Emir. J. Food Agric. 2013. 25 (1): 30-38
doi: 10.9755/ejfa.v25i1.5341
http://www.ejfa.info/

PLANT SCIENCE

Improper agricultural practices lead to landslide and mass movement disasters: A case study based on upper Madi watershed, Nepal

Anup Gurung[1], Om Prakash Gurung[2], Rahul Karki[3] and Sang Eun Oh[1*]

[1]*Department of Biological Environment, Kangwon National University (KNU), 192-1 Hyoja-dong, Chuncheon, Gangwon-do 200-701, Republic of Korea*
[2]*Himalaya Milan Secondary School, Tangting, Nepal*
[3]*ForestAction Nepal, Lalitpur, Nepal*

Abstract

Damage, destruction, and fatalities related to landslide and mass movement are common phenomena in the Himalayan countries like Nepal, especially during the monsoon period. In Nepal, landslides represent a major constraint on livelihood and development, causing high levels of economic loss and substantial casualties each year. This fact was tragically illustrated on 3 August 2010, when Nang-Nung of Taprang, situated at the 22 km away from the Pokhara valley, upper Madi watershed, experienced a catastrophe landslide powered by the Madi river. The landslide and the debris flow caused widespread damage to life and property and destroyed valuable infrastructure in the area and the adjoining villages. 72 houses were swept away, 59 houses were partially damaged, 58.4 ha of land was washed away, 6 people were wounded, 5 people were killed, and many social infrastructures were damaged. The disaster was a result of a landslide triggered by heavy precipitation and stream undercutting the existing landslide.

Key words: Adaptive capacity, Debris flow, Landslide, Summer monsoon, Upper Madi watershed

Introduction

Nepal is a small landlocked country with a total area of 147,181 km^2 and shares its political borders with China in the north and India in the east, west, and south. The geographical structure of Nepal resembles a rectangle with three main ecological zones running horizontally as continuous belts, namely, mountainous, hills, and terai (Degen et al., 2010; Gautam et al., 2009). Table 1 provides a summary of geographical and demographical features of Nepal (CBS, 2003; FAO, 2002). Nepal is one of the least developed countries in the world with low Gross National Income (GNI) per capita of about USD 440 per person per year (WB, 2010). Although certain level of urbanization is desirable for the overall development of a country, Nepal remains one of the least urbanized countries in the world, where still more than 80% of the population live in isolated and remote rural areas (Tiwari, 2008; WB, 2010). Nepal has a very low Human Development Index (HDI) of 0.509, which is measured based on the average progress of a country in overall human development (UNDP, 2009). In addition, it was estimated that still more than 30% of the Nepal's population lives below the poverty line as of USD 1.25 a day (UNDP, 2009).

Nepal is located in the heart of the Himalayas. About 83% of the country is mountainous terrain and the remaining 17% is flat land i.e. alluvial plains (Ray and De Smedt, 2009). Geographically, Nepal is characterized by a transitional mountain area between the fertile Gangetic Plain of India and the arid plateau of Tibet, China which further lies in the tectonically active zone (Pokharel et al., 2009). The elevation of the country varies from 100 m in Terai to 8,850 m in the Himalayas (CBS, 2003). Due to the sharp vertical variation, Nepal is susceptible to various types of natural disasters, especially water-induced disasters such as landslide, slope failure, soil erosion, landmass movement, and flood. The watershed areas in the hills and mountains of Nepal are with most fragile ecosystems and poor agricultural potential due to weak geological structure, steep and rugged surface, and poor quality of soil (Pandit et al., 2007).

Received 15 November 2011; Revised 15 January 2012; Accepted 13 February 2012; Published Online 24 November 2012

*Corresponding Author

Sang Eun Oh
Department of Biological Environment, Kangwon National University, Gangwondo Chuncheon 200-701, Republic of Korea

E-mail: ohsangeun@kangwon.ac.kr

Table 1. Geographical features of Nepal.

Parameters	Mountains	Hills	Terai
Altitude (m above sea level)	4877-8850	610-4877	100-610
Area (km^2)	51,817	61,345	34,019
% of Total area	35	42	23
Width (North-south)	25-60	60-80	25-40
Climate type	Tundra	Temperate	Subtropical
Population (% of total)	7	44	49
Cultivated area (% of total)	0.3	48.1	51.6
Dominant agricultural system	Livestock-based	Cereals, horticulture, livestock	Cereals, cash crops, livestock

As depicted in Table 1, approximately 50% of the Nepal's total population lives in hills and mountainous regions, usually with small land holding and over 60% of dwellers in these regions are considered below the poverty line (DFID, 2005). Predominantly, agriculture is the main source of subsistence, often supplemented by animal husbandry for poor dwellers in the mountainous and hilly regions (Degen et al., 2010). While the agricultural production is mostly in subsistence level; the modern developmental sector is incapable to provide enough economic opportunities within the country for the huge mass of the ever increasing economically active population (Subedi, 2009) making the people living in hills and mountainous regions with high exposer and low adaptive capacity more vulnerable and susceptible to different types of natural hazards in the country.

Throughout the world, landslides are a major hazard in mountainous regions (Fort et al., 2010). Rugged topography, unstable geological structures, soft and fragile rocks, common earthquakes, active tectonics, and highly seasonal and intensive rainfalls during monsoon periods has made the fragile Himalayan environment vulnerable to hazards and disasters, especially landslides (Adhikari and Koshimizu, 2005; Chalise and Khanal, 2000; Dahal and Hasegawa, 2008). Landslides, monsoon floods, glacier lake outburst floods (GLOF) and debris flow disasters are common phenomenon in Nepal, since it is situated entirely in the Himalaya (Adhikari and Koshimizu, 2005). Nepal suffers from tremendous landslides and debris flow disasters every year with heavy loss in term of economic and physical structures. Great number of people are affected by large and small-scale landslides throughout the country as well (Adhikari and Koshimizu, 2005; Pokharel et al., 2009). Intense pressure on natural resources, mass poverty and subsistence agriculture, and recent development of infrastructures such as road networks and irrigation canals in unstable mountain terrain without proper engineering and safety measures have further aggravated the problems of surface runoff, erosion, landslides, sedimentation, and floods, especially in mountainous watersheds (Chalise and Khanal, 2000).

Landslides, floods, and mass movement disasters are common phenomena in the upper Madi watershed associated with extreme weather events, especially during the summer monsoon period. Every year, people from Sikles, Parche, Khilang, Tangting, Taprang, Sondha, Seti Khola, and Chansu areas experience unprecedented channelized debris flow, landslides, and floods, destroying life and property. However, the cumulative data on landslides, floods, and debris flow disasters and their effect on public health and environment of the upper Madi watershed is limited. In addition, there has been very little systematic documentation of these events and the previous natural history is not known. Thus, this paper presents an analysis of the landslide and debris flow disasters in the upper Madi watershed and the damage caused by them to the local livelihoods. The main objective of this study is to investigate impacts of landslide and mass movement disasters on the local livelihoods. The result may help to draw attention of government as well as volunteer organization in the affected area which is essential for future likelihoods of the area.

Materials and Methods

Study areas

The Madi watershed is located on the Gandaki Zone, Western Development Region of Nepal. It has a total area of about 1,123 km^2 with estimated population of about 0.2 million (Khanal and Watanabe, 2004; Poudel, 2000). The elevation of the watershed varies from 307 m in the south to 7,937 m in the north encompassing three major physiographical regions- the middle mountain, the high mountain, and the high Himalaya (Khanal and Watanabe, 2004). Geologically, the watershed is divided into three forms- the Lesser Himalayan meta-sediments in the south, the Higher Himalayan crystalline, and Tibetan sedimentary Tethys sediment in the north (Khanal and Watanabe, 2004). The average annual precipitation in the watershed is about 4,000 mm in which more than 75% of the total annual precipitation occurs during the four months in summer (June–September) (Poudel, 1996). The topography of the watershed is very rugged and the Lesser Himalayan consists of intensively folded meta-sedimentary rocks whereas the Higher Himalayan crystalline consists of Precambrian high grade metamorphic rocks (Khanal and Watanabe, 2004; Poudel, 1996). Similarly, the Main Central Thrust (MCT) crosses in the east-west direction in the central part of the watershed (Khanal and Watanabe, 2004).

Madi River, one of the major tributaries of the Narayani River of the Gandaki basin after mixing with the Seti River, with average drainage density of 2,467.07 m/km^2 flows through the Madi watershed (Poudel, 2000). The area is inhabitated by more than 16 ethnic groups and predominantly, agriculture is the main source of subsistence, often supplemented by animal husbandry and natural resources. On the basis of elevation, the agricultural pattern has been classified into lowland (at 1,000 m or below) and highland agricultural land (above 1,000 m). Highland agricultural areas are generally called *bari* (non-irrigated land; mainly harvest maize, millet, barley, wheat and buckwheat) whereas lowland is called as *khet* (irrigated land; mainly harvest rice) (Figure 1).

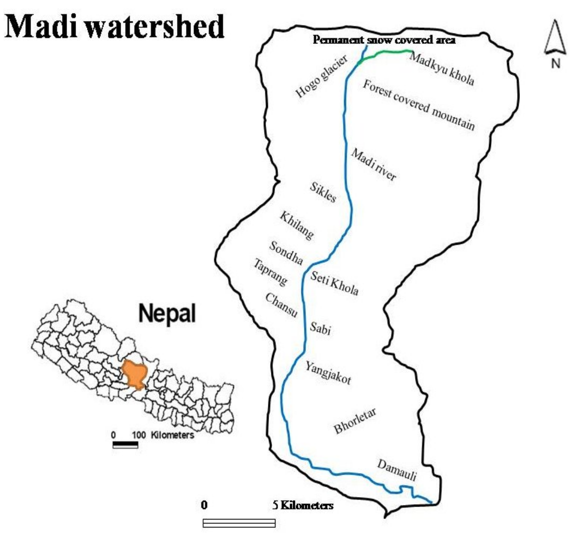

Figure 1. Location of study area, upper Madi watershed.

Data collection

Information and data quoted in this paper was collected during a baseline survey of 300, randomly selected households in Sikles, Tangting, and Taprang. A mixture of data collection methods were employed during the fieldwork from August 20–November 20, 2010. These included an in-depth household interview, a key informant opinion, and a focus group discussion (FGD). The survey was an integral part of the evaluation and was aimed at identifying the impacts of natural disasters in the studied areas. While this study incorporates both quantitative and qualitative methods more weight was put on the qualitative data.

Prior to primary data collection, one of the authors interacted with youth group, women group (especially mothers' party), community leaders, and village development committees (VDCs) officials in order to get acquainted and to explain goals of the research.

In order to evaluate the impact of landslides and debris flow disasters in the upper Madi watershed, an in-depth household interview was carried out by employing a self-administered questionnaire survey. A total of 300 households were randomly selected for the face-to-face questionnaire interview in three villages. The questionnaire was designed to assess impacts of natural disasters in the vulnerable areas of our target population and consists of different parameters. The first part of the household questionnaire concerned demographic structure such as caste, gender, family member, and occupation. The second part of the questionnaire concerned agriculture practices such as type of land ownership, cropping pattern, production of food grains, and numbers of livestock. The third part of the questionnaire concerned socio-economic information such as health, education, annual income, and sources of income. The fourth part of the questionnaire concerned issues related to natural disasters such as causes of landslides and debris flow, impacts of these disasters on the local livelihoods, adaptive capacity to cope with the disasters, and involvement of government in tackling the problems.

Similarly, elicited detailed qualitative data about rural livelihood experiences was also collected through informal, loosely structured, and open-ended interviews. A total of 20 key informants were selected from a range of categories in order to represent the broad interests and perspectives in studied communities. The interviewed key informants were: local entrepreneurs, school-teachers, youth leaders, mother's leaders, and elderly community members. Additionally, FGD was carried among villagers to encourage the participation of occupational castes and to hear their voices regarding their access to local resources and their involvement in decision making system.

Results and Discussion

On 3 August 2010 the "Nang Nung" of Taprang which is commonly called as "Taprang ko Pahiro" (Pahiro means landslide in Nepali) experienced an unprecedented landslide and channelized debris flow powered by the Madi river. According to the local dwellers, there was sustained rain over the preceding few days and heavy rainfall and higher stream discharge was observed on the evening of 2 August 2010. There was thunder and lightning and the area experienced threatening noise and ground shaking approximately on the early morning (5:00 am) of the day of the incident day. The landslide or mass movement occurred shortly after the cessation of the sounds and shaking; at 8:45 am of 3 August 2010. The sudden surge of debris flow inundated the part of the Madi river and carried much of it into the Madi river thereby blocking the river. Field observations confirmed that this landslide was shallow and mostly translational in nature, and expanded 1,600 m in length and 600 m in width, respectively (Figure 2). On the other hand, the Madi river was blocked by the debris (logs and sediments) for several days (20 days) particularly at the narrow sections of the channel resulting drastic change in the morphology of both the channel and flood plains even far downstream areas during this period (Figure 3).

Figure 2. Nang Nung Taprang landslide.

The water volume in the Madi river increased tremendously resulting a lake with width 80 m, length 1,500 m, and depth of 5 m, respectively. Additionally, due to blockage of the river, the water had collected nearly in 3 km of the river section. The landslide claimed life of five people, two of them were school children from Taprang and three of them were from Sikles heading towards Pokhara. The landslide caused high levels of economic loss and substantial numbers of fatalities in the area: 6 people were wounded, 72 households were displaced (61 from Taprang and 11 from Seti Khola), 59 households were partially damaged, 58.4 ha of agricultural land were swept away, 1.5 km of Kahu Khola - Dudhpokhari Rural roadway had been swept away, a suspension bridge was swept away that used to connect Namarjung VDC with Sildujare VDC, and many social infrastructures like school, community buildings, post office, and other physical structures were damaged (Figure 4).

Figure 3. Blockage of Madi river by the debris flow in Nang Nung Taprang.

Figure 4. Houses washed away by torrential flood in Sondha.

Approximately 1.5 km walking trail (from Taprang to Sikles) was washed away by the floods. 200 houses were evacuated in the affected area due to blockage of the Madi river (Figure 5). In addition, the blockage of the Madi river affected the downstream VDCs such as Ghumle Bazar, Chanchu, Bhainse, Majhthana, Hansapur, Thumki, and Mijure (Figure 6).

Figure 5. Disruption of gravel road due to landslide in Taprang.

Figure 6. Temporary bridge in the Madi river after the suspension bridge has been washed away.

In the Madi watershed, gently sloping land (<5°) comprises relatively low (9%) portion of the total basin area followed by moderately to steeply sloping (5-30°) mountain terrain and very steeply sloping (>30°) mountain terrain with rock headwalls (Khanal and Watanabe, 2004). “Slope Instability” is one of the important parameter which gives rise to gravity-dominated down-slope movements of ground-forming materials without the primary assistance of a fluid-transporting media (Poudel, 1996). Generally, all slopes are under stress owing to the force of gravity and once the forces acting on a slope exceed the strength of the materials forming the slope, then the slope will fail and thus, movement occurs (Jones, 1993; Poudel, 1996). Approximately, more than half of the total area falls under the inclination of 60% and above and thus, the length of slope and vertical exaggeration of steepness favors more susceptibility of hill-slope instability in the Madi watershed basin (Poudel, 1996).

Geologically, the upper Madi watershed is narrow, steep, and bounded by high rugged mountains. The Higher mountain slopes of the Madi watershed are composed either of bare bedrock or more commonly of bedrock mantled by thick to very thick unconsolidated soil cover. In addition, due to steep gradients, the rivers are energetic, producing high runoff and sediment discharge, especially during monsoon period. A combination of geologically active with glacially oversteepened slopes and deep gorges in places, rugged topography, and highly seasonal and intensive rainfall has made the region more vulnerable to hazards and natural disasters. Extreme weather events associated with the seasonal heavy rainfall is the principal causes of landslide and mass movement in the Madi watershed. Up to some extent, physical weathering of rocks in the Madi watershed basin is also responsible for contributing landslide and debris flow disasters in the area. In addition, deforestation, terracing, and the improper land use practices make the upper Madi watershed area most unstable landscapes that often lead to slope-failure. Due to marginalization of agricultural system, farmers were compelled to construct new terraces towards the toe of the old terraces which are highly susceptible to failure and also, most of these terraces slump down during the summer heavy monsoon rainfall. Since the upper Madi watershed region is rugged, steep, and narrow, a relatively small volume of material is sufficient to dam the Madi river. On the other hand, the lower Madi watershed slopes are sparsely vegetated along with dense settlement on the bank of the Madi river, and hence the incident of landslide and debris flow disasters often toll either of human lives or physical properties on the downstream as well.

Anecdotal evidence suggested that the upper Madi watershed has been suffering from tremendous landslides and debris flow since 1956. Based on the aerial photographs, a total of 236 active landslides and debris flow scars were identified in 1956/58, 18 in 1972, 5 in 1979, and 25 in 1996 in the Madi watershed (Khanal and Watanabe, 2004). Most of these landslide and debris flow scars were concentrated mainly in Sikles, Saimarang, Bhujung, Karapu, and Jita area (Khanal and Watanabe, 2004). Both natural and anthropogenic activities were responsible for these natural hazards and disasters in the past decades. Since majority of the people derive their livelihood from agriculture, paddy cultivation is one of the important farming practice in the locality. However, the inappropriate cropping system, especially paddy cultivation may favor the activity of slope-failure. Since water has to be retained for paddy cultivation in which the retaining water percolate down the rock strata and assist the weathering and paddy cultivation terraces are distributed even above 60% hill-slope gradient in the Madi watershed (Poudel, 1996). A study carried out by Poudel (2000), found that the Madi watershed has the maximum share of its area under the very high potential hazard zone. According to nature of terrain properties, Poudel (2000) divided the Madi watershed into five hazard class in which only 0.25 % of the area has very low hazard potential followed by low (22.66%), medium (35.74%), high (32.26%), and very high (9.09%), respectively. Thus, majority of the area are under the fragile environment vulnerable to hazards and natural disasters at the Madi watershed.

Altogether there are 25 settlements in very high hazard-prone zone in the Madi watershed (Poudel, 2000). The most vulnerable sites are Taprang of Sildujare VDC, lower part of Khilang, Sondha, Seti Khola, Chansu, Sabi, Pakhagaun of Saimarang VDC, Ghartidanda of Bhachock VDC, and Harse of Mijuredanda VDC. However, in recent years, three VDCs namely Parche, Namarjung, and Sildujare were severely affected by the landslide and debris flow disasters in the area. According to our fieldwork, the most vulnerable sites were Sondha, Taprang, Seti Khola, Chansu, and Sabi in the upper Madi watershed. It was observed that many existing landslides were started from the paddy terraces in the Madi watershed. The big “Nang Nung” slide in Taprang, landslide in upper Sondha, and landslide in lower Chansu were the prominent examples of slope failure in the upper Madi watershed which originated from the paddy field. According to the anecdotal evidence from the experience of local dwellers, Taprang village has been severely affected by the landslide and mass movement and there has been an increase in the number of such disasters over the past few decades. According to the interviewed key informants, the Nang Nung landslide in Taprang was initiated around 1973. Since then, the volume of the landslide has been increasing every year due to debris flow and stream side-cutting. From the experienced of local people, landslides occur frequently in this area during the monsoon season of July to September, usually leading to interruption of the transportation.

In 2003, another big incident occurred in the upper Madi watershed severely affecting Sondha, Chansu, and Sabi area. In the month of August 2003, after a torrential rainfall, the water volume in the Madi river increased tremendously and the river lost its regular course. The incident occurred during the night and the flash flood claimed life of 4 people in the Chansu area. Those who were asleep had no time to wake up, and those who were awake had no idea about what was happening in the darkness. The flood swept away a bridge over the Sondha, 20 livestock in the Sabi, and a major portion of Kahu Khola to Sondha road was washed away. Apart from the loss of lives and damage to infrastructure and property, the human suffering was tremendous because the flood washed away many houses and agricultural land in the affected areas. In the mountainous countries like Nepal, water-induced disasters such as landslides, debris flows, mass movement, and all types of floods are chronic hazards during the monsoon period causing widespread damage (Ray and De Smedt, 2009).

Generally, landslide and mass movement occur when the soil pores are saturated with water and sliding component of the mass becomes dominant than the vertical component (Pokharel et al., 2009; Poudel, 1996). The impacts of disasters are further aggravated by rapid and uncontrolled development as well as anthropogenic activities including deforestation, encroachment of the forest land for cultivation, and infrastructures development in weak and unstable terrain (Pokharel et al., 2009; Ray and De Smedt, 2009). Therefore, the combined effect of steep slope and heavy precipitation events enhance soil erosion and bank cutting which ultimately leads to mass movement or landslide.

Like in the upper Madi watershed, initiation of many small and shallow landslide and mass movements during and after highly localized torrential precipitation events were also reported from other areas of Nepal (Adhikari and Koshimizu, 2005; Pokharel et al., 2009). On 22 July 1996, Larcha experienced an unprecedented channelized debris flow down the valley of the Bhairab Kunda stream after heavy rainfall and 54 people were killed in the incident (Adhikari and Koshimizu, 2005). In another incident, the devastating flood and the landslide due to heavy rainfall for two consecutive days in the central region of Nepal (Bagmati, Kulekhani, and Narayani watersheds) in 1993 killed 1,160 people and affected 70,000 people (Pokharel et al., 2009). Similarly, heavy rains from the tail end of the monsoon in October 2009 caused floods and landslides in the mid- and far-western regions of Nepal, thereby killing a total of 78 people, injured 37 people, affected 175,000 people (29,141 families), and displaced 15,000 people (2,802 families) (IFRC, 2010). Due to extreme weather events such as landslides, floods, and avalanches, Nepal had to bear estimated loss of 21.2 million rupees in 1991 and 4904 million rupees in 1993 with average annual loss of 752.2 million rupees between the years 1983 and 1998 (Chalise and Khanal, 2000). Similarly, approximately 230 persons were killed by these disasters every year in Nepal between the years 1983 and 1998 (Khanal, 1999).

Generally, the victims of extreme weather events were those communities who heavily relied on natural resources, especially subsistence farmers and those living on unsustainable land, often unstable and flood prone areas lacking infrastructures (Chalise and Khanal, 2000; POSTNOTE, 2006). The poorest inhabitants of developing countries, especially those in the least developed countries (LDCs) were vulnerable to natural disasters before and after the events due to the low adaptive capacity to cope with the disasters (POSTNOTE, 2006). Although the frequency of occurrence of natural disasters is very high, the relief provided by the Nepal government to the affected area has been very small and uneven. In addition, geographically, the affected areas are very much scattered, isolated, and remote and often without road network that substantially prevent aid and other helps reaching the affected areas (IFRC, 2010). The upper Madi watershed had always received less attention from government and other voluntary organization during the past events. However, in the recent Taprang landslide of 3 August 2010, the affected areas were helped by individuals and different organizations (Table 2).

Table 2 clearly illustrated that non-governmental organizations are more reliable and active in providing financial aid and relief to the areas affected by natural disasters in the mountainous watersheds. Although the downstream impacts of upstream interventions are high in the discourse of natural disasters, there are very few programmes and achievements in terms of linking the two. The trickle down effects of water conservation, reduced soil erosion, and well managed agricultural practices will hence decrease sedimentation in the plains and reduced potential of hazards in the downstream when upstream watersheds are managed properly (Pandit et al., 2007). However, there is no such coordination among settlers in the upper Madi watershed and the magnitude of natural hazards and disasters is always unpredictable and widespread. Since there is always experiencing the losses of life and property as well as the damage to scarce agricultural land and costly infrastructures due to extreme weather events, especially landslide and flood, a large scale of outmigration has been taken place from those areas which were severely affected by landslide and flood. A large volume of households have migrated to Pokhara from Taprang and Sondha areas since the settlements in the areas have been threatened due to reactivation and enlargement of existing landslides.

Table 2. Funds collected for the victims of Taprang landslide, 2010.

Donor	Amount in rupees	Remarks
Pahar Trust Nepal: UK based International Non Governmental Office	612,576	To build new houses in Taprang and Seti Khola area for affected households
Nepal Red Cross Society	300,000	Will be used for the affected areas
John Riley Isle man of UK	100,000	Will be used for the affected areas
Taprang Pokhara Samparka Samaj	200,000	Will be used for the affected areas
District Development Committee	200,000	Will be used for the affected areas
Central District Officer (CDO) office of Kaski	25,000	Each families were given 25,000 who lost their lives in the landslide
Village Development Committee	Unknown	Provided to the families who lost their lives in the landslide
Nepal Red Cross Society	Unknown	Provided to the families who lost their lives in the landslide
Sikles village raised a fund	300,000-20,000	Three families from Sikles were given to 100,000/person died in the landslide and 10,000/person died in the landslide from Taprang

Nevertheless, outmigration is not a solution for mitigation to the affected areas. Although local dwellers are aware about the frequent problems of landslide and flood, still disasters control and mitigation as well as adaptation and management activities in organized way have not yet received priority in the upper Madi watershed. According to the interviewed key informants, there are no facilities to record hydro-meteorological data which can introduce an early warning system to reduce the impact of natural disasters. Due to lack of both technical as well as financial capability to cope with the natural disasters, the vulnerability of life and properties in the upper Madi watershed has been increasing continuously. The general consensus is that an improved knowledge about the frequency, magnitude, causes, and consequences of natural hazards and disasters is essential to develop short- and long-term mitigation measures (Chalise and Khanal, 2000). Thus long-term monitoring of climatic, hydrological, and other critical parameters in selected river basins is absolutely essential to reduce the risks and impacts of these natural disasters. The underlying causes and processes of landslides, mass movements, and floods need to be well studied to develop mitigation strategies and reduce the magnitude and impact of these disasters. It is also essential to cooperate with communities in order to control landslide, mass movement, and flood to minimize the loss of life and properties. Moreover, these community based institutions should be strengthened with provision of training and other necessary support including financial and manpower during the disasters period (Khanal and Watanabe, 2004).

Conclusion

Landslides, mass movements, and floods associated with extreme weather events are common phenomena in the mountainous terrain of Nepal. Torrential rainfall is the principal triggering factor for landslides, mass movements, and floods that often cause high levels of economic loss and substantial numbers of fatalities as well as destroy infrastructures and properties. Our study revealed that the upper Madi watershed has a greater number of landslides with extensive coverage. Each year, the occurrence of natural disasters, especially landslide and flood threatened the settlements by damaging agricultural land, properties and human life. Although the upper Madi watershed has been experiencing landslide and flood for more than half century, there are still no concrete strategies to mitigate the problems. There are no facilities to record and monitor the climatic, hydrological, and other critical parameters to introduce an early warning system. Moreover, the area received less priority in terms of relief and aid from Nepal government before and after the extreme weather events. Because of such discouraging government interventions as well as reactivation and enlargement of existing landslides, the vulnerability of life and properties have been increasing in the upper Madi watershed.

References

Adhikari, D. P. and S. Koshimizu. 2005. Debris flow disaster at Larcha, upper Bhotekoshi Valley, central Nepal. Isl. Arc 14:410-423.

CBS. 2003. Statistical yearbook: Central Bureau Statistics. National Planning Commission, Government of Nepal, Kathmandu.

Chalise, S. R. and N. R. Khanal. 2000. Recent extreme weather events in the Nepal Himalayas. The Extremes of the Extremes: Extraordinary Floods (In: proceedings of a symposium held at Reykjavic, Iceland, July 2000, 141-146.

Dahal, R. K. and S. Hasegawa. 2008. Representative rainfall thresholds for landslides in the Nepal Himalaya. Geomorphol. 100:429-443.

Degen, A. A., L. N. Pandey, M. Kam, S. B. Pandey, C. R. Upreti and N. P. Osti. 2010. Goat production and fodder leaves offered by local villagers in the Mid-Hills of Nepal. Human Ecol. 38:625-637.

DFID. 2005. Integrating indigenous and biological knowledge to implement improved dry season feeding strategies on farms in the hills of Nepal. Department for International Development (DFID), London.

FAO. 2002. Policy and strategy for poverty alleviation and sustainable household food security in Nepal. Food and Agriculture Organization (FAO) Regional Office for Asia and the Pacific, Bangkok.

Fort, M., E. Cossart and G. Arnaud-Fassetta. 2010. Hillslope-channel coupling in the Nepal Himalayas and threat to man-made structures: The middle Kali Gandaki valley. Geomorphol. 124:178-199.

Gautam, R., S. Baral and S. Herat. 2009. Biogas as a sustainable energy source in Nepal: Present status and future challenges. Renew. Sustain. Energy Rev. 13:248-252.

IFRC. 2010. Nepal: flood and landslide. International Federation of Red Cross and Red Crescent Societies, Kathmandu, Nepal.

Jones, D. K. C. 1993. Slope instability in a warmer Britain. Geogr. J. 159:184-195.

Khanal, N. R. 1999. Study of landslides and flood affected area in Syangja and Rupendehi districts of Nepal. Unpublished report submitted to Mountain Natural Resources Division, International Center for Integrated Mountain Development, Kathmandu.

Khanal, N. R. and T. Watanabe. 2004. Landslide and debris flow in the Himalayas: A case study of the Madi Watershed in Nepal. Himal. J. Sci. 2:180-181.

Pandit, B. H., M. P. Wagley, R. P. Neupane and B. R. Adhikary. 2007. Watershed management and livelihoods: Lessons from Nepal. J. Forest Livelihood 6:67-75.

Pokharel, D., B. S. Bhandari and T. Viraraghavan. 2009. Natural hazards and environmental implications in Nepal. Emerald 18:478-489.

POSTNOTE. 2006. Adapting to climate change in developing countries. Parliamentary Office of Science and Technology, No 269, London.

Poudel, K. 2000. Application of Geoinformatics on Mountain Land Hazard Mapping:A Case of Annapurna Himalayas, Central Nepal http://www.gisdevelopment.net/aars/acrs/2000/ts7/gdi007.asp

Poudel, K. P. 1996. Grographic information system based hill-slope instability analysis for land-use planning perspective: The case of upper Madi watershed Kaski, Nepal. Tribhuvan University J. XIX: 25-42.

Ray, R. L. and F. De Smedt. 2009. Slope stability analysis on a regional scale using GIS: A case study from Dhading, Nepal. Env. Geol. 57:1603-1611.

Subedi, M. K. 2009. The impact of labor migration and remittances on household income and welfare in Nepal. In: Pacific Conference for Development Economics, 14 March, San Fransisco University, USA.

Tiwari, I. P. 2008. Urban migration and urbanization in Nepal. Asia Pac. Popul. J. 23:79-104.

UNDP. 2009. Nepal Human Development Report 2009: State Transformation and Human Development. United Nations Development Programme (UNDP), Kathmandu.

WB. 2010. Migration and Remittances Factbook 2011. The interantional Bank for Reconstruction and Development, The World Bank, Washington DC.