Chapter 1

Flood Hazard, Risk and Vulnerability in Nepal: the Physical and Socioeconomic Environment

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Introduction

Floods causing loss of life and property are an annual phenomenon in Nepal. A combination of highly concentrated monsoon precipitation, high relief, steep mountain topography, and deep and narrow river valleys with frequent mass-wasting phenomena renders the country susceptible to flood hazards and disasters. Each year many people are killed and made homeless by floods. Private and public property and expensive and often vital infrastructure are damaged. As a consequence, the overall development of the country has been severely affected by repeated flooding.

In the context of recent global warming phenomena, a consequent increase in the intensity of extreme precipitation events, and the dynamics of glacial lakes in high mountain areas, the probability of potentially damaging floods occurring is likely to increase. The risk that is the expected degree of loss from flood hazard is also likely to increase. The encroachment of areas susceptible to floods to establish human settlements and to carry out infrastructural development in the recent past has increased the exposure of these areas to flood hazards. In the past, before the eradication of malaria in 1956, almost all the river valleys, including areas of the Dun or Inner Terai where the threat of floods is high, were prone to malaria. People used to shuttle between the mountain ridges during the summer monsoon and the lowland areas during winter in order to avoid malaria. This also helped to avoid or reduce the impact of floods. After the eradication of malaria, investment in development of human settlements, other infrastructure, and agriculture in lowland areas increased tremendously and, consequently, so did exposure to flood hazards.

Vulnerability to flood disasters is great. Nepal is a least-developed, landlocked, and mountainous country with limited access to socioeconomic infrastructure and service facilities. Inaccessibility, a low level of human development, and mass poverty are prominent reasons for the poor capacity to anticipate, cope with, resist, and recover from and adapt to different types of hazards, floods being among them. In addition, a high population growth rate, among other factors, has led to increasing poverty. As a result, vulnerability to flood hazards is likely to increase unless effective flood mitigation and management activities are implemented. An understanding of the types, frequency, and magnitude of flood events causing harm to life and property; the extent of loss and damage from such events; and their spatial concentration is necessary in order to develop appropriate mitigation and management strategies to reduce risk and vulnerability to flood hazards.

Physical and Socioeconomic Environment of Nepal

Nepal lies in the middle of the Hindu Kush-Himalayan region. Geographically it is located between 80° 4’ to 88° 12’ east longitude and 26° 22’ to 30° 27’ north latitude, covering an area of 147,181 sq. km. The country is divided into 75 administrative districts classified into three ecological regions – the Mountains, the Hills, and the Terai (Figure 1.1). The topography is extremely rugged with elevations ranging from 60m in the south to 8,848m in the north within a short distance of about 160 km. Different mountain chains extend from east to west. In physiographical terms, the country can be divided into five regions, viz., the Terai in the south, the Siwaliks (Churia), the Middle Mountains, the High Mountains, and the High Himal (Figures 1.2 and 1.3) (LRMP 1986a).

Figure 1.1: **Nepal administrative divisions and ecological regions**

The Terai is the northern extension of the Indo-Gangetic Plain. It covers about 13% of the country's land area with altitudes ranging from 60-300m. The area consists of three major landforms: Upper Piedmont, Lower Piedmont, and the Active Alluvial Plain. The Upper Piedmont is formed of a coalescence of fans made of coarse river deposits lying adjacent to the Siwaliks. The slope of the terrain is relatively steep (1-20°) compared to lower areas of the Terai. Bank erosion, channel shifting, and debris torrents are common. The Lower Piedmont is characterised by pebbly and sandy sediments with a few layers of clay. Spring lines, natural ponds, marshy land, and river meandering are common features. The water table is higher than in the Upper Piedmont. River shifting, bank scouring, and sheet flooding are common here. The Alluvial Plain is a typical Gangetic Plain. It is composed mainly of finer sediments comprising sand, silt, and clay. The water table is generally below four metres. Occasional to severe flooding is common. During heavy monsoons most areas remain inundated or wet for many days.

The Siwaliks or the Sub Himalayas constitute a 10-30 km wide foothill belt which includes the Inner Terai (Doon valleys). This area accounts for about 12% of the total area of Nepal. The Siwaliks have a relative relief of less than 1,000m; the slopes are generally steep with shallow soils. The Siwaliks can be stratified into

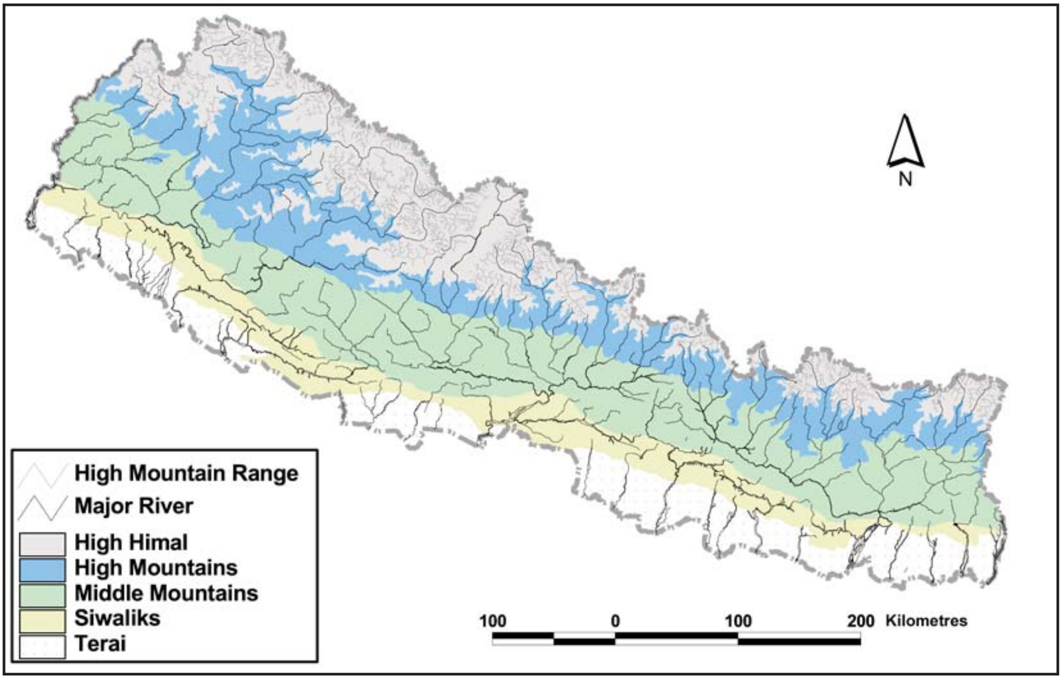

Figure 1.2: **Nepal physiographic regions and drainage network** Source: DWIDP

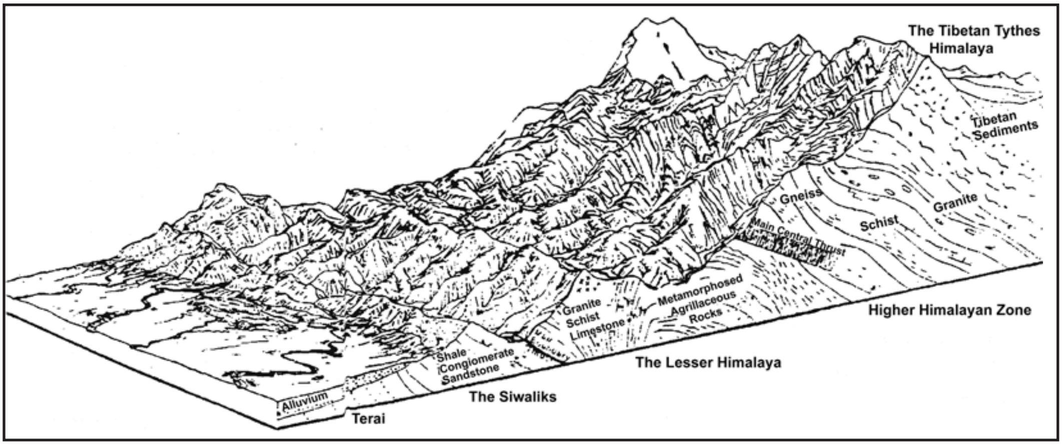

Figure 1.3: **Physiographic regions vis-à-vis major geological formations of the Nepal Himalaya**
Source: DWIDP

three formations: the Lower Siwaliks, the Middle Siwaliks, and the Upper Siwaliks. The Lower Siwaliks consist of hard sandstone with conglomerates containing pebbles of clay and shale, whereas the Upper Siwaliks are composed of coarse conglomerates, sands, grits, and clay. Rivers are extremely flashy; large coarse sediment deposits in a dry river make up a large proportion of the river system. These rivers are extremely unstable and cause immense damage to lives and property every year.

The Middle Mountains, also known as the Lesser Himalaya, cover about 30% of the total area of Nepal. The total width ranges from 60-80 km. These mountains are made up mostly of non-fossiliferous sedimentary and meta-sedimentary rocks such as shale, sandstone, conglomerates, slate, phyllite, schist, quartzite, limestone, dolomite, and others. Two distinct geomorphic units can be identified in the Lesser Himalaya: the Mahabharat Range and the Midland. The Mahabharat Range (lekh) rises fairly abruptly from the Siwaliks to elevations between 1,500 and 3,000 metres above mean sea level (masl). The terrain is rugged with sharp crests and steep slopes. This range also forms the first effective barrier to the monsoon clouds entering the Himalaya and has a considerable influence on the country's rainfall distribution. Due to its steep terrain and rain-bearing flanks, the south-facing slopes of the Mahabharat Lekh are highly prone to landslides, debris flows, and floods. The Midland consists of subdued hills, wide river valleys, and tectonic basins. This zone has an average width of 60 km and the relief ranges from about 1,000-1,500m from the valley bottom to the hilltops. Due to the gentle topography, wide valleys, and warm temperate climate, this zone is densely populated and nearly 40% of the total population of Nepal lives here.

The High Mountains (the Fore-Himalaya or temperate lekh or Higher Himalaya), composed of gneiss, quartzite, and mica schist, cover about 20% of the total area of Nepal. Altitudes range from 2,000 to 4,000m. Topographically, this mountain range has extremely rugged terrain with steep slopes and deeply cut valleys.

The Tibetan-Tethys Himalaya

The Tibetan-Tethys Himalaya or High Himal in the north is composed of gneiss, schist, limestone, and Tethys sediments. It occupies nearly 24% of the total area. The Himal represents four distinct landscape units: the Great Himalaya, trans-Himalayan valleys (Bhot), Tibetan marginal lands, and the Tibetan Plateau (LRMP 1986a; Gurung 2004; Upreti 2001). A large proportion of the Great Himalaya is covered by rock and ice. Snow avalanches, rockfalls, and gully erosion are common geomorphic hazards.

The climate at macro-level is dominated by the summer monsoon and topography plays an important role in creating meso- and micro-level differences (Chalise 2001). Hence, there are pronounced temporal and spatial variations in precipitation. The average area-weighted annual precipitation for Nepal is about 1,630 mm. More than 80% of the total annual precipitation occurs during the summer months (June-September). In extreme cases up to 37% of the mean annual precipitation occurs within 24 hours Spatially, mean annual precipitation ranges from only 163 mm in Lomangthang (Mustang) located in the trans-Himalayan zone north of the Higher Himalayan ranges, to more than 5,000 mm in Lumle (near Pokhara) located in the southern part of the Higher Himalayan ranges. A few isolated pockets of dense precipitation are located in different parts of the country. High intensity precipitation is a characteristic micro-climatic feature which is responsible for the repeated occurrence of devastating floods (Figure 1.4). For example, rainfall exceeding 300 mm within 24 hours, which generally disturbs both hill slope and river channel equilibrium on a regional scale, occurs frequently. Precipitation as high as 540 mm in 24 hours with a peak intensity of 70 mm per hour occurred on July 20, 1993 in Central Nepal, causing a big flood disaster. Several hundred people were swept away and much infrastructure and property damaged (Dhital et al. 1993). A preliminary analysis

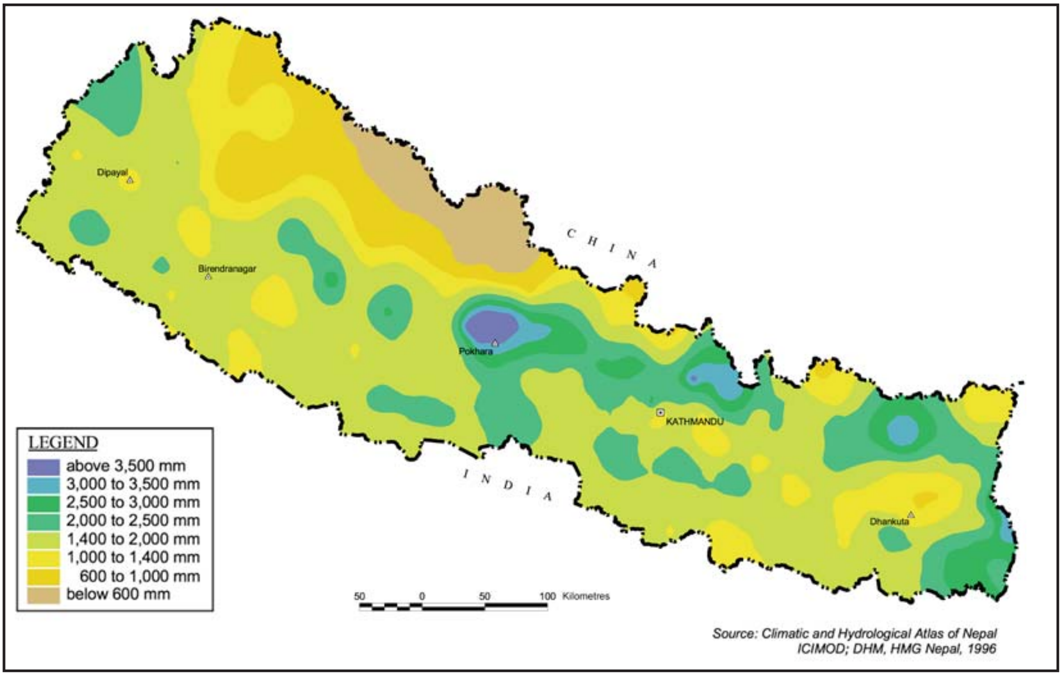

Figure 1.4: **Nepal distribution of mean annual rainfall**

of the frequency of extreme precipitation, with rainfall exceeding 100 mm within 24 hours, occurring between 1971-1990 in the country, indicated an increasing trend in such events in recent years (Chalise and Khanal 2001). This shows that the probability of occurrence of flood hazards has increased.

Nepal has a dense network of more than 6,000 rivers. Some of these rivers originate in the relatively drier Tibetan Plateau in the People's Republic of China to the north. These rivers are antecedent and have crossed high mountain ranges forming deep gorges and narrow river valleys. The total average annual runoff from these river systems is estimated at about 225 billion cubic metres. The rivers are characterised by high water and sediment discharge during summer. In the hydrological cycle, about 64% of all rainfall immediately drains as surface runoff. Inter annual variation in discharge is also very high. Based on temporal variation in water discharge these rivers can be divided into three types: snow-fed perennial rivers originating in the High Himal with low seasonal fluctuation in discharge; groundwater-fed intermittent rivers originating in the High Mountains and the Middle Hills with wide seasonal fluctuation; and ephemeral or flashy rivers with very high width-depth originating from the Siwalik (Churia) hills in the south. River channels in the Inner Terai and the Terai regions are extremely unstable and various forms of channel shifting, such as avulsion, chute-off, neck-off, and meander shift, are common.

According to the Population Census of 2001, Nepal had a total population of 23.15 million. Nearly 7.3% of the population lives in the northern Mountain Region, 44.3% in the Middle Hills, and 48.4% in the Terai region (CBS 2002). Population density ranges from 33 persons per sq. km in the Mountain Region to 167 persons per sq. km in the Middle Hills, and 330 persons per sq. km in the

Terai Region. The annual growth rate in population remained 2.25% between 1991 and 2001. It is comparatively high (2.62%) in the Terai region. Family size is rather large (5.4 persons) and the joint family system is common in many rural areas. There is wide cultural diversity with more than 100 ethnic/caste groups having their own distinct language and culture. The overall literacy rate for the population six years and above is still low at 54.1%; 65.5% for males and 42.8% for females.

Agriculture is the main source of income for the majority of people. More than 80% of the workforce is engaged in agriculture. However, agriculture is still subsistence-oriented and characterised by low input use and low productivity. Employment in agriculture is mostly seasonal and many people (50%) are underemployed. Nearly 8% of the total labour force is unemployed. Poverty is widespread with around 38% of the population living below the poverty line. More than one-third of all households have temporary (kachhi) houses constructed with non-durable materials like wooden matting, bamboo, straw/thatch, and mud which are highly susceptible to flooding. Sanitation is another important concern in rural areas. Only 47% of households have toilet facilities. Households with modern means of communication such as radio and television, are few: 53.1% and 23.5%, respectively. Access to social services, such as schools, health centres, and modern means of transport, is very limited. It takes several days to reach the road from many rural settlements.

Types, Magnitude, and Frequency of Natural Disasters in Nepal

The most frequent hazards causing tremendous losses in lives and property are floods, landslides, avalanches, hailstorms, windstorms, lightning, earthquakes, fire, and epidemics. On average, natural disasters take a toll of 951 lives and damage property worth NRs 1,242 million every year (Table 1.1). The actual figure is thought to be higher because the available statistics do not cover every disaster, particularly those in remote mountain areas, and do not include drought, frost, soil erosion, bank erosion, and so forth; and the impact of these are not immediate but over time they cost a great deal. In addition, most disaster reporting is biased towards human casualties.

Table 1.1: Average annual loss of life and property from natural disasters, 1983-2005

Types of Disaster	Loss of life		Families affected		Loss of property	
	No.	%	No.	%	million Rs	%
Floods, landslides and avalanches	309	32.5	27,654	69.7	749.58	60.3
Hailstorms, windstorms and thunderbolts	34	3.5	4,845	12.2	40.86	3.3
Earthquakes	32	3.3	2,979	7.5	228.54	18.4
Fire	52	5.5	3,192	8.0	223.45	18.0
Epidemics	524	55.2	982	2.5	0.00	0.0
Total	**951**	**100.0**	**39652**	**100**	**1242**	**100**

Source: compiled from *The Annual Disaster Review* (different issues), DWIDP

Of the different types of disaster, the overall impact caused by floods, landslides, and avalanches is most severe. Between 1983 and 2005, an average of 309 people died annually, which is lower only than the deaths caused by epidemics, i.e., 524 lives per year (Table 1.1). The loss of life from floods, landslides, and avalanches is about 32% of the total deaths (Figure 1.5).

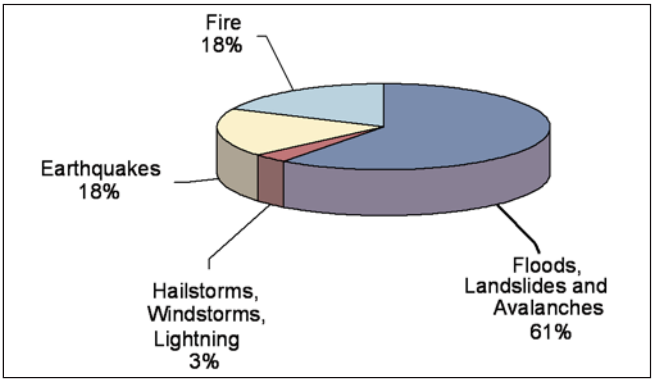

Figure 1.5: **Loss of life from different natural disasters in Nepal, 1983-2005**

Similarly, every year on average, more than 27,654 families are affected by these hazards. They represent about 70% of the total families affected by all types of natural disaster in Nepal (Figure 1.6). The average number of families affected annually by earthquakes and fire is more or less equal (8% of the total families affected by all types of disaster). Many families are also affected by hailstorms, windstorms, and lightning. They account for about 12% of the total families affected by all types of disaster.

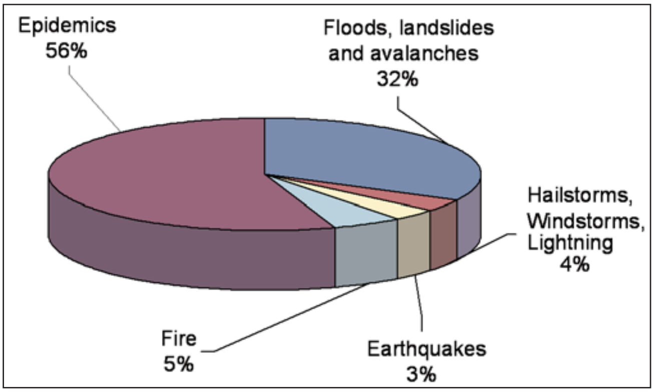

Figure 1.6: **Families affected by different natural disasters in Nepal, 1983-2005**

Annually, property worth more than NRs 749.58 million is lost from floods, landslides, and avalanches. Loss of property from all these types of disaster combined accounts for about 61% of all types of natural disaster in Nepal (Figure 1.7). Although the loss of life and property from earthquakes in a particular year remains quite high, the average loss over the long term is greater from floods and landslides. Nearly 18% of the total amount of property lost is from fire, which is more or less equal to the losses from earthquakes.

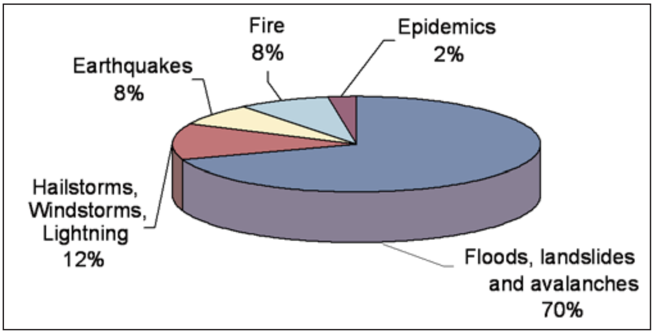

Figure 1.7: **Estimated amount of property lost, 1983-2005**

Floods

In Nepal, devastating floods are triggered by different mechanisms which can be classified into five major types: i) continuous rainfall and cloudburst, ii) glacial lake outburst floods (GLOFs), iii) landslide dam outburst floods (LDOFs), iv) floods triggered by the failure of infrastructure, and v) sheet flooding or inundation in lowland areas due to an obstruction imposed against the flow (Dixit 2003; Khanal 2005).

Continuous rainfall and cloudburst

Floods are common throughout the country in the latter stages of the summer monsoon when the land is saturated and surface runoff increases. Extremely high intensity precipitation in mountain areas cause landslides on mountain slopes and debris flows and floods along the river valleys. Extreme precipitation events between 1948 and 1955 caused landslides and debris flows in mountain areas and, consequently, destructive floods on many rivers in lowland areas. The highest flood recorded occurred on the Kosi River in 1954 and was the result of widespread rainfall in its mountain catchment area (Dixit 2003). Livelihood options for many families in mountain areas were threatened. As a response, the government began resettlement programmes in the Inner Terai and Terai regions in 1956 for severely affected families. At the same time, spontaneous large-scale migration from the mountains to the Terai and from ridge to river valleys took place immediately after these events and concomitant implementation of a malaria eradication programme in the lowland areas (Khanal 2004).

In recent years, between 1981 and 1998, three events of extreme precipitation with extensive damage have been reported (Chalise and Khanal 2002). Devastating floods associated with high intensity precipitation and consequent landslide and debris flow activities in the mountain terrain occurred in Lele (Lalitpur district) on September 30, 1981; in Kulekhani-Sindhuli area on July 19-20, 1993; and in Syangja district on August 27, 1998. In the 1993 event, the loss of life and property was not confined to the mountain areas where high-intensity precipitation had taken place; hundreds of people were also swept away in downstream areas as far away as Rautahat and Sarlahi districts in the Terai.

Glacial lake outburst floods (GLOFs)

Glacial lakes are common in the High Himal area of Nepal. A recent study shows that there are 3,252 glacial lakes in Nepal (Mool et al. 2001). Altogether 21 GLOF events were identified, of which 13 occurred in 34 years between 1964 and 1998. Out of 21 GLOFs identified, nine occurred in the Tibet Autonomous Region (China) affecting downstream areas along transboundary rivers like the Sunkoshi, Arun, and Trisuli in Nepal. A GLOF in 1981 damaged a hydropower plant and many houses along the Sunkoshi River and a similar event in 1985 swept away three persons, one hydropower plant, 14 bridges, and 35 houses along the Dudhkoshi River. Nearly 26 glacial lakes are identified as potentially dangerous and much of the infrastructure along the rivers originating from these lakes is at immediate risk.

Landslide dam outburst floods (LDOFs)

Formation of temporary lakes due to landslide damming is a common phenomenon in high mountain areas where there are very narrow river channels and steep mountain slopes. Eleven disastrous floods caused by breaching of landslide dams have been reported in Nepal between 1967 and 1989 (Khanal 1996). Budhigandaki River near Lukubesi in 1968, Sunkoshi River near Barhabise in 1982, Balephi Khola in Sindhupalchok in 1982, and Gyangphedi Khola in Nuwakot in 1986 were dammed by landslides and resultant outburst floods swept away many people and damaged infrastructure, including human settlements.

Floods triggered by infrastructural failure

Floods triggered as a result of poor infrastructural design are also common in Nepal. Eight floods from such causes have been reported. Failure of checkdams and embankments in Butwal in 1981 led to 41 people, 120 houses, and one bridge being swept away. Similarly, 26 people and 880 houses were swept away by a flood triggered by the failure of a checkdam on the Rapti River in Chitwan in 1990. In 1993, the Bagmati River was dammed for a few hours because of blocking by tree logs at the Bagmati barrage and an outburst flood swept away 816 people in Rautahat and Sarlahi districts. Larcha River was dammed by a boulder at the bridge over the highway in 1996 and an outburst flood swept away 54 persons and damaged 22 houses.

Sheet flooding

Sheet flooding or inundations are common during the summer monsoon in lowland areas in the southern Terai region. The risk of such hazards has been increasing in recent years as a result of increasing development of infrastructure such as roads, culverts, and checkdams, and consequent obstruction in the natural flow of surface runoff. Moreover, unilateral construction of roads perpendicular to natural flow without sufficient drainage and construction of barrages, dams, afflux bunds, and dykes on the rivers near the border area between India and Nepal have also exacerbated flooding in Nepal (Bhusal 2004). More than 10 cases of such infrastructure-induced flood disasters have been reported near the border area.

Information on losses from the different types of flood hazards mentioned above is not available. The information available is in combination with floods, landslides, and avalanches at district level. Table 1.2 shows the losses from floods, landslides, and avalanches in combination between 1983 and 2005. Annual deaths from floods, landslides, and avalanches in the recorded history of 23 years ranged from 49 to 1,336, with an annual average of 309 persons. Similarly, the number of persons injured ranged from 4 to 265 with an annual average of 68 persons. Another important element of loss is livestock. Figures ranged from 36 to 25,425 with an annual average of 2,161 livestock lost. Damage to houses ranged from 88 to 33,721 with an average of 7,241 houses destroyed annually. Similarly, the number of families affected by these hazards ranged from 545 to 128,540 with an annual average of 27,654 families. The estimated area affected ranged from 135 ha to 41,867 ha with an annual average of 3,914 ha. Data on the loss of infrastructure are scant; there has been no record for many years. However, earlier data show that the amount of infrastructure damaged by floods and landslides ranged from 25 to 869 structures with an average of 86 per annum. Estimated loss of property within this period ranged from NRs 10.78

Table 1.2: **Losses from floods, landslides, and avalanches, 1983-2005**

Year	Deaths (No.)	Injured (No.)	Livestock lost (No.)	Houses destroyed (No.)	Families Affected (No.)	Land Affected (ha)	Infrastructure damaged (No.)	Estimated losses (In million NRs)
1983	293	NA	248	NA	NA	NA	NA	240.00
1984	363	NA	3114	7566	NA	1242.00	869	37.00
1985	420	NA	3058	4620	NA	1355.00	173	58.10
1986	315	NA	1886	3035	NA	1315.00	436	15.85
1987	391	162	1434	33721	96151	18858.00	421	2000.00
1988	342	197	873	2481	4197	NA	NA	1087.00
1989	700	4	2979	6203	NA	NA	NA	2528.61
1990	307	26	314	3060	5165	1132.00	NA	44.00
1991	93	12	36	817	1621	283.00	25	21.20
1992	71	17	179	88	545	135.00	44	10.78
1993	1336	163	25425	17113	85254	5584.00	NA	4904.00
1994	49	34	284	569	3697	392.00	NA	59.00
1995	246	58	1535	5162	128540	41867.28	NA	1419.00
1996	262	73	1548	28432	37096	6063.40	NA	1186.00
1997	87	69	317	1814	5833	NA	NA	102.00
1998	273	80	982	13990	33549	326.89	NA	969.00
1999	214	92	331	2543	9769	182.40	NA	365.00
2000	173	100	822	5417	15617	888.90	NA	932.00
2001	196	88	377	3934	7901	NA	NA	251.10
2002	441	265	2024	18181	39309	10077.50	NA	418.91
2003	232	76	865	3017	7167	NA	NA	234.78
2004	131	24	495	3684	14238	321.82	NA	219.28
2005	162	34	588	1103	2130	NA	NA	137.81
Average*	309	83	2161	7570	27654	5627	328	750

* Average for years for which data are available (values would be lower if there was no loss in the years for which no data is available)

NA = no data available; Note: Figures rounded to the nearest whole number

Source: Compiled from the *Annual Disaster Review*, different series published by DWIDP million to 4,904 million with an average of 750 million annually. On average, the losses from floods and landslides are almost 0.6% of the GDP at current prices (2006), 3% of the total budget, 4.7% of total development expenditure, and 14.9% of foreign loans.

The estimated loss of life and property between 1983 and 2005 is shown in Figure 1.8. The loss fluctuated year by year and there is no clear trend. In one particularly bad year (1993), deaths of 1,336 persons were recorded, and the country's economy was badly ravaged. The estimated loss was equal to approximately 3% of the GDP, 23% of development expenditure, Losses unaccounted for from disruption in transportation, power and water supplies, and normal business were also discouraging. The government has to spend large amounts of money every year in relief and reconstruction activities. On average 12.9% of the development expenditure of Nepal and 5.39% of its real GDP are spent on disaster response and recovery activities every year (Li and Behrens 2002).

Since there are no separate statistics recorded for flood disasters in Nepal, the extent of flood disasters in the country can be inferred from the loss of life and property in the Terai districts where the impact of landslides and avalanches is almost absent. Table 1.3 shows the losses from floods, landslides, and avalanches by ecological regions in Nepal between 1992 and 2001. Though the loss of human lives from floods in the Terai is not as high as those in other ecological regions of Nepal, the damage to and loss of property are significantly high. The amount of damage and loss of property caused by floods in the Terai is 77% of the total loss due to floods, landslides, and avalanches combined from 1992-2001. During this period, the loss of housing, livestock, and farmland in the Terai was about 85, 71, and 69% of the total, respectively. Similarly, the number of families affected by floods was 70% of the total. It is difficult to quantify the losses and damage caused by floods or landslides separately in the Hill and the Mountain districts; the impact of floods, even in these districts, is significant. Hence the statistics indicate that the scale of disasters from flood hazards is very high. Coupled with rapid population growth and a high incidence of poverty and

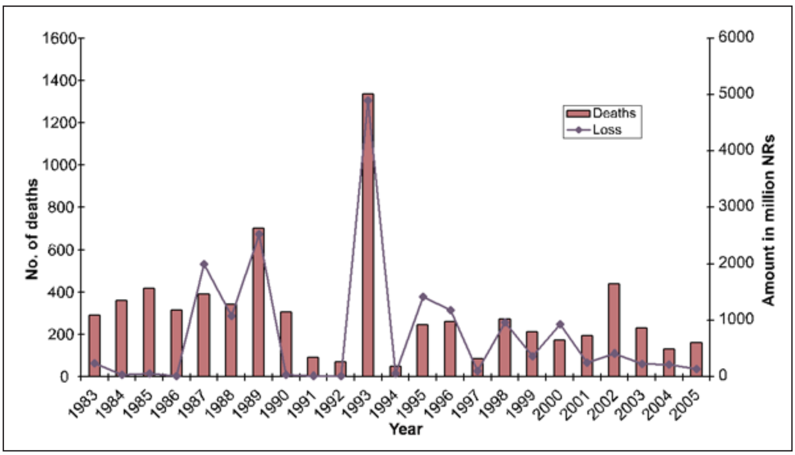

Figure 1.8: **Annual loss of life and property from landslides, floods, and avalanches**

Ecological region	Loss of lives (No.)	Persons injured (No.)	Houses destroyed partly (No.)	Houses destroyed completely (No.)	Cattle sheds destroyed (No.)	Families Affected (No.)	Loss of farmland (ha)	Loss of livestock (No.)	Amount lost (million (Rs)
Hills	1,488	413	7,941	12,510	1,380	80,475	37,283	7,214	4,053
Mountains	323	103	373	1,346	104	10,072	32,45	1,742	466
Terai	1,002	117	47,887	44,292	1,248	221,232	878,70	22,233	15,443
Total	**2,813**	**633**	**56,201**	**58,148**	**2,732**	**311,779**	**128,399**	**31,189**	**19,962**

Table 1.3: **Losses from floods and landslides by ecological region, 1992-2001**

Note: Total figures are rounded to the nearest whole number
Source: Compiled from *Annual Disaster Review*, different series published by DWIDP

landless and marginal farmers, the vulnerability in the Terai is high. Figure 1.9 shows the frequency of floods and landslides by district, and the annual number of deaths, families affected, and estimated losses from floods and landslides. Although the loss of life is comparatively low in the Terai districts where floods are the major natural disasters, the extent of impact in terms of the number of families affected and loss estimated is very high. Districts located in the central Terai, such as Rautahat, Sarlahi, Mahottari, and Dhanusa, are seriously affected by floods. A comparison made by Khanal (2005) of the loss and damage between 1970 and 1993-2002 shows that the central and eastern Terai have been experiencing increasing losses from water-induced disasters in the years after 1992. Again in the central Terai, Rautahat, Sarlahi, Mahottari, Dhanusa, and Sindhuli districts have been repeatedly and seriously affected by floods.

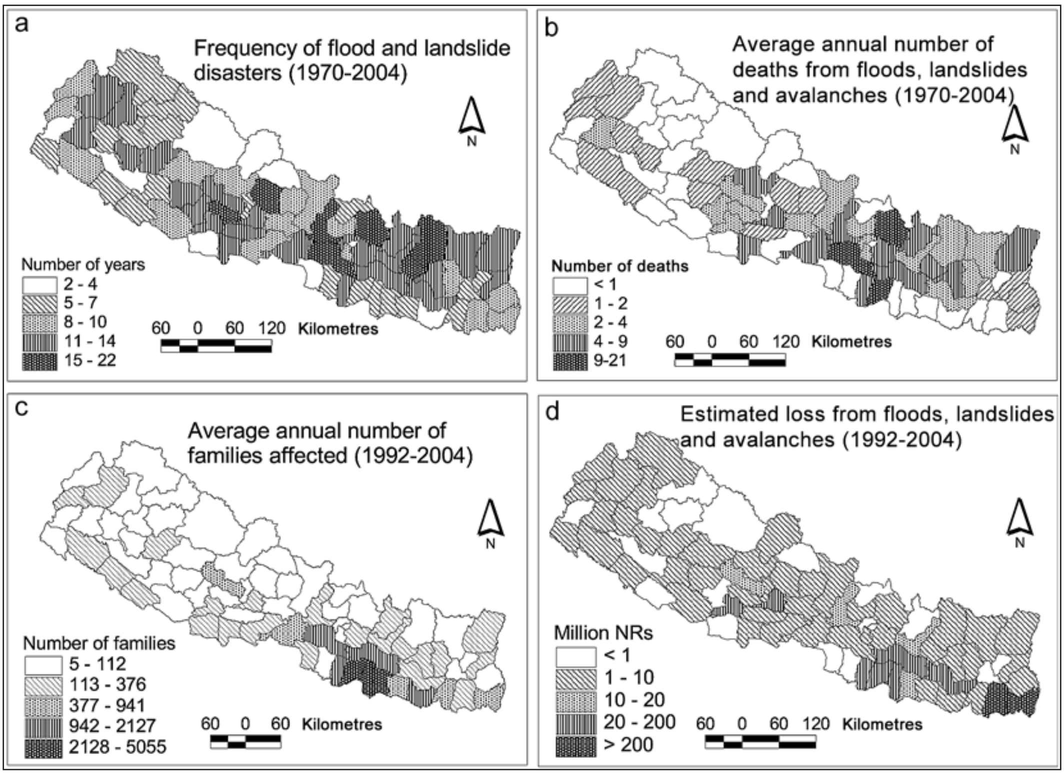

Figure 1.9: **Frequency of flood and landslide hazards and impact by district** Source: DWIDP

Vulnerabilty

Various definitions of vulnerability have been provided in the context of natural hazards and climate change (Varnes 1984; Blaikie et al. 1994; Twigg 1998; Kumar 1999; Kasperson 2001). From these definitions, vulnerability can be viewed from the perspective of the physical, spatial or locational, and socioeconomic characteristics of a region. Physical vulnerability could be referred to as a set of physical conditions or phenomena, such as geology, topography, climate, land use and land cover, and so forth, which renders a place and the people living there susceptible to disaster. The technical capacity of the built-up environment to handle the impact of a natural hazard is also a factor of physical vulnerability. Spatial vulnerability is closely related to physical vulnerability. The degree of danger or threat and the levels of exposure and resilience to threat are closely associated with location. Hence, spatial vulnerability is a function of location, exposure to hazards, and the physical performance of a structure, whereas socioeconomic vulnerability refers to the socioeconomic and political conditions in which people exposed to disaster are living. These vulnerabilities at national level are briefly discussed below.

Physical and spatial vulnerability

Different factors are responsible for physical and spatial vulnerability to flood hazards in Nepal. These factors are discussed below.

Extremely dynamic landscape

Nepal is situated in a high-energy environment because of its rugged relief, steep mountain slopes, active tectonics, highly concentrated precipitation, and intense human activities in landscapes associated with high growth and density of human and livestock populations, along with a subsistence agricultural economy. As a result, the rate and magnitude of occurrence and operation of geomorphic processes are high. Landslides, erosion, debris torrents in the hills, and rises in bed level due to excessive sediment loads in the rivers and the shifting of river channels in the Terai are typical geomorphic processes during the summer rainy season. Both accumulation of snow as a result of the availability of moisture in the atmosphere, and melting due to high temperatures, take place simultaneously during summer. Snow avalanches, intense glacial erosion, and formation and outburst of glacial lakes are common phenomena in the High Himal area. In periglacial areas, freezing and thawing of ground surfaces are common processes resulting in increased physical weathering and rupturing and dislocating of rock blocks leading to rockfall. These processes are responsible for the production of huge amounts of transported hill-slope materials and increased sediment loads in rivers. The highest global rate of sediment production has been reported for Himalayan river basins such as the Kosi, Narayani, and Karnali (2,000-5,000 tonnes km^{-2} $year^{-1}$). Similarly, rivers originating in the Siwaliks adjacent to the Terai region, such as the Tinau, Rapti, Bagmati, Kamala, and Lothar, carry disproportionately huge sediment loads. Immense fans formed by Himalayan rivers in the foothills indicate a high degree of sediment production and transport in upstream areas due to intense mass-wasting. The frequent seismic events and excessive rainfall make the terrain susceptible to erosion, landslides, debris flows, channel shifting, and sedimentation, and these are responsible for excessive sediment loads in the rivers. This increases water levels in the rivers and risk and vulnerability to floods.

Inaccessibility

Access to infrastructural services such as transportation, communications, health, marketing, and other extension services like education, skills development, and so on, plays an important role in all stages of flood-hazard mitigation and management: pre-disaster preparedness, during disaster evacuation and relief activities, and post-disaster rehabilitation and recovery. Nepal, being a landlocked country bordered by China in the north and India in the south, east, and west, does not have easy access to other countries via land and water transportation. This has created problems in the timely flow of goods and services, and the ability to take advantage of cheaper means of transportation. Moreover, Nepal's rugged topography has constrained the development of service infrastructure. Many areas are not yet connected by any modern means of transportation. The development of water and railway transportation in the country is insignificant. Even the road network is very poor. As of 2003 there was a total road length of 16,835 km out of which 28% was black topped, 27% gravelled, and 45% earthen (CBS 2005). The country's road density is only 11.4 km for an area of 100 sq. km and 7.2 km for every 1,000 people. However, its development is not uniform in all regions. Out of 75 administrative districts, 16 districts located in the mountain region are not connected by any type of road. Though the density of roads in terms of area in the Terai districts, which are highly prone to flood hazards, is comparatively high, a large proportion of roads are earthen and most of them are closed during the rainy season when flooding occurs. Improvements in accessibility through developing the road network is an essential prerequisite to reducing vulnerability to different types of hazard. Notwithstanding the absence of proper design, lack of road maintenance has increased vulnerability to landslides and floods. Poorly designed roads without regular maintenance have created serious problems in the form of landslides and erosion in mountain areas, and insufficient drainage along the roads has exacerbated inundation in the Terai.

Declining access to physical assets

Agriculture is the main economic activity in Nepal. Access to physical assets, particularly land and land-based resources, has declined and continues to decline with population growth. The quality of resources has been deteriorating. The result has been encroachment on marginal lands prone to soil erosion, landslides, and floods. The land capability survey (LRMP 1986) shows that about 67% of the land is unsuited to cultivation and human settlement due to different biophysical conditions. Geographical information systems (GIS) overlay analysis of the land utilisation and land capability map prepared by the Land Resources Mapping Project (1986) and carried out by Kenting Earth Sciences and the Government of Nepal indicates that about 30% of all hill slope cultivation is carried out on unsuitable land, increasing vulnerability to erosion, landslides, and debris flows. About 21% of lowland cultivation lies in flood-prone areas.

Widely-dispersed human settlements and migration

Human settlements in mountain areas are widely dispersed and small in size. In the past, security issues from the perspective of avoidance of wars and diseases, as well as access to food, water, and energy, were considered important factors in the development of human settlements. Hence, many permanent settlements, particularly in mountain areas, were developed on stable mountain slopes to avoid the malaria in lowland areas. The size of settlements was determined by the capacity of physical assets in the surrounding area to fulfil the needs of the encapsulated settlement and its population. However, the rapid growth in population and increasing pressure on available resources, on the one hand, and eradication of malaria from lowland areas, on the other, led to the emergence and expansion of human settlements in lower river valleys in the mountains, the Inner Terai, and the Terai. Both immigration from outside the country and in-migration in the Nepal Terai from the hills and mountains remained high since the 1950s. Evidence of this can be seen from the increase in population in the Terai from 35.2% in 1952/54 to 36.4% in 1961, 37.6% in 1971, 43.6% in 1981, 46.7% in 1991, and 48.4% in 2001 (Pantha and Sharma 2003).

The rapid rate of population growth has led people to encroach on even marginal areas susceptible to flood hazards. Moreover, people who moved to new places with experience of different environmental conditions and processes in their place of origin are less experienced in the type, frequency, and magnitude of floods in their new destinations and thus, less capable of anticipating flood hazards and invest unknowingly in hazard-prone areas. Along with the emergence and expansion of settlements, other infrastructure also developed in nearby areas. In the absence of building codes and proper technical standards for built-up environments, the risk of and vulnerability to floods have been increasing.

Socioeconomic vulnerability

The scale and magnitude of impacts of natural hazards are not only determined by physical vulnerability, they are derived from a combination of both physical and socioeconomic vulnerability. Socioeconomic vulnerability is the extent to which an individual, community, subgroup, structure, or geographical area is likely to be damaged or disrupted by a disaster. In the words of Blaikie et al. (1994) vulnerability is the characteristic of a people or group in terms of its capacity to anticipate, cope with, resist, and recover from the impact of a natural disaster. Hence, it refers to coping capacity/actions and resilience of the people, society, and institutions of a nation. A brief overview of socioeconomic vulnerability is discussed in the following sections.

The coping capacity for and social resilience to natural disasters assessed in terms of some key socioeconomic and infrastructural indicators presented in Table 1.4 indicate that these are among the low and lowest levels in the South Asian region. The causes of poor coping capacity are as follows.

Low human development index

Nepal's overall human development index ranking (based on 2000 data) is 142 out of 173, lower than all our Asian neighbours except Bangladesh. Poverty has

Table 1.4: Socioeconomic indicators of Nepal and other countries in South Asia

Country	Nepal	India	Bangla-desh	Pakistan	South Asia
Total population (millions)	23	997.5	131.1	138.1	1.4 billion
Population density (persons km^{-2})	148	335.5	997	179	283
Annual population growth (%)	2.4	1.8	1.7	2.4	1.9
National poverty rate (% of population)	42	35	35.6	34	
Life expectancy at birth (years)	58.9	61.4	61.2	63	62.4
Malnutrition prevalence (% of children under 5)	46.9	47	61.3		48.7
Urban population (% of total)	11.9	28.1	24.5	37	28.4
Illiteracy rate, adult male (% of males 15+)	40.4	32.3	47.7	42.5	33.9
Illiteracy rate, adult female (% of females 15+)	76	55.6	70.1	72.1	57.3
Improved water sources (% of total population with access)	81		97	88	87.2
Improved sanitation facilities, urban (% of urban population with access)	75		82	94	76
Energy use per capita (kg of oil equivalent)	357.9		139.3	443.9	440.6
Electricity use per capita (kWh)	47.1	379.2	89	321.2	337
GNI per capita, Atlas method (current US$)	240	440	370	440	440
Annual GDP growth (%)	6.5	7.1	5.9	4.4	4.2
Inflation, GDP deflator (annual %)	4.3		1.9	3.7	4.1
Agricultural productivity per agricultural worker (1995 $)	189	395	247	626	306
Agriculture, value added (% of GDP)	40.3	26.2	24.6	26.3	25.1
Industry, value added (% of GDP)	22.4	26	24.4	22.8	26.2
Services, etc., value added (% of GDP)	37.4	47.8	51	50.9	48.8
Exports of goods and services (% of GDP)	23.7	12	14	15.5	15.1
Imports of goods and services (% of GDP)	32	15.1	19.2	19.1	18.3
Gross capital formation (% of GDP)	24.3	24.3	23	15.6	22.9
Current revenue, excluding grants (% of GDP)	10.6	11.9	9.3	16.7	13.7
Fixed lines and mobile telephones (per 1000 people)	11.9	26.5	5	24.1	30.7
Paved roads (% of total)	30.8	45.7	9.5	43	36.9

Note: GDP= gross domestic product; GNI=gross national income; kWh=kilowatt hours
Source: World Bank Report 2002

been the major cause (and effect) of poor human development. About 40% of the population of 23.7 million live below the national poverty line of NRs 4,400 ($77) per capita per annum. Poverty is primarily rural, with urban poverty rates about half the national average. The incidence of poverty in the mid-western and far western development regions greatly exceeds the national average, as does the rate in mountain districts.

Poor economic growth

The economic growth has been less than 4% on an annual basis and is characterised by low agricultural growth, growth that is urban biased, and poor distributive capacity. In the FY2002, the gross domestic product (GDP) per capita was only $231, making Nepal one of the poorest countries in Asia. Government revenue and gross domestic savings have remained at only 8 and 11% on average of the GDP during the last decade. Low levels of revenue and savings limit the allocation of resources to social priority sectors, and thereby limit the capacity to cope with natural disasters

Disparity in productive assets and income

Out of the total households in the country, nearly 78% are agricultural households, cultivating land of at least 0.013 ha and about 2% are agricultural households without land (CBS 2004). The average size of agricultural land held is 0.83 ha and holding sizes have been decreasing. Small farmers operating less than 0.5 ha of land account for about 45% and they own only 13% of the agricultural land. Nearly 73% of households have less than one ha of land and own only 31% of the area. Similarly, the bottom 20% of households receive only 5.3% of the national income while the top 10% have nearly 54%. Such wide disparity and skewed distribution in productive assets and income result in a poor capacity to cope with disasters.

Heavy dependence on agriculture and its poor production potential

Agriculture is the principal economic sector, but its production has remained stagnant or has only marginally increased: it is poorly diversified and largely dependent on variable monsoons. The value added per unit of agricultural land and agricultural worker is low compared to South Asian levels. Since most farmers are marginal and landless or have very small farms and have limited access to technology or the formal credit sector, roads, and markets, the agricultural returns are very poor (Chettri 1996). Only 44% of the total cultivable land (18% of the land area) is irrigated, and the current irrigation system contributes approximately 33% to the country's current agricultural production. Even if all irrigable lands were irrigated, the total production would increase by only 50% (due to water inputs only) (WECS 2002).

Inadequate service provisions

Access to safe drinking water, and health and sanitation is below South Asian standards. The health service delivery system is inadequate in terms of both quantity and quality of services. There is only one health centre including hospitals and health posts per 186 sq. km, and one health centre has to serve nearly 29,000 people. The ratio of doctors to population is 1:18,000 with a hospital bed ratio of 1:4,000 (CBS 2005). According to the Nepal Living Standards Survey (2003/04), the percentage of households requiring travel times of more than 30 minutes is 33% for health posts, 38% for hospitals, 66% for market centres, 46% for telephone booths, and 66% for paved roads. In rural areas, the mean travel time to reach different facilities is one hour and 16 minutes for health posts/hospitals, 2 hours and 14 minutes for markets, 5 hours and 11 minutes for paved roads, 3 hours and 12 minutes for bus stops, and 2 hours and 13 minutes for telephone booths (CBS 2004a). The adult illiteracy rate for both males and females is high and is higher in females, and overall the highest in South Asia, implying a low level of human resource development. The electricity use per capita is much lower than South Asian levels. This low level of social and physical infrastructure implies low coping/adaptive capacities in the event of disasters.

Increased population pressure

Under conditions of poor economic growth, the increase in the population growth rate has meant an increase in poverty level. The population has increased by 2.25% annually over the last decade, which means the population might well double in the next few decades (CBS 2004). Since 1976, the absolute number of people living below poverty level has doubled to the extent of nine million. Every year, about 200,000 people enter the labour force, and not a small fraction of this is absorbed into the non-agricultural sector. As a result, pressure on farmland and forests has increased. At times, this has led to deforestation, intensifying the use of marginal land, and this has affected the environment adversely. This, in turn, has had devastating effects on the poor as they rely on marginal land (UNDP 2001). Because of increasing poverty and its adverse effect on the environment, the vulnerability to natural disasters is likely to be high in the context of a poor coping capacity.

Ineffective implementation of disaster management strategies, policies, and programmes

Government activities until 1982 were mainly directed towards post-disaster activities, viz., rescue, relief, and rehabilitation, only as voluntary social work (Chettri and Bhattarai 2001; Dixit 2003). The Natural Disaster Relief Act 1982 provided a legislative framework for disaster management in the country (MOL 1982). Several amendments to the Act were made later. In the Act, provision for disaster management committees was made at the national and district levels in order to expedite relief measures in an effective and coordinated manner. Although there was an increase in the logistic and institutional capability for emergency response, it still lacked a broad perspective of disaster and its management. In 1996, the National Action Plan on Disaster Management (MOHA 1996) was introduced to address the manifold issues of disaster such as disaster preparedness, early warning systems, disaster information systems, hazard and risk analysis, vulnerability and adaptation assessment, land-use planning, training, and simulation. The Local Self-Governance Act (MOL 1999) came into existence in 1999. It provided a legislative framework to carry out disaster mitigation activities at the local level by mobilising local communities. The 9th and 10th plans (NPC 2002; 1998) also emphasised prevention, mitigation, and reduction of natural disasters through advanced geological, hydrological, and meteorological technology.

The National Water Plan (2002-2027) prepared by the Water and Energy Commission (WECS 2005) outlined several activities for the mitigation and management of water-induced disasters. These include formulation of policies and programmes for better management of water-induced disasters, implementation of risk and vulnerability mapping and zoning work, preparation and implementation of a floodplains' action plan, development of disaster networking and information systems such as early warning systems, formulation and implementation of community-level disaster preparedness plans, and implementation of relief and rehabilitation activities. It discusses approaches to river basin planning and outlines some activities in this context (WECS 2005).

Many institutions are involved in disaster mitigation and management activities. The Ministry of Home Affairs (MOHA) formulates and implements overall disaster management strategies, policies, and plans. Relief and rehabilitation activities are carried out by the Ministry of Home Affairs, Nepal Red Cross Society, Royal Nepal Army, and local non-government organisations (NGOs). The Department of Water Induced Disaster Prevention (DWIDP) is responsible for managing and mitigating water-induced disasters. Similarly, the Department of Hydrology and Meteorology (DHM), the Department of Soil Conservation and Watershed Management, the Ministry of Local Development, the Ministry of Population and Environment (MOPE), and many NGOs, intergovernmental organisations (IGOs), and international non-government organisations (INGOs) are involved in disaster mitigation and management activities directly or indirectly; but there is poor coordination in implementing activities among these institutions. Besides these institutions, a special Inundation Committee has been formed under the jurisdiction of the Ministry of Water Resources to deal with the problems of inundation caused by infrastructure constructed by India just downstream of Nepal. But this committee has yet to be effective in solving outstanding problems of inundation in border areas.

In spite of these strategies, policies, guidelines, programmes, legislation, and institutional provisions, only a few goals have been achieved. The government's disaster-mitigation efforts until now have been confined to rescue operations and post-disaster activities. The reasons for this may be lack of resources, low technical and institutional capabilities, low level of public awareness, and less effective mechanisms and bad governance. Less effective legislation and action plans clearly imply that the state's disaster coping mechanisms are inefficient.

Mapping and Past Assessment Efforts

Efforts have been made to map flood hazards, risks, and vulnerability, although they are very limited in scope and scale. Attempts are made here to review the work carried out on flood hazard, risk, and vulnerability mapping. After the devastating floods and landslides in 1993 in Kulekhani and its adjacent area, efforts were made to identify and map hazardous sites in that area. Hazardous sites in the Agra, Belkhu, and Malekhu Khola watersheds were mapped (DPTC and CDG 1994). Similarly, hazard maps of severely affected areas from the high intensity precipitation event in 1993 in the Kulekhani area (Miyajima and Thapa 1995) and Sarlahi district (Lama 1995) were prepared. Probabilities of hazards with different ratings were used to delineate areas with different levels of hazard – low, medium, and high in the Kulekhani area. The degree of damage in Sarlahi district and its vicinity was mapped. It highlighted the fact that the rising of river beds was one of the main causes of flooding in Sarlahi district in the Terai.

Hazard maps have been prepared for the Sun Koshi and Bhote Koshi catchments in central Nepal (ITECO 1996). The conclusion of this mapping exercise was that development of human settlements in hazardous areas increases the risk of floods and landslides. Measures to reduce the impact of natural disasters in these catchments have also been suggested.

A map indicating the zone vulnerable to flood hazards along the Khando Khola in the eastern Terai was prepared using GIS methodology (Sharma et al. 2003). Risk zoning was carried out for flood hazards with return periods of 10 and 50 years Similarly, preliminary work for flood-risk mapping along the Tinau Khola (downstream from Butwal) and the Lakhandi Khola in Rupandehi district was carried out by the Department of Hydrology and Meteorology in 1998. A one-dimensional intelligent drive array (IDA) method was used to determine flood levels along river channels and river valley bottoms using seven river cross-sections surveyed for 42.5 km along the river. It highlighted the need to have a sufficient number of cross sections and longitudinal profiles for better mapping and assessment of flood hazards and risks.

The Japan International Cooperation Agency (JICA) and the Department of Irrigation (DoI) (1999ab) prepared a flood-hazard map of Lakhandei Khola based on a field study carried out after the 1993 flood under 'The Study on Flood Mitigation Plan for Selected Rivers in the Terai Plain in Nepal' [sic]. The study also carried out various analyses including a flood-flow analysis using an unsteady flow simulation model. Flood-hazard maps were also prepared based on field investigations and personal interviews. The simulated result shows that, in many sites, the simulated water level goes far beyond the river cross-section and this could not represent the actual flood-water levels. These maps bear no relationship to the hazard level, e.g., the return period of flooding and floodwater depth. It also pointed out the need to prepare new flood hazard maps refining those prepared for the study (JICA/DoI 1999a). The study concluded that the application of numerical modelling tools and GIS can provide effective and efficient means of floodplain analysis and flood-risk assessment. This can facilitate the transition from conventional flood-hazard mapping techniques based on field investigations to a knowledge-based system for a more objective analysis. This can also provide a framework for a decision-support system and facilitate the evaluation of alternative strategies for flood management.

An attempt was made at floodplain analysis and flood-risk assessment along the Babai Khola, using GIS and numerical modelling tools such as HEC-RAS (Shrestha 2000). Similarly, His Majesty's Government of Nepal (HMG/N), Department of Water Induced Disaster Prevention (DWIDP) and the Mountain Risk Engineering (MRE) Unit of Tribhuvan University (TU) (MRE 2003) prepared water-induced hazard maps of a part of Rupandehi District. A flood-hazard map has been prepared on the basis of field studies and numerical modelling.

The socio-technical aspect of flood-mitigation work in the Ratu Khola has been studied (R.S. Engineering Service 2000). The river basin was categorised into three zones based on vulnerability. Structural and non-structural measures have been recommended.

In 2003, the UNDP Office for Coordination of Humanitarian Affairs (UNDP/OCHA) carried out one mapping and assessment exercise entitled 'Multi-hazard Mapping and Vulnerability Assessment of Chitwan District'. This study attempted to identify settlements located in disaster-prone areas; estimate the number of households and population in those settlements; assess the risk; discuss the major causes of disaster; and prepare maps showing different types and levels of hazard in the district.

In addition to the flood-hazard and risk-mapping work in different parts of the country, several attempts have been made to review and analyse the issues of floods and their mitigation and management in Nepal. Khanal (1997) describes different types of floods frequently occurring in the country and discusses causes behind their increase and augmentation in the risk of flooding. The causes and extent of damage along with programmes recommended for managing floods through rehabilitation and preparedness activities have been reviewed on the basis of the flood events of 1993 in Chitwan, Makwanpur, Rautahat, and Sarlahi districts by the National Planning Commission (NPC 1994). Similarly, Chhetri and Bhattarai (2001) have reviewed some of the past flood and landslide events; highlighted the main factors contributing to increased vulnerability to flood disasters; and discussed flood-disaster management efforts – including policy, legislation, and institutional arrangements. The constraints to effective flood prevention and opportunities for technical exchange and collaborative work are also discussed. Similarly, Dixit (2003) has discussed the nature of frequently occurring floods and their impacts as well as responses in terms of mitigation and management; and he has highlighted the need for new approaches to flood mitigation and risk management.

ICIMOD's Activities

One of the goals of ICIMOD is to decrease the physical vulnerability within watershed and regional river basins and increase the evironmental security of mountain peoples and the downstream poor. The Water, Hazards and Environmental Management (WHEM) Programme of ICIMOD contributes directly to meeting this goal through its various programme activities. The overall goal of WHEM is to share information and knowledge on water, hazard, and ecosystem health, and secure environmental services in the Hindu Kush-Himalayan (HKH) region through regional collaboration. The Programe has three action initiatives, (i) water and floods, (ii) climate change and response, and (iii) environmental services. The activities under water and floods include the identification of measures to mitigate different types of natural hazard, particularly floods; promote skills and methodologies for natural hazard assessment; promote regional cooperation; and improve public awareness about disaster preparedness. In the past, ICIMOD's efforts were mainly concentrated on the publication of technical reviews on different issues related to water, e.g., flood hazard and risk (Carson 1985; Ives 1986; Bruijnzeel and Bremmer 1986). It also started to carry out case studies of extreme landslide and flood events occurring in the HKH region (Dhital et al. 1993; Khanal 1999) and organise workshops and meetings to initiate dialogue on better mitigation and management of flood disasters. ICIMOD, in collaboration with its regional member countries and the UNESCO International Hydrology Programme (UNESCO-IHP), was successful in launching the HKH-FRIEND (Flow Regimes for Experimental Network and Data) Project in 1996. A Regional Hydrological Data Centre (RHDC) has also been established to promote free exchange of data for hydrological research. ICIMOD has also promoted a Regional Flood Initiative in collaboration with the World Meteorological

Organization (WMO) to promote regional cooperation in flood forecasting and sharing of data and information among regional member countries. Its aim is to build trust and confidence amongst the participating countries through regional dialogues and to enable establishment of an operational flood information system providing reliable and timely flood forecasting and information to minimise the loss of lives and property in the Indus Ganges, Bramhaputra and Megne River Basins.

ICIMOD has carried out hazard and risk mapping and community risk and vulnerability assessment activities as a part of the Participatory Disaster Management Programme (NEP/99/014) implemented by UNDP/Nepal (ICIMOD 2002; 2002a). Its aim was to map hazards and risks in seven village development committees (VDCs) and one municipality in four districts of Nepal. Among them, two districts – Chitwan and Barida – lie in the Inner Terai and Terai regions where the main hazard is associated with floods and consequent changes in river channels. The relatively greater exposure of lives, buildings, land, crops, livestock, and infrastructure to water-induced disasters, on the one hand, and the lower overall response and recovery capacity of local people in VDCs located in the Inner Terai and Terai regions compared to VDCs located in the Hills, on the other, clearly indicate an increasing risk of flood hazards in the Inner Terai and Terai regions. It also shows that the application of GIS and remote sensing (RS) technology is very useful for flood-hazard and risk mapping. It concludes that such hazard and risk maps provide a basis for formulating different intervention strategies and programmes to reduce the adverse impacts of flood disasters

It was in this context that the study described in this publication was proposed with the objectives of preparing flood-hazard, risk, and vulnerability maps and assessments at watershed level with the active participation of local people. Keeping in mind the increasing loss of property from floods and other water-induced disasters in the central Terai region, Ratu Khola and its basin located in Mahottari and Dhanusa districts, were selected for flood-hazard, risk, and vulnerability mapping and assessment.