Chapter II
Basic Information

The Geographical Context

The Indus, Ganges, and Brahmaputra are of a comparable length and have their source in a common area, which is near the Mount Kailash Range (Map 1, Table 1). The flow direction in the mountainous catchments, however, is different for each river: the Indus to the west, Ganges to the south, and Brahmaputra to the east. The Ganges and Brahmaputra discharge as joint rivers into the Bay of Bengal, the Indus flows into the Arabian sea.

Table 1: **The Six Key Asian Watersheds - Statistical Figures**

River	Length (Km)	Watershed Size (Sq.Km	Countries Sharing the Watershed
Indus	3200	945,000	China, India, Afghanistan, Pakistan
Ganges	2950	1,050,000	China, Nepal, India, Bangladesh
Brahmaputra	2880	580,000	China, India, Bhutan, Bangladesh
Mekong	4800	795,000	China, Myanmar, Laos, Thailand, Cambodia, Vietnam
Yangtze	6290	1,808,500	China
Yellow	5464	752,443	China

Source: UNEP 1995

The Mekong, Yangtze, and Yellow rivers are considerably longer. The Yangtze and Yellow rivers form the two longest rivers in Asia and are the third longest and the seventh longest rivers in the world respectively.

Only 30 per cent of the total drainage area of the six river systems is located in the lowlands below 300m (1,000 feet). Twenty-seven per cent are located above 2,300m (7,000 feet). The area of the big watersheds located in hilly and high altitude zones is rather significant (Map 1, Table 2).

This general statement has to be differentiated for the six watersheds which can be seen also from the individual maps for each of the watersheds : Indus (Map 3), Ganges (Map 5), Brahmaputra (Map 7), Mekong (Map 9),Yangtze (Map 11), and Yellow River (Map 13). The catchments of the

Table 2: **Elevation Zones for Six Key Watersheds in Asia and the Pacific**

No	Elevation Zone (Feet)	River Basin (Area in thousand sq. km.)													
		Yangtze		Yellow		Indus		Ganges		Brahmaputra		Mekong		Total	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1	0 - 1,000	603.86	33.39	56.06	7.06	330.32	34.97	510.09	48.58	108.92	18.78	250.19	31.47	1,859.44	31.14
2	1,000 - 3,000	418.13	23.12	61.54	7.75	95.97	10.16	113.51	10.81	34.22	5.90	290.81	36.58	1,014.17	16.98
3	3,000 - 7,000	290.26	16.05	467.09	58.82	135.55	14.35	70.88	6.75	43.15	7.44	136.42	17.16	1,143.35	19.14
4	7,000 - 11,000	119.72	6.62	77.11	9.71	85.30	9.03	33.81	3.22	30.86	5.32	20.43	2.57	367.22	6.15
5	Above 11,000	338.91	18.74	132.22	16.65	263.35	27.88	82.74	7.88	315.23	54.35	93.65	11.78	1,226.10	20.53
6	No data	37.44	2.07	0.00		34.10	3.61	238.98	22.76	47.68	8.22	0.32	0.04	358.51	6.00
	Total	**1,809**	**100**	**794**	**100**	**945**	**100**	**1,050**	**100**	**580**	**100**	**795**	**100**	**5,972**	100

Source : USGS-IGBP Land Cover Classification Project June '97, 1992-93 NOAA (Loveland et al. 1997)

Ganges, the Yangtze, and the Mekong are dominated by elevations below 1,000m (3,000 feet). In contrast, more than 50 per cent of the Brahmaputra watershed is located above 3,600m (11,000 feet). The Indus catchment has considerable portions in the lowlands below 300m (1,000 feet) and in the highlands above 2,300m (7,000 feet). The Yellow River, finally, is dominated by altitudes between 1,000 and 2,300m (3,000-7,000 feet). This differentiation results in other patterns of natural resources in the watersheds, e.g., forests, and therefore has different implications for future strategies.

Climatic and Hydrological Conditions

General Climatological Conditions

The six key Asian watersheds are characterised by a variety of climatic conditions ranging from tropical/subtropical to alpine climates, e.g., the Ganges, Brahmaputra, and Mekong catchments, from rather humid to dry conditions, e.g., the Yangtze and Yellow rivers, from dry conditions to alpine climates, e.g., the Indus catchment. The rainfall diagrams in Figure 1 document a wide range of rainfall characteristics from west to east and from higher areas to lower areas. The diagrams are grouped according to the six key watersheds and within each watershed according to the position within the respective river system (higher to lower areas).

In general there is a dominance of monsoon rainfall patterns with maximum precipitation in the summer months. An exception is the Indus catchment where the winter precipitation, caused by the westerlies, is generally higher than the monsoon rains.

- The annual rainfall increases from the Indus to the Brahmaputra catchment and then decreases again further to the east.

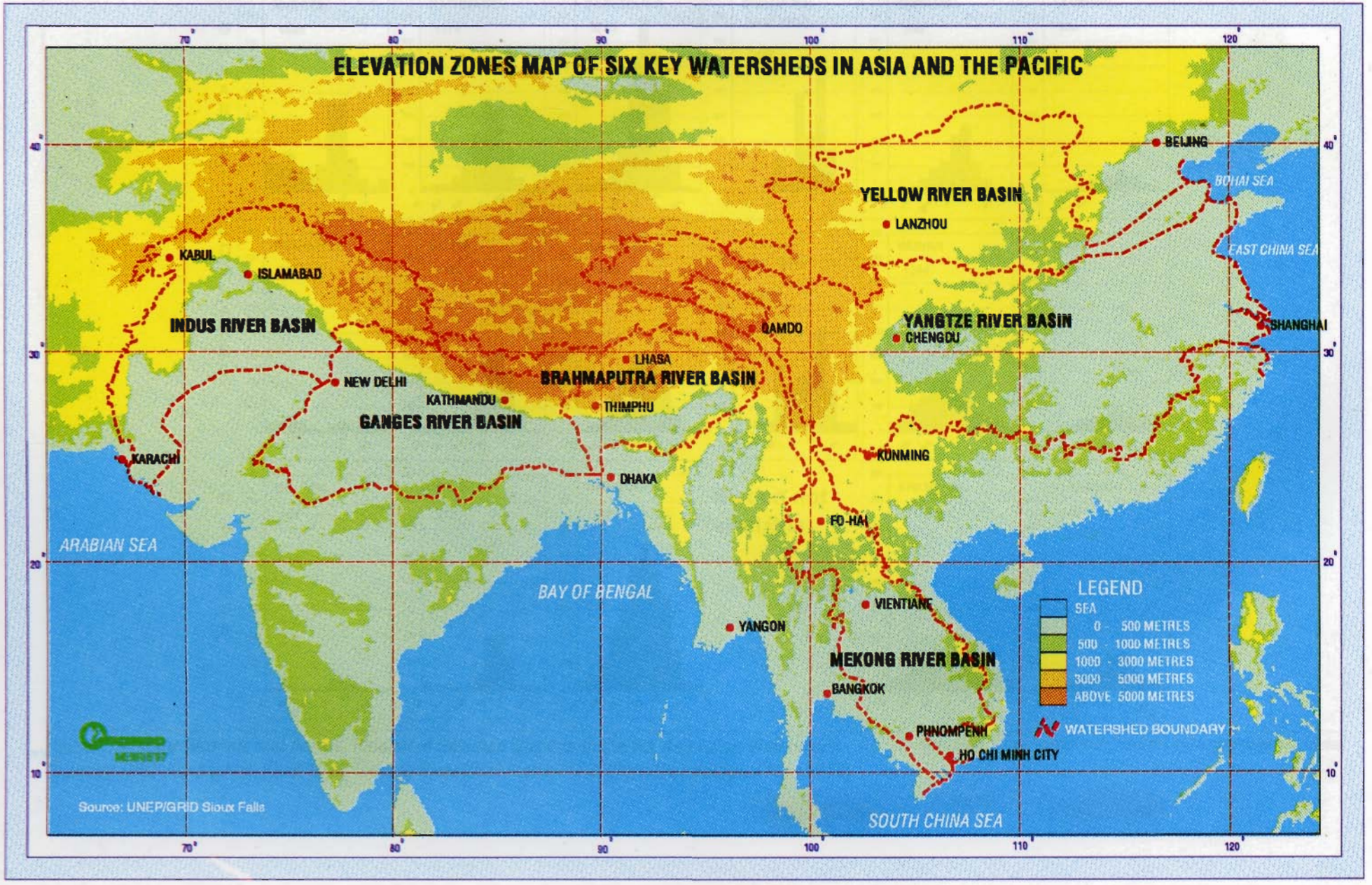
- The duration of the rainy season increases towards the east.

- In the Indus, Ganges, and Brahmaputra, the rainfall in the hills is higher than on the plains. For the other three watersheds, the situation is vice versa.

- In the Indus catchment, dry conditions prevail in the lowlands. In the Yellow River catchment, however, dry conditions are found on the highland plateaus.

The rainfall intensities during the monsoon season are very high, especially in the first ranges of the Himalayas where the humid winds have to rise. These rains exert a great deal of pressure in the context of erosion. This indicates that forests or good ground coverage are very critical, especially on the first Himalayan ridges, for protection against surface erosion and runoff.

MAP 1


ELEVATION ZONES MAP OF SIX KEY WATERSHEDS IN ASIA AND THE PACIFIC
BEIJING
BOHAI SEA
YELLOW RIVER BASIN
LANZHOU
EAST CHINA SEA
KABUL
ISLAMABAD
INDUS RIVER BASIN
QAMDO
YANGTZE RIVER BASIN
CHENGDU
SHANGHAI
LHASA
NEW DELHI
BRAHMAPUTRA RIVER BASIN
KATHMANDU
THIMPHU
GANGES RIVER BASIN
KARACHI
KUNMING
DHAKA
FO-HAI
ARABIAN SEA
BAY OF BENGAL
VIENTIANE
YANGON
MEKONG RIVER BASIN
BANGKOK
PHNOMPENH
HO CHI MINH CITY
SOUTH CHINA SEA
LEGEND
SEA
0 - 500 METRES
500 - 1000 METRES
1000 - 3000 METRES
3000 - 5000 METRES
ABOVE 5000 METRES
WATERSHED BOUNDARY
Source: UNEP/GRID Sioux Falls
70°
80°
90°
100°
110°
120°
40°
30°
20°
10°

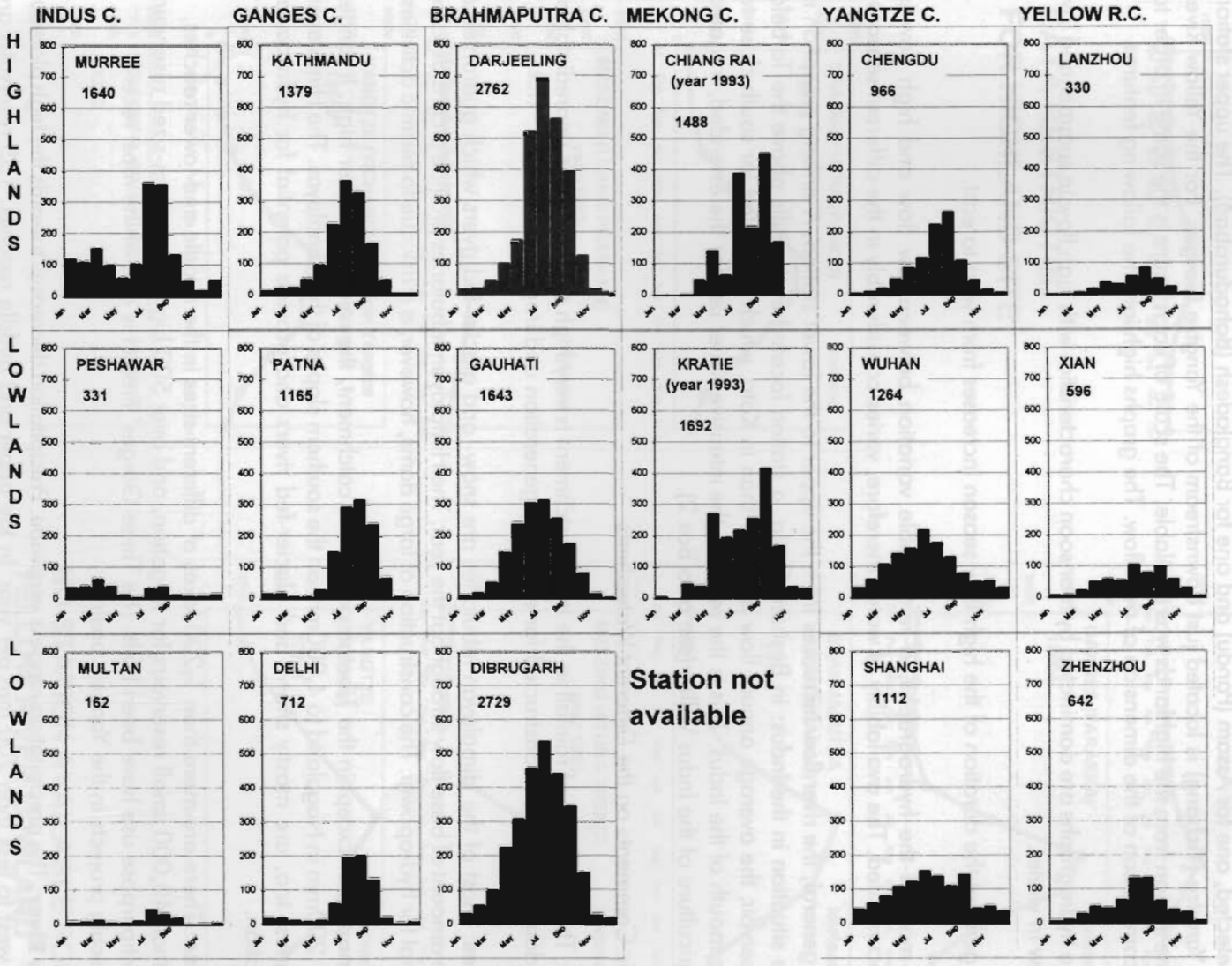


Figure 1: **Average Monthly and Annual Rainfall of Selected Stations in the Six Key Asian Watersheds** X-axis: months; Y-axis: rainfall in m; numbers in the graphs: annual rainfall
(Sources: CRU unpublished; Khan 1995; Mekong River Commission 1993, China Climatological Atlas 1978)

General Hydrological Conditions

In Figure 2, one or two typical hydrographs for each of the six rivers are shown. Except for the Mekong, the data represent average figures over a number of years. Where available (Indus, Mekong), one station in the highlands and one in the lowlands was selected. For the Ganges, only data of one station was available for the lowlands. For the Brahmaputra, two lowland stations were selected, one for Assam (Pandu) and one for Bangladesh (Bahadurabad). The upper station of the Yangtze (Yichang) is located just downstream of the Yangtze Gorges. For the Yellow River only one station from the highlands was available. The scale of each figure is the same in order to get a comparison of the dimension of river flow. The graphs highlight the following features.

- The hydrographs are dominated by monsoon characteristics with high flow in summer and low flow in winter.
- In general the duration of the high flow season increases from west to east.
- In most of the hydrographs, a remarkable variation between low flow and high flow is documented. The availability of water, therefore, varies considerably in the different seasons.
- In general, the river flow increases from the upper to the lower station. A striking exception is the situation in the Indus: in Besham Quila, a station located in the hills above the Tarbela reservoir, the average annual flow is higher than in Kotri, which is located far south close to the mouth of the Indus. This is the result of the intensive water use for the extended, irrigated agriculture of the Indus Valley (see also Box 2).

Specific Comments on the Different Watersheds

Indus: The variability of rainfall in the Indus catchment is very high and rainfall is unpredictable. Large dams have been constructed for electricity generation and irrigation.

Ganges: Most of the Himalayan tributaries are snow- and glacier-fed rivers which guarantee a certain amount of base flow throughout the year. The Himalayan tributaries provide a considerable potential for hydropower. The construction of large dams, however, is a risk due to seismic activities.

Brahmaputra: Except in the Tibetan part of the catchment, the rainfall is rather high. It ranges from 1,200mm in Nagaland to 4,000mm on the southern slopes of the Himalayas. The Himalayan tributaries, too, are mostly snow- and glacier-fed rivers and provide potential for hydropower generation.

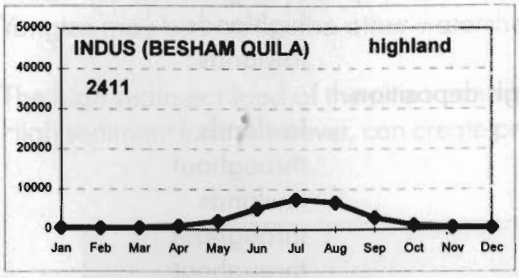
Yangtze: There are more than 1,200 lakes of different sizes in the middle and lower reaches, more than 40,000 small reservoirs for irrigation, and over 500 big and medium-sized reservoirs for multipurpose use have been built. The Three Gorges' Project is one of the most recent, large-scale projects in the Yangtze basin.

Yellow River: The precipitation range is very wide. Precipitation decreases towards the high plateaus in the west to less than 200 mm per year. In the upper and middle reaches, 155 reservoirs are operating. Thousands of checkdams and pumps are used for water harvesting.

Relevance of the Rivers within the Six Key Asian Watersheds

The rivers have a tremendous relevance for the watersheds. The relevance includes physical, economical, and cultural aspects. This relevance changes from the highlands to the lowlands.

X-axis: months; Y-axis: discharge in cubic metres per sec; numbers in the graphs: annual discharge in cubic metres per sec



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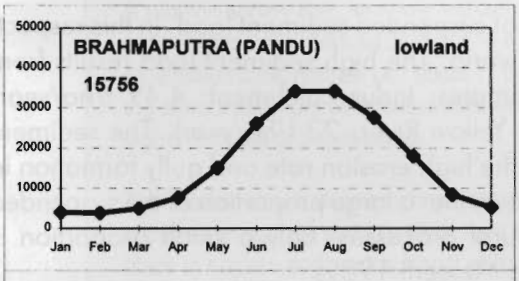
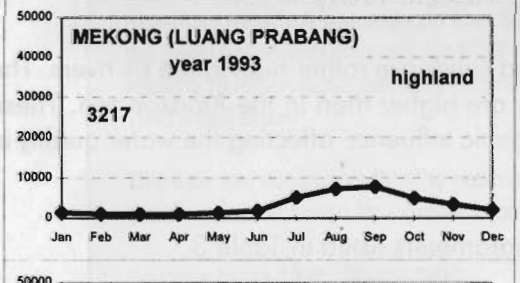
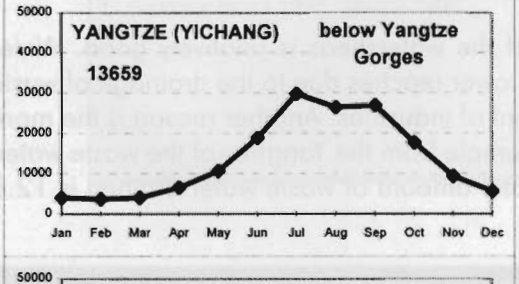
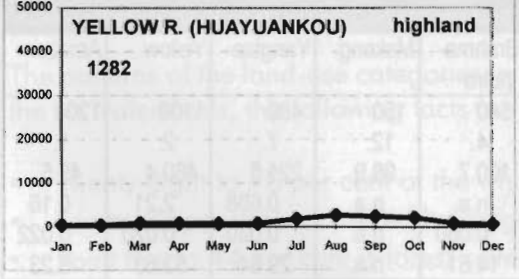
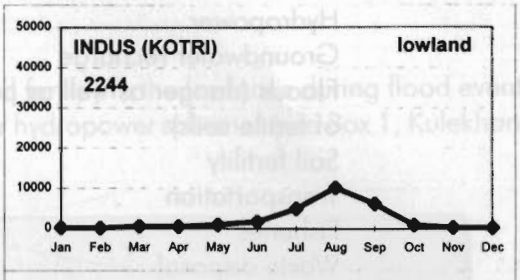
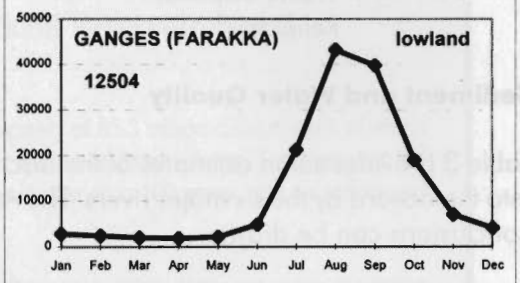


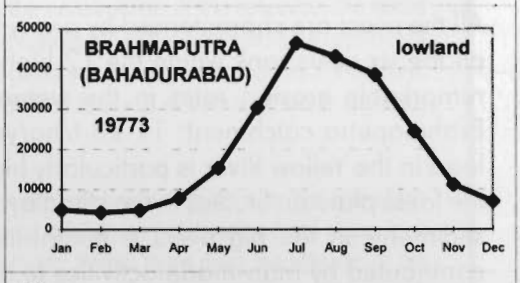


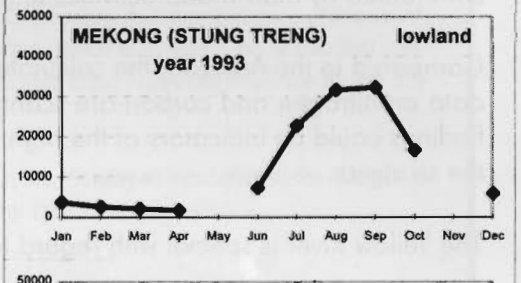


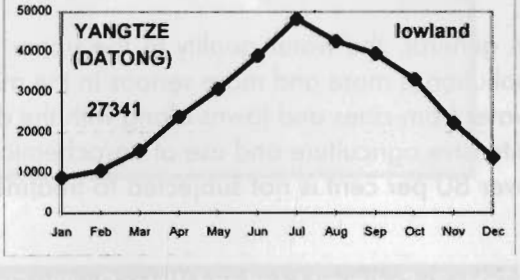












NO STATION AVAILABLE FOR YELLOW RIVER LOWLAND

Figure 2: **Average Monthly and Annual Discharge of Selected Stations in the Six Key Asian Watersheds** (Sources: GRDC, Mekong River Commission 1993, BWDB unpublished, Goswami 1983, GTZ unpublished)

Irrigation	throughout
Domestic use	throughout
Hydropower	highlands
Groundwater recharge	lowlands
Floods (danger as well as profit through deposition of fertile soils)	lowlands
Soil fertility	throughout
Transportation	lowlands
Fisheries	throughout
Waste disposal	throughout
Religion	throughout

Sediment and Water Quality

Table 3 provides some estimates of the discharge of suspended sediments and chemical elements into the oceans by the six major rivers. The Amazon River is included for comparison. The following conclusions can be drawn.

- All the rivers are characterised by a very high load of suspended sediment load. In this respect, all the six rivers rank within the 12 highest in the world. The high sediment load results from remarkable erosion rates in the watersheds (estimates: Indus catchment: 4.49 t/ha/year; Brahmaputra catchment: 11.28 t/ha/year; lower Yellow River: 23 t/ha/year). The sediment load in the Yellow River is particularly high due to the high erosion rate and gully formation in the loess plateau. Studies in the Himalayas have shown that a large proportion of the suspended sediments in the big rivers is contributed by natural processes, only a small proportion is contributed by man-made activities (e.g., Ives and Messerli 1989).

- Compared to the Amazon, the calculated dissolved solids are rather high in the six rivers. The data on nitrogen and carbon are scanty, but they are higher than in the Amazon too. These findings could be indicators of the high anthropogenic influence affecting the water quality in the six rivers.

- The Yellow River is special with regard to all the parameters listed in Table 3.

In general, the water quality in the upper reaches of the watersheds is relatively good. Water pollution is more and more serious in the middle and lower reaches due to the drainage of waste water from cities and towns along with the development of industries. Another reason is the more intensive agriculture and use of agrochemicals. An example from the Yangtze: of the waste water, over 80 per cent is not subjected to treatment. The total amount of waste water drained is 12.8

Table 3: Sediment Load and Water Quality Figures (Discharge into the Ocean) for the Six Rivers and for the Amazon

	Indus	Ganges	Brahma-putra	Mekong	Yangtze	Yellow	Amazon
Suspended sediment load (million tons/year)	250	520	540	150	480	1100	1200
Suspended sediment load (world rank)	9.	5.	4.	12.	7.	2.	1.
Calculated total dissolved solid loads (mg/l)[1]	180.1	185.6	100.7	98.9	221.0	460.4	43.5
Nitrogen (mg/l)[2]	2.2	n.a.	n.a.	n.a.	0.638	2.21	0.16
Phosphorus (mg/l)[3]	0.52	0.075	0.060	n.a.	0.020	0.020	0.022
Dissolved carbon (mg/l)	33.73	28.1	14.61	n.a.	29.54	53.63	8.23

Source: UNEP 1995

1) Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, $SO4^{-}$, HCO_3^{-}, SiO_2
2) Nitrate nitrogen, ammonia nitrogen
3) Orthophosphate phosphorus

billion tons/year. From the main cities, the drained waste water is about 5.4 billion tons/year, of which 4.3 billion tons/year of that amount comes from factories. A similar situation as for the Yangtze may be true for the other watersheds too.

The high sediment load of the rivers contributes to soil fertility in the lowlands during flood events. High sediment load, however, can create problems for hydropower schemes (see Box 1, Kulekhani).

Box 1
Sedimentation in the Khulekhani Reservoir, Nepal

The Kulekhani reservoir was designed with a gross capacity of 85.3 million cubic metres of which 73.3 million cubic metres is live and 11.2 million cubic metres is dead volume. The designed life span of the reservoir is 50 years, however the expected life period is 100 years, with an anticipated annual sedimentation rate of 7m³/ha.

A siltation survey has, however, indicated that, since the construction of the reservoir, the gross capacity has been reduced by about 14.47 million cubic metres out of the designed total capacity of 85.3 million cubic metres, i.e., about 17 per cent of the gross volume. Up to March 1993, therefore, the annual sediment contribution rate would have amounted to about 42m³/ha, which is six times higher than the anticipated rate.

The siltation rate is even much more dramatic during extraordinary events such as the one which occurred on July 19 and 20, 1993. As a result of extreme rainfall, an outstanding flood event took place in eastern and central Nepal with catastrophic effects. Within three days the lifespan of the Kulekhani Reservoir was reduced from 50 years to about 25 years. As a consequence of this event, the sediment contribution rate for 1993 rose to 415m³/ha, which is 59 times the anticipated rate. About 5.19 million cubic metres of sediment were contributed to the Kulekhani Reservoir by this July 1993 event alone!

This example documents that the sediment transport in the Himalayan tributaries to the Ganges is usually underestimated for extreme events and even for the average situation.

Sources: Hofer 1998, Sthapit 1996

Land Cover

The patterns of the land-use categories in the different watersheds are documented in Map 2. For the six watersheds, the following facts are worth mentioning.

- Twenty-eight to 78 per cent of the whole area is used by agriculture.
- Ten to 62 per cent is covered by rangelands.
- Point five to 44 per cent is forest cover.

In general, the available forest is concentrated on altitudinal ranges between 500 to 3,000m. Above 3,000m, it is usually too cold, below 500m the land is mostly used for agriculture. Forest cover and altitude vary between the river systems (Tables 2 and 4).

Table 4 : **Land Cover Categories in Per Cent of Total Watershed Area**

Land Cover	Indus	Ganges	Brahma-putra	Mekong	Yangtze	Yellow	Total
Forest	0.5	8.2	14.5	44.0	8.5	2.9	11.8
Rangelands *	45.9	10.2	53.6	18.4	25.1	62.2	32.6
Agriculture	37.5	77.5	26.6	36	64.1	27.8	50.0
Others **	16.1	4.1	5.3	1.6	2.4	7.1	5.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: USGS-IGBP Land-cover Classification Project, June 97; 1992-93 NOAA

* Include closed and open shrublands, woody savannas, and grasslands

** Wetlands, urban, snow and ice, barren

Specific Comments on the Different Watersheds

Indus: Almost no forest is left. In the west, it is too dry for the growth of high forest. Rangelands and shrublands are, therefore, the characteristic land-cover types. Agricultural land and natural mixed vegetation areas are widespread.

Ganges: As this watershed has a large area in the lowlands, agriculture is the dominant category.

Brahmaputra: The percentage of rangeland is high due to its vast upper watershed area in the Plateau of Tibet. Compared to the other watersheds, the percentage of forest coverage is also relatively high. However, forest cover in N. E. India has a distinct mixed agriculture and vegetation type, indicating shifting cultivation.

Mekong: The percentage of forest cover is the highest. Even land below 500m in altitude has forests.

Yangtze: Highlands above 3,000m have rangelands and agroforestry was widespread below 1,000m.

Yellow: Above 1,000m, grassland and open shrubland are found. Forest cover is very low. Agriculture and mixed vegetation land is found in the altitudinal ranges between 500 and 3000m. Very few mixed forests are found between 500 to 1,000m in altitude.

Apart from the Brahmaputra and Mekong watersheds, the forest areas are relatively small. The land is either used by agriculture or it is too high or too dry. This means that the potential to increase the forest area in the watersheds is relatively small due to natural as well as anthropogenic factors.

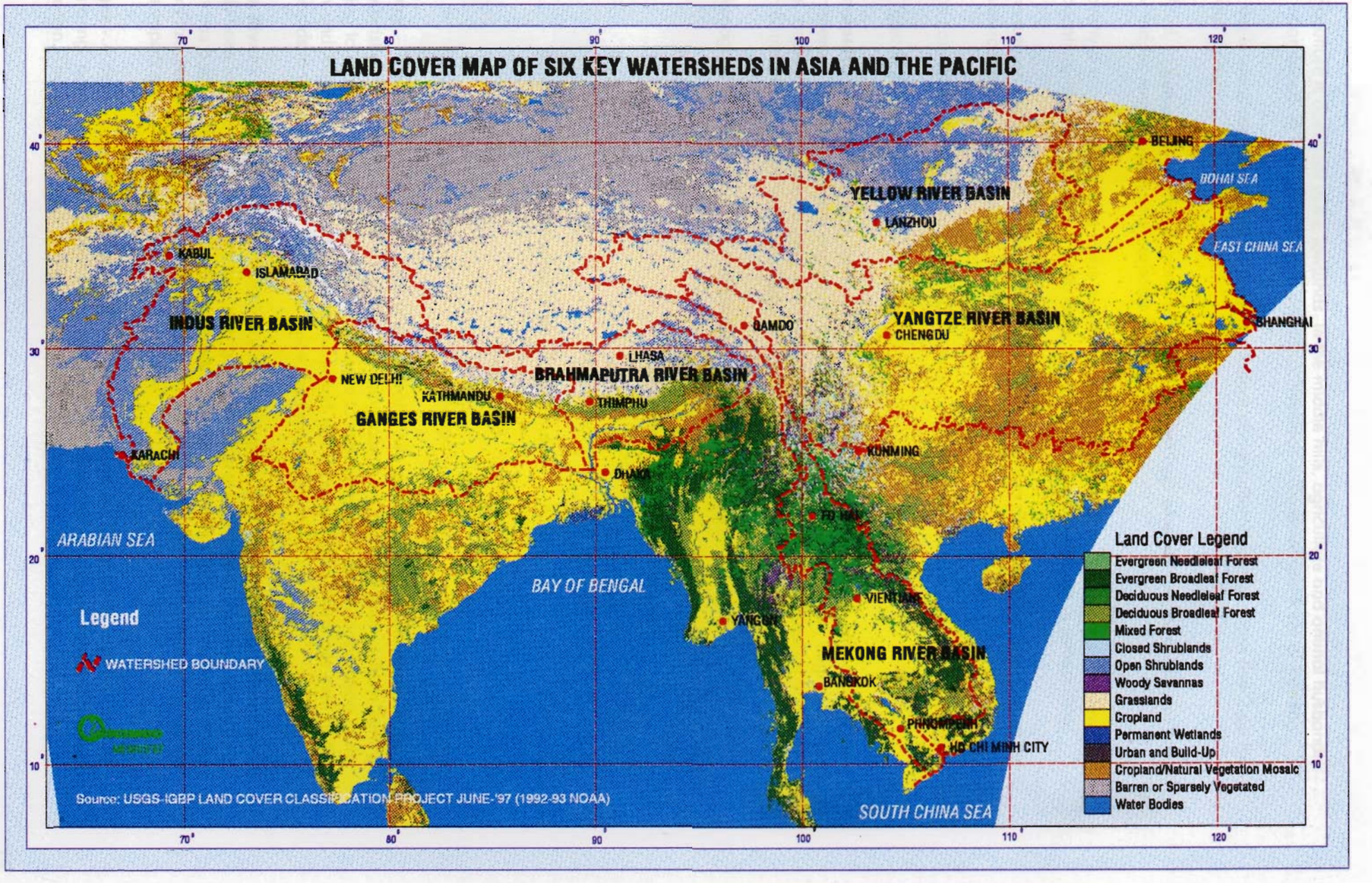
Socioeconomic Conditions

It is impossible to find comparable statistical figures for the different watersheds. The situation is not only variable between different watersheds, but also within a specific watershed. Therefore, this chapter highlights some general considerations and provides some details of the different watersheds.

General Considerations

- For all the watersheds, in many of the upland areas (above 900m) subsistence agriculture and livestock form the most important basis of the economy.

MAP 2


LAND COVER MAP OF SIX KEY WATERSHEDS IN ASIA AND THE PACIFIC
70°
80°
90°
100°
110°
120°
40°
30°
20°
10°
BEIJING
BOHAI SEA
YELLOW RIVER BASIN
LANZHOU
EAST CHINA SEA
KABUL
ISLAMABAD
INDUS RIVER BASIN
QAMDO
YANGTZE RIVER BASIN
CHENGDU
SHANGHAI
LHASA
NEW DELHI
BRAHMAPUTRA RIVER BASIN
KATHMANDU
THIMPHU
GANGES RIVER BASIN
KARACHI
KUNMING
DHAKA
ARABIAN SEA
BAY OF BENGAL
YANGON
VIENTIANE
MEKONG RIVER BASIN
BANGKOK
PHNOM PENH
HO CHI MINH CITY
SOUTH CHINA SEA
Legend
WATERSHED BOUNDARY
Land Cover Legend
Evergreen Needleleaf Forest
Evergreen Broadleaf Forest
Deciduous Needleleaf Forest
Deciduous Broadleaf Forest
Mixed Forest
Closed Shrublands
Open Shrublands
Woody Savannas
Grasslands
Cropland
Permanent Wetlands
Urban and Build-Up
Cropland/Natural Vegetation Mosaic
Barren or Sparsely Vegetated
Water Bodies
Source: USGS-IGBP LAND COVER CLASSIFICATION PROJECT JUNE-'97 (1992-93 NOAA)

- Agriculture is dominant in the lowlands. In the middle hills, agriculture and animal husbandry are combined. In high altitude or in dry areas, livestock is the dominant form of farming.
- In the lowland areas, irrigation is a typical feature of agricultural practices (see Box 2 on the Indus Valley).
- Wood, in general, has great importance as fuel. Other uses of wood are for timber, for fruit, for fodder, and for medicinal purposes (see Chapter 3).
- Poverty is a common feature in the six watersheds, in particular in the uplands. The levels of education, the accessibility to health care, sanitation, and safe water are in general low.
- Pressure on the land and on the natural resources in certain areas leads to depletion of the resources and to degradation.
- The conditions highlighted above are different in urban areas or areas with centres of industry.

Some Specific Information on Watersheds

Brahmaputra - The livestock population is a very important part of the economy, either subsistence or commercial. There is a strong impact on the forest by overgrazing of pastures, degradation of forests, depletion of vegetative cover, and compacting of soil. Livestock density varies from 114/km^2 in Bhutan to 1125/km^2 in Meghalaya.

The demographic situation varies considerably within the watershed.

Population density:	Tibet	6 inhab./km^2
	Bangladesh	828 inhab./km^2
Population growth rate:	Tibet	1.6 per cent
	Nagaland	4.6 per cent
Inhabitants/$km^2$of cultivated land:	India, Bhutan	419
	Assam	2388
	Nagaland	3101
	Sikkim	1161
	West Bengal	782

Mekong - The population growth rate is on average two per cent. There are some distinct characteristics of economic growth with the following common trends: transition from central planning to market-oriented economies and efforts to strengthen economic cooperation in the region and internally, which again leads to increased resource use rates. Thirty per cent of the households in the Mekong River Basin live below the poverty line.

Yellow River - In the upper reaches there is a vast potential for hydropower, several stations have already been built. In the middle reaches, over generations, a sophisticated, irrigated agricultural system has been developed comparable to those in the Indus and the Ganges lowlands. In the Hetao Plain, development of industries and mines has led to pollution and salinisation with a severe impact on agriculture.

Ganges - A dense population is observed in the watershed area. The main economic activities are farming, extraction of non-timber forest products, transportation, fisheries, and hydropower generation. The Ganges River is also a very important focus in the Hindu religion.

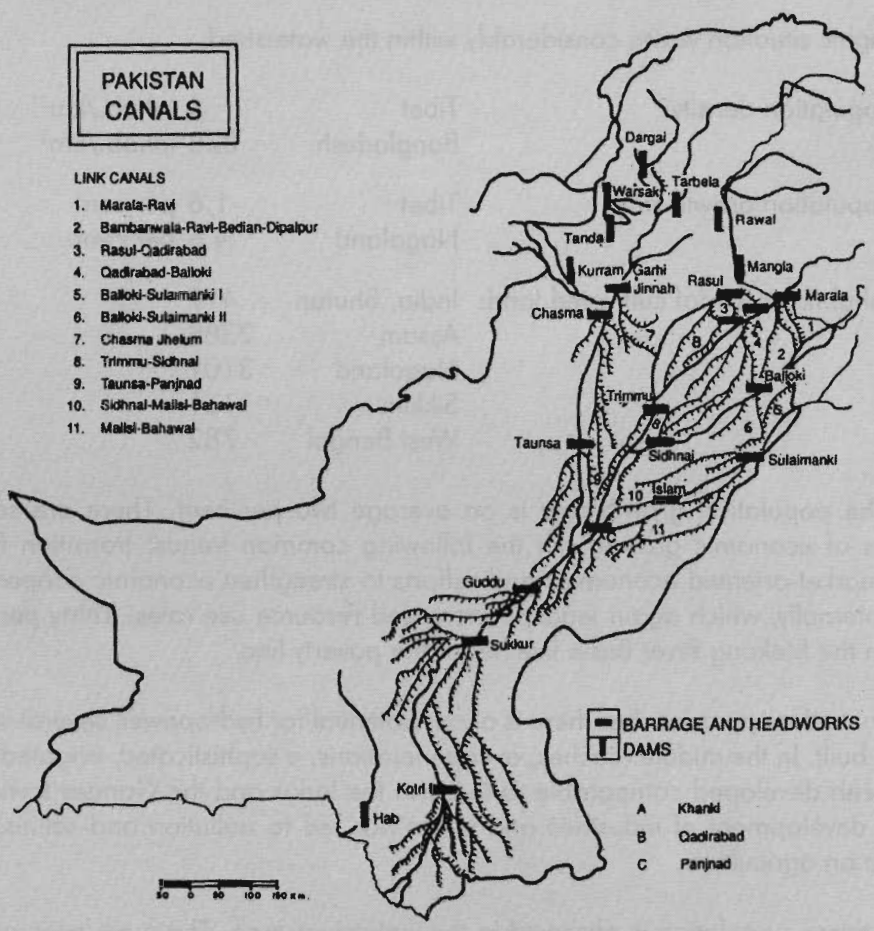
Box 2
Irrigation in the Indus Valley

Irrigation is a very old tradition in Pakistan. Beginning with simple lift irrigation, Pakistan has developed one of the most intricate and complex systems of canal irrigation in the world. The fact is that the development of agriculture in Pakistan is mostly dependent upon irrigation. About 75 per cent of the total cropped area is under irrigation (1984-85). The figures below provide some details about the development of irrigation from 1950 to 1985 and about the different types of irrigation.

Years	Percentage of area irrigated by				Area irrigated (in million ha)
	Canals	Tubewells	Wells	Others	
1950-51	81.4	----	11.7	6.9	9.25
1960-61	82.5	2.4	8.3	6.8	10.41
1970-71	63.2	21.2	12.2	3.4	10.59
1980-81	74.4	18.9	2.1	4.6	14.90
1984-85	72.6	21.3	1.7	4.4	15.62

The irrigated Indus Plain receives 120 billion cubic metres of water per year from the Indus River system. The upland areas of the watershed are the only continuous and reliable source of water for the uplands.

The irrigation system in the Indus Valley is characterised by a dense network of barrages and canals; these are illustrated in the figure below.



Source: Khan 1995

Indus - Livestock farming and agriculture are the major economic activities. Formation of a very large irrigation network is also found. Forestry for subsistence use is another important factor for the communities living in the Indus Basin where the products from farm forests are not sufficient. Community forestry and rehabilitation of degraded lands with the proper participatory practices may be a long-term solution.

Yangtze - Upland forests are degraded due to mismanagement. Not only has the extent decreased but the quality has also declined, resulting in natural disasters. The problem is well recognised and rehabilitation work has been designed and applied successfully. Income-generation factors were also incorporated and found effective in rebuilding the vegetation cover.