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Distribution of Houses Determined by Geomorphology, Landslides and People's Perception in Nallu Khola Watershed, Nepal

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This study was carried out to analyze the relationship among distribution of houses, geomorphological parameters, landslide distribution and people's perception in a middle mountain watershed of Nepal. It focuses on the analysis of distribution of houses with respect to slope gradient, relief, elevation, drainage frequency and landslide distribution. Stereo pairs of black and white aerial photographs, topographic map and updated field data of house and landslide distribution were used for geomorphological analysis. Density of houses with respect to slope, relief, elevation, drainage frequency and landslide density were estimated. A questionnaire survey was carried out to analyze peoples' perception regarding the landslide hazard around their residence. The study points out that the most preferred place for residence in the study area is gently sloping land around 10° slope gradient, relief about 20 m, elevation between 1700–1800 m and least dissected by the drainage which is comparatively safe and convenient. However, 20% houses are built in high hazard area of shallow landslides, mainly due to increased population, poor economic condition and lack of alternative safe place for residence. Majority of the inhabitants have stated that they are aware of landslide hazard around their residence, but they are not ready to migrate out side.

INTRODUCTION

Considerable human lives and property are exposed to the risk of widespread landslides occurring at increasingly shorter intervals (Daluwatta *et al.*, 1994). So, there is a greater need for study of human settlements in relation to their geophysical setting. Understanding the relationship among geomorphological characteristics of a watershed, common natural hazards like landslides and people's perception regarding natural hazards around their residence is of prime importance for disaster prevention planning and implementation of development schemes. In the case of human dominated fragile landscapes, a study of these aspects will certainly help to plan and implement any development program. Identification of critical areas and formulation of plan based on socioeconomic condition, status of natural resources and geophysical or geomorphological setting of the watershed are basic requirements for landslide or debris flow disaster prevention program. Since shallow or deep seated landslides are the most common natural hazards in Nepal, causing 300–400 hundred people's death each year including destruction of houses and other properties (Sharma 1988, MOH 1994), a study of distribution of houses in relation to geomorphological parameters, shallow landslide distribution and people's perception regarding the landslide hazard around their residence is carried out in a middle mountain watershed of Nepal.

The objectives of this study are: 1) to find out relationship between geomorphological characteristics of the watershed and distribution of dwellers' houses; and 2) to study the peoples' perception regarding landslide hazard around their residence.

STUDY AREA

This study is carried out in Nallu Khola watershed, which lies between 27°32' N and 27°34' N latitude and between 85°19' E and 85°25' E longitude (Figure 1). The study area (16.04 km^2) is located in Lalitpur district of Nepal, about 19 km south of Kathmandu valley. General and geomorphological characteristics of the watershed are shown in Table 1. Four major types of land use exist in the study area. These land use types are: 1) cultivated land, 2) forest, 3) shrub land, and 4) other. Cultivated land occupies 44 percent of total watershed area. It includes sloping terraces and the land used to produce fodder for cattle, locally called as "Kharbari". Forests are distributed through out the watershed and occupy 40 percent of total area. These forests can be classified into three types: pine forest, broad-leaved forest, and mixed forest. Pine forest is of mainly plantation forest that exists in the southern aspects of the study area below 2,000 m. Natural broad-leaved forest exists mainly in the northern aspects and mixed forest of pines and broad-leaf tree species exists in the transitional areas. Other land use type includes debris deposited areas along the streamside and bare land. Shrub land and other land use type occupy 15 and 1 percent of total watershed area respectively.

Climate of the study area is sub-tropical (< 2000 m) to lower temperate (2000–2625 m). The mean annual rainfall is 1889 mm estimated at the nearest meteorological

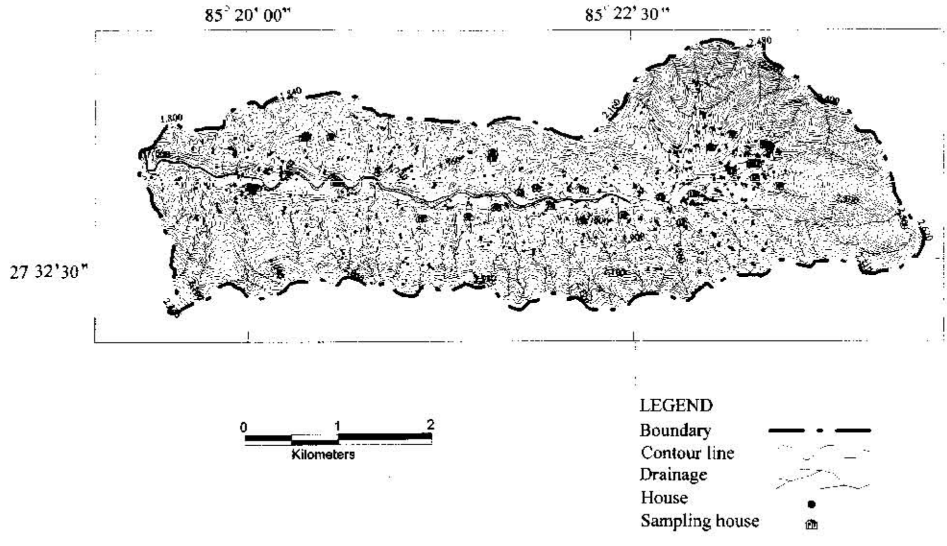

Fig. 1. Map of the study area.

Table 1. General and geomorphological characteristics of Nallu Khola Watershed.

Characteristics	Unit	
Area	(km^2)	16.04
Houses	(No.)	509
Population	(No.)	4,000 (Approx.)
Population density	(No./ km^2)	249.4
Density of houses	(No./ km^2)	31.7
People per house	(No./No.)	7.9
Land Use	(km^2)	
Cultivated Land		7.07 (44%)
Forest		6.46 (40%)
Shrub land		2.34 (15%)
Other		0.16 (1%)
Elevation	(m)	
Highest		2625
Lowest		1600
Relief	(m)	1025
Main Stream Length	(km)	9.8
Average Slope	(degree)	26
Drainage Density	(km/ km^2)	4.6

station in Godawari, which is about 5 km north from the study area (DPTC 1993).

The rocks of the Phulchauki group of Kathmandu complex (Chandragiri formation, Sopyang formation and Tistung Formation) underlie the Nallu Khola watershed (Stocklin and Bhattrai 1980). These formations consist mainly limestone quartzite, slates, phyllites, siltstone, sandstone and sandy limestone. The rocks are folded, faulted, fractured and highly weathered.

A big debris flow disaster occurred in Nallu Khola watershed on September 30, 1981. Because of heavy rain, many shallow landslides or slope failure occurred along each stream and gully in the upstream slopes and changed into debris flow when combined in the confluence. Due to this disaster 55 people were killed and many houses, roads, irrigation facilities, cultivated land and temples were damaged or destroyed (DPTC 1996).

MATERIALS AND METHODS

A variety of techniques and perspectives of data collection and analysis were used to approach a set of research questions and objectives. The study was accomplished in a series of phases from pre–field work to processing, analysis and integration of data. Secondary sources of information, such as published or printed materials and available documents, were reviewed before field investigation. A reconnaissance surveys was carried out before detail investigation of identifying geomorphological characteristics of the watershed and location of houses being studied. Primary data in the field were collected by means of observation, interviews and informal discussions with villagers. A total of 31 households (6.1% of total households) were sampled randomly for questionnaire survey. As shown in Figure 2, a set of questions were asked to the

Date:
Place (Location of house, slope, elevation):
Name of respondent:
Age:
Family members:
Occupation:

Q 1. Do you think there is a danger of landslide or debris flow around your residence?
A Yes No
Q1.1. If yes, are you worried about it now?
A Yes No
Q1.2. If yes, are you willing to migrate to another safe place?
A Yes No

Q 2. Do you think preventive measures carried out by HMG/JICA Water Induced Disaster Prevention Technical Center (DPTC) are enough to protect residential areas from future landslides or debris flow?
A Yes No
Q2.1. If no, why?
A (a) Area covered is small, (2) Counter measures are not appropriate
(c) Other ...

Q 3. What kind of help do you expect from the government of Nepal in order to make your residential area safe from future landslides or debris flow?
A (a) Intensive soil conservation works including landslide control
(b) Provide alternative safe place for residence
(c) Other ...

Q 4. Which of the following combination of counter measures will be most effective and appropriate around your residential area (Please write 1 in the bracket for your best choice and then 2, 3, 4 as you think) ?
A (a) Big concrete structures like Sabo dams and retaining walls ( )
(b) Small check dams and retaining walls ( )
(c) Gabion wire boxes filled with stones along the stream sides ( )
(d) Plantation (vegetative control works) ( )
(e) Other ...

Q 5. Which place do you chose to live if you have two alternatives?
A (a) Village ( ), Why ? ...
(b) City ( ), Why ? ...

Fig. 2. A questionnaire used to study people's perception of landslide and debris flow hazard in Nallu Khola watershed, Nepal.

respondents and filled on the spot. Important points raised during the informal discussion were also recorded. Field information such as locations of landslides and houses were marked on a topographic map of the area.

Stereo pairs of black and white aerial photographs were interpreted to plot landslides on the topographic map at a scale of 1:25,000 (HMG/Nepal 1994a and 1994b). House and landslide distribution maps of the study area were updated by combining data taken from the field.

In order to carry out geomorphological analysis, contour lines, drainage network, location of landslides and houses were digitized using a software program called MapInfo Professional from a scanned base map. Digitized map layers were superimposed. A net with unit cell size 0.5 cm×0.5 cm on the map, which is equivalent to 125 m×125 m in the field, was overlaid on all the map layers. Geomorphological analysis was carried out using 1,135 cells over the entire study area. A slope map was derived from digitized contour map. Quantitative data of landslide, drainage, relief, slope gradients and houses were obtained for each cell. Slopes were grouped into following classes: up to 10°, 11 to 20°, 21 to 30°, 31 to 40°, 41 to 50° and more than 50°. Area covered by each slope class was computed. Drainage frequency f, landslide density d_l and density of houses d_h in each slope class were estimated by applying the following equation

$$f \text{ or } d = \frac{\sum n}{\sum a}$$

where n is the number of drainage or landslide or house within a cell and a is the area of the cell in the same class.

RESULTS AND DISCUSSION

Nallu Khola watershed is elongated in east–west direction and highly dissected by the drainage system from north, west and south facing aspects. Average drainage density is estimated at 4.6 km/km^2. About 70 percent area has more than 20° slope gradient (Joshi 1999). There are a total of 509 houses, distributed from 1600 m to 2200 m elevation and 5 to 44° slope gradient in Nallu Khola watershed (Figure 1). There are hamlets as well as scattered and isolated houses constructed in different locations such as gently sloping hill top, sloping ridge, sloping terrace, gently sloping terrace, stream side, debris deposited area and debris fan (Figure 3). A typical hamlet located between streamside and gently sloping terraces is shown in Photo 1. Most of the houses are constructed on cut and filled base in the sloping land. Dwellers traditionally use locally available resources such as stone, slates, soil and wood to construct a typical two–story house of size about 30 m^2. Recently, tiles or zinc sheets are used as roofing materials. Clay soil is used as cementing material inside and out side of the walls. Doors, windows and beams of the roofs are made of wood. Houses are painted with white or red color soils. There are small mines of white and red soils within the watershed. People have made holes by digging the soils in the mining area located in the foot part of the hill. This practice has initiates a huge landslide in one of the white soil (lime stone) area, due to toe cutting.

Density of houses in relation to slope gradient is shown in Figure 4. Density of houses is relatively lower in almost flat area because such areas are mostly along the streamsides

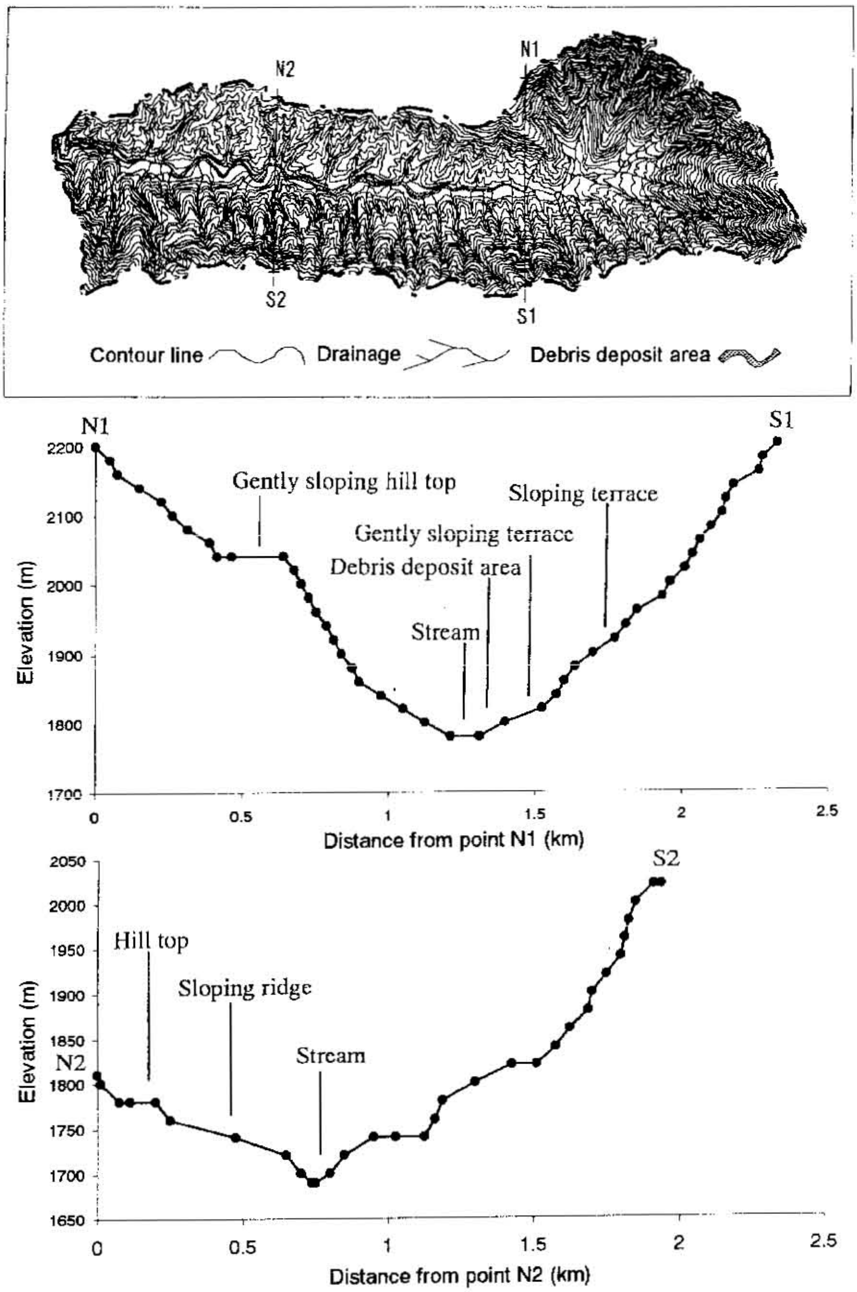

Fig. 3. Cross section along the line N1–S1 and N2–S2.

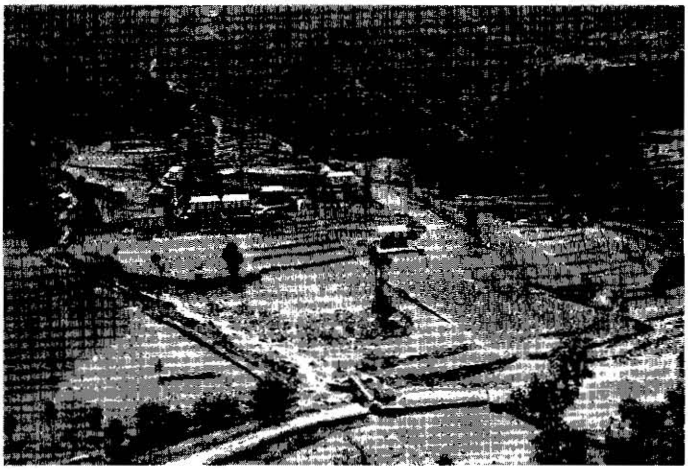

Photo. 1. A typical residential area in Nallu Khola watershed.

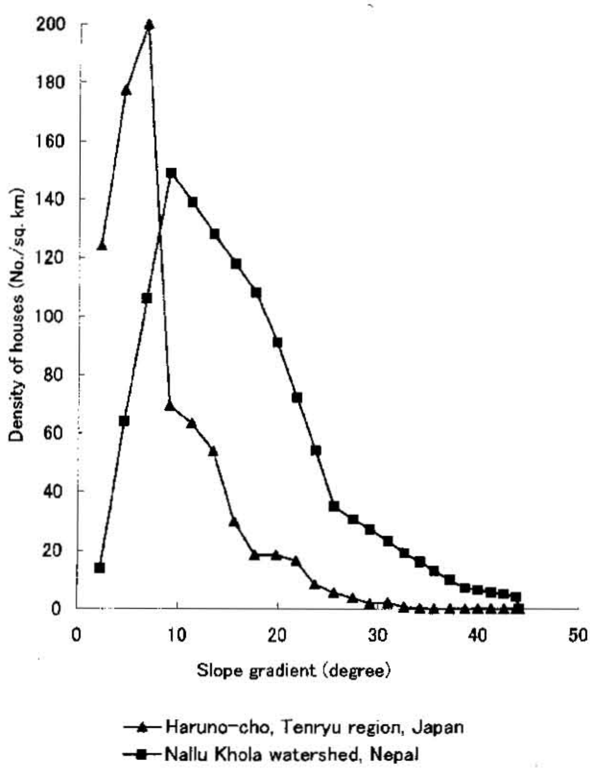

Fig. 4. Relationship between slope gradient and density of houses in Haruno-cho, Tenryu region, Japan and Nallu Khola watershed Nepal.

that have flooding or debris flow potentiality. Highest d_h is around 10° slope gradient, then decreases with the increase in slope gradient and becomes zero at 45° in Nallu Khola watershed. Relationship between slope gradient and density of houses in Haruno–cho, Tenryu region of Japan shows the similar trend (Omura 1978). But, more houses are distributed in steeper slopes in Nallu Khola watershed than Tenryu region. Figure 5 shows that d_h is highest where relief is 20 meters. This is the same area, which has about 10° slope gradient. Density of houses is highest where drainage frequency is zero and it decreases with increase in drainage frequency (Figure 6). It implies that people have a tendency to avoid gullied areas for residence as far as possible. Evidently, gullied areas are unstable. Distribution of houses with respect to elevation shows that highest percentage of house is located between 1800–1900 m (Figure 7), but d_h is highest between 1700–1800 m (Figure 8). This is mainly due to a link road, major part of which is constructed between 1700–1900m. Since accessibility below 1700 m and above 1900 m is difficult due to lack of branch road, people have constructed many houses on both sides of link road for their convenience after its construction. From these relationships it can be inferred that the most preferred place for residence in the study area is a gently sloping land, having relief around 20 m, elevation between 1700–1800 m and least dissected by the drainage which is stable and convenient. Since, such stable as well as convenient areas are limited and population is ever increasing, people have constructed houses in such places where slope gradient is up to 44°, relief is up to 120 m and drainage frequency is up to 4 (no./cell).

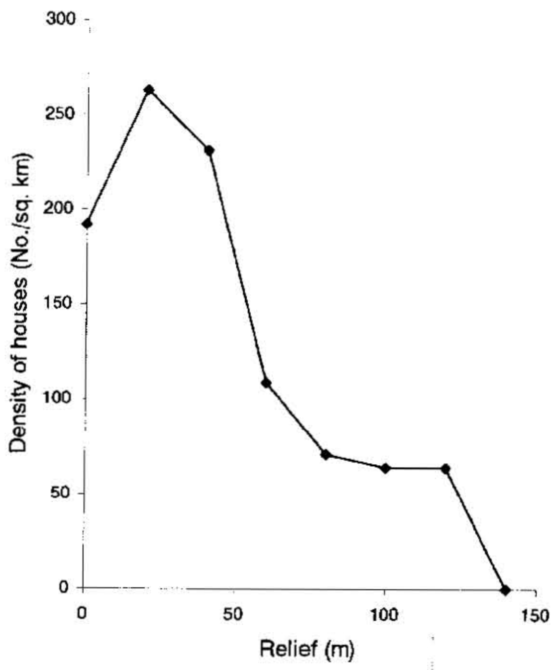

Fig. 5. Relationship between relief and density of houses in Nallu Khola watershed, Nepal.

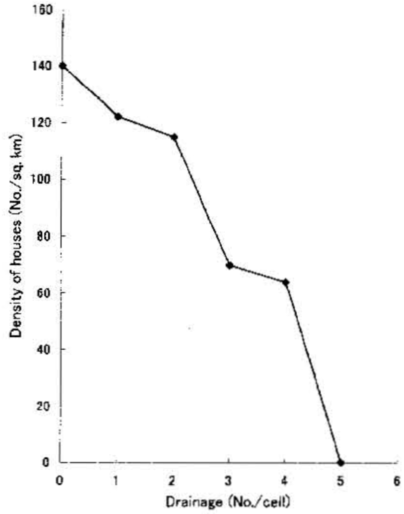

Fig. 6. Relationship between drainage frequency and density of houses in Nallu Khola watershed, Nepal.

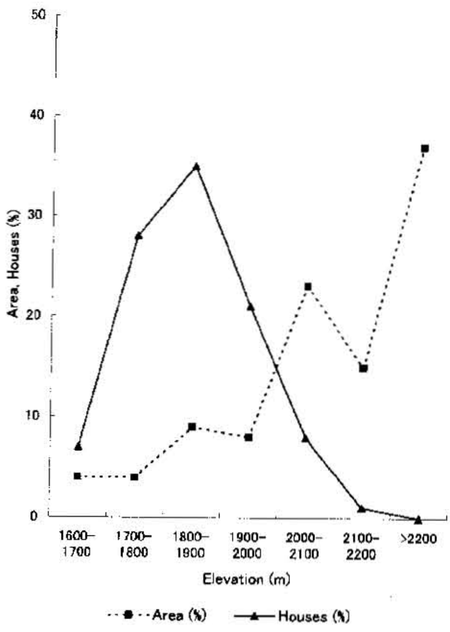

Fig. 7. Number of houses with respect to elevation in Nallu Khola watershed.

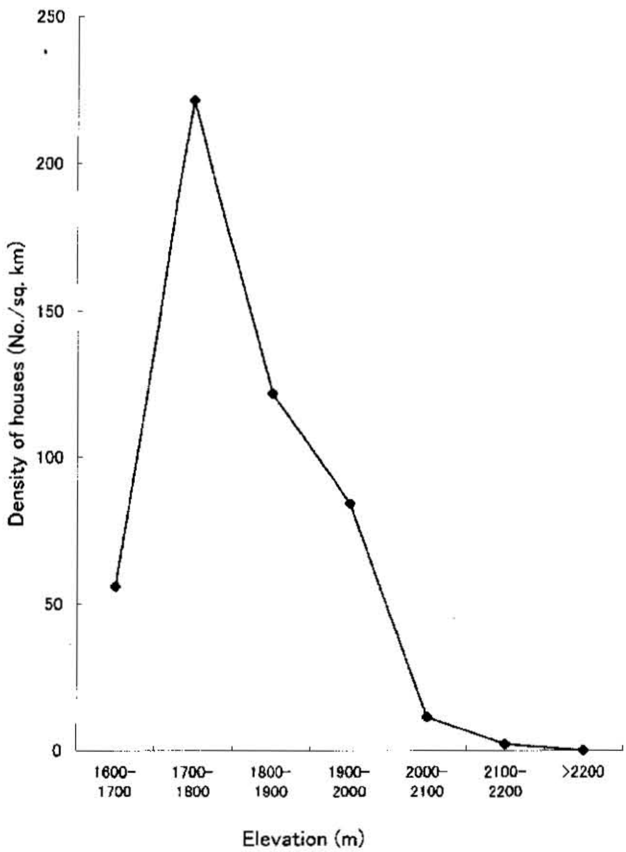

Fig. 8. Density of houses with respect to elevation in Nallu Khola watershed.

As shown in Figure 9, density of houses is highest where landslide density is lowest. It implies that majority of the people have avoided high landslide hazard areas for residence. However, there are some houses above 30° slope gradient, which is either high landslide hazard area or steep rock slope. It has been reported that the natural hill slopes with gradient between 30° and 40° are found to be most critical for failure in Nepal (Dikshit 1994, Joshi 1999). There are about 20% houses between 30° and 40° slope gradient, in Nallu Khola watershed. This is further supported by the landslide hazard map of the watershed, which shows 20% houses are constructed in dangerous locations that have been categorized as high hazard areas (Joshi, 1999). It means 101.8 houses are located in unstable areas. If a landslide or debris flow hits one house, 7.9 people will have potentiality of damage or may loose their life in an extreme case. In spite of such critical conditions, people are living there with their own perception of natural phenomena and

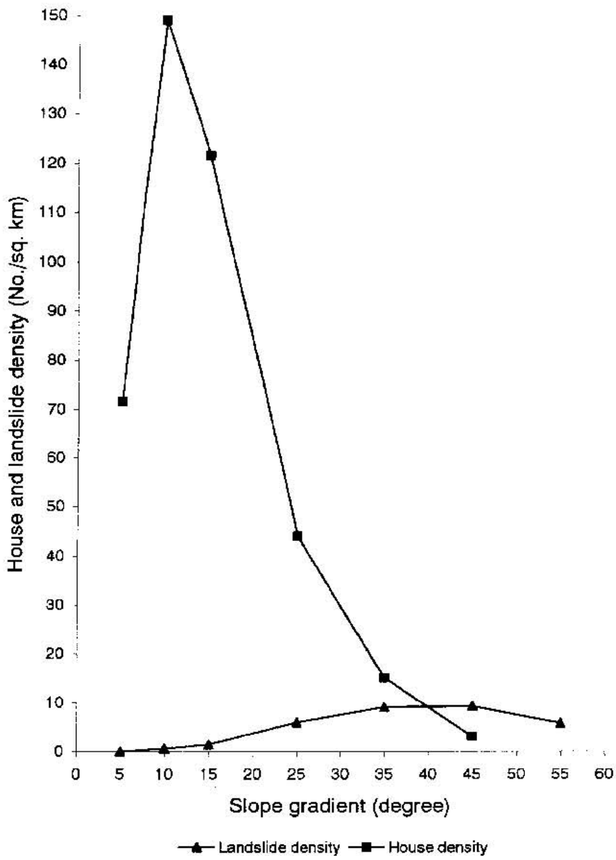

Fig. 9. Densities of houses and landslides with respect to slope gradient in Nallu Khola watershed.

ethic for living.

An analysis of questionnaire survey shows that, 90.3% households are subsistence farmers. As shown in Table 2, 80.6% inhabitants of Nallu Khola watershed think that there is a danger of landslide or debris flow around their residence. However, 54.8% households are worried about the future landslide or debris flow disaster. This suggests that majority of the people are aware of landslide hazard around their residence. Additional supporting fact is that 80% houses are built in low or medium landslide hazard area. But, only 12.9% households are willing to migrate if Government provide them alternative safe place for residence. It is mainly due to the poor socio-economic condition of the inhabitants, lack of alternative safe and convenient place in their vicinity, socio-psychological attachment to their birthplace and their traditional cultural background.

Table 2. Response of the sampling households living in different localities.

Location of Sampling Houses	Houses		Perception of households based on questionnaire survey							
			a	b	c	d	e	f	g	h
	(No.)	(%)	(No.)	(No.)	(No.)	(No.)	(No.)	(No.)	(No.)	(No.)
Debris deposit area/fan	4	12.9	4	4	2	2	2	4	0	0
Stream side	6	19.4	6	4	1	5	1	5	0	1
Sloping terrace	7	22.6	7	7	1	7	0	6	0	1
Gently sloping terrace	4	12.9	4	0	0	4	0	4	0	0
Sloping ridge	5	16.1	4	2	0	5	0	4	1	0
Gently sloping hill top	5	16.1	0	0	0	5	0	0	5	0
Whole watershed	31	100.0	25	17	4	28	3	23	6	2

a. Households aware about danger of landslide or debris flow around their residence

b. Households worried about future landslide or debris flow disaster around their residence

c. Households willing to migrate in another place

d. Households expecting intensive soil conservation works from the Government of Nepal

e. Households expecting alternative safe place for residence from the Government of Nepal

f. Households who think (1) Gabion wire filled with big stones along the stream sides, (2) Small check-dams in gullies and (3) Plantation in the bare land or degraded forest, are the most appropriate and effective countermeasures for landslides and debris flow

g. Households who think (1) Plantation in the bare land or degraded forest, (2) Small check-dams in gullies and (3) Gabion wire filled with big stones along the stream sides, are the most appropriate and effective countermeasures for landslides and debris flow

h. Households who think (1) Big concrete structures, (2) Gabion wire filled with big stones along the stream sides, and (3) Small check-dams in gullies, are the most appropriate and effective countermeasures for landslides and debris flow

Table 3. People's priority for living in village and city.

Respondents' Age	Priority for living (%)		Total (%)
	Village	City	
Below 30 years	3 (9.68)	6 (19.35)	9 (29.03)
30 years and above	22 (70.79)	0 (0)	22 (70.79)
Total	25 (80.65)	6 (19.35)	31 (100)

Regarding the expectations from Government of Nepal, 90.3% people gave priority to intensive soil conservation works including landslide control works. All the people opined that disaster prevention measures so far carried out in Nallu Khola are not enough because area covered is small. Water Induced Disaster Prevention Technical Centre (DPTC) of Nepal established with the help of Japan International Cooperation Agency (JICA) selected Nallu Khola watershed as a model site for debris flow disaster prevention works. DPTC has constructed some retaining walls and a series of check dams in two gullies where debris flow occurred in 1981. Based on their experience, 74.2% people have given the priority to gabion wire filled with large stone along the stream sides, small check dams in the gullies and plantation in all the bare land and degraded forest patches as the most appropriate and effective counter measure against landslide and debris flow disaster.

An analysis of inhabitants' priority for living shows that 80.6% people prefer to live in their own village (Table 3). All the people above 30 years age expressed their desire to live in village, because natural environment is clean, social environment is friendly and peaceful though life is hard. Moreover, they feel close affiliation with their birthplace. Among the young people below 30 years age, 75% answered that they prefer to live in city, since there are opportunities for employment and facilities to live comfortable life.

CONCLUSION

The natural hill slopes with gradient about 10°, relief around 20 m elevation between 1700–1800 m, least dissected by the drainage and lowest landslide potentiality are the most preferred places for residence in Nallu Khola watershed. Such areas are most convenient and safe for residence. Majority of the inhabitants are aware of landslides hazard but they are not ready to migrate out side due to the poor socio–economic condition, lack of alternative safe and convenient place in their vicinity, socio–psychological attachment to their birthplace and their traditional cultural background. Majority of the inhabitants seeks for intensive soil conservation works including landslide control measures from the Government of Nepal. Hence, it can be concluded that a study of relationship among geomorphological characteristics of a watershed, distribution of dwellers' houses and peoples' perception regarding landslide hazard around their residence will be of use as a guide to prepare sediment disaster prevention plans and to find out safe place for residence in the mountains.

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