Chapter 1: Introduction

> ***"There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people — and the environment — suffer badly."***
>
> ***(World Water Vision)[1]***

Chapter 1 will introduce the background and the reasons for this study in the context of the PARDYP project and the water-related issues of the Hindu Kush-Himalayan region. The key issues discussed in this study are:

- **water availability**
- **flooding**
- **water-induced land degradation and sedimentation**

Current knowledge about these issues with particular focus on the HKH is presented. The status, relevant processes, their impact, and possible future scenarios are discussed before introducing the operational background and the structure of this study.

The Hindu Kush-Himalayas (HKH) are known for their beauty, their peaks — including Sagarmatha (Mt. Everest), the highest peak in the world — and their diversity in flora, fauna, and culture. However, these mountain ranges are also known for their environmental problems and their impact on the adjacent plains. Several studies have been carried out in the HKH searching for the reasons and causes of these issues. These studies fall into two schools of thought (Zurick and Karan 1999).

One school believes that human activity is the main cause of land degradation and environmental crisis in the region. The fragility and impending ecological crisis of this mountain ecosystem as a result of rapid population growth, along with increased firewood demand, deforestation, expansion to marginal lands, and increased landslides and soil erosion affecting downstream flood and sedimentation behaviour, was first mentioned by Eckholm (1976), and was later termed the 'Theory of Himalayan Environmental Degradation' by Ives and Messerli (1989). Although restricting the discussion to Nepal, this study was followed by a number of studies that came to the same conclusion. A compilation of many of these studies, including their major arguments, is given in Ives and Messerli (1989).

The second school argues that natural processes outweigh the importance of human impact. Ives and Messerli (1989), the main defenders of this school, provided the first synthesised analysis of the natural causes of land degradation to contradict the Theory of Himalayan Environmental Degradation. They argue that whereas serious environmental and human problems exist in the HKH, their impact on the downstream areas cannot be proven. Furthermore, in many instances, increased stability of the mountain slopes has occurred after human intervention and rapid reclamation and stabilisation of landslides. In general, the impact of human interventions is a question of scale (Ives and Messerli 1989; Lauterburg 1993). While the impacts of soil conservation methods are directly visible in a micro-scale catchment as they reduce soil loss rates, the impacts of these interventions are not detectable in the meso- to macro-scale catchments. This school of thought was supported by many follow-up studies (Bruijnzeel and Bremmer 1989; Hofer 1998a; Schreier and Wymann von Dach 1996).

Zurick and Karan (1999), not following either of these two schools, argue that in a region of great natural and cultural diversity such as the Himalayas, a generalisation is not valid and the application of a single environmental model must be rejected. In their view, the current

[1] Cosgrove and Rijsberman (2000)

environmental conditions of the Himalayas, and therefore land degradation, has to be viewed as a product of natural and social forces. Increasing population growth and lack of governance and poverty are believed to be some of the main driving forces behind environmental degradation, besides the great natural potential for degradation in a high energy environment with steep topography, unstable geology, and short and intense rainfall periods (ICIMOD 2002a).

The above discussion focuses primarily on land degradation and the intertwined flood and sedimentation issues, both of which are related to water. In the context of water availability, the discussion centres on the importance of mountain waters and their proper management (Liniger et al. 1998). Mountains can be considered 'water towers' providing large portions of river flows in the plains. Bandyopadhyay et al. (1997) showed the global significance of mountain water resources. Viviroli (2001) demonstrated that mountains are 'humid islands' with increased specific yield, seasonal delay of discharge through storage of water in the form of ice and snow, and decreased seasonal discharge variability in comparison to their lowlands. Degradation of water resources in the mountains in terms of quantity and quality is therefore not only a threat to the people living in the mountain ranges, but also affects those in the adjacent plains. The HKH region is home to millions of people who rely on the water resources from the Indus and the Ganges-Brahmaputra-Meghna (GBM) rivers in the Indian subcontinent; the Mekong, Salween, and Indrawati rivers in South-east Asia; and the Yangtze and Yellow rivers in China. This region is projected as increasingly water-scarce in years to come (Rodda 2001). Causes of water resource degradation are population growth, increased water demand for intensive agriculture, industries and sanitation, and increasing water pollution (OECD 2001). At the local scale, mismanagement (Chalise and Sial 2000) and catchment degradation (Liniger et al. 1998) may also affect water availability. To what extent the impact of local catchment and land degradation affects water availability is still subject to discussion. The FAO (2002) showed that there is no visible effect of land-use change at the micro- and meso-scale to the macro-scale.

The impact of global climate change in years to come is unclear. A number of projections exist for the impact on hydrological parameters and water resources for this region, but no conclusive answers can be given at this stage (IPCC 1998). Not only climate change, but also population growth and potential conflicts between lower lying areas and mountain areas are scenarios that may affect mountain waters (Viviroli and Weingartner 2002).

In this context, water resources globally and in mountain areas such as the HKH face multiple challenges. The Ministerial Declaration of The Hague stated, "Business as usual is not an option", in order to drive the point home that water security in the 21st century is an issue that needs to be taken seriously (World Water Forum 2000).

New management options and tools must be considered in order to ensure water availability for future generations and sustainable use to the satisfaction of both upstream and downstream parties. These options and tools must be based on a profound understanding of the current state of affairs and the relevant processes, rather than on myths. It is exactly this understanding that is is largely missing in the mountainous regions of the developing world. Mountainous regions globally are considered 'the blackest of black boxes in the hydrological cycle' (Klemes 1988; cited in Rodda 1994) with respect to data availability and understanding.

On the basis of the above introduction it can therefore be concluded that the depletion of natural resources such as forest, land, and water in the HKH is a serious concern at the micro- to meso-scale. Direct interventions on this scale may improve the conditions of the local residents both in terms of livelihoods and water security. The impact at the regional scale of such interventions, however, is questionable, mainly in terms of water availability, flood protection, and sedimentation. In terms of water quality, upstream-downstream linkages are visible with respect to heavy metals, pesticides, nutrients, and salinity (FAO 2002). A detailed understanding of the conditions and processes, however, is still missing for the mountainous regions of the HKH. This study will attempt to fill some of the gaps and contribute to a better understanding of the relevant processes in upland catchments in the foothills of the HKH, mainly through the integration of findings from the People and Resource Dynamics in Mountain Catchments of the Hindu Kush-Himalayas (PARDYP) project in this field to date, and through the synthesising of new knowledge.

1.1 THE KEY ISSUES IN THE HKH RELATED TO WATER

Water is Life — a perception shared by more than 60% of the residents in two catchments of the Nepal Himalayas. The same statement is used on many occasions and can be read in many publications. Simultaneously, water is destructive and a reason for great despair in many regions of the world. Too little and too much water are issues that are both prevalent in the HKH region on an annual basis during both the monsoon season and the dry season.

On the basis of an opinion poll conducted in July 2002 through the Internet, four key water-related issues were identified as being of utmost importance at the regional scale (see also Table 1.1):

- water availability for human purposes (agricultural, domestic, and industrial use) (see Section 1.1.1),
- flooding in the foothills and adjacent plains (see Section 1.1.2),
- water quality and pollution (see Section 1.1.1), and
- water-induced land degradation and sedimentation (see Section 1.1.3).

Table 1.1: **Key issues in the HKH related to water***

Rank	Issue	No of responses [%]
1	Water scarcity	37.1
2	Floods	19.4
3	Water pollution	16.5
4	Erosion and sedimentation	13.5
5	Unequal access	8.2
6	Unproductive use of water resources	3.5
7	Biodiversity decline	1.2
8	Destruction of wetlands	0.6

(data source: own survey)

* The survey identified 170 issues from 49 respondents in 13 countries, including India, Nepal, China, the United Kingdom, and others. At the same time, 63 causes including water management, water institutions and policies, deforestation, and climatic constraints were mentioned.

Banskota et al. (2000) proposed the same issues as the key environmental issues related to water in the HKH region. The four key issues are discussed below in a global context with a focus on the HKH region. An attempt is made to provide an overview of the current status, the relevant processes, and the impact and future direction of each issue according to the literature available. Water quality and pollution are included in the section on water availability as they are often directly connected, and in the context of this study no particular emphasis is given to this key issue. Chalise (2000) provides a good overview of water resource management issues in the region, focusing on priority areas such as transboundary issues and data management.

1.1.1 Water availability

Adequate water resources for future generations are of great concern at the global scale. Water demand worldwide has increased six-fold over the past one hundred years, with approximately half of all available freshwater being used directly for human purposes (Cosgrove and Rijsberman 2000). Globally, about 38% of the population is living in countries where there is severe water stress (Alcamo et al. 2000). In the HKH, Pakistan and Afghanistan in particular are of concern as they have developed most of their available water resources. According to Shiklamonov's (2000) classification, water availability in South Asia was catastrophically low in 1995 and shows a decreasing trend by 2025.

This global view also has a local dimension. Water availability was identified as the main issue for residents of the selected middle mountain catchments (Table 1.2). Adequate water availability for irrigation in particular is in short supply, closely followed by drinking water shortage. Increasingly, water pollution is becoming a concern in some catchments. Other studies in the HKH region have revealed similar issues. In Changar, located in Himachal Pradesh/India and part of the Indian Western Himalayas, there is an acute water scarcity, both for drinking as well as for irrigation (IGCEDP 2001). Negi and Joshi (2002) identified drinking water as a major problem in the Central Himalayan region. In the Sikkim Himalaya, Sharma et al. (1998) likewise postulated that the drying up of springs and drinking water scarcity are placing considerable stress on the local population. Singh and Pandey (1989) experienced water scarcity due to the drying up and decreasing yields of springs in the Kumaon Himalaya. They mainly held the degradation of the natural oak forests responsible for this process. Hill towns in Darjeeling and Shillong, the wettest corner of the Indian sub-continent, face water scarcity all year round according to Subba (2001). Bhaumik (2003) recently

Table 1.2: **Water-related key issues at the catchment scale, PARDYP catchments** (light grey cells indicate relation to water availability)*

Priority	Hilkot	Bhetagad	Jhikhu	Yarsha	Xizhuang
1	Water shortage for irrigation	Depletion of water resources	Irrigation water shortage	Irrigation water shortage	Water shortage during dry season
2	Water management	Inappropriate management of water resources	Drinking water shortage	Drinking water shortage	Too much water during wet season
3	Poor water quality and quantity for drinking	Soil and nutrient losses	Deteriorating water quality		Drinking water shortage
4		Water pollution	Topsoil loss and nutrient build-up		

(data source: own survey)
* These issues were identified by the PARDYP country teams through household surveys, focus group meetings, hydro-meteorological monitoring, and several years of work experience in their respective catchments; for location of the catchments refer to Figure 2.3 in Chapter 2.

reported this again. Similar issues are also reported by Grassroots (no date) for the Gharwal and Kumaon regions in India. Chalise et al. (1993) report the drying up of local groundwater resources, which are affected by changes in local land-use patterns. Due to these changes, women and children are forced to walk longer distances to collect water. They also report on cases from the Nepal middle mountains where men experience difficulty in finding a bride — a situation blamed on the drudgery the wife would face fetching water in these areas. Similar cases were also found in Bhaktapur, where a Newari folk song describes this situation (Prajapati Merz, pers. communication [translated from Newari]):

There are proposals (for marriage) coming from the upper part
and from the lower part (of Bhaktapur).
Wherever you send me, dear mother,
do not send me to the Tuthimala Tole.
There it is difficult to fetch water.

In the Xizhuang catchment, the biggest problem, as indicated by the respondents of a PARDYP survey, is access to irrigation water (35 villagers, 80%; Ma et al. 2002). Drinking water availability is only point wise an issue in certain villages and at selected drinking water supply schemes.
While the people of the HKH have learned to cope with the inherent seasonality in the past, new pressure from decreasing water availability may threaten the livelihoods of marginalised people. The root causes of this crisis can be attributed both to human as well as natural factors. Possible factors leading to water availability concerns are discussed below.

1.1.1.1 Status

For the purpose of assessing water resources at the national or global scale, various authors have defined renewable water availability. Alcamo et al. (2000) define it as fast surface runoff and groundwater recharge. In the UNEP (2001) study, renewable water availability is defined as total available surface water. Falkenmark (2000) introduced the blue and green water concept, blue water being groundwater recharge, surface, and river runoff available for exploitation, and green water being the moisture that would have evaporated before contributing to runoff. The green water is very important for biomass production in forests and grasslands. The focus of this research is based solely on blue water. Non-renewable groundwater and groundwater exploitation above the annual recharge are likewise not included in this discussion, as they are unsustainable and cause follow-up problems such as falling water tables, subsidence, and large-scale water scarcity, particularly for smallhold farmers (Postel 1999).

Worldwide, the renewable water availability is estimated at 40,000 km^3, with withdrawals of 2500 km^3 for irrigation, 750 km^3 for industrial use, and 350 km^3 for municipal (mainly domestic) use (Cosgrove and Rijsberman 2000).

The estimates of water availability for different countries in the HKH region vary greatly according to authors. In the case of Nepal, UNEP (2001) estimated the per capita water availability as 10,300 m^3/y for 1998. The World Bank (1998) estimated 7714 m^3/y per capita water availability for Nepal in 1996. Seckler et al. (1998) estimated the annual water resources for Nepal as 170 km^3/y. With a population of 19.3 million people, water availability was 8808 m^3/y per capita in 1990 (Seckler et al. 1998). Kayastha (2001) estimated a seasonal difference of 6100 m^3/y per capita, assuming 8800 m^3/y per capita in monsoon season and 2700 m^3/y per capita in the dry season. Within Nepal, the per capita availability drops to 1400 m^3/y in the Kathmandu Valley. Figures for other countries of the HKH are given in Table 1.3. Note that these values are for entire countries, not only for the mountainous areas.

Table 1.3: **Water availability in selected countries in the HKH**
(entire countries; source: Seckler et al. 1998)

Country	Population (1990)	Annual water resources	Per capita water availability	Total withdrawals	Per capita withdrawals m^3/y		
	Million	km^3/y	m^3/y	km^3/y	Dom.	Ind.	Irr.
Afghanistan	15.0	65.0	4333	25.6	102	34	1566
Bangladesh	108.1	2357.0	2180	23.8	7	2	211
Myanmar	41.8	1082.0	2588	4.2	7	3	91
Nepal	19.3	170.0	8808	2.9	6	2	143
Pakistan	121.9	418.3	3431	155.7	26	26	1226

Dom. Domestic use Ind. Industrial use Irr. Irrigation use

Nepal has the highest renewable per capita water availability in the list of countries above. This is mainly due to the fact that the entire country is within the boundary of the HKH region. Bhutan's per capita water availability of 120,405 m^3/y exceeds that of Nepal, according to a study by Subba (2001). In contrast, Pakistan, with a large part of the country in the plains and with the world's largest irrigation network, relies heavily on water resources from the Indus River originating in the HKH region (Liniger et al. 1998). Bangladesh's water availability, although located in the delta of the GBM, is reduced mainly due to the large population. Irrigation is, in all of the above countries, the largest user of renewable water resources. In Nepal, Bangladesh, and Myanmar, the withdrawals for both domestic and industrial use are small to negligible. Domestic withdrawals according to these figures are calculated to about 16 l $person^{-1}day^{-1}$ in Nepal. Bangladesh and Myanmar show about 19 l $person^{-1}day^{-1}$ and in Pakistan this corresponds to a daily withdrawal of about 71 l $person^{-1}day^{-1}$.

For the estimation of whether a country is water scarce or not, different approaches have been applied. Alcamo et al. (2000) used the criticality ratio (CR), which describes the ratio of average annual water withdrawals to water availability. On the basis of the 1995 data, Alcamo et al. (2000) determined that 49% of South Asia[2] is under severe water stress. In Southeast Asia[3] 6% of the area is currently under water stress, while in China+[4] presently 32% of the country is facing severe water stress. Applying the same method to the above data from Table 1.3 shows that Afghanistan and Pakistan are currently under moderate water stress, while the remaining countries are well below the threshold of water stress (Table 1.4).

Table 1.4: **Criticality ratio for selected countries of the HKH**

Country	Annual water resources* km^3/y	Total withdrawals* km^3/y	Criticality ratio CR %
Afghanistan	65.0	25.6	39
Bangladesh	2357.0	23.8	1
Myanmar	1082.0	4.2	1
Nepal	170.0	2.9	2
Pakistan	418.3	155.7	37

* data source: Seckler et al. (1998)

2 South Asia here includes Bangladesh, India, Nepal, Pakistan, and Sri Lanka (Alcamo et al. 2000).

3 Southeast Asia here includes Bhutan, Brunei, Cambodia, East Timor, Indonesia, South Korea, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Taiwan (Alcamo et al. 2000).

4 China includes China, Hong Kong, North Korea, Laos, Macao, Mongolia, Vietnam (Alcamo et al. 2000).

According to Gleick (2000), the estimated per capita water use for all countries of the HKH for the year 2000 was below 100 l person^{-1}day^{-1}. Note that these figures are for the entire country, including the plain areas and large cities. It can, however, be assumed that the figures for the HKH are below the given values. This assumption is strengthened by the fact that the minimum was estimated for Bhutan with 10 l person^{-1}day^{-1} followed by Nepal with 12 l person^{-1}day^{-1}, when both countries have most of their territory in mountainous areas. Bangladesh follows with 14 l person^{-1}day^{-1}, Myanmar with 15 l person^{-1}day^{-1}, Afghanistan with 28 l person^{-1}day^{-1}, India with 31 l person^{-1}day^{-1}, Pakistan with 55 l person^{-1}day^{-1}, and finally China with 59 l person^{-1}day^{-1}. Note the differences between the figures on the basis of Table 1.3, which in general show the same order of magnitude except in the case of Afghanistan.

It is not only the quantity of water that determines water availability. In many cases, deteriorated water quality also reduces water availability. A large part of the world's population still has no access to safe and affordable drinking water (Cosgrove and Rijsberman 2000). In Nepal, 78.1% of the rural population had access to a water supply in 2000 (NPC 2000). The national average was 79.9 with 92.3% water supply coverage in the urban centres of Nepal. However, none of the screened surveys reported on the water quality of the supply schemes. Water supply coverage of the other countries in the region is as follows (WSSCC 2000; in brackets the percentage for rural areas): Afghanistan 13% (11%), Bangladesh 97% (97%), Bhutan 62% (60%), China 75% (66%), India 88% (86%), Myanmar 68% (66%), and Pakistan 88% (84%).

In Nepal, the water supplied by the different water suppliers, including the Government's Water Supply and Sewerage Corporation, is mostly unsafe (IIDS 2001). The main pollutants are of microbiological origin and other organic pollutants. This is certainly true in the case of Kathmandu, but also for most other major settlements. Even groundwater supply in the Kathmandu Valley is highly contaminated with nitrates, ammonia, and faecal coliforms (UNEP 2001).

1.1.1.2 Processes

The main driving forces for water availability issues globally are population growth and increased water demand for intensive agriculture, industries, and sanitation. Availability has also been influenced by increasing contamination of water (OECD 2001). The domestic use of water is crucial, but represents only a small part of the total global water demand. As mentioned earlier, water use has increased six-fold, but world population has only tripled (Cosgrove and Rijsberman 2000). This indicates the increased per capita demand for water, which is attributed to the increased demand of water for industries, which is about twice as much as for domestic use (Cosgrove and Rijsberman 2000). Industrial use of water is mostly for cooling in the production of electricity; and for intensive agriculture where the irrigation of higher-yielding varieties results in increased water demand. Shiklamonov (2000) determined a global increase of 492% for industrial use from 1940 to 1995. In the same period, municipal and agricultural use increased by 484 and 179%, respectively. This adds up to a total increase of 248%.

In the context of the HKH, Chalise and Sial (2000) discuss a number of factors, including increasing demand for water due to population growth, modern lifestyles which demand greater amounts of water, and increasing livestock numbers for dairy farming and meat production. They also attribute the crisis to the collapse of local institutions for water management, which are not able to meet the demand of present day needs. This collapse is a direct effect of the loss of local knowledge about local water resources' management, as reported in Agarwal and Narain (1997), and the impact of external interventions.

Water quality and pollution of watercourses are an increasing concern in the region due to the uncontrolled disposal of human and animal waste. Nepal's situation of sanitation (use of sanitary means of excreta disposal by means of flush toilets or pit latrines; NPC 2000) is very poor with sanitation coverage of just 23% for rural areas, 73% for urban areas and a national average of 29% (NPC 2000). The progress of sanitation in the last decade is particularly frightening with a progress of just 9% (NPC 2000). Afghanistan has the lowest sanitation coverage with only 12% of the population having access to adequate sanitation. Worldwide, only 60% of the population had access to adequate sanitation in 2000. Other countries in the region have the following sanitation coverage as shown in Table 1.5.

In selected areas, over use and indiscriminate use of pesticides and mineral fertilisers adds to the problem. According to Kraemer et al. (2001), Asia's surface waters have faced the most rapid growth in eutrophication due to fertilisers. The same authors argue that the high sediment loads, which are a major source of pollution, are another reason for concern in the region. In recent years, arsenic pollution has become a significant problem in Bangladesh and West Bengal in India (Smedley et al. 2002). The primary cause for this is geological, but the change from using surface waters for domestic purposes to the use of shallow groundwater, as encouraged by the government and aid organisations, has had a negative impact. The natural factors attributed to uncertain water availability, which Chalise and Sial (2000) discuss, are mainly associated with the impact of climate change.

Table 1.5: **Sanitation coverage**

Bangladesh	53%	(44% rural areas)
Bhutan	69%	(70% rural areas)
China	38%	(24% rural areas)
India	31%	(14% rural areas)
Myanmar	46%	(39% rural areas)
Pakistan	61%	(42% rural areas)

(WSSCC 2000)

1.1.1.3 Impact and Future

The deterioration of water quality has a major impact on the health of consumers. At a global scale, 3.4 million people died in 1998 from water-related diseases, and 2.2 million from diarrhoeal diseases alone (WSSCC 1999). In Nepal, 16.2% of the children in a survey had diarrhoea during the two weeks prior to this survey conducted during the peak season for diarrhoea in April to May (NPC 2000).

Population growth is still continuing at a fast rate and no major change is foreseen. According to UNFPA (2001), population growth rates in the region range from a maximum of 3.7 in Afghanistan to a minimum of 0.7% in China (Figure 1.1) The population in 2050 in the South Central Asian region (countries below, excluding China) is estimated to be about 2.5 billion, with India being the most populous country in the world.

As a large part of the population in the region does not yet have access to adequate sanitation and safe water, a major increase in water demand for domestic purposes can be expected.

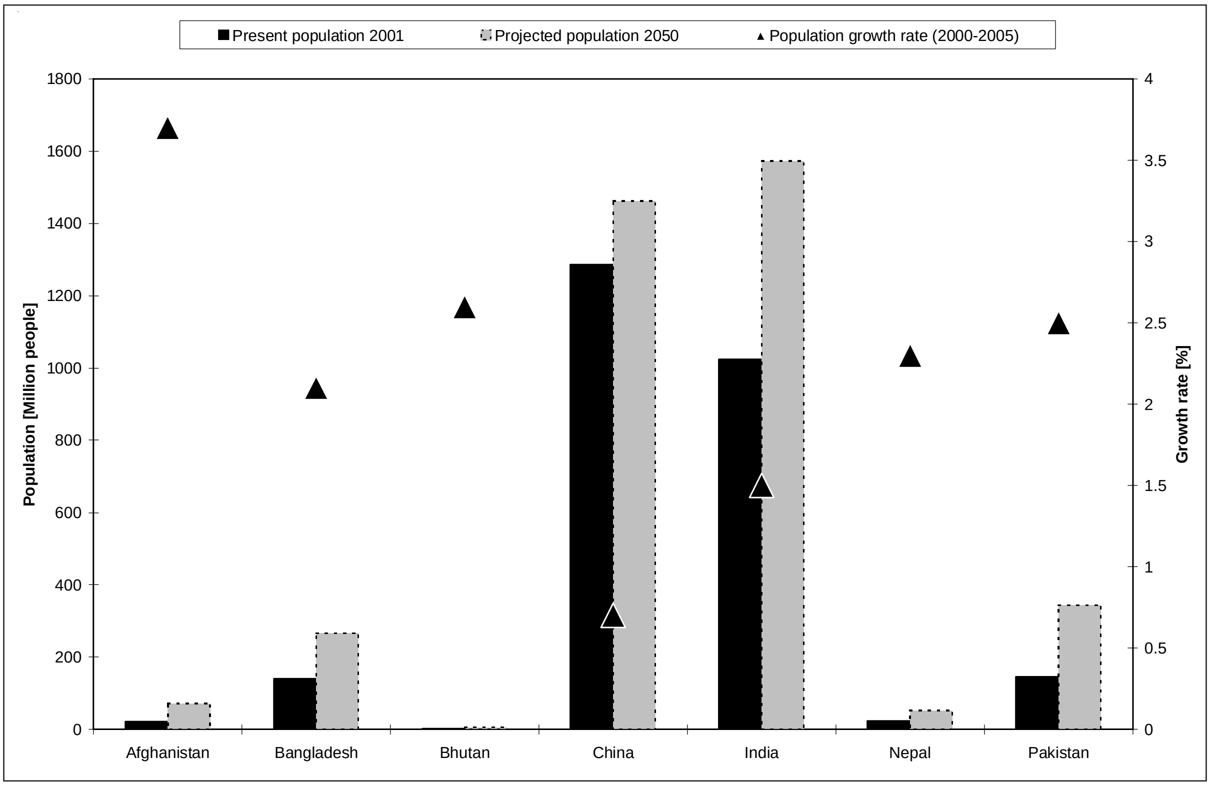

Figure 1.1: **Population development in the countries of the HKH**

(note: entire countries are included; data source: UNFPA 2001)

Gleick (2000) reviewed a number of projections published between 1967 and 1998. For the year 2025 the results ranged from 3625 km^3/y to 5500 km^3/y water withdrawal. He concluded that earlier studies mostly overestimated water withdrawals due to the selection of historical growth rates for projection. Increasingly, projection methods are becoming more sophisticated. He cautions that these projections should be used as possibilities, rather than as predictions, to make planners aware of the risks and benefits of certain policy implications.

Two of the later studies are the projections by Shiklamonov (2000) and Alcamo et al. (2000). On the basis of the 1995 data, Shiklamonov (2000) estimates the following increases by 2025:

- agricultural use +27% in withdrawal; +29% in consumption
- municipal use +77% in withdrawal; +49% in consumption
- industrial use +56% in withdrawal; +105% in consumption
- total water use +38% in withdrawal; +33% in consumption

Alcamo et al. (2000) noted that between 43 and 77% of the total population in South Asia[2] will face severe water stress by 2025 depending on different scenarios. In the case of China[4], 37 to 41%, and for Southeast Asia[3] between 33 and 46% will face water stress. Seckler et al. (1998) classified 116 countries into 5 groups according to the projected increase in total withdrawals for 1990 to 2025 and the percentage of the total withdrawals from the available water resources in 2025. This results in the following groups.

Group 1: water scarce countries; 8% of the population of the studied countries; these countries are mainly located in north Africa and west Asia; water scarcity major constraint on food production, human health, and environmental quality.
Group 2: 7% of the population of the countries studied; must develop more than twice the amount of water to meet reasonable future requirements.
Group 3: 16% of the population of the studied countries; must develop between 25% to 100% more of the current water resources for future needs.
Group 4: 16% of the population of the studied countries; must develop between 0 to 25% more of the current water resources for future needs.
Group 5: 12% of the population of the studied countries; no additional withdrawals required.

In the HKH region, Afghanistan and Pakistan belong to Group 1. Nepal and Myanmar were classified under Group 3 and Bangladesh under Group 4. India and China were not considered in this study due to their vast territory over a number of climatic zones and therefore their territory falls within multiple classes. Bhutan was likewise not included. These results suggest that major investments are required in the region to ensure adequate water supply for domestic and industrial demand and food production.

In addition, climate change may also have a major impact on water availability. Climate change could increase the rate of snowmelt and reduce the amount of snowfall due to shorter winters (IPCC 1998). This may have a major impact on downstream areas where rivers depend on the dry season flow from the upland areas, for example, 70% of the dry season flow in the Ganges is supplied from the catchments in Nepal (IPCC 1998). First examples of increases in anomalies, in this case droughts, are reported from the Western Himalayas and the Hindu Kush (Sial 2003). Any changes in the monsoon length or arrival may also be critical to soil moisture deficits in the region.

1.1.2 Flooding

Floods are not only the most frequently occurring natural disaster, they are also the most destructive natural disasters in terms of number of deaths, and are only overtaken by droughts in terms of affected people (Rodda 2001). In addition to drowning and direct injury, famine, and disease are often associated with flood disasters. It is important to note that floods only result in disasters if the natural flood hazard meets unsafe conditions such as low preparedness, a situation produced by a number of root causes and dynamic pressures (Blaikie et al. 1994).

1.1.2.1 *Status*

The HKH region has a long history of floods. Annually, tens of thousands of people are affected by medium to large flood events in the region. Floods are most destructive in terms of loss of life and financial loss in the plains adjacent to the mountain ranges. This is due not only to the force and magnitude of the flood, but also to the number of people and the values at risk.

In Bangladesh, globally the country worst affected by floods, flooding is an annual feature with 20% of the total area of the country being flooded every year (Hofer 1998a). Floods are very important for the Bangladeshi farmers and are considered to be a necessity for survival, as the agricultural calendar is highly adapted to the floods. Occasionally, catastrophic floods hit the country with return periods of 33 to 50 years (Miah 1988 cited in Hofer 1998a). Recent major flood events include the 1955, 1974, 1984, 1987, 1988, 1991, and 1993 floods (Hofer and Messerli 1997; Hofer 1998a).

According to Agarwal and Narain (1991), India is the most flood-affected country in the world after Bangladesh. The most flood-prone areas in India are the Ganges basin in Uttar Pradesh, Bihar, and West Bengal; and the Brahmaputra basin in Assam, followed by basins in Orissa (Agarwal and Narain 1991). Between 1953 and 1987 about 50,000 people died in floods in India and millions were displaced (CWC 1989; cited in Agarwal and Narain 1991).

Floods do occur in the inner Himalayan valleys. Agarwal and Narain (1991) and Subba (2001) present studies from the Gharwal-Kumaon Himalaya and the Eastern Himalaya in India where a number of destructive flood events occurred in the recent past. Recent disasters in Nepal include the 1981 flood in Lele, the 1993 flood of the Bagmati and Narayani, the 1998 Andhi Khola flood (Chalise and Khanal 2002), and the 2002 flood in the Kathmandu Valley. In the Lele flood, nearly all the agricultural land was damaged. Twenty-seven people died, more than 48 houses and seven water turbines were swept away. The 1993 flood disaster affected nearly 28,000 families in the middle mountains and 42,000 families in the lowlands. About 1000 people were killed during this event. The 1996 Larcha debris flow washed away roads, bridges, transmission lines, and 18 houses. Floods at a smaller scale with less disastrous, but still considerable, impact occur annually in a number of locations (Figure 1.2).

Figure 1.2: **Headlines on flood issues from the region**
(source: all clips from The Kathmandu Post, Kantipur Publications, Nepal, on different dates)

Glacial lake outburst floods (GLOF) have occurred over the entire glaciated history of the Himalayas. The most recent events in Nepal documented in Mool et al. (2001a) are the 1985 Dudh Khosi GLOF, the 1991 Tamakhosi GLOF, and the 1998 Dudh Khosi GLOF. In 1985, an ice avalanche from Langmoche caused the Dig Tsho glacial lake to burst. The resulting flood wave destroyed the Namche hydropower plant, a number of bridges, and caused loss of life. Bhutan experienced the most recent GLOF in 1994, when the Lugge Tsho partially burst. The flood wave caused loss of life and property in the downstream areas (Mool et al. 2001b).

1.1.2.2 *Processes*

The reasons for flooding, both in the plains as well as in the foothills has been subject to extensive scientific and emotional discussions in the past. The basic causes of the flood hazard, however, are of a climatic and geomorphologic nature. The causes of major disasters in the Nepal Himalayas were extreme weather events with exceptionally high rainfall intensities at a small spatial scale, which one might call cloudbursts (Chalise and Khanal 2002). Incessant rainfall over a longer time period often triggers landslides, causing debris flows and the generation of landslide-dammed lakes, potentially posing a risk in case of dam failure (ICIMOD 2000). GLOFs have caused significant destruction over their immediate downstream areas across the HKH (Ives 1986; Mool et al. 2001a/2001b).

To understand the process of flood generation under different circumstances and conditions, runoff generation studies were, and are, being conducted extensively throughout the world (Pearce et al. 1986; Leibundgut et al. 2001). While the processes are widely accepted (Figure 1.3), the importance of the different mechanisms of flood generation in particular is still subject to scientific discussion.

Various studies have been conducted in New Zealand, with a particular focus on the Maimai catchment on South Island. Mosley (1982) described the importance of subsurface flow, previously believed to be of less importance in the generation of floods. He mainly held rapid throughflow through macropores responsible for this, as was later emphasised by Germann (1990). Pearce et al. (1986) favoured the theory of displacement of old water, or piston flow effect, to explain the rapid response through subsurface flow. Merz and Mosley (1998) show the impact of landsliding on the hydrological processes and runoff generation in the Tutira catchment of North Island, New Zealand. The impact is mainly due to an increase in potentially saturated areas, as well as loss of soil from impermeable areas, and therefore loss in soil water storage capacity.

In Europe, several studies have been undertaken with a focus on runoff generation. In the Brugga catchment in southern Germany, Uhlenbrook (1999) identified three main runoff components: direct runoff from saturated and impermeable areas, shallow groundwater flow with piston flow and groundwater ridging, and finally deep groundwater flow with matrix flow (see also Figure 1.3). First results from the Leissigen catchment near Bern in Switzerland show that, in the very wet areas, saturation overland flow seems to be important and, in the other areas, mainly matrix flow seems significant (Laemmli 2000). On the basis of rainfall simulation experiments, Scherrer (1997) showed the variability of runoff generating processes at different sites in Switzerland. However, Hortonian (or infiltration excess) overland flow at rainfall intensities of 50 mm/h to 100 mm/h occurred most often. Saturation overland flow only occurred in follow-up experiments. Lateral soil matrix flow and macropore flow were less important at the selected sites.

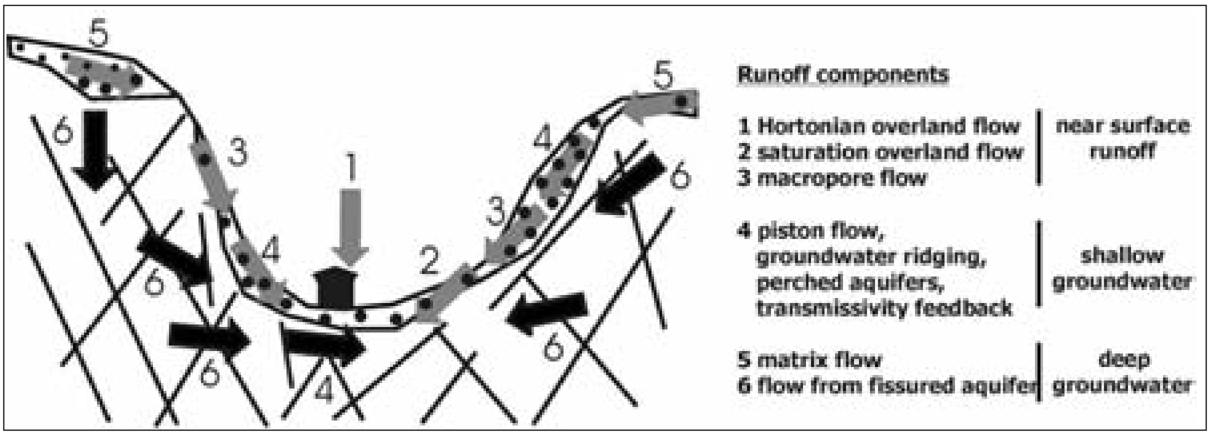

Figure 1.3: **Runoff generation (after Uhlenbrook and Leibundgut 2002)**

The number of investigations of runoff generation in the context of the HKH region, however, is limited. Collins et al. (1998a) report that, in the terraced land of the Middle Hills in Nepal, both infiltration excess and saturation overland flow contribute to runoff generation.

It is important to note that, although there is much information on runoff generation from Europe, America, and the Pacific, this information is only applicable to Asian conditions to a limited extent. In this context, it is mainly the impact of irrigation with prolonged saturation of large areas that should be mentioned. The time of extended saturation coincides with the time of highest rainfall input, the monsoon season, as well as the time with the most intense rainstorms. Saturation overland flow therefore is assumed to play a major role in the runoff generation process as also indicated by Collins et al. (1998b). The model shown in Figure 1.3 is therefore only applicable to the conditions prevailing in the Asian upland region to a limited extent. However, it shows schematically the different processes at different locations in a catchment.

In general, there is a popular feeling that human interventions in the upland areas of the HKH have aggravated floods in the plains; and this feeling can also be attributed to the Agricultural Development Bank (2003). Hofer (1998a) lists a number of causes cited in the literature for floods in Bangladesh. Most of the causes cited are of climatological and geomorphologic origin, both outside and inside Bangladesh, and are therefore not directly related to human activities. Deforestation in the Himalayas and land management practices of mountain farmers, however, top the list in terms of numbers of citations. However, this simplistic theory is heavily criticised by different authors referred to in Hofer (1998a). He proposes that:

- the rainfall in the Meghalaya hills and in Bangladesh itself is most relevant for flooding in Bangladesh;
- floods in Assam may be connected but, on the Indian Ganges plains, there is no obvious connection; and
- high baseflow may be imported, but flood peaks are home-made.

According to these theses, Himalayan farmers are not to be blamed for the floods in Bangladesh. In addition to this, Mirza and Dixit (1997) did not establish any conclusive trends of peak flood discharges at various stations on the Ganges, Brahmaputra, and Meghna rivers over the past decades. They concluded that there is no impact of human action on the mountains of their basins, nor is there any evidence of the impact of global climate change in terms of peak flows.

It is not only in the HKH where the role of forest cover with regard to flooding has been subject to discussion. There is little scientific evidence for the largest, most damaging flood events being caused by deforestation at the global scale (Calder 2000).

The most important factor in this discussion seems to be scale. While documentation of the effect of human intervention at the micro-scale is possible, the change in flood peaks and sediment load at a large scale is dominated by natural processes (Ives and Messerli 1989). Human intervention in the plains themselves becomes important, while the impact of the changes in the mountains becomes invisible. On the basis of a thorough literature review, FAO (2002) concluded that land-use impacts on hydrological parameters and sediment transport are inversely related to the spatial scale at which the impacts can be observed (Table 1.6). In contrast, the impact of land-use changes on water quality parameters may be relevant at the higher meso- and macro-scale.

Table 1.6: **Impact of land-use changes at different scales on various water-related parameters (FAO 2002)**

Impact	Basin size [km^2]						
	0.1	1	10	100	1000	10,000	100,000
Average flow	x	x	x	x	-	-	-
Peak flow	x	x	x	x	-	-	-
Base flow	x	x	x	x	-	-	-
Groundwater recharge	x	x	x	x	-	-	-
Sediment load	x	x	x	x	-	-	-
Nutrients	x	x	x	x	x	-	-
Organic matter	x	x	x	x	-	-	-
Pathogens	x	x	x	-	-	-	-
Salinity	x	x	x	x	x	x	x
Pesticides	x	x	x	x	x	x	x
Heavy metals	x	x	x	x	x	x	x
Thermal regime	x	x	-	-	-	-	-

Lauterburg (1993) notes that afforestation and soil conservation may be beneficial at the micro-scale, but that there is no impact at the upper meso- to macro-scale. A study of the impact of upstream catastrophic floods in Nepal has shown no more effect than the integration of this floodwater into the baseflow at the downstream location (Khanal et al. 1998). Hofer (1998a) gives several examples where upstream districts in India experience heavy flood events, without impacts in the downstream areas in Bangladesh.

In terms of people's vulnerability to flood disasters, it is important to remember that increased in-migration, intensified use, and urbanisation of flood zones and flood-prone areas have increased the number of people and values at risk (Blaikie et al. 1994). This was also shown in Switzerland where the damage potential increased exponentially after the Second World War (Weingartner 1999) due to land-use intensification and encroachment.

1.1.2.3 Impact and Future

The possible impact of climate change on flood behaviour in the region is uncertain and may have many facets (IPCC 1998). To date, no conclusive trends can be observed for precipitation in the Ganga basin (Mirza et al. 1998). Whetton et al. (1994; cited in IPCC 1998) predict increased frequency of heavy rainfall events. Wet season rainfall for the region is estimated to change by 0 to +10% by 2010. By 2070 an increase of +5 to +50% is estimated (Whetton 1994; cited in IPCC 1998). A change in monsoon duration, such as a prolonged wet season, may have a further impact on floods, as predicted by certain studies. Increasing temperature may also affect the occurrence of GLOFs (IPCC 1998). These authors report decreasing snowfall, deglaciation, and retreating glaciers in various parts of the HKH region; however, according to Mool et al. (2001a), it is premature to link these phenomena with the impact of climate change.

Population growth, further in-migration, urbanisation of flood areas, poverty, and inadequate planning may further increase the number of people and valuables at risk (Blaikie et al. 1994).

1.1.3 Water-induced land degradation and sedimentation

Soil erosion in the foothills of the HKH is considered a hot topic in land degradation research in the region (Scherr and Yadav 1996). This addresses mainly the issue of topsoil loss through surface erosion with a subsequent decline in the fertility of the land, which is a concern for agriculture and food security, and is believed to be one of the major ecological crises facing the HKH region today (Chalise et al. 1993). From the perspective of soil nutrient losses, nutrient leaching is however a more important mechanism (Gardner et al. 2000; Acharya et al. 2003). Mass wasting accounts for large parts of the sediment load in the rivers, but is only marginally responsible for soil fertility decline. In general, land degradation in this study is understood as the quantitative and qualitative loss of land resources (after Thapa and Weber 1995).

1.1.3.1 Status

Topsoil loss from water erosion is responsible for the degradation of 15.7% of the total land in South and Southeast Asia (Scherr 1999). Carson (1985) termed soil erosion the most serious resource problem in Nepal. Degradation of soils through erosion and fertility decline is, according to UNEP (2001), one of the key issues affecting the state of the environment of Nepal.

In terms of soil loss through surface erosion, some studies have been conducted in the region and rates of topsoil losses have been published in numerous publications. Some of these results are compiled in Appendix A1.1. In general, these results show degraded lands under different land management and use are most susceptible to soil erosion. Sal forests in different stages of degradation ranged from 3 t/ha to 10 t/ha soil loss per year, with this increasing according to the stage of degradation (Gerrard 2002). In terms of land use, forestland is least susceptible to soil erosion, followed by grassland, irrigated agricultural land, and finally rainfed agricultural land. In addition to land use, cover, and management, physical properties such as slope play a major role.

In the Likhu Khola catchment, sediment supply from mass wasting of approximately 7 t/ha*y was estimated for the 12.4 km^2 catchment in 1992 (Gardner and Jenkins 1995). Gerrard (2002) further detailed this information from the Likhu Khola catchment with 0.48 t/ha*y average soil loss from landsliding for irrigated terraces, 3.65 t/ha*y for rainfed terraces, 1.86 t/ha*y for grassland, 0.80 t/ha*y for forested land, and 23.95 t/ha*y for scrub and abandoned land. This study reports a total denudation rate due to landsliding of 5.55 t/ha*y.

The Himalayan rivers rank amongst the top rivers in terms of suspended sediment load (Meybeck and Ragu 1995; see also Figure 1.4). In terms of suspended sediment delivery, the rivers originating from the Central Himalayas such as the Karnali, Sethi Nadi, Tamur, Sun Khosi, Arun, and Marsyangdi show the highest figures, with values of more than 65 t/ha*y (Lauterburg 1993). In years with high intensity cloudburst in tributaries, such as from the Kulekhani catchment in Nepal during the 1993 event, sediment loads of 500 t/ha*y were reported (Galay 1995; cited in Schreier and Shah 1996). Over a time period of 13 years the sediment load was estimated to be approximately 53 t/ha*y. The western Himalayan rivers such as the Jhelum, Chenab, and Indus have low sediment delivery rates of below 15 t/ha*y. However, these rivers may have very high loads locally, as for example the rivers originating from the Karakorum draining into the upper Indus River. The Hunza and Gilgit rivers yield sediment above the global average, as shown in Figure 1.4. According to Lauterburg (1993), the rivers in the eastern Himalayas show likewise very low sediment loads. Merz et al. (2003a) reported a suspended sediment yield of 0.9 t/ha*y to 1.8 t/ha*y for the Wang Basin in Bhutan, the most important river for hydropower generation in the kingdom.

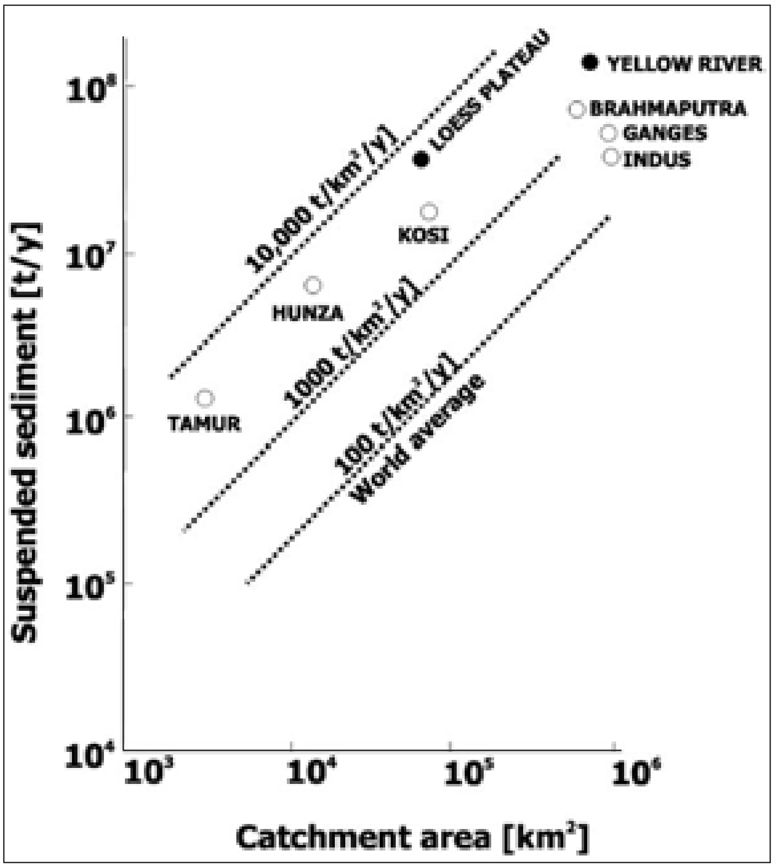

Figure 1.4: **The sediment load of selected South Asian rivers compared to the global average**
(Ferguson 1984 in Alford 1992)

1.1.3.2 Processes

Climatological extremes, such as the cloudburst of July 19 and 20, 1993 in the catchment draining into the Kulekhani reservoir, have a major impact, not only downstream in the reservoir (Sthapit et al. 1995) but also in the catchment itself, with numerous landslides and debris flows (Dhital et al. 1993). In general, the monsoon season rains have a major impact on sediment loads in the rivers. In the Wang Basin (3550 km^2) of Bhutan, the sediment load varies, on average, from approximately 15 t/day during the months of January to March in the dry season, up to 6000 t/day during August in the rainy season (Merz et al. 2003a). Maximum loads measured were 11,000 t/day.

Surface erosion is mainly influenced by the erosivity of the rainfall, the erodibility of the soils, topography, and land management practices (Carson 1985). The erosivity of rainfall measured with the erosivity index after Wischmeier peaks in the eastern Himalayas with EI30s of more than 1000 $J*mm*m^{-2}*h^{-1}$ (Lauterburg 1993). The central Himalayas have EI30s of 500 $J*mm*m^{-2}*h^{-1}$ to 800 $J*mm*m^{-2}*h^{-1}$. Erosivity decreases towards the west of the mountain range. However, from these figures it can be concluded that the Himalayas experience very intense erosivity as well as a high probability of catastrophic, high-intensity rains (Lauterburg 1993). Erodibility very much depends on soil characteristics. Carson (1985) identifies the red soils as being notorious for sheet and gully erosion. In terms of topography, the Himalayas contain some of the steepest relief in the world, and therefore are subject to increased erosion risk. In terms of crop cover and land management, the annual vegetation calendar is very important. Carson (1985) shows the vegetation cover in relation to the erosivity of rainfall (Figure 1.5).

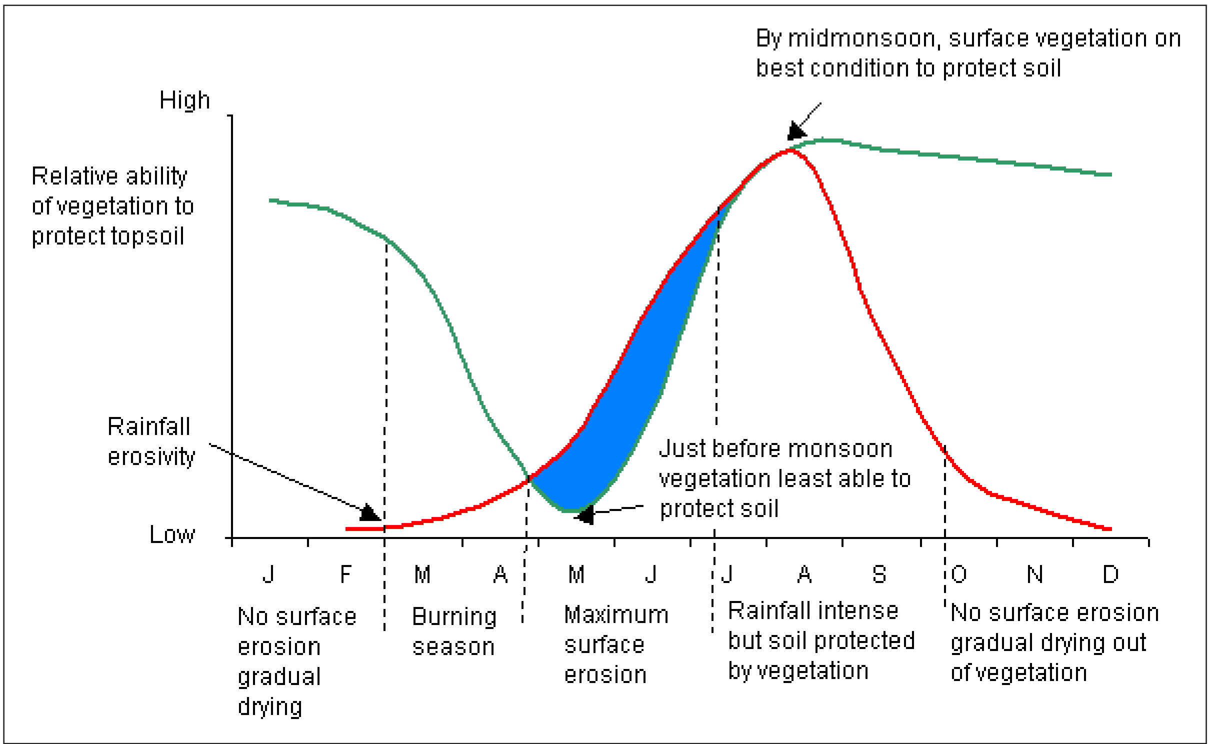

Figure 1.5: **Relationship between erosivity of rain and condition of surface vegetation throughout the year in the middle mountains of Nepal (Carson 1985)**

On the basis of this figure it can be concluded that the highest erosion risk occurs at times of low vegetation cover on agricultural land. This is supported by the findings of Carver and Schreier (1995), who have shown that the highest sediment concentrations are measured in the Jhikhu Khola during the pre-monsoon. Nakarmi et al. (2000) have further shown that in approximately 10 storms, more than 80% of the annual soil loss occurs from rainfed agricultural land. On grassland, 15 to 20 storms lead to the same percentage of soil loss.

Population is considered as the main push factor for degradation (Thapa and Weber 1995). An ever-increasing population has led to a reduction in landholding size which, for a family of five to six people, is currently below one hectare in Bhutan, the hill states of India, the mountain areas of Pakistan, and (except the Terai) large parts of Nepal (Thulachan 2001). Population density in 1991 was above 50 people per km^2 in most mountain parts of the HKH countries, peaking in Nepal with 126 people/km^2 (Sharma 1994). Since then, the population in all countries has increased (except in China, where the population is stagnant) aggravating the situation. In the Upper Pokhara Valley, agricultural expansion to steep and marginal lands used to be one of the strategies to supplement household crop production between 1957 and 1978 (Thapa and Weber 1995). Since then, this process has slowed down considerably with the remaining forest and shrub areas in steep and inaccessible areas. The same processes were documented for other parts of the HKH and were, amongst others, the reason for the implementation of the PARDYP project (ICIMOD 1996a).

Livestock are often blamed for land degradation, mainly due to overgrazing of forest and grasslands. In general, a decline in the number of cattle and sheep and an increase of buffaloes and goats have been observed throughout the HKH region in the last 20 years (Thulachan 2000). The change from cattle to buffaloes has had an especially positive impact on overgrazing. This is due to the fact that buffaloes are usually stall-fed and not grazed openly in the forests.

Deforestation and forest degradation were among the main issues in the 1970s and 1980s. Chalise et al. (1993) showed that 0.7% of the total forest area was deforested annually. Of the 613,000 ha deforested areas, only about half was replanted, and of this only half survived. The latest study on forest resources for the region shows that Nepal still loses approximately 78,000 ha of forest per year on the basis of 1990 and 2000 data, which accounts for about 1.8% of the total forest area of Nepal (FAO 2001a). This is the largest forest loss in the region in terms of national forest loss. Myanmar loses about 1.4% of its forest area annually (approximately 512,000 ha); the biggest forest losses in terms of area in the region. The reasons for this degradation of forest resources are stated as poverty and population pressure (FAO 2001a). Bhutan's forest area has remained roughly the same at 64.2% of the country's area. In Bangladesh, China, and India, forest cover has increased overall, due to plantations. To what extent this increase has occurred in the mountain areas of those countries is not described.

1.1.3.3 Impact and Future

In terms of soil fertility decline due to surface erosion, Nakarmi and Shah (2002), on the basis of figures from Brown et al. (1999), report that approximately 10% of the nitrogen losses on a rainfed agricultural terrace can be accounted for by surface erosion. One per cent of phosphate losses and approximately twenty per cent of calcium losses are lost through surface erosion. The areas most at risk in terms of fertility decline are the residual rainfed terraces, often owned by resource-poor farmers who do not have the capacity to improve their land (Gardner and Jenkins 1995). On the basis of soil formation processes, tolerable soil loss rates in the middle mountains of Nepal are estimated at 10 t/ha*y to 11 t/ha*y (Gardner and Jenkins 1995). This means that, with the exception of degraded lands and poorly managed agricultural land, there is no reason for concern at losing valuable soil resources. However, if terraces are poorly managed or land has reached a progressed stage of degradation this tolerable soil loss can be exceeded in the order of 20 times, and even up to 60 times (Laban 1978; see also Appendix A1.1).

In terms of impact on downstream infrastructure, Galay et al. (2001) show the impact of high sediment loads. These elevated loads often lead to the sedimentation of reservoirs as well as the aggradation of riverbeds. The 1993 storm in the Kulekhani catchment is only one example.

Future soil erosion rates and the subsequent impact on human life and infrastructure depend very much on future population growth, environmental policies regarding forests and land, and the impact of these policies on the respective resources. It is hoped that the current trend in policy towards increased community participation will support the increase in forest quality and to a certain extent the forest areas as well (FAO 2001a). Just how much precipitation alters as a result of climate change is uncertain (IPCC 1998).

1.1.4 Summary

The main issues related to water in the HKH region include water availability, floods, water quality, and land degradation caused by water. The current situation is rather bleak, with many areas of the HKH region already facing water shortages, flooding, and severe land degradation. The driving forces for all these key issues are population pressure, poverty, development status, inherent climatic conditions, bad governance of water resources, and, in future presumably, climate change and globalisation. The list of driving forces is not exhaustive, but should give an idea of the existing dynamics. The direct impact of these driving forces at the catchment scale and on larger basins is not yet fully understood. While certain forces may lead to decreasing water availability, which cause famine, thirst, and desertification, other forces may lead to increasing water masses and in extreme cases to more floods and land degradation. These processes may also increase the variability and frequency of events. Figure 1.6 shows this cause-effect chain in a very simplified form. It is important to remember the interdependency that is characteristic of water resources and the water use system (Moench 1999).

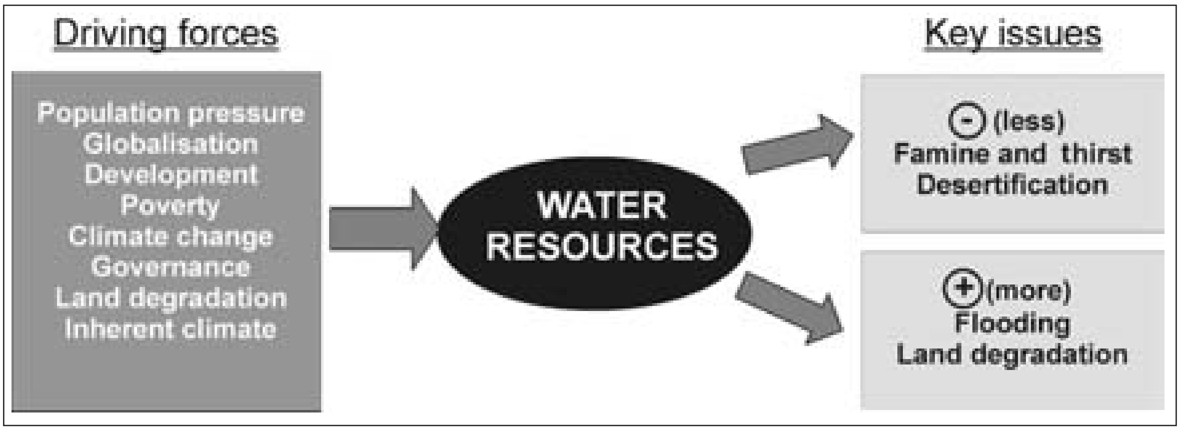

Figure 1.6: **Water resources in the future**

1.2 AIMS AND OBJECTIVES OF THIS STUDY

This study aims to contribute towards an improved understanding of the cause-effect chains in the HKH region that lead to flooding, water scarcity, and land degradation The discussion will mainly focus on the meso-scale with some deliberations at the regional level. The study tries to incorporate and synthesise information from different sources that influence water resource management. In this way it will contribute to the PARDYP project objective on water resources and to the overall goal of the project as documented by ICIMOD (1999).

The objectives of the study can be described as follow:

- to synthesise water-related information in order to reach an understanding of selected key issues related to water;
- to provide a methodology framework for the synthesis of a large amount of data and information to be considered for other project catchments, for comparison of catchments in the region, and potential up-scaling[5];
- to provide hydro-meteorological data and a number of basic analyses for further use in the project, such as diurnal temperature variation for agronomic trials, and rainfall frequency for water harvesting methods;
- to contribute towards the understanding of flood generation processes, the role of a catchment in flood generation downstream of the HKH middle mountains, and possible future threats;
- to contribute towards the understanding of water availability issues in a meso-scale catchment of the HKH;
- to contribute towards the understanding of land degradation through water and the relevant processes associated with this degradation; and
- to contribute towards an understanding of the dynamics of the above issues and their interaction.

Firstly, the study investigates the current status of the different key issues in each catchment and the processes leading to them (Figure 1.7). This is based on the assumption that each catchment has an inherent susceptibility to water scarcity, land degradation, and flood generation. In the second section, possible scenarios are explained and their impact on the catchments as well as on the processes discussed above are examined.

In this study, the term 'susceptibility' is understood according to the German word 'disposition' as discussed in Kienholz (1990: cited in Weingartner 1999). It is the base condition of a catchment disposing it towards the generation of a certain process or reaction. In other words, it is the vulnerability of a catchment to floods, degradation, or water scarcity. This susceptibility is not only a function of the biophysical environment and land use, but is also a function of the people's perceptions, needs, and ability to cope with the issue.

[5] **Up-scaling in this context is understood as the use of information and methodologies generated by the PARDYP project in other areas of the region, so that the project's efforts reach a wider audience.**

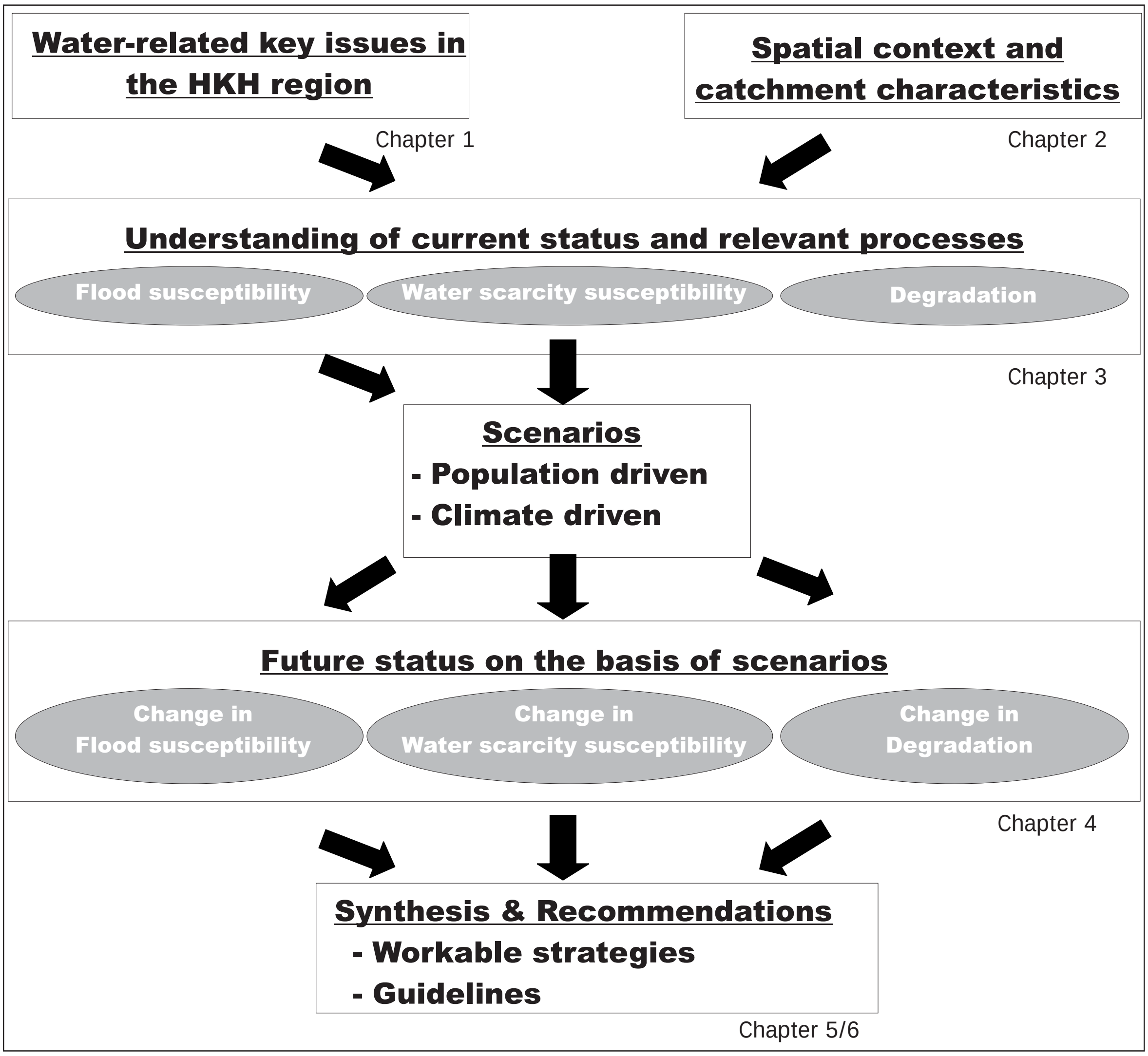

Figure 1.7: **Outline of the study**

Each susceptibility can be expressed as an index for the purpose of an objective catchment comparison and preliminary assessment of the conditions. It further helps in identifying potential areas for reduction in susceptibility. The indexes can also be used in other catchments of the area for a preliminary assessment of the situation. In this context, the Sustainable Livelihoods Approach (IDS 2000) provides a holistic framework to incorporate a wide range of views. This was then used to develop a proposed International Water Poverty Index (WPI) (Sullivan 2002; Lawrence et al. 2002; CEH 2002). The framework of the WPI has been adapted for this study to assess water scarcity. The two indexes related to flood generation and land degradation proposed in Chapter 5 are also adapted from this index to the specific requirements of these susceptibilities. For a more detailed discussion of the indexes and their indicators, please refer to Chapter 5.

The main research questions and hypothesis, which form the basis of this study, are as follow.

- Each catchment has an inherent flood, degradation, and water scarcity susceptibility on the basis of biophysical, socio-political, and economic variables.
  - What is the inherent flood, degradation, and water availability susceptibility of each catchment?
  - What biophysical and socioeconomic factors influence the different susceptibilities?

- Changes in these variables through superior driving forces have an impact on the different susceptibilities of the catchments.

– What changes in driving forces could occur in the context of the middle mountains of the HKH?
– What impact could these changes have on the different susceptibilities?

- The state of water resources in the catchments in terms of flood generation, land degradation, and water availability can be expressed as an index comparable to other catchments in the region.
  – What are the most appropriate indicators both in terms of sensitivity and in terms of measurability to form the backbone of these indexes?

1.3 OPERATIONAL BACKGROUND OF THE STUDY

This study was embedded in a long-term research-for-development project, the People and Resource Dynamics in Mountain Catchments of the Hindu Kush-Himalayas project (PARDYP). The project was initiated in order to provide an impetus for continuing a long-term monitoring programme that is essential for understanding the environmental dynamics and rates of change in catchments of the Hindu Kush-Himalayas.

The idea of PARDYP evolved over a period of seven years on the basis of three projects funded by the International Development Research Centre (IDRC), namely the Soil Fertility Project, the Mountain Resource Management (MRM) Project, and the Rehabilitation of Degraded Lands Project (more on the water and erosion component of all these projects can be found in the section on Water and Erosion Studies in PARDYP, below).

- **Soil Fertility Project**
  The Soil Fertility and Erosion in the Middle Mountains of Nepal Project (from 1989 to 1991) was an interdisciplinary project looking at resource use and related issues in a catchment. It was a collaborative research project between the University of British Columbia (UBC) and the Integrated Survey Section of the Topographical Survey Branch/Department of Survey, His Majesty's Government of Nepal.

- **Mountain Resource Management Project**
  The MRM project was implemented between 1992 and 1996 in the Jhikhu Khola catchment through the collaboration of UBC and ICIMOD. This project studied resource dynamics, concentrating on soil and water resources. Some achievements include the establishment of natural resources' baseline inventories, the setting up of an environmental monitoring programme, the documentation of land-use history over 50 years, and the rehabilitation of a degraded area.

- **Rehabilitation of Degraded Lands in Mountain Ecosystems Project**
  This project was conducted by research centres in four of ICIMOD's partner countries – Pakistan, Nepal, India, and China. It involved the rehabilitation of patches of degraded land and the screening of appropriate species and technologies for the revegetation of these barren slopes. Furthermore, the role of communities and individual landowners in the process of rehabilitation was better understood.

The evolving PARDYP project amalgamated the regional approach of the Rehabilitation project and the thematic thrust of the Soil Fertility and MRM projects.

1.3.1 The PARDYP Project

PARDYP is a regional research for development project in the field of integrated catchment and natural resource management. The first phase of the project began in October 1996 and ended in December 1999. A second phase lasted from January 2000 to December 2002. PARDYP is implemented in five catchments across the middle mountains of the HKH, with catchments in China, India, Nepal, and Pakistan. Overall coordination is provided by ICIMOD, while country activities are carried out by local country teams at the Kunming Institute of Botany (KIB) in China, the G.B. Pant Institute for Himalayan Environment and Development (GBPIHED) in India, ICIMOD in Nepal, and the Pakistan Forest Institute (PFI) in Pakistan, all along with their local partners. The project is supported by two international collaborators, UBC in the fields of resource management, soil fertility studies, and multimedia; and the Hydrology Group of the University of Bern/Switzerland (UoB) in the field of water and erosion studies. Funding for the project is received from the Swiss Agency for Development and Cooperation (SDC), IDRC, and in-kind contributions from all collaborating partners.

The project aims are the following:
- to build on the regional knowledge of resource dynamics in the middle mountains of the HKH;
- to help catchment residents, local groups, and line agencies to understand key issues in managing water, land, and forests;
- to improve natural resource management among farmers and communities through participatory action research, dissemination of knowledge and information, and demonstration and training;and
- to increase household and community benefits from farming and sustainable management of common resources through improved natural resource management.

In Phase 1 of the project, the overall goal was

> *"To further improve the understanding of the environmental and socioeconomic processes associated with the degradation and rehabilitation of mountain ecosystems, and to generate wider adoption and adaptation of proposed solutions by stakeholders in the HKH." (ICIMOD 1996a)*

The goal in Phase 2 then became:

> *"To contribute to balanced, sustainable, and equitable development of mountain communities and families in the HKH region." (ICIMOD 1999)*

The project includes the components 'community institutions', 'inequity and gender', 'economic potentials', 'water resources', 'common resources', 'on-farm resources', and 'implementation and management' (ICIMOD 1999). The project activities focus mainly on the generation and dissemination of information and knowledge and involve agronomic and horticultural initiatives, rehabilitation of degraded lands, forestry, socioeconomic and gender studies, participatory conservation activities, soil fertility considerations, and water and erosion studies.

In January 2003, a new phase was initiated in order to build on achievements to date and consolidate the databases as well as the findings. Furthermore, additional focus will be given to the regional nature of the project, fostering increased collaboration between the country teams and more regionally-based studies.

Further information on PARDYP is available on the web site: <http://www.pardyp.org/>. The project e-mail address is <pardyp@icimod.org.np>.

1.3.2 Water and erosion studies in PARDYP

The PARDYP project and its predecessors have carried out research related to water and erosion since 1989. Activities started in the Jhikhu Khola catchment in Nepal in 1989. Over time, the project has changed in terms of its objectives and main research interest. Below is a short description of the different phases and their focus on water and erosion studies.

1.3.2.1 Water and erosion studies in the soil fertility project

The aims of this project, as documented by Shah and Schreier (1991), were as follow (please note, only water and erosion related aims are listed):

- to map the basic topographic, geologic, geomorphologic, soils and land-use resources in a quantitative manner ;
- …
- to determine soil erosion and sedimentation rates from different land uses at three scales: catchment, sub-catchment, and plot studies;
- …

During the project, the first hydro-meteorological monitoring network was established in the Jhikhu Khola catchment. The use of Geographic Information Systems (GIS) was introduced to make the project a pioneer in this technology in Nepal. The project was able to initiate soil erosion research in the Jhikhu Khola and provide first ideas of possible erosion rates (Shah and Schreier 1991). However, the rates and sediment loadings identified were questionable, as high flow conditions were missed during the duration of the project. Upland and poor farmers were identified as the people most adversely affected by soil erosion, while downstream farmers owning irrigated land benefited from the fertile topsoil lost upstream. In terms of irrigation and water management, water availability was identified as key. Due to differing moisture conditions in different seasons, farmers are forced to adapt varying strategies during the monsoon, when drainage is critical, and during the dry season, when water has to be conserved.

While reviewing documentation and output it became evident that the main interest of this project was the question of soil erosion and sediment. Water was only of interest as an agent in sediment-related processes, only to a limited extent as a resource, and as a critical element in all natural resource interactions.

1.3.2.2 Water and erosion studies in MRM

The main aims of the MRM project as documented by Shah and Schreier (1995) were as follows (please note, only water and erosion related aims are given below):

- produce a detailed inventory of current climatic, soil, hydrological, land use, and socioeconomic conditions in the catchment;
- …
- identify major degradation processes such as soil erosion, sediment transport, and soil fertility decline, and determine rates of change in these processes under different land use practices;
- quantify stream flow and sediment dynamics and differentiate between naturally and human-induced processes and their effects on productivity and management in the catchment;
- identify successful land-use practices (traditional and introduced) that can be used to improve land use, productivity, and management in other parts of the middle mountains;
- …

The project's water and erosion studies were justified on the basis of the non-availability of scientific data and the scant understanding of hydrological processes in the middle mountains of the HKH region, endangered sustainability of the productive capacity through soil erosion, soil fertility decline, and irrigation issues.

The project was successful in:

- supplementing the basic resource surveys of the predecessor project and providing this information in digital format;
- setting up a detailed monitoring network and programme for climatic and hydrological parameters; and
- implementing small-scale community development projects in order to upgrade the infrastructure in the catchment.

In terms of water- and erosion-related findings, the project documented the critical time for soil loss during the pre-monsoon, where 60 to 80% of the annual soil and nutrient losses occurred during one or two major storms (Schreier et al. 1995). The concerns of farmers related to water shortages for both drinking and irrigation were documented and alternatives to flood irrigation were proposed. The interaction of upland rainfed agricultural land and lowland irrigated land in terms of nutrient and sediment dynamics was documented in Carver (1997), a very substantial PhD thesis on the topic of sediment dynamics and land management. During this project the use of CD-ROMS and multimedia was introduced.

This project, similar to its predecessor, was mainly interested in sediment dynamics and flood processes. Water as a resource was investigated in the context of irrigation efficiency and for household needs. No water balances were drawn up and the understanding of low flows was still missing.

1.3.2.3 Water and erosion studies in PARDYP Phase 1

The objective related to water and erosion studies in Phase 1 was:

> *"To generate relevant and representative information and technologies about water balance and sediment transport related to degradation on a catchment basis." (ICIMOD 1996a)*

The activities in this component involved the setting up of a hydro-meteorological and erosion research network in five catchments, an inventory of relevant resources in all catchments, the determination of water balances of different spatial and time scales, an investigation into sediment dynamics and water quality, and identification and testing of water management practices.

The project established a regional monitoring network in the fields of hydrology, meteorology, and erosion research, applying the same approaches and methods and using similar instruments (for reference see Hofer 1998b). Up until the end of the project, data analyses were still missing and no water balances and sediment related information were documented.

The focus of this project was regional and much effort was spent on setting up a regional network to contribute towards an understanding of key issues at the regional scale. The catchment scale along with local interventions and catchment specific activities were to a large extent neglected.

1.3.2.4 Water and erosion studies in PARDYP Phase 2

PARDYP Phase 2 was an extension of the earlier project with new activities, new organisation, and new objectives in the old framework. This phase lasted from 2000 to 2002.

The objective related to water and erosion studies in this phase was:

> *"To generate and exchange information on water as a resource and its role in land degradation, and to identify and test options to enhance water management decisions." (ICIMOD 1999)*

The activities in this phase included monitoring the research network and analysing data on water dynamics, water availability, sediment transport, and water quality. Several surveys were undertaken and water management at the local scale received much attention. The use of participatory rural appraisal methods (PRA) was intensified during the early stages of this phase.

Learning from Phase 1 of PARDYP, this project received more attention at the catchment scale at the cost of regional activities. Many questions targeted on-farm issues. At the regional scale, an analysis workshop to introduce HYMOS (a data management software) was held in March 2000. In 2002, the first steps in synthesising water- and erosion-related activities were taken. This involved a workshop (after intense preparation) attended by country team members working on water and erosion. The first ideas on this exercise are being published in Merz et al. (2003b) and the first output in the form of a CD-ROM is expected in mid 2004.

1.3.3 Summary

The scope of this study is the synthesis of a large amount of activities, resulting in a substantial body of data and information on key issues relating to water. In addition to contributing to an understanding of these issues, the study is also intended to provide an impetus for methodological development of integrated watershed management projects.

1.4 STRUCTURE OF THE REPORT

This report generally follows the outline presented in Figure 1.7. It is important to note that the methodologies applied in the study are discussed in the respective chapters.

Chapter 1 introduced the background to the study, including the reasons for concern and the urgent call for action. The study was introduced with its aims and objectives, and study's operational embedding within the PARDYP project described.

In Chapter 2, the report assesses the spatial context of the study and briefly discusses the selected catchments. The characteristics of the two catchments in Nepal are discussed in terms of catchment characteristics relevant for water scarcity susceptibility, flood susceptibility, and degradation susceptibility. The measurement networks in the selected catchments are briefly presented and the methods applied discussed.

The status in terms of different susceptibilities and the relevant processes leading to an increased or decreased susceptibility are discussed in Chapter 3. The main emphasis in this section is on the determination of relevant processes in the context of precipitation, evapotranspiration, discharge, and sediment mobilisation and transport. Water demand and supply in the catchments are presented. The resulting relationships and water balances are also presented.

Chapter 4 proposes four main scenarios, which may impact the relevant susceptibilities. After a detailed description of the scenarios, the possible impacts are presented by means of extrapolation and modelling techniques.

The information and findings from the preceding chapters are synthesised in Chapter 5 with the aim of presenting an overall view of the achievements of the study. The three indices, the Water Poverty Index, the Flood Generation Index, and the Water Induced Degradation Index are calculated for the two catchments in Nepal with a discussion of the different indicators, before a rapid assessment of these indexes is presented using data from the other PARDYP catchments.

The report ends with Chapter 6, where conclusions and recommendations for future research in the PARDYP catchments and in general are presented, keeping in mind the PARDYP project's various clients.

The appendices include relevant background information related to the text, such as statistical calculations and data tables (Appendix A), grey literature from the project, and the time series information used (Appendix B).

A number of boxes within the report refer to interesting experiences taking place during the PARDYP project, or interesting studies carried out in the PARDYP project with the involvement of the author, that are not directly the subject of this study.

Synopsis 1: Introduction

In the fragile mountain environment of the HKH region, three main issues related to water were identified on the basis of an opinion poll and literature review:

- **water availability for human purposes including water quality,**
- **flooding in the foothills and adjacent plains, and**
- **water induced land degradation.**

For each of these issues, current understanding at the global scale and in other areas of the world is advanced. In the HKH region, however, data availability often does not allow detailed studies and process analyses into the issues of catchment management at the meso-scale. The main questions to be answered are related to scales, relevant processes, and the impact of future changes.

The study presented therefore aims to:

- **contribute towards improved understanding of key water-related issues in the region and the relevant processes at the meso-scale,**
- **develop a preliminary framework for catchment synthesis and comparison for questions related to these key issues, and**
- **initiate studies on improved understanding of water-related dynamics on the basis of foreseen and potential scenarios.**