ADAPTATION FOR SMALLHOLDERS IN HILLY AREAS (ASHA) PROJECT

GIS BASED ASSESSMENT OF PADUKA RAMGHAT SUB-WATERSHED, DAILEKH

Credits

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Adaptation for Smallholders in Hilly Areas (ASHA) Project

Authors

This report was prepared by the ASHA Project District GIS and Spatial Planning Unit Dailekh.

The assessment team

District GIS Specialist: Mr. Dil Kumar Rai

Land Use Planner: Mr. Gyanendra Maharjan

Review team

Technical Team Leader: Mr. Navraj Baral

Forestry Specialist: Mr. Deepak Bahadur Chand

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ABBREVIATIONS AND ACRONYMS

ASHA	Adaptation for Smallholders in Hilly Areas
CC	Climate Change
CBS	Central Bureau of Statistics
CCA	Climate Change Adaptation
PRSW	Paduka Ramghat Sub Watershed
GoN	Government of Nepal
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
NAPA	National Adaptation Programme of Action
NGO	Non-governmental Organization
RUSLE	Revised Universal Soil Loss Equation
VDC	Village Development Committee

Table of Content

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 adaption 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 are imperative for the design of adaptation measures ensuring upstream and downstream linkages. Integration of sub-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 Soil Conservation (MoFSC) with the financial support of International Fund for Agricultural Development (IFAD) carried out this GIS based watershed assessment of Paduka Ramghat Sub Watershed Dailekh and prepared this study report.

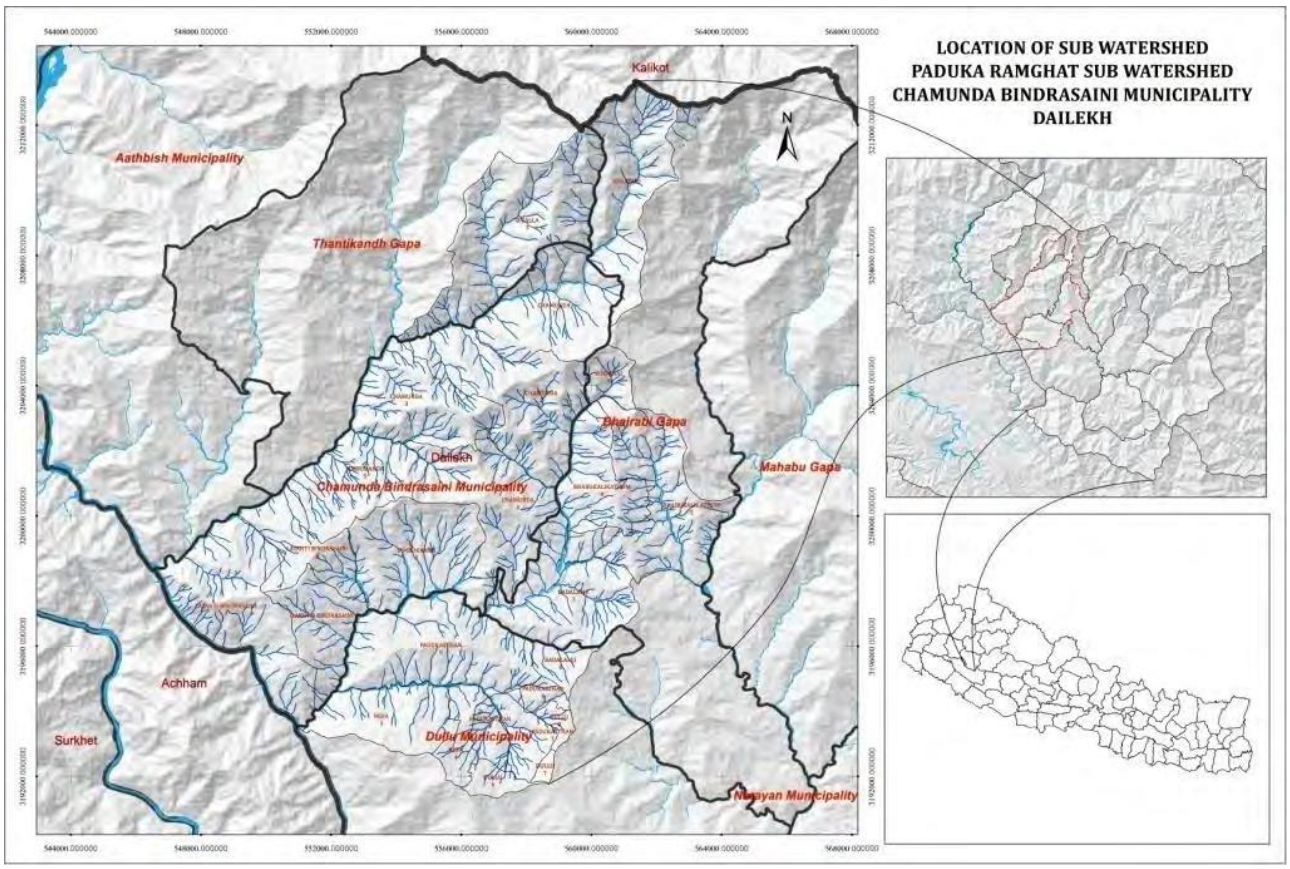
2. Objective

The objective of this assessment was to impart GIS based analytical assessment of the bio-physical and socio-economic conditions of Paduka Ramghat Sub Watershed Dailekh and to recommend strategies action for 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 Paduka Ramghat Sub Watershed.

3. Study Area

The Paduka Ramghat Sub Watershed (PRSW) is situated in western Nepal between $28^0$50'24" and $29^0$02'02" N latitude and $81^0$15'12"- $81^0$39'36" E longitude, covering an area of 186 square kilometers, altitude ranges from 580 meter to 3000 meter above mean sea level. The watershed includes Badalamaji, Bhairakalika Thum, Bisalla, Chamunda, Dullu, Jambukandh, Kusapani, Layanti Bindrasini, Nepa and Padukasthan VDCs (former) now which belong to Dullu Municipality, and Chamunda Bindrasaini Municipality, Thantikandh Rural Municipality and Bhairabi Rural Municipality of Dailekh district and is drained by Padukakhola and Ramghatkhola and its tributaries of the broader Middle Karnali Sub-Basin in the western Nepal. Physio-graphically, the Paduka Ramghat Sub Watershed belongs to mid hills, situated to the north of Mahabharat range and has sloppy hills with sub-tropical, warm temperate and temperate types of climate. The monsoon rainfall starts from June and ends in September. The annual total precipitation had recorded as 1700 mm in study area. Mean air temperature recoded as maximum 25.3 °C and minimum 10.5 °C. The maximum absolute extreme temperature recorded as 37.4 °C in June and minimum recorded as 2.2 °C in January (ISRC, 2008). Forest types in the sub-watershed that range from tropical mixed deciduous forests to temperate vegetation. According to the soil and terrain (SOTER) database of Nepal, the landform and soil texture of study area is categorized into four types as Eutric Regosols, Eutric Cambisols, Gleyic Cambisols and Chromic Cambisols.

Figure 1: Location of Paduka Ramghat Sub Watershed in Dailekh district



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 TM imageries that were used in land use analysis and land capability data.

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.

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.

Spatial Analyses

Land Use and Land Cover Changes

Landsat satellite images sets from 1996, 2006 and 2016 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.

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.

Spatial and Temporal Distribution of Forest Fires

Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets from 2000 to 2016 imported in Arc GIS to map spatial and temporal distribution of forest fires according to Parajuli et al. 2015 Annex 3.

Land Use Adjustment

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

Landslide Distribution

The study used secondary sources of information to map landslide spatial distribution map. Secondary data on landslides in the sub-watershed were obtained from Dailekh District Landslide Archive of District Soil Conservation Office Dailekh. Watershed landslides were mapped in ARC GIS environment based on visual interpretation of remote sensing data, i.e. Google Earth Image (2000-2016).

5. Bio-Physical Condition

5.1 Trends in Land Use/Land Cover Change in Paduka Ramghat Sub Watershed (1996-2016)

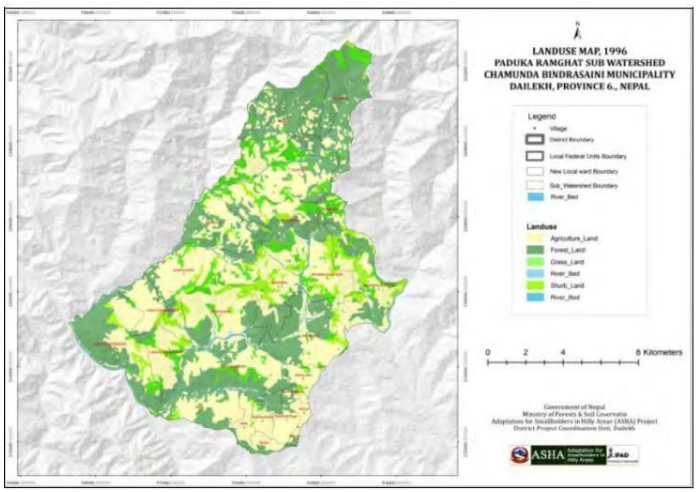
5.1.1 Changes in Land Use/Land Cover

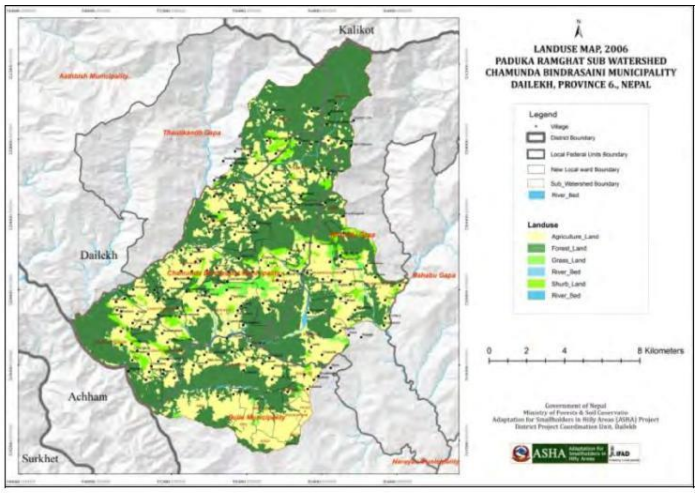
An analysis of changes in land use and land cover in the sub-watershed for the period 1996-2016 shows that the area under forest substantially increased, area under agriculture and water body decreased, area under shrub land and grassland substantially decreased. (Table 1; Figure 2.1 and 2.2). However, during 2006-2016 about 235.75 ha of forest area had transformed to shrub land but only about 187.41 ha of shrub land was converted to forest area.

Table 1: Areas under Land Use/Cover in 1996, 2006 and 2016

Land Use Class	1996		2006		2016		% Change in Land Use		
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	1996-2006	2006-2016	1996-2016
Agriculture	8380.1	45.03	7618.3	40.94	7468.6	40.13	-9.1	-2.0	-10.9
Forest	6961.2	37.41	9599.6	51.59	9535.9	51.24	37.9	-0.7	37.0
Shrub	1765.5	9.49	785.3	4.22	791.4	4.25	-55.5	0.8	-55.2
Grassland	1122.2	6.03	335.9	1.81	516.9	2.78	-70.1	35.0	-53.9
Barren land	0.0		0.0		0.0		0.0	0.0	0.0
Waterbody	380.2	2.04	269.9	1.45	296.3	1.59	-29.0	8.9	-22.1
Total	18609.1		18609.1		18609.1				

Figure 2.1: Area Under Different Land Use/Land Cover in Paduka Ramghat Sub-Watershed in 1996, 2006 and 2016





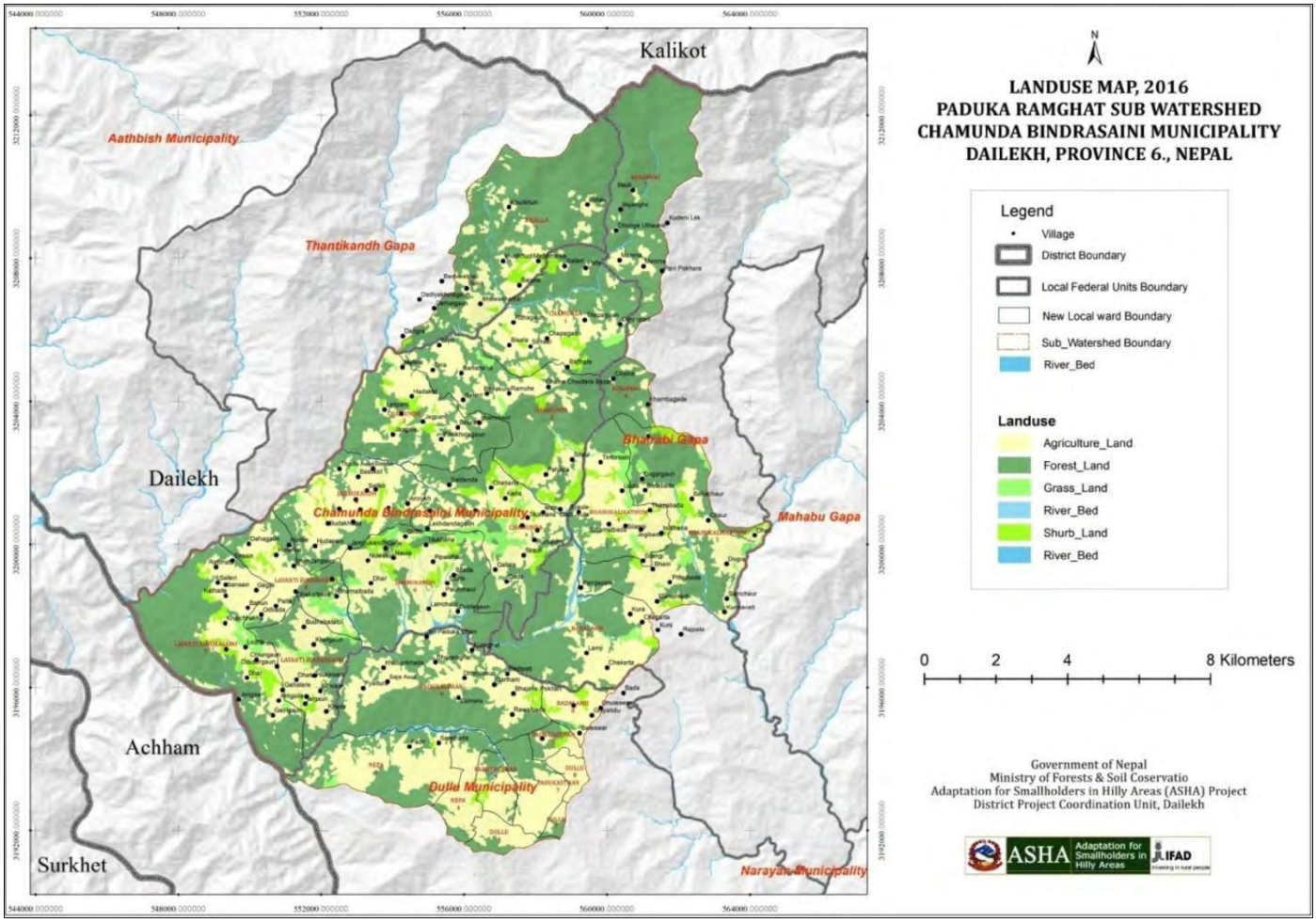
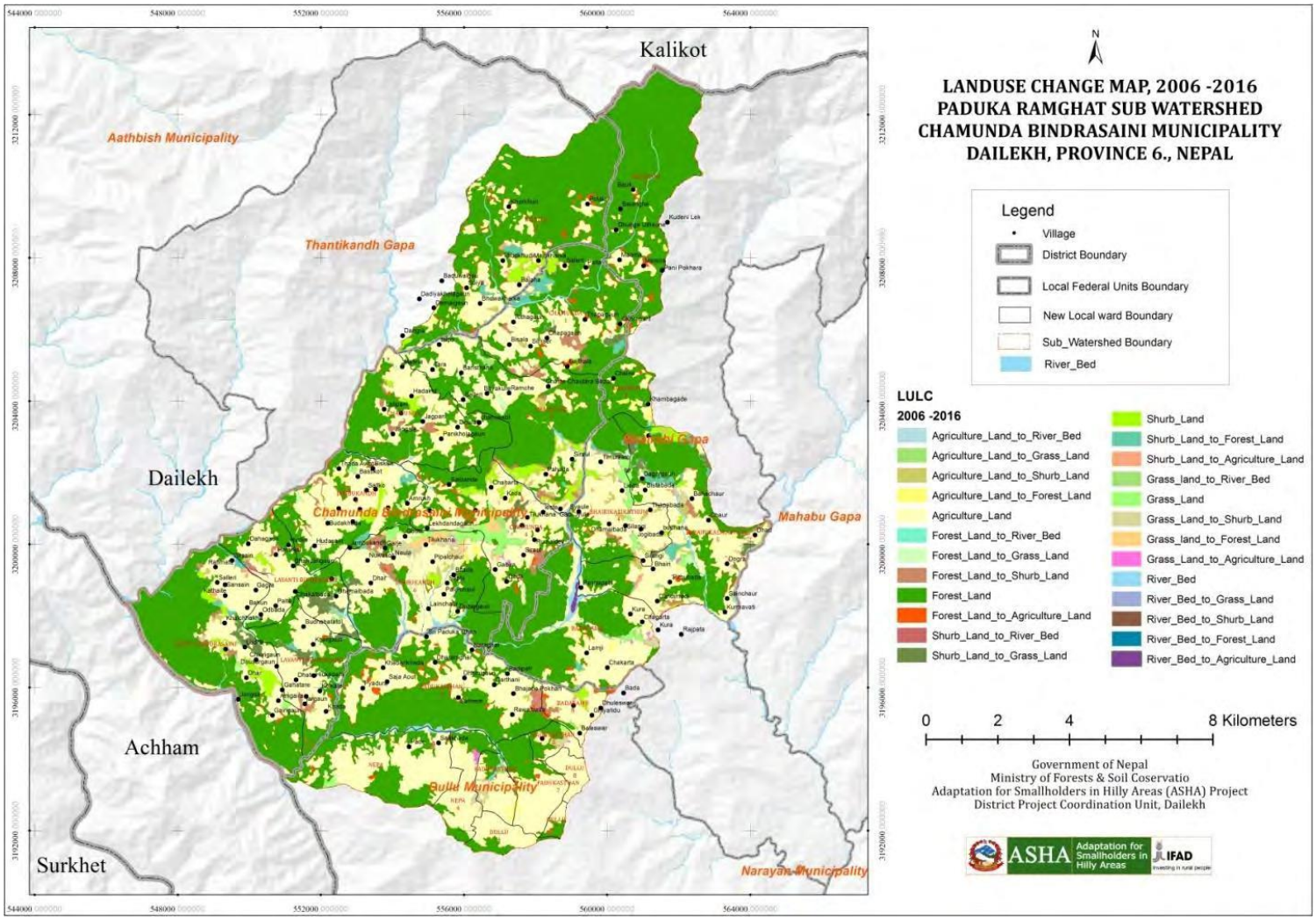


Figure 2.2: Change in Land Use/Land Cover and Change in Paduka Ramghat Sub-Watershed in 2006 and 2016



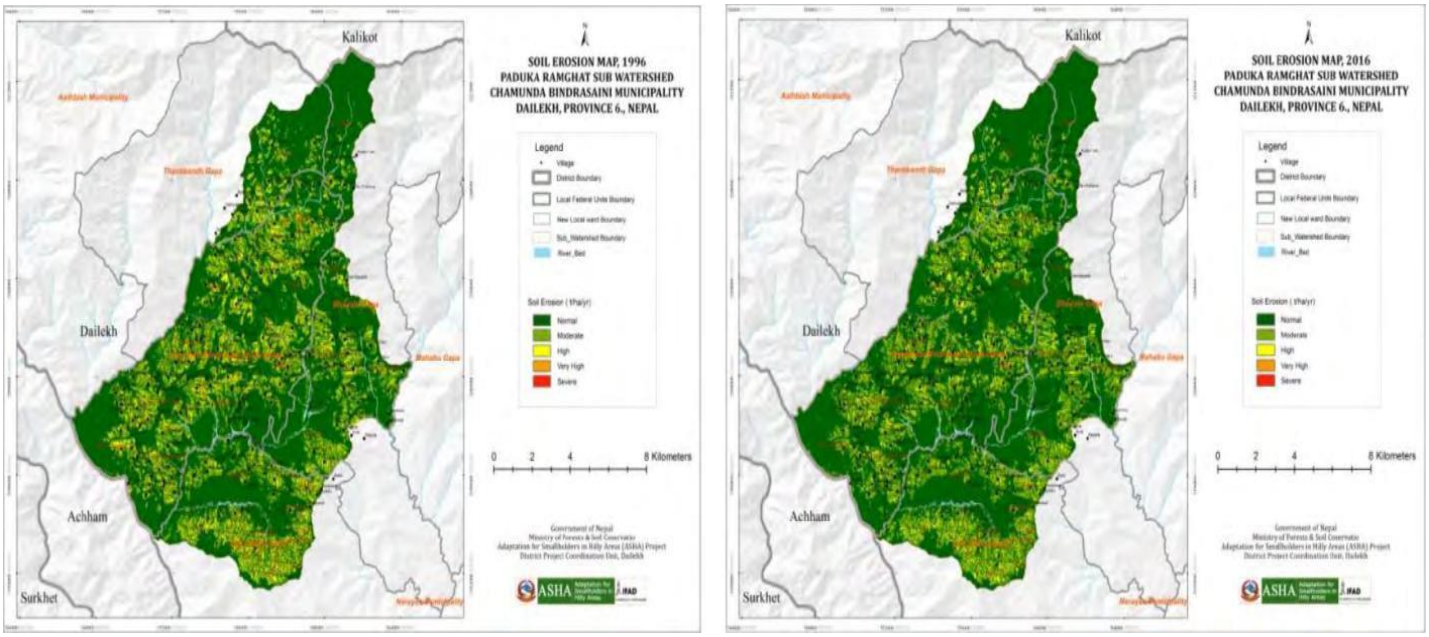
5.2 Estimation of Soil Erosion Loss Dynamics (1996-2016)

An analysis of soil loss in the sub-watershed for the period 1996-2016 shows that the area under agriculture has maximum soil loss rate, which followed by shrub land, grassland and forest. The estimated total soil loss for the entire area was 0.33 million t in 1996, and 0.29 million ton in 2016. (Table 2; Figure 3).

Table 2: Estimated Soil Erosion Rate of 1996 and 2016

S.N	Land Use	Land Cover Area (Km Sq.)		Annual Soil Loss (000 t)		Mean Erosion rate (t/ha/yr.)	
		1996	2016	1996	2016	1996	2016
1	Agriculture	83.81	74.70	308.37	270.16	3.10	3.05
2	Forest	69.63	95.35	14.03	19.64	0.17	0.17
3	Grassland	11.23	5.17	5.11	2.33	0.38	0.38
4	Waterbody	3.81	2.98	0.00	0.00	0.00	0.00
5	Shrub land	17.62	7.90	7.99	3.90	0.38	0.42
Total		186.10	186.10	335.5	296.03	4.03	4.02

Figure 3: Estimated Soil Erosion Rate in Paduka Ramghat Sub Watershed in 1996 and 2016



5.3 Spatial and Temporal Distribution of Forest Fire (2000-2016)

An analysis of forest fire in the sub-watershed for the period 2000-2016 shows that inter annual variation in the spatial and temporal distribution of fire and magnitude of burnt area. During hot and dry season (March-June) found to be maximum forest fire occurrence season and April month found to be most fires occurrence month, which is followed by June and May. Forest area under Lyati bindrasaini VDC, Jambukandh VDC, Chamunda VDC, and Bhairikalikathum VDC found to be VDC with high risk of forest fire (Table 4.1 and 4.2).

Figure 4.1: Forest Fire Hotspots in Sub-Watershed

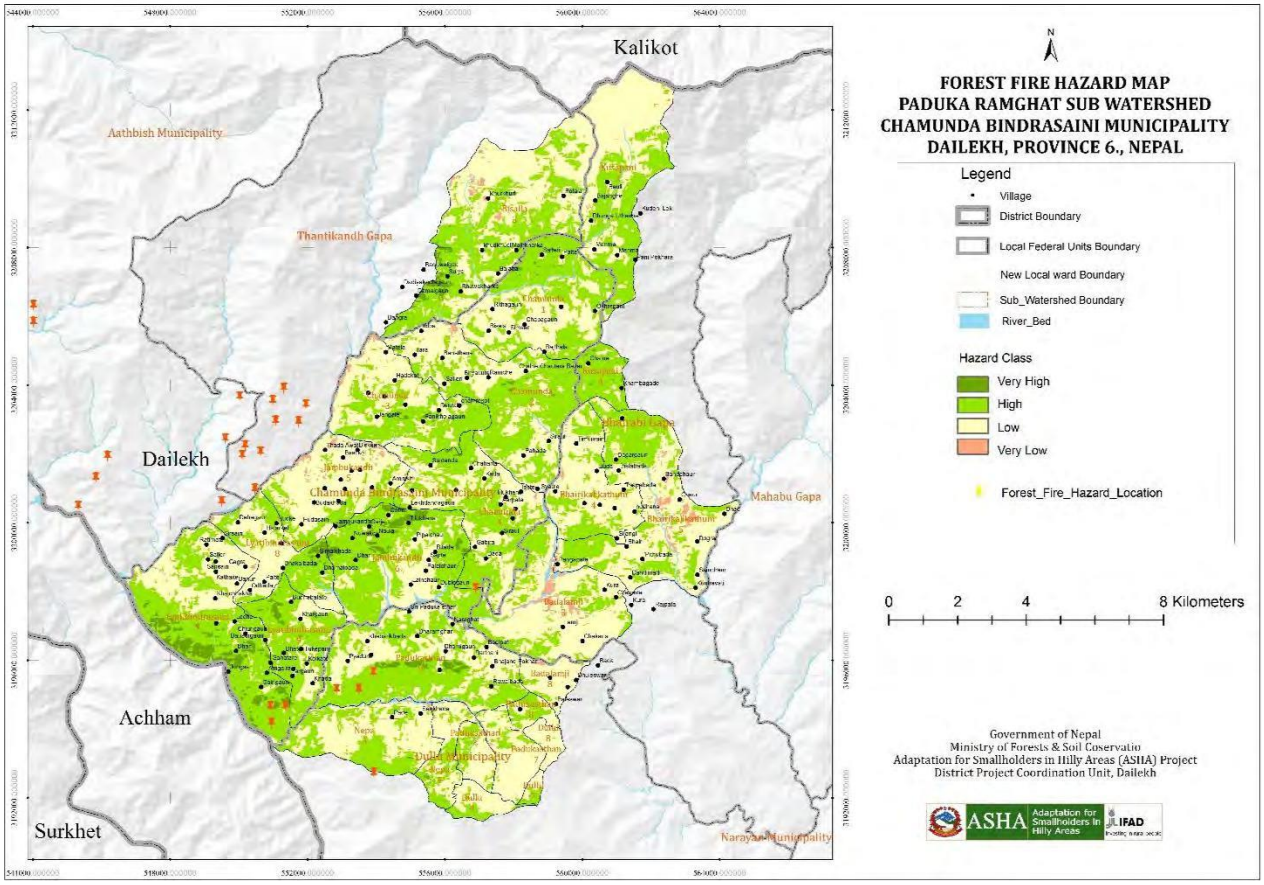
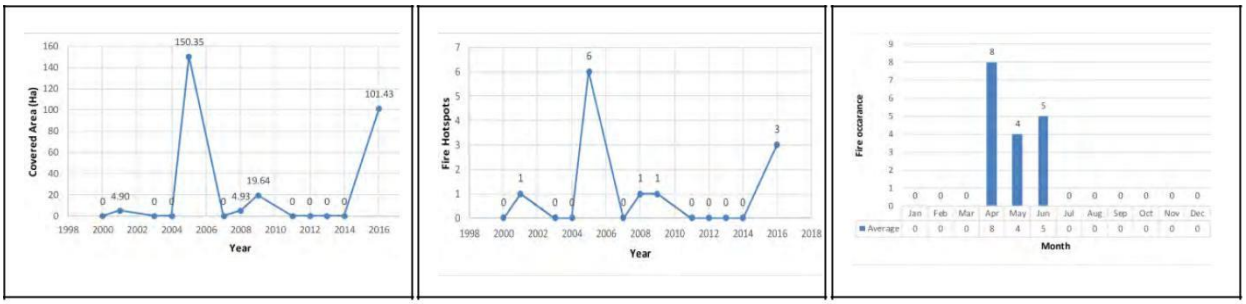


Figure 4.2: Magnitude of Forest Fire Burnt Area, Forest Fire Hotspots and Monthly Forest Fire Hotspots 2000-2016



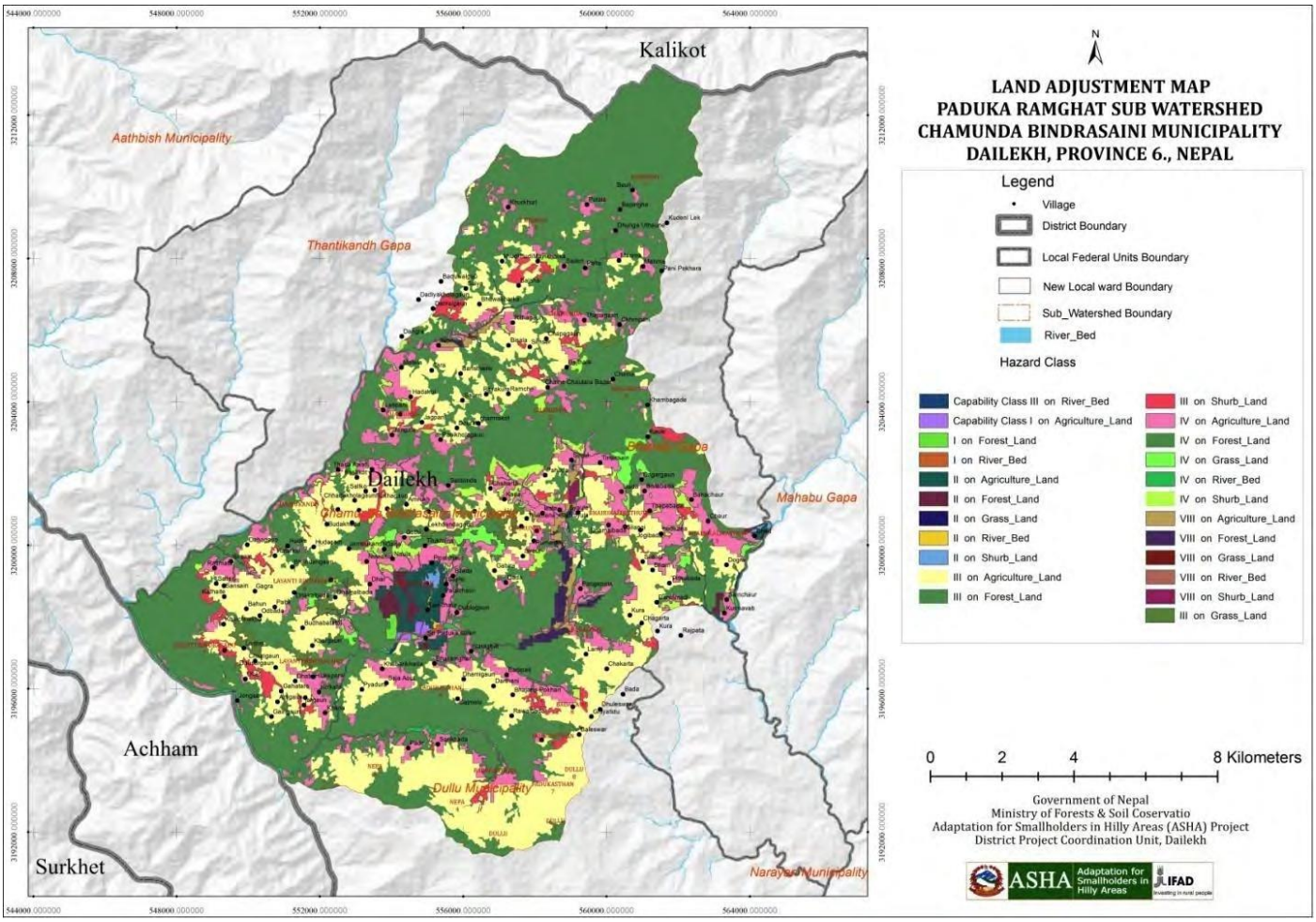
5.4 Land Use Adjustment

An analysis of land capability and current land use in the sub watershed shows that the land being over used. In 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 land. In the areas where land being over used, land use adjustments are required. (Table 3; Figure 5).

Table 3: Land use Adjustment in Sub Watershed

Land Use Adjustment	VDC	Area (Hectare)
Agriculture in Land Class III and Class IV	Lyantibindrasaini VDC	123.12
Agriculture in Land Class III and Class IV	Jambukandh VDC	171.80
Agriculture in Land Class III and Class IV	Chamunda VDC	460.41
Agriculture in Land Class III and Class IV	Padukasthan VDC	94.41
Agriculture in Land Class III and Class IV	Nepa VDC	55.08
Agriculture in Land Class III and Class IV	Kusapani VDC	46.23
Agriculture in Land Class III and Class IV	Bisalla VDC	92.22
Agriculture in Land Class III and Class IV	Badalamaji VDC	44.04
Agriculture in Land Class III and Class IV	Bhairikalikathum VDC	219.38
Total		1306.69

Figure 5: Land Use Adjustment in Paduka Ramghat Sub Watershed



5.5 Landslide Distribution

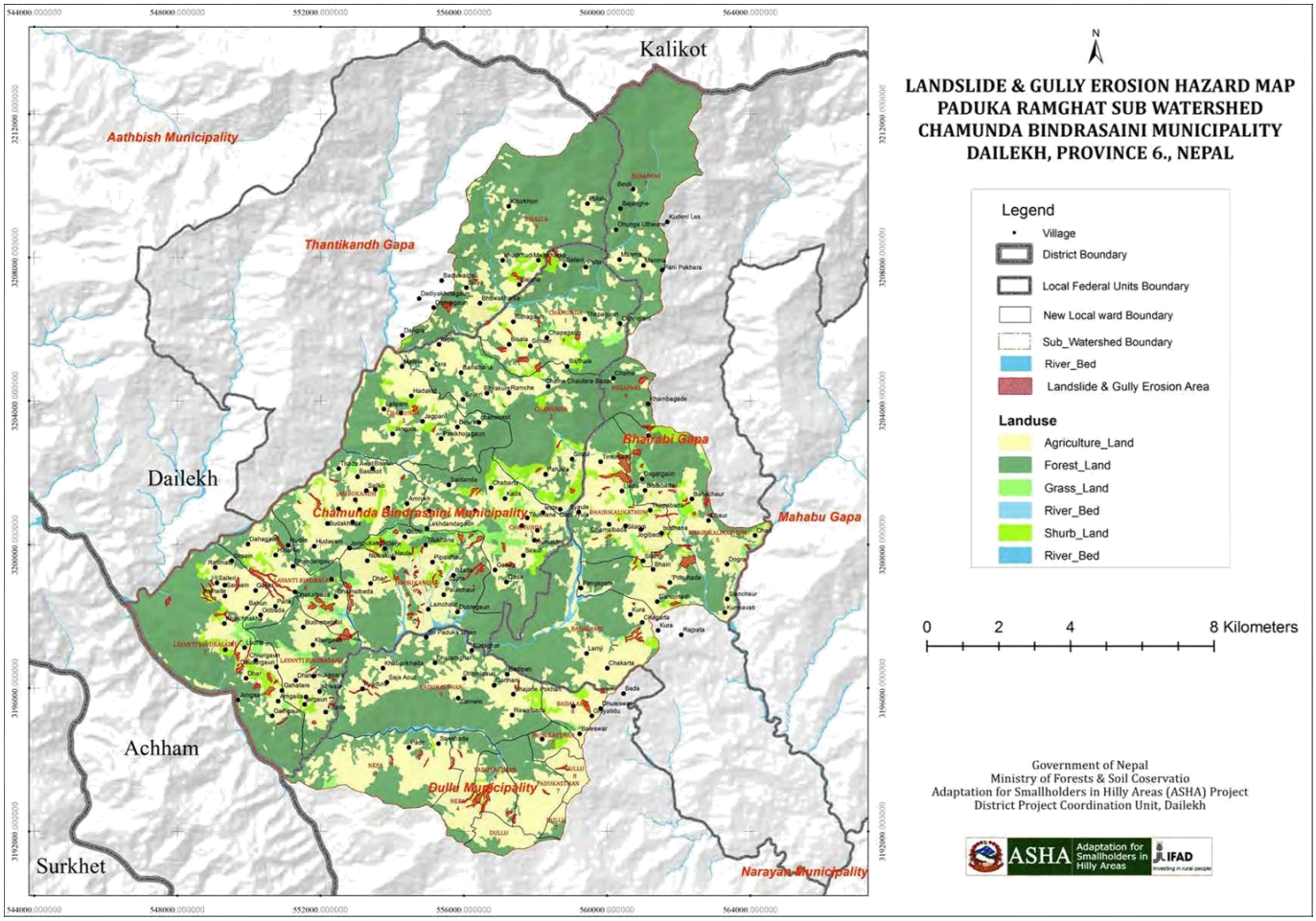
An analysis of landslide distribution in the watershed shows landslide occupies the greatest area in Layanti Bindrasini VDC, which is followed by Bhairikalikathum VDC, Chamunda VDC, Jambhukandh VDC, Padukasthan VDC, Badalamaji VDC, Nepa VDC, Bisalla VDC, Kusapani VDC and Dullu Municipality (Table 4; Figure 6).

Table 4: Landslide Distribution in Paduka Ramghat Sub-Watershed

SN	Type	Area covered in former VDCs (Ha)										Total area
		1	2	3	4	5	6	7	8	9	10	(Ha)
1	Landslide Area(Ha)	8.82	39.06	6.75	25.11	1.35	23.49	3.51	45.72	8.91	17.37	180.09
2												
	Landslide (%)	4.9	21.7	3.7	13.9	0.7	13.0	1.9	25.4	4.9	9.6	100 %
3	Gulley Erosion											33.23

1-Badalamaji, 2- Bhairikalikathum, 3- Bisalla,4-Chamunda, 5- Dullu, 6-Jambhukandh, 7-Kusapani, 8-Layanti Bindrasini, 9- Nepa, 10- Padukasthan

Figure 6: Landslide Distribution in Paduka Ramghat Sub-Watershed



6. Upstream and Downstream Linkages

Analysis of bio-physical condition (land use/land cover, soil loss, forest fire, landslide, land capability and current land use) in the sub-watershed shows that upstream and downstream linkages sites within VDC and beyond VDCs within Paduka Ramghat Sub Watershed (Table 5 and 6.1, 6.2, 6.3 and 6.4).

Table 5: Upstream and Downstream Linkages Sites beyond VDCs within Paduka Ramghat Sub Watershed

Linkage	Upstream	Downstream
Landslide and Deforestation and Degradation	Piladi VDC, Jambukandh VDC, Dullu Municipality, Bhairikalikathum VDC	Layanti Bindrasini VDC
Landslide and Deforestation and Degradation	Chamunda VDC Dandimadi VDC, Bhairikalikathum VDC & Dullu Municipality	Jambhukandh VDC
Landslide and Deforestation and Degradation	Chamunda VDC	Jambhukandh VDC and Layanti Bindrasini VDC
Landslide and Deforestation and Degradation	Bhairikalikathum VDC	Rawatkot VDC

Table 6.1: Up and downstream linkages sites within Layanti Bindrasini VDC

VDC	Layanti Bindrasini	
Linkage	Upstream	Downstream
Landslide	Ward 4 of Layanti Bindrasini	Ward 1 and 2 of Layanti Bindrasini
Soil Erosion	Ward 3 and 4 of Layanti Bindrasini	Ward 1 and 2 of Layanti Bindrasini
Soil Erosion	Ward 5 of Layanti Bindrasini	Ward 6 of Layanti Bindrasini
Soil Erosion	Ward 9 of Layanti Bindrasini	Ward 8 of Layanti Bindrasini
Deforestation and Degradation	Ward 4 of Layanti Bindrasini	Ward 3 of Layanti Bindrasini
Deforestation and Degradation	Ward 4 of Layanti Bindrasini	Ward 2 of Layanti Bindrasini
Deforestation and Degradation	Ward 5 of Layanti Bindrasini	Ward 6 of Layanti Bindrasini
Deforestation and Degradation	Ward 9 of Layanti Bindrasini	Ward 6 of Layanti Bindrasini
Deforestation and Degradation	Ward 8 of Layanti Bindrasini	Ward 9 of Layanti Bindrasini

Table 6.2: Up and downstream linkages sites within Jambhukandh VDC

VDC	Jambhukandh	
Linkage	Upstream	Downstream
Landslide	Ward 1,2 3 of Jambhukandh VDC	Ward 4,3,2 of Jambhukandh VDC
Soil Erosion	Ward 1, 4 of Jambhukandh VDC	Ward 2,3,4 of Jambhukandh VDC
Landslide	Ward 9 of Jambhukandh VDC	Ward 9 of Jambhukandh VDC
Deforestation and Degradation	Ward 1,2 3 of Jambhukandh VDC	Ward 4,3,2 of Jambhukandh VDC

Table 6.3: Up and downstream linkages sites within Chamunda VDC

VDC	Chamunda VDC	
Linkage	Upstream	Downstream
Landslide	Ward 1,3,5,9 of Chamunda	Ward 4,7,8 of Chamunda
Soil Erosion	Ward 1,3,5,6,8,9 of Chamunda	Ward 4,7,8 of Chamunda
Deforestation and Degradation	Ward 1,2,3,6,8 of Chamunda	Ward 4,7,8 of Chamunda

Table 6.4: Up and downstream linkages sites within Bhairikalikathum VDC

VDC	Bhairikalikathum VDC	
Linkage	Upstream	Downstream
Landslide	Ward 4 of Bhairikalikathum VDC	Ward 1 and 2of Bhairikalikathum VDC
Soil Erosion	Ward 1,2,5,7,9 of Bhairikalikathum VDC	Ward 6,8,9 of Bhairikalikathum VDC
Deforestation and Degradation	Ward 1,2,3,9 of Bhairikalikathum VDC	Ward 6,8,9 of Bhairikalikathum VDC

7. Socio-Economic Assessment

Demography

According to the national population census of 2011, the population of sub-watershed has reached to 65019 in 2011 with 11945 households. Of the total persons, the numbers and percentages of male and female were 32111 (49.38%) and 32908 (50.61%) respectively (CBS 2011).

Caste and ethnic distribution

Majority of the population in sub-watershed are Dalits which is followed by Chhetris, Brahmin, Thakuri, Janajati and others. Out of the total households, 29.42 percent are Dalit, 25.87 percent Chhetri, 19.77 percent are Brahmin, 16.32 percent are Thakuri, 5.76 percent are Janajati and 2.86 percent are others (CBS 2011).

Literacy

Population Census 2011 shows that 52.85 percent of population aged 5 years and above were literate in the sub-watershed. Male is 56.82 percent while the female literacy is about 43.18 percent. About 47.88% population 5 years and above have gain primary level education 21.47% have gain lower secondary level education, 10.55 % have gain secondary level, 6.06 % SLC and equivalent, 4.28 % Intermediate & equivalent, 0.65 % graduate and 0.17 % post graduate in the sub-watershed (CBS 2011).

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)

Usual fuel for cooking

About 98.59 of the total households use firewood as the usual source of fuel for cooking in the sub-watershed followed by biogas (0.32 percent), cow dung guitha (0.24 percent), LPS gas (0.19 percent), and 0.15 % of households use kerosene (CBS 2011).

Economically active population

There are 47.37 % economically active populations in study area which include 48.79 % males and 51.29 % females (CBS, 2011). Females are economically active than male since the economy is highly

dependent on agriculture together with livestock which is also the prime occupation and source of employment and income for a large majority of the people in the study area. Almost all people of the population of the study area depend on agriculture (farming, livestock raising, poultry, dairy sale, agriculture labor etc.) for their livelihood. Besides, the other occupations of the people include labor, daily wages, hotels, service, administrative service etc. 59 years' age also contribute to household works including the income generating activities either in farm or business activities or through pension (CBS, 2011).

8. Paduka Ramghat 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. Paduka Ramghat Sub Watershed VULI has been illustrated in (Table 7).

Table 7: Vulnerability Index of VDCs in Paduka Ramghat Sub Watershed Dailekh

S.N.	VDC/Municipality	Vulnerability Class
1	Badalamji	Very High
2	Bhairikalikathum	High
3	Bisalla	Moderate
4	Chamunda	Very High
5	Dullu	Very High
6	Jambukandh	Very High
7	Kusapani	High
8	Layanti Bindrasaini	Very High
9	Nepa	High
10	Padukasthan	Very High

Source: ASHA Project 2016

9. Drivers of Paduka Ramghat Sub Watershed Degradation

Drivers of Paduka Ramghat Sub-Watershed degradation have been identified. These include a) unscientific cultivation where land capability not considered, b) deforestation, c) soil erosion, d) landslide and e) forest fire 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 watershed. The following sections imparts information about each of the drivers.

Unscientific cultivation

Paduka Ramghat Sub Watershed has five land capability classes namely Class I to Class IV and VIII as categorized by Land classification undertaken by Land Resource Mapping Project (LRMP). Land use in the watershed has been analyzed according to land use capability class. According to the land use capability class, Class IV and 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 IV 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 1306.69 hectare land in Class III and Class IV; Layanti Bindrasaini VDC (123.12 ha), Jambukandh VDC (171.80 ha), Chamunda VDC (460.41 ha), Bhairikalikathum VDC (219.38 ha), where land capability not considered resulted d the problems of soil erosion in this sub-watershed.

Deforestation

An analysis of changes in land use and land cover in the sub-watershed for the period 2006-2016 shows that the about 235.75 ha of forest area had transformed to shrub land but only about 187.41 ha of shrub land was converted to forest area. During 2006-2016, deforestation areas were mostly observed in and around Layanti Bindrasaini VDC, Jambukandh VDC, Chamunda VDC, and Bhairikalikathum VDC. Forest and shrub land 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. The energy demand for cooking is met by burning fire wood in watershed. Fire wood is the main source of energy in villages as well as urban centers. Every household collects fire wood to meet its domestic needs. High dependency of people on forests for firewood. Nearly 98.59 percent of the population still uses firewood as main source of energy. Likewise, limited portion of the households use alternative energy sources. 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. Likewise, development of the road network has been a priority development objective in recent years, particularly at local levels. From field verification and key

informant, road construction, particularly along forest tracts has been found in the sloped hills of Layanti Bindrasini VDC, Jambukandh VDC, Chamunda VDC and Bhairikalikathum VDC of Paduka Ramghat Sub Watershed. The major found includes first, unplanned and unregulated construction of rural roads which generally found in environmentally fragile lands such as near river banks or along steep and fragile hills. This resulted massive earthworks, loss of natural vegetation cover, landslides and soil erosions. Second, roads often go through forestland due to the resistance of private landowners to provide alternative land for roads. Development agencies prefer to construct roads through forestlands as they get the land free and can also avoid diverse types of local disputes. Third, most of the roads are constructed with minimum consideration of environmental concerns during construction and management. The construction of roads can permanently change the land use type and can results in the local biophysical environment becoming prone to vegetation loss followed by erosion and landslides.

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 agriculture land. Study revealed that soil loss maximum in agriculture land. The estimated total soil loss for the entire area was 0.33 million t in 1996, and 0.29 million ton in 2016. In sub-watershed landslides found to be maximum in Layanti Bindrasini VDC, which is followed by Bhairikalikathum VDC, Chamunda VDC, Jambhukandh VDC, Padukasthan VDC, Badalamaji VDC, Nepa VDC, Bisalla VDC, Kusapani VDC and Dullu Municipality resulted due to steep terrain and changes in slope due to river cutting of the toe of a slope, or bank scouring by debris flows, excavation for road, cultivation or removal of material from the slope were one of the major issues in Paduka Ramghat Sub Watershed. Weak geology with high number of gullies has also contributed to accelerate the erosion process and landslide in the watershed.

Forest fire:

The threat of forest fires is usual and will continue to remain so. Forest fires destroy grasses, shrubs and young plants and expose base slopes during the dry months of April and May. Forest area under Lyati bindrasaini VDC, Jambukandh VDC, Chamunda VDC, and Bhairikalikathum VDC found to be VDC with high risk of forest fire. The condition of sub-watersheds has been deteriorating due to destruction of natural vegetation by forest fire in the watershed.

10. Recommendations

The study suggested following programs for improving Paduka Ramghat Sub-Watershed condition.

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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 4, 6, 8, and 9
- Jambukandh VDC Ward 1, 2, 3, 4, 6, and 9
- Chamunda VDC Ward 1, 3, 4, 6, 7, 8 and 9
- Bhairikalikathum VDC Ward 1, 2, 3, 5, 7 and 9

Programme: Soil conservation and land conservation 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 conserve water sources, increase land productivity, minimize erosion and landslide in the watershed while maintaining the hydrological linkages of the upstream and downstream.

- Implement conservation education and extension activities aiming to create awareness of erosion and landslide problems
- 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)
- Implement stall feeding and control over grazing
- Promote income generation and conservation oriented plantations of forests and grasses in degraded lands
- Implement river bank stabilization program through bio-engineering methods
- Implement conservation education and extension activities aiming to create awareness of erosion problems, farming practices and soil fertility management
- Implement landslide bank stabilization program through bio-engineering methods

Forest Restoration

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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 4, 5, 6, 7, 8, and 9
- Jambukandh VDC Ward 1, 3, 6, 7, and 8
- Chamunda VDC Ward 1,2,3 and 5
- Bhairikalikathum VDC Ward 1, 2, 3, 8 and 9

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 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 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)
- Control grazing pressure inside the forest
- Reduce transhumance animal herding system in the watershed by developing fodder and forage nearby the settlement
- Control the forest fire
- Promote non-timber forest product cultivation
- Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock
- Promote leasehold forestry to restore the fragmented habitats
- Develop and implement business plan of the commercially viable NTFPs
- 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.
- Implement stall feeding and control over grazing

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 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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 6, 8, and 9
- Jambukandh VDC Ward 1, 2, 3, 4, 6, 7, and 8
- Chamunda VDC Ward 1,2,3,4, 5, 6, 7, 8, and 9
- Bhairikalikathum VDC Ward 1, 2, 5 and 9

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

Forest Fire Prevention and Control Program

Objective: The objective of this program is to reduce incidence and extent of forests fire by developing knowledge, skill and capacity of forests officials, villagers and other stakeholders and involving local community directly on prevention and control of forest fire.

Target Area: The program will be implemented in the following area:

- Lyantibindrasaini VDC Ward 7and 8
- Jambukandh VDC Ward 6

Programme: Proposed program will reinforce the system for fire management. These include fire control measures, effective communication and information system and providing defined responsibilities and incentives to the local community for participation in fire management

- Create awareness about causes of forest fire, ill effect of forest fire and prevention and control methods
- Develop capacities of forest guards and local communities in fire prevention and control
- Initiate preventive measures in fire sensitive area such as litter removal, controlled burning, cutting fire lines, and engaging fire watchers to reduce the risk of fire
- Adopt improved and modern fire management practices with the fast and efficient communication system
- Replant brunt forests
- Promote participatory forest management in fire sensitive area
- Supply adequate firefighting equipment's at range post or VDC level for immediate response
- Participatory forest management in fire sensitive area
- Firefighting equipment for immediate response
- Preventive measures in fire sensitive area such as litter removal, controlled burning, cutting fire lines, engaging fire watchers to reduce the risk of fire
- Replant brunt forests
- Improved and modern fire management practices with the fast and efficient communication system
- Piloting incentive mechanism for involving local communities in forest fire control and prevention

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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 4, 5, 6, 7, 8, and 9
- Jambukandh VDC Ward 1, 3, 6, 7, and 8
- Chamunda VDC Ward 1,2,3 and 5
- Bhairikalikathum VDC Ward 1, 2, 3, 8 and 9

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

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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 4, 5, 6, 7, 8, and 9
- Jambukandh VDC Ward 1, 3, 6, 7, and 8
- Chamunda VDC Ward 1,2,3 and 5
- Bhairikalikathum VDC Ward 1, 2, 3, 8 and 9

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

Alternative Energy Development Program

The main purpose of alternative energy development is to narrow down 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:

- Lyantibindrasaini VDC Ward 1, 2, 3, 6, 7, 8, and 9
- Jambukandh VDC Ward 1, 2, 3, ,4 , 6, 7, and 8
- Chamunda VDC Ward 1,2,3, 4 5, 7, 8 and 9
- Bhairikalikathum VDC Ward 1, 2, 5, and 9

Program

- Promote non-conventional energy sources such as biogas, solar and wind 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

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:

Table 8: Program target sites beyond administrative boundary

Linkage	Upstream	Downstream
Landslide and Deforestation and Degradation	Piladi VDC, Jambukandh VDC, Dullu Municipality, Bhairikalikathum VDC	Layanti Bindrasini VDC
Landslide and Deforestation and Degradation	Chamunda VDC Dandimadi VDC, Bhairikalikathum VDC & Dullu Municipality	Jambhukandh VDC
Landslide and Deforestation and Degradation	Chamunda VDC	Jambhukandh VDC and Layanti Bindrasini VDC
Landslide and Deforestation and Degradation	Bhairikalikathum VDC	Rawatkot VDC

Program

- Enhance the capacity of the local people to plan and implement landslide control and deforestation
- Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation)
- Implement landslide bank stabilization program through bio-engineering methods
- Assist in managing monsoon run-off
- Reclaim the landslides sites by appropriate vegetative and structural methods
- Promote income generation and conservation oriented plantations of forests and grasses in degraded lands
- Improve the status of poorly stocked forests through natural regeneration or appropriate intervention (reforestation, plantation)

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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 7. Methodological flowchart of land use land cover change. The materials that were used for this study involve both primary and secondary data.

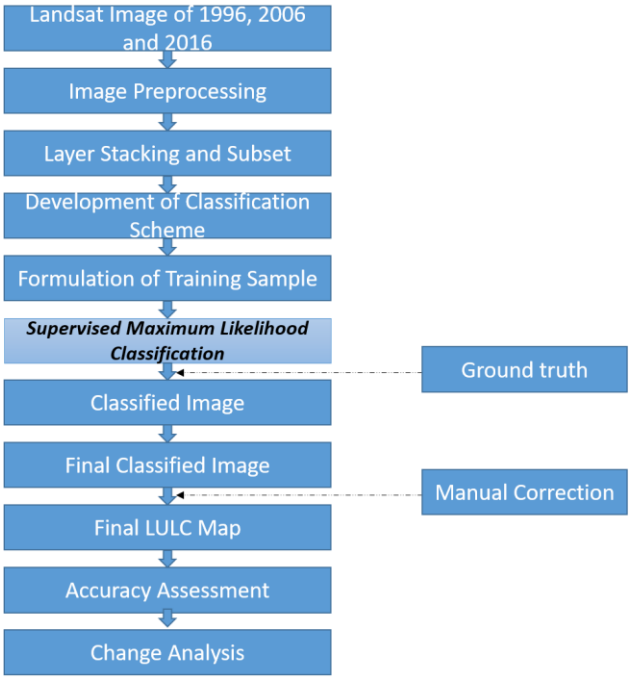

Figure 7 Methodological Flow chart of Land use Land cover change

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; 1996, 2006 and 2016 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 10 shows the characteristics Landsat Satellite images of the study area.

Table 9: Characteristics of acquired satellite image

S.N	Image	Year	Sensor	Resolution	Date of Acquisition	Bands
1	Landsat 5	1996	TM	30m	1996-01-02	7
2	Landsat 5	2006	TM	30m	2006-03-02	7
3	Landsat 8	2016	OLI/TIRS	30m	2016-04-30	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 groups or sets on the basis of relationships. These relationships can be based upon observable or inferred properties". Area of Interest i.e. Sharada 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 11

Table 10: 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 2004, 2006, 2008, 2016. 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 2. 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:

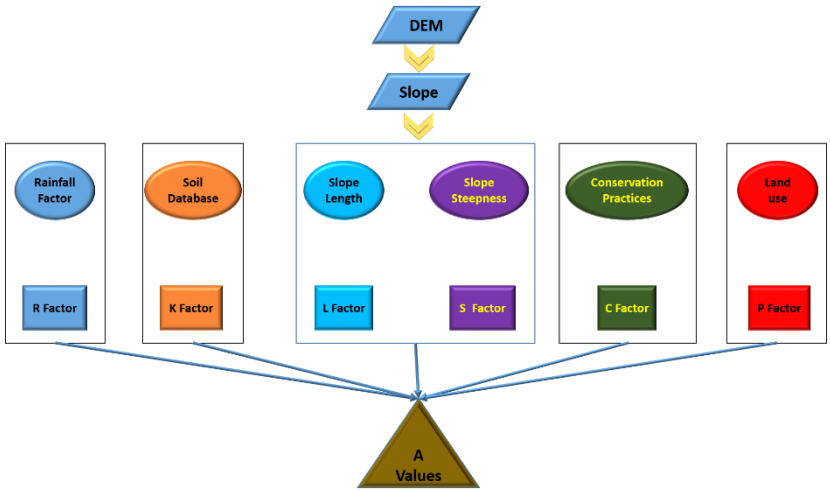

Figure 8 Methodological framework of soil erosion dynamics

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.

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.

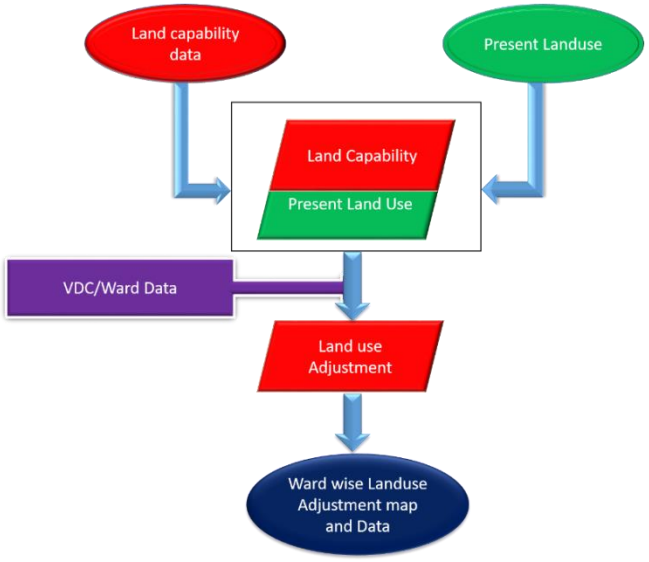

Figure 9: Methodological Framework of Land Use Adjustment