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Disasters and environmental degradation in Nepal: focus on urban areas

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ABSTRACT

Nepal is prone to various disasters like earthquake, landslide, debris flow, flood, and glacier lake outburst flood (GLOF). In the last 23 years natural disasters have caused tremendous losses of lives and property. The disasters have brought about the average loss of about 6% of the annual development expenditure of the government. Their frequency is also increasing due to a high rate of population growth and multiple human activities. Disasters disturb the normal life and social system, degrade the environment, and aggravate the poverty and eco-system in the affected areas. Both natural and anthropogenic disasters are deteriorating the natural environment mostly in the urban areas of Nepal. Since there is no effective forecasting and early warning system for such disasters there will be no time for the vulnerable people to save from possible disaster by taking themselves in safe places. Previously the Nepal government put its efforts mainly on post-disaster activities like rescue, relief, and rehabilitation. Only after the 1985 Dig Tso GLOF, 1988 earthquake in eastern Nepal, and 1993 flood and landslide disaster in central Nepal, people realised the importance of pre-disaster preparedness. For the preparedness and mitigation of hazards, geological, geomorphological, hydrogeological information and hazard maps are extremely important. Consequently, the Department of Mines and Geology is publishing the engineering and environmental geological maps of urban areas, which are quite helpful for infrastructural planning, disaster management, and environmental protection.

Keywords: Disaster, environmental degradation, earthquake, landslide, flood, debris flow, Nepal

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INTRODUCTION

The Himalayan belt is the result of collision of Indian plate with the Eurasian (Tibetan) plate. It is bounded within two syntaxial bends of the Brahmaputra River in the east and Indus River in the west. The Nepal Himalaya lies in the central part of the 2400 km long Himalayan belt and occupies about 1/3 part of it. Because of its location in the Himalaya, rugged topography, high relief, steep slopes, a high precipitation rate during monsoon, variable climatic conditions, complex geology with sharp linear thrust or fault structures, active tectonic processes and continued seismic activities there in, Nepal as a whole is prone to various types of natural hazards. Deforestation and haphazard developmental activities have also made many areas vulnerable to disaster.

In Nepal the main natural hazards are earthquake, landslide, soil erosion, debris flow, flood, glacier lake outburst flood (GLOF), thunderstorm, windstorm, hailstorm, land subsidence, and sinkholes, whereas the anthropogenic hazards are mainly fire and epidemic. Since Nepal lies in the tectonically active Himalayan belt almost all parts of it are prone to earthquake hazard. Depending on the topography and climatic factors, soil erosion, landslides, and debris flow are quite common in the hilly region. The flat piedmont plains of Terai and lower part of mid valleys in the Midlands are susceptible to floods during a cloud burst or heavy monsoon rain. In many cases, flooding in the Terai is due to the blockage of a natural drainage by anthropogenic structures. More than 3000 glacier lakes are recorded in the Higher Himalayan regions of Nepal. It is reported that 27 of them can burst at any time and cause GLOFs.

COMMON DISASTERS IN NEPAL

From the World Disaster Record it is known that 80% of the total disasters happen in Asia. South Asia is the most disaster-prone region in the world. Furthermore, the Himalaya–Karakorum region is also highly prone to earthquakes. A recent study (UNDP/BCPR 2004) ranked Nepal the 11th among the 200 countries in terms of earthquake risk and the 30th in terms of flood risk. Nepal is ranked the second highest with 13.58 deaths per million people among the regional countries. The earthquakes of 1934, 1980, and 1988 as well as the flood of July 1993, the landslide of 2002, and the fire of 1989 were devastating. According to the Ministry of Home Affairs (MOHA), in the last 23 years (1983–2005), about 21,840 (i.e., an annual average of 950) people lost their lives and the property worth over 28 billion rupees was lost due to the disaster. Annually, more than 21,000 families are affected by various disasters in Nepal. Out of them, 16,000 households suffer from floods and landslides. The average estimated property loss is about 1,208 million rupees per annum, which is about 6% of the total development budget of the country (Kaphle and Nakarmi 1997).

The death due to landslides and floods is almost 1/3 of the total number. Similarly epidemics are causing about 56% of the total death. The historical earthquakes in Nepal (UN/UNCHS 1993; Pandey and Molnar 1988; Bilham and Jackson 1995) recorded in the 19th century (1810, 1826, 1833, 1837, 1869, 1897) and 20th century (1917, 1934, 1936, 1954, 1966, 1980, 1988) are notable (Table 1). Earthquakes in the Himalayan region could also trigger landslides, GLOFs, and floods. Bilham et al. (2001) reported that Nepal is under the threat of a large earthquake of magnitude over 8 on the Richter scale.

Earthquake

The amount of destruction by the earthquake depends on its intensity, the strength of ground or foundation, and the quality of construction materials used. Eight major earthquakes measuring 7.5 or more on the Richter scale have already struck the Himalaya in the last 100 years. In the 1934 Nepal–Bihar great earthquake (magnitude 8.3 on Richter scale) 8,519 people died and about 207,248 houses were damaged in Nepal (Rana 1935). Out of which about 4,296 lives were lost and 80,890 houses were damaged (Fig. 1) in the Kathmandu valley alone (Rana 1935; Pandey and Molnar 1988). Recent studies carried out by different organisations and individuals have shown that Kathmandu is ranked one of the world's most vulnerable cities for an earthquake disaster (DMG/NSC 2007; JICA (2002) reported that if an earthquake similar to that of 1934 hits the Kathmandu valley, there will be a huge loss of lives and property. The Kathmandu Valley Earthquake Risk Management Project (KVERMP 1999) has predicted that an earthquake similar to that of 1934 would cause 40,000 deaths and 95,000 serious injuries. From 600,000 to 900,000 residents of the Kathmandu valley could be homeless and almost 60% of the infrastructures will either be damaged (40%) or destroyed (20%). Many losses will also be brought about by creeping disasters like fire and epidemic after the earthquake. KVERMP (1999) has also reported that 11,000 people lost their lives in past 4 major earthquakes of past century.

Though the Natural Calamity Relief Act came into existence in 1982, disaster management did not receive much attention before the 1988 earthquake of eastern Nepal. Only after this earthquake and the heavy floods of 1993 in central Nepal, disaster management activities were intensified in the country. The government prepared the Building Code in 1994. However, the activities were mainly focused on rescue, relief, and rehabilitation. Since the UN declaration of 1990–1999 as the International Decade for Natural Disaster Reduction (IDNDR) a Natural Disaster Reduction Committee (Natural Calamity Relief Committee) was formed under the Ministry of Home Affairs. After that a National Action Plan for disaster management was formulated in 1996 and some programmes were implemented. The National Action Plan was updated and presented in the World Conference on Disaster Reduction in Kobe, Japan, held between 18 and 22 January 2005. The Hyogo Framework for Action 2005–2015 reflects a holistic and multi-hazard approach to disaster risk management.

Landslide and debris flow

Landslides are the most common geogenic hazards that affect some parts of the country every year. Topography, high-angle slopes, fragile geology, earthquake, deforestation, improper cultivation practices on steep lands, and high precipitation during the monsoon season are the causes of

Table 1: Historical earthquakes in Nepal

Year	Richter scale	People killed	Houses destroyed	Remarks
1255 AD	>8	No proper records	No proper records	No proper records exist
1310 BS	Large earthquake	No proper records	No proper records	No proper records exist
1373 BS	Large earthquake	No proper records	No proper records	No proper records exist
1810 AD	>8	No proper records	No proper records	Almost 30% people of Kathmandu valley were affected
1833 AD	7.8	No records	4214 houses collapsed	Kathmandu valley was highly affected
1866 AD	>8	No proper records	No proper records	No proper records available
1934 AD	**8.4**	**8519**	**80,890 houses collapsed and 207,248 damaged**	**Huge loss of lives, properties, and damage of infrastructures**
1966 AD	6.5–7.0	24	>1300 houses collapsed	Hilly districts of Far-western Nepal were affected
1980 AD	6.5	178 died and 391 injured	40,000 houses damaged	Far-western Nepal was affected
1988 AD	6.6	721 died and 6553 injured	65,432 houses collapsed 235,403 damaged	Houses and physical structures collapsed

Source: Earthquake Catalogue

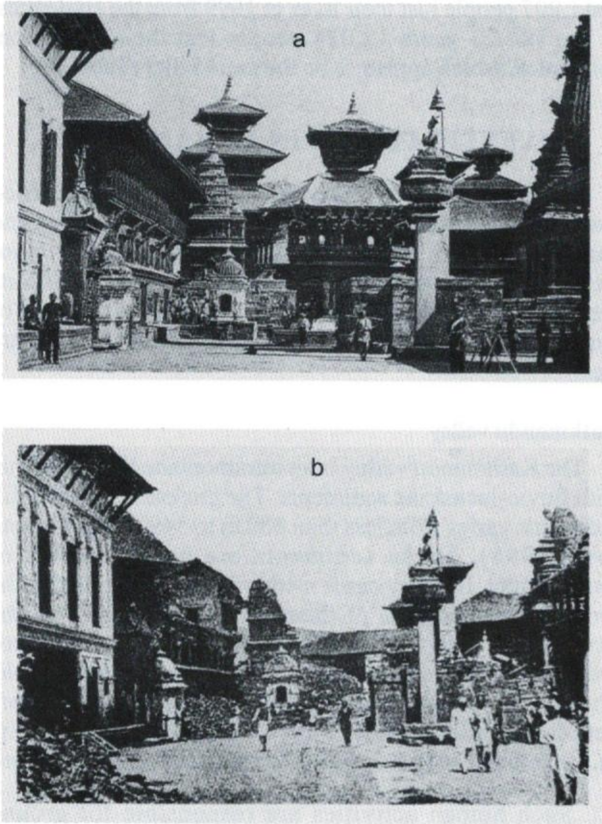


Fig. 1: Bhaktapur Durbar Square: a. before and b. after 1934 Bihar –Nepal Great Earthquake (Rana 1935).

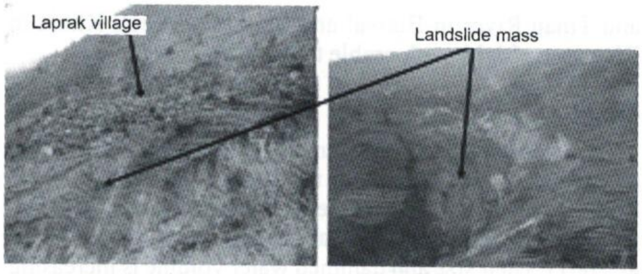


Fig. 2: The Laprak Landslide in Gorkha (Photo by Rajendra Khanal 2006)

Fig. 3: Phewa lake is filled up with the debris

soil erosion and landslides in Nepal (Fig. 2). As a result, there is a significant loss of lives, damage or blockage of road, destruction of houses and other infrastructures, and a loss of cultivated land and crops. Some of the examples are the occurrences of more than 2000 landslides in 7 districts of central Nepal during the 1993 landslide and flood disaster. According to MOHA, the Tribhuvan Highway was washed away at 20 places and 3 major concrete reinforced bridges of the Prithvi Highway over the Agra Khola, Belkhu Khola, and Malekhu Khola collapsed. In this disaster 1336 people lost their lives, 408,109 people of 72,091 families were affected, and 32,765 houses collapsed and infrastructures worth of millions of US dollars were damaged.

Similarly, a number of large landslides on the south- and southeast-facing hills of the Pokhara valley brought a huge amount of debris in Lake Phewa. As a result, almost half of the beautiful lake is already filled up with the debris (Fig. 3). Another example is the huge landslide on the right bank of the Tinau River that destroyed a reinforced concrete bridge over the East–West Highway in 1978. The mass movements on the left bank of the Tinau River in 1998 destroyed 37 houses and damaged many others. The damaged highway bridge and other large landslides in Butwal are located very close to the Main Frontal Thrust (MFT).

Flood

Flood is one of the most frequent hazards triggered mainly by a prolonged monsoon rainfall. The lowlands of Terai and some parts of mid valleys frequently suffer from flooding. It is partly because of poor land and water management. Flooding also takes place due to the overbreak of a landslide dam or any other anthropogenic structure. Occasionally debris flows change their course and scour or inundate large areas. Squatter settlements on river banks, floodplains, at the base of steep slope, and on old landslide debris are vulnerable. In many cities the encroachment of river banks and floodplains by the people and haphazard construction of houses and compound walls have narrowed down the stream course. As a result, during a heavy rainfall they suffer from bank erosion and collapse of bridge embankments. Some examples are the Bagmati, Bishnumati, Tukucha, and other streams in Kathmandu; the Seti River in Pokhara; the Sardu Khola and Seuti Khola in Dharan; the Tinau Khola in Butwal; and the Rapti Khola in Hetaunda. The settlements on the Seti River banks and Laltin Bazaar are vulnerable to block falls and flooding respectively. Because of bank erosion and block fall the highway bridge over the Seti River in Pokhara collapsed in 1991. The settlements on lowlands by the side of the Tinau River and those between the Dobhan Khola and Tinau River in Butwal and Sardu and Seuti Khola in Dharan are highly vulnerable to flooding.

GLOF

In the last 100 years, rapid melting of glaciers has created a number of glacier lakes at the terminal moraines in the Higher Himalayan region of Nepal. There are more than 3000 glacier lakes, out of which 27 are highly vulnerable (Mool et al. 2001). Their size and dammed water volume is increasing year after year. Once the natural dam is breached by the impounding water or some seismic vibrations, a sudden release of the voluminous water in the form of GLOF brings about severe damage to lives, infrastructures, and properties in the downstream areas.

Only after the 1985 Dig Tsho GLOF leading to the complete destruction of the Namche hydropower plant, damage to some bridges, and agricultural land, the Department of Hydrology and Meteorology and ICIMOD started their study of most dangerous 6 glacier lakes and possible GLOF from them (Mool et al. 2001). Out of these, the Tsho Rolpa glacier lake in the Koshi River basin and the Thulagi glacier lake in the Marsyangdi River basin are well studied. As a result, the lake level of Tsho Rolpa was reduced by digging a channel. An early warning system was also established there. Such an early warning system can help the people residing downstream to reach a safe place and save their life and some properties in case of a GLOF.

Windstorm and thunderbolt

Windstorm and thunderbolt are quite common in Nepal. Every year some people lose their lives and properties by these disasters in different parts of the country. The storm of 1991 affected 121 families and 60 people lost their lives. In 1994 about 47 people died, 74 were injured, 4,440 families were affected and 312 houses were destroyed, and similarly in 1996 about 75 people died by these disasters. In the last 23 years, 636 people lost their lives from such disasters (MOHA).

Fire

Fires are particularly common during the dry season mostly in the Terai of Nepal. As a result, 109 persons lost their lives by fires in 1989. Fires in 1992 destroyed 13,876 houses, affected 10,956 families, and killed 97 people, whereas in 1994 about 4440 families were affected, 312 houses were destroyed, 47 persons died, and 74 persons were injured. In the last 23 years 1,196 people have lost their lives from fires.

Epidemic

Epidemics like diarrhoea, gastroenteritis, typhoid, cholera, pneumonia, measles, encephalitis, and meningitis are common in remote areas and densely populated regions of Terai. Most of the epidemics are caused by poor sanitary practices and the use of contaminated water. The epidemics of 1989 killed 879 people and affected 2,986 persons. Similarly 1,101 people died in 1996, there were 1,128 deaths in 1992, and 1,207 people lost their lives in 1999 from the epidemics. In the last 23 years 12,024 people lost their lives from epidemics, which appear to be the main killer (Table 2).

INVESTIGATIONS IN URBAN AREAS

The Department of Mines and Geology (DMG) carried out engineering and environmental geological mapping and hazard assessment in some fast-growing cities and towns of Nepal. In addition to these preliminary investigations efforts were also made to locate landfill sites in a number of municipalities (Fig. 4). Some of these investigations are summarised below.

Kathmandu valley

The Kathmandu valley is an intramontane basin filled up with fluvio-lacustrine sediments. The thickness of valley fill sediments varies from less than 400 m to 549 m (Kaphle and Joshi 1998). These sediments are good aquifers of groundwater. In many cases methane gas is dissolved in the groundwater and both of them can be extracted from the same deep well. At present the over-extraction of groundwater has resulted in a rapid drawdown of water table. There is an ever increasing trend of inflow of people from outside the valley and the construction of more houses (Fig. 5), correspondingly increasing the demand of groundwater.

Such human activities are responsible for ground subsidence in some parts of the Kathmandu valley. Earthquake, landslide, flood, riverbank erosion, and riverbank collapse are the main hazards in the Kathmandu valley. Landslides, block falls, and soil erosion are common in the hilly regions of the valley. A few active faults are also helping to destabilise the ground. The saturated sandy sediments are susceptible to liquefaction during an earthquake and they may cause heavy destruction of infrastructures and a loss of lives. Human encroachment of river banks of almost all the rivers and streams, improper land use and haphazard construction of buildings are helping to make many parts of the Kathmandu city vulnerable to

Table 2: Historical records of loss of lives by various disasters in last 23 years (1983–2005)

Disaster	Loss of lives
Earthquake	727
Landslide, flood, GLOF	7084
Windstorm and thunder	636
Avalanche	102
Fire	1196
Epidemic	12024
Stampede	71
Total	**21,840**

Source: MOHA and DWIDP Disaster Review

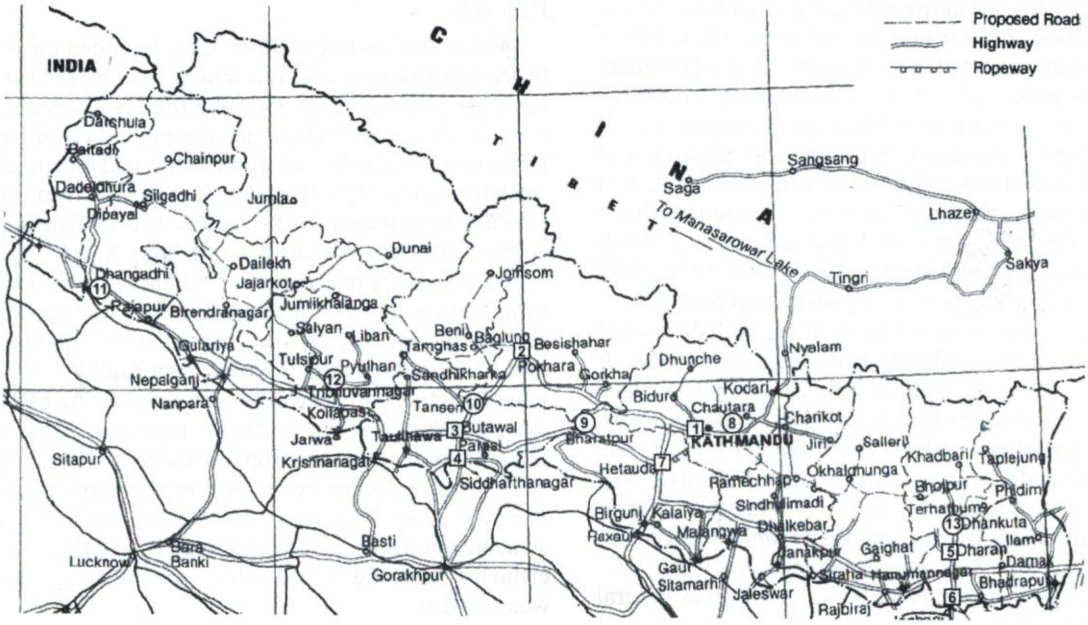


Fig. 4: Location map of engineering and environmental geological study carried out by the DMG in some urban areas of Nepal. Squares: detailed investigation, circles: preliminary investigation. 1. Kathmandu valley and Kathmandu Metropolis, 2. Pokhara valley and Pokhara Sub-Metropolis, 3. Butwal Municipality, 4. Bhairahawa – Lumbini area, 5. Dharan Municipality, 6. Biratnagar Sub-Metropolis, 7. Hetaunda Municipality, 8. Banepa Municipality, 9. Bhartpur Municipality, 10. Tansen Municipality, 11. Dhangarhi Municipality, 12. Tribhuvannagar Municipality, 13. Dhankuta Municipality

Fig. 5: Part of Kathmandu metropolis from Swayambhu. View to SE.

flood disaster. The increasing tendency of constructing multi-storeyed buildings and housing complexes on the Kathmandu valley-fill sediments without considering the ground conditions have increased the vulnerability of such structures during an earthquake. Their vulnerability is also affected by the use of substandard construction materials and an improper design.

Pokhara valley

The Pokhara city is situated on the debris comprising angular to subangular boulders, gravels, and fragments of carbonate rocks, marbles, schists, and gneisses cemented with calcareous materials. The debris was derived mainly from the Annapurna region in far north and deposited during three different catastrophic debris flow events in Seti River in the past (Upper Pleistocene to Holocene Epoch, 700–10,000 years before present). These sediments are rich in calcareous constituents and susceptible to karstification in the form of sinkholes, caverns, and subsoil pinnacles (Koirala et al. 1998). Earthquake, sinkhole, land subsidence, block fall, riverbank erosion, and landslide are the main natural hazards in the Pokhara valley. Sinkholes and land subsidence are mainly recorded in the northwestern part of the old Pokhara city, southeastern part of Phewa Lake, Hengja Bensi, and at many other places lying mostly west of the Seti River.

At places, the Seti River has made narrow and deep gorges (up to 56 m near Mahendrapul). Karsts (sinkholes, caves, caverns, pinnacles) and bank collapses (Fig. 6) are frequent in Pokhara. Several earthquakes greater than 4 on the Richter scale occurred within the valley and its close proximity in the past. The largest events were the earthquakes of 1936 (magnitude = 7) and 1954 (magnitude = 6.5) which caused considerable damage in the valley. Soil erosion and landslides frequently occur on steep slopes around the valley, and deforestation and haphazard exploitation of construction materials have aggravated the situation.

Butwal Municipality

This municipality is located at the Siwalik foothills, right on the alluvial fan of the Tinau River. Some parts of the

Butwal Municipality and surrounding regions are vulnerable to landslide, flood, and earthquake. Since the MFT passes through the northern part of the city and the Main Boundary Thrust (MBT) passes 10–12 km further north, Butwal is highly sensitive to earthquakes. Because of the presence of soft Siwalik rocks with steep topography and occurrence of heavy rainfall, landslides and floods are also frequent. As a result, the Butwal town was severely affected by huge landslides in 1978, 1998, and 1999. It also suffered from floods in 1971, 1981 and 1998, and earthquakes in 1969, 1971, 1990, and 1991. The whole hill slope in the northern part of Butwal is susceptible to soil erosion and landsliding. Well developed 3 to 4 joint sets in the sandstone beds trigger rock falls. A huge landslide in 1978 blocked the Tinau River and damaged a reinforced concrete bridge of the East–West highway. Similarly the landslides of 1998 at Jyotinagar (Fig. 7) and those of 1999 at Laxminagar destroyed 37 houses and damaged many other infrastructures. Overextraction of river gravel from the Tinau River is another problem leading to riverbank cutting and river course changes. In 1970, 1981, and 1986 flash floods in the Tinau River swept away several houses and killed many people.

Dharan Municipality

This town in eastern Nepal is also located at the Siwalik foothills, on the alluvial fans of the Sardu Khola and Seuti Khola. Some parts of Dharan Municipality and surrounding areas are vulnerable to soil erosion, landsliding, debris flows, and flooding. Since the MBT lies about 3–4 km further north, this area frequently suffered from earthquakes. The 1988 Udayapur Earthquake damaged many houses in Dharan and killed over 700 people. Landslides are quite common in the watersheds of both the Sardu Khola (Fig. 8) and Seuti Khola. They bring a huge amount of debris during the rainy season. Floods from the two rivers also destroy cultivated land, houses, and public properties.

Fig. 6: Collapsed highway bridge over the Seti River at Pokhara

Hetaunda

Hetaunda lies in the inner Terai bounded on both sides by the Siwalik foothills. It is a fast-growing industrial town having a population of about 85,000. Soil erosion, debris flow, landslide, and flood are the main natural hazards in Hetaunda. A number of landslides had occurred in the catchment areas of the Rapti Khola, Samari Khola, and Kisedi Khola lying to the north of Hetaunda Bazaar. The Rapti River is the trunk river and the Karra Khola, Samari Khola, and Kisedi Khola are its tributaries. All these rivers and streams bring much debris during the monsoon period. Some settlements located on river terraces and floodplains are prone to flooding. Almost every year highway bridges and other structures are threatened by floods. The MBT is very close (within 3–4 km north) to Hetaunda. This area has suffered for many times from the earthquakes of magnitude over 6 on the Richter scale. Soil erosion and landslides are common in the hilly areas towards the north. There is also an acute environmental problem of smoke (Figs. 9a, b) and effluents from industries, which are polluting the ground, water, and air.

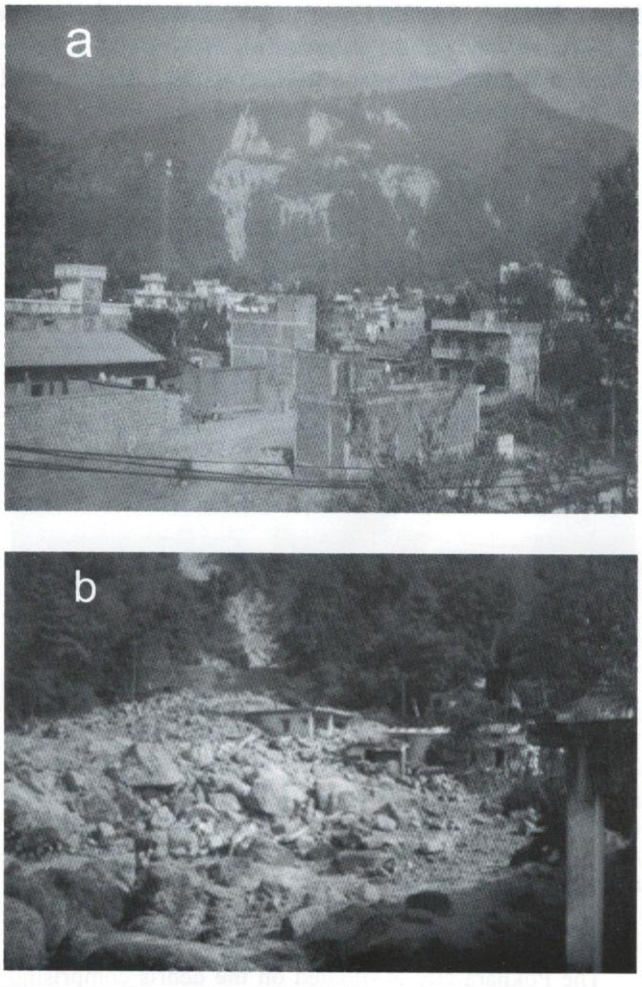


Fig. 7: Jyotinagar Landslide in Butwal, a: landslide scars, b: damaged structures

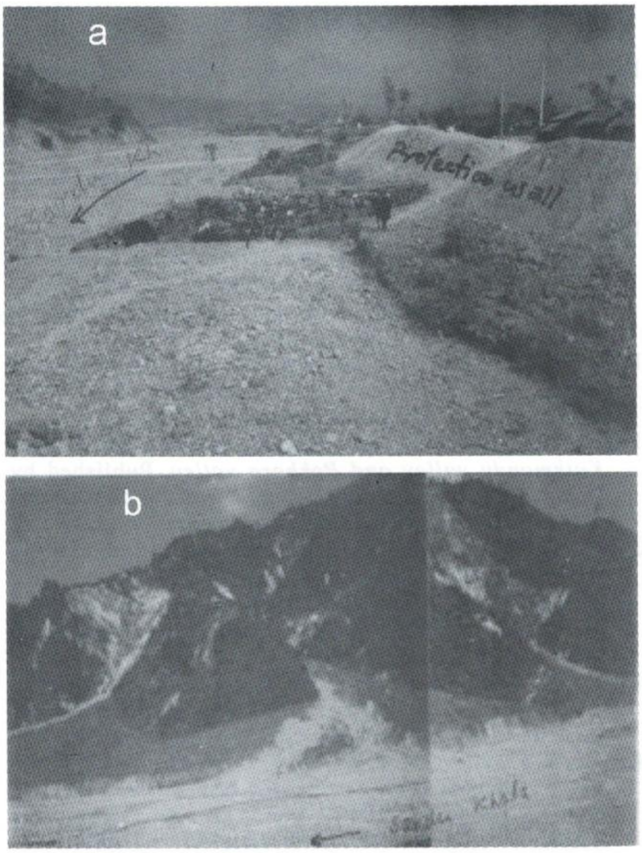


Fig. 8: a. Sardu Khola river bed and protection wall. b. Landslide, debris flow and riverbank erosion in Sardu Khola, Dharan

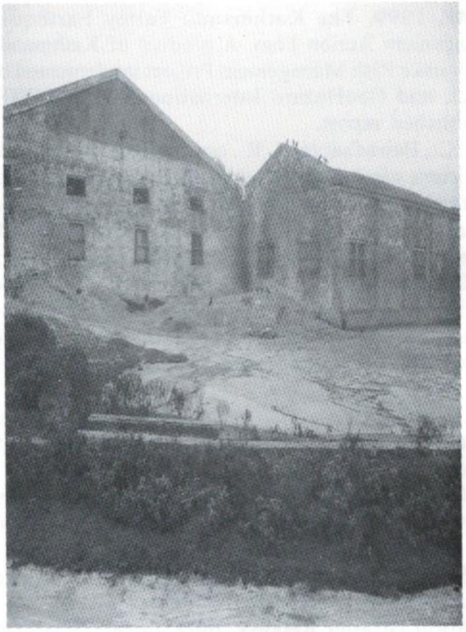


Fig. 10: Haphazard disposal of decayed organic materials and chemicals from a leather factory in Biratnagar

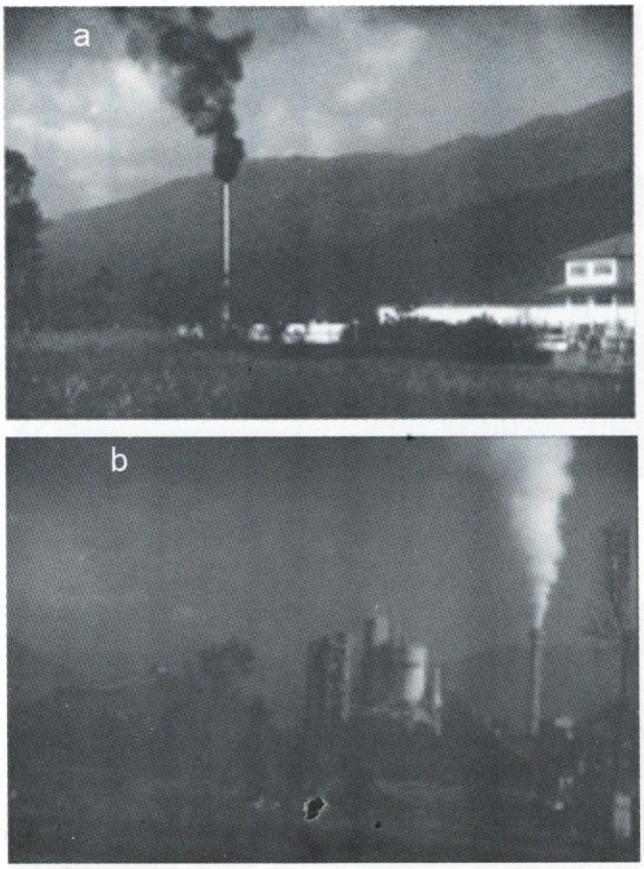


Fig. 9a, b: Air pollution from industries in Hetaunda

Biratnagar Municipality

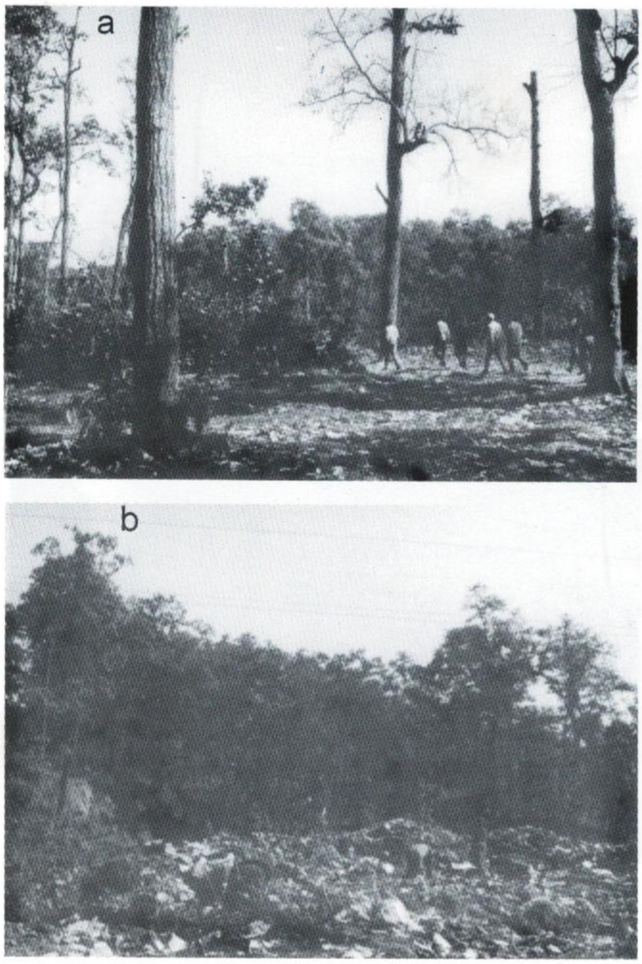
Biratnagar is the biggest industrial town in Nepal. It is located in the eastern Terai and situated about 44 km south of Dharan and 24 km south of Itahari on the East–West highway. Earthquake, soil degradation and erosion, riverbank cutting, flood, fire, and epidemic are the major hazards in Biratnagar. Since the water table is high (within 8 m) in many parts of Biratnagar sub-metropolis, there are high chances of liquefaction during an earthquake. Many industries (e.g. a leather factory, Fig. 10) are polluting the air and groundwater.

Bharatpur Municipality

The towns of Bharatpur and Narayanghat are expanding rapidly due to the migration of people from different parts of the country. Consequently the amount of daily solid waste is also increasing day by day. At present the municipality is dumping the waste in the middle of the forest. As a result trees are dying (Figs. 11a, b).

DISCUSSIONS AND CONCLUSIONS

Disaster management must equally focus on pre-disaster prevention, mitigation, and preparedness to reduce the effect



Figs. 11a, b: Trees are dying due to haphazard disposal of solid waste in the middle of the forest in Bharatpur Municipality

of disaster in addition to post-disaster response, rescue, and rehabilitation works. It should be integrated into national development plan for sustainable development and poverty reduction. In many cases earthquake, landslide, and flood are not treated as important parameters during planning and designing the infrastructures. As a result, the country faces serious problems and needs a huge amount of money for maintenance. Consequently, the Department of Mines and Geology is publishing the engineering and environmental geological maps of urban areas, which are quite helpful for infrastructural planning, disaster management, and environmental protection.

The government, NGOs, and INGOs as well as bilateral and multilateral agencies have been dealing with the disaster in isolation. Hence, there is a need of co-ordination among the partners and other related organisations. Local people and communities are the first victims of natural disaster and the first respondents. Without their participation, disaster cannot be well managed.

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