
8	Bagale Gaubasti & Bhote kholsa Water source	Bhimsen 1	Need to be conserved	Construction Maintenance work needed

f. Lakes, Conservation pond and Wetland Conservation Program

Roads are major factors of accelerating the soil erosion. Now a 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 13: Needs of Lakes, ponds or wetland conservation work

S.N.	Name of ponds, lakes or wetlands	Address	Status	Conservation measures needed
1	Bhete Pokhari & Mathure pokhari	Siranchowk 4	Need to be conserved	Pond maintenance/ Construction
2	Chitre Pokhari & Gagre dainda pokhari	Siranchowk 5	Need to be conserved	Pond maintenance/ Construction
3	Sunpokhari, Illam pokhari and Okhale	Siranchowk 7	Need to be conserved	Pond maintenance/ Construction
4	Khurpajung, Lunga and Bandre	Palungtar 1	Need to be conserved	Pond maintenance/ Construction
5	Rip gau, Bijuli dainda	Palungtar 2	Need to be conserved	Pond maintenance/ Construction
6	Chyan dainda	Gorkha 2	Need to be conserved	Pond maintenance/ Construction
8	Mulabari	Barpak sulikot 7	Need to be conserved	Pond maintenance/ Construction
9	Dharapani, Archale aahal	Barpak sulikot 8	Need to be conserved	Pond maintenance/ Construction
10	Thulopokhari	Bhimsen 1	Need to be conserved	Pond maintenance/ Construction

3.4.12.4. 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.

3.4.12.5. 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.

3.4.13. Costs and funding

3.4.13.1. 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.

Table 14: Estimation of activities for the five years planning

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	1	1	1	1	1	5	5000	1000/No
1.b	Gully/torrent treatment	Place	1	1	1	1	1	5	5000	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	2	2	2	2	2	10	15000	1500/Km

4.b	Drinking water supply system improvement / Irrigation canal maintenance	No	1	1	1	1	1	5	1000	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	1500	300/Year
5.e	Income generation activities	Package	1	1	1	1	1	5	250	100/Packa
6	**Institutional development**									
6.a	Users and farmers training	Times	1	1	1	1	1	5	500	100/Times
6.b	Women motivators / youth club	No	1	1	1	1	1	5	500	150/No
6.c	Study tours and cross visits	Times	1	1	1	1	1	5	250	200/Times
6.d	Production of extension materials	L.S.	1	1	1	1	1	5	250	50/Times
6.e	Conservation education in secondary school program	Times	1	1	1	1	1	5	250	50/Times
6.f	Miscellaneous (programs as per need)	L.S.							200	
Total									67550	

3.4.14. 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, Gorkha
4. Baudikaali and Buligtar Rural 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.

3.4.15. Plan implementation approach

SWMO Tanahun is doing the watershed management activities in GorkhaDistrict 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.

3.4.16. 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 Agriculture, Livestock, Irrigation, Tourism, Road sector,

Bungdi Kali and Bulingtar Rural Municipality, INGOs/NGOs working on the sub watershed area and at local level representative of local CBOs, and political leaders.

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.

3.4.17. 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 groupmaintenances.

3.4.18. 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 of Industry, Tourism, Forest and Environment (MOITFE) as well will frequently monitorthe works. Public auditing will be done at various stages of activity implementation in order to maintain transparency, accountability and reliance.

3.4.19. 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 15: 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 and stabilized	SWMO activity profiles, report of MOITFE, FD, DCC, RM and 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 subbasin and subwatersheds of the GorkhaDistrict. 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 11 sub watersheds were identified. During the study, Grindri Khola Sub Watershed of Kawasoti 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 Bungadi - Dungre Khola Sub Watershed which is second top prioritized sub watershed of the district. Resourceallocation to these prioritized sub watersheds are 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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APPENDICES

PHOTO PLATES

Landslide caused by the road

Landslide caused by the road

Landslide

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