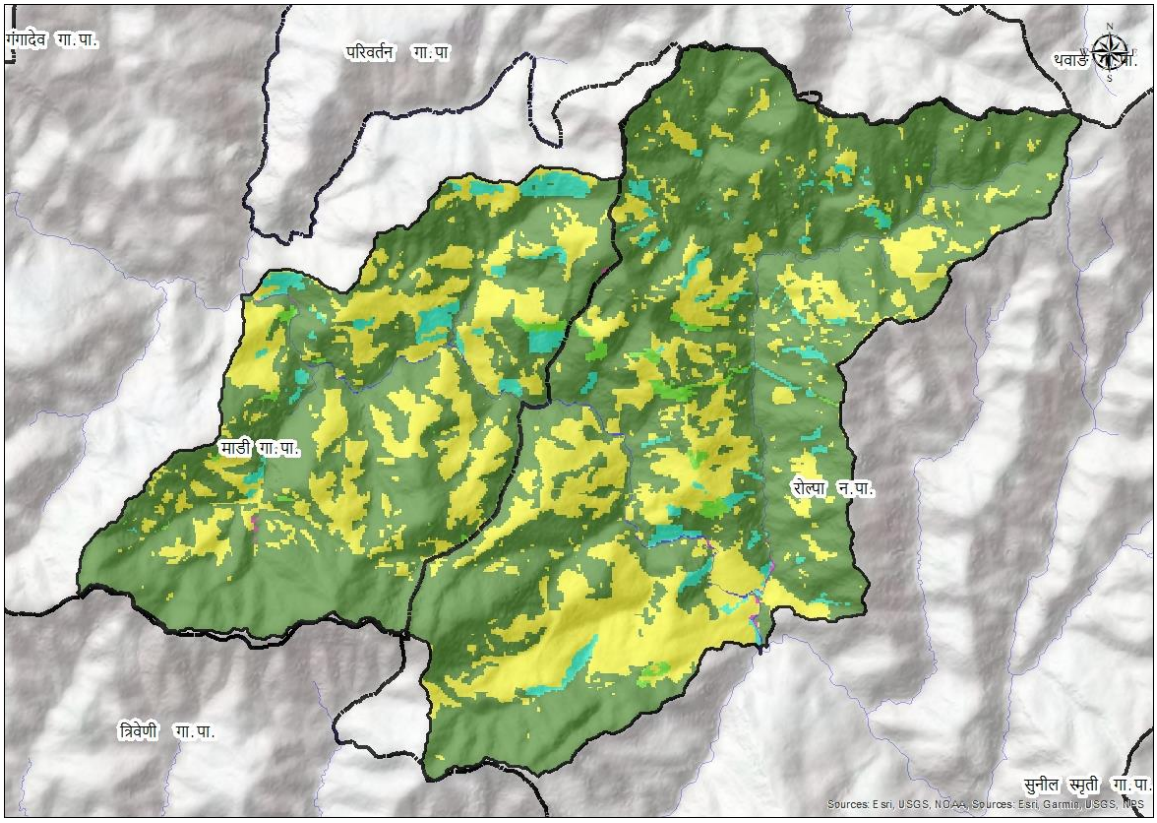
ADAPTATION FOR SMALLHOLDERS IN HILLY AREAS (ASHA) PROJECT

GIS BASED ASSESSMENT OF

HUNGRI MADI SUB-WATERSHED, ROLPA



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ABBREVIATIONS AND ACRONYMS

ASHA	Adaptation for Smallholders in Hilly Areas
CBS	Central Bureau of Statistics
CFUG	Community Forest User Group
DLSO	District Livestock Office
FAO	Food and Agriculture Organization
Ga Pa	Gaupalika
GIS	Geographic Information System
GoN	Government of Nepal
IAS	Invasive Alien Speies
IFAD	International Fund for Agricultural Development
INGO	International Non-Governmental Organization
LAPA	Local Adaptation Plans for Action
LRMP	Land Resource Mapping Project
MODIS	Moderate Resolution Imaging Spectroradiometer
MoFE	Ministry of Forests and Environment
Na Pa	Nagarpalika
NAPA	National Adaptation Programme of Action
NGO	Non-governmental Organization
RUSLE	Revised Universal Soil Loss Equation
SALT	Sloping Agriculture Land Technology
SLC	School Leaving Certificate
VDC	Village Development Committee
VULI	Vulnerability Index

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1. Introduction

The Himalayan catchments of Nepal including watersheds in mountain regions are considered to be very sensitive to climate change due to the high variation in altitudes. Changes in cloud cover and rainfall, particularly over land; melting of ice caps and glaciers and reduced snow cover are some of the prominent threats due to rise in temperature. The significant effect of climatic variability in major rivers and their tributaries has already been observed. As a result, rivers and tributaries, catchments and watersheds are at risk from increased flooding, landslides and soil erosion and more intense rain during the monsoon. Besides, water scarcity and droughts pose a similar threat to livelihood systems and ecosystem functioning (Siddiqui et al., 2012). Thus, adaptation to climate change must be the priority for the country to help poor communities to cope with, and adapt to, the impacts of climate change in mountain region.

In this milieu, the Government of Nepal (GoN) has been facilitating climate adaptation planning and implementation. The National Adaptation Programme of Action (NAPA) was endorsed by the Government in September 2010, which expresses how changes in temperature and precipitation patterns and climate induced disasters are undermining development initiatives, livelihood assets and natural and physical infrastructure. GoN has also prepared a national framework for development of Local Adaptation Plans for Action (LAPA), which supports the operationalization of the NAPA priorities by facilitating the integration of climate change resilience into development planning processes and outcomes from local-to national levels.

Considering sub-watersheds as organizing units for planning and implementation for adaptation to climate change is a new approach in climate change adaptation arena, where large regions can be divided along topographic lines that transcend administrative boundaries and the status and trends analysis can be done on the basis of entire natural systems in concert with social conditions (Siddiqui et al., 2012). The assessment of entire natural systems is imperative for the design of adaptation measures ensuring upstream and downstream linkages. Integration of watershed assessment findings could contribute for the local adaptation planning to address adverse impact of climate change in a more comprehensive manner ensuring adaptation intervention programs to be targeted to areas where the risks of catastrophic climate-induced impacts are highest.

With this background, Adaptation for Smallholders in Hilly Areas (ASHA) Project under Ministry of Forests and Environment (MoFE) with the financial support of International Fund for Agricultural Development (IFAD) carried out this GIS based watershed assessment of Hungri Madi Sub Watershed Rolpa and prepared this study report.

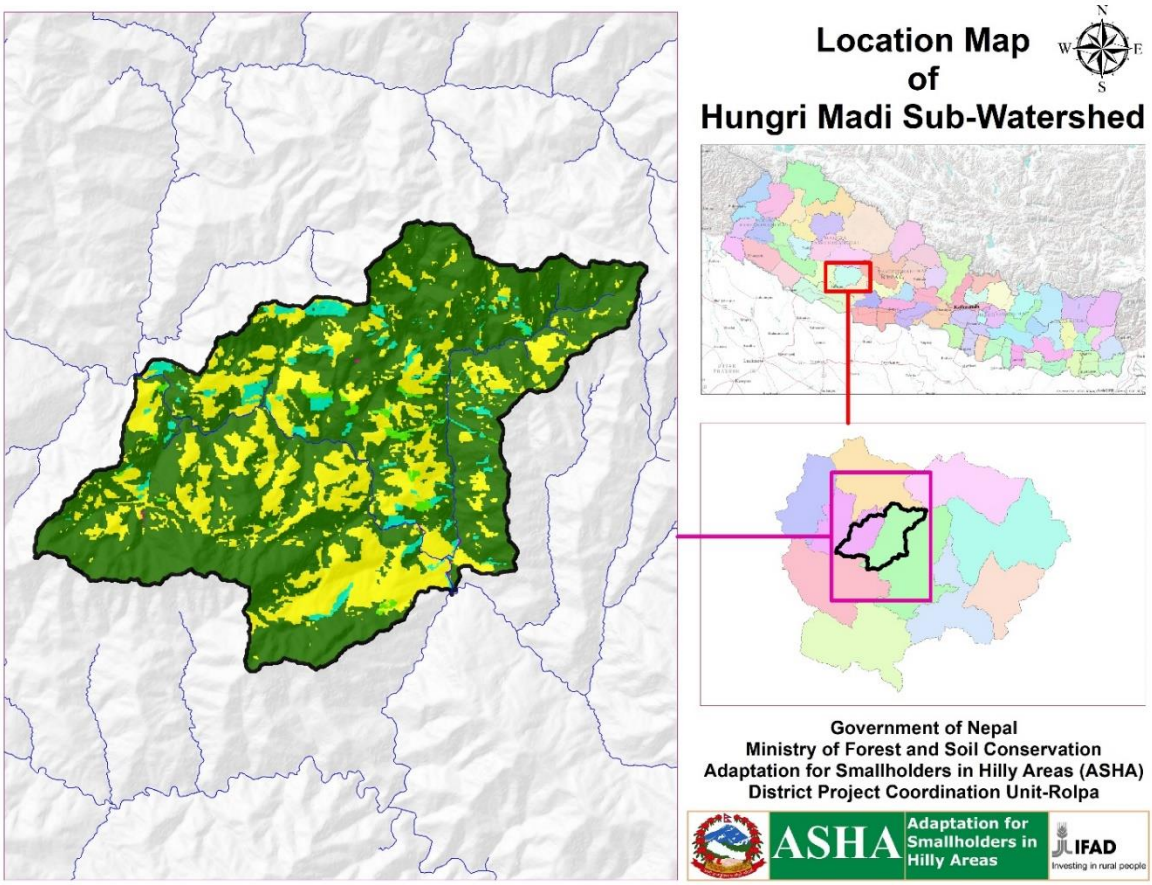
2. Objective

The objective of this assessment was to impart GIS based analytical assessment of the bio-physical and socio-economic conditions of Hungri Madi Sub Watershed Rolpa and to recommend strategies action for sub-watershed conservation and management. The findings are expected to provide a basis for developing local adaptation plan to cope with, and adapt to, the impacts of climate change in the sub-watershed.

3. Study Area

The Hungri Madi Sub-Watershed is situated in Rolpa district of Provience 5 between 28°20'49.59"N and 28°25'20.68"N latitude and 82°32'23.88"E- 82°35'30.43"E longitude, covering an area of 122.12 square kilometers, altitude ranges from 909 meter to 2990 meter above mean sea level. The sub-watershed covers all or part of 1 Gaupalika and 1 Nagarpalika and is drained by Byan Khola, Bahula Khola and Hungri Khola and many others small tributaries. Physio-graphically, the Hungri Madi Sub Watershed is divided into two major zones: the middle mountain and high mountain of the total area of the sub-watershed, more than 75% of area is covered by middle mountain. The wide variation in climate, elevation and topography has contributed to occurrence of different forest types in the sub-watershed that range from Lower temperate oak forest to temperate mountain oak forest *(Chirpine-Broadleaf forest, Chir pine forest, lower temperate oak forest and temperate mountain oak forest)*. The average annual rainfall is 13.88 to 18.36 mm and average annual temperature is 3.6ºC to 31.2ºC. Geologically, there are 5 formations in this sub watershed. They are Lakharpata Formation, Ranimatta Formation, Siuri Formation, Suntar Formation, Surbang Formation.

Figure 1 Location of Hungri Madi Sub Watershed in Rolpa district in Western Nepal



4. Methodology

The study is the combination of both primary and secondary source of information. Information on the trends of land use and land cover changes, estimation of soil erosion dynamics over the last three decades was primarily obtained from analysis of Landsat satellite images. Information on the forest fire was primarily obtained from the analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) active fire data sets. Information on landslide distribution was obtained from analysis of secondary data and Google Earth Image. Similarly, information on land use adjustment was primarily obtained from same Landsat imageries that were used in land use analysis and land capability data.

4.1 Collection and Analysis of Primary Data

Consultations with stakeholders at district and selected community level within the sub-watershed were the major sources of primary data and information. District Forest Office, District Soil Conservation Office, District Agriculture Development Office, District Livestock Service Office, Office of District Development Committee and other government offices, International Non-Governmental Organizations (INGOs), Non-governmental Organizations (NGOs), and civil society groups based in district were consulted through informal and formal meetings. Group discussions, key informant interviews and other participatory rapid appraisal techniques were used to collect data and information.

4.2 Collection and Analysis of Secondary Data

Secondary data and information was collected through review of relevant literature and collection and analysis of secondary data available from the District Soil Conservation Office, District Forest Office, District Agriculture Development Office, District Livestock Service Office, Office of District Coordination Committee and other agencies. Socio-economic data available from the Central Bureau of Statistics, soil data available from SOTER, climatic data available from Bioclim and land capability data available from Department of Survey were collected and analyzed.

4.3 Spatial Analyses

4.3.1 Land Use and Land Cover Changes

Landsat satellite images sets from 1995, 2008 and 2018 were used to analyze and map land use land cover for the three periods. The main satellite data used in the analyses included Landsat Thematic Mapper images and Landsat Thematic Mapper images. The images were Downloaded from the Earth Resource Observation System Data Center of the United States Geological Survey Annex 1.

4.3.2 Estimation of Soil Erosion Dynamics

Revised universal soil loss equation (RUSLE) was used in an Arc GIS environment with rainfall erosivity, soil erodibility, slope length and steepness, cover-management, and support practice factors to estimate soil erosion dynamics in the watershed according to Uddin et al. 2016 Annex 2.

4.3.3 Spatial and Temporal Distribution of Forest Fires

Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets from 2000 to 2018 imported in Arc GIS to map spatial and temporal distribution of forest fires according to Parajuli et al. 2015 Annex 3.

4.3.4 Land Use Adjustment

Same Landsat imageries that were used in land use analysis and land capability data were used to analyze and map land use adjustment of Hungri Madi Sub-Watershed according to FAO 2006 Annex 4.

4.3.5 Landslide Distribution

Watershed landslides were mapped in ARC GIS environment based on visual interpretation of remote sensing data, i.e. Google Earth Image (2000-2018).

5. Bio-Physical Condition

5.1 Trends in Land Use/Land Cover Change in Hungri Madi Sub Watershed (1995-2018)

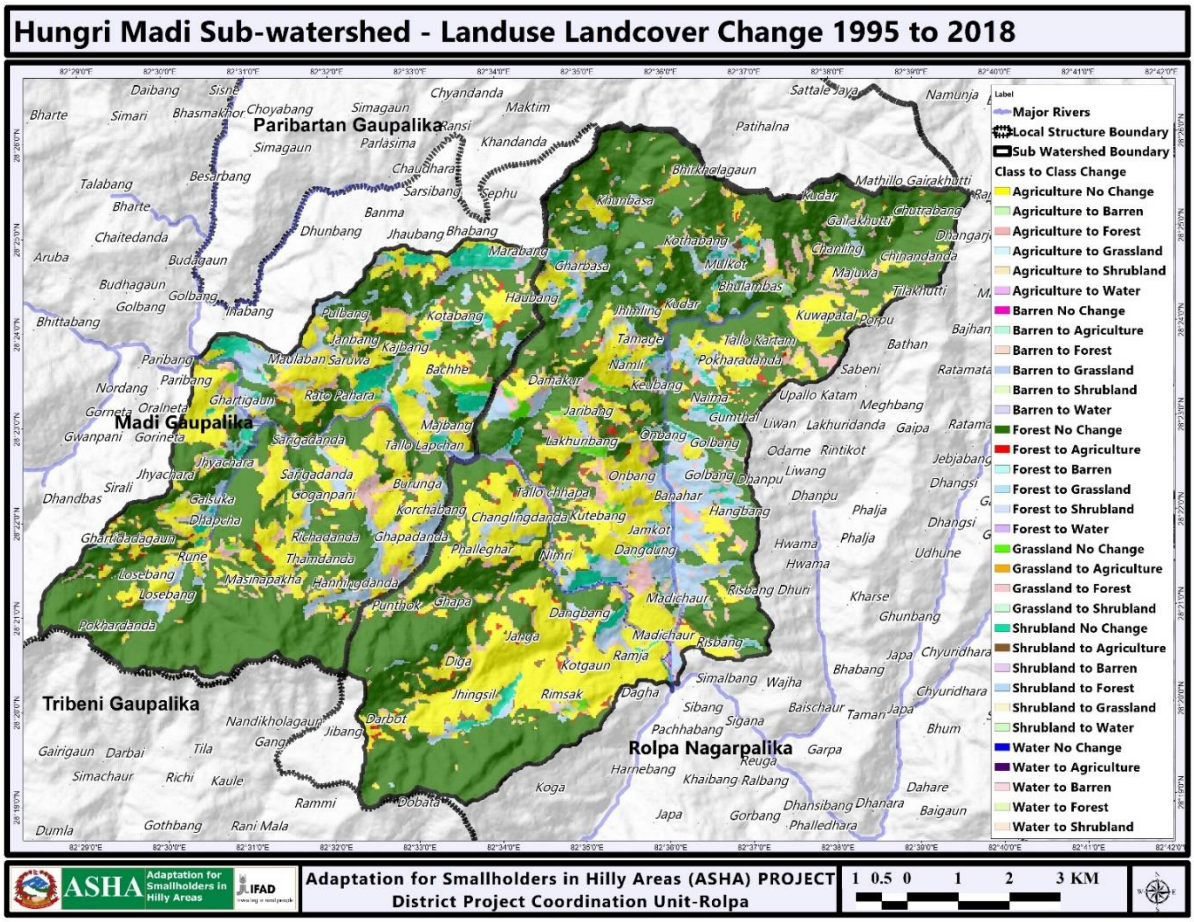
5.1.1 Changes in Land Use/Land Cover

An analysis of changes in land use/land cover in the sub-watershed for the period 1995-2018 shows that the area under forest increased, area under cultivation decreased and area under waterbody, grassland, shrub land, barren land substantially decreased (Table 1; Figure 2).

Table 1 Areas under Land Use/Cover and Change in Land Use/Land Cover in 1995, 2008 and 2018

Land Use Land Cover	1995		2008		2018		Change between 1995 & 2008		Change between 2008 & 2018		Change between 1995 & 2018	
	Area (Sq.KM)	Area (%)	Area (Sq.KM)	Area (%)	Area (Sq.KM)	Area (%)	Area (Sq.KM)	Area (%)	Area (Sq.KM)	Area (%)	Area (Sq.KM)	Area (%)
Forest	64.27	52.6	74.39	60.9	83.41	68.3	10.12	15.8	9.02	12.1	19.14	29.8
Shrub land	15.35	12.6	7.61	6.2	4.13	3.4	-7.74	-50.4	-3.49	-45.8	-11.22	-73.1
Grassland	3.42	2.8	2.86	2.3	1.33	1.1	-0.56	-16.4	-1.53	-53.4	-2.09	-61.1
Cultivation	38.38	31.4	36.70	30.1	33.03	27.0	-1.68	-4.4	-3.67	-10.0	-5.35	-13.9
Barrenland	0.49	0.4	0.12	0.1	0.08	0.1	-0.37	-76.3	-0.03	-27.9	-0.41	-82.9
Water	0.21	0.2	0.44	0.4	0.14	0.1	0.23	109.0	-0.30	-69.2	-0.07	-35.6
Total	122.12	100	122.12	100	122.12	100	****	****	****	****	****	****

Figure 2 Change in Land Use/Land Cover in Hungri Madi Sub Watershed in 1995 and 2018



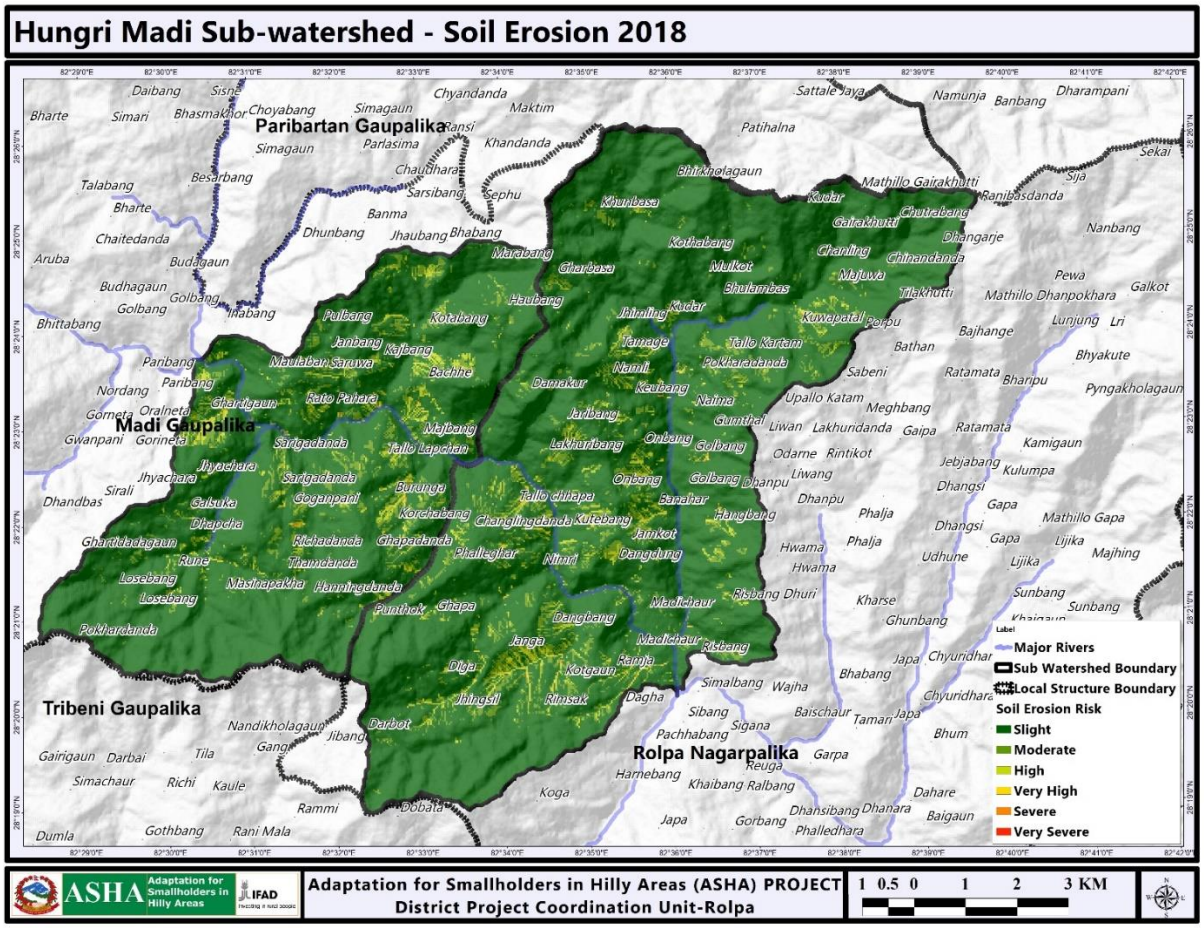
5.2 Estimation of Soil Erosion Loss Dynamics (1995-2018)

An analysis of soil loss in the sub-watershed for the period 1995-2018 shows that the area under waterbody has maximum soil loss rate, which followed by barren land, agriculture land, shrub land, grass land and forest. The estimated total soil loss for the entire area was around 23710 million tons in 1995, 22569 million tons in 2008 and 19604 million tons in 2018. (Table 2; Figure 3).

Table 2 Estimated Soil Erosion Rate of 1995, 2008 and 2018

Land Cover	Land Cover (KM^2)			Annual Soil Loss ('000 t)			Mean Erosion Rate (t/ha/yr.)		
Year	1995	2008	2018	1995	2008	2018	1995	2008	2018
Forest	64.268	74.392	83.413	2011	2387	2712	28.2	28.88	29.26
Shrub land	15.352	7.615	4.128	1237	619	329	72.5	73.15	71.78
Grassland	3.418	2.858	1.331	242	200	97	63.7	62.94	65.71
Agriculture	38.380	36.698	33.026	19560	18603	16276	458.7	456.23	443.54
Barren land	0.490	0.116	0.084	383	62	1	703.3	483.88	648.09
Waterbody	0.210	0.438	0.135	278	698	189	1193.2	1433.66	1262.91
Total	**122.117**	**122.117**	**122.117**	**23710**	**22569**	**19604**	**159.7**	**148.22**	**133.10**

Figure 3 Estimated Soil Erosion Rate in Hungri Madi Sub Watershed in 2018



5.3 Spatial and Temporal Distribution of Forest Fire (2000-2018)

An analysis of forest fire in the sub-watershed for the period 2000-2018 shows that Hungri Madi Sub Watershed has not forest fire yet during all season.

5.4 Land Use Adjustment

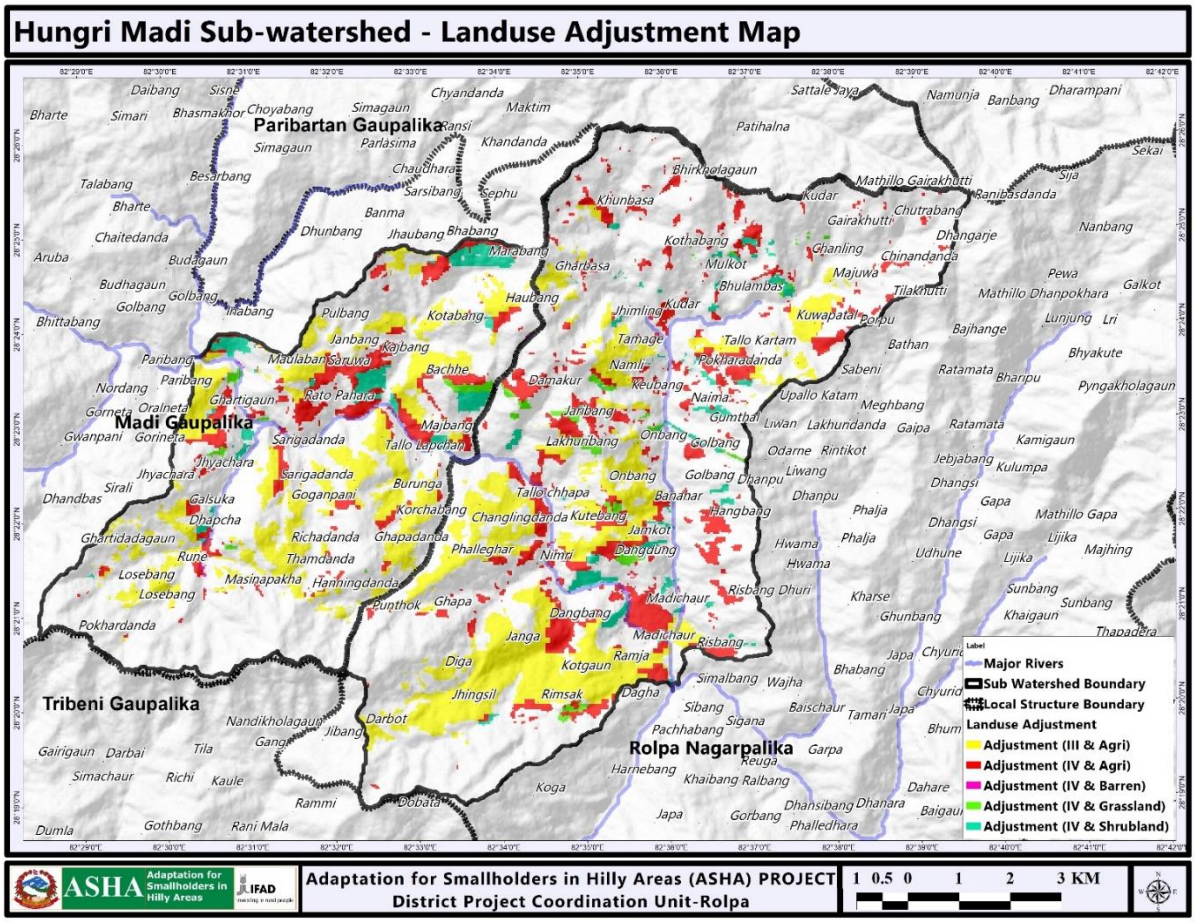
An analysis of land capability and current land use in the sub watershed shows that the land being over used. In sub-watershed natural environment of fragile and slope land (land class III and land class IV having moderate to steep slope) found managed or modified into agriculture, grassland, shrub land, waterbody and barren land. In the areas where land being over used, land use adjustments are required. (Table 3; Figure 4).

Table 3 Land use Adjustment in Sub Watershed

Land Use Adjustment	Rural Municipality/Municipality Ward	Area (Hectare)
Agriculture in Land Class III	*Madi Ga Pa 2, 5 and 6, Rolpa Nagarpalika 6 to 9*	2142.4
Agriculture in Land Class IV	*Madi Ga Pa 2, 5 and 6, Rolpa Nagarpalika 6 to 9*	1138.1
Barren land in Land Class IV	*Madi Ga Pa 2, 5 and 6, Rolpa Nagarpalika 6 to 9*	4.7

Grassland in Land Class IV	*Madi Ga Pa 2, 5 and 6, Rolpa Nagarpalika 6 to 9*	**103.1**
Shrub land in Land Class IV	*Madi Ga Pa 2, 5 and 6, Rolpa Nagarpalika 6 to 9*	**293.5**
Total		3681.8

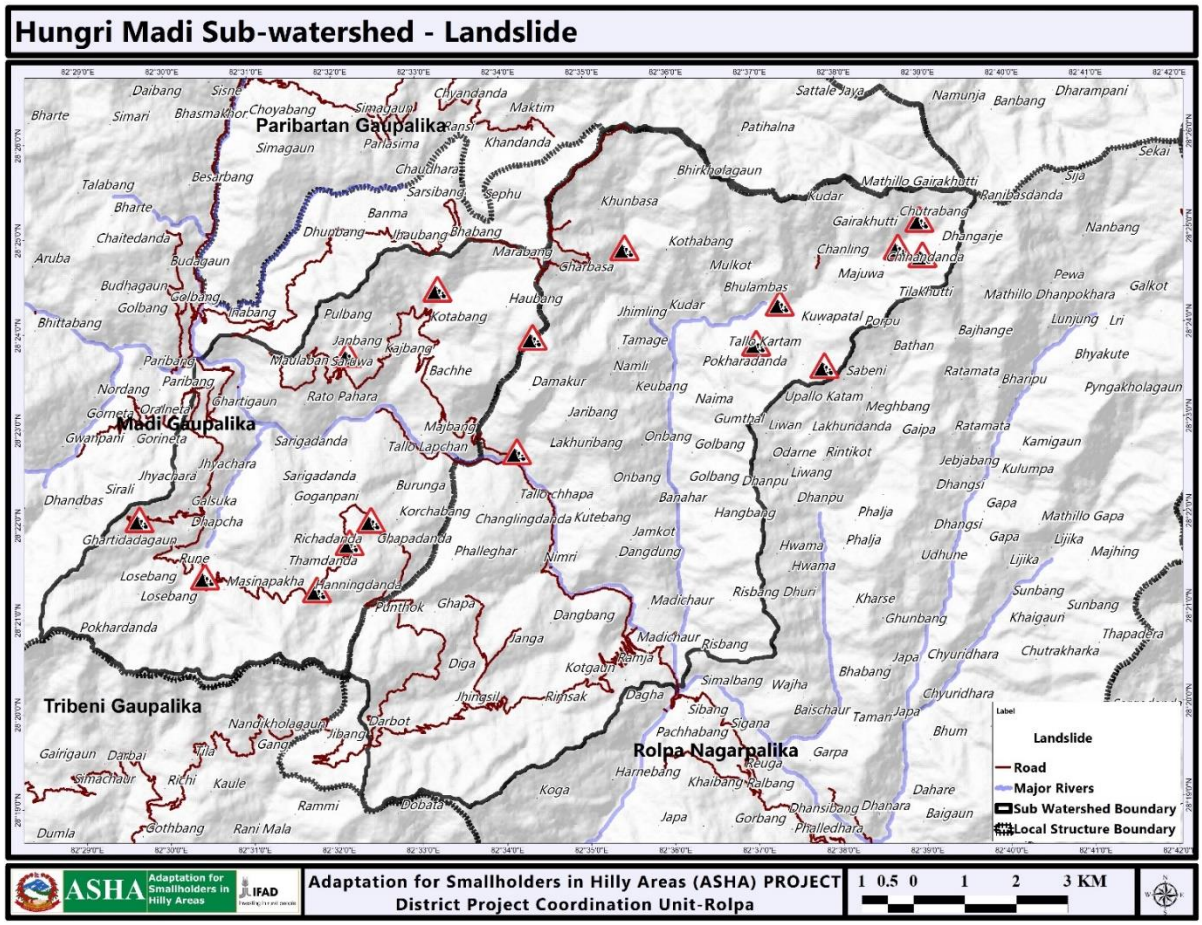
Figure 4 Land Use Adjustment in Hungri Madi Sub Watershed



5.5 Landslide Distribution

An analysis of landslide distribution in the sub-watershed shows landslide occur in Madi Gaupalika 2,5 and 6 and Rolpa Nagarpalika 8 and 9 of the Hungri Madi Sub-Watershed. Most of the landslide are caused by rural road construction.

Figure 5 Landslide Distribution in Hungri Madi Sub-Watershed



6. Upstream and Downstream Linkages

Analysis of bio-physical condition (land use/land cover, soil loss, landslide, land capability and current land use) in the sub-watershed shows that upstream and downstream linkages sites within Local Structure and beyond Local Structure within Hungri Madi Sub Watershed (Table 4 and 5).

Table 4 Upstream and Downstream Linkages Sites beyond Local Structure within Hungri Madi Sub Watershed

Linkage	Upstream	Downstream
Landslide	Madi	Thabang 3 north of Saipu
Deforestation and Degradation	Parivartan-1 Adjoining area of Makhola gaun, East of Sibari Kuleri, East of Lek jaya Parivartan 2 Adjoining area of Simagaun, Chayagaun	Thabang 2 Adjoining area of Mirul Sibari, Jaiyabari, South of Saipu Madi GaPa-3 East of Bhasmakhor, Sisne

Table 5 Upstream and Downstream linkages sites within Local Structure

Linkage	Upstream	Downstream
Landslide	Madi 2	
Deforestation and	Parivartan-1 Adjoining area of Jamli Pokhara and Bhutkhola Gaun	Parivartan-2 East of Selachar
Deforestation and	Parivartan-2 Adjoining area of Chapka, Pakhabang, Dandagaun	Parivartan-6 East of Obang, Naphe, Junban near the Madi river
Deforestation and	Parivartan-3 Northeast of Jumle Pokhari	Parivartan-4 Southwest of Arakholagaun
Deforestation and	Parivartan-3 Adjoining area of Sanighat	Parivartan-5
Deforestation and	Parivartan-4 East of Jhumma Bisauna	Parivartan-5 Adjoining area of Bhalukhore
Deforestation and	Parivartan-4 Adjoining area of Arakholagaun	Parivartan-3
Deforestation and	Parivartan-5 Adjoining area of Phumidhara, Jayapa, Sanighat,	Parivartan-3, 4

7. Socio-Economic Assessment

7.1 Demography

According to the national population census of 2011, the population of sub-watershed has reached to 14543 in 2011 with 3097 households. Of the total persons, the numbers and percentages of male and female were 56% and 44% respectively. Average household size found to be greater in Madi Ga Pa - 1 as 5.27 and lowest in Madi Ga Pa - 6 as 4.39 (CBS 2011 & modified).

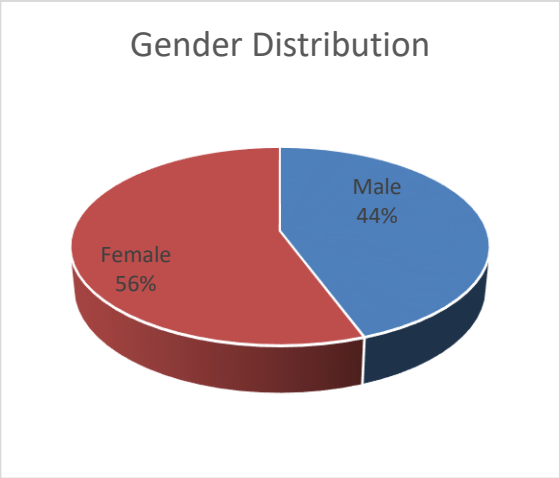


Figure 6 Gender Distribution

Population density determines pressure on land, which is expressed as average number of people per square kilometer. Population density has reached 119 persons per square kilometer in 2011. Rolpa Nagarpalika – 7 has highest population density with 170 persons per square kilometer followed by Madi Ga Pa - 6 with 153 persons per square kilometer and Rolpa Nagarpalika – 8 has the lowest population density with 68 persons per square kilometer in 2011. Likewise, number of person per square kilometer of agricultural land in the sub-watershed has reached 556 in 2011. Population density per square kilometer of forest has reached 221 persons per square kilometer of forests in 2011 (CBS 2011 & modified)

7.2 Caste and ethnic distribution

Majority of the population in sub-watershed are Jananati which is followed by Brahmin/Cheetri/Thakuri, Dalits, others and Dasnami. Of the total Population, the percentages of Jananati Brahmin/Cheetri/Thakuri, Dalits, Others and Dasnami were 52.73%, 26.84%, 19.71%, 0.48% and 0.23% respectively (CBS 2011).

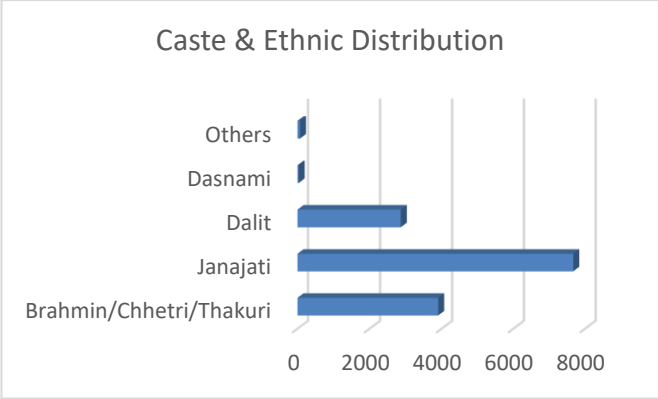


Figure 7 Caste and Ethnic Distribution

7.3 Literacy

Population Census 2011 shows that 60.95 percent of population aged 5 years and above were literate in the sub-watershed. Male is 70.94 percent while the female literacy is about 53.20 percent. About 55.55 % population 5 years and above have gain primary level education, 16.39 % have gain lower secondary level education, 5.54 % have gain secondary level, 3.38 % SLC and equivalent 1.95 % Intermediate & equivalent, 0.33 % graduate and 0.07 % post graduate in the sub-watershed (CBS 2011 & Modified).

7.4 Gender Relation

Similar in other area of Nepal, women of sub-watershed have been assuming culturally defined responsibilities such as spending massive time in household chores such as cooking, child raising, collecting forest product, building social relationships and socialization and so forth. This has compelled them in disadvantaged position in terms of education and improved career opportunities. Male usually takes not only most of the household decisions but also manage cash and financial activities. Position of women in household and communities is bleak. However, recent women empowerment programs advanced by the Government agencies, NGOs and CBOs have enabled many women particularly from the poor households to cross fortress walls of their houses and participate in the community activities such as natural resources management (Field Survey, 2017).

7.5 Usual fuel for cooking

About 99.16% of the total households use firewood as the usual source of fuel for cooking in the sub- watershed and 0.84 % of households use other source of energy for cooking e.g. Cow dung (guitha), biogas, Electricity, LP Gas etc. (CBS 2011 & Modified).

7.6 Main source of drinking water

In total 4422 households have piped waters facilities in the sub-watershed. Remaining 704 households have been using other source for drinking water out of which 190 households have been using traditional uncovered well for drinking water. Other sources are tube well, covered well, spout water, river, and stream (CBS 2011 & Modified).

7.7 Economically active population

More than two third of the economically active population are engaged in skilled agriculture and livestock sector followed by elementary occupations, craft and related trades work, service and sale work. Rest of the population is employed as technicians and teacher and armed forces employee and other professions (Field Survey 2017).

8. Hungri Madi Sub-Watershed Climatic Vulnerability

Vulnerability as the function of exposure to hazard-risk, sensitivity of the system and adaptive capacity is represented by functional aggregates of these factors to represent its indicator or score. Mathematically, Vulnerability Index (VULI) is computed as the product of exposure, sensitivity and inverse of adaptive capacity given by the equation. Hungri Madi Sub Watershed VULI has been illustrated in (Table 6).

Table 6 Vulnerability Index of Local Structure in Hungri Madi Sub Watershed Rolpa

S.N.	Former VDC	Local Structure	Vulnerability Class
1	Ghartigaun 5, 7-9	Madi-1	Moderate
2	Wot 3-5	Madi-1	High
3	Ghartigaun 1-4, 6	Madi-2	Moderate
4	Bhabang 1-9	Madi-5	Very High
5	Korchabang 1,2,6-9	Madi-6	Moderate
6	Kotgaun 2-7, 9	Rolpa-6	Moderate
7	Korchabang 3-5	Rolpa-7	Moderate
8	Kotgaun-1,8	Rolpa-7	Moderate
9	Jangkot-1	Rolpa-7	Low
10	Jangkot 2-8	Rolpa-8	Low
11	Whama 1-9	Rolpa-9	Very High

Source: ASHA Project 2016

9. Drivers of Hungri Madi Sub Watershed Degradation

Drivers of Hungri Madi Sub-Watershed degradation have been identified. These include a) unscientific cultivation where land capability not considered, b) destruction of natural vegetation and deforestation, c) soil erosion and d) landslide together with natural forces such as fragile geology, steep slopes, loose sandy soil and uneven distribution of rainfall with high intensity during monsoon has compounded the problems of degradation in this sub-watershed. The following sections imparts information about each of the drivers.

9.1 Lack of Alternative Source of Energy

Firewood is the major source of cooking fuel in this sub-watershed. About 99.16% of total household of this sub-watershed are using firewood as major source of cooking fuel. Rest 0.84 % of Household are using Kerosene, LP Gas and others source of energy. As a result, there is high pressure on Forest which leads to deforestation and forest degradation. With increasing in

population, the demand of fuelwood is also increasing day by day. Ultimately, forest resource receives more pressure.

9.2 Invasion by Alien Plant Species

Invasive alien plant species are rapidly colonializing. Ageratum conyzoides, Amaranthus spinosus, Bidens pilosa, Eupatorium adenophorum are some of the IAS which is degrading this watershed. Mostly is river and shade area Eupatorium adenophorum is spreading rapidly.

9.3 Rural Road Construction

Construction of road is the primary element for development of any country. As development is rapidly increasing in comparison to past decades, Road network is one of the major indicator of development. Road construction in steep slope, fragile rocks and soil, unscientific manner leads to forest degradation and deforestation. But in this watershed maximum landslide is occurred due to road construction which is leading to watershed degradation. In this watershed there is also constructed many rural roads without proper design, environmental study, drainage system, and scientific knowledge. Several roads can be seen through present Google earth image within this watershed. These unplanned roads are not only causing deforestation and forest degradation but also these unplanned road constructions trigger the landslide, soil erosion and unwanted deposition. Debris deposition causes loss of fertility of agriculture land.

9.4 Unscientific cultivation

Land classification undertaken by Land Resource Mapping Project (LRMP) has categorized Hungri Madi Sub watershed into seven land capability classes namely Class I to Class VI and VIII. Land use in the watershed has been analyzed according to land use capability class. According to the land use capability class, class IV to VIII are not suitable for agriculture practice. In class II and III, agriculture can be practice with conservation measures. Class I and II are taken as land with minimal potentiality to soil erosion. According to land capability they have very few limitations when used for arable agriculture. But Class III, Class IV and Class VI requires full vegetation cover, if agriculture practiced is such classes have moderate to high risk of soil erosion and soil damage. In this sub-watershed unscientific cultivation has been found in 3280.5-hectare land in Class III and Class IV where land capability not considered has compounded the problems of soil erosion and landslide in this watershed.

9.5 Destruction of natural vegetation and deforestation

Forest and shrub in the watershed meets the demands for fuel and timber of the people living in the sub-watershed and the surrounding urban areas. The demand for fuel-wood is on the rise. Pressure on the existing forest resources comes from one or a combination of the following factors; a) unsustainable harvesting of timber, b) fuel-wood collection, c) uncontrolled grazing, and d) forest fires contributed forest deforestation. Grazing in the forest area is quite common and causing soil compaction and heavy damage to the natural regeneration. The intensity of such disturbances, especially near the habitation, is far beyond the carrying capacity of the forests.

9.6 Erosion and landslide:

The frequency of natural hazards increased after the watershed began getting cleared for settlement, agriculture expansion and unscientific cultivation where land capability not considered about decades ago. The high rate of erosion and landslide poses a major threat to the settlement and land resources in sub-watershed. Major soil loss in the sub-watershed has mainly from cultivated land. It is almost equal to total soil loss in the entire sub-watershed. Total annual soil loss in the watershed found to be in decreasing order. The study found that the annual soil loss in 1995 was 23710 million tons. Similarly, total soil loss for 2008 and 2018 were 22569 million tons and 19604 million tons respectively. Study shows that landslide due to road constructions have been contributing for sub-watershed degradation.

10. Recommendations

The study suggested following programs for improving Hungri Madi Sub-Watershed condition.

10.1 Soil and Land Conservation Program

Objective: The main objective of this program is to protect land degradation by soil erosion, landslides and improve livelihoods of people, especially the poor and vulnerable group by developing sustainable resource conservation, utilization and management system of land, water and forest resources at farm household and community incorporating concerned at sub-watershed level while maintaining the hydrological linkages of Upstream and Downstream.

Target Area: Soil and land conservation program will cover the following area:

Rural Municipality ward	Location
Madi-2	Adjoining areas of Ghartigaun, Jhyachara, Galsuka, Lamidanda, Masinapakha, Losebang, Rune, Ghartidandagaun,
Madi-6	Adjoining areas of Mathillo Lapchan, Burunga, Korchabang, Ghapadanda, Richadanda, Goganpani, Sarigadanda, Thamdanda, Hanningdanda
Madi-5	Adjoining areas of Ratopahara, Maulaban, Saruwa, Pachhabang, Baibang, Dahabang, Kotabang, Haubang, Bachhe, Majbang, North of Kotabang
Rolpa-6	Adjoining areas of Diga, Jhingsil, Rimsak, East of Rimsak
Rolpa-7	Adjoining areas of Punthok, Ghapa, Phalleghar, Janga, Danbang, Ghiu Pokhara, Changlingdanda, Tallo Chhapa
Rolpa-8	Adjoining areas of Mathala, Paribang, Kutebang, Jamkot, Onbang, Bamarup, Lakhuribang, Bhagachaur, Damakhur, Challibang, Namli, Keubang, Tamage, Gharbasa, Kudar, Khunbasa, Ghuyalchaur, Mulkot, Chanling
Rolpa-9	Adjoining areas of Majuwa, Kuwapatal, Chutre Gatina, Pokharadanda, Tallo Kartam, Upallo KArtam, Suga Pokhara, Naima, Golbang, Hangbang, Risbang Dhuri, Risbang

Programme: Soil conservation and land conservation at the sub-watershed level will be implemented on the basis of number of affected households/area and its impact to the physical environment and Downstream. This programs will be implemented to conserve water sources, increase land productivity, minimize erosion and landslide in the watershed while maintaining the hydrological linkages of the upstream and downstream.

- Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring upstream and downstream linkages
- Reclaim the degraded land by appropriate vegetative and structural methods
- Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others
- Assist farmers in managing monsoon run-off
- Assist in development and protection of water resources
- Rehabilitate the erosion hot spots (severely eroded area)
- Promote income generation and conservation oriented plantations of forests and grasses in degraded lands
- Implement landslide bank stabilization program through bio-engineering methods

10.2 Forest Restoration Program

Objectives: The objective of the forest restoration is to restore, protect and conserve forest by adopting appropriate participatory forest management modality. It further will contribute to reduce soil erosion, landslides, and damages due to floods and effect of anthropogenic activities like forest resource exploitation and uncontrolled grazing in the sub-watershed.

Target Area: Forest restoration program will cover the following area:

Rural Municipality ward	Location
Madi-2	Adjoining areas of Losebang, Rune, Ghartidandagaun, MasinaPakha, Dapcha, Galsuka, North of Ghartidandagaun, South of Ghartigaun North of Gharti gaun (Upstream) & MAdi-5 (Downstream), East of Jhyara (Upstream) & MAdi-6 (Downstream)
Madi-6	Adjoining areas of Thamdanda, Hanning Danda, Misidanda, Goganpani, Korchabang, Burunga West of Thamdanda, Richadanda, Sarigadanda (Upstream) & Madi-2 (Downstream)
Madi-5	Adjoining areas of Saruwa, Janbang, Kajbang, Pachhabang, Haubang, Bhakarbang, Baibang, Dahabang, Kotabang South and Southeast of Ratopahara, Majbang (Upstream) & MAdi-6 (Downstream)
Rolpa-6	Adjoining areas of Diga (Upstream) & Rolpa-7 Janga (Downstream), West of Kotgaun (Upstream) & Rolpa-8 Danbang (Downstream)

Rolpa-7	Adjoining areas of Darbot, Phanrang, Jhinsil, Kutebang, Rimask, East of Rimsak Chanlingdanda, Tallochapa, Ghiupokhara, Nimri (Upstream) Rolpa-8 (Downstream), Janga, Danbang (Upstream) & Rolpa-6 (Downstream)
Rolpa-8	Adjoining areas of Mathhilo Changling, Bhirkholagaun, Khunbasa, Ghuyalchaur, Kothabang, Gharbasa, Jhimling Hwama, Tamage, Challinbang, Lakhuribang, Paribang, Kutebang, Mathala (Upstream) & Rolpa-7 (Downstream), Onbang, Keubang, Kudar, Pathihalna, Changling (Upstream) & Rolpa-9 (Downstream)
Rolpa-9	South of Dhangarje, Adjoining areas of Porpu, Chutre Gatina, Upallo Katam North of Risbang, Adjoining areas of Risbang Dhuri, Naima, Gumthal, Sugapokhara, Pokharadanda, Tallo Kartam, Kuwapatal (Upstream) & Rolpa-8 (Downstream)

Programme:

Forest restoration is a process which aims at regaining ecological integrity and enhancement of human well-being. This will put in place a mix of land-use practices for restoring the functions of forests across a whole watershed by a) restoring forest functionality at a sub-watershed, which translates into gaining the optimal quantity and quality of forest resources necessary for improving and maintaining people's well-being and ecological integrity and b) strengthening the relationship between rural development, forestry and other disciplines of natural resource management and conservation approaches. The focus of the forest restoration program will be on conservation and protection of the forest in the sub-watershed. Forest resource will be managed sustainably to satisfy the needs of the community while conserving biodiversity and balancing the environmental values. Likewise, degraded forest and forest around the erosion and landslide prone area will be managed.

- Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation and forest restoration
- Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation)
- Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock
- Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, community and private owned land to show the tree crop interactions and its resultant benefits
- Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.

10.3 Land Use Adjustment Program

Objectives: The objective of the land use adjustment program is to adjust and minimize soil erosion, landslides, and other damages in the sub-watershed due to unscientific cultivation and improper land use practices where land capability not considered.

Target Area: Land use adjustment program will cover the following area:

Rural Municipality ward	Location
Madi-2	Land use adjustment (III & Agriculture) Adjoining areas of Ghartigaun, Jhyanchara, Dhapcha, Ghartidandagaun, Losebang, Rune, Masinapakha Land use adjustment (IV & Agriculture) East and South of Ghartigaun, Adjoining areas of Jhyachara, Galsuka, Lamidanda, North of Lamidanda, Pokhardanda, East of Masinapakha Land use adjustment (IV & Shrubland & Grassland) West of Sarigadanda, East of Dhapcha
Madi-6	Land use adjustment (III & Agriculture) Adjoining areas of Thamdanda, Richadanda, Goganpani, Misidanda, MAthillo Lapchan, Burunga, Ghapadanda, Tallo LApchan, Sarigadanda Land use adjustment (IV & Agriculture) Adjoining areas of Sarigadanda, Hanningdanda, Korchabang, East of Misidanda, South of Ghapadanda, North of Tallo Lapchan
Madi-5	Land use adjustment (III & Agriculture) Adjoining areas of Maulaban, Janbang, Pulbang, Pachhabang, Baibang, Haubang, Jhaubang, Land use adjustment (IV & Agriculture) Adjoining areas of Rato Pahara, Saruwa, Kajbang, Bachhe, Dahabang, Majbang South of Marabang, Haubang, Dahabang, Land use adjustment (IV & Shrubland & Grassland) West of MAulaban, South of Kajbang, Dahabang, Haubang, Marabang, Southeast of Majbang
Rolpa-6	Land use adjustment (III & Agriculture) Adjoining areas of Phanrang, Diga, Jhingsil, Kutebang, Rimsak, Kotgaun, Jhilibang Land use adjustment (IV & Agriculture) South of Rimsak, East of Rimsak Land use adjustment (IV & Shrubland & Grassland) East of Rimsak, South of Kutebang

Rolpa-7	Land use adjustment (III & Agriculture) Adjoining areas of Tallo Chhapa, Changlingdanda, Phalleghar, Ghiu Pokhara, Ghapa, Janga, Dangbang, Ramja, Land use adjustment (IV & Agriculture) Adjoining areas of Punthok, Madichaur, South of Ghapa, East of Dangbang, Ghiu Pokhara, Phalleghar, Tallo Chhapa Land use adjustment (IV & Shrubland & Grassland) East of Mimri, West of madichaur, North of Madichaur
Rolpa-8	Land use adjustment (III & Agriculture) Adjoining areas of Mathala, Jamkot, Onbang, Banahar, Bamarup,Lakhuribang, Namli, Tamage, Gharbasa, Khunbasa Land use adjustment (IV & Agriculture) Adjoining areas of Kutebang, Jaribang, Damakur, Challibang, Kudar, Kothabang, Bhulambas, Chanling, Ghuyalachaur, Bhirkholagaun, Mathillo Changling, Bhedakhor, Gaiirakhutti, Chutrabang Land use adjustment (IV & Shrubland & Grassland) South of Mathillo Changling, Tallo Changling, Jhimling, Damakur, Jaribang, Onbang, Jamkot
Rolpa-9	Land use adjustment (III & Agriculture) Adjoining areas of Majuwa, Kuwapatal, Pokharadanda, Tallo Kartam, Chutre Gatina, East of Upallo Katam, North of Risbang Land use adjustment (IV & Agriculture) Adjoining areas of Risbang, Risbang Dhuri, Hangbang, Golbang, Naima, Suga Pokhara, Upallo Katam, Tilakhutti, Chinandanda, East of Dhangarje, Kuwapatal, North of Kuwapatal Land use adjustment (IV & Shrubland & Grassland) North of Golbang, Adjoining areas of Gumthal, Golbang West of Suga Pokhara,

Programme: Land use adjustment program at the catchment level will be implemented on the basis of number of affected households/area and its impact to the physical environment and Downstream. This programs will be implemented to minimize erosion and landslide, conserve water sources and increase land productivity in the sub-watershed while maintaining the hydrological linkages of the Upstream and Downstream.

- Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems
- Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry
- Promote conservation pond/runoff harvesting dam
- Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques

- Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system
- Protect agriculture land from erosion
- Develop and disseminate information related to conservation agriculture, SLAT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects
- Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management
- Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock

10.4 Grazing Control and Fodder Development Program

Objective: The objective of this program is to reduce the incidence and extent of grazing on natural forests by enhancing the cultivation of improved varieties of fodder crops, grasses on private and communal land.

Target Area: Grazing control and fodder development program will cover the following area:

Rural Municipality ward	Location
Madi-2	Adjoining areas of Losebang, Rune, Ghartidandagaun, MasinaPakha, Dapcha, Galsuka, North of Ghartidandagaun, South of Ghartigaun North of Gharti gaun (Upstream) & MAdi-5 (Downstream), East of Jhyara (Upstream) & MAdi-6 (Downstream)
Madi-6	Adjoining areas of Thamdanda, Hanning Danda, Misidanda, Goganpani, Korchabang, Burunga West of Thamdanda, Richadanda, Sarigadanda (Upstream) & Madi-2 (Downstream)
Madi-5	Adjoining areas of Saruwa, Janbang, Kajbang, Pachhabang, Haubang, Bhakarbang, Baibang, Dahabang, Kotabang South and Southeast of Ratopahara, Majbang (Upstream) & MAdi-6 (Downstream)
Rolpa-6	Adjoining areas of Diga (Upstream) & Rolpa-7 Janga (Downstream), West of Kotgaun (Upstream) & Rolpa-8 Danbang (Downstream)
Rolpa-7	Adjoining areas of Darbot, Phanrang, Jhinsil, Kutebang, Rimask, East of Rimsak Chanlingdanda, Tallochapa, Ghiupokhara, Nimri (Upstream) Rolpa-8 (Downstream), Janga, Danbang (Upstream) & Rolpa-6 (Downstream)
Rolpa-8	Adjoining areas of Mathhilo Changling, Bhirkholagaun, Khunbasa, Ghuyalchaur, Kothabang, Gharbasa, Jhimling Hwama, Tamage, Challinbang,

	Lakhuribang, Paribang, Kutebang, Mathala (Upstream) & Rolpa-7 (Downstream), Onbang, Keubang, Kudar, Pathihalna, Changling (Upstream) & Rolpa-9 (Downstream)
Rolpa-9	South of Dhangarje, Adjoining areas of Porpu, Chutre Gatina, Upallo Katam North of Risbang, Adjoining areas of Risbang Dhuri, Naima, Gumthal, Sugapokhara, Pokharadanda, Tallo Kartam, Kuwapatal (Upstream) & Rolpa-8 (Downstream)

Programme: The grazing practices will be reduced by introducing better quality nutritious grasses and fodder promotion on farm land. Breed improvement for cattle will be intensified and services will be provided at door steps. Likewise, unrestricted breeding of the herds of less productive cattle will be discouraged and stall feeding and cut and carry practices will be encouraged. Cattle shed and grazing area will be developed around the trails to address the grazing pressure of temporary migratory livestock. Apart from the above, coordination between stakeholder's agencies will be strengthened.

- Reduce pressure on the forest from cattle grazing by inducing stall feeding, controlled grazing and promoting cut and carrying practices
- Promote fodder tree and grasses plantation on farm land without affecting their farming system
- Strengthen coordination with municipality/rural municipality, the DLSO and other line agencies to address the grazing issues/problems

10.5 Income Generation Programme

The major purpose of income generation program is to enhance income and employment opportunities in farm and non-farm activities, especially targeted to vulnerable women, poor, disadvantage group and conflict affected people.

Target Area: Income generation program will cover the following area:

Rural Municipality ward	Location
Madi-2	Adjoining areas of Losebang, Rune, Ghartidandagaun, MasinaPakha, Dapcha, Galsuka, North of Ghartidandagaun, South of Ghartigaun North of Gharti gaun (Upstream) & MAdi-5 (Downstream), East of Jhyara (Upstream) & MAdi-6 (Downstream)
Madi-6	Adjoining areas of Thamdanda, Hanning Danda, Misidanda, Goganpani, Korchabang, Burunga West of Thamdanda, Richadanda, Sarigadanda (Upstream) & Madi-2 (Downstream)
Madi-5	Adjoining areas of Saruwa, Janbang, Kajbang, Pachhabang, Haubang, Bhakarbang, Baibang, Dahabang, Kotabang

	South and Southeast of Ratopahara, Majbang (Upstream) & MAdi-6 (Downstream)
Rolpa-6	Adjoining areas of Diga (Upstream) & Rolpa-7 Janga (Downstream), West of Kotgaun (Upstream) & Rolpa-8 Danbang (Downstream)
Rolpa-7	Adjoining areas of Darbot, Phanrang, Jhinsil, Kutebang, Rimask, East of Rimsak Chanlingdanda, Tallochapa, Ghiupokhara, Nimri (Upstream) Rolpa-8 (Downstream), Janga, Danbang (Upstream) & Rolpa-6 (Downstream)
Rolpa-8	Adjoining areas of Mathhilo Changling, Bhirkholagaun, Khunbasa, Ghuyalchaur, Kothabang, Gharbasa, Jhimling Hwama, Tamage, Challinbang, Lakhuribang, Paribang, Kutebang, Mathala (Upstream) & Rolpa-7 (Downstream), Onbang, Keubang, Kudar, Pathihalna, Changling (Upstream) & Rolpa-9 (Downstream)
Rolpa-9	South of Dhangarje, Adjoining areas of Porpu, Chutre Gatina, Upallo Katam North of Risbang, Adjoining areas of Risbang Dhuri, Naima, Gumthal, Sugapokhara, Pokharadanda, Tallo Kartam, Kuwapatal (Upstream) & Rolpa-8 (Downstream)

Program:

- Identify feasible farm and non-farm based income generating activities
- Organize short term skill development training on farm and non-farm enterprises according to their interest and market potential
- Establish revolving fund for effective implementation of income generating program
- Mobilize FUGs resources and funds in forestry based income generating activities prioritizing especially poor and marginalized people
- Provide technical and financial support to small-scale poor focused income generating programs with immediate impact on livelihood
- Establish linkages with market and provide market information system
- Establish linkages with different government line agencies, NGOs and international agencies to promote income generating activities

10.6 Alternative Energy Development Program

The main purpose of alternative energy development is to narrow downstream the gap between demand and supply of forest products by promoting the use of fuel-efficient stove, developing fuelwood substitute like biogas and increasing their supply. Efficiency in the consumption and substitution of firewood with alternative fuel will be emphasized especially targeting Dalit community and other firewood scarce area.

Target Area: Alternative energy development program will cover the following area:

Rural Municipality ward	Location
Madi-2	Adjoining areas of Losebang, Rune, Ghartidandagaun, MasinaPakha, Dapcha, Galsuka, North of Ghartidandagaun, South of Ghartigaun North of Gharti gaun (Upstream) & MAdi-5 (Downstream), East of Jhyara (Upstream) & MAdi-6 (Downstream)
Madi-6	Adjoining areas of Thamdanda, Hanning Danda, Misidanda, Goganpani, Korchabang, Burunga West of Thamdanda, Richadanda, Sarigadanda (Upstream) & Madi-2 (Downstream)
Madi-5	Adjoining areas of Saruwa, Janbang, Kajbang, Pachhabang, Haubang, Bhakarbang, Baibang, Dahabang, Kotabang South and Southeast of Ratopahara, Majbang (Upstream) & MAdi-6 (Downstream)
Rolpa-6	Adjoining areas of Diga (Upstream) & Rolpa-7 Janga (Downstream), West of Kotgaun (Upstream) & Rolpa-8 Danbang (Downstream)
Rolpa-7	Adjoining areas of Darbot, Phanrang, Jhinsil, Kutebang, Rimask, East of Rimsak Chanlingdanda, Tallochapa, Ghiupokhara, Nimri (Upstream) Rolpa-8 (Downstream), Janga, Danbang (Upstream) & Rolpa-6 (Downstream)
Rolpa-8	Adjoining areas of Mathhilo Changling, Bhirkholagaun, Khunbasa, Ghuyalchaur, Kothabang, Gharbasa, Jhimling Hwama, Tamage, Challinbang, Lakhuribang, Paribang, Kutebang, Mathala (Upstream) & Rolpa-7 (Downstream), Onbang, Keubang, Kudar, Pathihalna, Changling (Upstream) & Rolpa-9 (Downstream)
Rolpa-9	South of Dhangarje, Adjoining areas of Porpu, Chutre Gatina, Upallo Katam North of Risbang, Adjoining areas of Risbang Dhuri, Naima, Gumthal, Sugapokhara, Pokharadanda, Tallo Kartam, Kuwapatal (Upstream) & Rolpa-8 (Downstream)

Program

- Promote non-conventional energy sources such as biogas, solar and other energy
- Raise plantation of fast growing short rotation site specific firewood species on government and private land particularly in degraded forest areas and community forests
- Provide extension support, training and seedling transport subsidy on fuelwood plantation both in private and public land
- Encourage people to use energy saving devices such as improved cooking stove
- Mobilize FUGs and community based organizations in promoting alternative energy technology by providing technical, material and financial support needed

- Establish linkages with national alternate energy related programs based on the local demand
- Conduct pilot testing and demonstration of the community owned biogas plants in the lower economic class population in collaboration with concerned agencies
- Provide subsidized financing and loan from the NGOs and financial institutions on installation of biogas

10.7 Program beyond Administrative Boundary

Objective: The main purpose of this program is to address the linkages between the changes in the physical environment of Upstream areas (land use, soil erosion, landslide etc.) and of climate change on the Downstream water availability, flood and dry season flow, and erosion, sedimentation and others beyond administrative boundary maintaining the hydrological linkages of the Upstream and Downstream.

Target Area: Program beyond administrative boundary will cover the following area:

Linkage	Upstream	Downstream	Activities
Landslide	Madi-5 Northwest of Haubang	Rolpa-8 North of Damakur	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods
Deforestation and Degradation	Madi-2 East of Haningdanda, Ghapadanda, Korchabang	Rolpa-7	• Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement

	Madi-2 North of Burunga	Rolpa-8	and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.

11. Action Plan

11.1 Action Plan Madi 2

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others	South of Lamidanda, North of Ghartidandagaun	

		• Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods		
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-	North of Gharti gaun (Upstream) & MAdi-5 (Downstream), East of Jhyara (Upstream) & MAdi-6 (Downstream) East of Haningdanda, Ghapadanda, Korchabang (Upstream) & Rolpa-7 (Downstream), North of Burunga (Upstream) & Rolpa-8 (Downstream) Adjoining areas of Losebang, Rune, Ghartidandagaun, MasinaPakha, Dapcha, Galsuka, North of	

		hydro, biogas, improved cooking stove, solar power etc.	Ghartidandagaun, South of Ghartigaun	
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices • Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge	Adjoining areas of Ghartigaun, Jhyachara, Galsuka, Lamidanda, Masinapakha, Losebang, Rune, Ghartidandagaun	

Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry • Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness	Land use adjustment (III & Agriculture) Adjoining areas of Ghartigaun, Jhyanchara, Dhapcha, Ghartidandagaun, Losebang, Rune, Masinapakha Land use adjustment (IV & Agriculture) East and South of Ghartigaun, Adjoining areas of Jhyachara, Galsuka, Lamidanda, North of Lamidanda, Pokhardanda, East of Masinapakha Land use adjustment (IV & Shrubland & Grassland) West of Sarigadanda, East of Dhapcha	

		of erosion problems, farming practices and soil fertility management		

11.2 Action Plan- Madi 6

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods	Adjoining areas of Hanningdanda, West of Korchabang (road side landslide)	
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry	West of Thamdanda, Richadanda, Sarigadanda (Upstream) &	

		• Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.	Madi-2 (Downstream) Adjoining areas of Thamdanda, Hanning Danda, Misidanda, Goganpani, Korchabang, Burunga	
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources	Adjoining areas of Mathillo Lapchan, Burunga, Korchabang, Ghapadanda, Richadanda, Goganpani, Sarigadanda, Thamdanda, Hanningdanda	

		• Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices • Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge		
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry • Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques	Land use adjustment (III & Agriculture) Adjoining areas of Thamdanda, Richadanda, Goganpani, Misidanda, MAthillo Lapchan, Burunga, Ghapadanda, Tallo LApchan, Sarigadanda Land use adjustment (IV & Agriculture) Adjoining areas of Sarigadanda, Hanningdanda,	

		• Encourage and sUpstreamport farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management	Korchabang, East of Misidanda, South of Ghapadanda, North of Tallo Lapchan	

11.3 Action Plan- Madi 5

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off	Northwest of Maulaban (Upstream) & Madi-2 North of Ghartigaun (Downstream) Northwest of Haubang (Upstream) & Rolpa- North of Damakur (Downstream)	

		• Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods	Northeast of Saruwa, Southeast of Jangkot	
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.	South and Southeast of Ratopahara, Majbang (Upstream) & MAdi-6 (Downstream) Adjoining areas of Saruwa, Janbang, Kajbang, Pachhabang, Haubang, Bhakarbang, Baibang, Dahabang, Kotabang	

Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices • Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge	Adjoining areas of Ratopahara, Maulaban, Saruwa, Pachhabang, Baibang, Dahabang, Kotabang, Haubang, Bachhe, Majbang, North of Kotabang	
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry	Land use adjustment (III & Agriculture) Adjoining areas of Maulaban, Janbang, Pulbang, Pachhabang, Baibang, Haubang, Jhaubang,	

		• Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management	Land use adjustment (IV & Agriculture) Adjoining areas of Rato Pahara, Saruwa, Kajbang, Bachhe, Dahabang, Majbang South of Marabang, Haubang, Dahabang, Land use adjustment (IV & Shrubland & Grassland) West of MAulaban, South of Kajbang, Dahabang, Haubang, Marabang, Southeast of Majbang	

11.4 Action Plan Rolpa 6

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages	*Maximum Landslide has been identified on rural road construction site*	

		• Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods		
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry	Adjoining areas of Diga (Upstream) & Rolpa-7 Janga (Downstream), West of Kotgaun (Upstream) & Rolpa-8 Danbang (Downstream)	

		system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.		
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices	Adjoining areas of Diga, Jhingsil, Rimsak, East of Rimsak	

		• Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge		
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry • Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different	Land use adjustment (III & Agriculture) Adjoining areas of Phanrang, Diga, Jhingsil, Kutebang, Rimsak, Kotgaun, Jhilibang Land use adjustment (IV & Agriculture) South of Rimsak, East of Rimsak Land use adjustment (IV & Shrubland & Grassland) East of Rimsak, South of Kutebang	

		extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management		

11.5 Action Plan- Rolpa 7

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands	*Maximum Landslide has been identified on rural road construction site*	

		• Implement landslide stabilization program through bio-engineering methods		
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.	Chanlingdanda, Tallochapa, Ghiupokhara, Nimri (Upstream) Rolpa-8 (Downstream), Janga, Danbang (Upstream) & Rolpa-6 (Downstream) Adjoining areas of Punthok, Phalleghar (Upstream) & Madi-6 (Downstream), Adjoining areas of Darbot, Phanrang, Jhinsil, Kutebang, Rimask, East of Rimsak	
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages	Adjoining areas of Punthok, Ghapa, Phalleghar, Janga, Danbang, Ghiu	

		• Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices • Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge	Pokhara, Changlingdanda, Tallo Chhapa	
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry	Land use adjustment (III & Agriculture) Adjoining areas of Tallo Chhapa, Changlingdanda, Phalleghar, Ghiu Pokhara, Ghapa,	

		• Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management	Janga, Dangbang, Ramja, Land use adjustment (IV & Agriculture) Adjoining areas of Punthok, Madichaur, South of Ghapa, East of Dangbang, Ghiu Pokhara, Phalleghar, Tallo Chhapa Land use adjustment (IV & Shrubland & Grassland) East of Mimri, West of madichaur, North of Madichaur	

11.6 Action Plan- Rolpa 8

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods	West of Lakuribang (Upstream) & Rolpa-7 North of tallo chhapa near river (Downstream), South of Chutrabang (Upstream) & Rolpa-9 (Downstream), Southeast of Tallo Changling (Upstream) & Rolpa-9 (Downstream) West of Namli, Kothabang, East of Chutrabang, East of Tallo Kartam, Chutre GAtina, ChinanDanda	
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation) • Encourage CFUGs to carry livestock assessment, estimate fodder requirement and	Lakhuribang, Paribang, Kutebang, Mathala (Upstream) & Rolpa-7 (Downstream), Onbang, Keubang, Kudar, Pathihalna, Changling (Upstream) & Rolpa-9 (Downstream)	

		adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.	North of Damakur (Upstream) & Madi-5 (Downstream) Adjoining areas of Mathhilo Changling, Bhirkholagaun, Khunbasa, Ghuyalchaur, Kothabang, Gharbasa, Jhimling Hwama, Tamage, Challinbang,	
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands and promote stall feeding practices	Adjoining areas of Mathala, Paribang, Kutebang, Jamkot, Onbang, Bamarup, Lakhuribang, Bhagachaur, Damakhur, Challibang, Namli, Keubang, Tamage, Gharbasa, Kudar, Khunbasa, Ghuyalchaur, Mulkot, Chanling	

		• Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge		
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry • Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects • Implement conservation education and extension activities aiming to create awareness	Land use adjustment (III & Agriculture) Adjoining areas of Mathala, Jamkot, Onbang, Banahar, Bamarup,Lakhuribang, Namli, Tamage, Gharbasa, Khunbasa Land use adjustment (IV & Agriculture) Adjoining areas of Kutebang, Jaribang, Damakur, Challibang, Kudar, Kothabang, Bhulambas, Chanling, Ghuyalachaur, Bhirkholagaun, Mathillo Changling, Bhedakhor, Gaiirakhutti, Chutrabang Land use adjustment (IV & Shrubland & Grassland) South of Mathillo Changling, Tallo Changling, Jhimling, Damakur,	

		of erosion problems, farming practices and soil fertility management	Jaribang, Onbang, Jamkot	

11.7 Action Plan Rolpa 9

Issues	Action	Activities	Location	Budget
Landslide	Land conservation	• Enhance the capacity of the local people to plan and implement soil and land conservation activities ensuring Upstream and Downstream linkages • Reclaim the degraded land by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Rehabilitate the landslide hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in degraded lands • Implement landslide stabilization program through bio-engineering methods	*Maximum Landslide has been identified on rural road construction site*	
Deforestation and forest degradation	Forest restoration	• Social mobilization and awareness raising of forests dependent communities and other stakeholders on watershed conservation, forest restoration and leasehold forestry • Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation)	North of Risbang, Adjoining areas of Risbang Dhuri, Naima, Gumthal, Sugapokhara, Pokharadanda, Tallo Kartam, Kuwapatal	

		• Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock • Establish different on-farm agroforestry demonstration plots of different agroforestry system in government, leasehold forest community and private owned land to show the tree crop interactions and its resultant benefits • Promote conservation oriented energy development such as installation of micro-hydro, biogas, improved cooking stove, solar power etc.	(Upstream) & Rolpa-8 (Downstream) South of Dhangarje, Adjoining areas of Porpu, Chutre Gatina, Upallo Katam	
Erosion	Soil Conservation	• Enhance the capacity of the local people to plan and implement soil conservation activities ensuring Upstream and Downstream linkages • Reclaim the soil erosion sites by appropriate vegetative and structural methods • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, agro-forestry and others • Assist farmers in managing monsoon run-off • Assist in development and protection of water resources • Rehabilitate the erosion hot spots (severely eroded area) • Promote income generation and conservation oriented plantations of forests and grasses in	Adjoining areas of Majuwa, Kuwapatal, Chutre Gatina, Pokharadanda, Tallo Kartam, Upallo KArtam, Suga Pokhara, Naima, Golbang, Hangbang, Risbang Dhuri, Risbang	

		degraded lands and promote stall feeding practices • Construction of contour bunds, terraces building, broad bed and furrow practice, soil-moisture conservation practices • Management practices reduce peak discharge		
Land Use Over	Land Use Adjustment	• Implement conservation education and extension activities aiming to create awareness of unscientific cultivation where land capability not considered and erosion problems • Promote conservation farming techniques such as orchard establishment, on-farm conservation, bio-terracing, and agro-forestry • Construction of contour bunds, terraces building, broad bed and soil-moisture conservation practices • Promote conservation pond/runoff harvesting dam • Promote agroforestry techniques such as cropping of fruit trees with medicinal and aromatic plants as well as other multiple land use techniques • Encourage and support farmers to plant fodder tree and grasses in their field without affecting their farming system • Protect agriculture land from erosion • Develop and disseminate information related to conservation agriculture, SALT technique and agroforestry through the use of different extension media on technical, economic and environmental aspects	Land use adjustment (III & Agriculture) Adjoining areas of Majuwa, Kuwapatal, Pokharadanda, Tallo Kartam, Chutre Gatina, East of Upallo Katam, North of Risbang Land use adjustment (IV & Agriculture) Adjoining areas of Risbang, Risbang Dhuri, Hangbang, Golbang, Naima, Suga Pokhara, Upallo Katam, Tilakhutti, Chinandanda, East of Dhangarje, Kuwapatal, North of Kuwapatal Land use adjustment (IV & Shrubland & Grassland) North of Golbang, Adjoining	

		• Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management	areas of Gumthal, Golbang West of Suga Pokhara,	

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Annex 1 Land use/ land cover change methodology

The methodology used in this study was summarized as shown in the flow chart Figure 9. Methodological flowchart of land use land cover change. The materials that were used for this study involve both primary and secondary data.

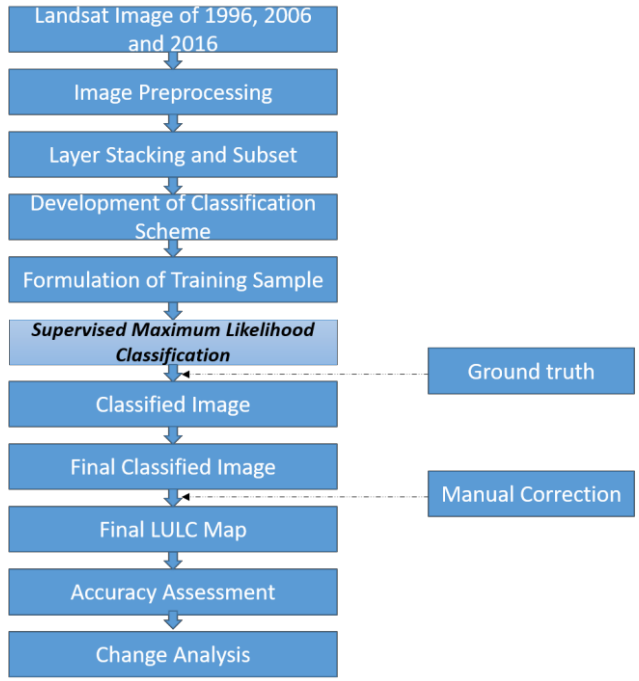

Figure 8 Methodological Flow chart of Land use Land cover change

Primary Data:
Primary data was collected through field observation and Google Earth Image to collect the coordinates of features in the study area for ground truthing which was integrated into the Geographic Information System (GIS) environment for error matrix in order to ascertain the accuracy level of the classified images according to number of classes.

Secondary data:
For this study Landsat Satellite images of Path 143 & Row 040 were acquired for three Epochs; 1995, 2008 and 2018 were obtained from USGS an Earth Science Data Interface. It is also important to have local government boundary map and administrative map which was obtained from Department of Survey with Modified Universal Transverse Mercator. Table 7 shows the characteristics Landsat Satellite images of the study area.

Table 7 Characteristics of acquired satellite mage

S.N	Image	Year	Sensor	Resolution	Date of Acquisition	Bands
1	Landsat 5	1995	TM	30m	1995-03-20	7
2	Landsat 5	2008	TM	30m	2008-0-24	7
3	Landsat 8	2018	OLI/TIRS	30m	2016-03-19	11

Data Processing
This study adopts three epochs of Landsat satellite images as described in Table 1. All of the images were processed using geometric and radiometric corrections. Digital land-use maps and administrative maps of 1996 with vector structures and topographical maps of 1996 with a 1:25,000 scale also provided important information for identifying and assessing land use types. Band 1, 2, 3, 4, 5 and 7 were layer stacked into RGB layer for better visualization in order to ease the classification through band rationing.

Classification is a complex process that can be defined as "the ordering or arrangement of objects into group or sets or sets on the basis of relationships. These relationships can be based Upon observable or inferred properties". Area of Interest i.e. Hungri Madi Sub Watershed was extracted from the stacked image and land-use land-cover classification system was developed. The use of too many or too few land- use land-cover classification types affects the results of change analyses. Various publications have discussed land-use and-cover classification systems and have proposed appropriate classification systems for watershed research. Therefore, for this study land-use land-cover classification system was proposed for this study as shown in Table 8

Table 8 Classification scheme design for study

CODE	LULC Types	Descriptions
1	Forest	Area covered by Trees
2	Shrub Land	Closed to open shrub land (thicket), meadows, scrub, bushes
3	Grassland	Small rangelands, open grasslands
4	Agricultural Land	Irrigated land, Terrace land, unirrigated dry land
5	Barren Land	Bare rock, bare soil, Sand
6	Waterbody	Lake, Reservoirs, Ponds, rivers

In this study, supervised maximum likelihood method was used for the land-use/land-cover classification. A numbers of AOIs were selected in every image for different land-use/land-cover types to develop signature for classification through visual interpretation of Google Earth Image of 2006, 2008, 2016, 2018. The accuracy of the classification results was assessed using the total accuracy and the Kappa coefficient.

Annex 2 Estimation of Soil Erosion Dynamics Methodology

The methodology used to estimate soil erosion dynamics was summarized as shown in the flow chart Figure 10. Based on the rainfall storm events, DEM, soil type map, and land cover map, six parameters of the RUSLE model estimated and verified as to the reasonability of the parameter estimation results. The following equation RUSLE equation is used:
RUSLE to compute average annual soil erosion expected on Upland (field) slopes:

$$A = R \times K \times L \times S \times C \times P$$

Where: A is the amount of eroded material calculated or measured in tons per hectare for a specified duration of rain. A&K has units in the time period selected for R.

R is the rain factor as a (EI30) index, which is measured by the erosive power of there in in tons per hectare hour meter or joule per square meter, As the erosive forces of rain and associated runoff;

K is the soil erodibility factor is standard erosion ton per hectare per erosivity R unit, for a specific ground with a uniform gradient of 9% 22.1 m gradient and slope length clean tilled fallow, is a measure of the inherent susceptibility of soil particles to erosion;

L is the length of slope factor, expressing the ratio of soil loss of a slope with a given length and soil loss of a slope with a standard length 22.13 m, with identical values erodibility and slope gradient;

S is the slope gradient factor expresses the ratio of soil loss specific gradient slope and soil loss of a slope gradient standard 9%, under similar conditions, define the effect of the inclination of the pending on soil loss per unit area;

C is the combined vegetation and management factor expresses soil loss ratio of an area covered and specific to a similar area but continually tilled fallow management; and

P is the practice soil conservation factor that expresses the ratio of soil loss from an area with coverage and specific management, such as contour plowing, strip cropping or terraces, one with tillage for the slope.

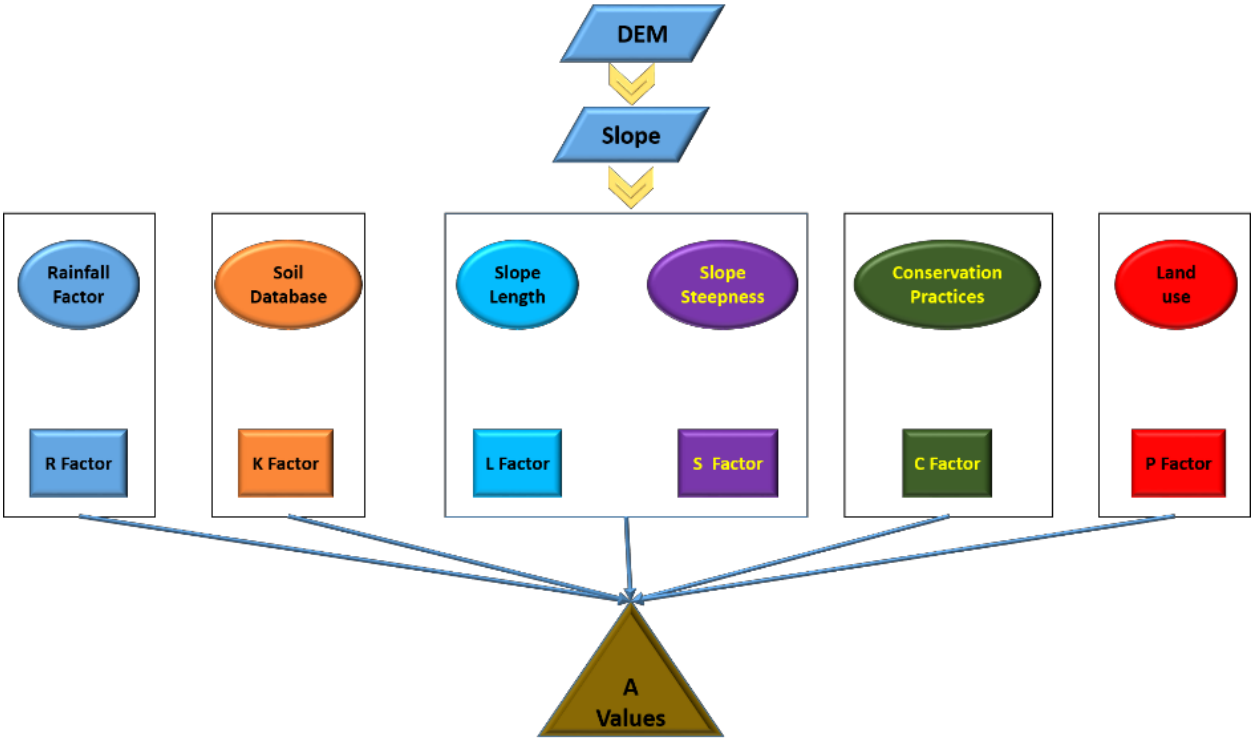

Figure 9 Methodological framework of soil erosion dynamics

Annex 3 Spatial and Temporal Distribution of Forest Fires Methodology

Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets were extracted through FIRMS (ftp://ba1.geog.umd.edu/Collection51) in Shape (*.shp) format) dated from 2000 to 2016 A.D. Digital layer of Watershed overlapped over the fire datasets and clipped the dataset of the watershed. Area for each polygon according to year (or month) basis was calculated to identify the magnitude for each year. To identify the temporal distribution, centroid point for each polygon was calculated using ArcGIS and point for each year/month was counted.

Annex 4 Land Use Adjustment Methodology

The land use adjustment map is produced by overlaying a present land use map on a land capability map. The methodology used was summarized as shown in the flow chart figure.

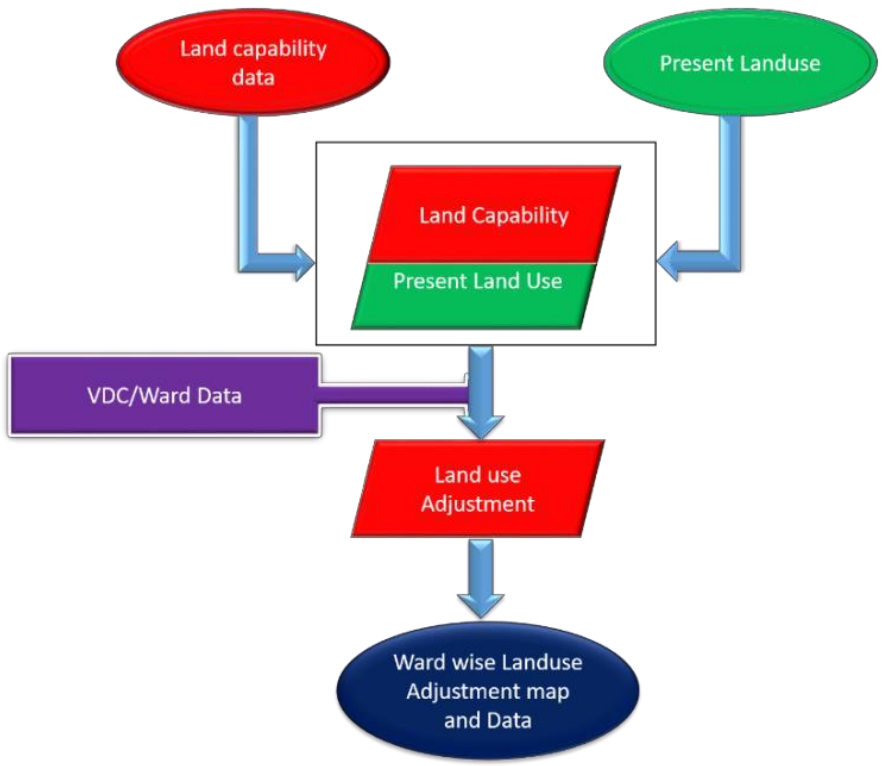

Figure 10 Methodological Framework of Land Use Adjustment