Sub watershed delineation, prioritization and preparation of sub watershed management plan of Nawalparasi (Bardaghat Susta Purba) District of Gandaki Province, Nepal

Submitted to:

Soil and Watershed Management Office, Tanahun

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FOREWORD

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

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

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

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

With the advent of modern technologies such as Geographic Information System and Remote Sensing, the prioritization of sub watersheds of Nawalparasi (Bardaghat Susta Purba) District has been carried out and management plan of the prioritized sub watershed areas have been prepared by using these tools. I would like to express my thanks to the consulting team of SMART Pvt. Ltd. I also express my thanks to office staff particularly Soil Conservation Officer Bidurnath Sapkota, Chandra Prakash Sedai, Watershed Management Officer Shyamsundar Adhikari, Soil Conservation Assistant Umanga Baral, Administration Officer Shreekant Neupane, Accountant Kamal Bhattarai and all other staff of SWMO Tanahun for their help in the course of prioritization of sub watersheds and preparing the management plan of Bungadi_Dungre Sub Watershed of this district.

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

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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 Nawalparasi (Bardaghat Susta Purba) 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 bio-physical and anthropogenic value. Bio-physical value provides 60% weight and anthropogenic value provides 40% weight for the study. A total of 11 sub watershed are delineated in this district. Finally, sub watershed management plan of Bungadi-Dungre Khola Sub Watershed was prepared. This sub watershed covers the 68 km^2 area of Bungdikali and Bulingtar Rural Municipality of Nawalparasi (Bardaghat Susta Purba) District. Total NRs 6,75,50,000 is proposed for proper management of Bungadi-Dungre Khola Sub Watershed for five years. This sub watershed may be taken up with development and management plans to conserve natural resources on a sustainable basis with immediate effect, which will ultimately lead to soil and water conservation for benefit of people.

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

1. INTRODUCTION

1.1. Background

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

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

Soil conservation and watershed management activities have been widely acknowledged at field level but necessary data, technology, planning, and budget are felt insufficient. Moreover, the implementation part has been a challenge for the different political units in different aspects like lack of coordination, consideration of upstream-downstream linkages, partial and incomplete solutions of problems on the same river system and other socio-cultural issues at the field level.

As water runs across different political boundaries, the best way to manage is to address the natural and hydrological units of the river basin by bringing together all the interests of upstream and downstream. However, previously implementation of soil and watershed conservation programs had been implemented within the political units (districts) as working boundaries. That approach makes life difficult for the natural resource manager to bring coordination, cooperation and synergy of the conservation efforts among the upstream and downstream stakeholders.

Nepal is situated in the central part of the Himalaya (26022' - 30027' N, 80004' - 88012' E), covering an area of 1,47,181 km^2 and an elevation ranges from 67 m to 8848 m. Nepal has diverse climates due to the large variation in elevation. The climate varies from a humid tropical type in the tropical lowlands in the south to alpine cold semi-desert type in the trans-Himalayan zone (Ohsawa et al., 1986). Nepal's forest ecosystems can be categorized into 10 major groups based on climatic conditions: (1) tropical, (2) subtropical broad-leaved, (3) subtropical conifer, (4) lower temperate broad-leaved, (5) lower temperate mixed broad-leaved, (6) upper temperate broadleaved, (7) upper temperate mixed broadleaved, (8) temperate coniferous, (9) subalpine, and (10) alpine scrub (Stainton, 1972). The average annual rainfall is around 1000 – 2000 mm, but sometimes it exceeds 3000 mm in some lower parts of the country (Ichiyanagi et al., 2007). Nepal has a diverse geography that ranges from permanent snow and ice-covered very rugged Himalayan Mountains in the north to the tropical alluvial plains in the south. Due to variations in climate and topography, Nepal is classified into five physiographic zones (i.e., Terai, Siwalik, Middle Mountain, High Mountain and Himalaya) (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: Nawalpur, Tanahun, Gorkha, Lamjung, Kaski, Syanjya, Parbat, Baglung, Myagdi, Manang, and Mustang. Similarly, there are 85 local administrative bodies, Nepal's biggest Pokhara Metropolitan City, 26 Municipalities and 58 Rural Municipalities. There is a constitutional provision of 60 members including proportional to the state assembly (MoITFE, 2018). In the north-central part of Nepal, the Gandaki Province is spreading from Himal to Terai from north to south. Near the border of India, the lowest part near the Gandak canal of Narayani River is at the height of 93 meters above sea level. This height

went up gradually to Dhaulagiri is a huge iceberg with 8,167 meters, Manasalu 8,163 meters, and Annapurna first 8,091 meters. In this state, only the high Himalayan mountain range has fallen to the middle of the country. The valley is situated in the upper part of Manang, Mustang, and 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 *Castenopsis indica.* The major forest management models exercised in the province 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. Guchchi Chyau (*Morchella esculenta*), Kurilo (*Asparagus officinalis*), Lauth Salla (*Taxus baccta*), Nirmasi (*Delphinium denudatum*), Okhar (*Juglans regia*), Paakhanved (*Bergenia ciliate*), Panchaule (*Dactylorhiza hatageria*), Satuwa (*Paris polyphylla*), Sungadhwal (*Valeriana jatamansi*), and Timur (*Zanthoxylum piperitum*) 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 planning and 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 Nawalparasi (Bardaghat Susta Purba) district
- To prepare the management plan of top vulnerable sub watershed

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. Baudikaali Rural Municipality also demands the similar type of work in this site as this is very important to conserve this area. Almost all people of Bungdikali Rural Municipality and some people of Bulingtar Rural Municipality (wards: 5 and 6) 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 Bungadi-Dungre Khola 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.

Bio-physical and socio-economic 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 Nawalparasi (Bardaghat Susta Purba) District of Gandaki Province (**Figure 1**). The district covers an area of 1,043 km^2 and geographically located at 27.32°N latitude and 83.40°E longitude. The district is divided into 8 local level in which 4 are municipality and 4 are rural municipality. Sal forest is the major forest type of this district. Lowest elevation of the district is 103 m (from mean sea level) whereas highest elevation is 1872 m (from mean sea level).

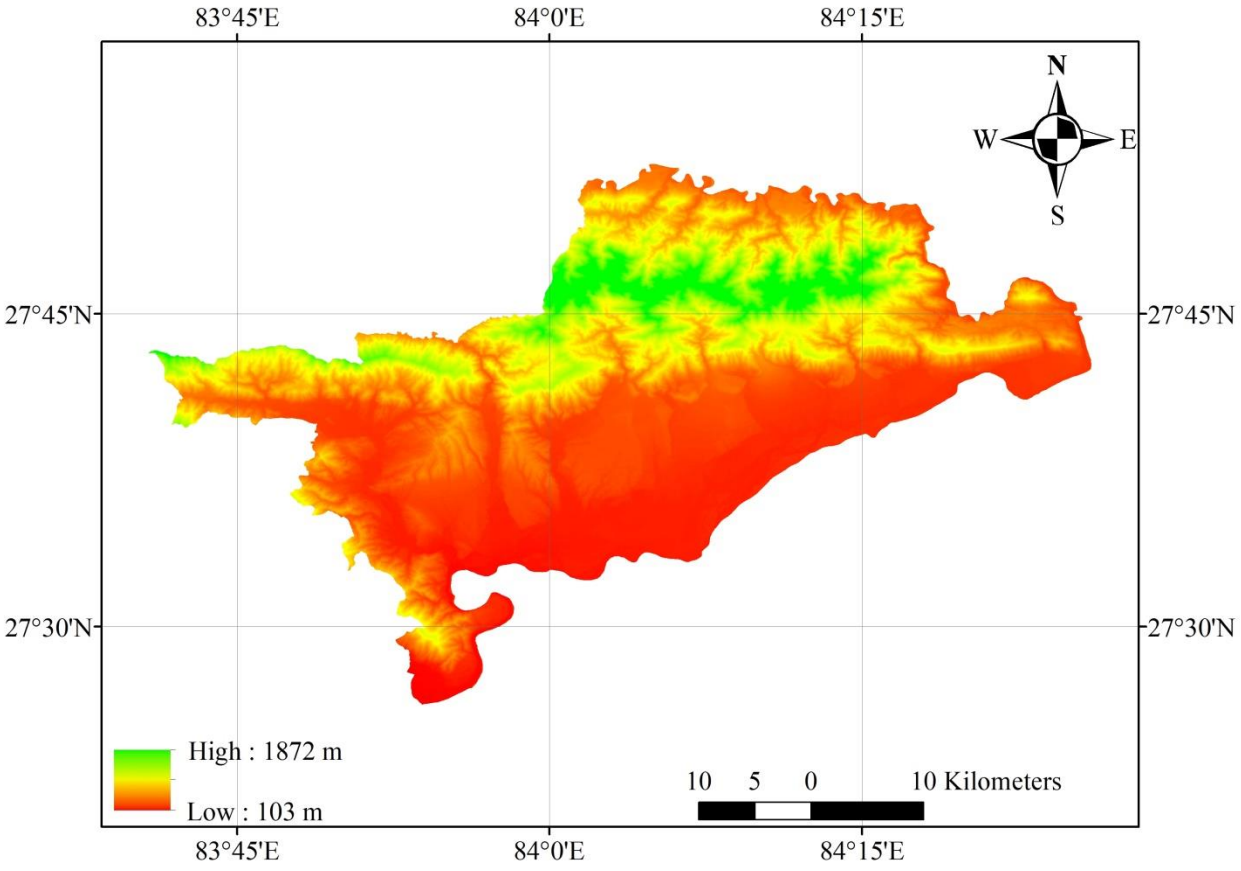

Figure 1: Study area with digital elevation model

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 United States Geological Survey (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.

2.3. Sub watershed delineation

Similar to the 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 sub watershed; watershed tool of ArcGIS was used (use flow direction raster as input raster) to prepare the raster file of sub watershed. Finally, raster files were converted to polygons using raster to polygon tool. For large streams, segments of stream were delineated as sub watersheds. At the time of segmentation, areas of sub watersheds were balanced (try to make equal sizes of watershed within the district) and considered the local level (try to segment based on the boundary of the local level). Delineation process tried to inbound the watershed in a single local level (Metropolitan City, Municipality and Rural Municipality).

2.4. Sub watershed prioritization

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

2.4.1. Bio-physical characteristics

Bio-physical 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 considered as low erosion potentials. Slope map of Nawalparasi (Bardaghat Susta Purba) District is shown in **Figure 2**.

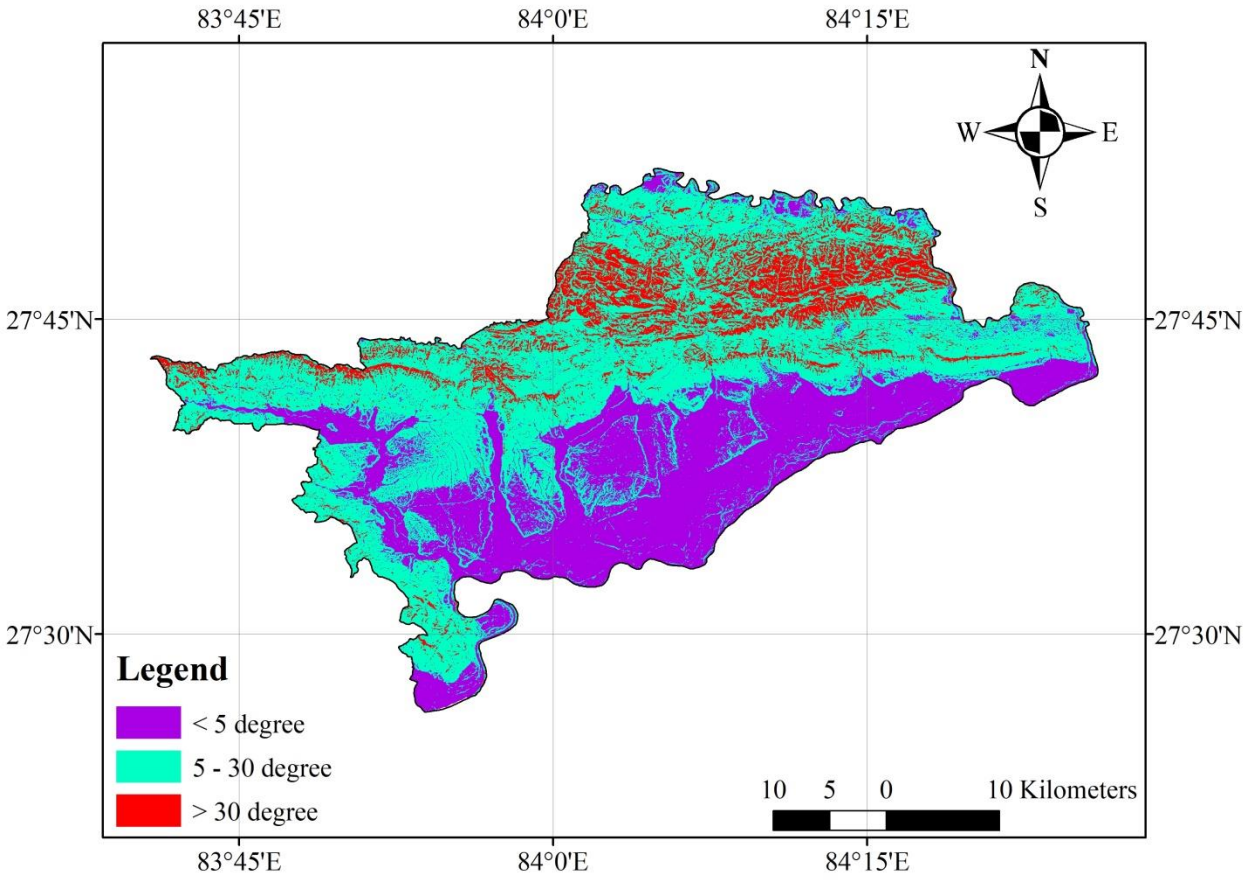

Figure 2: Slope of the Nawalparasi (Bardaghat Susta Purba) District

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, shrub land, grassland and lake were considered as medium and close forest, built-up area, snow and glacier were considered as low erosion potentials. Land use / land cover maps of this district is shown in **Figure 3**.

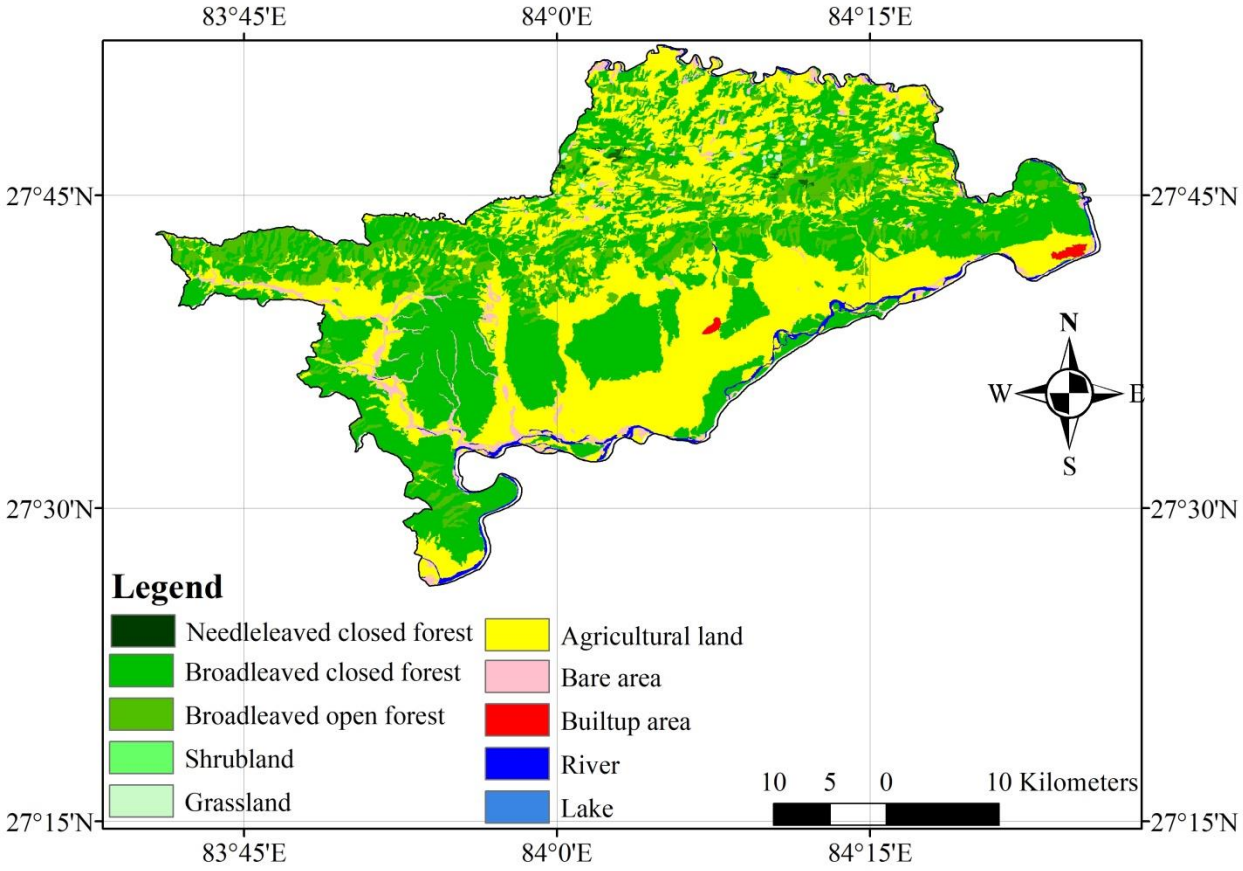

Figure 3: Land use/land cover of Nawalparasi (Bardaghat Susta Purba) District

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 bio-physical 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 bio-physical value (SWSBPV)

Bio-physical and population parameters are combined in finalizing the sub watershed prioritization. Bio-physical 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. Following equation where LULSEPV is the land use land system erosion potential value of the sub watershed derived in Step IV.

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

2.4.2. Anthropogenic characteristics

Resource degradation caused by ecological phenomena in the Nepalese hills is thought to be beyond the control of soil conservation and watershed management measures on financial and economic 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 network 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 and 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 (https://www.geofabrik.de/data/shapefiles.html). This downloaded network and boundary shapefile of 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 bio-physical and anthropogenic characteristics

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

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

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

SWSPCV = SWSBPV + SWSPDNV + SWSRDNV + SWSLDNV

Step II Priority ranking

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

2.5. Hazard mapping

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

2.5.1. Data collection

2.5.1.1 Primary data collection

First of all, discussion with government officials and other stakeholders were conducted in district to identify the potential risk zone and locations of hazards. Then study team visited and identified locations for collection of GPS points for modeling and mapping. The team also

recorded other information likes photos, type of hazards, condition of hazards, affected population, and impact of hazards, land use types and possible remedy measures.

2.5.1.2 Secondary data collection

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

2.5.1.3 Environmental variables

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

Table 1: Environmental variables used for the study

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

Topographical variables

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

Climatic variables

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

Vegetation-related variables

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

Forest cover data prepared by Hansen et al. (2013) was downloaded from the Global Forest Change website and 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 was smoothed by using an adaptive Savitzky-Golay filter in the TIMESAT

program (Jönsson and Eklundh, 2004) to reduce the cloud effect. Finally mean EVI was calculated and used for the modeling.

Anthropogenic variables

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

2.5.2. Modeling

Maximun Entropy (MaxEnt) is a software program used to model species distributions by using geo-referenced occurrence data and environmental variables to predict suitable habitat for a species (Phillips et al., 2006). This model is also successfully used for disaster risk modeling. Variables listed in **Table 1** were incorporated into MaxEnt (version 3.4.1) along with occurrence data of hazards to determine potential disaster risk zone. We selected 1000 maximum iterations and 10 replicates during the 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 flood risk 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 during the 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.

2.6. Preparation of management plan

2.6.1. Data collection

2.6.1.1. Primary data sources

Household survey

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

PRA and RRA

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

Field observation

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

Local body profile survey

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

2.6.1.2. Secondary data sources

District profiles 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 for planning.

2.6.2. Data analysis

GIS software followed by Google Earth were used to delineate a sub watershed area for conservation of water sources in the long run. Thematic layers were gathered from ICIMOD and DEM from USGS website for slope, aspect, altitude variation, LULC. Problems identified from field survey was analyzed and appropriate activities was recommended to overcome the issues. Excel was used to analyze the data during the study.

3. RESULTS AND DISCUSSION

3.1. Sub basins of Gandaki Province

This study identified and delineated four sub basins (Budhi Gandaki, Marsyangdi, Seti and Kali Gandaki) 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.

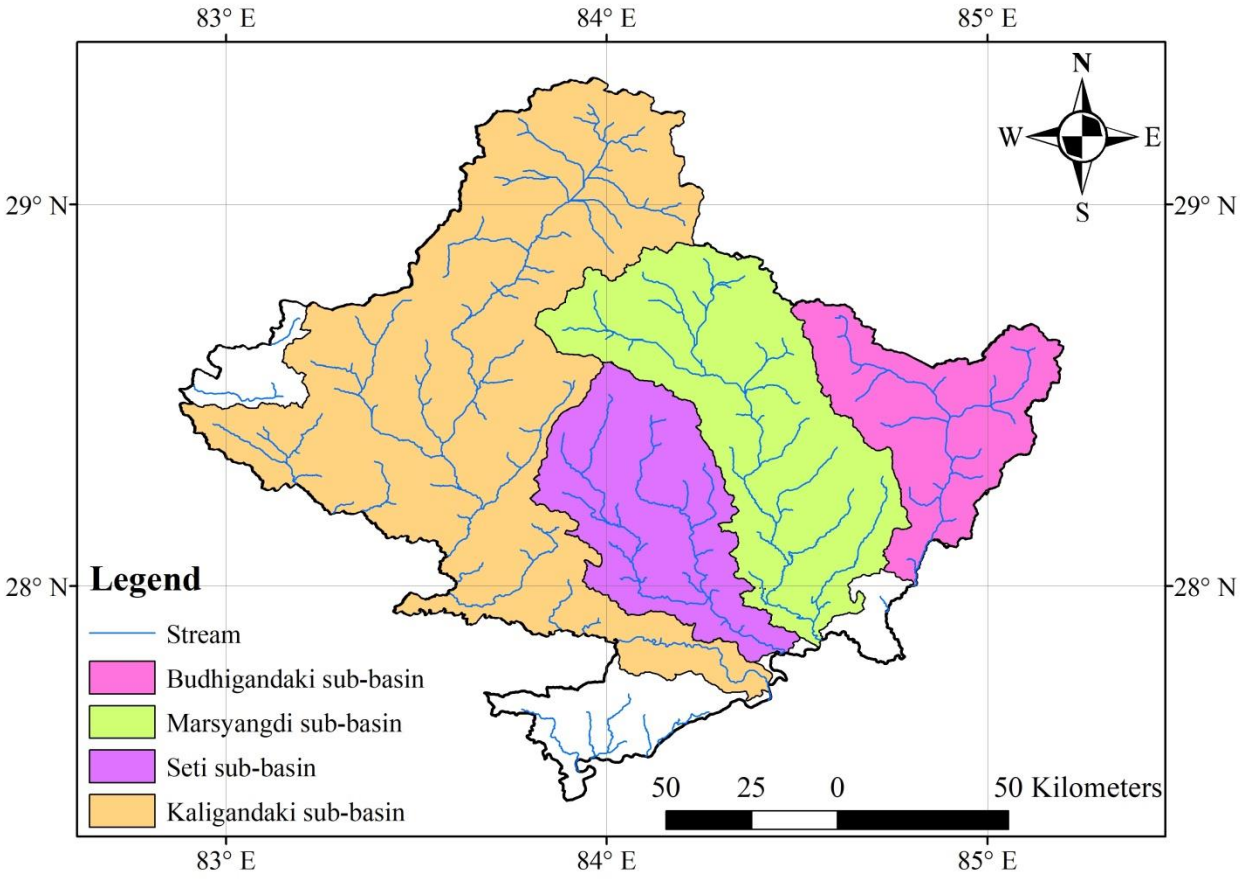

Figure 4: Sub basins of Gandaki Province

3.2. Sub watersheds of district

A total of 11 sub watersheds are delineated in the Nawalparai (Bardaghat Susta Purba) District. The range of the sub watershed is 257 km^2 to 48 km^2. The largest sub watershed is Binayee Khola and smallest is Mahisob Khola - Narayani (**Table 2**).

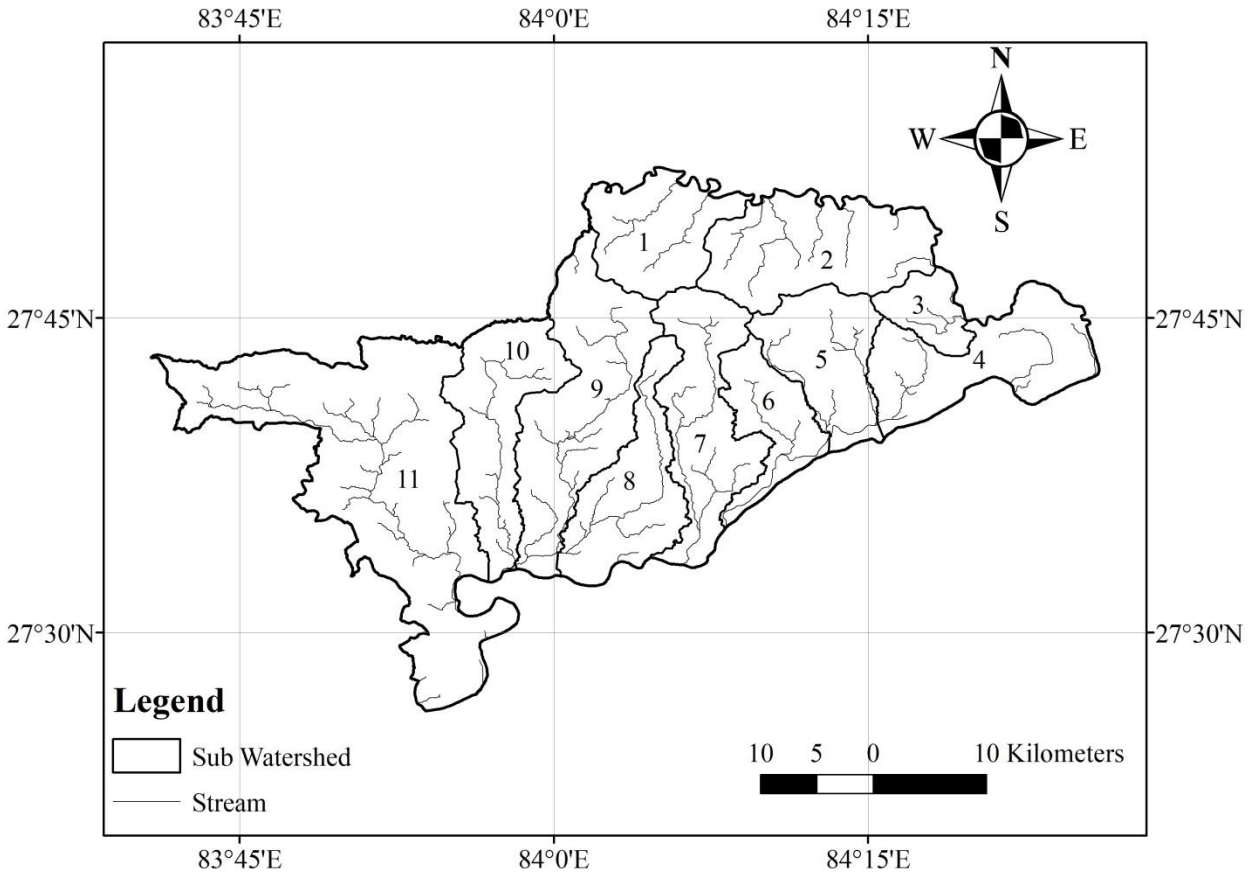

Figure 5: Sub watersheds of Nawalparasi (Bardaghat Susta Purba) District

Table 2: Sub watersheds of Nawalparasi (Bardaghat Susta Purba)

S.N.	Name of sub watershed	Area (km^2)	Corresponding local level
1	Bungadi -Dungre Khola	68	Bungdi Kali Rural Municipality
2	Pulamdi-Deusat-Saudi Khola	102	Bulintar Rural Municipality
3	Mahisob Khola -Narayani	26	Gaidakot Municipality
4	Jayasri Beldiya Khola	92	Gaidakot Municipality
5	Barlangdi-Khahare-Deusat	68	Devchuli Municipality

	Khola		
6	Laukaha Khola	48	Devchuli and Kawasoti Municipality
7	Gindri Khola	91	Kawasoti Municipality
8	Lindi Khola	77	Kawasoti Municipality and Hupsekot Rural Municipality
9	Gadar Khola	127	Madhya Bindu Municipality and Hupsekot Rural Municipality
10	Arun Khola	86	Madhya Bindu Municipality and Hupsekot Rural Municipality
11	Binayee Khola	257	Binayee Tribeni Rural Municipality

3.3. Prioritized sub watersheds

Gindri Khola sub watershed is top prioritized sub watershed of the Nawalparasi (Bardaghat Susta Purba) District with an area of 91 km^2. This sub watershed located to Kawasoti Municipality. Similarly, Bungadi - Dungre Khola is the top second prioritized sub watershed of this district and located at Bungdi Kali and Bulingtar Rural Municipality.

Table 3: Sub watershed prioritization of Nawalparasi (Bardaghat Susta Purba)

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
7	Gindri Khola	91	Kawasoti Municipality	46	39	85	1
1	Bungadi - Dungre Khola	68	Bungdi Kali Rural Municipality	59	23	82	2
2	Pulamdi-Deusat-Saudi Khola	102	Bulintar Rural Municipality	60	15	75	3
5	Barlangdi-	68	Devchuli	45	30	75	4

	Khahare Deusat Khola		Municipality				
3	Mahisob Khola - Narayani	26	Gaidakot Municipality	46	27	73	5
6	Laukaha Khola	48	Devchuli and Kawasoti Municipality	35	35	70	6
8	Lindi Khola	77	Kawasoti Municipality and HupsekotRural Municipality	36	32	67	7
4	Jayasri Beldiya Khola	92	Gaidakot Municipality	34	31	66	8
9	Gadar Khola	127	Madhya Bindu Municipality and Hupsekot Rural Municipality	45	19	63	9
10	Arun Khola	86	Madhya Bindu Municipality and Hupsekot Rural Municipality	41	17	59	10
11	Binayee Khola	257	Binayee Tribeni Rural Municipality	33	12	45	11

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) 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 6**.

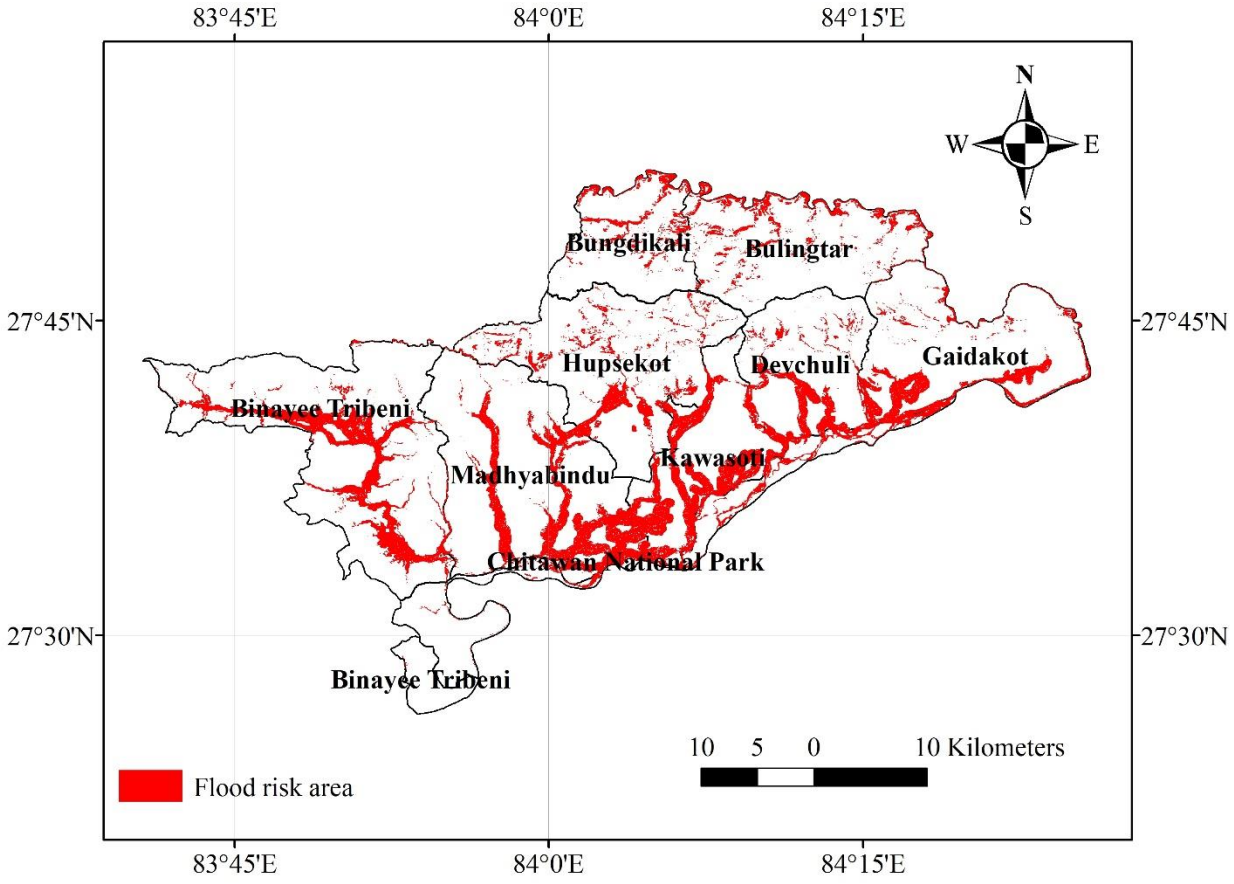

Figure 6: Flood risk in Nawalparasi (Bardaghat Susta Purba) District

Due to flat territory, the Nawalparasi (Bardaghat Susta Purba) is flood prone district of the Gandaki Province. Madhyabindu and Kawasoti Municipality and Binyee Triveni Rural Municipality are more flood prone local levels of this district (**Figure 6**). Details of flood prone area of this district is shown in **Table 4**.

Table 4: Flood risk area of Nawalparasi (Bardaghat Susta Purba)

Rural Municipality (RM)/ Municipality	Ward	Location of Flood	River/stream
Binayi Triveni RM	1	Both side of Binayi Khola from Bahuban to Dumkibas	Binayi Khola
	2	Khumaltar, Jyamire, Suntandi, Dadajhor, Graderitari through Sansarkot	Binayi Khola
	3	Sunal River area, Patukhahare area, Khorandi Khola area, Bharta, Katasgare,	Sunal Khola, Khorandi Khola, Patu Khahare
	4	Sihe, Bogadi, Sardi,Ghumaure, Bagaincha,	Binayi Khola
	5	Dharapani,Gorijhok, Admare, Deurali, Kusunde, Barbishe	Binayi Khola
Madhyabindu Municipality	1	Dandior, Rammandi, Chanuli	Danda Khola, Rammandi
	2	Surrounding area of Sitapur	Stream
	3	Northern part of Narayani and Rammandir area	Narayani
	4	Western side of Ulti Khola, Bhdhkhor Gaun	Ulti Khola
	5	Eastern part of Ulti khola, Western part of Godar Khola	Ulti, Godar Khola
	7	Eastern part of Gadar Khola	Godar Khola
	8	Dewakotatol and Surrounding settlement of Godar Khola	Godar Khola
	9	Basantapur, Maqarsin, Simreni	Girwan Khola
	10	Charikun, Arun khola bazaar, western part of Arun Khola	Arun Khola
	11	Eastern part of Arun Khola, Kusunde	Arun Khola
	12	Western part of Arun Khola	Arun Khola
	13	Western part of Mainadhar Khola	Maindhara Khola
	14	Western part of Dwaredaha	Arun Khola
	15	Chisapani, Prasauni, Muslimtol, Bhawanitol	Arun Khola
Hupsekot RM	1	Jugepani, Eastern part of Nayabasti	Stream
	2	Western part of Koliya and Chpanagaun, Gori	Girwan Khola

	3	Western part of Girwari, Northern part of Bailani	Girwan Khola
	4	Jhyalbas, Dihi	Girwan Khola
	5	South east part of ward no. 5	Girwan Khola
Devchuli Municipality	1,3,5, 9,10,14,15,16	Both side of Gindri Khola	Gindri Khola
	1,11,12	Eastern part of Laukaha Khola	Laukaha Khola
	9,10,15	Eastern part of Laukaha Khola	Laukaha Khola
	1,3,5, 7,12,13	Both edge part of Deusal Khola	Deusal Khola
	1,2,4, 16,17	Both edge part of Mukunde Khola	Mukunde Khola
	17	Kottadi, Kujauli and edge of Narayani river, Western part of Khahare Khola	Narayani River, Khahare Khola
	16	Western part of Rajahar bazar	Mukunde Khola
Gaidakot Municipality	1,2,5, 6,7, 9,10, 11,12, 13, 17	Northern edge of Narayani River	Narayani River
	17	Eastern part of Khahare Khola	Khahare Khola
	13,16, 12,14	Both side of Beldiya Khola	Beldiya Khola
Bungdikali RM	4,3,6, 2	Both side of Bungdi Khola	Bungdi Khola
	2	Lower part of Kharsantar Dedgaun	Kaligandaki River
	3	Banjhobari	Stream
Bulingtar RM	4	Lower part of Korbetar	Stream

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. Land risk area of district is shown in **Figure 7** and **Table 5**.

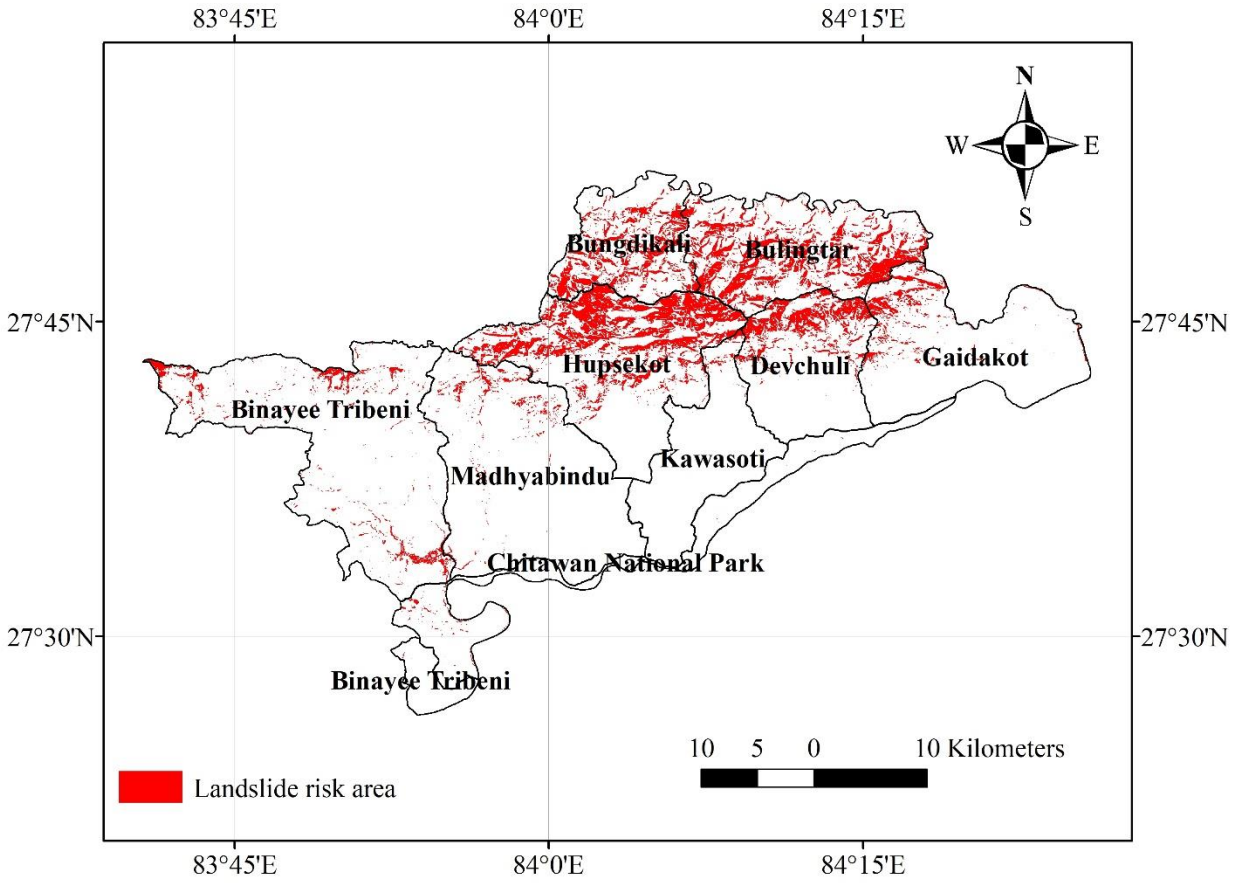

Figure 7: Landslide risk area of Nawalparasi (Bardaghat Susta Purba) District

Table 5: Landslide risk area of Nawalparasi (Bardaghat Susta Purba) District

Rural	War	Locations of Landslide	Potential Hazard

Municipality (RM)/ Municipality	d		
Binayi Triveni RM	1	Both side of Binayi Khola and Khahare Khola	Edge cutting, edge fall
	2	Jyamire Khola northern side	Edge fall
	3	Upper part of Dangie Khola and Dhago Khola, Harbare and northern part,	Landslide
	5	Dhurkot, Majhkot area, Near Binayi Khola	Landslide, edge fall
	10	Near Charikun	Edge fall
	14	Charange, Jilan Khola	Landslide, edge cutting
	2	Western side of Girwan Khola	Edge cutting
	4	Eastern side of Girwan Khola, northern side of Girdi Khola, Rumse area	Edge cutting, landslide
	5	Most of the part of ward no. 5 (Baseni, Ramjikot, Kamigaun, Dhawadi, Pahereghat)	Landslide
	6	Pipaldanda area, northern and southern upper part of Keuradhap and Birkharka, Southern part of Bharidare and Dhobala	Landslide
Devchuli Municipality	5	Northern part of ward no. 5 Bardipur area	Landslide
	6	Both side of Deusal Khola, northern part of ward 6 Mahabharat Lek area	Edge fall, landslide
	16	Northern part of Mahabharat Lek area	Landslide
Gaidakot Municipality	3	Hattisal area	Landslide,
	14	Upper part of Taun Khola	Landslide
	18	Ratanpur area, Belthumka area	Landslide
Bungdikali RM	1	Hatiya area, Mithukaram danda area	Landslide
	2	Northern upper part of Bungdi khola	Landslide
	3	Upper part of Madanswanra	Landslide
	4	Tallo kuwakot area, Ruchan area, southern part of ward no. 4	Landslide
	5	Jaubari area	Landslide
	6	Eastern part of Becchhap, Northern, eastern and southern part of Naram village	Landslide
Bulintar RM	1	Northern part of Tarang khola, Satikot area and Southern part of Koldada	Landslide
	2	Dadajhari area	Landslide
	3	Southern part of Batase, Dadathok and Thapre area	Landslide
	4	Near Kuwakot area,westernern part of Deusat Khola, Tallo Arkhala, Eastern and southern part of Deurali	Landslide
	5	Lapak area, northern and eastern part of Bhadure,	Landslide, edge

		Phulandi khola ege fall and northern part of Phulandi Khola	fall
	6	Southern part of Bharatipur, Hatiya area, Udayapur, edge cutting of Phulmadi Khola	Landslide

3.5. Sub watershed management plan

3.5.1. Bungadi - Dungre Khola Sub Watershed

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 top second prioritized sub watershed of the district. This sub-watershed covers the 68 km^2 area of Bungdikaaali and Bulingtar Rural Municipality of the Nawalparasi (Bardaghat Susta Purba) District. This sub watershed is situated in the southern part of the Kaligandaki River (**Figure 8**).

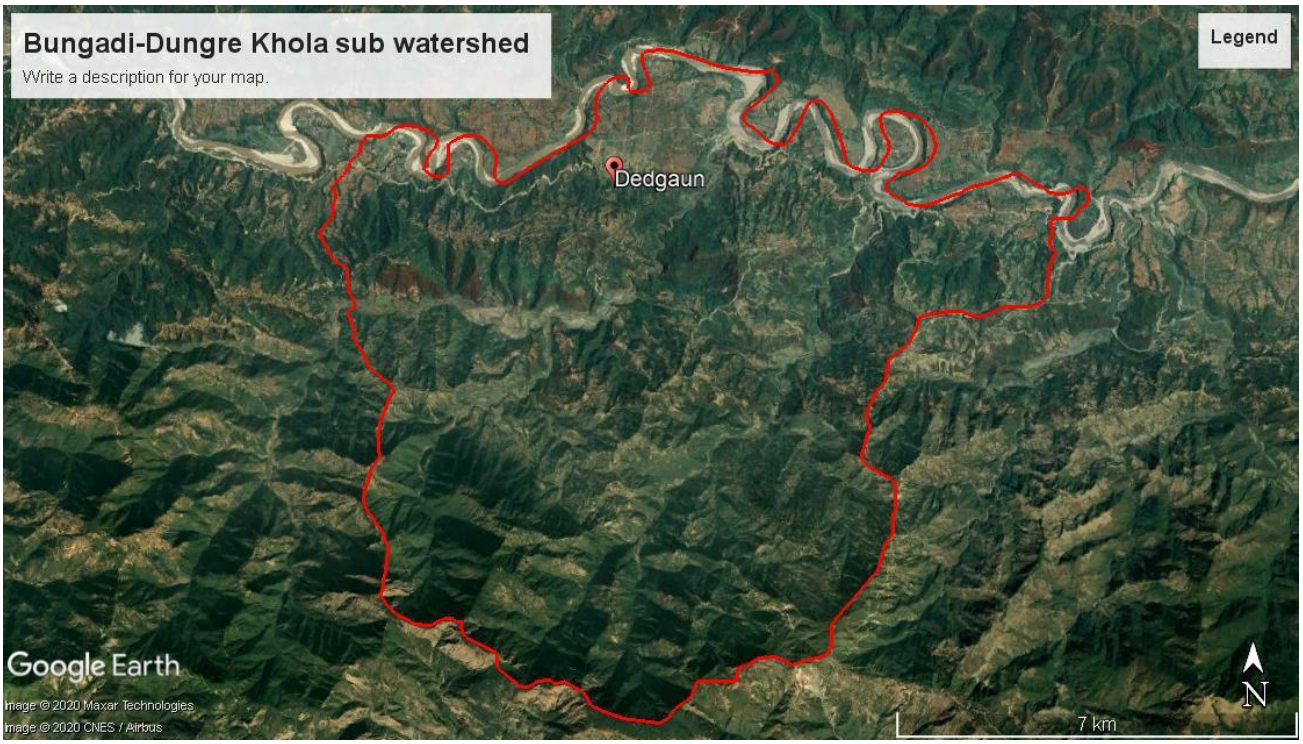

Figure 8: Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

3.5.2. Location

Majority part of the Bungadi-Dungre Khola Sub Watershed lies in Bungdi Kali Rural Municipality. Only few areas are fall in the ward no 5 and 6 of Bulingtaar Rural Municipality (**Figure 9**). This sub watershed covers the whole wards of 1,2,3,5,6 of Baudikaali Rural Municipality, and some parts of ward 4 of Baudikaali Rural Municipality and 5 and 6 of Bulingtaar Rural Municipality.

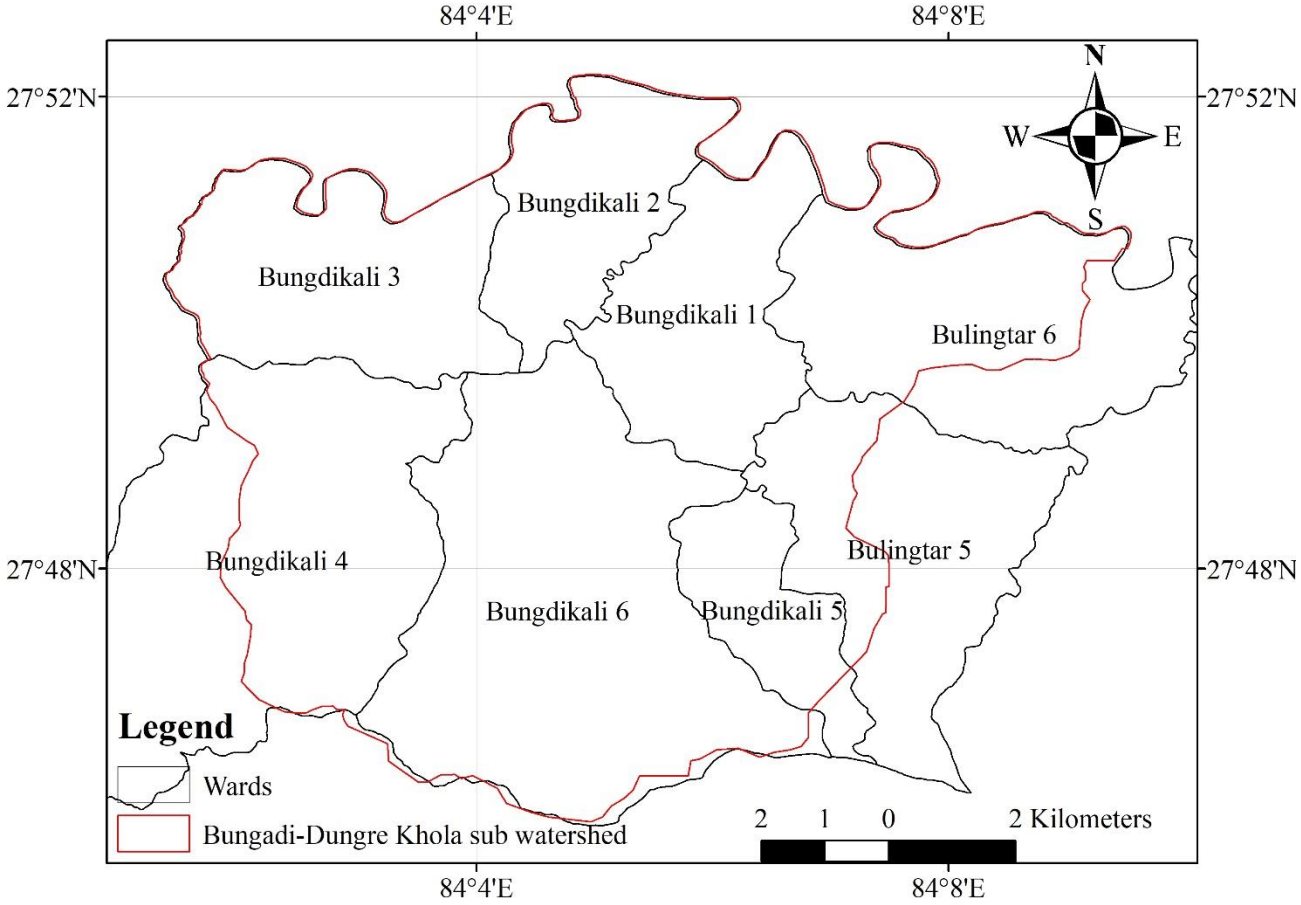

Figure 9: Location of Bungdi-Dungre Khola Sub Watershed of of Nawalparasi (Bardaghat Susta Purba) District

This Bungdi-Dungre Khola Sub Watershed is situated in the northern part of the Nawalparasi (Bardaghat Susta Purba) District (**Figure 10**). Major two streams (Bungadi Khola and Dungre

Khola) are in this sub watershed. Boundary points of this sub watershed are shown in **Table 6** in Degree Decimal format.

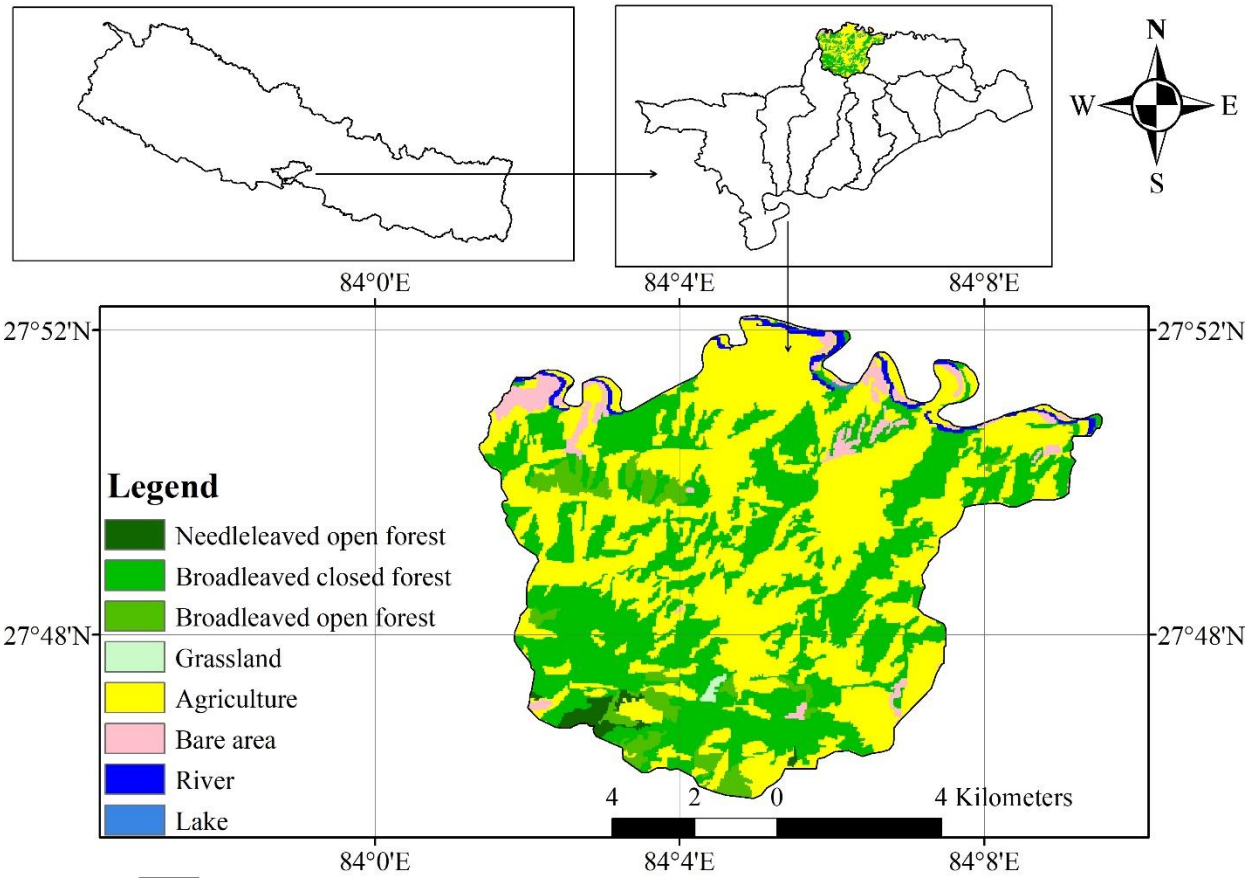

Figure 10: Land use land cover map of Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

Table 6: Boundary points of Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

S.N.	X	Y
1	84.0828	27.7643
2	84.0845	27.7649
3	84.0857	27.7665
4	84.0888	27.7687
5	84.0897	27.7707
6	84.0966	27.7707
7	84.0969	27.7729

8	84.1006	27.7744
9	84.1036	27.7746
10	84.1066	27.7734
11	84.1125	27.7749
12	84.1135	27.7762
13	84.1136	27.7797
14	84.1218	27.7883
15	84.1245	27.7938
16	84.1248	27.8019
17	84.1188	27.8058
18	84.1204	27.8107
19	84.1197	27.8131
20	84.1212	27.8158
21	84.1232	27.8181
22	84.1236	27.8212
23	84.1271	27.8237
24	84.1291	27.8279
25	84.1366	27.8289
26	84.1388	27.8280
27	84.1407	27.8281
28	84.1440	27.8295
29	84.1484	27.8295
30	84.1506	27.8301
31	84.1518	27.8310
32	84.1534	27.8380
33	84.1529	27.8435
34	84.1568	27.8435
35	84.1579	27.8452
36	84.1586	27.8452
37	84.1591	27.8463
38	84.1591	27.8474
39	84.1585	27.8482
40	84.1527	27.8474
41	84.1470	27.8504
42	84.1288	27.8454
43	84.1232	27.8480
44	84.1264	27.8506
45	84.1309	27.8523
46	84.1316	27.8564
47	84.1292	27.8592

48	84.1226	27.8599
49	84.1231	27.8564
50	84.1223	27.8517
51	84.1164	27.8519
52	84.1125	27.8612
53	84.1098	27.8617
54	84.1059	27.8554
55	84.1042	27.8550
56	84.0981	27.8586
57	84.0982	27.8600
58	84.1040	27.8653
59	84.1033	27.8664
60	84.0799	27.8692
61	84.0811	27.8637
62	84.0778	27.8634
63	84.0772	27.8655
64	84.0758	27.8657
65	84.0735	27.8647
66	84.0721	27.8631
67	84.0719	27.8590
68	84.0713	27.8576
69	84.0699	27.8564
70	84.0561	27.8491
71	84.0551	27.8489
72	84.0538	27.8495
73	84.0536	27.8504
74	84.0540	27.8531
75	84.0517	27.8559
76	84.0486	27.8564
77	84.0455	27.8551
78	84.0454	27.8508
79	84.0445	27.8500
80	84.0412	27.8511
81	84.0417	27.8528
82	84.0432	27.8547
83	84.0435	27.8556
84	84.0426	27.8567
85	84.0397	27.8579
86	84.0362	27.8577
87	84.0342	27.8564

88	84.0310	27.8564
89	84.0297	27.8545
90	84.0292	27.8532
91	84.0286	27.8528
92	84.0278	27.8520
93	84.0266	27.8499
94	84.0259	27.8496
95	84.0249	27.8485
96	84.0254	27.8469
97	84.0248	27.8435
98	84.0237	27.8422
99	84.0228	27.8415
100	84.0252	27.8368
101	84.0273	27.8357
102	84.0276	27.8328
103	84.0291	27.8297
104	84.0280	27.8292
105	84.0278	27.8281
106	84.0282	27.8270
107	84.0289	27.8261
108	84.0285	27.8252
109	84.0290	27.8240
110	84.0298	27.8231
111	84.0314	27.8200
112	84.0353	27.8174
113	84.0358	27.8162
114	84.0334	27.8117
115	84.0333	27.8062
116	84.0318	27.8043
117	84.0306	27.8007
118	84.0304	27.7988
119	84.0348	27.7921
120	84.0334	27.7841
121	84.0359	27.7815
122	84.0412	27.7796
123	84.0447	27.7806
124	84.0470	27.7801
125	84.0484	27.7778
126	84.0541	27.7753
127	84.0542	27.7728

128	84.0584	27.7699
129	84.0616	27.7709
130	84.0636	27.7710
131	84.0661	27.7708
132	84.0696	27.7690
133	84.0709	27.7669
134	84.0768	27.7649

3.5.3. Slope

Land slope affects the erosion predominantly. As the slope increases, the runoff coefficient, kinetic energy and carrying capacity of surface runoff also increase while soil stability and slope stability both decrease. Thus it is very important to identify different slope in watershed. Slope map was prepared is three categories: less than 5 degree, 5 to 30 degree and more than 30 degree. Southern part of the watershed is more stepper than northern parts. In the middle part of the watershed there is medium slope. Slope analysis was carried out 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 68 km^2 of sub watershed, slope less than 5 degree covers 4 km^2, slope between 5 and 30 degree covers 47 km^2 and slope more than 5 degree covers 17 km^2.

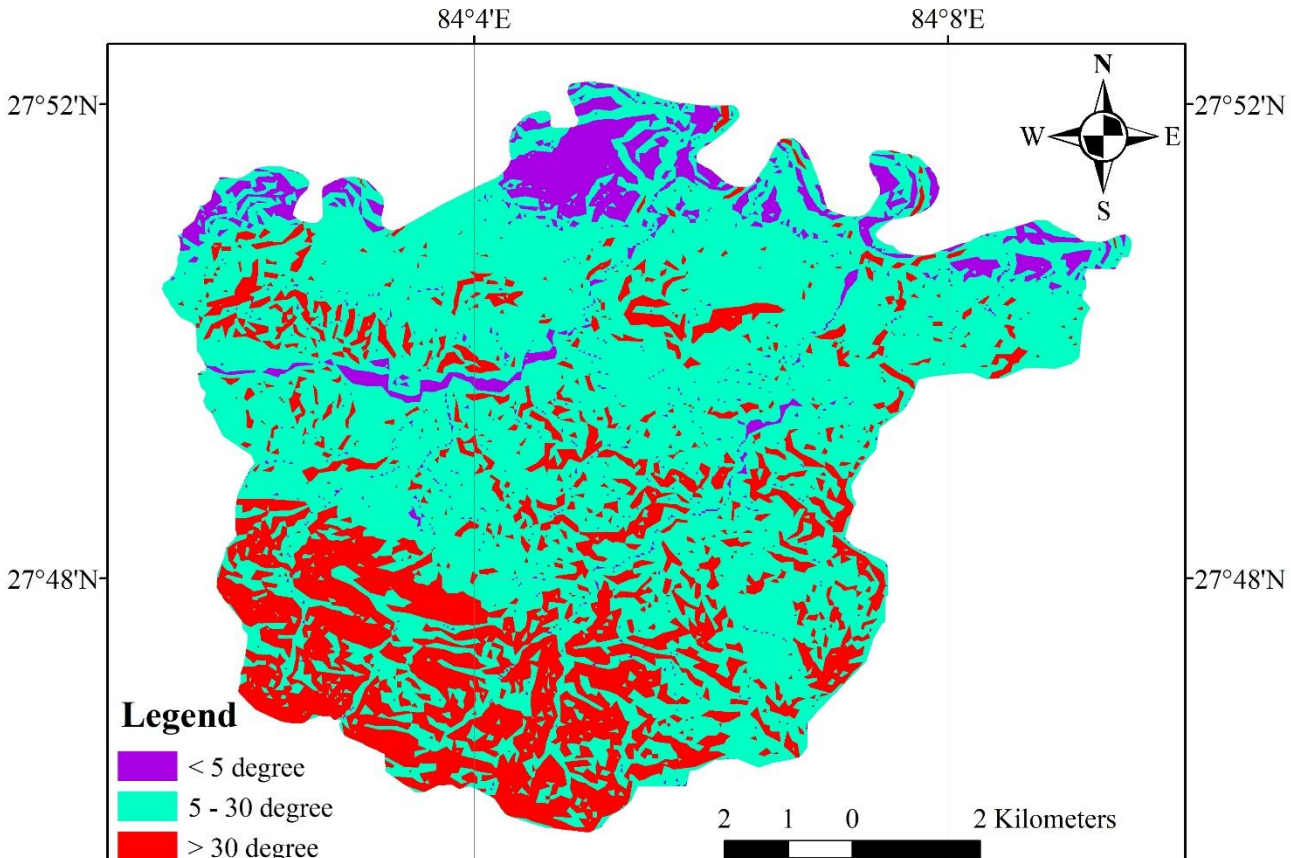

Figure 11: Slope map of Bungadi-Dungre Sub Watershed

3.5.4. Aspect

Aspect is the compass direction where the slope faces. For example, a slope on the eastern edge of watershed is described as having an 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**).

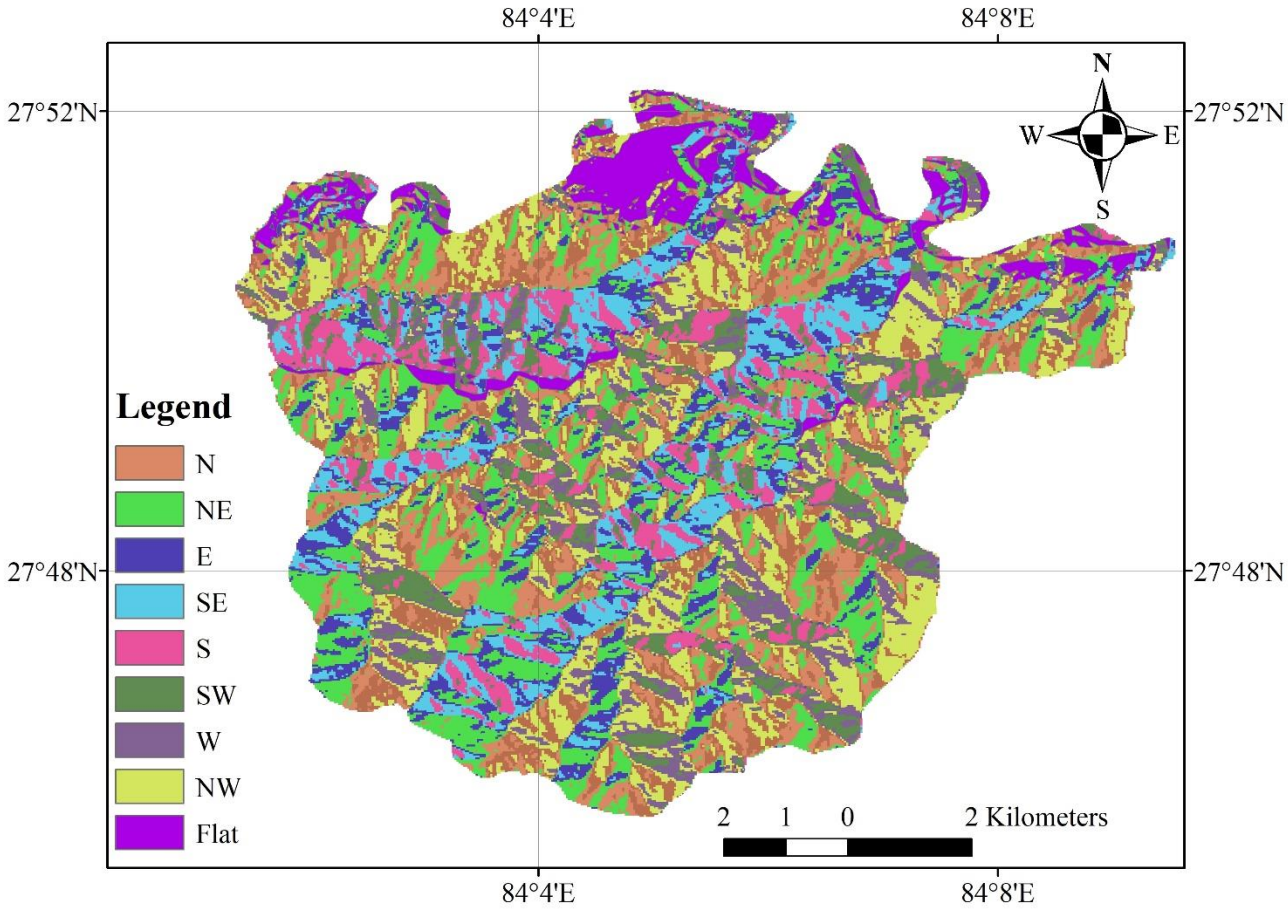

Figure 12: Aspect map of Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

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 7**).

Table 7: Aspect of Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

S.N.	Aspect	Area (km^2)
1	North	16
2	North East	11
3	East	6
4	South East	6
5	South	5
6	South West	4
7	West	5
8	North West	10
9	Flat	4
	Total	68

3.5.5. 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 agricultural land and broadleaved close forest whereas lake and grassland cover only few areas (**Table 8**).

Table 8 Land use land cover of Bungadi-Dungre Khola Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District

S.N.	Land cover type	Area (km^2)
1	Needle leaved open forest	1
2	Broadleaved close forest	27
3	Broadleaved open forest	2

4	Grassland	0.49
5	Agriculture	34.5
6	Bare area	2
7	River	1
8	Lake	0.01
Total		68

3.5.6. Population

According to the population census of 2011, total household and total population of the district are 66,934 and 311,604 repectively. Out of total population, 142,779 are male and 168,825 are female. The population density of the district is 298/km^2. Population density of the Bungadi-Dungre Khola Sub Watershed is 225/km^2. Major casts of Bungadi-Dungre Khola Sub Watershed are Magar, Dalits, Newar and Darai Total 34 schools are in Baudikaali Rural Municipality where as five health post and two police are in this Rural Municipality.

3.5.7. Agriculture and livestock

Rice, maize, millet, wheat, orange and lemon are major agricultural product of Bungadi-Dungre Khola Sub Watershed. Agriculture of this area is facing lack of irrigation, manure, market and mechanized technology. Goat, buffalo, pig, poultry and fish are major livestock of this area. Livestock (cattle, goat, and sheep) density with a spatial resolution of 1 km was obtained from the Center for Earth Observation and Citizen Science (see https://www.geo-wiki.org)" (Robinson et al., 2014). Livestock density of the district is 63/km^2 whereas that of Bungadi-Dungre Khola Sub Watershed is 68/km^2.

3.5.8. Road networks

Road networks were downloaded from the Geofabrik website (http://download.geofabrik.de/asia/nepal.html; OpenStreetMap Contributors, 2017). Total road length of the district is 2275 km where as that of the Bungadi-Dungre Khola Sub Watershed is 190 km. Similarly, road density of the district is 2181 m/km^2 and that of Bungadi-Dungre Khola Sub Watershed is 2791 m/km^2.

3.5.9. Forests

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

3.5.10. Micro watersheds

This Bungadi-Dungre Sub Watershed of Nawalparasi (Bardaghat Susta Purba) District covers two micro watersheds: Bungadi Micro Watershed and Dungre Micro Watershed. The area of Bungadi Dungre Micro Watershed are 35 and 33 km^2 respectively. **Figure 13** is showing two micro watersheds of this sub watersheds.

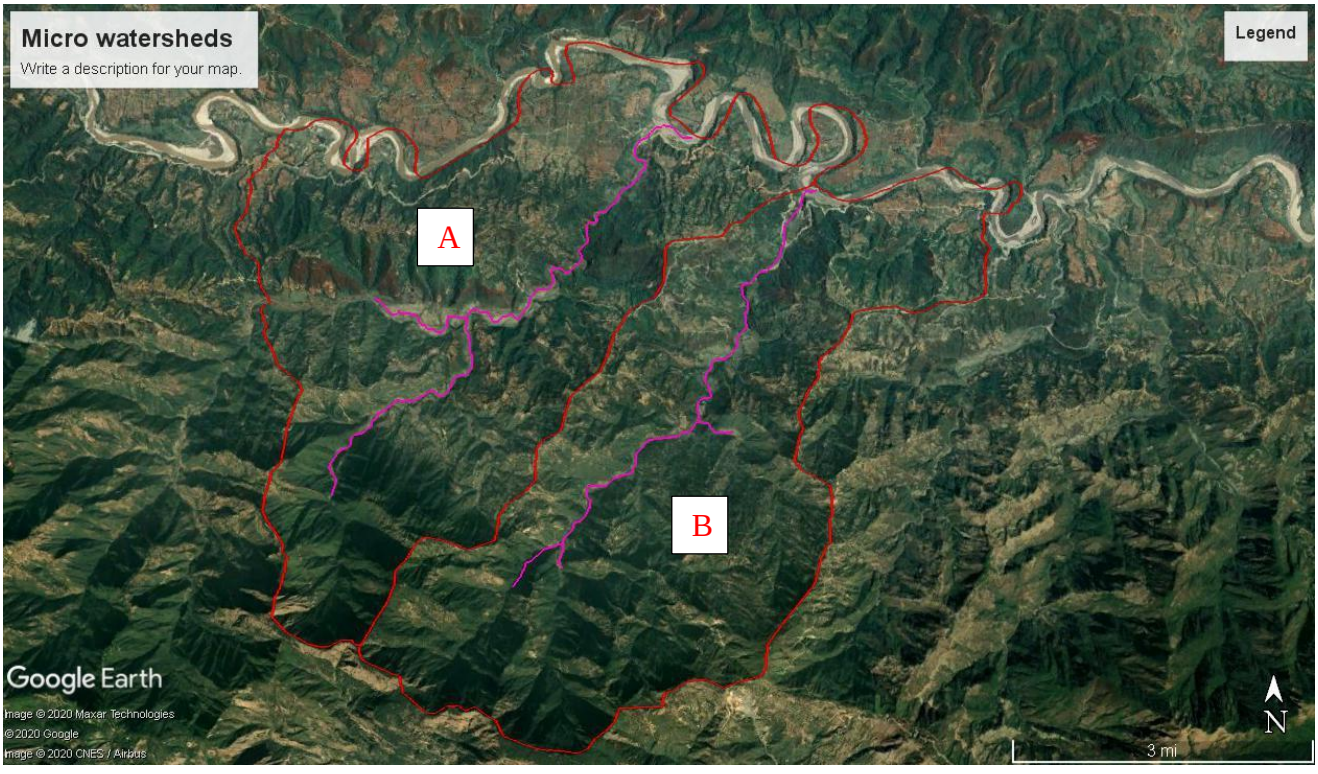

Figure 13: Bungadi (A) and Dungre (B) Micro Watersheds

3.5.11. Problems observed within sub watershed area

Watershed is an integration of land, water, forest, people and livestock within the drainage area of any water body (**Figure 14**). These five major and all other associated components within the drainage area of 68 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.

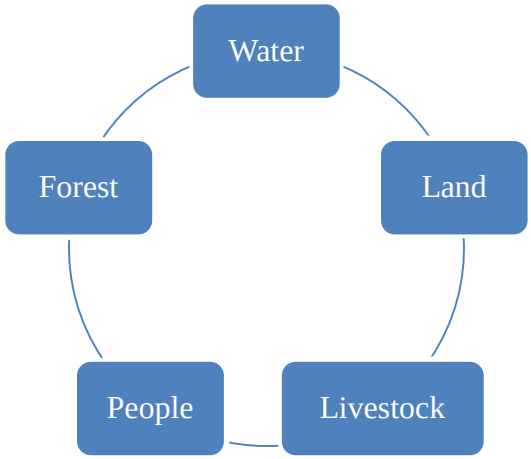

Figure 14: Major components of watershed

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 sub watershed area are as follows:

- The landslide both at the upstream and downstream area is causing the soil erosion in the monsoon season.
- The water resource is used without proper intake and collection tank and the series of pipes from the individual household is causing the seepage of water and it is underutilized.
- The river banks of the three different streams (Kaligandaki, Bungadi and Dungre) are degrading day by day.
- The irrigation canals of sub watershed area needs to be maintained.
- The landslide within the sub watershed area needs to be treated.

- Increasing rural roads construction in haphazard way without any IEE / EIA and supporting structures is resulting huge soil erosion. Every year large volume of sedimentation on the River.
- Deforestation and human encroachment to the forest area.
- Unscientific agricultural practice, unplanned land use and poor land / soil quality.
- Lack of awareness of conservation of soil and water resources.
- Lack of irrigation, drinking water, education and other facilities

3.5.12. 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 9: 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 3.4. Hotspot treatment	Rural/national road side slope stabilization measures (structural / nonstructural), national heritage and other infrastructure protection hard / soft activities
4. **Institutional development**	4.1.Partnership program 4.2. CRMP (community resource management plan) formulation 4.3. Group's tour / training 4.4. Income generation support 4.5. Group monitoring / extension	Partnership with GO/NGO/CBOs organizations, income generation support (conservation oriented), and group strengthening activities, best practice findings documentation and extension related activities.
5. **Program management**	5.1.Erosion hazard map preparation 5.2. Sub 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.

3.5.13. Plan of activities

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

3.5.13.1. Land use planning

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

3.5.13.2. Land productivity conservation

Appropriate land uses on the basis of land capability are encouraged through different land productivity conservation activities for improved land productivity and soil depth. On farm conservation, degraded and reclaimed land rehabilitation, fruit / fodder tree plantation, grass plantation, green belt / shelter belt construction, nursery management and seedling production are the major activities under this component. Improved productivity, increased agricultural land and greenery promotion are expected outcomes from these activities.

3.5.13.3. 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 10: Needs of river bank cutting stabilization

S.N.	Flood causing stream	Address (Ward no of Baudikaali Rural Municipality)	Status	Affected area
1	Kaligandaki	1, 2, 3	Active in monsoon	Agriculture land, Forest, Grazing land
2	Baudi Khola	1,2, 3, 4, 6	Active in monsoon	Agriculture land, Forest, Grazing land
3	Itli Khola	1, 4, 6	Active in monsoon	Agriculture land, Forest, Grazing land
4	Naridi Khola	1, 5, 6	Active in monsoon	Agriculture land, Forest, Grazing land

b. Irrigation canal maintenance work

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

Table 11: Needs of irrigation canal maintenance work

S.N.	Name of irrigation canal	Area of irrigation	Benefited household	Status
1	Macheditaar irrigational canal	approx. 220 Ropani	600	Need for protection
2	Dedhgautaar irrigational canal	approx. 150 Ropani	500	Need for protection
3	Raabang Tari irrigational canal	approx. 150 Ropani	50	Need for protection
4	Gadhiya Khola, Baida irrigational canal	30 Ropani	15	Need for protection

c. Landslide control

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

Table 12: Needs of landslide treatment.

S.N.	Name of landslide	Address	Status	Affected area	Remarks
1	Kuwakot Pahiro	Baudi Kaali – 4 Rujhang	Active	Health Post	Large
2	Bhimakot Muni ko Pahiro	Baudi Kaali - 1 Bhirunga	Active	Roads	
3	Tokne Kholsa Pahiro	Baudi Kaali -2	Active	Roads	

d. Gully control

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

Table 13: Needs of assessment of gully control

S.N.	Name of gully	Address	Status	Affected area	Remarks
1	Narag danda to Daduwa	Jhyalbaas	Serious	Settlement, Agricultural land, Grazing land, Forest	Large
2	Naram Laahape	Jhyalbaas	Serious	Serious	Settlement, agricultural land, grazing land, forest

e. 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 14: Needs of irrigation canal maintenance work

S.N.	Name of road	Address (Ward of Baudikaali)	Status of soil erosion	Status of road
1	Dedhgaun-Machedi - Dhaldaley	2, 3	Active	Kachhi, Hile
2	Ruchang-Byadhan - Naram-Babak	4, 5, 6	Active	Kachhi, Hile
3	Rakuwa-Dedhgaun	2, 3	Active	Kachhi, Hile
4	Rakuwa-Rruchang-Hupsekot	3, 4	Active	Kachhi, Hile
5	Babak-Naram-Ruchang-Nisdi	4, 5, 6	Active	Kachhi, Hile
6	Dedhgaun-Minaamkot-Motipalak-Babar	2, 1, 5	Active	Kachhi, Hile

3.5.13.4. Plantation and income generation activity

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

3.5.13.5. Capacity building and technology development support program

Capacity building of natural resource users groups and people's organizations is another important aspect of the development processes as their engagement can contribute in achieving

targeted goal. They have better knowledge of local context and resources. However, they need additional supports to improve knowledge, skills and organizational functions in dealing with the enormously damaged landscapes and its resources. Thus, capacity building (training, coaching and organizational supports) should be an integral part of soil conservation and watershed management. Besides, it is also recommended to promote awareness and meaningful participation people of watershed in soil conservation and watershed management.

3.5.14. Costs and funding

3.5.14.1. 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 15: 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	

3.5.15. 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, Nawalpur
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.

3.5.16. Plan implementation approach

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

3.5.17. 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.

3.5.18. Working modality

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

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

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

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

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

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

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

3.5.19. 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 monitor the works. Public auditing will be done at various stages of activity implementation in order to maintain transparency, accountability and reliance.

3.5.20. Log frame

Log frame 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 16: 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 sub basin and sub watersheds of the Nawalparasi (Bardaghat Susta Purba) District. Furthermore this study prioritized the identified sub watersheds and prepared the management plan of most vulnerable watershed for effective and efficient management of sub watershed. Although this district does not support any sub-basin, total 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. Resource allocation 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

Details of schools of Baudi Kaali Rural Municipality

S.N.	Name of school	Address	No. of teachers	No. of students
1	Dipjyoti Primary School	Mithukaram	0	8
2	Janajyoti Primary School	Mithukaram	2	4
3	Krishnagandaki Primary School	Mithukaram	2	33
4	Siddha Primary School	Mithukaram	3	5
5	Dharmatma Ma. Bi	Mithukaram	12	315
6	Siddhibidhyashram Aa. Bi.	Mithukaram	4	176
7	Janata Primary School	Dedhgaun	4	53
8	Kaligandaki Primary School	Dedhgaun	3	81
9	Balkalyan Basic School	Dedhgaun	6	207
10	Dedhgaun Secondary School	Dedhgaun	23	324
11	Namuma Primary School	Rakuwa	0	0
12	Durga Primary School	Rakuwa	2	38
13	Siddhi Primary School	Rakuwa	2	23
14	Sharada Basic School	Rakuwa	6	176
15	Bel bhanyanj Secondary School	Rakuwa	14	241
16	Nepal Primary School	Ruchang	0	16
17	Balkalyan Primary School	Ruchang	3	37
18	Mahendra Jyoti Primary School	Ruchang	4	60
19	Lokpriya Primary School	Ruchang	3	33
20	Sarba Priya Basic School	Ruchang	4	172
21	Nagardanda Secondary School	Ruchang	12	163
22	Padamkanya Primary School	Babak	1	41
23	Uttam Baalhit Basic School	Babak	3	75
24	Udaya Basic School	Babak	5	84
25	Panchakanya Primary School	Naram	1	0
26	Uddham Primary School	Naram	3	72
27	Chandideurali Primary School	Naram	3	39
28	Baalhit Primary School	Naram	2	32
29	Rupikanya Primary School	Naram	2	23
30	Mahabharat Primary School	Naram	2	27
31	Janata Basic School	Naram	3	78
32	Laxmi Basic School	Naram	3	46

33	Nagardanda Secondary School	Naram	7	287
34	Nagardanda Secondary School	Byaghan	12	163

Photo plates

Landslide caused by the road

Landslide caused by the road

Landslide

Landslide

Infra-structure protection

Infra-structure facing the risk