THE STATE OF THE PHYSICAL ENVIRONMENT IN THE UPPER REACHES OF THE YANGTZE

Soil erosion depends on the physical environment, socioeconomic environment, and the interactions between them.

The physical factors influencing soil erosion are the geological conditions, topographical conditions, hydrological conditions, climate, soil, and vegetation. Soil erosion can be perceived as an integrated consequence in terms of the interaction between different ecological components in the "land-vegetation-atmosphere" system.

Figure 2.1 shows the ecological components associated with the soil erosion process (Carpenter 1983).

Geological Structure and Rock Characteristics

The upper reaches of the Yangtze constitute an area of neotectonic activity. According to relevant data, the Yangtze Valley from the Qiaojia hydrometric station up to the headstream is an emergent area of neotectonic activity; and from Qiaojia down to Yizhang there is a transitional area from emergence to submergence.

Soil erosion is indirectly influenced by rock characteristics, because the rocks influence the chemical and physical characteristics of the soil and soil structure. Under the same climatic and biological conditions, soils with different parent rocks have different levels of erodibility. In addition, the rocks have a direct influence over the erodibility of the less-developed young soils, and the physical characteristics and structure of these soils are directly determined by the rocks (Shenyu Chang 1965).

Principal Rock Outcrops in the Region

The principal rock outcrops in the upper reaches of the Yangtze are given below.

- Alluvial Deposits from Rivers. Alluvial deposits from rivers are mainly found on both banks of the river, wherever it is more even, therefore soil erosion in these areas is not always apparent. Accumulated Quaternary Glacial Deposits are mainly distributed in high mountain areas where soil erosion is very weak.
- Loess and Loess Accumulation. Loess and loess accumulation mainly outcrop in the Anning River Valley and in Songpan, Nanping, and Sichuan provinces they are locally distributed. The loess has a soft texture, poor structure, vertical joint development, and silt composition, therefore it is easily eroded by runoff. The loess area in the region is heavily eroded.
- Siltstone. Siltstone is widely distributed throughout the region. The main outcrops are in the Sichuan Basin and in the Bijie - Liupanshui District in Guizhou Province. The erodibility of soil formed on siltstone as parent material varies according to the composition of the fragments. If the fragments are mainly composed of quartz, the soil erodes easily. If the fragments are mainly composed of laglociose, the soil does not erode easily.
- Mudshale. Mudshale is mainly found in the central foothills of the Sichuan Basin and can also be found in Bijie District of Guizhou Province. The soil forms quite rapidly as a result of physical weathering. This soil is called purple soil and erodes easily because of its loose structure. The purple soil areas are densely populated and the impact of human activities on soil systems is heavy, resulting in the following cycle: weathering - farming - erosion.

- Carbonate. Carbonate is composed of calcite and dolomite. It is distributed throughout the fringe areas of the Sichuan Basin, the eastern and southern mountains of Sichuan Province, Guizhou Province, the Wu Basin, and on both banks of the Li-Batang Section of the Jinsha River. Black lime soil and red lime soil have been formed by carbonate weathering. Black lime soil is rich in calcium which combines with humic materials to form a stable granular structure and, therefore, does not erode easily, but the red lime soil erodes easily because of a poor granular structure and strong eluviation.
- Neutral and Acid Intrusive Rock. This rock is mainly distributed in the western part of Sichuan Province over a small area. The soil formed on this kind of rock is rich in quartz with a poor structure, therefore it erodes easily.
- Basic Rock. This kind of rock outcrops in Jianwei Erbian, Sichuan Province, the northeastern part of Yunnan Province, and the north-western part of Guizhou Province. The soil formed after weathering is rich in clay minerals, therefore it does not erode easily.
- Phyllite. Phyllite mainly outcrops on both sides of Longmen mountain and the Huidong Section of the Jinsha. The soil formed after weathering erodes easily because of its poor structure.
- Schist. Schist is mainly distributed throughout Huidong, Sichuan Province and Wuding, Yunnan Province. The soil formed on this kind of rock erodes easily.
- Slate. This kind of rock is mainly distributed throughout the Qinghai - Tibetan Plateau and the western part of Sichuan Province. The soil formed after weathering erodes easily.

Gradation of the Anti-erosive Capability of the Major Rocks and Surface Materials in the Region

The major rocks and surface materials in the region have been graded according to their capability to withstand erosion. The principal rocks and surface materials in the region have been classified into 10 grades which are listed in Table 2.1 (Northwestern Institute of Soil and Water Conservation, CAS, 1986).

Similarly, the stones in the upper reaches of the Yangtze have been classified into three grades as follows:

- stones highly susceptible to erosion: shale, phyllite, schist, and slate;
- stones with medium susceptibility: sandstone, granite, and diorite; and
- stones with strong resistance to erosion: limestone, dolomite, marble, and basalt.

Topographical and Morphological Conditions

The topography of China from the Qinghai-Tibetan Plateau eastwards broadly falls into four great steps (see Figure 2.2).

1. The Qinghai-Tibetan Plateau with a mean elevation above 4,000m.

2. From the eastern margin of the Qinghai - Tibetan Plateau eastwards up to the Da Hinggan -Taihang-Wushan mountain line, composed mainly of plateaux and basins with elevations from 1,000 to 2,000m.

3. From the above-mentioned line eastwards up to the coast lie the largest plains in China: the Northeast China Plain, the North China Plain, and the middle and lower reaches of the Yangtze River Plain. These plains are also interspersed with hills generally below 500m in elevation.

4. The continental shelf, including water depth, is generally lower than 200m (Zhao Songqiao 1986).

Table 2.1: Gradation of the Anti-erosive Quality of Surface Materials

Anti-erosive Grade Quality	Surface Materials	Note
	Soil-like materials	
1	Sandy (alluvial deposits, diluvial deposits. .)	Anti-erosive capability increases as the number increases
2	Loamy (loess, lacustrine deposits, slope wash. .)	
3	Loose mud (red earth type regolith)	
4	Tight mud (Quaternary yellow clay)	
	Thin layer eluvium	
5	Sandy soil mantle (soil mantle developed on granite sandstone and gneiss)	
6	Loamy soil mantle (soil mantle developed on slate, basalt, mud limestone, and siliceous limestone)	
7	Muddy mantle and mantle with rich organic materials (mantle developed on limestone phyllite)	
	Semi-weathered rocks	
4	Red earth type semi-weathered purple stone	
6	Semi-weathered shale	
7	Semi-weathered sandshale	
8	Semi-weathered sandstone	
	Bare Rocks	
9	Granite, sandstone, bedding, limestone, siliceous limestone	
10	Block limestone, basalt, dolomite	

Source: Northwestern Institute of Soil and Water Conservation, CAS, 1986

The upper reaches of the Yangtze drain the Qinghai, Tibet, Yunnan, Sichuan, Guizhou, and Hubei provinces across the first great topographical step and the second one. The region is characterised by a massive relief; the Tongtian River Basin in the upper reaches of the Jiangsha with a mean elevation of 4,000masl, where soil erosion is scarcely observed; and the section of the Jinsha in the Hengduan Mountains lined on both banks by numerous mountain canyons. The 350km section from the headstream to Yibin falls more than 6,000 m, 90 per cent of the total drop of the Yangtze River.

The Hengduan Mountains are a series of parallel north-south ranges running from Western Sichuan and Yunnan Province to Eastern Tibet. Among these are, from west to east, the Gaoligong, Nushan, Daxue and Qionglai mountains. The Hengduan range is 3,000 to 4,000masl, 5,000 to 6,000 metres at some points and its highest peak, Mount Gongga, is 7,556 metres. The Hengduan Mountains are characterised by certain features that determine the state of soil erosion in the mountains.

1. Complicated geological structure, fault development, broken strata, and unstable surface materials on slopes.

2. Sharply divided dry and wet seasons, 80 per cent of the annual precipitation is concentrated in the rainy season. There are clearly defined vertical climate zones - tropical temperate and cold, soil and plant life covered with snow but it is warm halfway down the slopes where there are dense forests. In the valleys, at 1,000masl where there are dense forests, it is very hot.

The valleys in the Hengduan Mountains are dry and hot and the population is dense. Therefore, in these areas soil erosion and other types of soil and water losses; for example, gravitational erosion and debris flow, are accelerated.

The Sichuan Basin is also known as the **Purple Basin** because of the colour of its shale and soil. The Sichuan Basin is situated along the upper reaches of the Yangtze in the east and bounded by the Qiaonglai Mountain on the Qinghai-Tibetan Plateau in the west the Dalou Mountain on the Yunnan - Guizhou Plateau in the south, the Daba Mountain in the north, and the Wushan Mountain in the east. It is bordered on all sides by mountains of about 2,000 to 3,000 metres in height. These mountains are deeply cut by rivers, and some mountains, for example, the Daba and Mishan in the north and the Langmen, Jiajin, Xiaoxiangling, and the Daxiangling in the northwest and southwest are rainstorm prone areas lying in the upper reaches of the Yangtze. Therefore, these areas have a strong tendency towards soil erosion.

The Sichuan Basin can be divided into three parts: the western part consists of orderly ranged rows upon rows of mountains and valleys; the central part is a major farming area with numerous flat-topped hills of less than 400 metres in elevation; the eastern part is the Chengdu Plain which is the most affluent area in the basin; and the Sichuan Basin has less relative relief, ranging from 20 to 150 metres. The slopes are generally less than 20°. The basin receives less precipitation than the fringe mountain areas but has a higher precipitation intensity. Soil erosion on the slopes is prominent in the basin.

In the middle and upper reaches of the Wu and the northeastern part of Yunnan Province, the relative difference in elevation ranges from 200 to 700 metres. The rocks in these areas are mainly carbonate, under tropical climatic conditions, the karst morphology is well-developed and cave, dolines, and karst depressions are widely distributed. Therefore, surface soil erosion is not obviously observed.

In the field, soil erosion is closely related to slope, length, and shape. Relationships between soil erosion and slope, length, and shape are outlined below. These relationships are based on the data available.

Relationship between Slope and Soil Erosion

In certain areas, soil erosion increases with slope length. In Sichuan Province, the relationship between soil erosion and slope is unlinear (Figure 2.3). The relationships between soil erosion and slope length and shape for Suining County (Sichuan Province) are listed in Table 2.2 (Northwestern Institute of Soil and Water Conservation, CAS, 1986).

Table 2.2: Relationship between Slope and Soil Erosion

Item, Slope	Water Loss		Soil Loss	
	m^3/h	% to 5° slope	kg/h	% to 5° slope
5°	631.5	100.0	7011.0	100
10°	1021.5	161.8	59067.0	826.6
15°	1374.0	217.6	92667.0	1296.3

Source: Government of China, 1986

Soil erosion can reduce the soil depth, and this is demonstrated in Figure 2.4, which shows the relationship between slope and soil depth.

Work on the relationship between soil erosion and slope in Yangting County, Sichuan Province, has been carried out by the Chengdu Laboratory of Soil Science under the Chengdu Branch of the Chinese Academy of Sciences. The results are shown in Table 2.3.

Table 2.3: The Relationship between Soil Erosion and Slope

Item	Slope 2°-4° (Pilot, Corn)	5°-10° (Control, Corn)
Precipitation (mm)	74.0	79.5
P. intensity (mm/30 min)	37.0	13.1
Runoff m^3/h	43020.0	76575.0
Runoff Percentage to Pilot (%)	100.0	178.0
Soil Loss T/h	0.6045	1.5795
Soil Loss Percentage to Pilot (%)	100.0	261.3

Source: The Chengdu Laboratory of Soil Sciences 1988

The research results indicate that runoff and soil loss increase with slope increase under certain degrees of precipitation and precipitation intensity. This conclusion is shown in Table 2.3.

Relationship between Slope Length and Soil Erosion

Slope length like slope is also closely related to soil erosion. As slope length increases, soil erosion can increase because the dynamic energy of water increases. In addition, the lower sections of slopes are susceptible to gully erosion because of accelerated water flow. Some field surveys on the relationship between area and depth of gullies and slope length have been carried out by the Northwestern Institute of Soil and Water Conservation in Hanyuan County, Sichuan Province, and these indicated that increase of slope length could sharply increase gully soil erosion and density, as well as the depth of the gully (Figure 2.5).

The Relationship between Soil Erosion and Surface Relief

Generally, surface relief has no strong influence on soil erosion in the low mountains and hills of the Sichuan Basin and other parts of the upper reaches of the Yangtze, because the surface relief in these areas is gentle. A field survey carried out by the Department of Geography, Chongquing Normal College in Chongquing indicates that relief range from $20m/4km^2$ to $50m/4km^2$ (21.6%) and 200 to 400m/4km (25.6%) respectively. More than $700m/4km^2$ accounts for only 0.24 per cent of the total area which is listed in Table 2.4 (Zhao Chun Yong 1987).

Table 2.4: The Surface Relief in Chongquing District

Relief ($m/4km^2$)	20	20-50	50-100	100-200	200-400	400-700	> 706
Percentage to total area	0.38	20.1	24.6	21.6	25.6	7.1	0.24

Source: The Department of Geography, Chongquing Normal College, 1987

Climate in the Upper Reaches of the Yangtze

Apart from the geological structure and topographical and morphological conditions, climate is also an important factor in determining the characteristics of soil erosion.

The climate in the upper reaches of the Yangtze has three predominant characteristics (Domros and Peng Gongbing 1988).

- The monsoon climate is dominant, with significant changes in or even reversal of wind direction from winter to summer as well as a seasonal variation in precipitation according to whether the moisture of the monsoon advances or retreats.

- The climate is continental and mainly characterised by higher temperatures in summer and lower temperatures in winter.

- There are many varieties of climate in the upper reaches of the Yangtze.

Different Climates in the Upper Reaches of the Yangtze

The upper reaches of the Yangtze have many types of climate because of the vast area and degree of topographical relief.

According to the climate regionalisation scheme (Table 2.5) of China drawn up by Huang Bing Wei (1986), the following observations can be made about the upper reaches of the Yangtze.

The Aba - Naqu Area and the Southern Qinghai and Qiangtang Plateaux fall into the subalpine plateau zone. Yushu Station in Qinghai Province, which is located in the Jinsha Basin, can be taken as representative of the climatic characteristics in this area. The climatic diagram (Figure 2.6) shows a pronounced seasonal contrast between summer and winter, both in terms of precipitation and temperature. With regard to precipitation, Yushu demonstrates a summer maximum during which more than 90 per cent of the annual total rainfall (484mm) is recorded. The annual temperature variations suggest a fair summer (July 125.5°C) compared to a more pronounced winter (January - 7.8°C). The number of snowy days is, however, rather low, because of the dry conditions in winter.

The High Mountains and Gorges of Western Sichuan fall into the Humid and Sub-humid Temperate Plateau Zone.

Despite its high elevation (mostly between 3,000 to 4,000masl), average annual precipitation totals between 600 to 800mm. The annual variation in precipitation is, however, wide, expressing a pronounced wet season from May to September and alternatively a distinct dry season from November through March.

July is the wettest month, December and January are the dryest months. During the wet summer season of five to six months, up to 90 per cent of the annual total precipitation may be received. In the winter, most precipitation occurs as snow. With increasing elevation above sea level however, precipitation may turn into snow all the year round. Accordingly, the number of snowy days and the length of the period under snow cover may extend from winter and last throughout the year.

Because of the rapid change in landforms and elevation, the temperature conditions may differ substantially. In the context of thermal conditions, winter and summer are clearly established seasons. The annual variation in temperature is obviously influenced by the elevation of the location.

Table 2.5: Climate Division Scheme of China

1.	Cold Temperate		
a.	Humid	1)	Northern Da Hinggan
2.	Middle Temperate		
a.	Humid	(1) (2) (3)	San Plain Mountains of North - Northeastern China Piedmont Plain of Eastern - Northeastern China
b.	Sub-humid	(1) (2) (3)	Central Songhua - Liache Plain Middle Da Hinggan Piedmont Plain and Hills of Sanhe
c.	Semi-arid	(1) (2) (3)	Southwestern Songhua Plain Southern Da Hinggan Eastern Nei-Mongol High Plain
d.	Arid	(1) (2) (3) (4) (5)	Western Nei-Mongol High Plain Area of Lanzhou and Eastern Heixi (Gansu Corridor) Jujjan Basin Altony Mountains, Tacheng Basin Ili Basin
3.	Warm Temperate		
a.	Humid	(1)	Hills and Mountains of Liaodong and Eastern Shandon
b.	Sub-humid	(1) (2) (3) (4)	Hills and Mountains of Central Shandon North China Plain Mountains and Hills of North China Plains of Southern Shanxi and Weihe Valley
c.	Semi-arid	(1)	Loess Highlands of Central Shanxi, Northern Shanxi
d.	Arid	(1)	Tarim Basin and Tuypen Basin
4.	Northern Subtropical		
a.	Humid	(1) (2)	Huainan and Lower Reaches of the Yangtze River Hanzhong Basin
5.	Middle Subtropical		
a.	Humid	(1) (2) (3) (4) (5)	Hills and mountains of Nanling Guizhou Plateau Sichuan Basin Yunnan Plateau Southern Slope of the Eastern Himalayas
6.	Southern Subtropic		
a.	Humid	(1) (2) (3)	Central and Northern Taiwan Hills and Plains of Guangdong, Guangxi, and Fujian Mountains and hills of Yunnan between Wenschuan and Teng chong

Contd......

7.	Peripheral Tropical		
a.	Humid	(1)	Lowlands of Southern Taiwan
		(2)	Central and Northern Hainan and Leizhou Peninsula
		(3)	Valleys of Southern Yunnan
8.	Middle Tropical		
a.	Humid	(1)	Southern Hainan and Dongsha, Xisha and Zhougsha Islands
9.	Equatorial Tropical		
a.	Humid	(1)	Nansha Islands
10.	Plateau Alpine		
d.	Arid	(1)	Kunlun Mountains
11.	Plateau Subalpine		
b.	Sub-humid	(1)	Aba-Naggu Area
c.	Semi-arid	(2)	Southern Qinghai - Tibetan Plateau
12.	Plateau Temperate		
a/b.	Humid and sub-humid	(1)	High mountains and gorges of Western Sichuan and Eastern Tibet
c.	Semi-arid	(1)	Plateau and Mountains of Eastern Qinghai
		(2)	Mountains of Southern Tibet
d.	Arid	(1)	Qaidam Basin
		(2)	Nigari Mountains

Source: Huang Bing Wei 1986

For stations between 3,000-4,000masl, summer temperatures are still fair (at the most rising to a mean monthly average of from 10° - 15°C), while winter temperatures at this elevation decrease, at the most to a monthly (January) mean temperature of from -3°C to -7°C. The daily range of temperatures may become rather high, often indicating a negative daily minimum temperature for most months of the year. Subsequently, the number of frost days may be extremely high, for example, there are 147.5 frost days per year in Ganze which is located on the left bank of the Yalong in the Upper Reaches of the Yangtze.

<u>The Yunnan-Guizhou Plateau and Sichuan Basin</u> fall in the Humid Subtropical Middle Zone. The climatic conditions may vary considerably in these areas, but still "subtropicality" is valid. As such, the year-round, positive mean temperature is the main characteristic, and, at the same time, this is manifest in a remarkably lesser degree of coldness in winter. This is also valid for the mountain areas. For example, the Yunnan Plateau, where the winter temperature, even at high altitudes, drops only slightly below zero. Because of the overall moisture conditions, these areas are considered to be humid throughout the year with a long wet season from about April until September or October with maximum rain in July and August, alternating with a winter period of meagre precipitation which is partly in the form of snow.

Precipitation in the Upper Reaches of the Yangtze

Precipitation is the basic agent triggering soil erosion. In other words, the fundamental cause of soil erosion is rain acting upon the soil. Any study of soil erosion can actually be divided into how it will be affected by different kinds of precipitation and how this will vary for different conditions of soil; the former is concerned with precipitation and the latter is concerned with the soil.

In the following passages, the parameters of precipitation will be discussed.

Principal Distribution of Annual Precipitation

Generally, China can be divided into the following two major precipitation regions.

- A dry western area which mainly consists of Xinjiang and the Qinghai-Tibetan Plateau, but which also includes Inner Mongolia.
- A relatively wet eastern area.

These two major regions can be divided by a 5000mm isohyet which generally crosses China in a southwesterly-northwesterly direction from the eastern parts of the Tibetan Plateau - roughly via Lanzhou and Taiyuan to Harbin (Figure 2.8). From Figures 2.7 and 2.8 some observations can be made: apart from a small section of the upper reaches of the Yangtze River in the Qinghai-Tibetan Plateau, most of the region falls into the monsoon area of China; and most of the region experiences heavy precipitation which provides an important dynamic to soil erosion in functioning together with the prevailing natural conditions.

In Sichuan Province, more than 80 per cent of the total area receives an annual precipitation of up to 1,000mm. The mountains in the western part of Sichuan Province can experience more than 1,300mm of mean total precipitation per annum. In some places, for example, Yaann, Tianquan, Hongya, and Emei, the mean annual precipitation can reach 1,500 to 1,900mm (Emei - 1909.6mm/a; Yaan - 1776mm/a). In the Xichang and Liangshan districts of Western Sichuan, the mean annual precipitation is about 1,000mm (see Figures 2.8 and 2.9) (Chengdu Institute of Mountain Disasters and Environment 1980).

The basin of the Jinsha on the Qinghai-Tibetan Plateau receives a total mean annual precipitation of 500mm (Gao You Xi et al. 1984).

Annual Variation in precipitation in the Upper Reaches of the Yangtze. The annual variations in precipitation are an equally important factor to be taken into consideration in issues relating to soil erosion.

Specific Precipitation Types

In the upper reaches of the Yangtze, as in China as a whole, a distinct annual variation of precipitation can be perceived showing a pronounced seasonality between a wet summer and a dry winter, with transitional conditions in spring and autumn.

Three types of annual precipitation variation can be perceived, each of which represents far-reaching homogeneity in terms of the precipitation variation over the year. These are given below.

Type I - Weak Midsummer Precipitation Type. This type shows a summer peak in July and August, June and September are still part of a fairly wet summer, while during most of the time it is dry and sometimes even extremely dry.

Type II - Strong Midsummer Precipitation Type. This type is similar to Type I, showing maximum precipitation in July and August, and also producing substantial precipitation in the preceding months of May and June as well as in the succeeding month of September and sometimes even in October.

Type III - Strong Early Summer Precipitation Type. In this type, maximum precipitation occurs in May and June, although a long and pronounced wet season continues from March or April through September and sometimes even October.

Figure 2.10 shows three types of annual precipitation variation.

The annual variations in precipitation for selected stations along the upper reaches of the Yangtze are described here, demonstrating the general situation of variation in annual precipitation in the region.

The main contrasting conditions between wet summers and dry winters are also expressed by diagrams showing the monthly percentages of precipitation against the annual total for the selected stations (Figure 2.11a-d with mean monthly and annual totals of precipitation for each of the selected stations). In China, values > 8.33% can be regarded as a relative precipitation surplus, while a precipitation deficit is given in the case of figures < 8.33%. From these figures it can be observed that most of the areas along the upper reaches of the Yangtze River fall into Types I, II, and III.

A field survey carried out in Sichuan Province points out that the variation in annual precipitation and soil loss by soil erosion have a positive correlation which is shown in Figure 2.12, and this means that different types of annual variation in precipitation can cause different types of soil erosion.

Precipitation Intensity in the Region

Soil erosion is a working process in the physical sense of 'expenditure of energy', because energy is used in all the phases of soil erosion - in breaking down aggregates, in splashing them into the air, and in carrying away soil particles. Calculations have been made of the kinetic energy of rain and runoff and these calculations suggest that the rain, in certain conditions, has 256 times more kinetic energy than surface runoff.

As an indicator of the nature and effectiveness of precipitation, its intensity can be used to identify the kinetic energy of rain; and precipitation frequency and rainstorm are also considered to be closely related to the kinetic energy of rain. The precipitation intensity is much more important than annual precipitation, which has been demonstrated by field experiments in Yenting County, Sichuan Province. The observations are listed in Table 2.6.

From Table 2.6, it can be seen that precipitation intensity plays a much more important role in soil erosion. For example, the precipitation event from May 24-26, 1983, is 37.9mm higher than the May 21 precipitation event. The precipitation intensity of the former event is 24mm/minute less than the latter event, but, in terms of soil loss on forested plots, for the former event it is 0.71h higher than for the latter event and 0.38h higher on farm land.

Extremely high precipitation intensities are normally called rainstorms. In China, a daily rainfall of > 50mm is commonly defined as a rainstorm. Rainstorms are regarded as strong rainstorms, when a daily total of > 100mm is recorded. Rainstorms can cause more serious runoffs and soil erosion than ordinary precipitation events.

Many field observations suggest that precipitation > 25mm/day could obviously cause soil erosion in the upper reaches of the Yangtze where a high number of rainstorm events are recorded.

Table 2.6: The Relationship between Precipitation Intensity, Precipitation, and Soil

Date of Precipitation	Total Precipitation (mm)	Maximum Daily Precipitation (mm)	Precipitation Intensity (mm/30 min)	Forested Land Soil Loss (T/h)	Farmland Soil Loss (T/h)
May 13-14, 1983	79.0	41.0	37.0	1.56	0.60
May 21, 1983	65.0	65.0	39.0	0.90	0.68
May 24-26, 1983	102.9	44.4	15.0	0.19	0.30
June 4-7, 1983	35.4	16.0	4.7	0.08	0.14
June 21-23, 1983	36.2	12.5	1.8	0.00	0.00

Source: Yenting County Government 1983

The State Bureau of Meteorology has estimated the number of rainstorms from 1951 - 1957 (based on a maximum precipitation total/day which is shown in Table 2.7).

Table 2.7: The Number of Rainstorms from 1951 - 1957

Grade mm/day ----------- Province	100	100-200	200-300	300-400	400-600	600-800	> 800
Qinghai	17	4					
Tibet	13	2	16	15	7		
Sichuan		10	6	14	2		
Guizhou			5		4		
Yunnan			9				
Hubei							

Source: State Bureau of Meteorology 1984

From Table 2.9, it can clearly be observed that the highest number of rainstorms was recorded in Sichuan Province, rainstorms of from 200 to 300mm occurred 16 times, of from 300 to 400mm/day 15 times, and of from 400 to 600mm/day 17 times. Generally, in the upper reaches of the Yangtze River, the mountains on the fringes of the Sichuan Basin experience a high precipitation intensity, for example, the mean annual number of rainy days (> 25mm/day) ranges from 8.9 to 13.2 days, next are the hilly areas of Sichuan Province with from 8 to 13 days, and then the mountains of the western part of Sichuan Province with from 1 to 5 days.

The above-mentioned precipitation characteristics in the upper reaches of the Yangtze clearly suggest that they contribute to soil erosion in the region.

The Wu River is the largest tributary on the south bank of the upper reaches of the Yangtze. The Wu Basin covers the eastern part of the Yunnan - Guizhou Plateau and the south fringe of the Sichuan Basin. According to statistics from 1900 to 1963 and from 1965 to 1976, 18 heavy rainstorms (total precipitation of each event was more than 150mm/day) were recorded in the Wu Basin. These are listed in Table 2.8.

Table 2.8: Heavy Rainstorm (> 150mm/day) from 1960 to 1976 in the Wu Basin

Time	Rainstorm Centre	Total Precipitation Over 24 Hours (mm)
60.6.12 - 13	Qingzhen	232.5
63.7.10 - 11	Hongfeng	256.1
63.6.21 - 22	Shuicheng	171.6
64.6.17 - 18	Jiangkou	183.3
64.6.27 - 28	Qianxi	169.0
64.6.28 - 29	Pu Ding	215.4
65.5.23 - 24	Wu Dong (Yang Chang)	173.2
65.5.31	Zheng An (Wu Xi)	189.9
68.6.5 - 6	Ping Ba	241.0
68.6.16	Lang Tou	164.4
68.7.19	Zhangan (Xinzhou)	186.8
69.6.23 - 24	Si Nan	204.4
71.5.22 - 23	ZunYi (Tuanxi)	198.9
72.5.21 - 22	Mei Tan	200.4
72.7.11 - 12	Jinsha	152.8
73.6.23 - 24	Xiuwen (Jiuchang)	221.2
74.5.21 - 22	Zhijin (Qingzhen)	236.4
74.9.5 - 6	Weining (Fa De)	118. 3

Source: State Bureau of Meteorology 1985

The lower reaches of the Jinsha also experience heavy rainstorms, the annual average number of rainstorms per day are from 0.8 to 3.8. Extra-heavy rainstorms have been recorded in Yibin and Huili counties. Table 2.9 lists data on rainstorms in selected stations in the lower reaches of the Jinsha.

Table 2.9: Rainstorms in Selected Stations in the Lower Reaches of the Jinsha

Station	Max. precipitation per day during recording period (mm)	Number of rainy days with daily precipitation > 50mm	Number of rainy days with daily precipitation > 1000 mm	Number of rainy days with daily precipitation > 150mm
Yibin	218.8	1.1	0.7	0.1
Pingshan	165.0	0.8	0.3	not available
Leibo	130.4	1.6	0.1	not available
Jinyang	74.8	2.9	not available	not available
Ningnan	106.3	2.3	0.1	not available
Huidong	105.5	3.8	0.7	not available
Huili	172.0	2.5	0.3	0.1

Source: State Bureau of Meteorology 1985

Influence of Topography and Elevation on Precipitation

For two reasons, the influence of topography and elevation on precipitation has to be considered in particular.

(1) The landforms in major sections of the upper reaches of the Yangtze are of a mountainous nature.
(2) Strong advectional activity prevails all the year round, caused by the persisting air masses

Depending upon the location of the mountains, the influence of topography and elevation on precipitation can be expected on a regional and local scale only. In contrast, effects on a large scale seem to be of minor importance.

The influence of topography and elevation on precipitation is clearly confined to two aspects.

(1) The influence of slope exposure.
(2) The effects of elevation for both aspects, the total amount of precipitation as well as the number of rainy days, together with various expressions of them, can be considered.

Influence of Slope Exposure on Precipitation

In the Hunduan Mountains in the upper reaches of the Yangzte, the comparison of mean annual precipitation among different locations at the same latitude and same elevation suggested that, in the western mountains, the mean annual precipitation on western slopes (windward slopes) is higher than the one on the eastern slopes (leeward slopes). On Gaoligong Mountain, ranging from 1,500 to 2,700masl, mean annual precipitation on the western slopes is 200 to 400mm higher than on the eastern slopes. In contrast, in the eastern mountain areas, precipitation on the windward slopes is higher than on the leeward slopes. For example, on Gugal Mountain, ranging from 3,461m to 3,795masl, the main annual precipitation on eastern slopes is 100mm higher than on western slopes.

The precipitation in the eastern and western sections is heavier than precipitation in the central area of the mountain area. Taking an east-westwards trend cross 28°C, the mean annual precipitation in Yongshan in the eastern section is 663mm, in Gongshan in the western section, 1,667mm, but in Benzilan in the central section only 336mm mean annual precipitation occurs.

Effect of Elevation on Precipitation

As a principal rule, generally in non-tropical regions, precipitation increases with altitude, because of prevailing advectional processes. Evidence of this has been obtained in the Hunduan Mountain and other mountain areas in the upper reaches of the Yangtze by comparing the precipitation totals of top mountain and valley stations, and these are shown in Figure 2.13 (Wang Yanlong and Shao Wenzhang 1983).

Generally, precipitation increases with elevation in the mountains, but, in the upper reaches of the Yangtze, it is observed that, at some elevations, precipitation decreases, and perhaps such elevations, at which maximum precipitations are recorded, have cellular type isohyets (Figure 2.14) (Wen Chuanjia 1989). The influence of topography and elevation on precipitation could cause diverse types of soil erosion in mountains in the upper reaches of the Yangtze.

The Erosive Nature of Rainfall in the Region

The relationship between precipitation and soil erosion is very complicated. Rainfall erosivity has been calculated to describe the relationship between precipitation and soil erosion.

The W.H. Whichmen soil loss equation has been used to calculate rainfall erosivity, R, in the upper reaches of the Yangtze.

The equation is as follows:

R = rainfall erosivity index
Px = mean monthly precipitation (mm)
P = mean annual precipitation (mm)

The R calculated from selected stations are drawn on the map of the R - isoline. High R are observed on the northeastern slope of Daxiangling and on the eastern slope of Jianjinshan a rainstorm-prone area with Yaan at its centre, and a low R occurs in the valley of the Min from Maowen to Wenchuan and also in the mountains of Northwestern Sichuan. In Miyi, in the mountain areas at 1,120masl, R is 224 and has a relationship with the mean monthly precipitation as follows:

R month = 0.310 P month - 8.715

in which P month is the mean monthly precipitation (mm)

In Table 2.10 rainfall erosivity R at selected stations in the upper reaches of the Yangtze River are given (Chengdu Institute of Mountain Disasters and Environment 1988).

Table 2.10: Rainfall Erosivity R at Selected Stations in the Upper Reaches of the Yangtze

Station	Mean Annual Precipitation (mm)	R
	Sichuan	
Emei	1909.6	618.3
Guanxian	1253.7	329.0
Bazhong	1150.9	214.5
Wanyuan	1192.0	235.0
Yoayang	1183.2	174.0
Nanchong	1019.1	143.0
Gan Zi	637.1	103.5
Maowen	486.1	60.0
Wenchuan	540.8	68.1
Yanyuan	834.1	237.1
Heishu	836.3	126.0
	Guizhou	
Daozhen	1072.0	138.5
Zunyi	1140.0	152.0
Guiyang	1128.0	168.1
	Yunnan	
Zhaotong	746.2	131.5
Dongchuan	863.9	160.0
Yuanmou	653.6	145.3
Zhongdian	616.3	156.1
Deqin	660.1	102.0

Source: Chengdu Institute of Mountain Disasters & Environment 1988

River Hydrology in the Upper Reaches of the Yangtze River

Water is an active and moveable element in the physical environment as well as an important resource. River hydrology and soil erosion are interrelated and interact with each other. Therefore, in this section, runoff, river flow, and sedimentation are examined in the context of river hydrology in the upper reaches of the Yangtze River.

The River System in the Upper Reaches of the Yangtze River

The major rivers in the upper reaches of the Yangtze River are shown in Figure 2.19 (Editing Commission for the "Physical Geography of China" 1981).

The River System in the upper-reaches of the Yangtze is shown in Figure 2.15. The major hydrological features of major rivers in the upper-reaches of the Yangtze are also given in Table 2.11.

Table 2.11: The Major Rivers in the Upper Reaches of the Yangtze

River	Length (km)	Catchment Area (sq.km.)	Drainage	Remarks
Yalong	1500	129930	Qinghai and western part of Sichuan	Tributary of the Jinsha River (the mainstream of the upper reaches of the Yangtze River) with turbulent waters flowing between towering mountains, rich in water power
Jialing	1119	159710	Shaanxi, Gansu, and eastern part of Sichuan	Tributary of the upper Yangtze River and meets the Yangtze River at Chongquing City
Dadu	1070	90700	Qinghai, western part of Sichuan	The largest tributary of the Min which is a first order tributary of the Yangtze River
Wu	1018	86135	Northern Guizhou and Southeastern Sichuan	Tributary of the upper Yangtze River, joins the Yangtze River at Fuling, Sichuan Province
Min	735	135788	Central Sichuan	Tributary of the upper Yangtze River joins the River at Yibin

Source: China Handbook Editorial Committee 1983

The River Flow of the Upper Reaches of the Yangtze

The upper reaches of the Tongtian, YaLong, and Dadu rivers - flowing through the Qinghai-Tibetan Plateau - are fed by meltwater. The rest of the sections of the upper reaches of the Yangtze are fed by rainwater, accounting for 70 to 80 per cent of the total annual river flow; underground water feeding 20 to 30 per cent.

The Yangtze has abundant flow because of its vast basin which receives abundant precipitation. The basin area of the Yangtze is only one and a half times longer than the Yellow River, but the flow of the former is 20 times the flow of the Yellow River. Table 2.12 shows the variations in river flow in the upper reaches of the mainstream of the Yangtze along its course.

Table 2.12: The Variation in the River Flow in the Upper Reaches of the Yangtze along its Course

Station	Catchment Area (sq.km.)	Sectional Drainage Area (sq.km.)	Measured Flow (10^8m^3)	Sectional Flow (10^8m^3)	Years
Shiqu	232651		414.9		1956-1970 for all stations
Shiqu-Qiaojia		218045		857.1	
Qiaojia	450696		1272.0		
Qiaojia-Pingshan		34403		183.0	
Pingshan	485099		1455.0		
Pingshan-Cuntan		381460		2104.0	
Cuntan	866559		3559.0		
Cuntan-Yichang		138942		815.0	
Yichang	1005501		4374.0		

Source: Editing Commission for the "Physical Geography of China", 1981

The flow of the upper reaches of the Yangtze accounts for 46.4 per cent of the total flow of the river. The flows of the major tributaries of the upper reaches of the Yangtze are listed in Table 2.13.

Table 2.13: The Flows of the Major Tributaries of the Upper Reaches of the Yangtze

River	Station	Catchment Area against Total Area of the Upper Reaches sq.km.		Flow 10^8m^3	% against Total Flow of the Upper Reaches	Years
Jinsha	Pingshan	485099	48.2	1437.0	31.6	1940-1944; 1947-1948; 1950-1970
Min	Gao	132926	13.2	915.6	20.2	1940-1970
Tuo	Lijia	22472	2.2	133.9	2.9	1952-1970
Jialing		157900	15.7	682.9	15.0	1940-1941; 1943-1970
Wu Da		83035 1120	8.4	502.5	11.1	1952-1970; 1958-1970
	Yichang	1005501	100	453.0	100	1878-1879; 1882-1970

Source: Editing Commission for the "Physical Geography of China", 1981

Figure 2.16 shows the flow of the Yangtze and its upper reaches, as well as the distribution of annual precipitation in China.

The annual variation in river flow is very significant for soil and water conservation, therefore the extent of annual variation in river flow should be taken into consideration.

The tributaries of the upper reaches of the Yangtze have different annual variations in river flow as outlined in the following passages.

Sichuan Basin Type. The Jialing, Fu, Qu, Tuo, and Qingyi, which are tributaries of the Min, fall into this category. This type is characterised by summer floods. Flow is concentrated in the summer, accounting for 50-60 per cent of the total annual flow. Generally, the maximum flow occurs in July and August. Figure 2.17 shows a typical discharge hydro-graph of the Sichuan Basin type of flow.

Dian-Gui Type. The tributaries in the upper and middle reaches of the Jinsha fall into this category. This type is characterised by predominantly summer floods and autumn floods with distinctly separate dry and wet seasons during the southwestern monsoon. Generally, maximum flow takes place during July, August, and September (Figure 2.18).

Ganzi Type. The upper tributaries of the Jinsha River belong to this category. The rivers in this category have summer and autumn floods. Maximum flow occurs during July, August, and September and occasionally in June, July, and August. Figures 2.19a and 2.19b show a representative mean relative discharge hydrograph for this type of river flow.

Surface Runoff in the Upper Reaches of the Yangtze

Surface runoff is an important element in hydrology, and it occurs as an integrated function of many physical and socioeconomic factors. Surface runoff is also a principal factor in wasting soil into river and other surface waters. Therefore, it should be understood that surface runoff is a major factor of the soil and river system. The annual runoff depth is widely used to express the distribution of surface runoff.

Surface runoff in the upper reaches of the Yangtze varies from section to section. The characteristics of annual runoff depth for different areas are described below.

Sichuan Basin. Annual runoff depth in the border areas of the basin is higher than in the central area. Mountains in western Sichuan Province have a high annual runoff depth. Some places, for example the Emei and Yaan mountains, have values of more than 1,600mm. Annual runoff depths in the Jianjinshan, Longmen, and Daxue mountains reach 1,200mm, and constitute the highest runoff areas in western China.

The Southern Part of the Hengduan Mountains. The Gaoligong and Jiangao mountains have annual runoff depths of from 1,000 to 1,800mm because of high precipitation. In the leeward valleys, the annual runoff depth is only from 300 to 400mm. In the central part of the Yunnan Plateau, the annual runoff depth is less than 200mm, making it the lowest runoff area in southern China.

According to the distribution of annual runoff depth (Figure 2.20), it is observed that most of the upper reaches of the Yangtze fall into an Adequate Runoff Belt (II) with annual runoff depths of from 200 to 900mm and annual precipitations of from 800 to 1,600mm, and the upper reaches of the Jinsha are in a Transitional Runoff Belt (III) with annual runoff depths of from 50 to 200mm and annual precipitations of 400 to 800mm.

Sediment

River sediment is an important consideration, reflecting as it does the extent of soil erosion in the catchment areas and also influencing river systems' management.

Three parameters should be taken into consideration in the context of river sediment; namely the soil erosion modulus, sediment concentration, and sediment discharge.

The soil erosion modulus is used to express the intensity with which soil is eroded by water. According to the distribution of the soil erosion modulus in China (Editorial Committee of the Physical Geography, 1981), the soil erosion modulus in the Sichuan Basin ranges from 200 to 500T/km^2.a, but the Chengdu Plain of the Basin is a sedimentary area. The purple soil and rolling hilly landform are responsible for a high modulus in the basin. The Yunnan Plateau has a higher modulus than the Sichuan Basin and varies from place to place: in the central part of the plateau, it is less than 100T/km^2.a., and, in the surrounding area, it is more than 1,000T/km^2 per annum. In the eastern section of the Qinghai-Tibetan Plateau, the modulus is normally less than 100 to 200T/km^2 per annum.

The sediments recorded at selected hydrometric stations in the area are listed in Table 2.14.

Based on the soil erosion modulus, the upper reaches of the Yangtze can be divided into five categories: extra heavily eroded areas, heavily eroded areas, medium eroded areas, moderately eroded areas, and marginally eroded areas.

Table 2.14: Sediment at Selected Hydrometric Stations in the Upper Reaches of the Yangtze

River	Station	Basin		Average annual soil erosion modulus (T/km^2)
		Area (sq.km.)	% against total from Yichang up	
Yalong	Xiaodeshi	121433	12.1	239
Jinsha	Dukou	284540	28.3	146
Jinsha	Pingshan	485099	48.2	538
Jinsha	Qujian	79126	7.8	2412
Da Du	Shaping	75036	7.5	404
Min	Gaochang	135378	3.5	315
Tuo	Lijiawan	23283	2.3	548
Pei	Xiaohe Ba	29488	2.0	686
Qu	Luodu Xi	38071	3.9	770
Jialin	Wusheng	78850	7.8	947
Jialin	Bei Pei	156142	15.5	1032
Wu	Wulong	83035	8.3	386
Yangtze	Yichang	1005501	100	538

Source: Chengdu Institute of Mountain Disasters and Environment 1988

Extra Heavily Eroded

The average annual soil erosion modulus is from 400 to 1,051T/km^2. The Xihanshui river system, which is a tributary of the Jialin in the upper reaches of the Jialin, and the Xiaojiang Basin fall into this category.

Heavily Eroded Area

The average annual soil erosion modulus is from 1,001 to 1,500T/km^2. Anning River Basin up to Dechang station, the Heishuihe Basin up to Ningnan station, the Meighuhe Basin up to Meigu station, the upper reaches of the Pei, the upper reaches of the Bailong, and the Duoyingping district of Qingyi Basin fall into this category.

Medium Eroded Area

The average annual soil erosion modulus is from 501 to 1,000T/km^2.

Moderately Eroded

The average annual soil erosion modulus is from 101 to 501T/km^2.

Marginally eroded

The average annual soil erosion modulus ranges from 20 to 100T/km^2. The upper reaches of the Jinsha up to Jinjiang Station, the Yalong Basin up to Jiju Station, and the Min Basin up to Zhenjiangguan Station fall into this category.

Sediment Concentration and Sediment Discharge

Concentration and sediment discharge as recorded by major stations in the upper reaches of the mainstream of the Yangtze are listed in Table 2.15 and are based on data on soil conservation provided by the Ministry of Water and Energy (1986).

Table 2.15: The Flow, Sediment Concentration, and Sediment Discharge in the Upper Reaches of the Mainstream of the Yangtze

Station	Item	1954-1959	1963-1968	1980-1985
Yichang	flow (10^8 m^3) sediment discharge	4430	4770	4560
	(10^4 T) sediment concentration	58100	61300	60900
	(kg/m^3)	1.31	1.29	1.33
Cuntan	flow (10^8 m^3) sediment discharge	3600	3870	3550
	(10^4 T) sediment concentration	53900	53300	51900
	(kg/m^3)	1.50	1.38	1.46
Pingshan	flow (10^8 m^3)	1520	1590	1370
	sediment discharge (10^4 T)	2660	28400	25400
	sediment concentration (kg/m^3)	1.75	1.78	1.85

Source: Ministry of Water and Energy 1986

From Table 2.15 it can be seen that the rate of flow/sediment discharge at Yichang Station, taken at three intervals, is 0.076, 0.078, and 0.075; at Cuntan Station 0.067, 0.073, and 0.068; and at Pingshan 0.057, 0.056, and 0.054. This means that the relationship between flow and sediment discharge from Pingshan to Yichang is not constant.

Two tables, Tables 2.16 and 2.17, show the sediment regime in the upper reaches of the Yangtze, including its mainstream and major tributaries.

Table 2.16: The Sediment Regime in the Upper Reaches of the Mainstream of the Yangtze River

Station	Catchment Area (sq.km)	Mean annual sediment concentration (kg/m^3)	Mean annual sediment discharge (10^4 T)	Mean Modulus (T/km^2.a.)	Years
Zhimenda	132865	0.813	970	74.1	1957-1970
Pingshan	485099	21.17	25480	1920	1954-1970
Lizhuang	639227	1.47	38700	605	1953-1959
Cuntan	866559	1.38	49490	570	1953-1970
Yichang	1005501	1.25	55870	555	1950-1970

Source: Editing Commission for the "Physical Geography of China" 1981

Table 2.17: The Sediment Regime of Selected Tributaries in the Upper Reaches of the Yangtze River

River	Station	Catchment Area (sq.km.)	Mean annual sediment concentration (kg/m^3)	Mean annual sediment discharge (10^4T)	Mean modulus ($T/km^2.a$)	Years
Min	Gaochang	132926	0.638	5731	431	1951-1970
Jialin	Beipei	157900	2.31	15555	985	1956-1970
Wu	Wulong	83035	0.563	2769	333	1951-1970

Source: Ibid

From the above two tables, three conclusions can be drawn.

(1) When the rivers fall from 4,000m to 1,000masl, the sediment concentration and sediment discharge increase rapidly, because conditions are conducive to soil erosion. For the Jinsha, the increase in sediment concentration is faster than the increase in sediment discharge because of the higher surface runoff in the Jinsha Basin.

(2) In the Sichuan Basin, the sediment concentration in the Jinsha decreases because of the decrease in the slope of the river bed, but the sediment discharge in the river increases continuously because of the flow increase.

(3) After the Yangtze leaves the Sichuan Basin, the sediment discharge increases more than once from 255 x 10^6T to 55° x 10^6T. Half the increment is from the Jialing which drains the area with purple soil. The maximum sediment discharge is recorded at Yichang Station as 55,870 x 10^4T.

Variation of Sediment

Generally, in China, for most rivers, the maximum sediment concentration and sediment discharge occur in the flood period because, during the rainy season, the surface is seriously eroded. The annual range of sediment concentration in most cases is higher than the annual range in river flow. The upper reaches of the Yangtze have maximum sediment concentration in July, August, and (sometimes) even in September.

For most rivers, including the Yangtze in the arid region, the sediment concentration hydrograph is positively phased to the discharge hydrograph, and sediment peak and flood peak occur in the same period. The example of two rivers, the Lei and the Eerqisi, can be given to show the annual variation in flow and sediment concentration (Figures 2.21 and 2.22).

Table 2.18 also lists the mean annual sediment concentration and mean annual sediment discharge of major river systems in the upper reaches of the Yangtze.

Tables 2.19 and 2.20 and Figures 2.23 and 2.24 show the annual variation in sediment concentration in the Jialing, which is a tributary of the upper Yangtze, and the annual sediment discharge of the Yangtze at Yichang Station (Editing Commission for the "Physical Geography of China" 1981).

In Figure 2.23, the positive correlation between sediment concentration and precipitation can be seen because, during the rainy season, the soil is seriously eroded and this increases sediment concentration. A similar correlation can also be seen in Figure 2.24.

Table 2.18: Sediment Discharge and Sediment Concentration in the Upper Reaches of the Yangtze (1958-1986)

River	Station	Catchment Area		Mean Annual sediment discharge (10^4T)	% against the total at Yichang Station	Mean annual sediment concentration (kg/m^3)
		sq.km	% against the total up Yicheng			
Jinsha	Pingshan	485099	48.24	23671	44.84	1.69
Yalong	River mouth	128444	12.47	3877	7.34	0.68
Min	Pingpu	22664	2.25	861	1.63	0.618
Min	River mouth	135868	13.51	5092	9.65	0.59
Tuo	River mouth	27840	2.77	1530	2.90	1.08
Pei	River mouth	35903	3.57	2410	4.57	1.35
Qu	River mouth	39199	3.90	2989	5.66	1.27
Jialing	River mouth	157928	15.71	14947	28.32	2.11
Wu	River mouth	87920	8.74	3364	6.37	0.64
Yangtze	Yichang	1005501	100	52789	100	1.22

Source: Commission Office for Soil-water Conservation 1990

Table 2.19: Annual Variation of Sediment Concentration in the Jialing River

River	Station	Catch-ment (km^3)	J	F	M	A	M	J	J	A	S	O	N	D
Jialing	Beipei	157900	0.79	0.32	0.101	0.621	1.58	2.69	3.89	2.55	3.57	1.37	0.412	0.168
Mean annual (kg/m^3) 2.31		Maximum month kg/m^3 July 3.89		Minimum month kg/m^3 February 0.32										

Source: Ibid

Table 2.20: Annual Variation of Sediment Concentration in the Yichang Station

River	Station	Catch-ment (km^3)	J	F	M	A	M	J	J	A	S	O	N	D
Yan-gtze	Yi-Chang	1005501	0	0.0	0.3	1.1	5.4	8.9	29.7	26.4	18.0	7.3	2.3	0.6
Mean annual (kg/m^3) 5.58		Maximum month kg/m^3 July - 29.7		Minimum month kg/m^3 July-September - 74.1										

Source: Editing Commission for the "Physical Geography of China" 1981

It should be pointed out that the bedload is high in rivers in the upper reaches of the Yangtze, for example, the Jinsha, Min, and Jialing, but no details can be given because of the scarcity of data.

Soil

Soil erodibility can be defined as the vulnerability of soil to erosion, and this depends upon the physical and chemical characteristics of the soil, soil structure, and soil texture. Therefore, certain aspects of the soil should be taken into consideration.

In order to make necessary comparisons with soil from other parts of the world, Table 2.21 correlates the soil types from China's traditional soil classification system (1978) and the FAO-UNESCO soil map of the world (1977) (Zhao Songqiao 1986).

Table 2.21: Correlation of Soil Types

Soil Units FAO-UNESCO System	 Traditional Chinese Classification System
Fluvisols (J)	*Choutu* (wet soil), meadow soil
Gleysols (G)	Meadow soil, bog soil, paddy soil, irrigated oases soil, and Alpine meadow soil
Regosols (R)	Alpine frozen soil, aeolian sandy soil, purple soil, saga soil (alpine steppe soil)
Lithosols (I)	Mountain soils
Rendzinas (E)	Limestone soil, phosphocalcic soil
Rankers (U)	Alpine meadow soil, subalpine meadow soil
Vertisols (V)	*Shachiang* soil, paddy soil, heavy cracking clay soils
Solonchaks (Z)	Solonchak (Salt affected soils)
Solonetz (S)	Solonetz (Salt affected soils)
Yermosols (Y)	Grey desert soil, grey-brown desert soil, brown desert soil, takyric soil, alpine desert soil (Desert Soils)
Xerosols (X)	Sierazem, semi-desert brown soil, irrigated oases soil (Semi Desert)
Kastanozems (K)	Chestnut soil
Chernozems (C)	Chernozem
Phaeozems (H)	Black earth
Greyzems (M)	Grey forest soil
Cambisols (B)	Burozem, drab soil, grey drab forest soil, *mean tu* (cultivated loess), *lou tu* (stratified old manual loess), *heilu tu* (dark loess), subalpine meadow soil
Luvisols (L)	Dark-brown forest soil, burozem, yellow-brown earth, *heilu tu*, limestone soil, dry red earth
Podzoluvisols (D)	Leached grey soil
Planasols (W)	*Baijiang tu*, yellow-brown earth, burozem
Acrisols (N)	Laterite, red earth, yellow earth
Nitosols (N)	Laterite, red earth, dry red earth
Ferralsols (F)	Laterite
Histosols (O)	Peat soil, bog soil

Source: Zhao Songqiao 1986

The Major Soil Units in the Upper Reaches of the Yangtze

The soil-forming process is chiefly a function of parent material, climate, landform, vegetation, and time. In the upper reaches of the Yangtze because of topographic complexity and climatic diversity, the soil-forming process varies according to the place, therefore many soil units can be found in the region. The major soil units in the region are as follows:

paddy soil,
purple soil,
limestone soil,
red earth,
yellow earth,
mountainous yellow-brown earth, mountainous red-brown earth ,
mountainous grey-brown earth,
mountainous drab soil,
mountainous grey-drab soil,
mountainous podzolic soil,
mountainous meadow soil, plateau meadow soil,
bog soil, and
alpine desert soil.

Distribution of Soil and Soil Erodibility

The above-mentioned soil units can be divided into two categories: zonal and azonal soil groups. The zonal soil group includes red earth, yellow earth, brown earth, padzolic soil, meadow soil, and desert soil.

Because of the topographic relief in this region, the vertical distribution of soil in the upper reaches of the Yangtze is important to the understanding of soil and farming systems at different elevations.

Vertical Distribution of Soil in the Region

Western Sichuan and Northern Yunnan are examples of vertical mountain spectra of soil and vegetation (Figure 2.25) (Ren Mei et al. 1985).

Figure 2.25 is a generalised model of a mountain vertical spectrum of soil.

The vertical distribution of soil in the region can be observed in the Wu Basin, and this is listed in Table 2.22.

The soil distribution in mountain areas in the region is described below.

Mountain Podzolic Soil is distributed at elevations ranging from 3,200m to about 3,500m. Above these elevations accelerated man-made soil erosion is not obviously observed, because of the cold climate and the lack of agricultural activities, but, in some places in the mountains and on the plateau, soil erosion is caused by overgrazing.

Mountain Brown Earth. This type of soil is found up to 3,000masl. In some localities, for example, Xinlong and Deming, it is found up to 3,500m to 4,000masl; Mountain Yellow-brown Earth is found from 1,800m to 2,000masl in the Wu Basin of Guizhou Province and, in the mountain fringe of the Sichuan Basin, from 1,500 to 2,000m; the Mountain Brown Earth Zone is mainly associated with a warm temperate climate and characterised by warm humidity or cool humidity and fertile soils. Therefore, this zone is a place where agricultural and other human activities are intensified. As a result, soil erosion is more serious.

Below the Mountain Brown Earth Zone, red earth and yellow earth are found with good thermal and water conditions. Accelerated man-made soil erosion in this zone is more serious than in the Mountain Brown Earth Zone because of intensive human activities.

Table 2.22: The Vertical Distribution of Soil in the Wu Basin

Section of the river	Mountain	Soil & elevation of distribution (m)	Yellow-red earth	Quasi yellow earth	Yellow brown earth	Acid brown earth	Humic brown earth
Upper reaches	Wu-Mengshan				< 2400	> 2400	> 2400
Middle Reaches	Daloushan			< 1400	1400-1800		> 1800
	Miaoling			< 1400	1400-1800		> 1800
	Fenjingshan		< 500	< 1400	1400-1800	1800-2300	> 2300
Lower reaches	Jinfoshan			< 1400	1400-1800	> 1800	> 1800

Source: The Chengdu Institute of Mountain Disasters and Environment 1990

Red Earth is concentrated in valleys and among the low mountains in the Southwestern part of Sichuan Province; for example, Xichang District, and it is also widely distributed on the old alluvial platforms in the western part of Sichuan Basin and the intermontane basins of Southeastern Sichuan Basin. The soil-forming parent materials are granite, limestone, metamorphic rock, sand shale, and old Quaternary alluvial deposits. The erodibility of red earth varies from place to place, because of different climatic conditions, parent materials, and human activities.

The red earth in the Western section of Sichuan Basin developed on Quaternary deposits and is characterised by topsoil with a granular structure, a poor water-holding capacity, high disintegration tendencies, and a distinct soil profile. Therefore, unvegetated red earth is easily eroded. The red earth in Southwestern Sichuan Province is strongly influenced by sharply-divided wet and dry seasons, especially long seasons, and has dry and loose topsoil. As a result, it erodes easily in the rainy season. The red earth in the dry-hot valleys of Western Sichuan is subject to soil erosion because of its low content of organic matter and a poor soil structure. Generally, the economy in the Red Earth Zone is predominantly agricultural and serious soil erosion is caused by steep slope cultivation.

Yellow Earth

Yellow earth is found in the low mountains of the Eastern Sichuan Basin and at elevations ranging from 800m to 1000masl in the Wu Basin where it is strongly influenced by human activities. Eroded soil can be observed in most of the regions, but, in terms of anti-erodibility, yellow earth is stronger than red earth because of the higher organic content and its clayey structure.

Purple Soil

Purple soil occurs on purple rocks as a result of weathering. This type of soil is concentrated in the hills of the Sichuan Basin and in the lowlands below 800m. There are also a few areas of purple soil in

Xichang District and in Bijie, Tongzi, Chishui, and Xishui in Guizhou Province. The areas where purple soil is found in the upper reaches of the Yangtze are estimated to cover about 180,000 sq.km., of which about 160,000 sq.km., or 98 per cent, are distributed throughout the Sichuan Basin, accounting for 16 per cent of the total drainage area of the upper reaches of the Yangtze. Table 2.23 gives the physical and chemical properties of purple soil.

Table 2.23: The Physical and Chemical Properties of Purple Soil

Profile (cm)	Organic matter (%)	Total N (%)	Total P (%)	pH	$CaCo_3$	Exchangeable base (mg/100g soil)				Chemical composition (% against oven-dried soil)					Granular composition (Grain size: mm)	
						Ca	Mg	K-Na	Total	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	< 0.001	< 0.01
1 - 15	4.60	0.2	0.25	7.6	4.34	16.20	0.50	0.19	16.89	60.84	3.94	14.27	4.53	2.39	11.79	41.05
15 - 49	2.16	0.11	0.23	7.5	5.32	13.08	0.38	0.03	13.49	61.84	3.84	15.14	4.75	2.32	9.97	39.68
49 - 76	1.63	0.05	0.24	7.8	6.29	13.48	0.29	0.10	13.87	61.34	3.79	16.60	5.71	2.13	12.07	43.9
76 - 105	1.68	0.07	0.23	7.6	1.66	13.29	0.33	0.19	13.81	65.34	3.36	14.78	3.46	2.09	7.91	38.71

Source: Academy of Survey and Planning of Forestry 1981

Purple soil is fertile, especially that found in the Sichuan Basin which is valuable in terms of agricultural cultivation. It has been used to ameliorate poor soils in other areas of the region. Purple soil is suitable for maize, sweet potatoes, peanuts, beans, wheat, rape, tobacco, and subtropical fruit trees (e.g., pears, oranges, and dates). Therefore, purple soil areas are densely populated and strongly influenced by human activities. For example, 68 per cent of the total farmland in Sichuan Province suffers from accelerated soil erosion and is concentrated in the purple soil area, of which 60 per cent is on dry land. Therefore, accelerated man-induced soil erosion is very serious (Editing Commission for the "Physical Geography of China" 1981).

The purple soil in Sichuan Basin has the following characteristics:

- poor cementation and poor structure stability,
- strong disintegration, and
- less microaggregate content.

(Chengdu Institute of Mountain Disasters and Environment 1988).

Such micropedological characteristics give purple soil high erodibility. Data from the Committee Office of Water and Soil Conservation of Sichuan Province point out that 0.33 to 0.74cm of topsoil is subject to erosion each year in the purple soil area of Sichuan Province (Sichuan Office for Soil-Water Conservation 1991).

The organic matter content in the top layer of purple soil (which is strongly influenced by human activities) is very low; usually less than one per cent. The texture is coarse, especially in rega-purple soil where it is from 30 to 40 per cent. The organic matter content in the top layer of purple soil in the Three Gorges Area is 1.48 per cent and among clay particles < 0.01mm constitutes only 18.8 per cent of the soil. The structure coefficient of purple soil is lower than those of other soils (Chengdu Institute of Mountain Disasters and Environment 1988).

In China, the following equation is used to calculate the structure coefficient of soils:

$$K = \frac{b-a}{b} \times 100$$

in which

K : soil erodibility

a : clay content under micro-aggregate analysis in percentage

b : clay content under mechanical analysis

From the analysis of organic matter content, the soil texture and permeability of purple soil suggest that the erodibility factor K of purple soil is usually greater than 0.5, and this is higher than the erodibility factors of other soils (Northwestern Institute of Soil and Water Conservation, CAS, 1986).

Limestone

Limestone is found throughout the limestone mountains. The calcium content of the soil is high because the soil-forming process is influenced by parent material. Calcium is favourable for humus accumulation, therefore limestone soil is good for aggregate structure and stickiness. In this region, limestone soil can be divided into three categories: black, brown, and red. Due to the variable topography, physical and chemical properties also vary. Red limestone soil has high erodibility, the other two types have lower erodibility than yellow-brown earth, red earth, and purple soil.

Relationship between Soil Erosion and Soil Type

The disintegration of soils is a useful indicator of soil erodibility. Some laboratory research on soil disintegration has been carried out in China. The Institute of Forest Science in Hunan Province has carried out experiments on the disintegration of red earth in water (Table 2.23).

From Table 2.24 it can be observed that red earth disintegrates into small particles at greater speed and in larger quantities. This means that the disintegrated red earth is easily washed away by runoff, and intensified gully erosion in red earth areas may be influenced by this. Work on the disintegration of soils has been carried out at the Northwestern Institute of Soil and Water Conservation of the Chinese Academy of Sciences (Figure 2.26). From Figure 2.26 the following conclusions can be drawn.

Purple soil samples completely disintegrate in three minutes, and this affects 31 per cent of the sample; it takes 10 minutes for eight per cent of the yellow-drab soil to disintegrate and for two per cent of the yellow earth. The subsoil of the purple soil sample totally disintegrates in four minutes and 15 seconds, and this affects 45 per cent of the sample in six minutes and 20 seconds, 96.5 per cent of the yellow - drab soil sample and 84 per cent of the yellow earth sample disintegrate. Therefore, the erodibility of the cultivated horizon of the soils ranks as follows: purple soil > yellow - drab soil > yellow earth.

A comparison of topsoil and subsoil among soils examined points out that the topsoil is less subject to erosion than the subsoil. This is because there is more organic matter content in topsoil. Therefore, soil amelioration methods should be used to reduce the soil erodibility of topsoil, because the erosion of topsoil accelerates subsoil erosion (Northwestern Institute of Soil and Water Conservation, CAS, 1986) (Figure 2.25).

Table 2.24: The Disintegration of Red Earth in Water

Type of Sample	Disintegration of soil in still water	After 1 hr	After 24 hrs
Many root systems in top horizon	10 seconds after placing the sample in water, the soil sample begins to disintegrate slowly. After two minutes, disintegration stops and the water is clear.	no change	no change
Few root systems in top horizon	10 seconds after placing the soil sample in water, the soil sample completely disintegrates into small particles and the water is clear.	no change	no change
Net horizon (C) with white clay	6 seconds after placing the soil sample in water, the soil completely disintegrates into fine-sized particles and the water is clear.	no change	no change
Net horizon (C) with red clay	90 seconds after placing the soil sample in water, the sample ceases to disintegrate and the water is clear.	no change	no change
Net horizon (C) with yellow clay	60 seconds after placing the soil sample in water 10% of the soil sample disintegrates, disintegration ceases and the water is clear.	no change	no change

Source: Hunan College of Forest Sciences 1960

Soil Texture

Soil texture is an important factor influencing soil permeability and soil erodibility, and it is important in studying factors leading to soil erosion. Generally, under the same precipitation regime, fine-textured soils have lower erodibility than coarse-textured soils. Table 2.25 gives the relationship between soil erosion and soil texture based on experiments carried out in Zizhong, Sichuan Province.

Table 2.25: Soil Loss and Soil Texture on Different Slopes

Annual Soil Loss (m^3/h)

Soil *	Slope > 10°	Slope between 10° to 20°	Slope > 20°
Sandy soil	109.5	259.5	390.0
Mud	33.0	199.5	330.0
Yellow mud	6.0	25.5	66.0

Source: Zizhong 1986

* The local soil names are used, from top to bottom the soil texture becomes finer.

Similar work on the relationship between soil loss and soil texture has been carried out in Ankang, Shanxi, and the results are listed in Table 2.26.

Table 2.26: Soil Loss and Soil Texture

Soil *	Slope (0)	Texture	Annual soil loss m³/h)
Yellow sandy	20	sandy	44-66
Yellow mud	30	mud	1.2 - 2.2

Source: Bureau of Hydraulic and Hydroelectric Engineering 1986

* Local soil name is used

Natural Vegetation

The natural vegetation in the upper reaches of the Yangtze plays a very important role in soil formation and soil and water conservation. Firstly, this paper describes the natural vegetation in the region. Crops and other cultivated vegetation will be discussed below as socioeconomic factors.

Natural Vegetation in the Upper Reaches of the Yangtze

The distribution and type of natural vegetation are shaped by both zonal and azonal factors and classified according to the comprehensive physical regionalisation of China (Zhao Songqiao 1986).

A large part of the region falls into a montane and alpine grassland region (31) and a montane needle - leaved forest and alpine meadow region (29), and these can be found in Table 2.27.

The upper reaches of the Jinsha are in the montane and alpine grassland region (31). The main type of vegetation is alpine steppe consisting chiefly of *Stipa purpurea, S. subsessiliflora,* and *Carex moorcroftiana.* Above the alpine steppe belt are the alpine meadows of *Kobresia pygmaea.* Valleys or basins are covered by marshy meadows consisting of *Kobresia littledalei* and *K.tibetica.* The southern part of the Qinghai-Tibetan Plateau is drained by the Jinsha. A larger part of the upper reaches of the Yangtze is covered by montane needle-leaved forest and alpine meadow region (29).

The region is one of the richest areas for alpine flora in the world. The vegetation varies greatly through distinct vertical changes. On the floor of the dry valleys in Eastern Tibet, the thorny shrubs are principally those of *Sophora viciflora* and *Ceratostigma griffithii.* In Western Sichuan, thorny and succulent shrubs, mainly those of *Opuntia monacantha, Acacia farnesiana,* and *Pistacia weinmaunifolia,* are found at the bottom of dry valleys at altitudes below 1,800m. With the exception of valleys below 2,400masl, a number of montane, evergreen broad-leaved forests exist. Most areas are covered by montane, mixed needle and broad-leaved forests and needle-leaved forests; the former consisting of *Pinus densata, Tsuga dumosa,* and *Quercus aquifolioides,* the latter consisting of numerous trees of the genera *Picea, Abies, Sabina,* and *Larix.* Another feature is that only one or two species predominate in these forests. The upper forest limit for *Picea balfouriana* is 4,400masl on the shady side and that of *Sabina tibetica* is 4,600masl on the sunny side. Above the upper timber line, alpine shrubs and meadows are found. These alpine shrubs include *Rhododendron microphyll, Salix, Dasiphora arbuscula,* and *Caragana jubata* and the alpine meadows *Kobresia, Polygonum, and Saussurea.* In the northern part of the region, alpine shrub and meadow vegetation predominate. The lowlands of broad valleys and basins are covered by marshy meadows and swamps, consisting mainly of *Kobresia littledalei, K. tibetica, Carex lanceolata, C. mullensis,* and *Blysmus sinocompressus.* The southern part of the region is rich in forest resources, and the timber volume is about 500 to 800m³/ha.

Table 2.27: Thirty-three Natural Regions in China

Natural Division	Natural Region
I. Temperate humid and sub-humid division	1. Da Hinggan Mts-needle-leaved forest region 2. Northeastern Mountains-mixed needle-and broad-leaved forest region 3. Northeastern Plain-forest-steppe region
II Warm temperate humid and sub-humid division	4. Liaoding-Shandong peninsulas-deciduous broad humid and sub-humid-leaved forest region division 5. Northern Chinese Plain-deciduous broad-leaved forest region 6. Shanxi-Hebei mountains-deciduous broad-leaved forest and forest steppe region 7. Loess Plateau-forest steppe and steppe region
III Subtropical humid Region	8. Middle and Lower Changjiang (Yangtze) Plain-mixed forest region 9. Qinling-Dabie Mts-mixed forest region 10. Southeastern coast-evergreen broad-leaved forest region 11 South Changjiang hills and basins-evergreen broad-leaved forest region 12. Sichuan Basin-evergreen leaved forest region 13. Guizhou Plateau-evergreen broad-leaved forest region 14. Yunnan Plateau-evergreen broad-leaved forest region 15. Lingnan Hills-evergreen broad-leaved forest region 16. Taiwan Island-evergreen broad-leaved forest and monsoon forest region
IV. Tropical humid division	17. Leizhou-Hainan-tropical monsoon forest region 18. Southern Yunnan-tropical monsoon region 19. South China Sea islands-tropical rain forest region
V. Temperate grasslands division	20. Xi Liahe Basin-steppe region 21. Nei Mongol Plateau-steppe and desert-steppe region 22. Ordos Plateau-steppe and desert-steppe region
VI. Temperate and warm temperate desert division	23. Alashan Plateau-temperate desert region 24. Junggar Basin-temperate desert region 25. Altay Mts-montane grasslands and needle-leaved forest region 26. Tianshan Mts-montane grassland and needle-leaved forest region 27. Tarim Basin-warm-temperate desert region
VII. Qinghai - Tibetan Plateau	28. Southern Himalayan slope-tropical and subtropical montane forest region 29. South-eastern Qinghai-Tibetan Plateau-montane needle-leaved forest and alpine meadow region 30. South Qinghai-Tibetan Plateau-shrubby grass-Plateau, shrubby, grass-land region 31. Central Qinghai-Tibetan Plateau-montane and alpine grassland region 32. Qaidam Basin and Northern Kunlun Mts slopes-desert region 33. Ngari-Kunlun Mts-desert-steppe and alpine desert region

Source: Editorial Committee of Physical Geography of China 1985

The remainder of the upper reaches of the Yangtze is on the Yunnan Plateau - an evergreen broad-leaved forest region (14), the Guizhou Plateau - an evergreen broad-leaved forest region (13), and the Sichuan Basin - an evergreen broad-leaved forest region (12) and these are shown in Figure 2.27.

Vegetation on the Yunnan Plateau is varied. Zonal vegetation types consist of evergreen broad-leaved forests. *Cyclobalanopsis glaucoides, C. delavayi,* and *Castanopsis delavayi* are the dominant species. After heavy human intervention the drought-tolerant Yunnan Pine forest now prevails. The vertical distribution of vegetation is conspicuous. A typical, well-known example is the snow-capped Yulong Mountain (5,595m) overlooking the Jinsha River Valley. Fine vertical zones are demarcated (Figure 2.28): (1) the Jinsha Valley below 2,000m flows through the semi-arid subtropical shrubby savanna; (2) the basic vegetation belt (2000m to 3100m) is mainly covered by Yunnan pine forest; (3) fir forest occurs between 3,100 to 3,800m; (4) alpine meadow occurs between 3,800m to 4,500m; and (5) perpetual snow appears above 4,500m. Three sub-regions can be identified.

(1) The Eastern Yunnan Plateau, mainly covered by Yunnan pine or oak forest.
(2) The Central Yunnan Plateau and lake basin is the main agricultural area.
(3) The Hengduan Mountains are mainly located in western Yunnan. Below 2,500m, on the western slopes of the Gaoligong Mountain, lies an area consisting of secondary vegetation and farmland; between 2,500 to 2,700m, there is luxuriant, evergreen broad-leaved forest; between 2,700 to 2,960m, mixed needle and broad-leaved forest, and between 3,500 to 3,680m, alpine shrubs predominate.

The vegetation on Guizhou Plateau is characterised by its transitional features both from east to west and from south to north. In the east, evergreen broad-leaved forests predominate, in the west, a considerable proportion of deciduous broad-leaved trees are mingled in with the forest. In the south monsoon-type forests are most common, in the north, the forest type is typical of the middle subtropical zone of evergreen broad-leaved forest.

The flora of the Sichuan Basin are varied. Zonal vegetation in the basin tends to the subtropical broad-leaved varieties, but these have been virtually disappearing, with only a few remnants distributed on the mountain slopes and hills between 1,500m to 1,800m. There are also large patches of secondary oak forest and needle-leaved forest and bamboo grove, because the basin has been subjected to intensive cultivation for more than 2,000 years (Beijing Institute of Geography 1983).

Relationship between Soil Erosion and Vegetation

The natural vegetation in the upper reaches of the Yangtze is a very important factor in protecting soil from erosion and its functioning depends upon its form and coverage. The forest ecosystem should first be taken into consideration.

Forests in the Upper Reaches of the Yangtze River

In China, natural forests are preserved only in the high mountains. For instance, tropical and subtropical forests are widely distributed throughout the southeastern Himalayan Mountains where the forest coverage amounts to about 50 per cent. The elevation of forest lines reaches from 4,000 to 4,100m.

The Present State of Forests in the Upper Reaches of the Yangtze

The forests in the mountainous areas of the region play a very important role in water and soil conservation, and this is why the southwestern mountains of China are demarcated as the "Southwestern High Mountains and Deep Valley Water Resource and Timber Forest Division" (Dong Zhiyong 1986).

The high mountains of the upper and middle reaches of the Jinsha, Yalong, Dadu, and Min are covered by needle-leaved forests. The forest area covers about eight million hectares and there are about 1,500 million cubic metres of timber stock accounting for seven per cent and 22 per cent of the national total respectively.

There are abundant forest resources in China's southwestern mountainous districts, including Tibet, the three prefectures of Liangshan, Ganzi, and Aba, in western Sichuan Province, and the three prefectures of Nujiang, Diquing, and Lijiang, in northwestern Yunnan Province. Table 2.28 shows the state of the forests in the district (Han Yu Feng 1986).

Table 2.28: The Forests of the Southwestern Mountainous Districts

Place	Forest area (million ha)	Timber stock (million cubic metres)	Mature forest area (% against total forest area)	Mature stock (% against total stock)	Needle-leaved forest area (% against total forest area)	Needle-leaved timber stock (% against total stock)
Western part of Sichuan Province	3.88	1,010	80	90	90	96
North-western part of Yunnan Province	1.77	315	70	90	83	77
Tibet	6.13	1,390	85	95	61	66
Total	11.78	2,715				

Source: Han Yu Feng 1986

In the upper reaches of the Yangtze and surrounding areas, the distribution of forests is not even. A selection of provincial examples of forest destruction is given in Table 2.29.

Table 2.29: The Forest Resources in Selected Provinces

Province	Forest area 10^4 ha	Timber stock (million cubic metres)	Coverage (%)
Qinghai	19	31	0.3
Tibet	632	1,436	5.1
Yunnan	956	989	24.5
Guizhou	256	159	14.5
Sichuan	746	1,347	13.3

Source: Beijing Institute of Geography 1983

Most of the forests in the region are virgin forests. In the western part of Sichuan Province and the northwestern part of Yunnan Province, 90 per cent and 83 per cent respectively of all forest areas are dominated by needle-leaved forest. Among the needle-leaved forests, the species *Picea* and *Abies* are extensively distributed and widely utilised.

Growth Characteristics of Forests in the Region

One of the prominent characteristics of forest growth in the upper reaches of the Yangtze is that the forests have abundant biomass. For instance, in northwestern Yunnan Province, the forest biomass could be over 1,000m^3/ha. The average timber stock in Tibet is 260m^3/ha in western Sichuan Province 225m^3/ha and, in northwestern Yunnan Province, 180m^3/ha. The problem with forests in the region is that the trees are old; most are over 100 years and some are 150 to 200 years old or even more. Decayed timber appears everywhere throughout the forests.

Another characteristic of forest growth is that the trees have a much longer period to grow. Many trees grow to be quite big. For instance, some trees under favourable water and temperature conditions can reach a height of 80m with 2.5m diameters and 40 cubic metre volumes for single trees in the *Picea* and *Abies* forests.

People in the region not only acquire timber and other by-products from the forests but also attach importance to the role of the forests for water conservation, soil preservation, climate regulation, and environmental protection (Han Yu Feng 1986).

Vertical Distribution of Regional Forests

Like other vegetation types, the regional forests are characterised by vertical distribution. The vertical spectrum of forest distribution varies from place to place. Vertical distribution of forests is characteristic of most of the forest areas in the various reaches of the Yangtze as shown in Figure 2.29 (1,2,3,4) (Chengdu Institute of Mountain Disasters and Environment 1980).

The natural forests in the upper reaches of the Yangtze can be placed into three categories.

1. *Extremely Dense Forests*

Extremely dense forests have three layers: tall trees, shrubs, and undergrowth with coverages of more than 80 per cent. In western Sichuan Province, the broad-leaved forests, mixed needle and broad-leaved forests, and needle-leaved forests are of this kind. The forest soils are well-developed with the deepest soils ranging from one to 1.5m. The depth of the litter layers is about 10-15cm and the non-capillary porosity of the soil is large. Therefore, this kind of forest is good for conserving water and soil.

2. *Medium-Dense Forests*

This kind of forest is composed of two layers: tall trees and undergrowth or shrubs and undergrowth. In some cases there are three layers: tall trees, shrubs, and undergrowth with coverage ranging from 60cm to 10cm. The non-capillary porosity of the soil is less than in the first kind of forest. Therefore, this kind of forest is not fully functioning in terms of water and soil conservation, but soil erosion in such forests is not severe.

Medium-dense forests are mainly distributed throughout secondary forest areas and can be found in State-run and forest farms and collectives.

Medium-Dense Vegetation

This kind of vegetation can be found in the upper reaches of the Yangtze River and mainly consists of dense grasslands distributed above the snowline with coverage ranging from 60 to 70 per cent. Soil erosion in areas with such vegetation is not severe because of the dense forest root system and the lack of human activities.

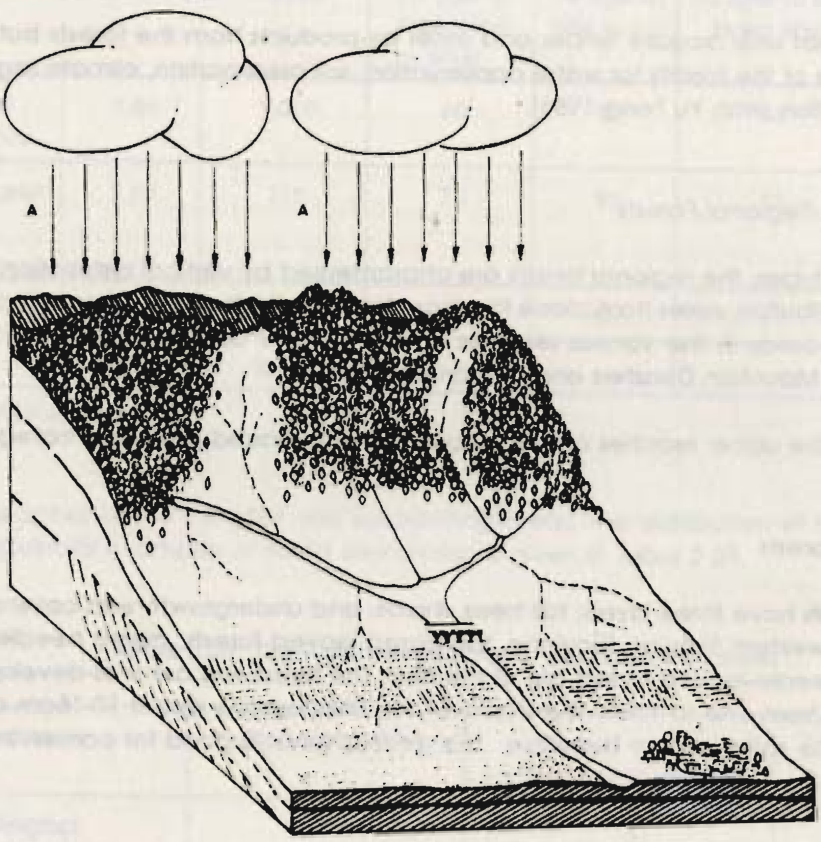


Figure 2.1: Ecological Components Associated with Erosion Processes

Source: Carpenter 1983

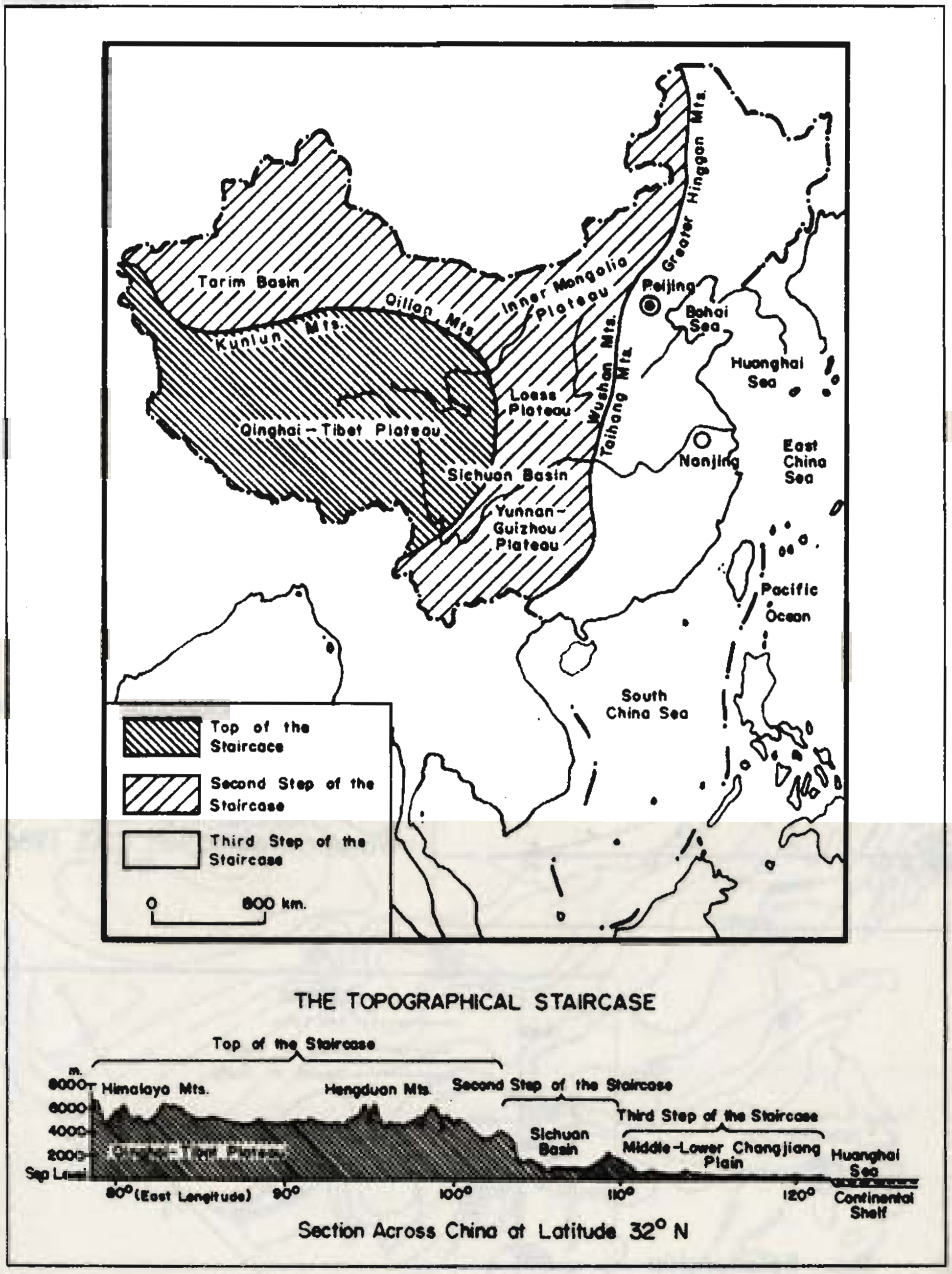


Figure 2.2: The Topographical Staircase in China

Source: Government of China 1983

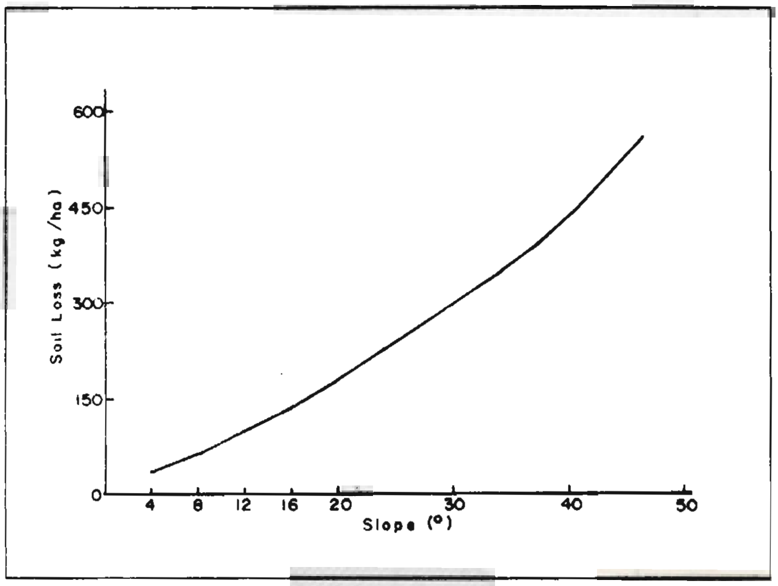


Figure 2.3: The Relationship between Soil Erosion and Slope

Source: Northwestern Institute of Soil and Water Conservation, CAS, 1986

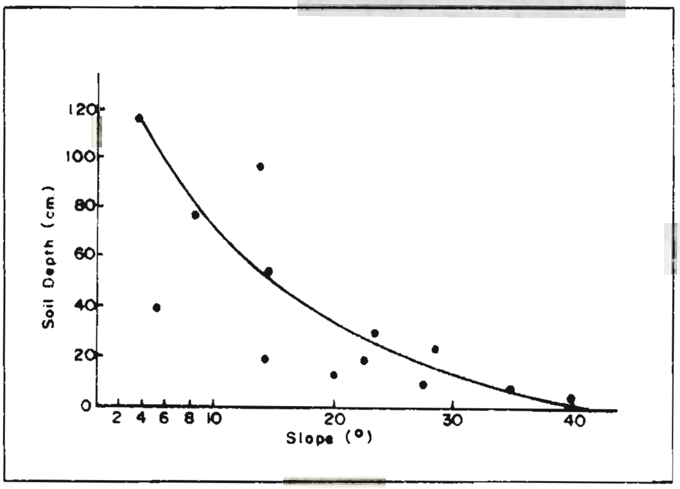


Figure 2.4: The Relationship between Slope and Soil Depth

Source: Northwestern Institute of Soil and Water Conservation, CAS, 1986

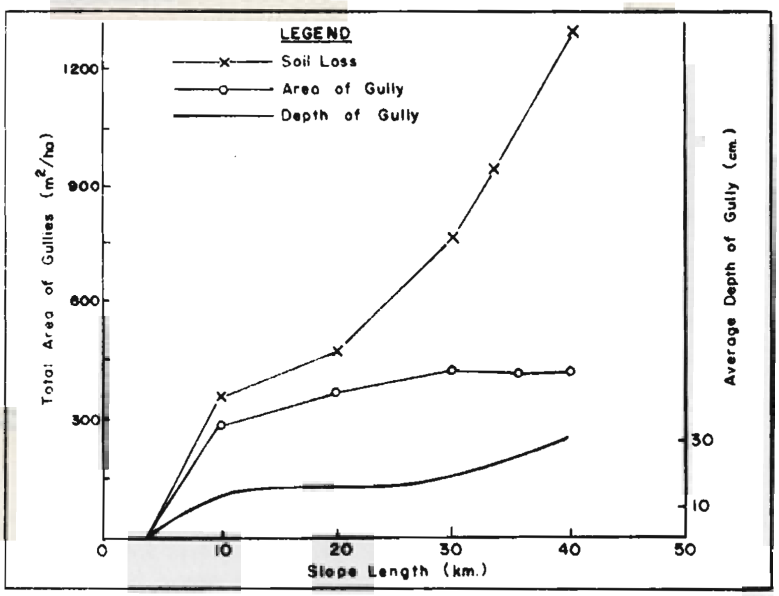
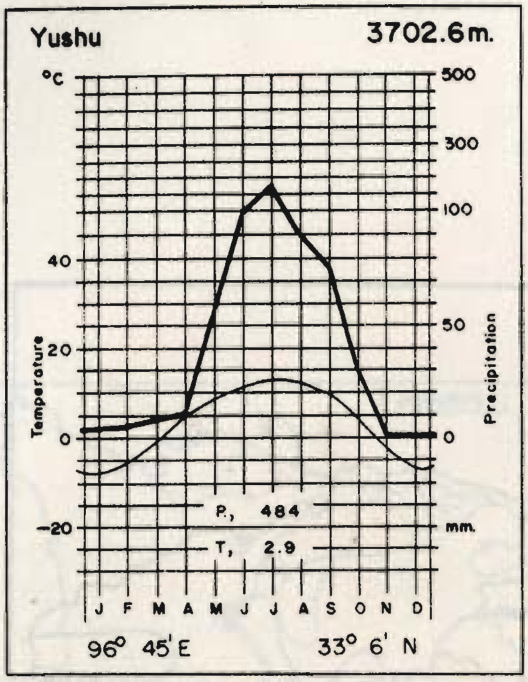


Figure 2.5: The Relationship between Soil Erosion and Slope Length (Red Earth, Hanyuan Sichuan Province)

Source: Soil-Water Conservation Office of Sichuan 1986



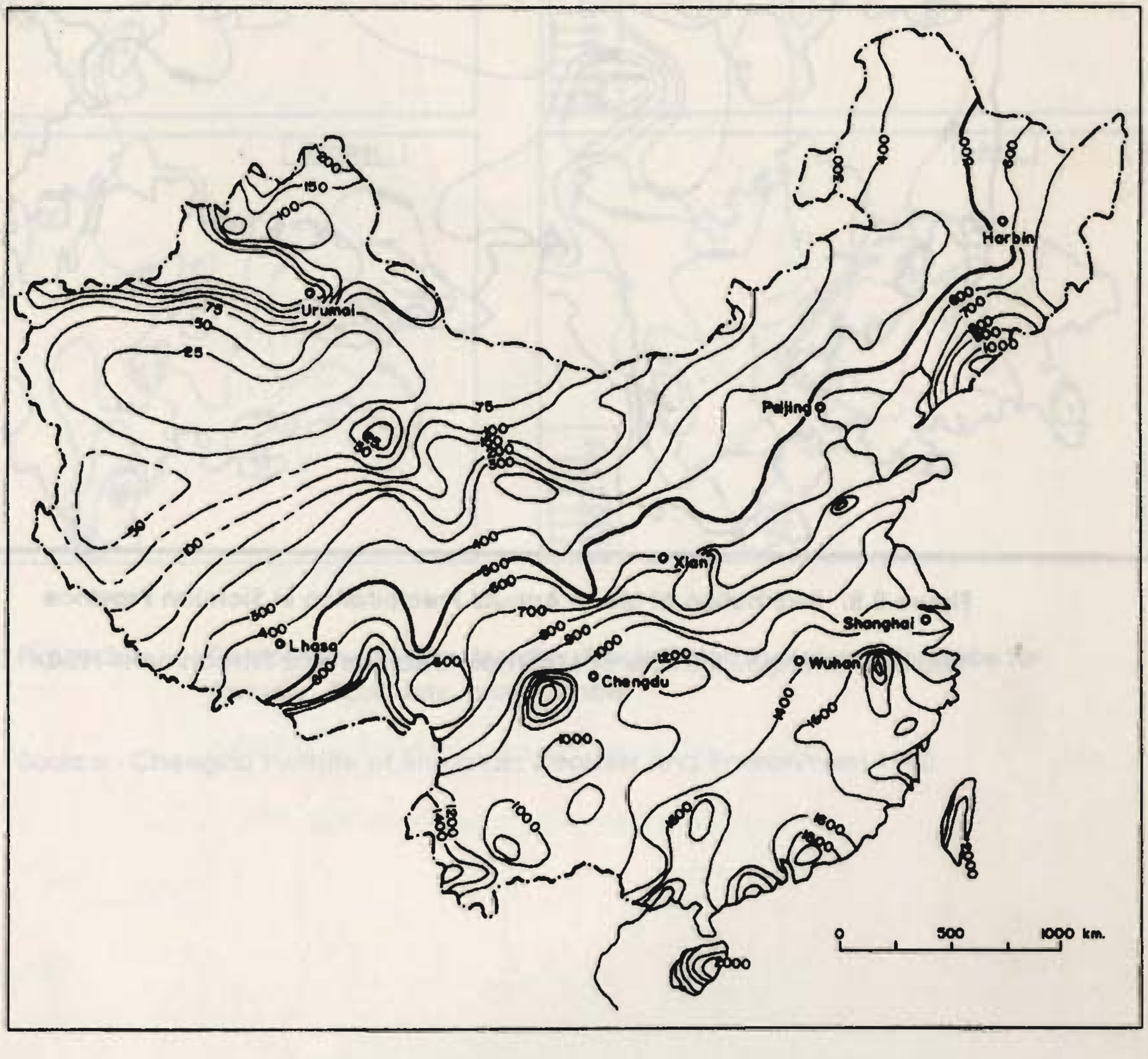
◂ **Figure 2.6: The Reference Diagram of the Subalpine Plateau Zone (Representative Station: Yushu)**

Source: Domros and Peng Gongbing 1988

Figure 2.7: Distribution of Mean Annual Precipitation

Source: Editorial Committee for the Physical Geography of China 1984

▾



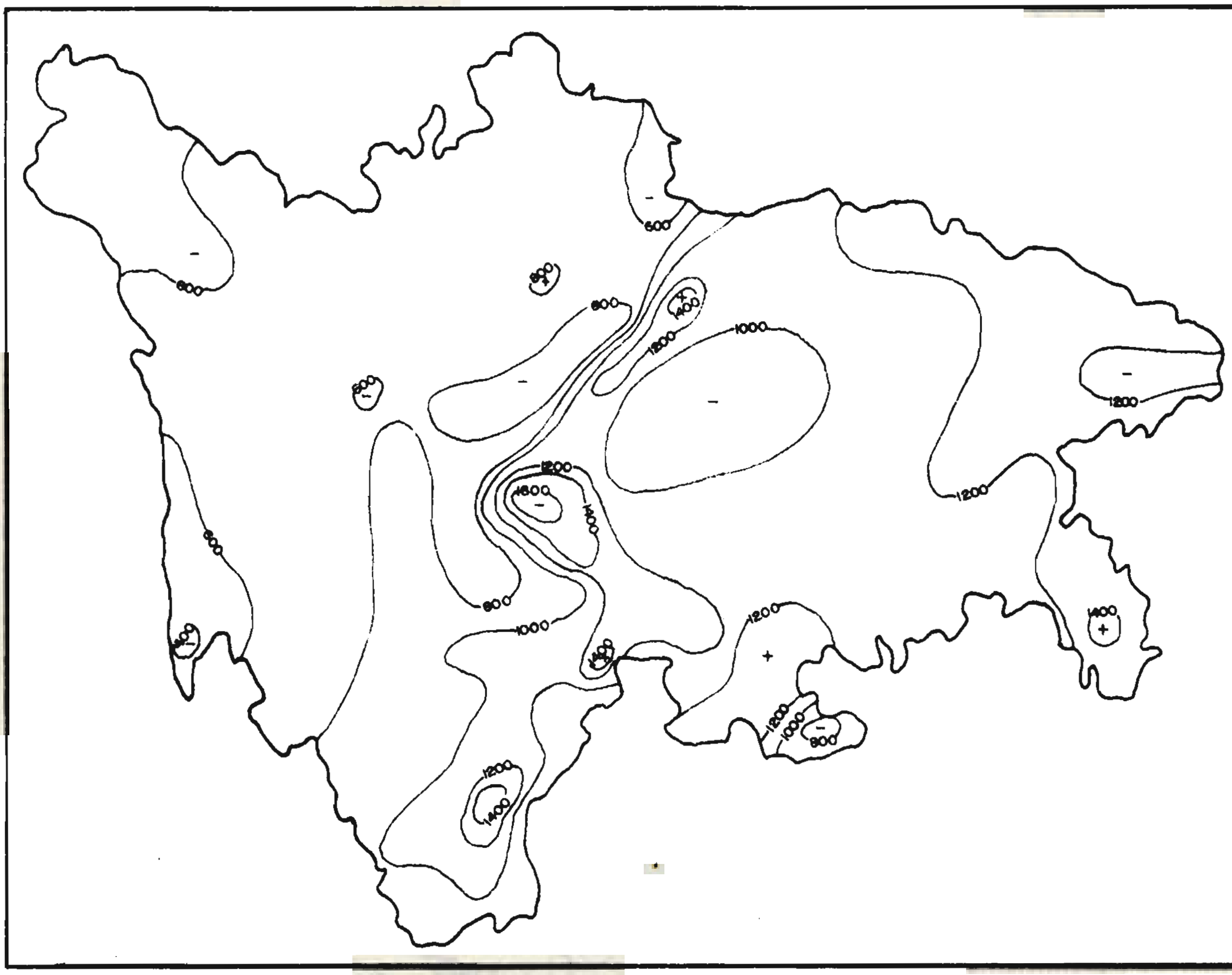


Figure 2.8: Distribution of Mean Annual Precipitation in Sichuan Province

Source: Chengdu Institute of Mountain Disasters and Environment 1980

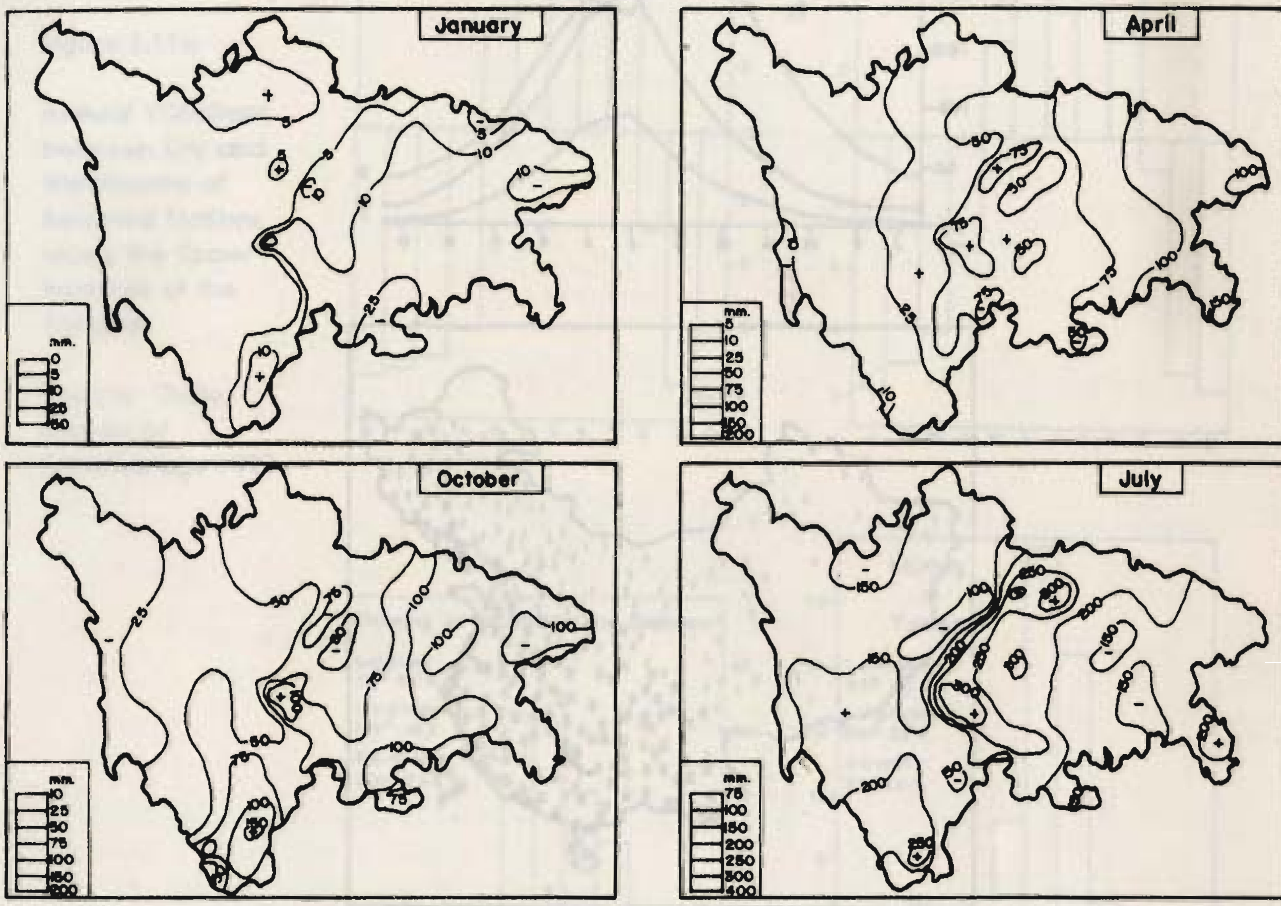


Figure 2.9: Distribution of Mean Monthly Precipitation in Sichuan Province for January, April, July, and October

Source: Chengdu Institute of Mountain Disasters and Environment 1980

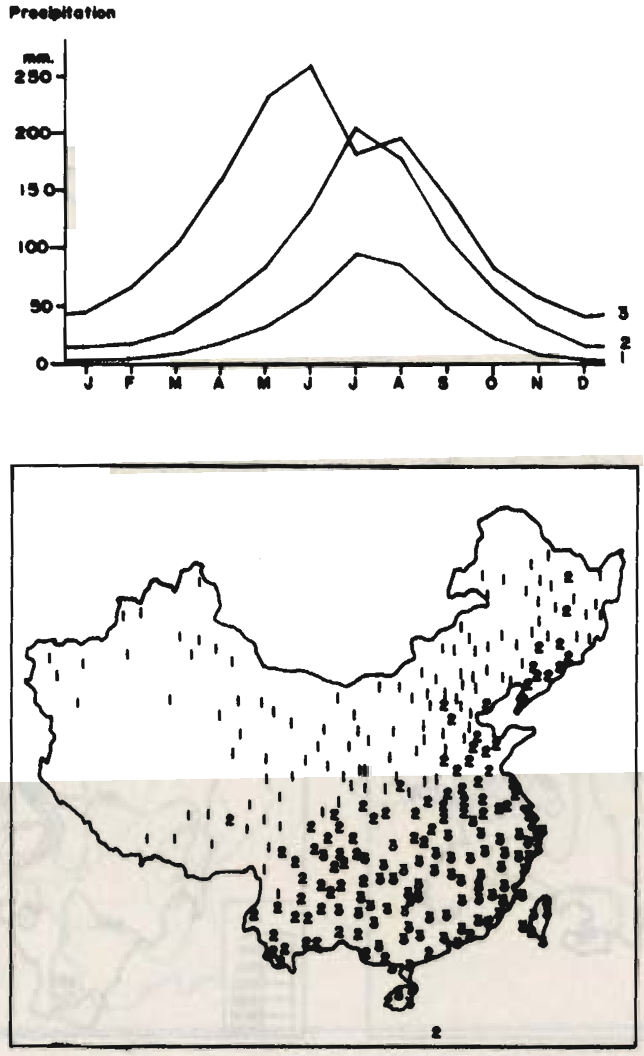


Figure 2.10: Three Types of Annual Precipitation

Source: Domros and Peng Gongbing 1988

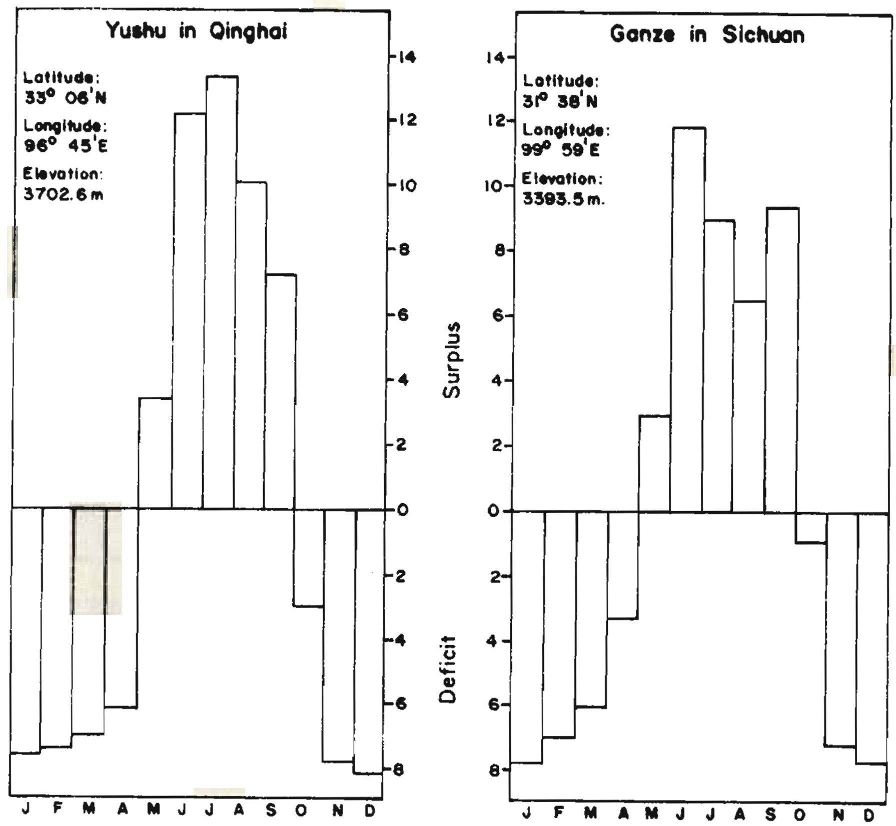


Figure 2.11a

Annual Variations between Dry and Wet Months of Selected Stations along the Upper Reaches of the Yangtze

Source: State Bureau of Meteorology 1980

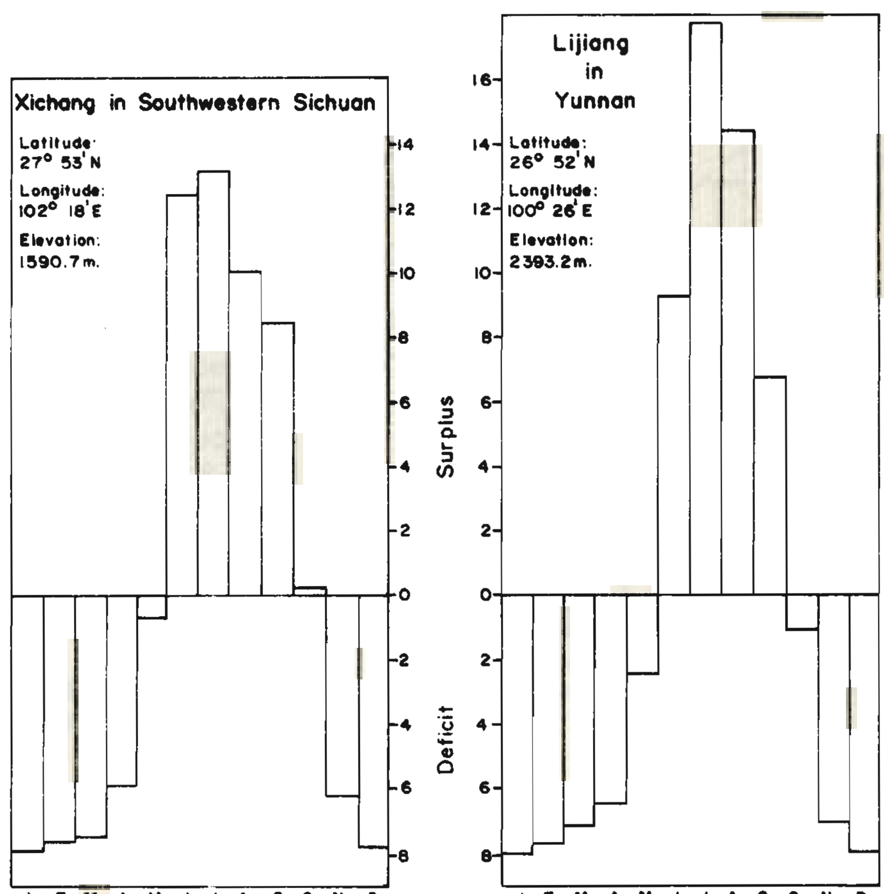


Figure 2.11b

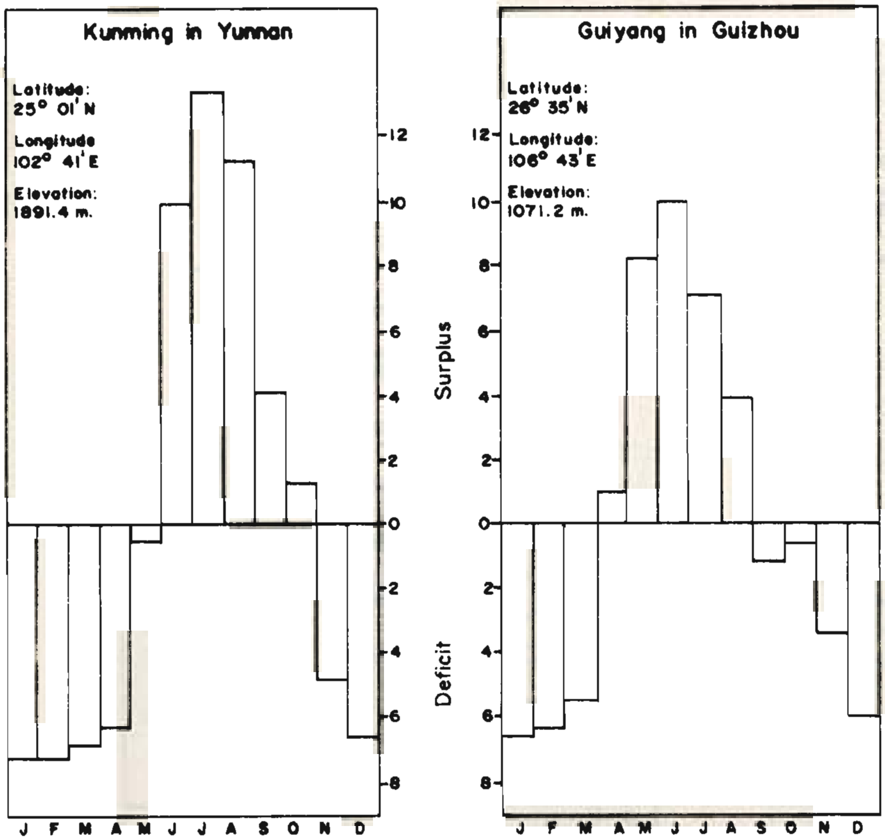


Figure 2.11c

Source: Ibid

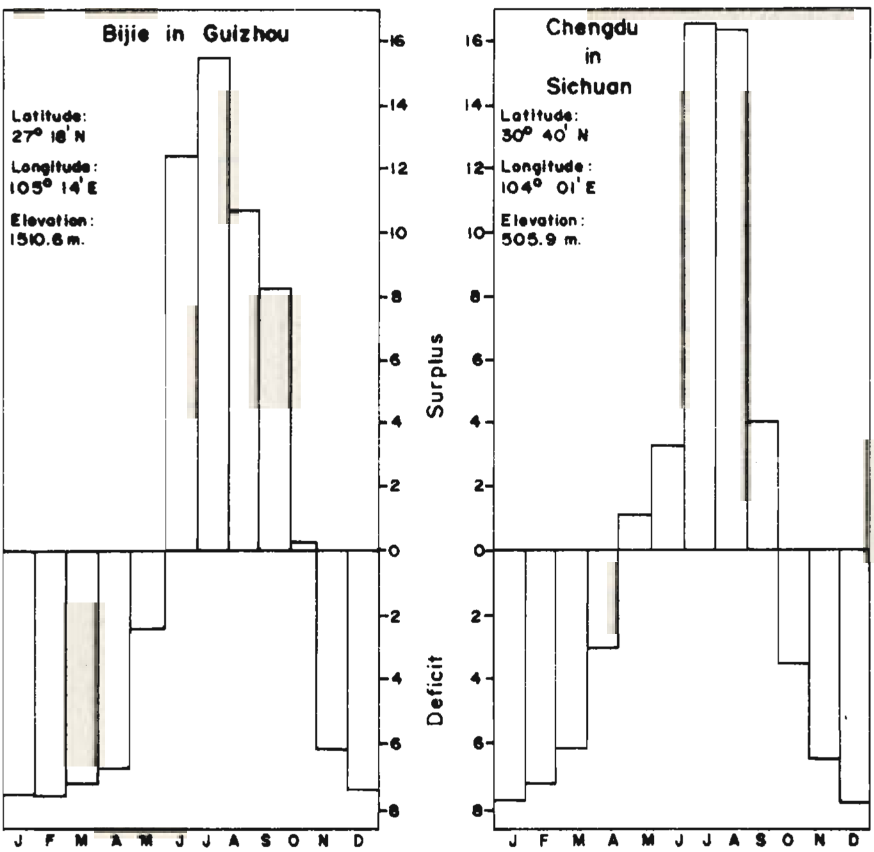


Figure 2.11d

Source: Ibid

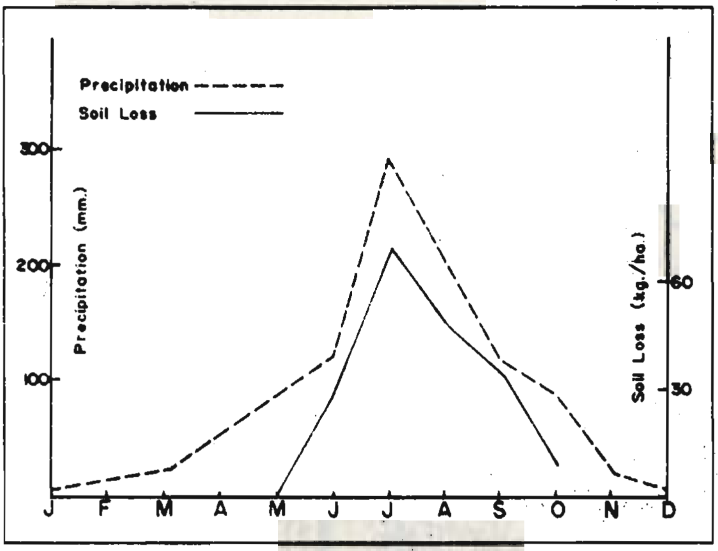


Figure 2.12: The Relationship between Annual Precipitation and Variations in Annual Soil Loss Variation

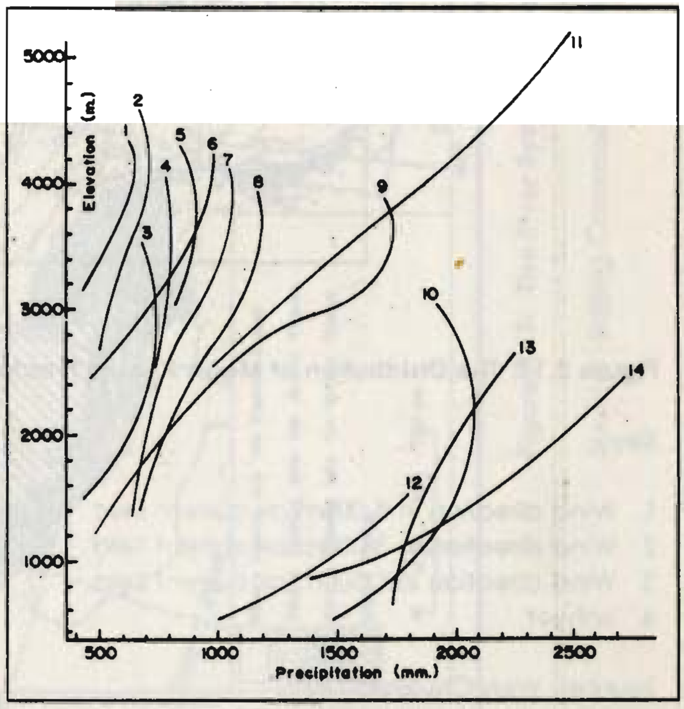
Source: Soil-Water Conservation Office of Sichuan 1986

Figure 2.13: Vertical Variations in Mean Annual Precipitation in Mountain Areas in the Upper Reaches of the Yangtze ▸

Key:

1. Chengdu - Dingquing; 2. Queershan; 3. Maowen - Hongyuan; 4. Yajiang - Liftang; 5. The western slope of the Cheduo Mountain; 6. Batan - Yidin; 7. Luding - Eratizi (the eastern slope of the Zheduo Mountain); 8. Dochuan in Yunnan; 9. Li-jiang in Yunan; 10. Emei Mountain; 11. for Bomi District; 12. Eastern slope of the mountains; 13. Yaan - Erlang Mountains; 14. the Rongjiang - Daxiagling.

Source: Wang Yanlong and Shao Wenzhang 1983



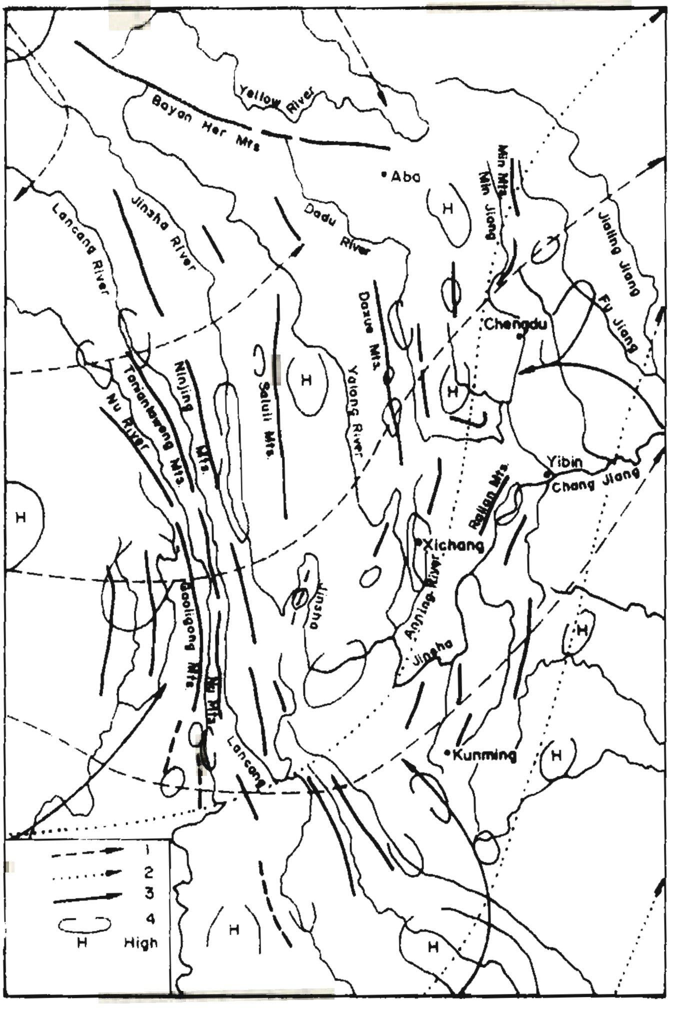


Figure 2.14: The Distribution of Mean Annual Precipitation in the Hengduan Mountains

Key:-

1. Wind direction in 5,000m air current field
2. Wind direction in 3,000m air current field
3. Wind direction in 1,500m air current field
4. Isohyet

Source: Wen Chuanjia 1989

Figure 2.15: The River System in the Upper Reaches of the Yangtze River

Source: Editing Commission for the "Physical Geography of China" 1981

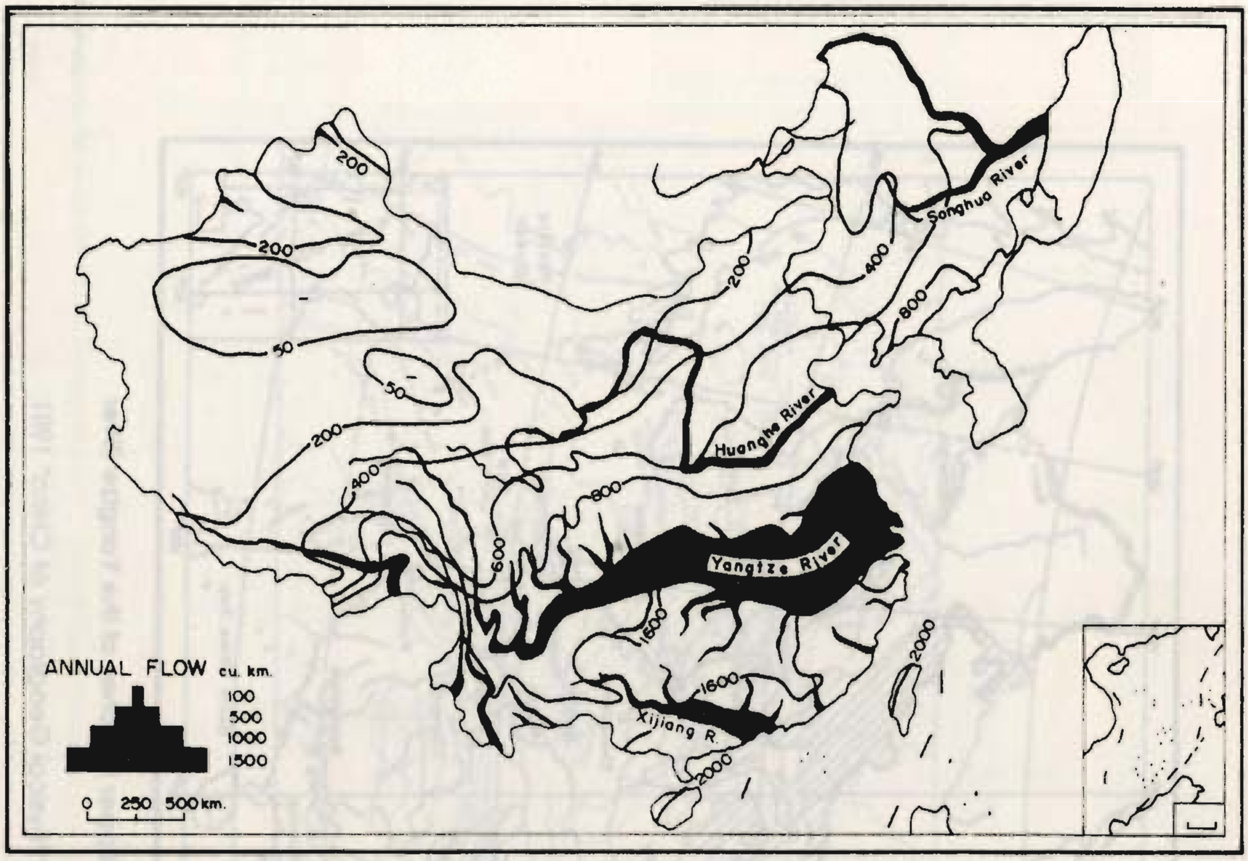


Figure 2.16: The Flow of Rivers in China

Source: After Liuchang Min 1990

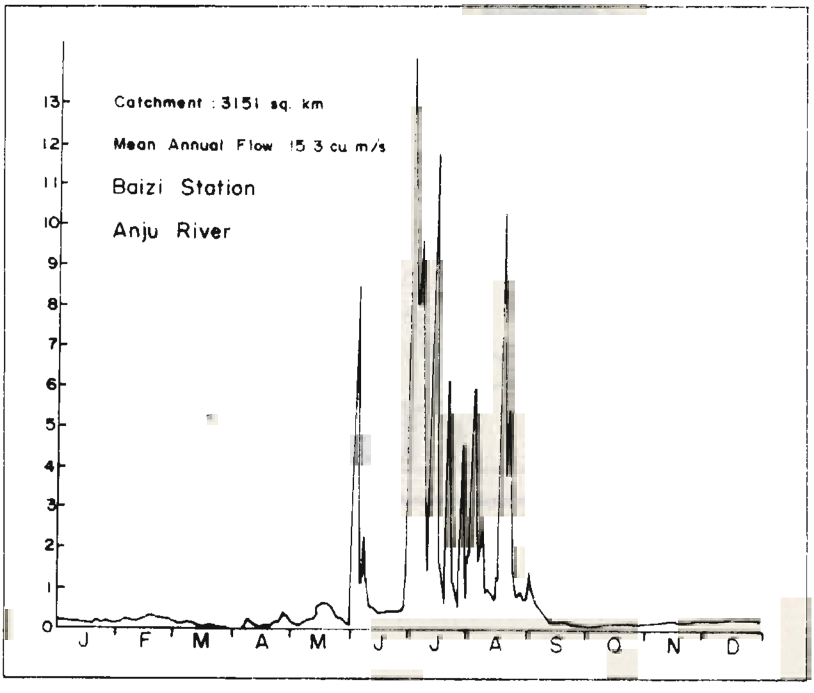


Figure 2.17: **Mean Relative Discharge Hydrograph of the Sichuan Basin Type**

Source: Editing Commission for the "Physical Geography of China" 1981

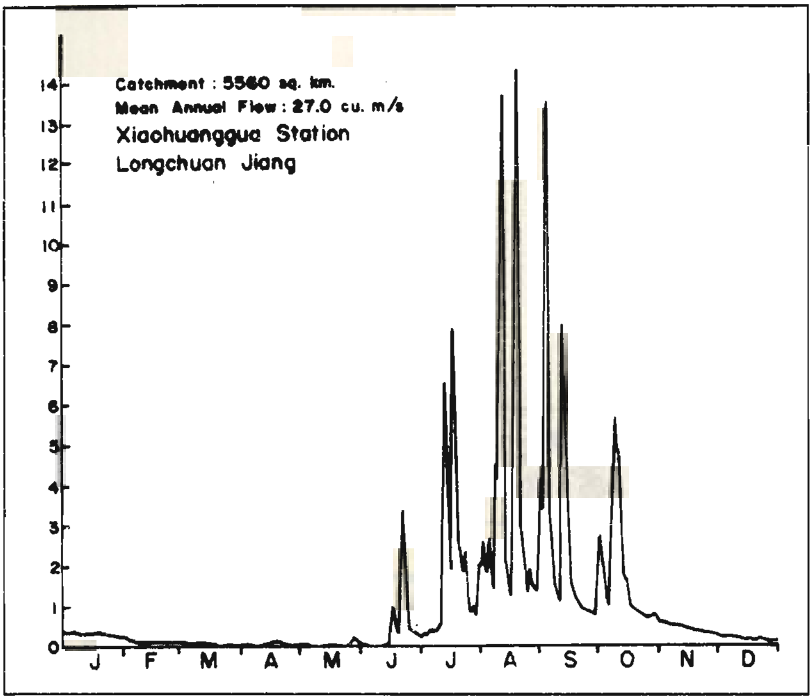


Figure 2.18: Mean Relative Discharge Hydrograph of the Dian-Guo Type

Source: Editing Commission for the "Physical Geography of China" 1981

Figure 2.19a: Mean Relative Discharge Hydrograph of the Ganzi Type

Source : Editing Commission for the "Physical Geography of China" 1981

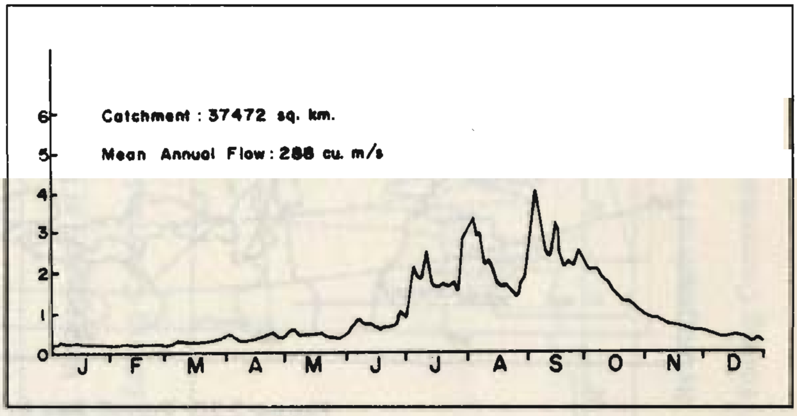
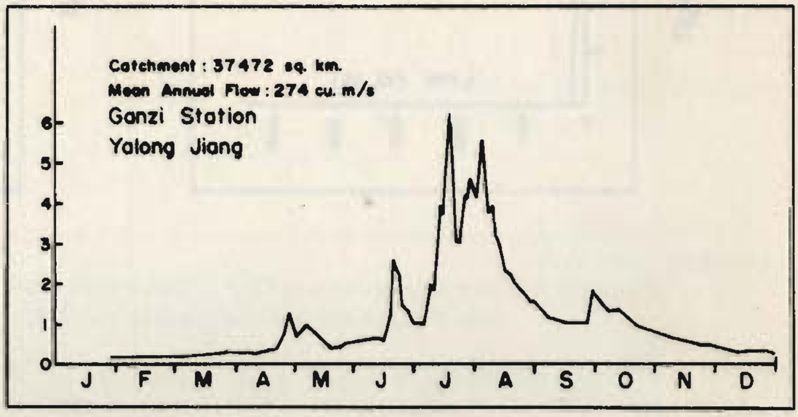


Figure 2.19b: Mean Relative Discharge Hydrograph of the Ganzi Type (based on 1970 data)

Source: Editing Commission for the "Physical Geography of China" 1981



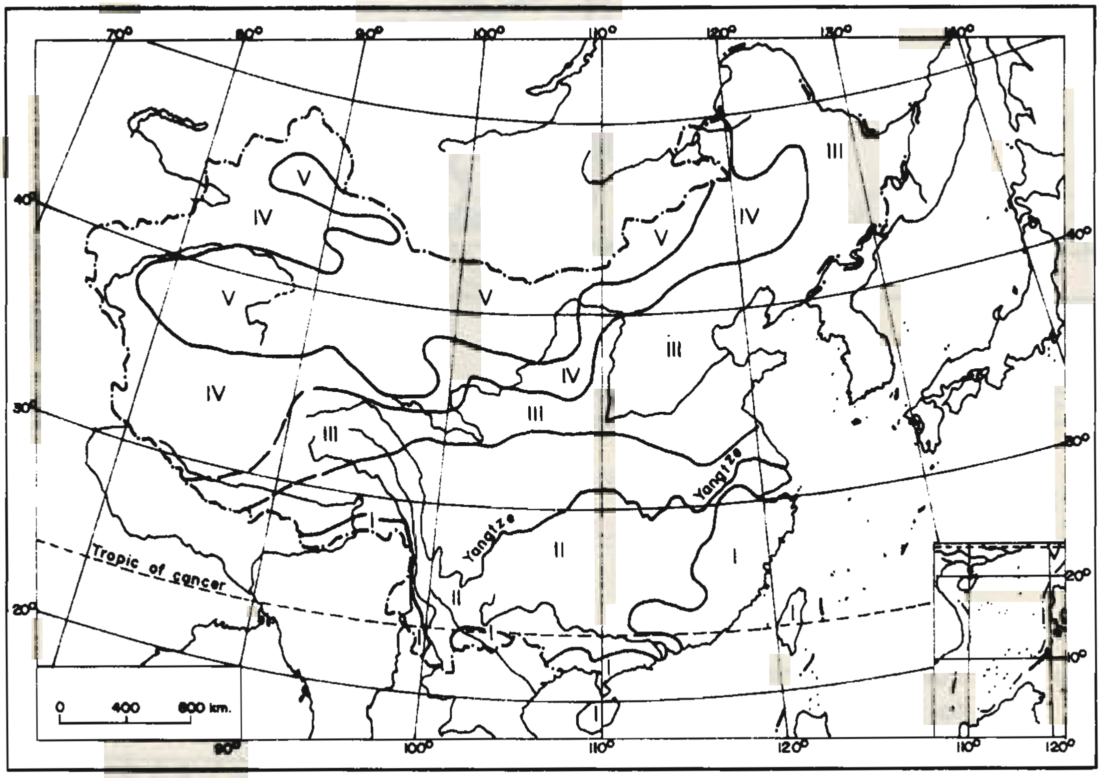


Figure 2.20: Runoff Belt in China

Source: Editing Commission for the "Physical Geography of China" 1981

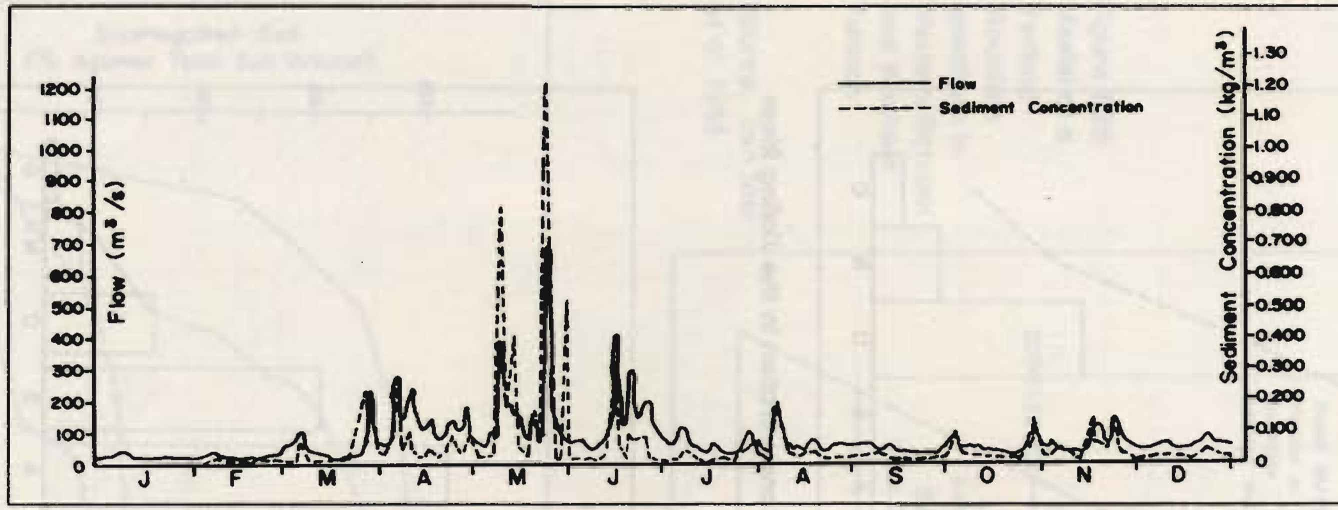


Figure 2.21: Hydrograph of Flow and Sediment Concentration in the Lei River

Source: Editing Commission for the "Physical Geography of China" 1981

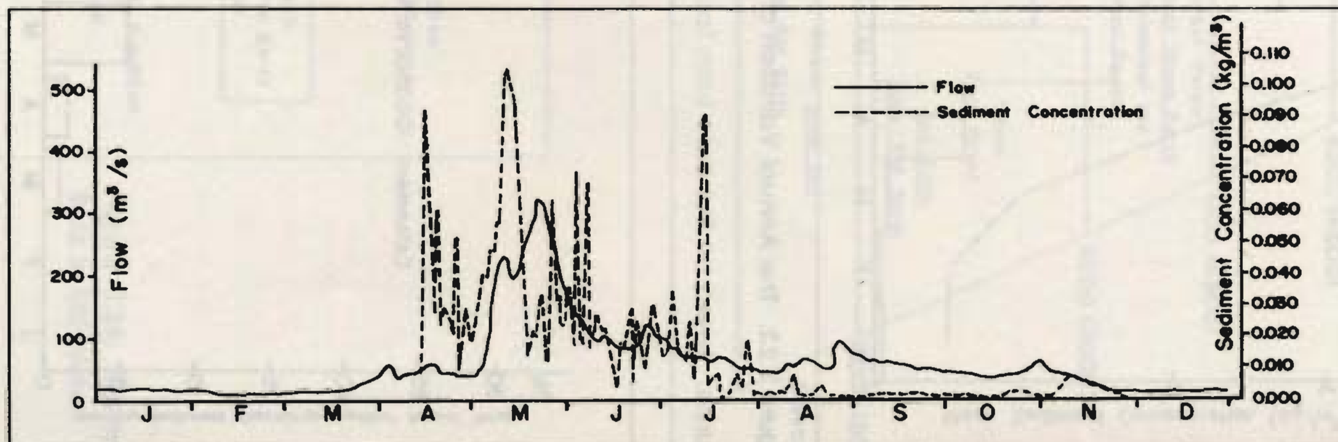


Figure 2.22: Hydrograph of Flow and Sediment Concentration in the Eergisi River

Source: Editing Commission for the "Physical Geography of China" 1981

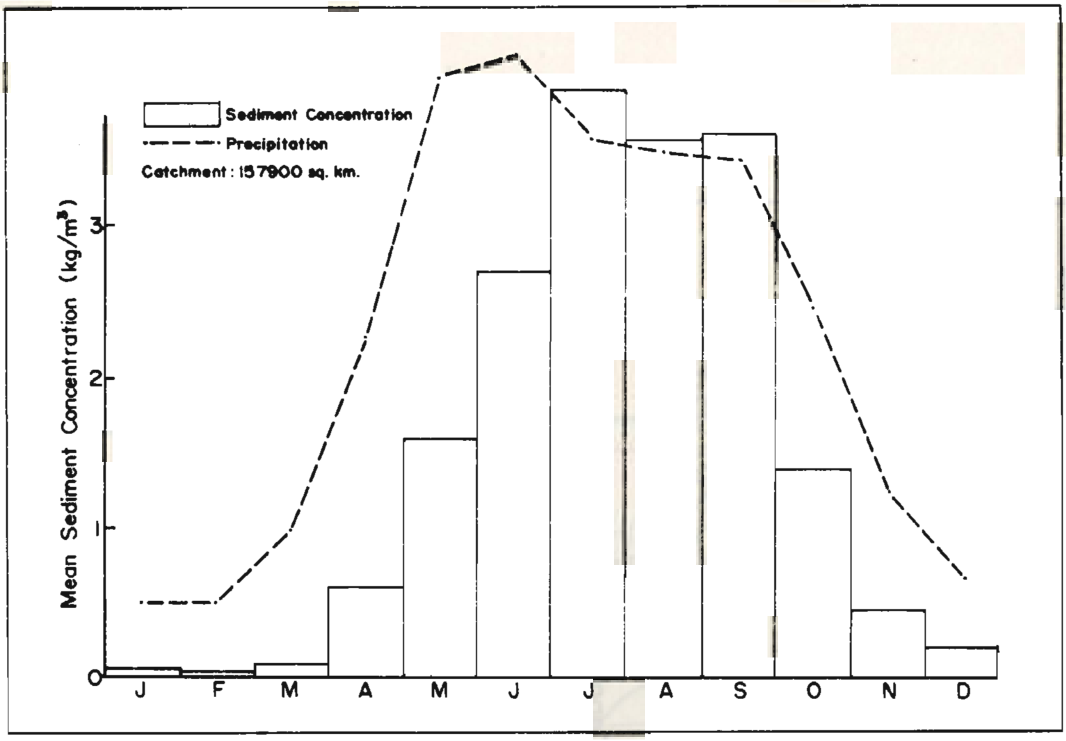


Figure 2.23: The Annual Variation of Sediment Concentration in the Jialing River

Source: Based on the data from Table 2.19

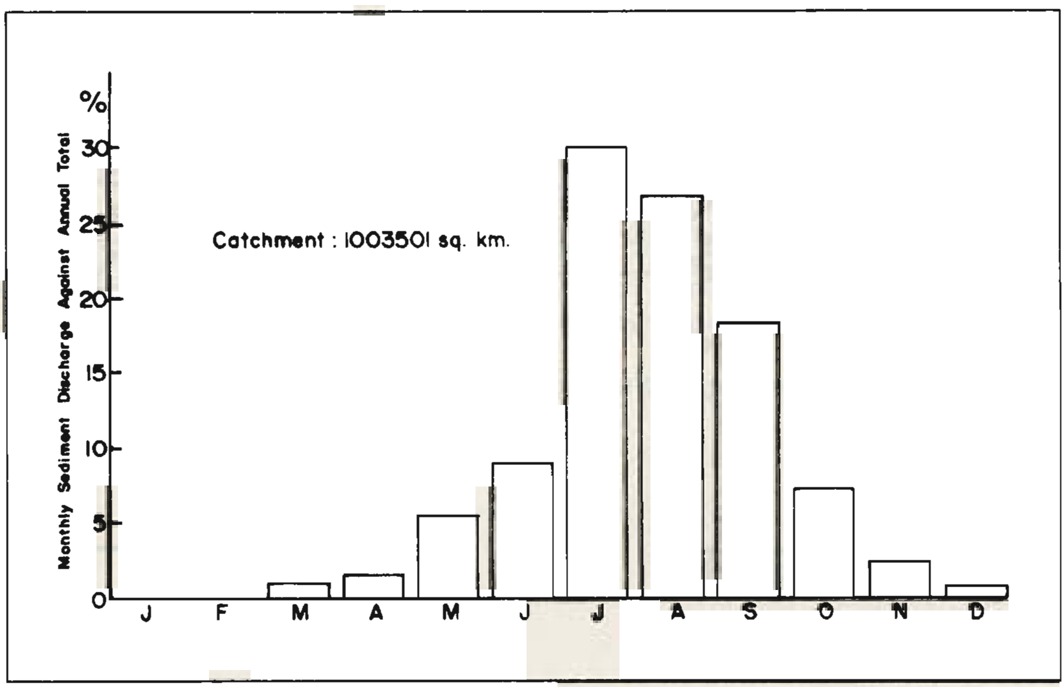


Figure 2.24: The Annual Variation of Sediment Discharge in the Upper Reaches of the Yangtze River at Yicheng Station

Source: Based on the data from Table 2.20

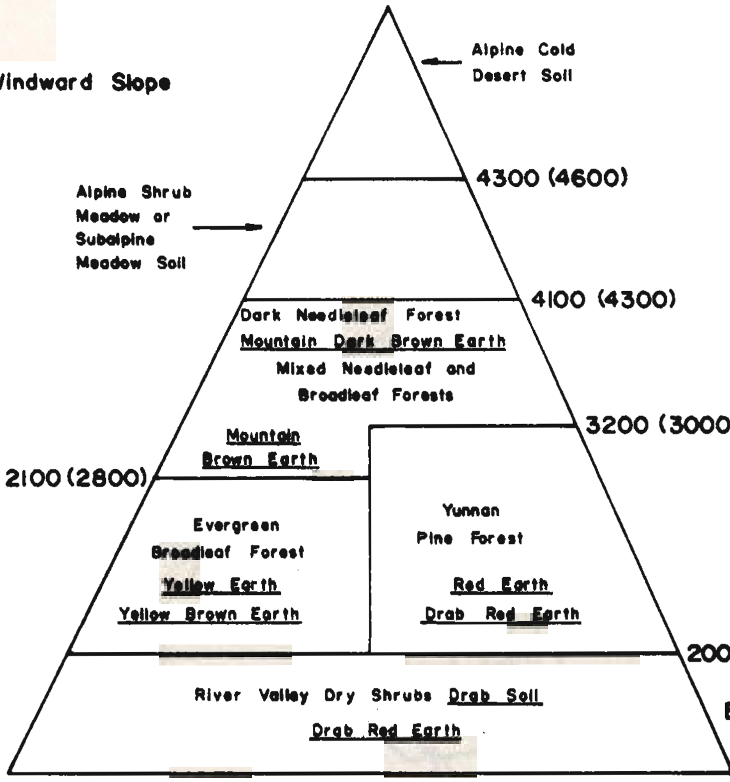


Figure 2.25: Model of a Vertical Mountain Spectrum in Western Sichuan and Northern Yunnan

Source: Ren Mei et al. 1985

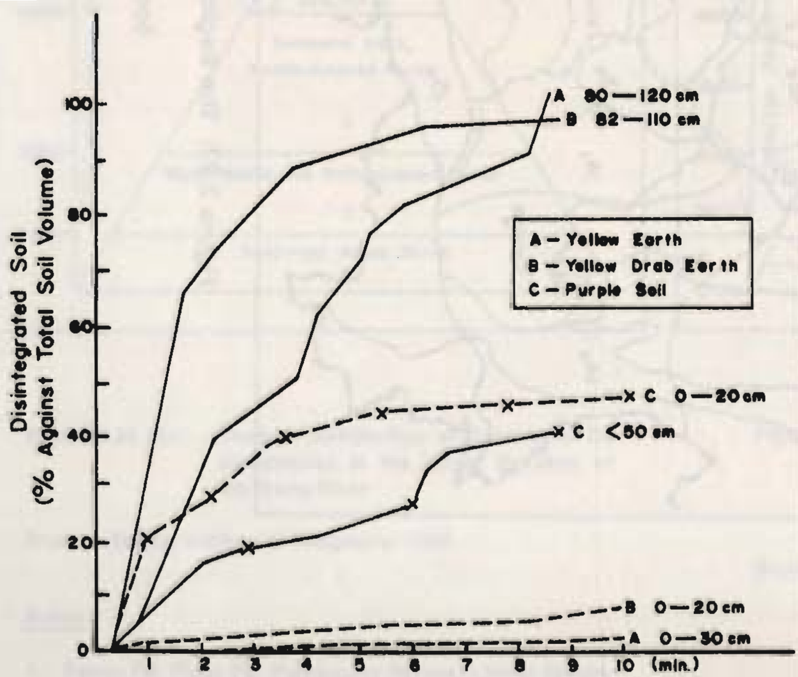


Figure 2.26: Disintegration of Soils in Still Water

Source: Northwestern Institute of Soil and Water Conservation, CAS, 1986

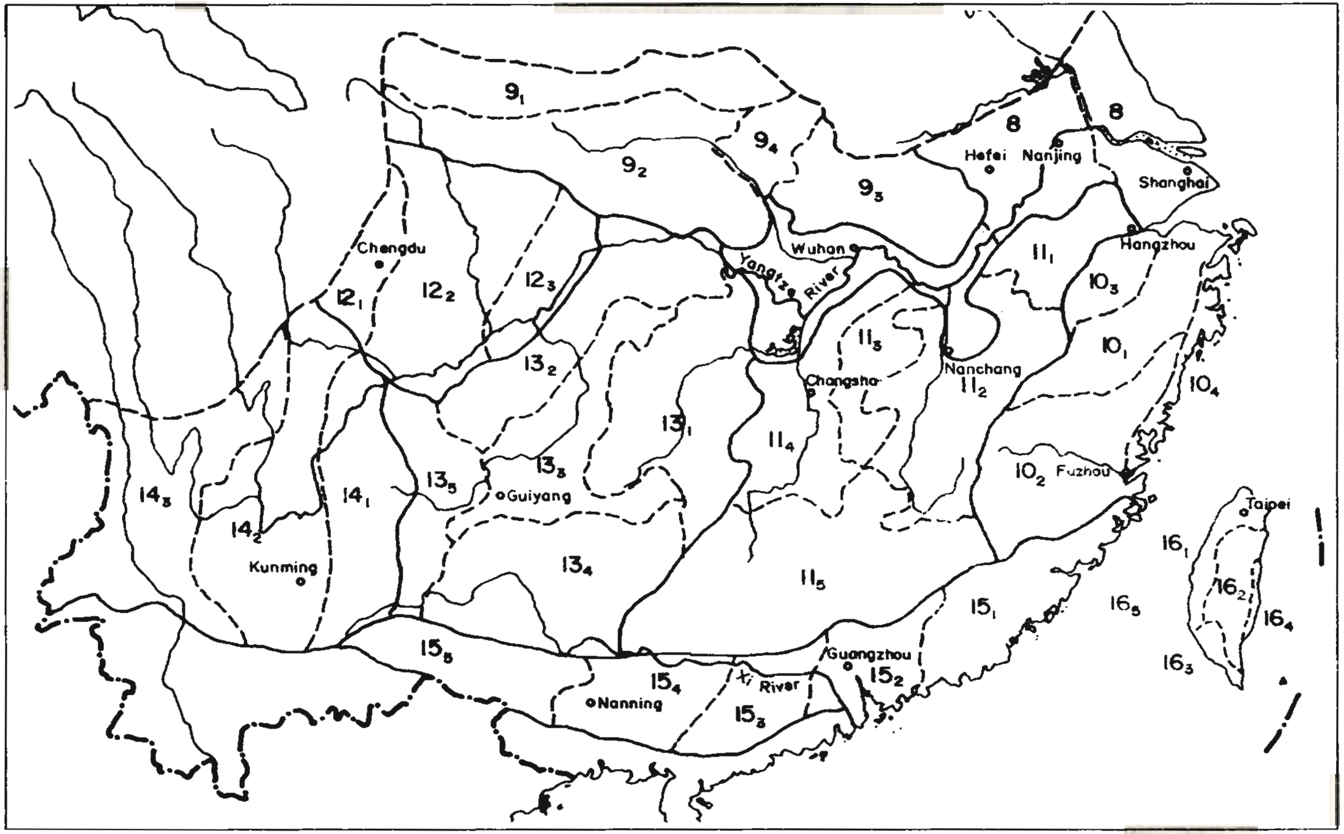


Figure 2.27: The Regions of the Upper Reaches of the Yangtze River

Source: Zhao Songqiao 1986

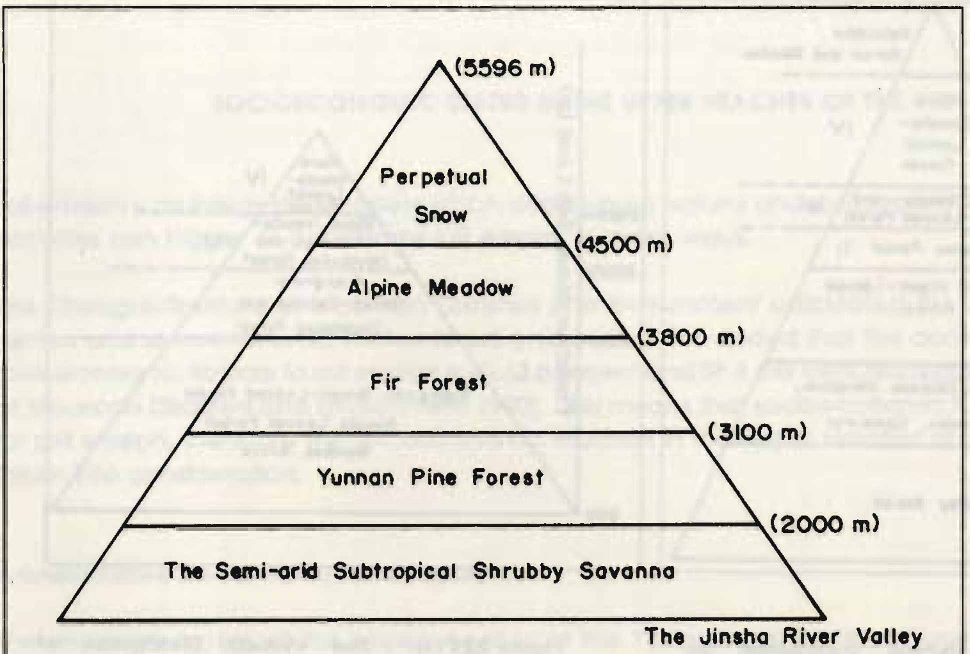


Figure 2.28: Vertical Distribution of Vegetation on Yulong Mountain

Source: Beijing Institute of Geography 1983

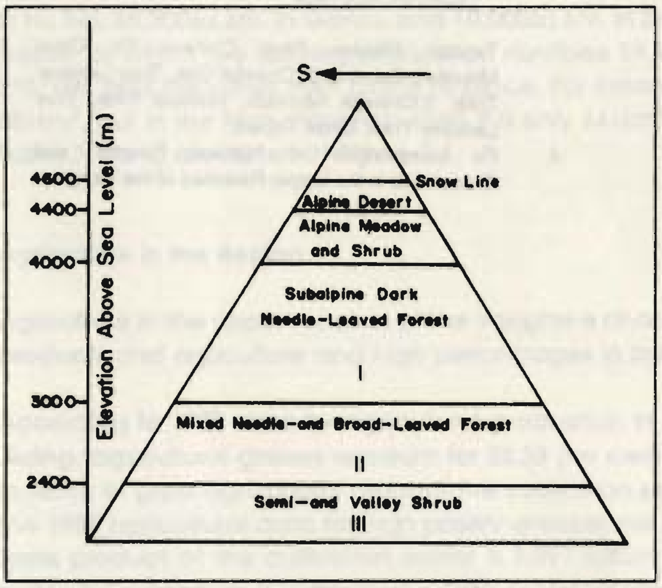


Figure 2.29 (1): Vertical Distribution of Forests in Da Xiaojinshan in the Upper Reaches of the Dadu River

Source: Beijing Institute of Geography 1983

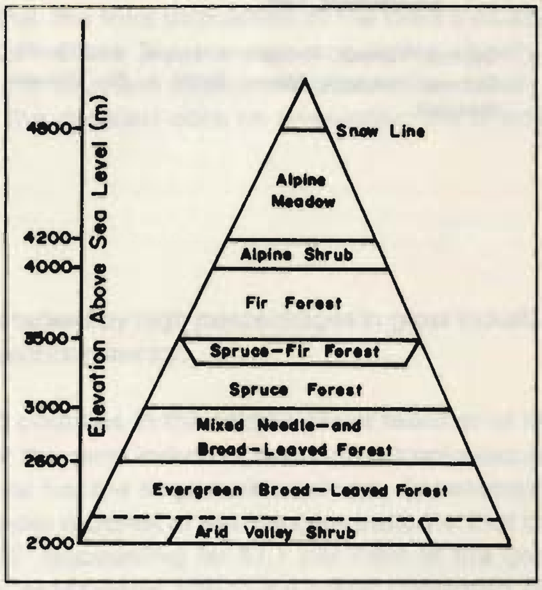
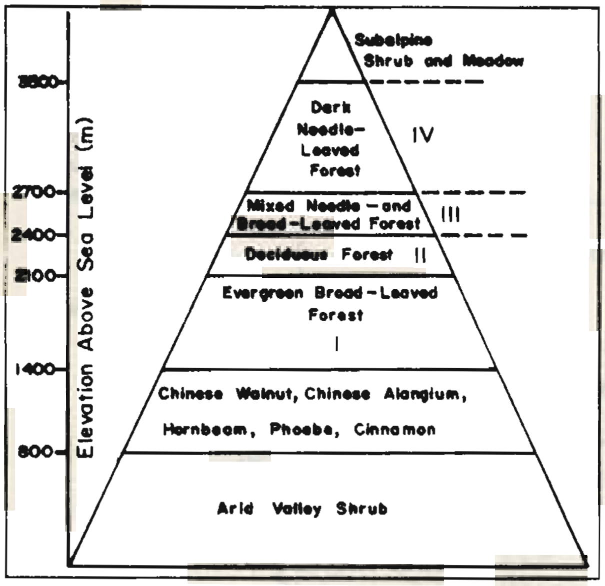


Figure 2.29 (2): Vertical Distribution of Forests on Saluli Mountain in the Middle Reaches of the Jinsha River

Source: Beijing Institute of Geography 1983

Notes:

1. Faxon Fir, Flaky Fir, Purplecone Spruce, Lijiang Spruce, Chinese Larch, Alpine Oak, Chinapaper Birch
2. Alpine Pine, Armand Pine, Chinese Hemlock David Maple, Baron Oak, East-Liaoning Oak
3. Siberian Nitravia, Barberry, Mana plant, Alhagi



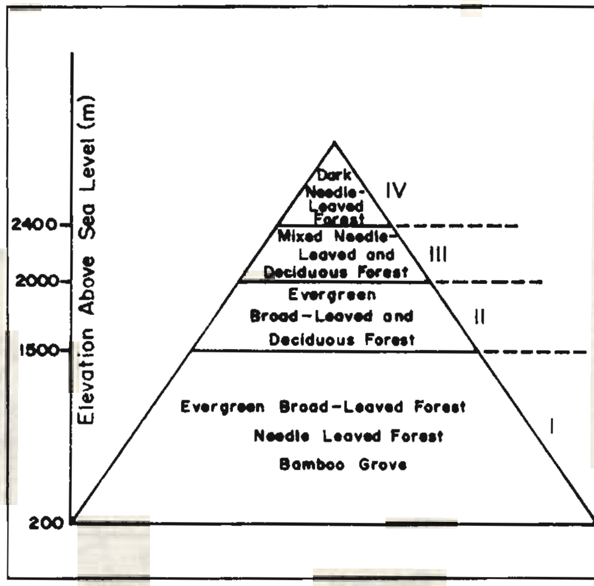


Figure 2.29 (3): The Vertical Distribution of Forests On Xiaoliang Mountain

Source: Chengdu Institute of Mountain Disasters and Environment, 1980

1. Schima, Tanoak, Phoebe; 2. Maple, Birch 3. Fir, Chinese Hemlock, Maple, Birch; 4. Fir, Chinese Hemlock

Figure 2.29 (4): The Vertical Distribution of Forests on Wushuan Mountain

Source: Chengdu Institute of Mountain Disasters and Environment 1980

1. Tanoak, Masson Pine, Chinese Fir, Omei Mountain Bamboo 2. Oriental Oak, True Lacquer Tree; 3.Chinese hemlock, Armand Pine, True Lacquer Tree, Birch, Filbert.
4. Fir composition of Natural Forests and Grasslands in the Upper Reaches of the Yangtze.