

Hill slope terrain and land-use assessment using GIS and Remote Sensing techniques: A case of Pikhuwa sub-watershed in the Mid-hill, Nepal

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Abstract

Agriculture practice on hill-slope terrain depicts the sensitivity indicators of the vulnerability in terms of global climate change. The major aims of the present research are to assess the land-use pattern conditioned by existing hill-slope terrain based on different land capability class recommend by land resources mapping project, 1986 in the Pikhuwa sub-watershed of Mid-hills, Bhojpur, Nepal. An overall research data derived, processed and analyzed using Geographic Information System and Remote sensing tools and techniques. The land capability class, current land-use and digital elevation model with 30 meter spatial resolution have primarily considered as a major variable for spatial analysis. The analysis estimated about 33.68% individual area of overall agriculture patches have remained on above 30 degrees slope of the terrain topography, which denotes the condition of land-use is not suited technically based on land capability class and recommendation made by LRMP, 1986. In the sub-watershed, the current land-use condition on hill-slope is being much vulnerable due to the steep slope, poor slope terracing and unmanaged surface runoff during monsoon.

Keywords: GIS, Hill-slope, Land-overuse, Mid-hills, Pikhuwa, RS

Introduction

Agriculture practice on steep rain-fed terraces of Middle-hills is the characteristics of the farming system of Nepal with the functioning of well magnitude and intensity of soil erosion due to the rainfall runoff on steep terraces (Gardner & Gerrard, 2003). Steep topography itself is default vulnerability, while terracing for agricultural farming practice leads the remarkable rate of the landslide, slope failure, debris flow and mass wasting events in hilly areas (Gerrard & Gardner, 2002; Ives & Messerli, 1981; Ives & Messerli, 1989). In context of Nepal, Gurung (2004) has noted that land-use and land-cover and its dynamic trend on the spatial extension has been significant functioning result of anti-reciprocal relation between increasing population and its dependency on natural resources on hilly areas. It has been obstructed condition of land overused on high steep topography because of the increased population pressure on land resources on the Middle-hills of Nepal (Gautam et al., 2003; Lefroy et al., 2000). Agriculture practices on steep hill slope with poor terracing has reflected that increasing pace and magnitude of climate-induced geo-hydro hazard events, e.g. erosion, landslide, gully erosion, debris flow, mass wasting and flooding, depicting the decrease in productivity and loss in soil fertility capacity (Dhital et al., 1993; Khanal et al., 2007). In context of Nepal, the topography above 30 degree slope with the soil depth for drain

the surface runoff is more potential factors for soil erosion in terms of land resources exploitation (LRMP, 1986). Despite findings and recommendations by LRMP on hill-slope cultivation practices, the issues and implication are the same as before and land utilization on steep topography being physically vulnerable itself on default system up to now. Therefore, in the present research attempt has been made to assess the location of land-overused area on steep topography for indicating acceptable management practices within the sub-watershed in terms of Land Capability Class limitations and recommendations.

Materials and Methods

Study Area

The Pikhuwa sub-watershed spatially spaced in the Middle-hill of Bhojpur District, Nepal (Fig. 1). It lies at 27°06' 43" N to 27°11' 53" N latitudes and 87°10' 56" to 87°0' 37" E longitudes with elevation range from 207 m to 3322 m above sea level. The Pikhuwa sub-watershed is considerably largest sub-watershed of Bhojpur district, which spread over 588 km². The sub-watershed geographically belongs to the world deepest valley known as "Arun River Valley". The sub-watershed is administratively shared by different local units- Hatuwagadhi, Ram Prasad Rai, Temke Maiyung, Pauwadumma Rural Municipality and Bhojpur

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Municipality of Bhojpur District of Province-1 of Nepal. CBS (2011) shows the sub-watershed to have around 22374 Household and 101,101 populations (male 46544 and female 53557). More than 70% households involved in agriculture as their major occupation in which livestock and remittance obtained from seasonal migration to foreign country as the major livelihood options (CBS, 2011).

Data sources

The different spatial based digital map layers of the Pikuwa sub-watershed for portraying the topography contour, hydrology stream, land-cover, foot-trail, building unit and administrative units (1: 50,000) were acquired from the Department of Survey, Government of Nepal. The Land Capability class on polygon thematic basic vector digital data defined by (LRMP, 1984) was obtained from the ICIMOD map library or Regional Database System (available on rds.icimod.org). The GCS_WGS_1984 geodetic system was used for geographic projection system and Mercator WGS_1984_UTM_Zone_44N was used as a projected coordinator system.

The extent of current land-use and land-cover was extracted from the Landsat-8 OLI/TIRS C1 Level-2 LANDSAT image with 30-meter spatial resolution. The scene number of the image is (LC81400412018345LGN00) taken on 2018/12/11, in which the land and cloud cover scene was 4.42%. The supervised image classification was used for estimating the current land-use and land-cover of the study area. The Digital Elevation Model (DEM) showing three dimensional aspects of the topography was obtained from the www.earthexplorer.usgs.gov, which is the

quality product of Advance Space-born Thermal Emission and Reflection Radiometer (ASTER) by the government of Japan since 2000. The spatial territory of the selected sub-watershed was delineated using Arc Swath tools incorporated in Arc GIS (version) as a component toolbar, in which ASTER-DEM is used. The geo-processing steps to processing and analyzing spatial data, e.g. clip, intersect and additional data were superimposed and mapped on Quantum GIS.

Data Analysis

A watershed-based analysis is a holistic approach which allows integration of hydrology, ecology, climatology and other sciences within the socioeconomic context taking into consideration the interactions and implications among land resources and the linkages between upstream and downstream areas (Brooks et al., 1991; Sen et al., 1997). Spatially, the research study has been conducted based on the sub-watershed area.

The overall research processes were carried out using GIS techniques considering the land capability class generated by LRMP (1986), and current land-use and Digital Elevation Model produced by ASTER. In the present time, the science-based research field has adapted geo-informatics tools and techniques resulting the shifting of paradigm on research techniques (Brabb, 1955; Dhital et al., 1991 & Ghimire, 2011; Western, 1997). In this regard, geo-informatics technique was adapted as the major means of research analysis. Therefore, as the prime methods for achieving research objectives, simple spatial based geo-processing methods based on sub-watershed area have been adapted.

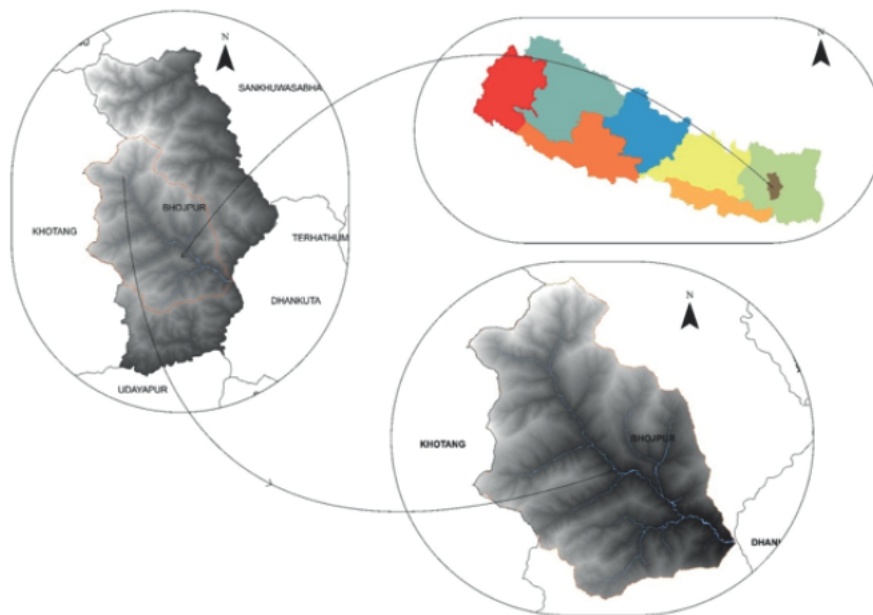


Figure 1 Location of the Pikuwa sub-watershed

A simple geo-processing technique was applied here for the calculation of research findings. Initially, the variables like land capability class and current land-use condition were superimposed and these layers were intersected into shape layer using geo-processing tools. This shape layer represents the situation and condition of current land-use which rely on Land capability classes and recommendations. The new shape layer that attributes with current land-use patches hold by land capability class IV was extracted from the base layers. Then, that new shape layer was masked by terrain surface slope above 30 degrees using the spatial analysis extraction tools. Finally, the output shape layers depicting results were superimposed into Google Earth Pro Image for visual presentation as well as its accuracy with local places validated from related places of the sub-watershed. A condition of land-use was assessed in terms of crossing variables shape layers between current land-use pattern and land capability class given by LRMP. Principally, the land capability class IV and VI defined as the non-suitable area for cultivation and suitable for timber and forestry activities where terracing is mandatory for reducing the soil erosion (LRMP, 1986). The principles and recommendation for land capability IV do not accord with the current condition of land-use and land-cover practices on hill-slope areas.

Results and Discussion

Land-use and Land-cover

The major identified land-use/land-cover features of the study area are agriculture field, forest, grass-land, shrub-land, sand barren land followed by other land-covers, e.g. water-body and barren-lands. The agriculture land predominately exists on the overall catchment of the sub-watershed. It covers 50% of the total land with having 293.7 km² area followed by forestland cover having 41% of the total land with 238.0 km² area. The shrub-land has the third position with 4.8% with having 28.22 km² area. Other different land-use and land-cover including barren land, orchard, grasslands and water body occupies less coverage in the sub-watershed. The numerical figures of agriculture land show 50% of the total area of the sub-watershed against other land-use and land-cover suggesting high human pressure on resources within the sub-watershed, in terms of people and resources relationship. The CBS (1991, 2001, 2011) shows that population of the sub-watershed is trending on growth rate in the forms of positive way and such condition depicts that sub-watershed is susceptible for ecosystem vulnerability reducing the carrying capacity of sub-watershed for maintaining the ecosystem balance. It easily helps to assume that increase in population and their activities are more responsible for such condition of the sub-watershed.

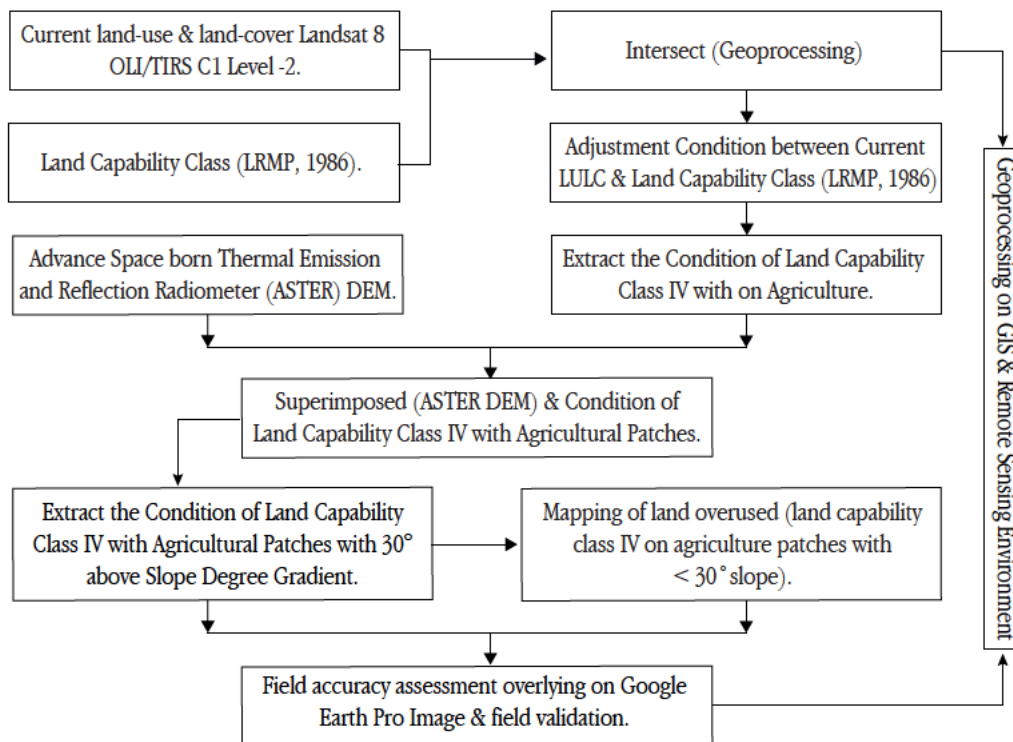


Figure 2 Methodological framework for data acquisition and analysis



Figure 3 Land-use and Land-cover map of the sub-watershed

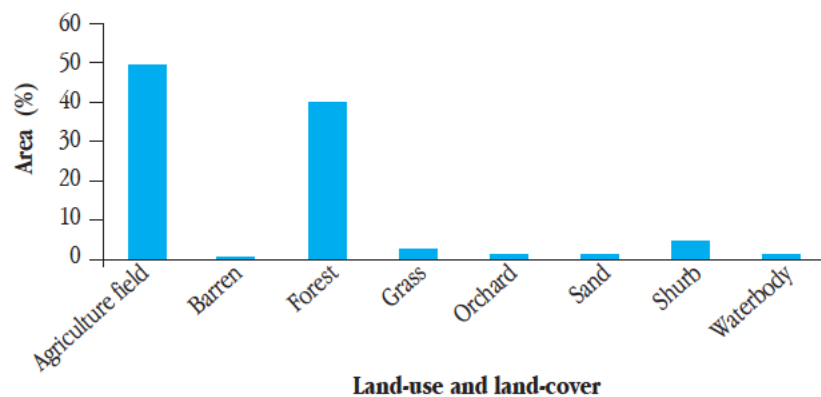


Figure 4 Distribution of Land use land cover on sub-watershed

Topographic terrain features

In the current Era, the computer-based GIS techniques perform DEM analysis making possible the fast and more accurate generation of terrain parameter substituting the previous manual based morphological studies of topography (Ghimire, 2014). The DEM showing three dimensional aspects topography facilitates studies of the morphological characteristics and properties e.g. altitude, slope, and curvatures and their relationship for the functioning geomorphic process (Evans, 1984; Selby, 1993). This indicates that DEM is more applicable for defining slope gradient for the studies. Advance Space-born Thermal Emission and Reflection Radiometer (DEM) were used as the platform for the analysis of geomorphic properties e.g. relative relief, slope and aspect. Several researches (Devkota & Gautam et al., 2003; Gerard & Gardener, 2002; Gyawali, 2015; Ramsay, 1985; Sharma et al., 2016; Sherchan et al., 1991; Thapa & Paudel, 2004;) related to

geomorphic process, climate change adaptation and mitigation, hydrology and environmental issues have considered the technical efforts and application of slope terrain for their research findings in the Mid-hill areas.

Slope is an area of land that makes a definite angle to horizontal landscape. The slope may be defined as the vertical inclination between the hill top to valley bottom, stands with the horizontal line and expressed generally in the degrees (Strahler, 1964).

In the sub-watershed, gradients of slope degree within landscape and terrain features range from 0 to 60 degree. The gentle slope considered as 0 to 20 degree on landforms surfaces, spatially covered 31.50% areas of the total area of the sub-watershed. Similarly, the second class slope gradient is moderate that ranges

from 20 to 40 degree covered 61.35% of the total area. A slope degree ranges from 40 to 50 degree covers 6.48% of the total area, where human activities lead dramatic role in creating condition of occurrences of geomorphic processes. It is more likely to be susceptible than other slope classes in terms of geomorphic processes e.g. landslide, debris and slope failures. The topography terrain structured above 50 degree slope gradient is considered as properly stable landscape, with 0.68% area.

Land Capability Class

Land capability classification is a system of grouping soil primarily based on their capability to produce common cultivated crops and pasture plants without deteriorating soil over a long period (LRMP, 1986). Similarly, the Land Resources Mapping Project, LRMP (1986) has recommend five different land capability classes e.g. I, II, III, IV and VI in the Pikhruwa sub-watershed.

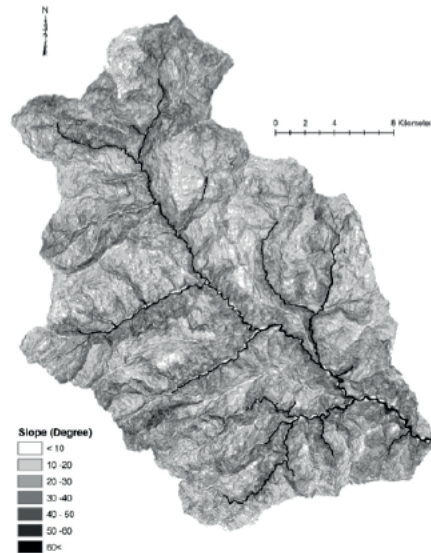


Figure 5 Slope terrain Map of the study area

Table 1 An account of distribution of slope degree in the sub-watershed

S.N	Slope Class (Degree)	Area (km ²)	%	Cumulative %	Remark
1	< 10	33.3	5.66	5.66	Gentle
2	10 to 20	151.9	25.84	31.50	Moderately Gentle
3	20 to 30	223.6	38.03	69.53	Moderate
4	30 to 40	137.1	23.32	92.84	
5	40 to 50	38.1	6.48	99.32	Moderately Steep
6	50 to 60	3.9	0.66	99.98	Very Steep
7	60 <	0.1	0.02	100.00	
	Total	588	100		

Source: ASTER DEM

Table 2 Distribution of Land Capability Class in the sub-watershed

S.N.	Capability Class	Area (km ²)	Area (%)
1	I	3.5	0.59
2	II	6.5	1.10
3	III	317.8	54.04
4	IV	237.3	40.36
5	VI	22.9	3.89
		588.0	100

Source: LRMP (1986)

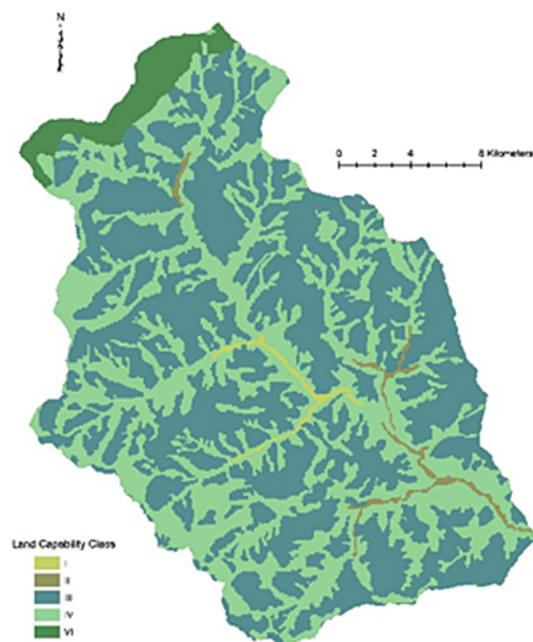


Figure 6 Land Capability Class maps of the sub watershed.

According to the LRMP reports, the land capability data constitute slope gradient and soil depth in order to drain the surface run off. The spatial extent of land capability class portrays the land capability class III is significantly distributed covering 54% of the total area of the sub-watershed (Table 3). It is followed by the land capability class IV with 237.3 km² (40.3%) of the total area, which depicts that areas in capability class IV is more vulnerable to agriculture practices. Similarly, land capability class II and I covered 1.69% and 3.8% of the total area, respectively.

In context of the Pikhuwa sub-watershed, it reflects that slope steepness in the most part of the areas is suitable for cultivation. The land capability classes I, II, III and IV are spread on the overall locations of the sub-watershed. Landscape of the upstream of the sub-watershed was found with land capability class VI, which lies on Temke Maiyung Rural Municipality. The capability class I & II

found in the valley with river terraces along the Pikhuwa, Kawa and Behere Khola,

The analysis shows the current condition of the land-use land-cover linked with the land capability classes and recommendations and their spatial coverage. Each land capability classes have a typical recommendation and limitation to use the land resources. According to the LRMP (1984) land capability classes I is suitable for cultivation purpose. The land capability classes II recommends that terracing and counterering is necessary for agriculture activities in which surface slope consists of 1-5 degree. The land capability class III encompasses the moderate to steep slope gradient (5-30 degree) and recommends mandatory terracing for erosion control for agriculture and cultivation purposes. The terrain slope gradient (0 < 30) degree denotes the Land capability class IV and VI, which recommend that the land is suitable for fuel-wood, fodder and timber production. It offers permanent ground cover to minimize erosion and is not suitable for agriculture activities. Therefore, the majority of the current land-use for the cultivation of Pikhuwa Sub-watershed allied with land capability class IV, principally do not accord with the limitations and recommendations by LRMP (1984). It means that land-use contains land capability IV with a high steep slope gradient depicts the major sources of sensitivity indicators for vulnerability.

According to Land Resources Mapping Project, the variables e.g. soil types and the slope has been primarily considered for mapping the land capability class. The LRMP (1986) suggests that land terrain characteristics and soil depth which drain the surface runoff, and limitations and recommendation of each capability class. In context of land-use, about 33.68% of the total area holds capability class IV and VI. It helps to meet the fact and evidence that current land-use practices do not accord with recommendations of land capability classes IV and VI. The maximum spatial coverage of land-use and land-cover belongs to above 30 degree slope gradient. About 41% area of the total agriculture land located on greater than 30 degree slope, which denotes that cultivation practices on steep hill-slope is making the Pikhuwa sub-watershed more vulnerable.

Table 3 Distribution of LULC based on capability classes and slope classes

Land Capability Class (Degree)	Land-use and Land-cover (Area km ²)						Total
	Cultivation	Grass	Forest	Bush	Barren	Sand	
I (<1)	0.39	0.06	1.99	0.92	0.03	5.22	3.48
II (1-5)	1.42	0.02	2.08	2.54	0	0.09	6.52
III (5-30)	192.97	10.73	103.56	8.57	0.89	0.46	317.73
IV (>30)	98.02	6.04	112.34	16.42	0.83	1	237.34
VI (<40-50)	0.91	1.05	18.12	0.08	2.73	3.69	22.89
Total	293.72	17.9	238.09	28.53	4.48		588.00

Sources: LRMP (1986), LULC and ASTER DEM (2018)



Figure 7 Current condition of LULC according to land capability class (LRMP, 1986).

Similarly, the seven features of LULC have encompassed land capability classes I and II e.g. agriculture, forest, shrub land, barren land, water-body, grass and sand, which extend spatially over 10 km² of the sub-watershed. As the continuity of such condition, land capability class III grips seven different LULC features covering the 317.73 Km² of the total area. The case of current land-use and land-cover against the land capability class IV spatially cover the 40.3% area of the total area. It represents that land capability class IV holds the six types of land features covering 237.34 km² of the sub-watershed area. Finally, different six land features encompass land capability class VI. It extends over an area of 22.89 km² of the sub-watershed.

Individually, the analysis shows that land-use and land-cover extension per land capability classes in the sub-watershed. It shows that the cultivation land allied with land capability classes e.g. I and II holds farmland to be about 1.81 km² of the total area, which has few limitations for use. The land capability class III holds 192.9 km² of the total area and in such land; it is mandatory for terracing and ground vegetation cover to control the erosion for cultivation activities. According to LRMP (1986), it has been noted that under the agriculture system, large portion of class III land is required for fodder production and grazing in order to maintain the productivity of the cultivated lands. In context of Pikuwa sub-watershed, it has been found that terracing and agro-forestry based cultivation lands hold by class III. Likewise, the current cultivated land in capability class IV spatially covers 98.02 km² of the total area; it represents about 33.3% of the total area. In context of the land allied with class IV, the LRMP has recommended land under this class is suitable for fodder,

fuel-wood, timber production and it requires permanent vegetation cover to minimize the erosion and is not suitable for arable agriculture. It has been found that cultivation activities on high steep hill-slope have made remarkable sensitivity indicators for vulnerability. In the current years, the sensitivity indicators of vulnerability to upgrade with the support of rural road extension over cultivated land areas linked land capability class IV. Another last land classes of the-sub watershed is VI, it remains on high steep slope gradient (40-50 degree). It extends with an area of 0.91 km² of the total area of agriculture area, which is not applicable as per principle of land capability recommendations and limitations. It recommends that land considered as a fragile due to extreme hard erosion and poor regeneration potential. The existences of cultivated land on land class VI depict high vulnerability.

Conclusion

Despite the hill slope cultivation, characteristics of mountain farming system, has been recognized as the major means of adapting mountain environment, the cultivation practices on hill slope topography terrain has been a major issue in the study area for environment and agriculture practices in terms of lessening mountain resilience. The study shows that one-third area coverage of the total agriculture land suspected with such problems. It strongly believes that the range of vulnerability will be increased due to the stressing factors e.g. cultivation practices on steep slopes, rainfall with runoff and expansion of basic rural infrastructure. As a result, sustaining life and managing subsistence agriculture based livelihood options will be at risk. Alternatively, it is necessary to build climate resilient farming system with enhanced adaptive capacity of the local community.

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