

Chapter 2

General Characteristics of the Country

2.1 PHYSICAL FEATURES

Bhutan is situated in the eastern Himalayas between the latitudes 26° 45' N to 28° 10' N and longitudes 88°45' E to 92°10' E. It is 340 km in length with an approximate area of 40,077 sq.km. It is bordered by the Tibetan plateau of China in the north and the Indian States of Sikkim in the west, West Bengal, and Assam in the south, and Arunachal Pradesh in the east. The terrain is mostly rugged and mountainous with elevations ranging from 200 masl to above 7,000 masl (Figure 2.1) within a distance of less than 175 km. The area above 4,200 masl covers 20.5% of the total land (MoA 1997) and is covered by the perpetual snow and ice forming the glaciers and glacial lakes. The variation of the climate is extremely dependent on the altitude.

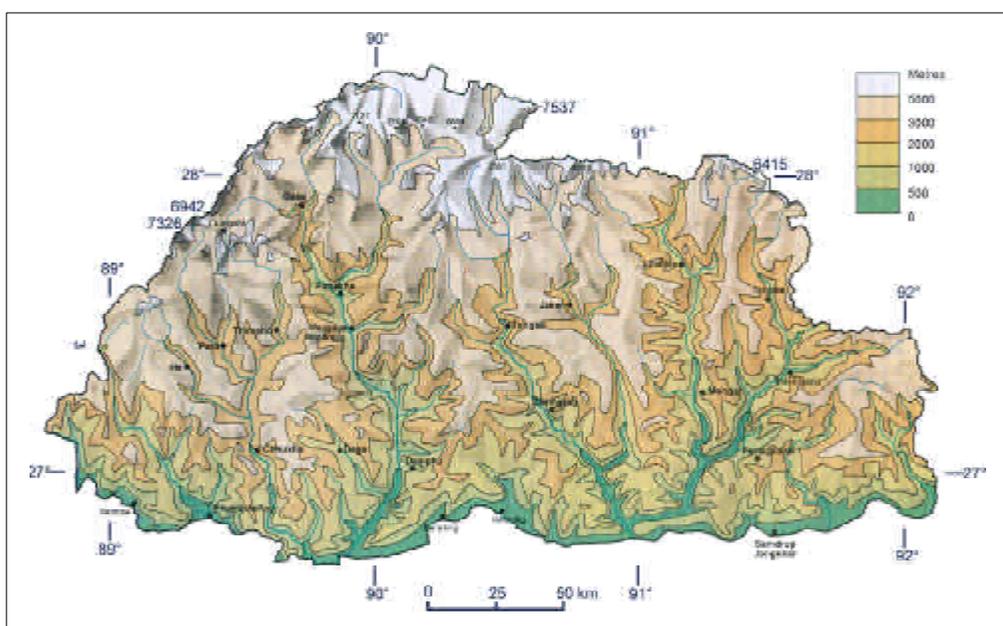


Figure 2.1: Topographic map of Bhutan (Ministry of Planning 1997)

2.2 CLIMATE

The climate in Bhutan is dominated by a southwestern monsoon, which originates from the Bay of Bengal. Generally the monsoon starts from the month of June and lasts until the first week of September. Occasionally during the months of October and November post monsoon rain occurs and can be quite severe. The period from November to March is usually dry, although small showers may occur at any time due to the westerly wind that brings winter rains in the foothills of the Himalayas. During the months of April and May the pre-monsoon occurs with light showers accompanied by hailstorms and thunder. From past records the mean annual rainfall varies approximately from 2,500 to 5,500 mm in the southern foothills, from 1,000 to 2,500 mm in the inner valleys, and from 500 to 1,000 mm in the northern part of the country.

Climatically Bhutan can be divided into three broad zones: subtropical in the southern foothills, temperate in the middle valleys or inner hills, and alpine in the northern part. Generally, southern foothills are hot and humid during the summer months and quite cool in winter. The middle valleys are cold in winter and warm in summer with a pleasant spring and autumn with mild temperatures.

2.3 RIVER SYSTEM

The river system of Bhutan can be divided into six major river basins mostly flowing from north to south in Bhutan except for the northern basin (Figure 2.2). The rivers of northern basin flow from south to north and are not shown in the figure.

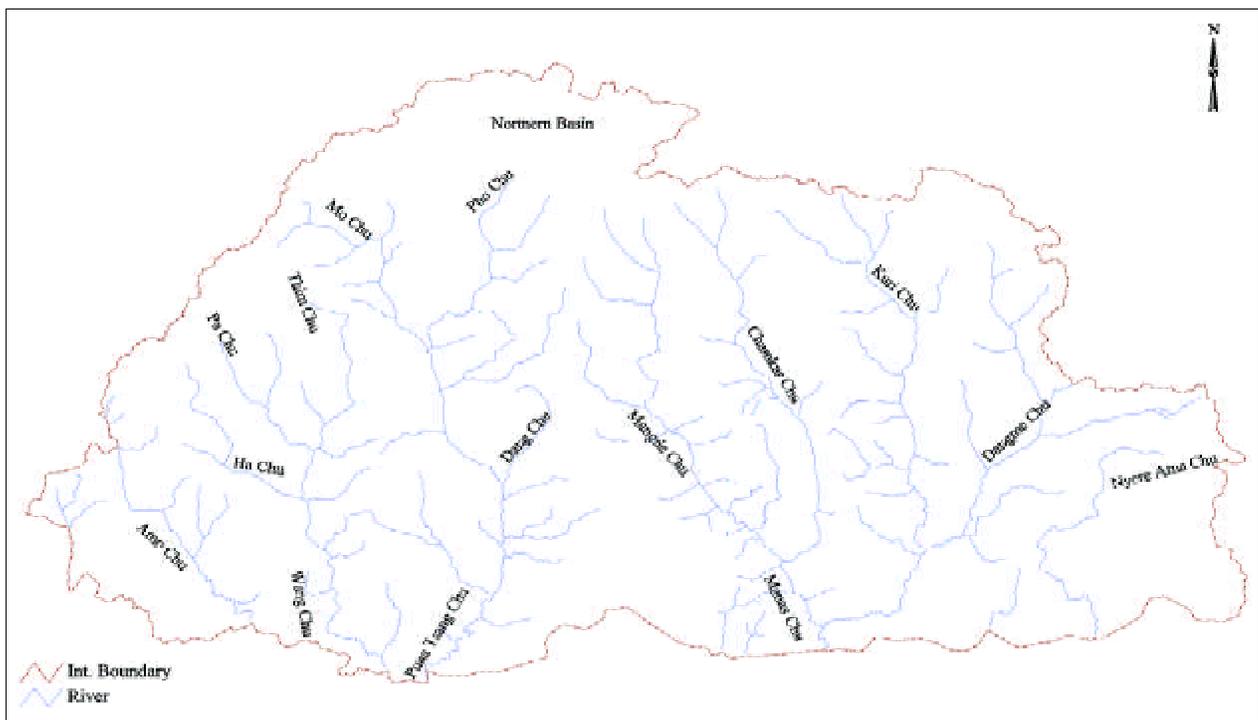


Figure 2.2: Major rivers of Bhutan

To date, a detailed inventory of the rivers in Bhutan is not available. The Puna Tsang Chu or The Sankosh is the longest river measured in Bhutan. It has a length of about 250 km. The south flowing river systems from west to east are the Amo Chu, Wang Chu, Puna Tsang Chu, Manas, and Nyere Ama Chu rivers respectively. Except for the Amo Chu and the Nyere Ama Chu, the river systems are joined by tributaries of appreciable size. These major tributaries are the Ha Chu, the Pa Chu, the Thim Chu, the Mo Chu, the Pho Chu, the Dang Chu, the Mangde Chu, the Chamkhar Chu, the Kuri Chu, and the Dangme Chu. Of these tributaries, the first three belong to the Wang Chu, the second three belong to the Puna Tsang Chu, and the remaining four belong to the Manas River system.

2.4 GEOLOGY AND GEOMORPHOLOGY

Geology

Only about 30% of the country has been geologically mapped and the following three main geo-tectonic units have been recognised (ESCAP 1991).

- Frontal Belt, making up the foothills and parts of the Lesser or Lower Himalaya
- Central Crystalline Belt, occupying portions of the Lesser and Higher Himalaya
- Tethyan Belt, covering the Higher Himalaya and isolated but large portions of the Lesser Himalaya

These three belts have been affected by at least three successive cycles of deformation. The first main deformation took place under a north–south stress field resulting in a tight east–west striking, overturned fold with a generally north dipping axial plane cleavage. Towards the final stage of tectonic activities, shearing and over thrusting took place resulting in the main central thrust (MCT). The second deformation was also under the north–south stress field producing upright open folds; this is associated with the main boundary fault and thrusting of Paleozoic rocks over the Tertiary Siwalik Group of rocks. The third phase of deformation operated under an east–west stress field resulting in north–south trending round hinged upright open folding. In the southern foothills it has been observed that terraces have been affected by over thrusting by Quaternary to sub-recent morphogenic uplift.

Frontal belt

Rocks in the southern foothills consist of recent deposits of sand, gravel, and boulders in the foothill terraces of southwestern and south central parts of the country at about 300 masl. The Siwalik group of rocks consists of sedimentary and metasedimentary rocks extending in an east–west direction and dipping north. They are exposed in the south central part of Bhutan extending from the east of Raidak River to the west of Sarpang town and in eastern Bhutan stretching from the east of Manas River to the eastern boundary with the Indian State of Arunachal Pradesh. The Damuda and Diuri Formations are exposed in the eastern part of Bhutan. The Damuda (Gondwana) rocks of Permian age consist of sandstone, shale, and coal seams, they overlie the Siwalik rocks along the MBT. The Diuri Formation, at times considered part of the Damuda, comprises grey slate boulders, made up of pebbles of quartzite, phyllite, dolomite, and gneiss in a slaty matrix. The Buxa group of rocks consists of dolomite, variegated phyllites, quartzites, and conglomerates. This group of rocks stretches from the westernmost part of Bhutan to the east along the foothills. The Shumar Formation overlies the Buxa Group of rocks and consists of metasedimentary phyllite, quartzite, and thin marble bands.

Central crystalline belt

The two main lithological groups of metamorphic thrust sheets of this belt are the Thimphu Gneissic Complex and the Paro Formation. The Thimphu Gneissic Complex is characterised by migmatites and biotite-granite-gneisses with thin beds of quartzite, quartz mica schists, calc-silicate rocks, and marble, and it is the major rock type covering Bhutan. The Paro Formation is characterised by quartz mica schist, quartzites, calc-silicates, marble, and a thin bed of graphitic schist, and this is exposed in and around Paro. The Central Crystalline Belt is affected by intrusion of tourmaline bearing granites and pegmatites in the form of dykes, sills, laccoliths, and larger intrusions. The larger intrusive bodies are concentrated in the northern ranges.

Tethyan belt

The metamorphic and granitised contact of the Tethyan rocks with the underlying Thimphu Gneissic Complex is gradational. The Tethyan rocks are exposed in the extreme north of the country and the central area of the Black Mountains and their surroundings. This rock type basically comprises quartzites, siltstones, sandstones, phyllites, calcareous phyllites, slates, limestone, and conglomerates.

Geomorphology

Bhutan lies on the southern face of the eastern part of the Great Himalayan Range. It is divided broadly into three physiographic zones, viz., Southern Foothills, Lesser Himalaya, and Higher Himalaya.

One conspicuous feature of the Bhutan Himalayas is their abrupt rise in altitude from south to north in comparison to the other parts of the Himalayas.

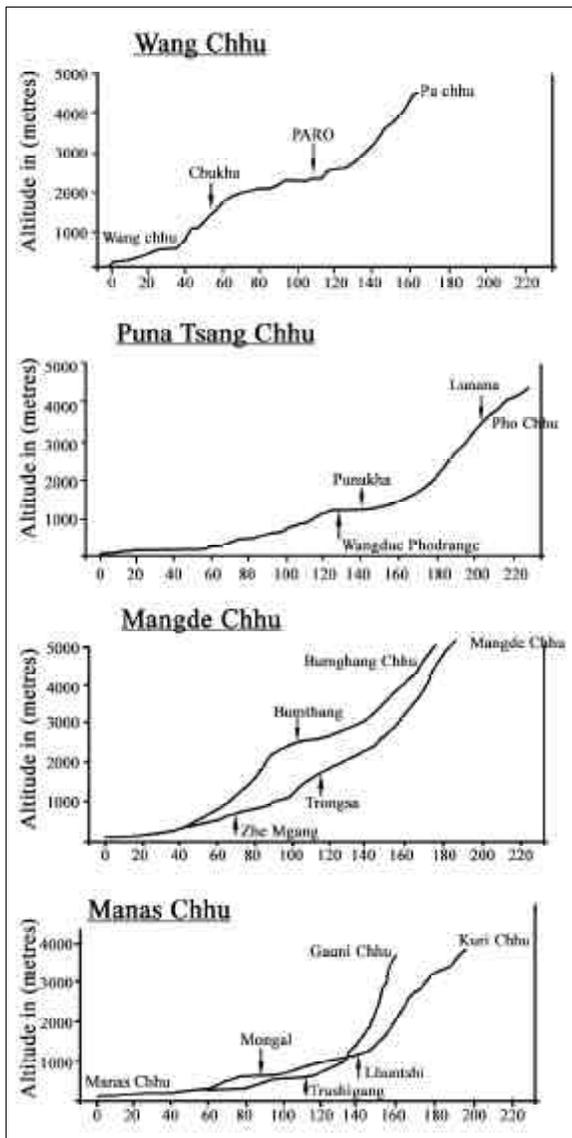


Figure 2.3: Profiles of the major rivers of Bhutan

All the inventoried rivers except Amo Chu and Kuri Chu have their origins within Bhutan and all flow north to south as individual major basins. This explains how the upheaval of the Siwaliks was not enough to block the river system forcing them to breach as one outlet. The longitudinal sections of major rivers presented in Figure 2.3 show nick points in two places, midway and further up, which indicate the uplift in two phases.

2.5 SEISMICITY

Bhutan is prone to earthquakes. It lies in zones 4–5 on the Richter scale. There is no seismic station in Bhutan. Although there have been earthquakes in the past, there are no documented records of magnitude or damage caused.

2.6 LAND USE/LAND COVER

Bhutan's total area deduced from Système Probatoire Pour l'Observation de la Terre (SPOT) imagery is approximately 40,077 sq.km (Ministry of Agriculture 1997). The dominant land cover of Bhutan is forest, and it occupies 72.5% of the total area (Table 2.1). Agricultural land constitutes 7.7% of the total land. The dominating land uses for agriculture are 'kamzhing' (dry land), 'chhuzhing' (irrigated/wet land), and 'tseri' (slash and burn cultivation). The horticultural area is expanding. The main crops grown are rice, maize, wheat, barley, millet, potato, mustard, beans, ginger, chilli, and other green vegetables. Cash crops grown are oranges, apples, and cardamom. 'Tsamdo' (pasture) land is another land use where livestock are sent for grazing. 'Sokshing' is also a form of land use where dry leaf litter is used to make farmyard manure for use in the fields. Although the area under sokshing is small, it plays a very important role in maintaining soil fertility.

2.7 ECONOMY

Bhutan's economy is dominated by agriculture and the majority of the population depends on agriculture for their livelihood. In 1985 the contribution to the gross domestic product (GDP) from agriculture was 54.9%. The construction sector contributed 11.1%, financial services contributed 7.2%, and the transport/communication and manufacturing sectors contributed 5.2 and 4.9% respectively. The other sectors that contributed significantly to the GDP were community and social services and trade and related activities, each contributing more than 8%. Prior to the commissioning of the Chukha Power Project (1986–87) the contribution from the power sector was

Table 2.1: Land cover of Bhutan 1997*			
S. No.	Land use	Area (km ²)	Percentage of total area
1	Forest	29045	72.5
1a	The conifer forest	10616	26.5
1b	Broad leaf forest	15107	37.7
1c	Forest plantation	64	0.2
1d	Shrub forest	3258	8.1
2	Agriculture	3088	7.7
2a	Wetland cultivation	388	1.0
2b	Dry land cultivation	977	2.4
2c	Mixed cultivated land	840	2.1
2d	Tseri (Slash & burn)	883	2.2
3	Pasture	1564	3.9
4	Horticulture	58	0.1
5	Settlement	31	0.1
6	Snow/glaciers	2989	7.5
7	Others	3301	8.2
Total		40 076	100

*Source: Atlas of Bhutan, Land use planning section)

negligible. During the period from 1985 to 1995, Bhutan's economy experienced a growth rate of 6.8% per annum almost doubling the real GDP from Nu 1,519.8 million to Nu 2,946 million. This was mainly due to the commissioning of the Chukha Power Project, which gave rise to other allied activities. During that period the agricultural contribution to the GDP decreased to 38%. Table 2.2 shows the change that occurred in the sector-wise share of the GDP in the period from 1985 to 1995.

2.8 NATURAL RESOURCES

Flora and fauna

Bhutan has an exceptionally diverse range of flora due to a wide range in altitude, climatic conditions, and 72% of the country being covered by forest. Bhutan's rich flora includes 50 species of rhododendron and over 300 species of medicinal plants. About 60% of the endemic species of the eastern Himalayan region can be found in Bhutan and as a result it has been declared one of the ten global 'hot-spots' for conservation of biological diversity.

Since Bhutan's flora have remained undisturbed a number of rare animals can be found in the country. Over 165 species of animals have been reported which include the golden langur, takin, blue sheep, snow leopard, red panda, Himalayan black bear, wild pig, and musk deer. These are found widely distributed within the country. The rare black-necked crane can be seen in Phobjikha Valley in Wangdue Dzongkhag and in Bomdiling in Yangtse.

Mineral resources

Most of the mineral deposits are extracted in the southern foothills. This is basically because of easy access compared to the northern region, which is very rugged. The minerals that are being exploited are dolomite, limestone, gypsum, marble, coal, quartzite, and talc.

In 1980 there were only 8 mines operating in the country. In 1996 the number of mining leases had risen to 33 with 29 mines in actual operation. There are at present eight mineral-based industries, which are fully dependent on indigenous raw materials. In 1980 the revenue generation from the mines was only Nu 2.1 million. In the 1995–1996 fiscal year the revenue figure was Nu. 32 million.

Hydropower resources

Most of the rivers are fed by glaciers and glacial lakes located at the source of these rivers. The altitude difference provides huge scope for hydropower development (Figure 2.4). The Power Master Plan estimated a theoretical hydropower potential of 20,000 MW from the rivers in the country (Ministry of Planning 1997).

The Department of Power of the Ministry of Trade and Industry is responsible for the supply of power in the Kingdom. It draws most of its power from the Chukha Project Authority. The Department of Power also operates some isolated systems (small/micro hydro and diesel generators) in central and eastern parts of the country. The power in the border towns of Geylephug and Samdrup Jongkhar is supplied from India. At present the installed hydropower capacity of Bhutan is 344 MW in 23 hydropower plants. Within the eighth five year plan period (1997–2002) an additional 105.8 MW from two new hydropower plants is expected (Ministry of Planning 1997).

Table 2.2: Sector-wise share of GDP in 1985 and 1995 (1980 prices)*

Sectors	1985		1995		Average growth (%)
	Product (million Nu)	%	Product (million Nu)	%	
Agriculture	834	54.9	1119	38.0	2.9
Mining/quarrying	13	0.8	38	1.3	11.6
Manufacturing	75	4.9	268	9.1	13.5
Electricity	6	0.4	245	8.3	48.2
Construction	169	11.1	317	10.8	6.5
Trade and other activities	132	8.7	178	6.0	3.0
Transport and communication	79	5.2	242	8.2	11.8
Financial services	110	7.2	281	9.5	9.8
Community and social services	126	8.2	322	10.9	9.8
Less imputed bank service changes	-25	-1.6	-63	-2.1	
Total GDP	1520	100	2946	100	

*Source: Eighth Five-year Plan 1997–2002 (Ministry of Planning 1997)

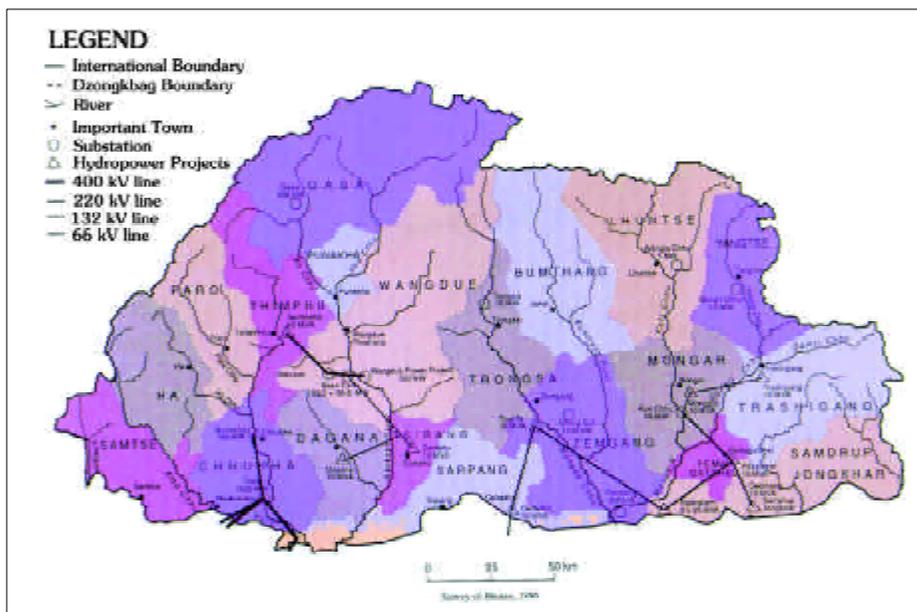


Figure 2.4: Map showing existing hydropower plants and transmission grid of Bhutan

2.9 POPULATION

Bhutan is one of the least populated countries in South Asia. Its population is estimated to be 600,000. The population growth rate is estimated at 3.1%, the fertility rate is 5.6 (Ministry of Planning 1997).

Bhutan has achieved universal coverage of health services. Health coverage has increased from 50% in 1985 to over 90% in 1996. Life expectancy has increased from 48 years in 1985 to 66 years in 1994 and infant mortality rate has decreased from 142 per 1,000 in 1985 to 70.7 per 1,000 in 1994.

Enrollment in education and the literacy rate have shown a dramatic increase. In 1985 there were 183 schools and institutes with 52,835 students. Now there are 301 schools and institutes with 85,000 students. Total enrolment is over 72% and the literacy rate has increased from 23% in 1980 to 54% in 1996.

All the district headquarters have digital telephone and facsimile services. There are 6,074 telephones and 103 post offices in the country. Various parts of the country are connected by 3,284 km of road.

2.10 GLACIERS

A glacier is a huge flowing ice mass. The flow is an essential property in defining a glacier. Usually a glacier develops under conditions of low temperature caused by the cold climate, which in itself is not sufficient to create a glacier. There are regions in which the amount of the total depositing mass of snow exceeds the total mass of snow melting during a year in both the polar and high mountain regions. A stretch of such an area is defined as an accumulation area. Thus, snow layers are piled up year after year in the accumulation area because of the fact that the annual net mass balance is positive. As a result of the overburden pressure due to their own weight, compression occurs in the deeper snow layers. As a consequence, the density of the snow layers increases whereby snow finally changes to ice below a certain depth. At the critical density of approximately 0.83 g cm^{-3} , snow becomes impermeable to air. The impermeable snow is called ice. Its density ranges from 0.83 to a pure ice density of 0.917 g cm^{-3} . Snow has a density range from 0.01 g cm^{-3} for fresh snow layers just after snowfall to ice at a density of 0.83 g cm^{-3} . Perennial snow with high density is called firn. When the thickness of ice exceeds a certain critical depth, the ice mass starts to flow down along the slope by a plastic deformation and slides along the ground driven by its own weight. The lower the altitude, the warmer the climate. Below a critical altitude, the annual mass of deposited snow melts completely. Snow disappears during the hot season and may not accumulate year after year. Such an area in terms of negative annual mass balance is defined as an ablation area. A glacier is divided into two such areas, the accumulation area in the upper part of the glacier and the ablation area in the lower part. The boundary line between them is defined as the **equilibrium line** where the deposited snow mass is equal to the melting mass in a year. Ice mass in the

accumulation area flows down into the ablation area and melts away. Such a dynamic mass circulation system is defined as a glacier.

A glacier sometimes changes in size and shape due to the influence of climatic change. A glacier advances when the climate changes to a cool summer and a heavy snowfall in winter and the monsoon season. As the glacier advances, it expands and the terminus shifts down to a lower altitude. On the contrary, a glacier retreats when the climate changes to a warm summer and less snowfall. As the glacier retreats, it shrinks and the terminus climbs up to a higher altitude. Thus, climatic change results in a glacier shifting to another equilibrium size and shape.

Among the basins and sub-basins of the Bhutan Himalayas, Amo Chu and Nyere Ama Chu Basins as well as Ha Chu and Dang Chu Sub-basins have no glaciers. The Pho Chu Sub-basin has the highest number of glaciers and the Thim Chu Sub-basin the lowest. The northern basin, where the drainage originates in Bhutan and flows towards Tibet (China), has only 59 glaciers but the area occupied by the glaciers in this basin is largest. Altogether there are 677 glaciers with an area of around 1,317 sq.km (Figure 2.5). The estimated ice reserve is 127 km³.

2.11 GLACIAL LAKES

The study of glacial lakes is very important for the planning and implementation of any water resources' development project. Past records show that glacial lakes have produced devastating floods and damage to major constructions and infrastructure. Prior to the present study, there has been no inventory of glacial lakes for the country. The present study on glacial lakes has been carried out considering all the lakes at elevations higher than 3,500 masl as glacial lakes. Some of the lakes are isolated and far behind the ice mass, which may or may not be of glacial origin. Altogether there are 2,674 glacial lakes covering an area of about 107 sq.km. The Pho Chu, Mangde Chu and Chamkhar Chu Sub-basins consist of more than 500 glacial lakes each. The distribution of glaciers and glacial lakes is shown in Figure 2.5.

2.12 GLACIAL LAKE OUTBURST FLOOD EVENTS

In Bhutan three glacial lake outburst flood (GLOF) events have been reported over the past few decades. Of these, the 1994 GLOF event that occurred from Lugge Tsho (eastern Lunana area) has written records of damage.

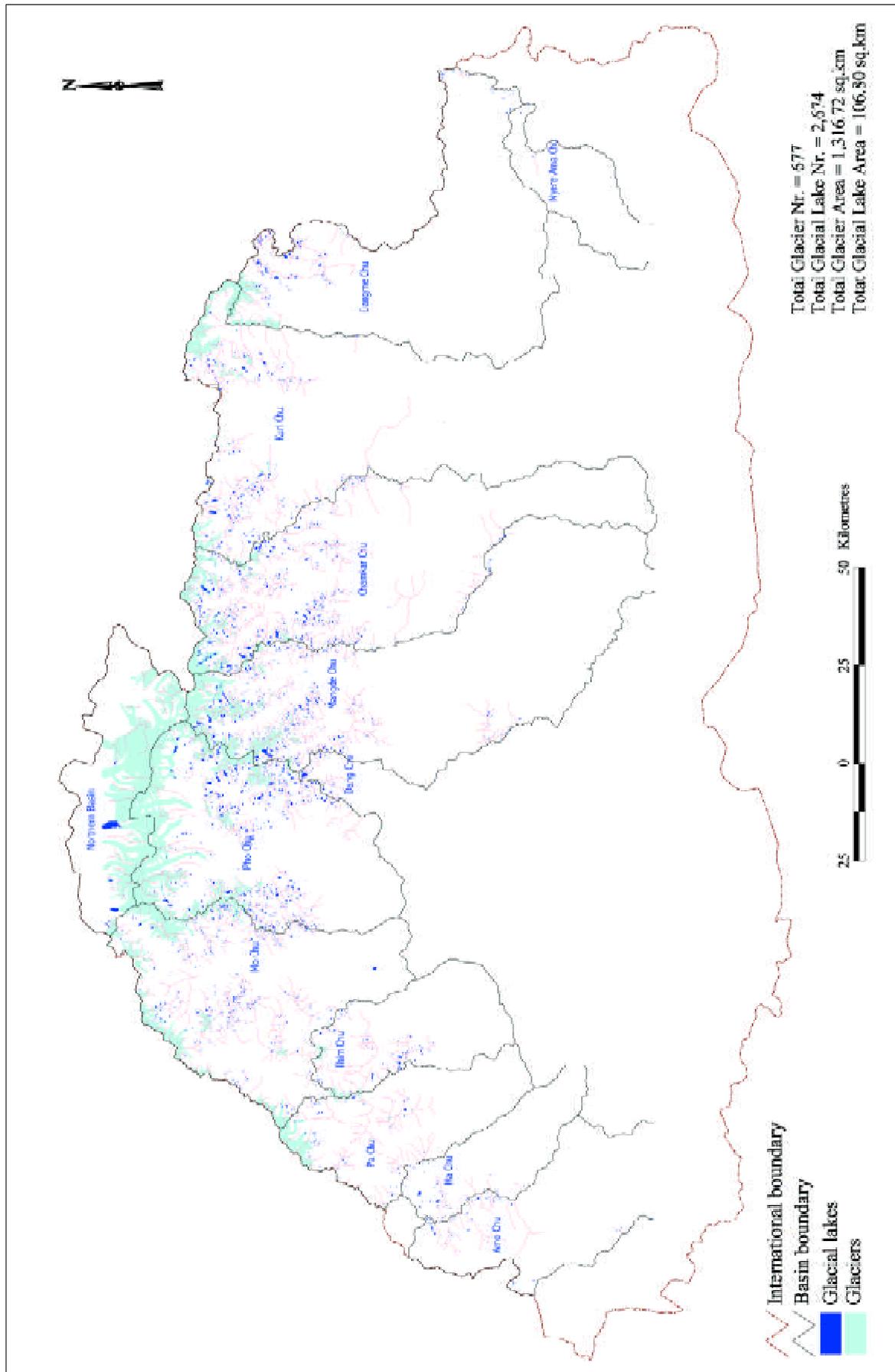


Figure 2. 5: Distribution of glaciers and glacial lakes of Bhutan