ADAPTATION FOR SMALLHOLDERS IN HILLY AREAS (ASHA) PROJECT

GIS BASED ASSESSMENT OF SHARADA WATERSHED, SALYAN

Credits

ASHA Project Ministry of Forests and Soil Conservation Government of Nepal

Kathmandu Nepal

Published by

Adaptation for Smallholders in Hilly Areas (ASHA) Project

Authors

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

The assessment team

District GIS Specialist: Mr. Bishal Kumar Rayamajhi

Land Use Planner: Mr. Sudeep Adhikari

Review team

Technical Team Leader: Mr. Navraj Baral

Forestry Specialist: Mr. Deepak Bahadur Chand

Photo credits

Citation

Please cite this report as: Adaptation for Smallholders in Hilly Areas Project 2017. GIS Based Assessment of Sharada Watershed Salyan. Adaptation for Smallholders in Hilly Areas Project, Ministry of Forests and Soil Conservation Kathmandu Nepal.

Acknowledgements

We would like to express our great appreciation to the Technical Support Unit- Surkhet and Adaptation for Smallholders in Hilly Areas (ASHA) Project, Project Coordination Unit-Hattisar, Kathmandu and International Centre for Integrated Mountain Development (ICIMOD) for imparting technical support for conducting this assessment.

Special thanks also go to the officers of district level government line agencies, particularly District Forest Office, District Soil Conservation Office, District Livestock Office, District Women Development Office, District Development Office and District Education Office. We would also like to thank individual experts and representatives of various NGOs and civil society and local people who generously provided their valuable time to contribute for this assessment.

ABBREVIATIONS AND ACRONYMS

ASHA	Adaptation for Smallholders in Hilly Areas
CC	Climate Change
CBS	Central Bureau of Statistics
CCA	Climate Change Adaptation
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
SW	Sharada Watershed

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 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 Sharada Watershed Salyan and prepared this study report.

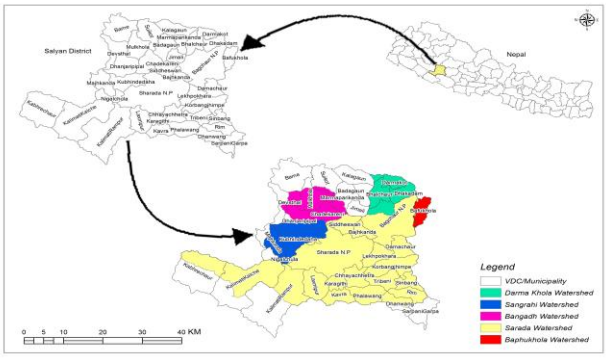
2. Objective

The objective of this assessment was to impart GIS based analytical assessment of the bio-physical and socio-economic conditions of Sharada Watershed 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 watershed.

3. Study Area

The Sharada Watershed (SW) is situated in western Nepal between $28^0$13'50" and $28^0$32'25" N latitude and $81^0$46'5"- $82^0$24'15" E longitude, covering an area of 971.39 square kilometers, altitude ranges from 400 meter to 2800 meter above mean sea level. The watershed includes all or part of 21 Village Development Committees and 2 Municipalities of Salyan district and is drained by Sharada River and its tributaries of the broader Babai Sub-Basin in the western Nepal. Physio-graphically, the Sharda Watershed is divided into two major zones: the Siwalik, and mid hills. Of the total area of the watershed, 14.64 percent and 85.36 percent are covered by Siwalik, and mid hills region respectively. The wide variation in climate, elevation and topography has contributed to occurrence of different forest types in the watershed that range from tropical mixed deciduous forests to temperate vegetation. It has a tropical monsoon climate, average maximum temperature recorded is 31º C in summer while the average minimum temperature is 14 ºC recorded during the winter. Over 90 percent of the annual rainfall occurs during monsoon between June and September. Average annual rainfall is around 1000-1100 mm with maximum concentration around July-September.

Figure 1: Location of Sharada Sub-Watershed in Salyan 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 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 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 3.

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 4.

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 Sharada Watershed according to FAO 2006 Annex 5.

Landslide Distribution

The study used secondary sources of information to map landslide spatial distribution map. Secondary data on landslides in the watershed were obtained from Salyan District Landslide Archive of District Soil Conservation Office Salyan. 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 Sharada Watershed (1996-2016)

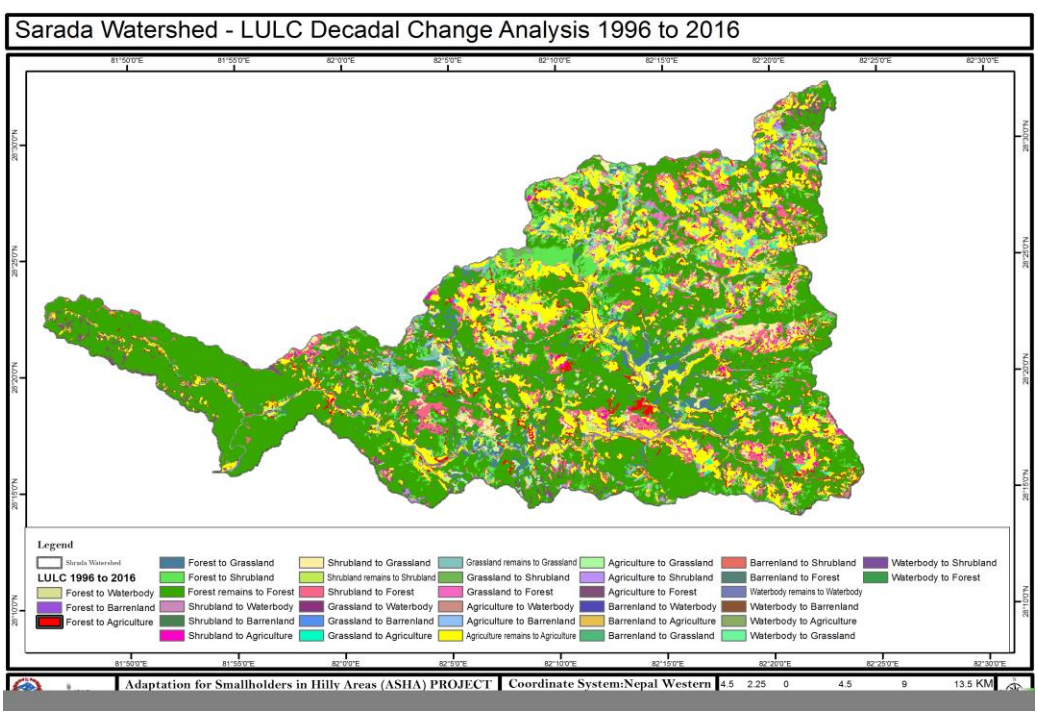
5.1.1 Changes in Land Use/ Land Cover

An analysis of changes in land use/land cover in the watershed for the period 1996-2016 shows that the area under forest slightly decreased, area under agriculture decreased, area under shrub land and water body substantially decreased and grass land and barren substantially increased (Table 1; Figure 2).

Table 1: Areas under Land Use/Cover and Change in Land Use/Land 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
Forest	58769.7	60.5	53789.4	55.4	57412.3	59.1	-8.5	6.7	-2.3
Shrub Land	9678.4	10	14957.1	15.4	7403.2	7.6	54.5	-50.5	-23.5
Grassland	4165.6	4.3	5901.6	6.1	9688.1	10	41.7	64.2	132.6
Agriculture	22864.6	23.6	21442.3	22.1	21489.1	22.1	-6.2	0.2	-6.0
Barren Land	12.8	0	170.9	0.2	106.7	0.1	1237	-37.5	735.2
Waterbody	1580	1.6	809.8	0.8	971.7	1	-48.7	20	-38.5
Total	97071.1	100	97071.1	100	97071.1	100			

Figure 2: Change in Land Use/Land Cover s Change in Sharada Watershed in 1996 and 2016



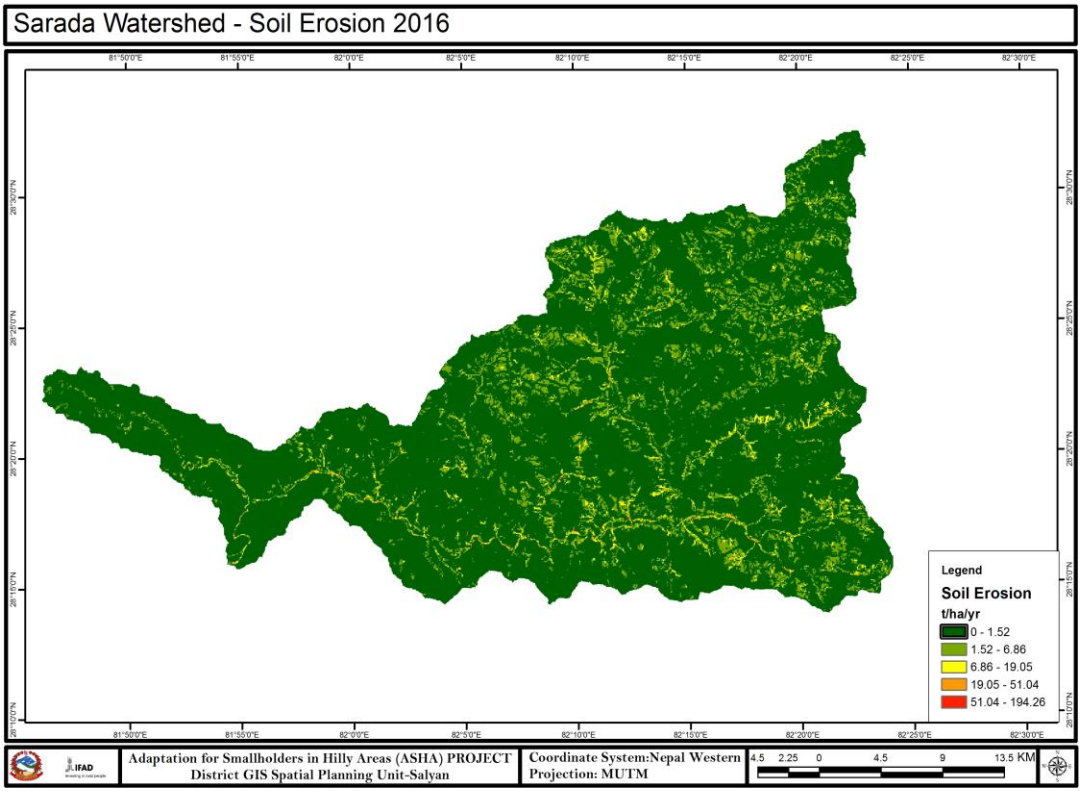
5.2 Estimation of Soil Erosion Loss Dynamics (1996-2016)

An analysis of soil loss in the watershed for the period 1996-2016 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 1.03 million t in 1996, .857 million t in 2006 and .859 million ton in 2016. (Table 2; Figure 3).

Table 2: Estimated Soil Erosion Rate of 1996, 2006 and 2016

Land Cover	Land Cover (KM^2)			Annual Soil Loss (Tones)			Mean Erosion Rate (t/ha/yr)		
Year	1996	2006	2016	1996	2006	2016	1996	2006	2016
Forest	587.6973	537.894	574.1226	46801	75769	42654	0.0725	0.1281	0.0678
Shrub land	96.7842	149.571	74.0322	38267	73575	26817	0.3628	0.4529	0.3334
Grassland	41.6556	59.0157	96.8805	12469	24746	41743	0.2742	0.3854	0.3906
Agriculture	228.6459	214.4232	214.8912	673861	579138	632404	2.6756	2.4446	2.6660
Barren land	0.1278	1.7091	1.0674	666	13563	5449	4.6901	7.1724	4.6853
Waterbody	15.8004	8.0982	9.7173	261044	90545	110875	14.8650	10.0617	10.2934
Total	970.7112	970.7112	970.7112	1033108	857336	859942	0.9694	0.8042	0.8069

Figure 3: Estimated Soil Erosion Rate in Sharada Watershed in 2016



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

An analysis of forest fire in the 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 May and June. Watershed's south western part found to area with high spatial and temporal distribution of forest fire. Forest area under Kaprechaur VDC and Kalimatikalche VDC found to be VDC with very high risk of forest fire. Similarly, Forest area under Bajhakanda VDC, Phalawang, Siddheswari VDC, and Sharada Municipality found to be VDC with high risk of forest fire.

Figure 4.1: Spatial and Temporal Distribution of Forest Fire

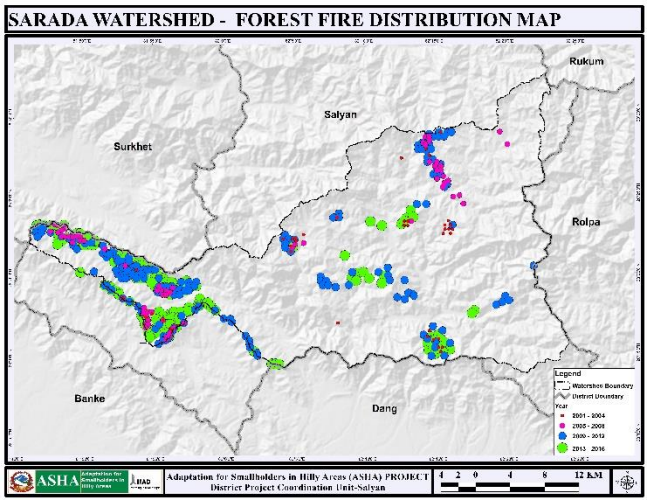


Figure 4.2: Forest Fire Risk Zone Map

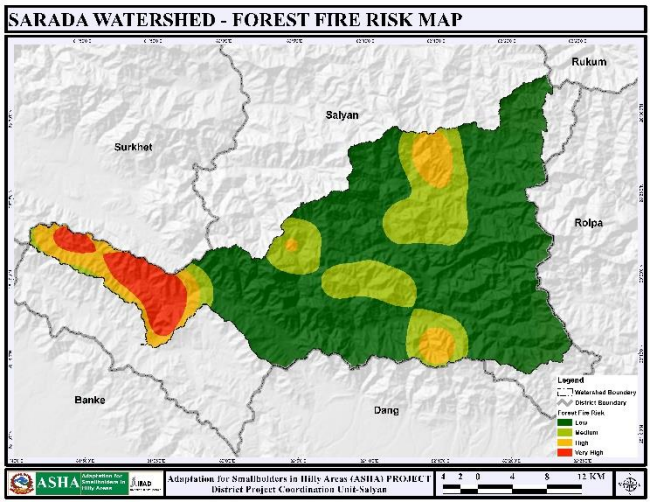


Figure 4.3: Magnitude of Forest Fire Burnt Area 2000-2016

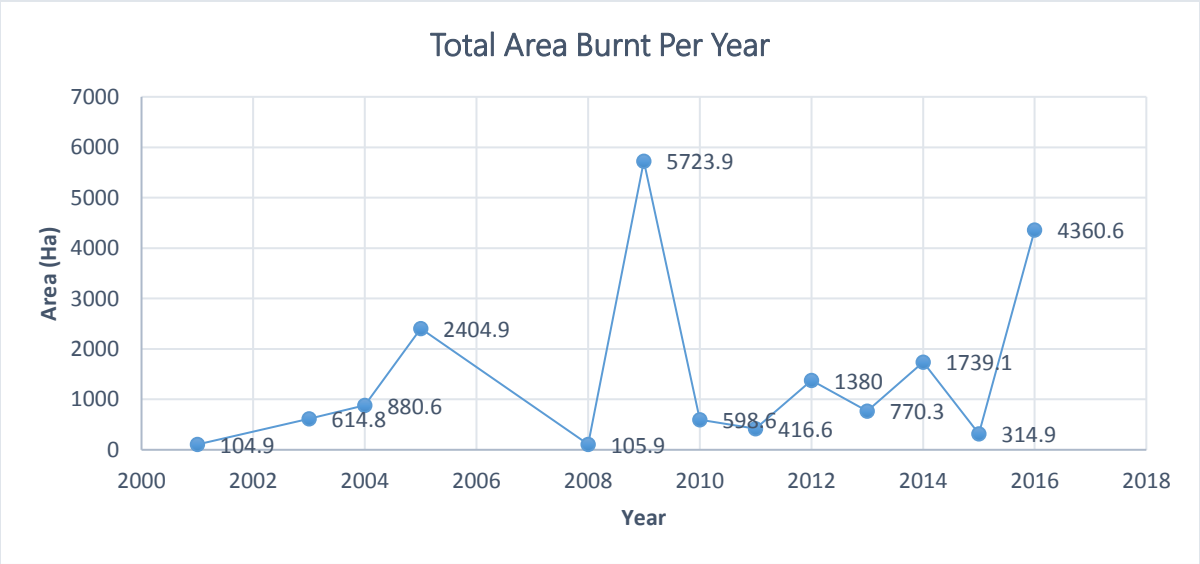


Figure 4.4: Forest Fire Hotspots 2000-2016

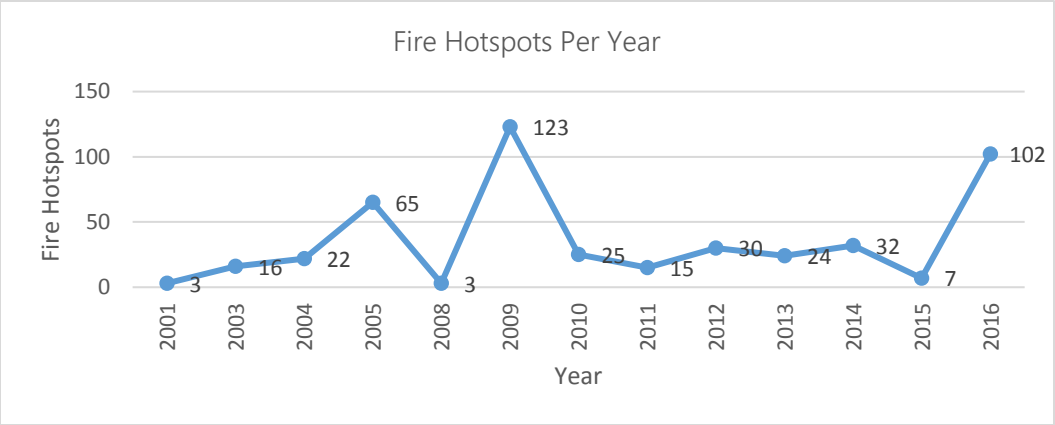


Figure 4.5 Monthly Forest Fire Hotspots 2000-2016

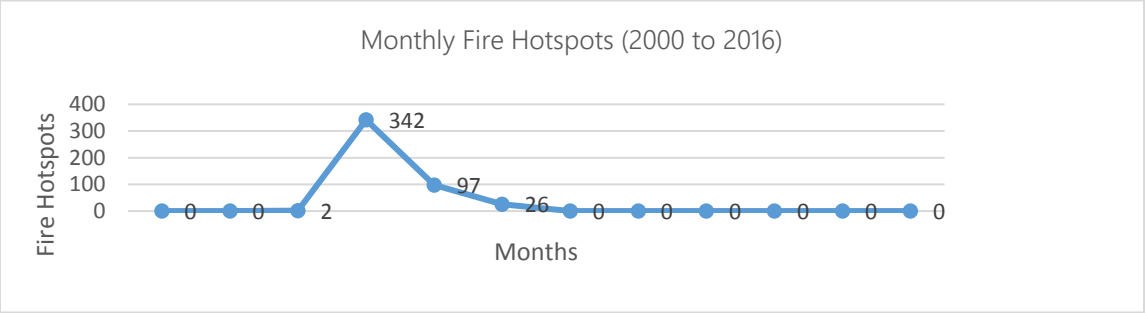


Table 3: VDC Wise Forest Fire Distribution 2000-2016

VDC_NAME	2001	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
BAGCHAUR N.P			93.7	302.5		500.7								896.9
BAJHKANDA			73.8	448.2		369.1			84					975.1
CHHAYACHHETRA						436.3			356.6				24	816.9
JIMALI						1								1
KABHRECHAUR				611		1320.7	99.6	167.9	166	297.2	403.3		1137	4202.7
KALIMATIKALCHE		194.8		536.4	63.8	836	308.9	245.4	563.1	346.6	160.9	293.8	2622.3	6172
KALIMATIRAMPUR		0.1		0.4	0.2	58.1	1.2	3.1	0.3	0.5	0.1		14	78
KORBANGJHIMPE						8.6								8.6
LAXMIPUR			21			300.1								321.1
LEKHPOKHARA			155.7	11					21					187.7
PHALAWANG		398.9				944.8					692.9			2036.6
SHARADA N.P	104.9	21	494.6	471	42	920.5			188.8	126	398.4	21	563.1	3351.3
SIDDHESWARI			41.9	25.1		28.6								95.6
SINBANG							188.9							188.9
TRIBENI											83.9			83.9
GRAND TOTAL	104.9	614.8	880.7	2405.6	106	5724.5	598.6	416.4	1379.8	770.3	1739.5	314.8	4360.4	19416.3

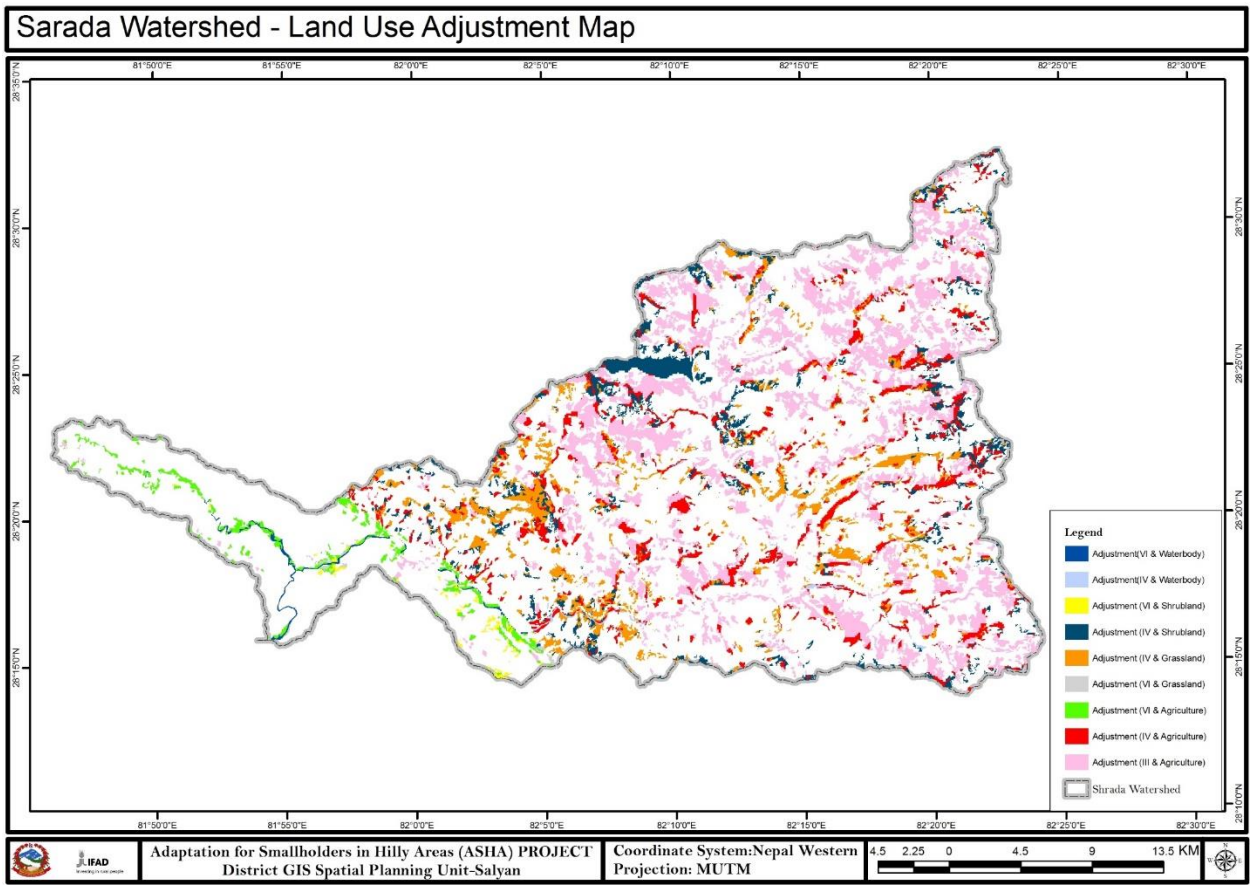
5.4 Land Use Adjustment

An analysis of land capability and current land use in the watershed shows that the land being over used. In watershed natural environment of fragile and slope land (land class III, land class IV and land class VI 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 4; Figure 5).

Table 4: Land use Adjustment in Watershed

Land Use Adjustment		Area (Hectare)
Agriculture in Land Class III	Tribeni VDC, Kavra VDC, Karagethi VDC, Kaprechaur VDC, Siddheshwari VDC	4645.6
Agriculture in Land Class IV	Tribeni VDC, Kavra VDC, Karagethi VDC, Siddheshwari VDC	14054.3
Barren land in Land Class IV	Kalimati Rampur VDC and Sharada Municipality	23.0
Grassland in Land Class IV	Tribeni VDC, Kavra VDC, Karagithi VDC, Siddheshwari VDC	4460.5
Shrub land in Land Class IV	Tribeni VDC, Kavra VDC, Karagithi VDC, Siddheshwari VDC	3594.8
Waterbody in Land Class IV	Kavra VDC, Karagithi VDC	184.7
Agriculture in Land Class VI	Kaprechaur VDC	1013.3
Barren land in Land Class VI	Kaprechaur VDC	9.7
Shrub land in Land Class VI	Kaprechaur VDC	209.6
Grassland in Land Class VI	Kaprechaur VDC	113.1
Waterbody in Land Class VI	Kaprechaur VDC	238.5
Total		28547.3

Figure 5: Land Use Adjustment in Sharada Watershed



5.5 Landslide Distribution

An analysis of landslide distribution in the watershed shows landslide occupies the greatest area in Kaprechaur VDC, which is followed by Kavra VDC, Kalimatikalche, Sarada Municipality, Tribeni VDC, and Bagchaur Municipality.

Figure 6.1: Landslide Distribution in Watershed

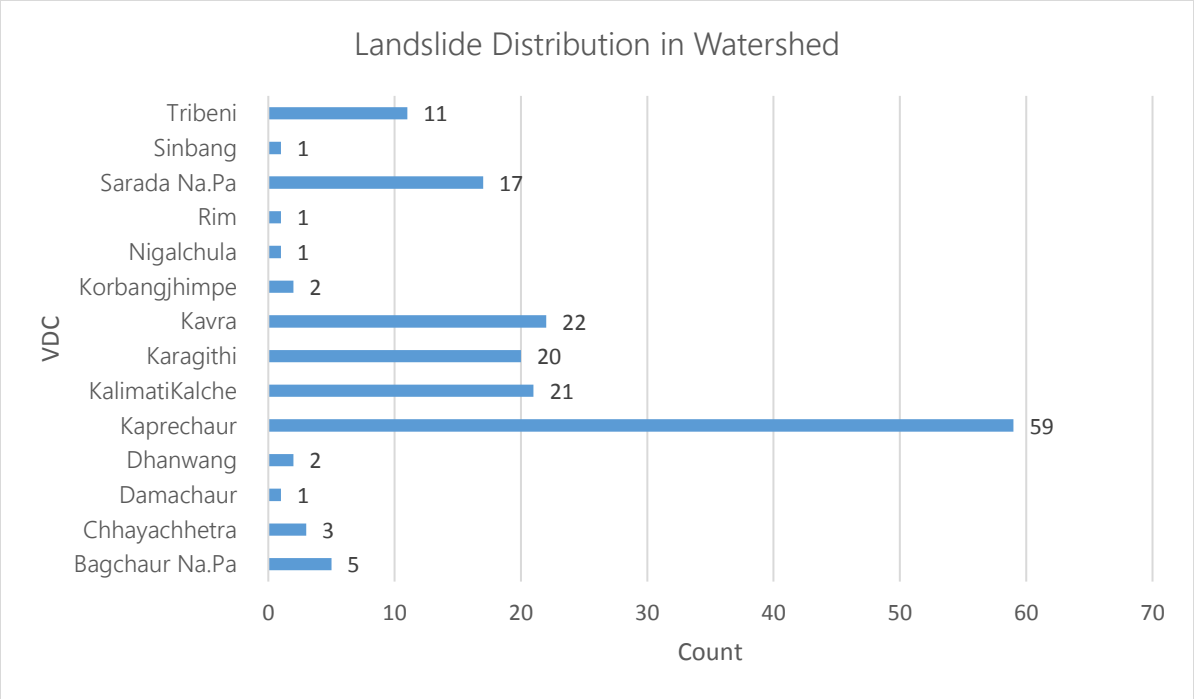
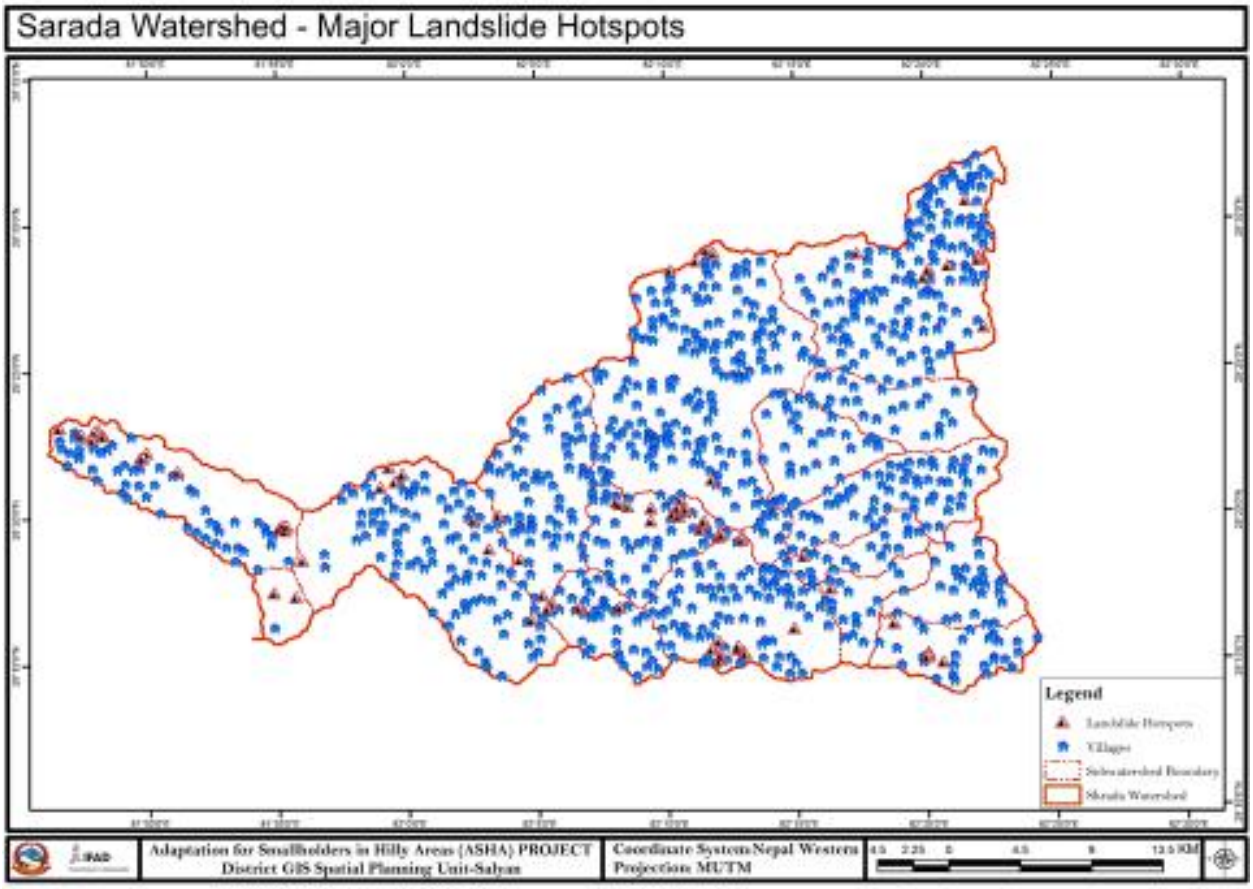


Figure 6.2: Landslide Distribution in Watershed



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 watershed shows that upstream and downstream linkages sites within VDC and beyond VDCs within Sharada Watershed (Table 5 and 6.1, 6, 2, 6.3, 6.4 and 6.5).

Table 5: Upstream and Downstream Linkages Sites beyond VDCs within Sharada Watershed

Linkage	Upstream	Downstream
Landslide	Ward 8 of Tribeni VDC Adjoining Rapti Rajmarga	Ward 2 of Chayachhetra VDC near Sankhamul
Landslide	Ward 3 of Karagithi VDC Tirse Village	Ward 7 of Kavra VDC Ram bazar (Rithachaur) Jumledhunga Village
Landslide	Ward 5 North upper part of Sano Giddhe Khola	Banke District
Landslide	Ward 1 of Siddheshwari VDC South of Barachaur	Ward 7 of BajhkandaVDC- Chaklighat & Sharada Municipality - Syala
Deforestation and Degradation	Ward 1 of Siddheshwari North of Barachaur	Ward 7 of BajhkandaVDC- Chaklighat & Sarada Municipality - Syala

Table 6.1: Up and downstream linkages sites within Tribeni VDC

VDC	Tribeni	
Linkage	Upstream	Downstream
Landslide	Ward 5 of Tribeni VDC, East of Ghopte Oral	Ward 6 of Tribeni VDC
Landslide	Ward 3 of Tribeni VDC Southwest of Gaira Salya, Near Local Road of Salya Khola	Ward 2 of Tribeni VDC
Landslide	Ward 8 of Tribeni VDC adjoining Rapti Rajmarga adjoining Sankhamul area	Ward 2 of Tribeni VDC
Deforestation and Degradation	Ward 2 of Tribeni VDC North of Danda Salya	Ward 3 of Tribeni VDC
Deforestation and Degradation	Ward 3 of Tribeni VDC	Ward 2 of Tribeni VDC

Table 6.2: Up and downstream linkages sites within Kavra VDC

VDC	Kavra	
Linkage	Upstream	Downstream
Landslide	Ward 2 of Kavra North of Rikhe Village	Ward 3 of Kavra VDC
Landslide	Ward 3 of Kavra VDC North of Sagine	Ward 2 of Kavra VDC Forest East of Gogane Village
Landslide	Ward 4 of Kavra VDC	Ward 4 of Kavra VDC near Tintale
Landslide	Ward 5 Grassland of Kavra VDC	Ward 8 of Kavra VDC

Table 6.3: Up and downstream linkages sites within Karagithi VDC

VDC	Karagithi	
Linkage	Upstream	Downstream
Landslide	Ward 9 of Karagithi VDC Burhbhadau	Ward 9 of Karagithi VDC Forest
Landslide	Ward 6 of Karagithi VDC	Ward 5 of Karagithi VDC Forest
Landslide	Ward 2 of Karagithi VDC ChorKhola Village	Ward 3 of Karagithi VDC Agriculture Land near Ghareli Village
Deforestation and Degradation	Ward 6 of Karagithi VDC Forest	Ward 7 of Karagithi VDC North of Bahuntakura
Deforestation and Degradation	Ward 4 of Karagithi VDC Jamire Village	Ward 7 of Karagithi VDC Forest
Deforestation and Degradation	Ward 7 of Karagithi VDC – Bahuntakura	Ward 4 of Karagithi VDC Tintale

Table 6.4: Up and downstream linkages sites within Kaprechaur VDC

VDC	Kaprechaur	
Linkage	Upstream	Downstream
Landslide	Ward 2 of Kaprechaur VDC East of Archale near Jum Khola	Ward 3 of Kaprechaur VDC North of Saldanda
Landslide	Ward 2 of Kaprechaur VDC South Part	Ward 5 of Kaprechaur VDC Adjoining Forest and Babai River
Landslide	Ward 4 of Kaprechaur VDC Northwest of Sajhkharka	Ward 3 of Kaprechaur VDC North of Lamitara
Landslide	Ward 4 of Kaprechaur VDC South	Ward 9 of Kaprechaur VDC Upper part of Choke Khola
Landslide	Ward 8 of Kaprechaur VDC near confluence of Dhuliya Khola	Babai River
Deforestation and Degradation	Ward of Kaprechaur VDC Big patch Near School North Part of Bhirkuna	Jum Khola Adjoining area of Kaphali pata

Table 6.5: Up and downstream linkages sites within Siddheshwari VDC

VDC	Siddheshwari	
Linkage	Upstream	Downstream
Landslide	Ward 6 of Siddheshwari VDC Reule Village	Ward 7 of Siddheshwari VDC near Phalate Village
Landslide	Ward 6 of Siddheshwari VDC Upper part of Jhargau Khola	Ward 7 of Siddheshwari Phalate Village
Deforestation and Degradation	Ward 2 of Siddheshwari VDC On the way to Kaghkhola Village	Ward 3 of Siddheshwari VDC Kakre Khola Area
Deforestation and Degradation	Ward 3 of Siddheshwari VDC North of Takura	Ward 2 of Siddheshwari VDC Pedikholagau
Deforestation and Degradation	Ward 6 of Siddheshwari VDC Northwest of Reulegaun/West of Kalalek	Ward 7 of Siddheshwari VDC East of Phalante(Jhargau Khola Area)
Deforestation and Degradation	Ward 8 of Kaprechaur VDC Southwest of Jyula	Ward 7 of Kaprechaur Jhargaun Khola
	Ward 9 of Kaprechaur VDC South part	Sarada Municipality near Tusare Gaun

7. Socio-Economic Assessment

Demography

According to the national population census of 2011, the population of watershed has reached to 165,225 in 2011. Of the total persons, the numbers and percentages of male and female were 78372 (47.43%) and 86853 (52.57%) respectively.

Population density determines pressure on land, which is expressed as average number of people per square kilometer. Population density has reached 135 persons/square kilometer in 2011. Likewise number of person per square kilometer of agricultural land in the watershed has reached 537 in 2011. Population density per square kilometer of forest has reached 230 persons/square kilometer of forests in 2011.

Caste and ethnic distribution

Majority of the population in watershed are Chhetris which is followed by Janajati, Dalits and others. Out of the total households, nearly 60.7 percent are Chhetri, 16 percent are Janajati, 15.4 percent are Dalit, 4.5 percent are Dashnami, 2.6 percent are Brahmin and 0.5 percent are others.

Literacy

Population Census 2001 shows that 65.5 percent of population aged 6 years and above were literate in Sharada watershed. Male is 75.25 percent while the female literacy is about 56.90 percent. About 48.19% population 5 years and above have gain primary level education, 22.30% have gain lower secondary level education, 9.22 % have gain secondary level, 6.55 % SLC and equivalent 3.82 % Intermediate & equivalent, 0.82 % graduate and 0.22 % post graduate in the watershed.

Gender Relation

Like in other area of Nepal, women of 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 DCC, 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. From the natural resources management perspective, the roles and responsibilities of male and female varies in the district. Compared to men, women interact with forests resources more frequently. Activities such as grass, fodder, fuelwood collection are mostly carried out by women. While for men, their involvement is largely seen as decision makers both within households and in communities, partly because of the culturally excepted male dominating modus operandi and partly because of the dominance of men in the leadership positions in decision making bodies on most of the forest based institutions in the watershed.

Usual fuel for cooking:

About 96.52 of the total households use firewood as the usual source of fuel for cooking followed by LPG (1.87 percent), and 1.62 % of households use other source of energy for cooking e.g. kerosene, guitha, biogas etc.

Economically active population

More than 78 percent of the economically active population are engaged in skilled agriculture, forestry and fishery work, agriculture and livestock sector followed by elementary occupations (6.49 percent), craft and related trades work (4.16 percent), service and sale work (3.37). Rest of the population is employed as manager, professionals, technicians and associate professor, office assistant and armed forces employee and other professions. Table 7 presents details on population engaged across different types of service sectors.

Table 7: Economically active population aged 10 years and over by major occupation, employment status

SN	Type	2011	Percent
1	Armed Forces	88	0.09
2	Managers	488	0.52
3	Professionals	3166	3.35
4	Technicians and associate Prof.	704	0.75
5	Office assistance	648	0.69
6	Service & sale workers	3181	3.37
7	Skilled Agriculture, forestry & fishery workers	74563	78.95
8	Craft and related trades workers	3926	4.16
9	Plant & machine operators & assemblers	405	0.43
10	Elementary Occupations	6126	6.49
11	Not stated	1144	1.21
	Total	94439	100.0

Source: CBS 2011

8. Sharada 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. According to ASHA Project, Sharada Watershed VULI, is observed as the very high vulnerability VDCs with 7 out of 23 VDCs and 3 out of 23 in high vulnerability.

Table 8: Vulnerability Index of VDCs in Sharada Watershed Salyan

S.N.	VDC	Vulnerability Class	S.N	VDC	Vulnerability Class
1	BajhKanda	Low	13	Kotbara	Very High
2	Chhayakshetra	High	14	Lakshmipur	High
3	Damachaur	Moderate	15	Lekhpokhara	Low
4	Dandagaun	Very High	16	Phalawang	Low
5	Dhanbang	Moderate	17	Rim	Moderate
6	Kaprechaur	Very High	18	Sarpani	Low
7	Kalimati Ramche	Very High	19	Bagchaur Municipality	Very High
8	Kalimati Rampur	Very High	20	Siddheshwar	Low
9	Karagithi	Moderate	21	Sinbang	Low
10	Kabhra	Low	22	Syanikhal	High
11	Sharada Municipality	Very High	23	Triveni	Low
12	KorbangJhimpe	Low			

Source: ASHA Project 2016

9. Drivers of Sharada Watershed Degradation

Drivers of Sharada 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, 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

Land classification undertaken by Land Resource Mapping Project (LRMP) has categorized Sharada watershed into seven land capability classes namely Class I to Class VI and VIII. Erosion, sedimentation and watershed conditions vary with these classes. These categories are indicative of their potentials to be modified for different land use purposes. Class I is considered as a land without limitation to any use while Class VIII has little use potential except for watershed management and scenic tourist activities. Class IV and Class VI are considered as land demand full vegetation cover. However, unscientific cultivation has been found in Class IV and Class VI in the watershed where land capability not considered has compounded the problems of soil erosion and landslide in this watershed.

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 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. 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. Landless and small landholders sell fire wood for cash. They primarily meet the demands of the section of the urban population. High dependency of people on forests for firewood. Nearly 96 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. Apart from this, traditional practice of open grazing of cattle in community and national forest in common phenomenon in the watershed which has contributed for watershed degradation.

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 watershed used to be covered with dense forests, which restricted the movement of sediment and debris. The high rate of erosion and landslide poses a major threat to the settlement and land resources in watershed. Sharada River and streams are causing soil erosion, river cuttings

and flood damages problems. Sub-watershed of Siwalik region has been facing the highest erosion. The major causes of this erosion are overgrazing of forest that lie in this region and forest fire. This region also receives comparatively high rainfall. 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. 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 Sharada Watershed condition.

Soil and Land Conservation Program

Objective: The main objective of this program is to protect land degradation by soil erosion, landslides, desertification, and other ecological disturbances 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 watershed level while maintaining the hydrological linkages of upstream and downstream.

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

- Tribeni VDC-Ward Number 1, 2, 3 4, 5, 6 7, 8 and 9
- Kavra VDC- Ward Number 2,3,4,7 and 8
- Karagethi VDC Ward 1, 2, 4, 5, 6, 7 and 9
- Kaprechaur VDC Ward 1, 2,3,4,5,6,7,8 and
- Siddheshwari VDC Ward 1, 2, 3,4,5,6 and 7

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 riverbank cuttings, and effect of anthropogenic activities like forest fire, forest resource exploitation and uncontrolled grazing in the watershed.

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

- Tribeni VDC- Ward 1,2,4,5,6,7,9
- Kabhra VDC- Ward 1, 2, 3, 4 and 5
- Karagethi VDC- Ward 1, 2, 4,6,7,8 and 9
- Kaprechaur VDC – Ward 1, 2,3,4,5,6,7,8 and 9
- Siddheshwari VDC 2, 3,4,5,7 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:

- Tribeni VDC- Ward 1,2,4,5,6,7,9
- Kabhra VDC- Ward 1, 2, 3, 4 and 5
- Karagethi VDC- Ward 1, 2, 4,6,7,8 and 9
- Kaprechaur VDC – Ward 1, 2,3,4,5,6,7,8 and 9
- Siddheshwari VDC 2, 3,4,5,7 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 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
- Implement stall feeding and control over grazing
- 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:

- Tribeni VDC– Ward 4, 6, and 7
- Kaprechaur VDC– Ward 2,3,4,8
- Siddheshwari VDC – Ward 1 and 2.

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:

- Tribeni VDC- Ward 1,2,4,5,6,7,9

- Kabhra VDC- Ward 1, 2, 3, 4 and 5
- Karagethi VDC- Ward 1, 2, 4,6,7,8 and 9
- Kaprechaur VDC – Ward 1, 2,3,4,5,6,7,8 and 9
- Siddheshwari VDC 2, 3,4,5,7 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:

- Tribeni VDC- Ward 1,2,4,5,6,7,9
- Kabhra VDC- Ward 1, 2, 3, 4 and 5
- Karagethi VDC- Ward 1, 2, 4,6,7,8 and 9
- Kaprechaur VDC – Ward 1, 2,3,4,5,6,7,8 and 9
- Siddheshwari VDC 2, 3,4,5,7 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
- Provide training and support to promote occupation based traditional skill with market facility
- 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 electricity and increasing their supply. Efficiency in the consumption and substitution of firewood with alternative fuel will be emphasized especially targeting ethnic community and other firewood scarce area.

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

- Tribeni VDC- Ward 1,2,4,5,6,7,9
- Kabhra VDC- Ward 1, 2, 3, 4 and 5
- Karagethi VDC- Ward 1, 2, 4,6,7,8 and 9
- Kaprechaur VDC – Ward 1, 2,3,4,5,6,7,8 and 9
- Siddheshwari VDC 2, 3,4,5,7 and 9

Program

- Promote non-conventional energy sources such as hydro-electricity, 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
- Encourage low cost technology for biomass based fuel, e.g. bio briquettes
- 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:

Linkage	Upstream	Downstream
Landslide	Ward 8 of Tribeni VDC Adjoining Rapti Rajmarga	Ward 2 of Chayachhetra VDC near Sankhamul
Landslide	Ward 3 of Karagithi VDC Tirse Village	Ward 7 of Kavra VDC Ram bazar (Rithachaur) Jumledhunga Village
Landslide	Ward 5 of Kavra North upper part of Sano Giddhe Khola	Banke District
Landslide	Ward 1 of Siddheshwari VDC South of Barachaur	Ward 7 of BajhkandaVDC- Chaklighat & Sharada Municipality - Syala
Deforestation and Degradation	Ward 1 of Siddheshwari North of Barachaur	Ward 7 of BajhkandaVDC- Chaklighat & Sarada Municipality - Syala

Program

- Enhance the capacity of the local people to plan and implement landslide control
- Reclaim the degraded land by appropriate vegetative and structural methods
- Assist in managing monsoon run-off
- Assist in development and protection of water resources
- Rehabilitate the landslide hot spots
- Implement stall feeding and control over grazing
- 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)
- 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
- Encourage CFUGs to carry livestock assessment, estimate fodder requirement and adapt stall feeding and control grazing and rearing of improved variety livestock

References

Adab H, Kanniah KD, Solaimani K (2013) Modeling forest fire risk in the northeast of Iran using remote sensing and GIS techniques. Natural Hazards 65, 1723–1743. doi:10.1007/S11069-012-0450-8

ASHA 2016. Pre-Project GIS Exercise Report. ASHA

Chitwan-Annaupurna Landscape Drivers of Deforestation and Forest Degradation, Hariyo Ban Program, Hariyo Ban Program publication number: Report 013, ISBN: 978-9937-81548-2

Chowdhury EH, Hassan QK (2015) Operational perspective of remote sensing-based forest fire danger forecasting systems. ISPRS Journal of Photogrammetry and Remote Sensing 104, 224–236. doi:10.1016/ J.ISPRSJPRS.2014.03.011

Cruden, D.M., 1991. A simple definition of a landslide. Bulletin International Association for Engineering Geology, 43: 27-29.

Dimyati, et al.(1995). An Analysis of Land Use/Land Cover Change Using the Combination of MSS Landsat and Land Use Map- A case study of Yogyakarta, Indonesia, International Journal of Remote Sensing 17(5): 931 – 944.

FAO: http://www.fao.org/docrep/006/t0165e/t0165e01.htm

Foster, G. R. and Meyer, L. D. (1977). "Soil erosion and sedimentation by water – an overview." Procs. National Symposium on Soil Erosion and Sedimentation by Water, Am. Soc. Of Agric. Eng., St. Joseph, Michigan, 1-13.

Giglio L (2010) MODIS Collection 5 active fire product user's guide version 2.4. University of Maryland. Available at http://www.fao.org/fileadmin/ templates/gfims/docs/MODIS_Fire_Users_Guide_2.4.pdf [Verified 4 March 2017].

Giglio L, Csiszar I, Restas A, Morisette JT, Schroeder W, Morton D, Justice CO (2008) Active fire detection and characterization with the advanced spaceborne thermal emission and reflection radiometer (ASTER). Remote Sensing of Environment 112, 3055–3063. doi:10.1016/J.RSE.2008.03.003

Giglio L, Descloitres J, Justice CO, Kaufman YJ (2003) An enhanced contextual fire detection algorithm for MODIS. Remote Sensing of Environment 87, 273–282. doi:10.1016/S00344257(03)00184-6

GON (2013) Nepal disaster report, 2013. Ministry of Home Affairs (MoHA), Government of Nepal Available at http://flagship4.nrrc.org.np/sites/ default/files/documents/Nepal%20Disaster%20Report%202013.pdf [Verified 4 March 2017].

http://cbs.gov.np/image/data/Population/Ward%20Level/55Salyan_WardLevel.pdf

http://moha.gov.np/district/custom/uploads/downloads/1439929042.pdf

IFAD. 2014. ASHA: Adaptation for Smallholders in Hilly Areas: Final Project Design Report. IFAD.

Jansen, L.J.M.; Gregorio, A.D. Parametric land-cover and land-use classifications as tools for environmental change detection. Agric. Ecos. Environ. 2002, 91, 89–100.

Julien, P. Y. (1998). "Erosion and sedimentation". Cambridge University Press,Cambridge, New York. 59

Lane L, Renard K, Foster G, Laflen J. Development and application of modern soil erosion prediction technology-The USDA experience. Soil Research. 1992;30(6):893–912.

M.G.R. Cannel, Growing trees to sequester carbon in the UK:Answers to some questions, Forestry 72 (1999)

McGarigal K. Landscape pattern metrics. Encyclopedia of Environmentrics. 2002;2.

Meusburger K, Steel A, Panagos P, Montanarella L, Alewell C. Spatial and temporal variability of rainfall erosivity factor for Switzerland. Hydrol Earth Syst Sci. 2012;16(1):167–77.

Meyer W.B. (1995). Past and Present Land-use and Land-cover in the U.S.A. Consequences. p.24-33.

Meyer WB, Turnnor BC (1995). Change in Land Use and Land Cover: A Global Perspective. Camprage: Cambridge University Press. Nunes C, Auge JI (1999). Land-Use and Land Cover Implementation

Ministry of Environment. 2010. Climate Change and Vulnerability Mapping for Nepal. Kathmandu, Nepal: Government of Nepal/Ministry of Environment.

Ojima, D.S., Galvin, K.A. & B.L. Turner II (1994): The Global Impact of Land-useChange. BioScience, 44(5): 300-304.

Pandey, Ashish, S.K. Mishra, and Amar Kant Gautam. 2015. "Soil Erosion Modeling Using Satellite Rainfall Estimates." Journal of Water Resource and Hydraulic Engineering 4(4): 318–25. http://www.academicpub.org/DownLoadPaper.aspx?paperid=16827.

Prenzel, B.; Treitz, P. Remote sensing change detection for a watershed in North Sulawesi, Indonesia. Prog. Plann. 2004, 61, 349–363.

Renard, K., Foster, G., Weesies, G., McDool, D., and Yoder, D. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook 703, USDA-ARS.

Riebsame WE, Meyer WB, Turner BL II (1994). Modeling Land-useand Cover as Part of Global Environmental Change. Climate Change. Vol. 28. p. 45.

Saran, S.; Sterk, G.; Kumar, S. Optimal land use/land cover classification using remote sensing imagery for hydrological modeling in a Himalayan watershed. J. Appl. Remote Sens. 2009, doi:10.1117/12.769056.

Siddiqui, Salman, Luna Bharati, Menaka Panta, Pabitra Gurung, Biplob Rakhal, and Laxmi D. Maharjan. 2012. Climate Change and Vulnerability Mapping in Watersheds in Middle and High Mountains of Nepal. In Nepal: Building Climate Resilience in Watersheds in Mountain Eco-Regions. Kathmandu: International Water Management Institute (IWMI).

Sokal, R. Classification purposes principles progress prospects. Science 1974, 185, 1115–1123.

Turner, B.L. II & W.B. Meyer (1994): Global Land-Use and Land-Cover Change: An Overview. In: Meyer, W.B. & B.L. Turner II (eds): Changes in Land Use and Land Cover: a Global Perspective. University of Cambridge.

Varnes, D. J. 1978. Slope movement types and processes. In: Special Report 176: Landslides: Analysis and Control (Eds: Schuster, R. L. & Krizek, R. J.). Transportation and Road Research Board, National Academy of Science, Washington D. C., 11-33

Wischmeier, W.H. and Smith, D.D. (1965) "Predicting rainfall erosion losses from cropland east of the Rocky Mountains: Guide for selection of practices fro soil and water conservation." U.S. Department of Agriculture handbook No. 537.

Wischmeier, W.H. and Smith, D.D. (1978) "Predicting rainfall erosion losses –A guide to conservation planning." U.S. Department of Agriculture handbook No. 537.

Y. P. Rao, "Evaluation of cropping management factor in universal soil loss equation under natural rainfall condition of Kharagpur, India". Proceedings of Southeast Asian regional symposium on problems of soil erosion and sedimentation. Asian Institute of Technology, Bangkok, pp 241–254, 1981

Yang J, He H S, Shifley S R, (2007). Spatial patterns of modern period human-caused fire occurrence in the Missouri Ozark Highlands. Forest Science, 53(1): 1–15

Zhao, Y.; Murayama, Y. Effect of spatial scale on urban land-use pattern analysis in different classification systems: An empirical study in the CBD of Tokyo. Theory Appl. GIS 2006, 14, 29–42.

वार्षिक कृ र्ष र्वकास कार्क्रिम तथा तथ्याङ्क एक झलक, आ.व .२०७१/०७२, र् िल्ला कृ र्ष र्वकास कार्ालिर्, सल्यान सल्यान र्िल्लाका स्थानीर् वन समुहरूको तथ्याङ्क संगालो ,आ.व .२०७०/०७१, र्िल्ला वन कार्ालिर् , सल्यान सल्यान र्िल्ल्ला को पर्हरोको अर्िलेख ,आ.व .२०६८/०६९ ,र्िल्ला िू संरक्षण कार्ालिर् ,सल्यान

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.

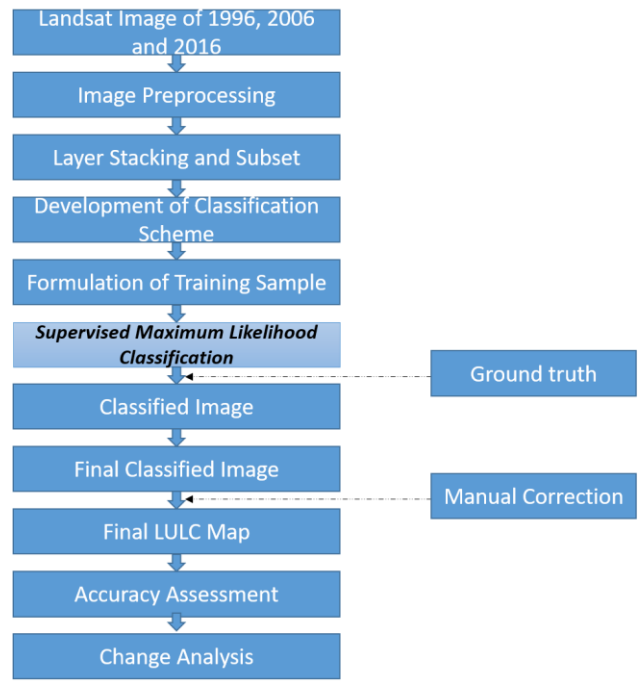


Figure 7 Methodological Flow chart of Land use Land cover change

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 10: 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 11: 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:

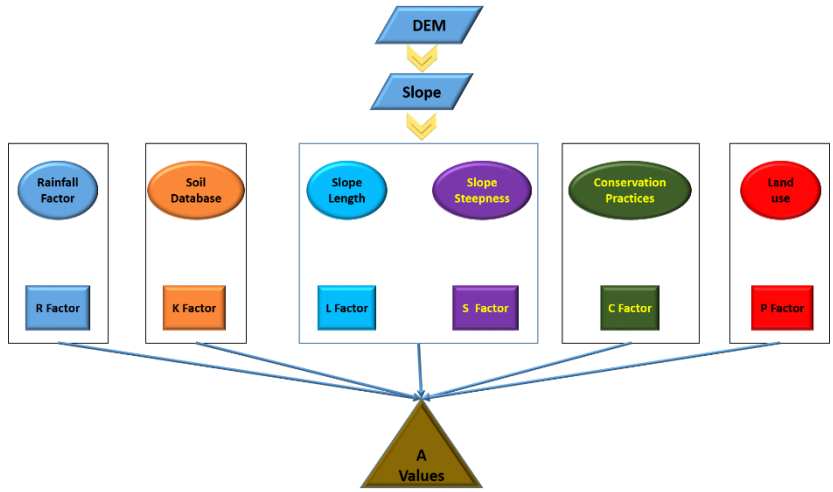


Figure 8 Methodological framework of soil erosion dynamics

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.

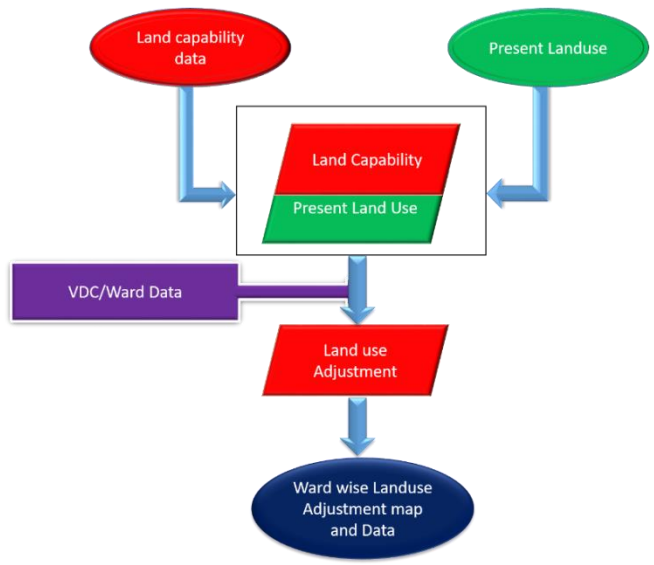


Figure 9: Methodological Framework of Land Use Adjustment