ICIMOD

MOUNTAIN ENVIRONMENTAL MANAGEMENT

Discussion Paper Series

Soil Erosion in the Upper Reaches of Yangtze Jiang

A Review of Chinese Literature

Sun Jizheng

MEM Series No. 11

1993

International Centre for Integrated Mountain Development

SOIL EROSION IN THE UPPER REACHES OF YANGTZE JIANG

A Review of Chinese Literature

Sun Jizheng

MEM Series No. 11

Sun Jizheng was a staff member of the Mountain Environmental Management Programme of ICIMOD while writing the paper.

1993

International Centre for Integrated Mountain Development

Kathmandu (Nepal)

PREFACE

This Discussion Paper is based principally on a selection of Chinese research documents on land resources. Most of these documents have not been published outside of China and, apart from the papers co-authored with ex-patriate scientists, are not available in the English language.

Professor Sun Jizheng's efforts, not only in researching these documents but also in providing us with a selective review of the information contained in them in the English language, are highly commendable.

The document contains invaluable information for researchers in the field of environmental management, in general, and in mountain environmental management in particular.

Table of Contents

	Page
INTRODUCTION	1
THE STATE OF THE PHYSICAL ENVIRONMENT IN THE UPPER REACHES OF THE YANGTZE	6
Geological Structure and Rock Characteristics	6
Principal Rock Outcrops in the Region	6
Gradation of the Anti-erosive Capability of the Major Rocks and Surface Materials in the Region	7
Topographical and Morphological Conditions	7
Relationship between Slope and Soil Erosion	9
Relationship between Slope Length and Soil Erosion	10
The Relationship between Soil Erosion and Surface Relief	10
Climate in the Upper Reaches of the Yangtze	11
Different Climates in the Upper Reaches of the Yangtze	11
Precipitation in the Upper Reaches of the Yangtze	14
Principal Distribution of Annual Precipitation	14
Specific Precipitation Types	14
Precipitation Intensity in the Region	15
Influence of Topography and Elevation on Precipitation	18
Influence of Slope Exposure on Precipitation	18
Effect of Elevation on Precipitation	18
The Erosive Nature of Rainfall in the Region	18
River Hydrology in the Upper Reaches of the Yangtze River	20
The River System in the Upper Reaches of the Yangtze River	20
The River Flow of the Upper Reaches of the Yangtze	20
Surface Runoff in the Upper Reaches of the Yangtze	22
Sediment	22
Soil Erosion Modulus	23
Sediment Concentration and Sediment Discharge	24
Variation of Sediment	25
Soil	27
The Major Soil Units in the Upper Reaches of the Yangtze	28
Distribution of Soil and Soil Erodibility	28
Vertical Distribution of Soil in the Region	28
Relationship between Soil Erosion and Soil Type	31
Soil Texture	32
Natural Vegetation	33
Natural Vegetation in the Upper Reaches of the Yangtze	33

Relationship between Soil Erosion and Vegetation 35
Forests in the Upper Reaches of the Yangtze River 35
The Present State of Forests in the Upper Reaches of the Yangtze 35
Growth Characteristics of Forests in the Region 36
Vertical Distribution of Regional Forests 37
Medium-Dense Vegetation 37

SOCIOECONOMIC STATUS IN THE UPPER REACHES OF THE YANGTZE 59

Administrative Demarcation and Population 59
Agriculture in the Region 59
Population 60
Economic and Living Conditions in the Upper Reaches of the Yangtze 61
Natural Resources 63
Land Use 63

Vertical Distribution of Agriculture in Mountainous Areas in the Upper Reaches of the Yangtze 65
Dry and Hot Valleys 66
Wide Valleys and Basins 67
Middle and Low Mountains 67
High Mountains 67

Mountain Agriculture and Soil Erosion 68
Root System in Grassland and Soil Erosion 68

Forestry in the Region 69
Animal Husbandry in the Region 70

RECENT STATUS AND CHARACTERISTICS OF SOIL EROSION IN THE REGION 73

Recent Status of Soil Erosion 73
Soil Erosion on Dry Sloping Farmland 73
Low Frequency of Soil Erosion and Short Duration of Rainy Periods 76
Characteristics of Soil Erosion in the Upper Reaches of the Yangtze Jiang 76
Regionalisation of Soil Erosion in the Upper Reaches of the Yangtze Jiang 79
Principles of the Regionalisation of Soil Erosion 79
Criteria for Regionalisation of Soil Erosion 79
The Hengduan Mountains 93
Qinghai-Tibetan Plateau 93

FACTORS BEHIND SOIL EROSION AND THE IMPACT OF SOIL EROSION ON SOCIOECONOMIC DEVELOPMENT 96

Rapid Population Growth and Scarcity of Skilled Human Resources 96
Deforestation 97

Unreasonable Use of Sloping Agricultural Land 101
Impact of Soil Erosion on Socioeconomic Development 102

Damage to Rivers, Lakes, and Water Conservation Projects 103
Aggravation of Flood Damage 103
Damage to River Navigation 104
Silting and Shrinking of Lakes 104
Silting of Water Conservancy Projects 104
Reducing the Effective Use of River Flow 105
Degradation of Eco-environmental Conditions and Poverty in Soil Erosion-prone Areas 105

NATIONAL SOIL-WATER CONSERVATION PROJECTS IN THE REGION AND LESSONS FOR THE FUTURE 107

National Planning of Soil-Water Conservation in the Upper Reaches of the Yangtze 107
Principles of Planning 107
Planning Procedure 109
Targets of the Soil-Water Conservation Project in the Upper Reaches of the Yangtze River 109
Management Aspects 111
Training 111
Financial and Economic Aspects 111
Soil-Water Conservation Benefits 112
Direct Economic Benefits 112
Indirect Economic Benefits 112
Increment of Vegetation Area and Coverage 113
Soil-Water Conservation Project 113

Case Study - The Project in Practice 113
Ningnan Case Study 113
Shizhong District of Suining City (County Level) 114
Guangan County 115

CONCLUSIONS 119

Environmental Conditions in the Region 119
Recent Status of Soil Erosion in the Region 119
Factors behind Soil Erosion in the Region 120
Constraints to Socioeconomic Development in the Region 120
Soil-Water Conservation in the Region 121

REFERENCES 122

LIST OF FIGURES

1.1:	The Course of the Yangtze River	3
1.2:	The Upper Reaches of the Yangtze River	4
1.3:	Different Types of Water and Soil Loss and Their Interrelationships	5
3.1:	Population of the Chang Valley	71
3.2:	Multiple Crop Index in China	72
4.1:	Graph Depicting Annual Precipitation, Runoff, and Sediment Discharge Variations in the Anning River Basin (based on Data in Table 4.4)	94
4.2:	Regional Map of Soil Erosion in the Upper Reaches of the Yangtze	95
5.1:	Variation of Dongtin Lake in Area and Water Storage Over Time	106
6.1:	Sketch Map of the Four Key Soil-Water Conservation Zones in the Upper Reaches of the Yangtze River	117

LIST OF TABLES

2.1:	Gradation of the Anti-erosive Quality of Surface Materials	8
2.2:	Relationship between Slope and Soil Erosion	9
2.3:	The Relationship between Soil Erosion and Slope	10
2.4:	The Surface Relief in Chongquing District	10
2.5:	Climate Division Scheme of China	12
2.6:	The Relationship between Precipitation Intensity, Precipitation, and Soil	16
2.7:	The Number of Rainstorms from 1951 - 1957	16
2.8:	Heavy Rainstorm (> 150mm/day) from 1960 to 1976 in the Wu Basin	17
2.9:	Rainstorms in Selected Stations in the Lower Reaches of the Jinsha	17
2.10:	Rainfall Erosivity R at Selected Stations in the Upper Reaches of the Yangtze	19
2.11:	The Major Rivers in the Upper Reaches of the Yangtze	20
2.12:	The Variation in the River Flow in the Upper Reaches of the Yangtze along its Course	21
2.13:	The Flows of the Major Tributaries of the Upper Reaches of the Yangtze	21
2.14:	Sediment at Selected Hydrometric Stations in the Upper Reaches of the Yangtze	23
2.15:	The Flow, Sediment Concentration, and Sediment Discharge in the Upper Reaches of the Mainstream of the Yangtze	24
2.16:	The Sediment Regime in the Upper Reaches of the Mainstream of the Yangtze River	24
2.17:	The Sediment Regime of Selected Tributaries in the Upper Reaches of the Yangtze River	25
2.18:	Sediment Discharge and Sediment Concentration in the Upper Reaches of the Yangtze (1958-1986)	26
2.19:	Annual Variation of Sediment Concentration in the Jialing River	26
2.20:	Annual Variation of Sediment Concentration in the Yichang Station	26
2.21:	Correlation of Soil Types	27
2.22:	The Vertical Distribution of Soil in the Wu Basin	29
2.23:	The Physical and Chemical Properties of Purple Soil	30
2.24:	The Disintegration of Red Earth in Water	32
2.25:	Soil Loss and Soil Texture on Different Slopes	32
2.26:	Soil Loss and Soil Texture	33
2.27:	Thirty-three Natural Regions in China	34
2.28:	The Forests of the Southwestern Mountainous Districts	36
2.29:	The Forest Resources in Selected Provinces	36

3.1: Population in High Priority Areas for Water - Soil Conservation in the Upper Reaches of the Yangtze (based on 1988 data) 60
3.2: Population Breakdown by Age Group 61
3.3: Selected Economic Indicators 62
3.4: The Current Status of Land Use in the Region (unit: 10^4 ha) 64
3.5: Morphological Classification of Selected Provinces (Number of County and Prefecture) 65
3.6: Vertical Distribution of Agriculture in Western Sichuan Province and Northern Yunnan Province 66
3.7: Vertical Distribution of Farming Systems in the Xichang District of South Western Sichuan Province 67
3.8: Precipitation and Soil Water Losses on Dry Farmland 68
3.9: Soil and Water Losses on Farmlands with Different Crop Combinations and with Grass Cover 69
3.10: Soil Disintegration and Crop Roots in Soil 69
3.11: The Water-Stable Granular Structure of Purple Soil under Vegetation 70
3.12: The Composition of Forests in the Lower-Reaches of the Jinsha 70
4.1: Soil Erosion Areas and Moduli in the Upper Reaches of the Yangtze 73
4.2: Distribution of Different Types of Soil Erosion in Sichuan Province 74
4.3: Status of Soil Erosion in the High Area of Soil-Water Conservation in the Upper Reaches of the Yangtze 75
4.4: Variations in Annual Precipitation, Runoff, and Sediment Discharge in the Anning River Basin 77
4.5: The Variation in Annual Precipitation, Runoff, and Sediment Discharge in Qiongjiang Basin 78
4.6: The Soil Erosion Regionalisation Scheme in the Yangtze Basin 81
4.7: Regionalisation of Soil Erosion in Sichuan Province 92
5.1: Unit Outputs of Major Crops in Southwestern China 96
5.2: Population Density, Land Available Per Capita, Forest Coverage, and Soil Erosion in the Central Hills of the Sichuan Basin 98
5.3: Population Density and Firewood Deficit in Some Selected Countries 99
5.4: Soil Erosion in Selected Districts of the Jinshan Basin 100
5.5: Forest Coverage and Soil Erosion in Bijie District in the Wu Basin 100
5.6: Forest Coverage and Soil Erosion in Selected Counties in the Upper Reaches of the Wu Basin (based on 1988 data) 100
5.7: The Breakdown of Farmland into Morphological Types in Sichuan Province 101
5.8: Erosion Loss on Sloping Farmland in the Wu Basin 102
5.9: The Frequency of Floods in Sichuan Province 103
6.1: The Area of Each of the Four Key Soil-Water Conservation Zones 108
6.2: Land Use Change in Soil Erosion Conservation Zones (unit: million ha) 110
6.3: Subsidies for Soil-Water Conservation Engineering Projects (unit: U.S $/ha) 111
6.4: Breakdown of Direct Economic Benefits 112

INTRODUCTION

"Soil is a crucial life-support system, since the bulk of all food production depends upon it."

- World Conservation Strategy

Teaming with life of myriad forms - soil, flora, and fauna, soil deserves to be classified as an equal system in itself or rather as many ecosystems. Therefore, the soil system has its own specific functions, structure, and products. One important function is the stabilisation of the nutrient cycle of soil-based ecosystems, for example, agriculture and forests. Without a soil system, there would be no soil-based ecosystems, even human beings would not be able to survive. Soil erosion reduces the inherent carrying capacity of the land because both loss of nutrients and degradation of the physical structure increase the cost of food production. Soil erosion may compromise economic progress and even political stability.

Soil erosion in mountain areas is an integral element in the following cycle: population growth - unreasonable use of natural resources and marginal land use - degradation - soil erosion - distribution of the water balance in watershed - degradation of mountain ecoystems - unsustainable development - poverty. Therefore, one major concern in sustainable development is how to form land without losing soil.

In China, the fourth major food-producing country in the world, dust storms and siltation in the major rivers cause heavy soil losses. According to a rough global estimate, China's excessive loss of topsoil from its crop lands totals 4.3 billion tonnes per year. Information on soil erosion from various regions in China indicates that soil erosion may be even more serious today than during the days of the founding of the People's Republic of China.

In the Yangtze basin, the soil erosion-prone area covers about 360,000sq.km., accounting for 20 per cent of the total basin area of which sloping farmland accounts for 18 per cent; commercial plantations four per cent; and barren land and foothills 78 per cent.

In the context of socioeconomic development, the Yangtze is a life-support river in China. Because of the large amount of discharge in the mainstream and tributaries of the Yangtze, there is a huge sediment discharge from the river, for example the sediment discharge recorded at Yizhang hydrometric station on the mainstream of the Yangtze is 500 million tonnes per year, of which about 200 million tonnes are transported into Dongting Lake. Because of siltation, the lake surface decreased from 4,700sq.km. in 1932 to 3,141sq.km. in 1958. The rapid increase of the Yangtze silt load has led many Chinese scientists to dramatise the worsening situation by stating that the river is becoming a second Yellow River. Even the former premier, Zhao Ziyang, used this in his exortations for accelerated afforestation in the region.

The Yangtze is the longest river in China and one of the three largest rivers in the world. The mainstream of the Yangtze, from the head in Yushu county on the Qinghai-Tibetan Plateau, flows through Yunnan, Sichuan, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, and Shanghai until it enters the sea in the east, and it is about 6,300km. long. The Yangtze Basin is about 1.8 million sq.km., accounting for one fifth of the total area of China. The annual runoff into the sea is about 100,000 cubic metres, accounting for one third of the total runoff in China as a whole. The water power resources of the Yangtze are the largest in China; the total drop of the mainstream of the Yangtze River from head to mouth is more than 6,000m, and the total water power carried by the river accounts for 40 per cent of the total amount in China.

The total length of the upper Yangtze from the head to Yizhang is about 4,529km, accounting for 72 per cent of the total length of the Yangtze River mainstream. The basin area in the upper-reaches of the Yangtze River is 1.0006 million sq.km., accounting for 55.6 per cent of the total basin area of the river and 100.46 million people are living in the region, about 34 per cent of the total population in the Yangtze River Basin as a whole. Therefore, the upper reaches of the Yangtze occupy an important economic base in the river basin.

The upper-reaches of the Yangtze River mainstream drain Qinghai, Tibet, Yunnan, Sichuan, and Hubei, and the river is known as the Tong Tian River, the Jinsha, and the Chuan respectively. In the upper reaches of the Yangtze the first order tributaries on the left bank of the river are the Walong, the Minj, and the Jialing and on the right bank of the river the Wu, the Heng, and the Chisui respectively. The principal second order tributaries are the Dadu, the Annin, the Fu, and the Xiahangshui (see Figures 1.1 and 1.2) (Survey Team of the Ministry of Water Resources and Electric Power 1986).

In terms of socioeconomic development, the upper reaches of the Yangtze are characterised by rich natural resources and an underdeveloped economy. Water power, coal, and iron, account for 81.5 per cent, 67 per cent, 46 per cent, and 100 per cent of the total deposits in the whole of the Yangtze Basin respectively. But the total output from agriculture and industry in the region accounts for only 20 per cent of the output of the whole basin.

The economy in some parts of the upper reaches of the Yangtze has been historically exploited and developed since the founding of the People's Republic of China and, to a certain extent, the economy in these parts of the region has indeed developed. Nevertheless, because of irrational development and mistakes in policy-making, conflicts concerning population, resources, and environment have emerged, of which soil erosion as a serious problem has drawn the attention of the Chinese Government and of scientists at home and abroad. Therefore, for the sake of water and soil conservation and for the sustainable development of the region, the soil erosion in the upper-reaches of the Yangtze should be analysed systematically. In the upper reaches of the Yangtze, the physical components; for example, topography, geological structure, and climate are conducive to water and soil losses, through water erosion, gravitational erosion, wind erosion, glacial erosion, and debris flow. In general, glacial erosion and wind erosion are not serious and not widely distributed and will not be taken into consideration in this paper. Figure 1.3 gives the different types of water and soil losses in the region and their interrelationships (Chengdu Institute of Mountain Disasters and Environment 1988).

In China a lot of research on water and soil loss and on aspects of soil erosion, gravitational erosion, and debris flow has been carried out. This paper will mainly concentrate on soil erosion in the upper reaches of the Yangtze.

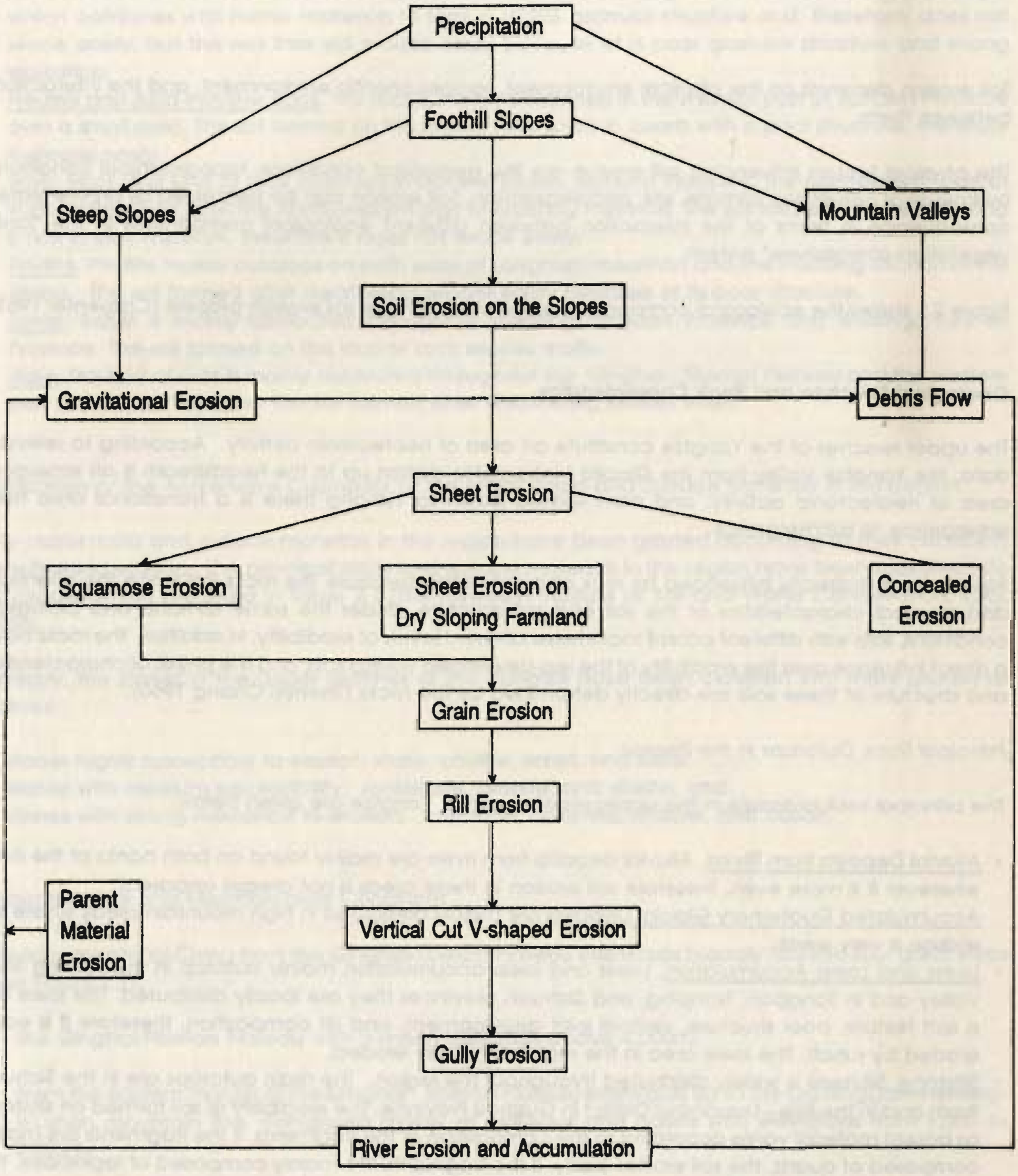
Figure 1.1: The Course of the Yangtze River

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

Figure 1.2: The Upper Reaches of the Yangtze River

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

Figure 1.3: Different Types of Water and Soil Loss and Their Interrelationships



Source: Chengdu Institute of Mountain Disasters and Environment 1988

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

Contd......

7.	Peripheral Tropical		
a.	Humid	(1) (2) (3)	Lowlands of Southern Taiwan Central and Northern Hainan and Leizhou Peninsula 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. c.	Sub-humid Semi-arid	(1) (2)	Aba-Naggu Area 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) (2)	Plateau and Mountains of Eastern Qinghai Mountains of Southern Tibet
d.	Arid	(1) (2)	Qaidam Basin 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)	4430	4770	4560
	sediment discharge (10^4 T)	58100	61300	60900
	sediment concentration (kg/m^3)	1.31	1.29	1.33
Cuntan	flow (10^8 m^3)	3600	3870	3550
	sediment discharge (10^4 T)	53900	53300	51900
	sediment concentration (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 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.

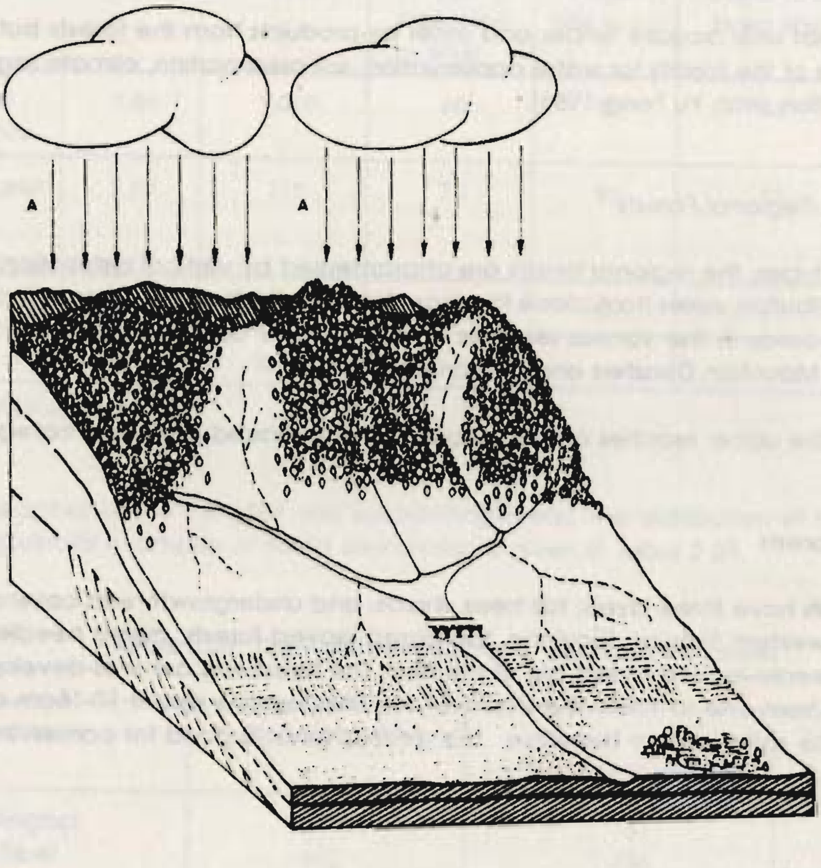


Figure 2.1: Ecological Components Associated with Erosion Processes

Source: Carpenter 1983

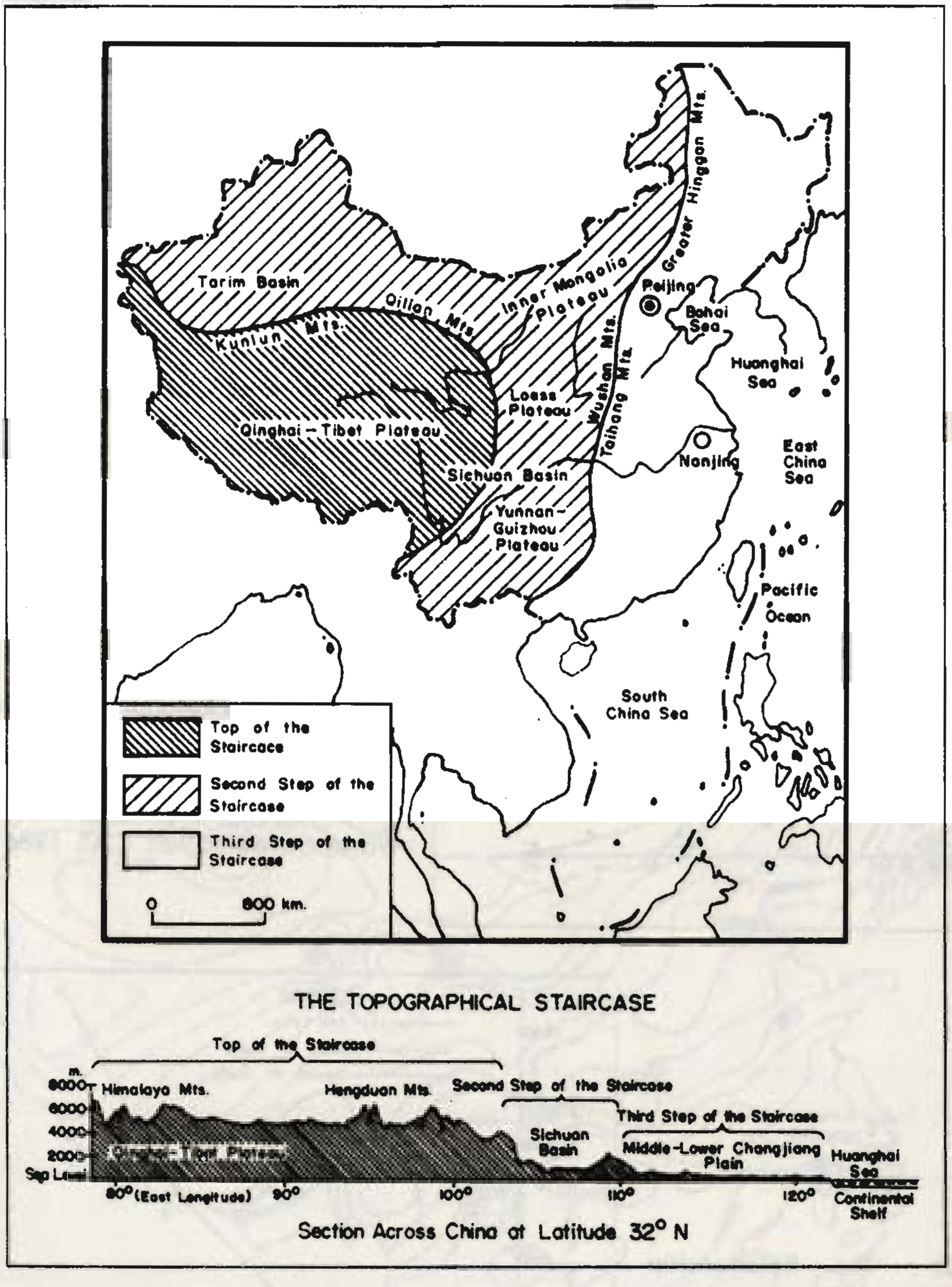
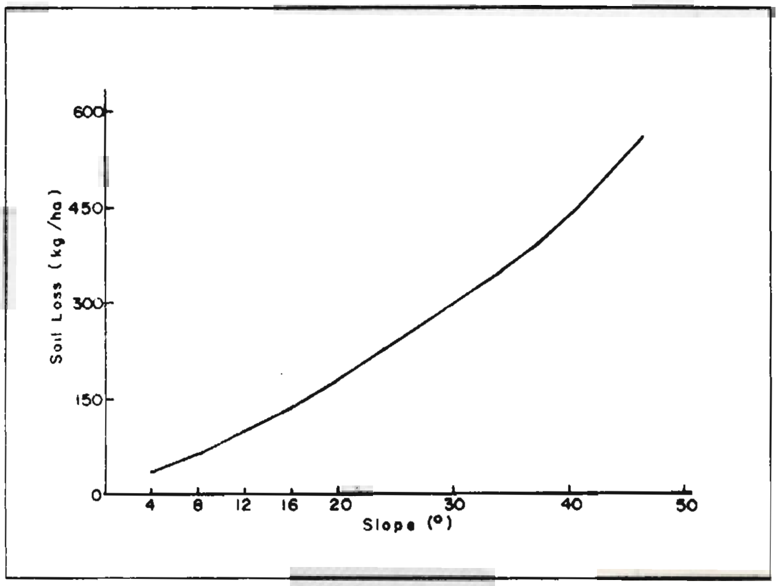


Figure 2.2: The Topographical Staircase in China

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



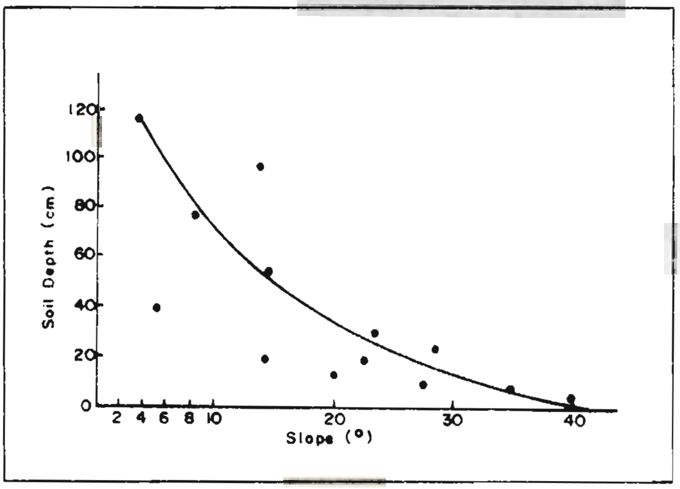
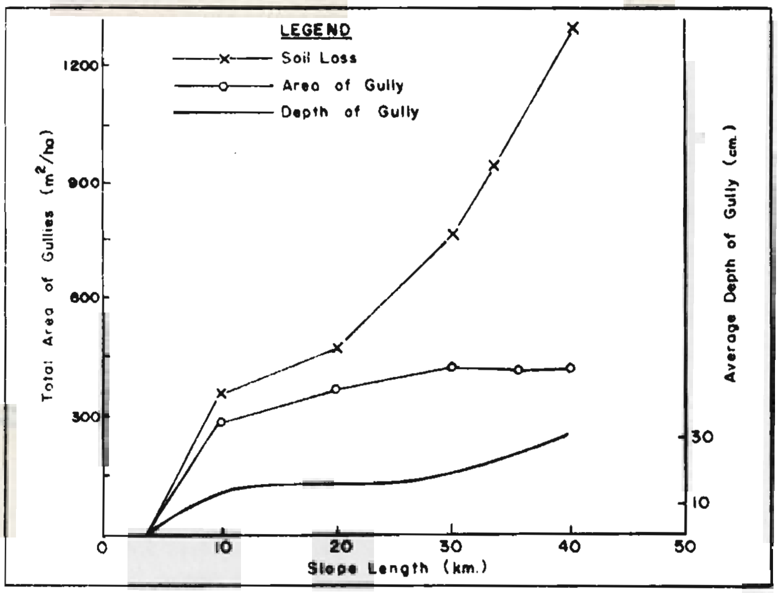


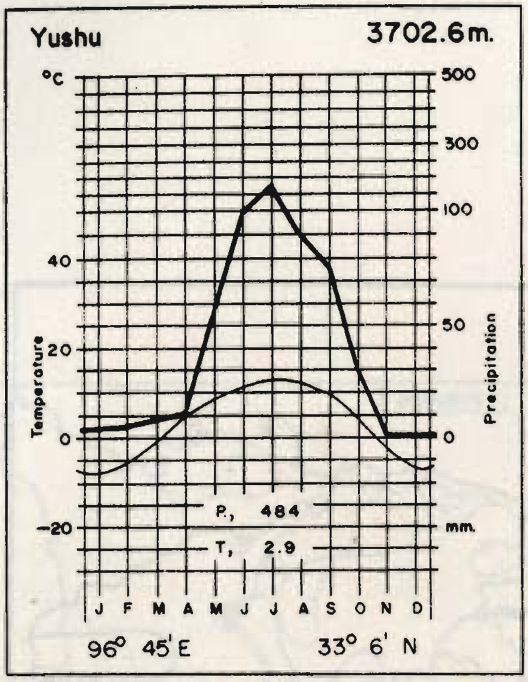
Figure 2.4: The Relationship between Slope and Soil Depth

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





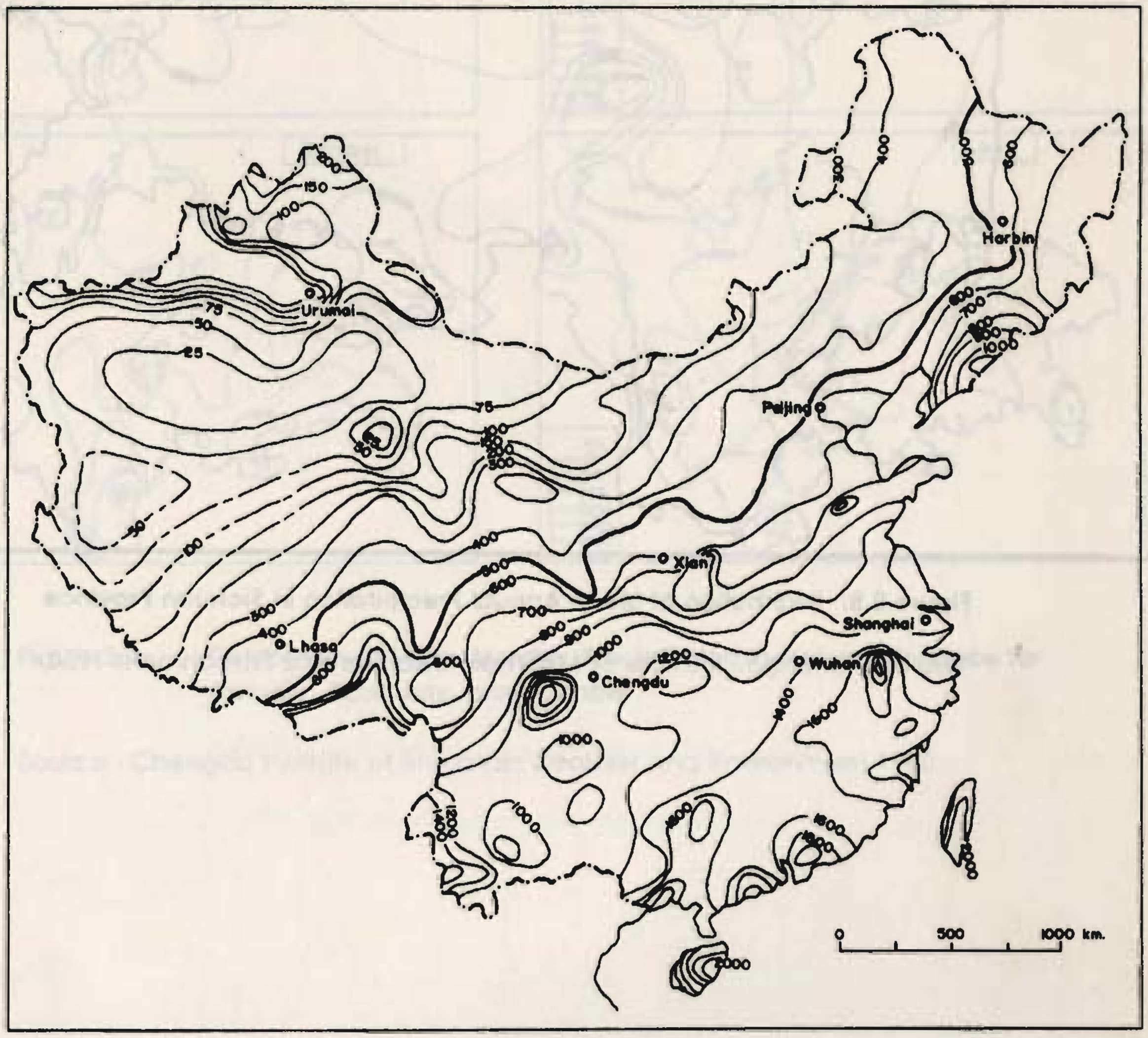
◂ **Figure 2.6: The Reference Diagram of the Subalpine Plateau Zone (Representative Station: Yushu)**

Source: Domros and Peng Gongbing 1988

Figure 2.7: Distribution of Mean Annual Precipitation

Source: Editorial Committee for the Physical Geography of China 1984

▾



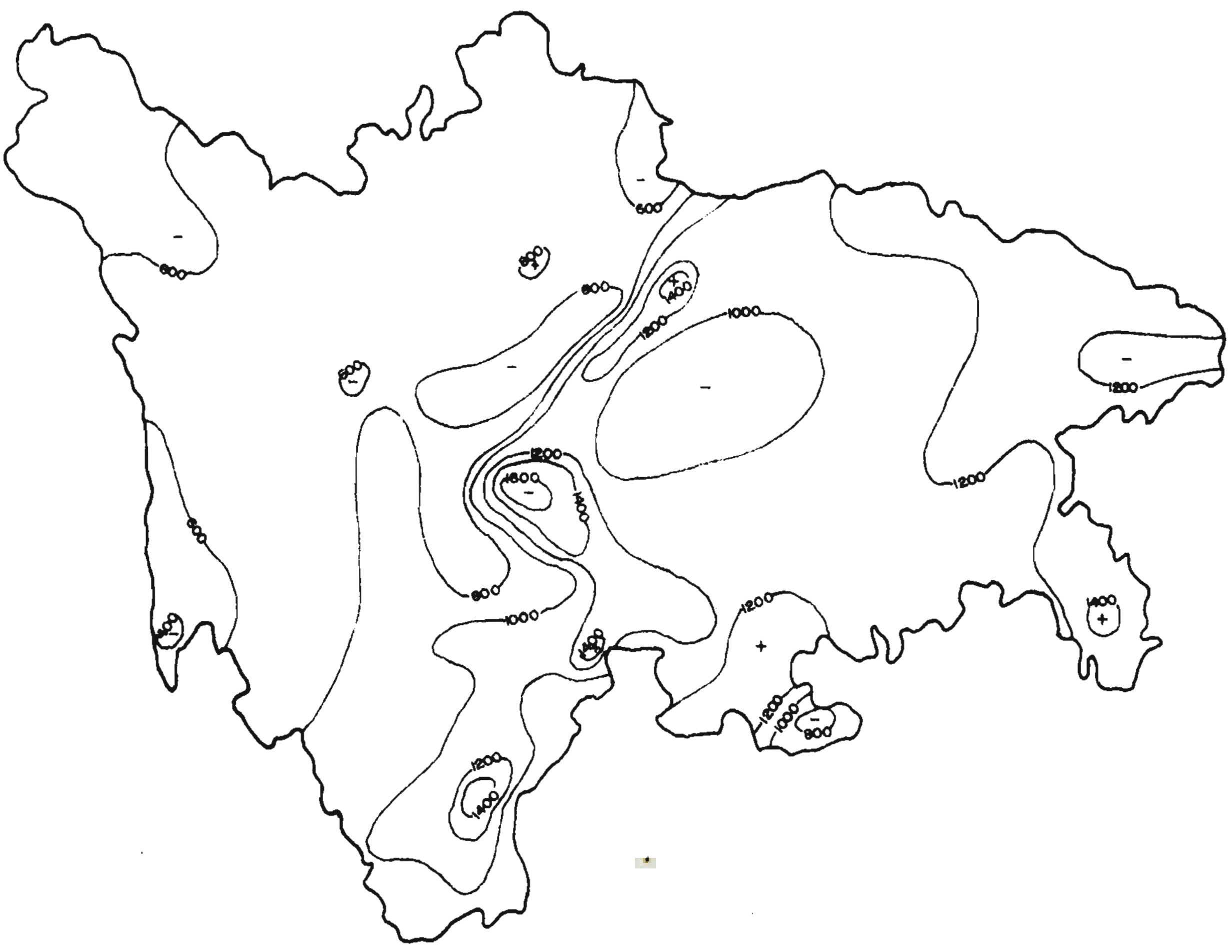


Figure 2.8: Distribution of Mean Annual Precipitation in Sichuan Province

Source: Chengdu Institute of Mountain Disasters and Environment 1980

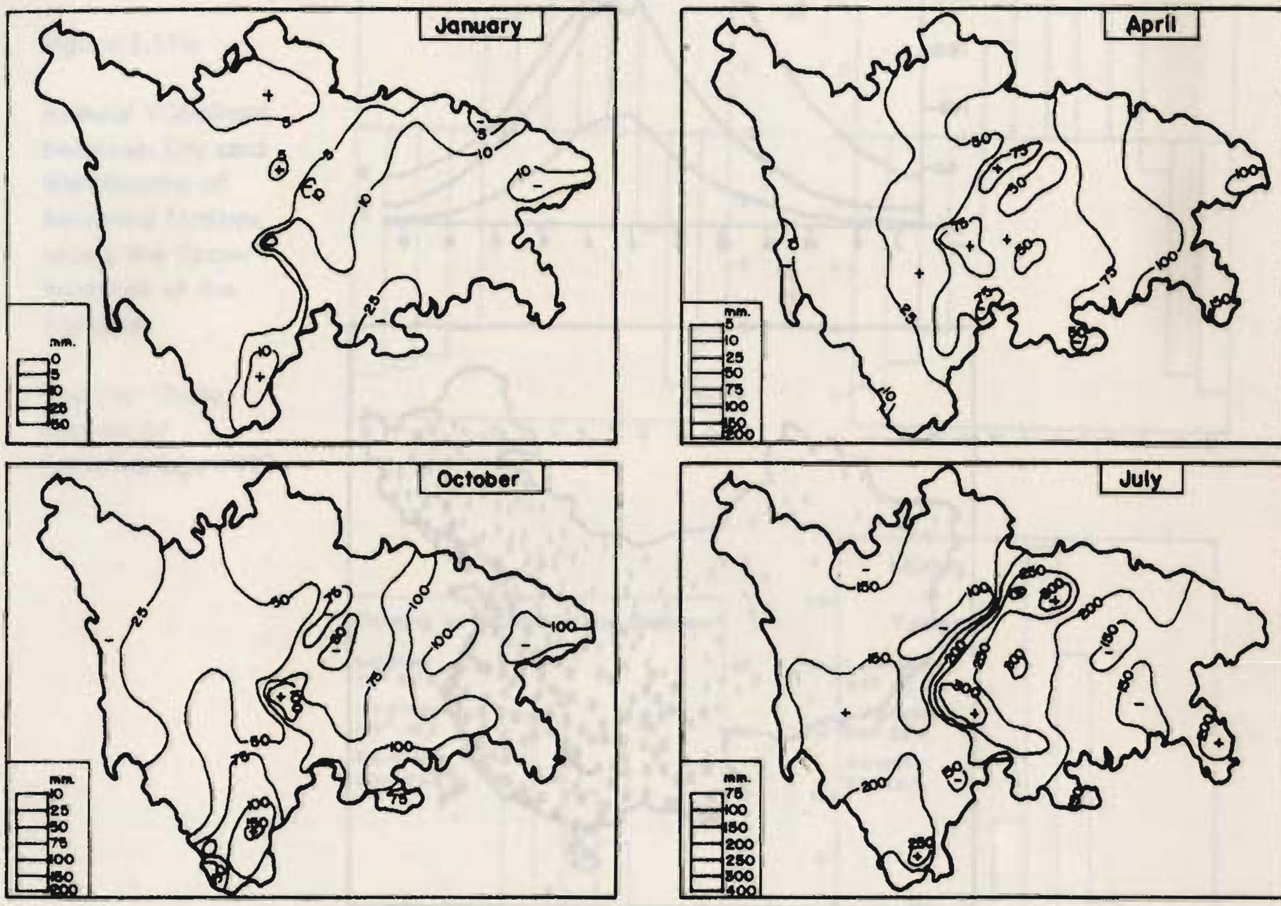


Figure 2.9: **Distribution of Mean Monthly Precipitation in Sichuan Province for January, April, July, and October**

Source: Chengdu Institute of Mountain Disasters and Environment 1980

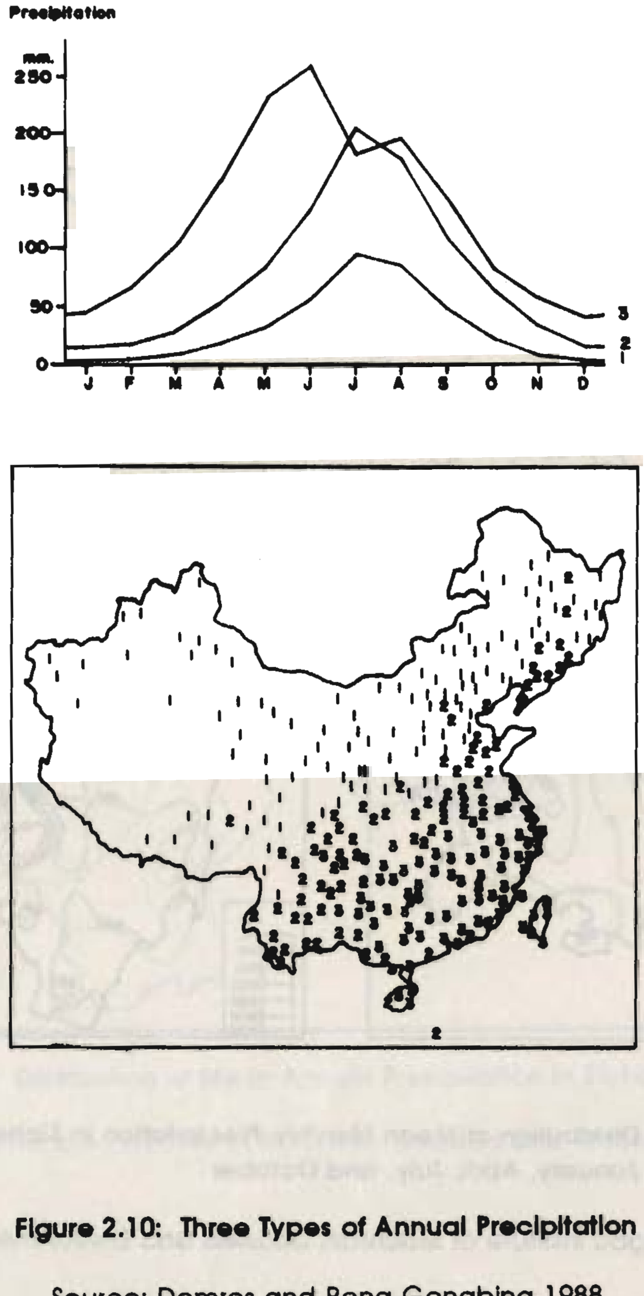


Figure 2.10: Three Types of Annual Precipitation

Source: Domros and Peng Gongbing 1988

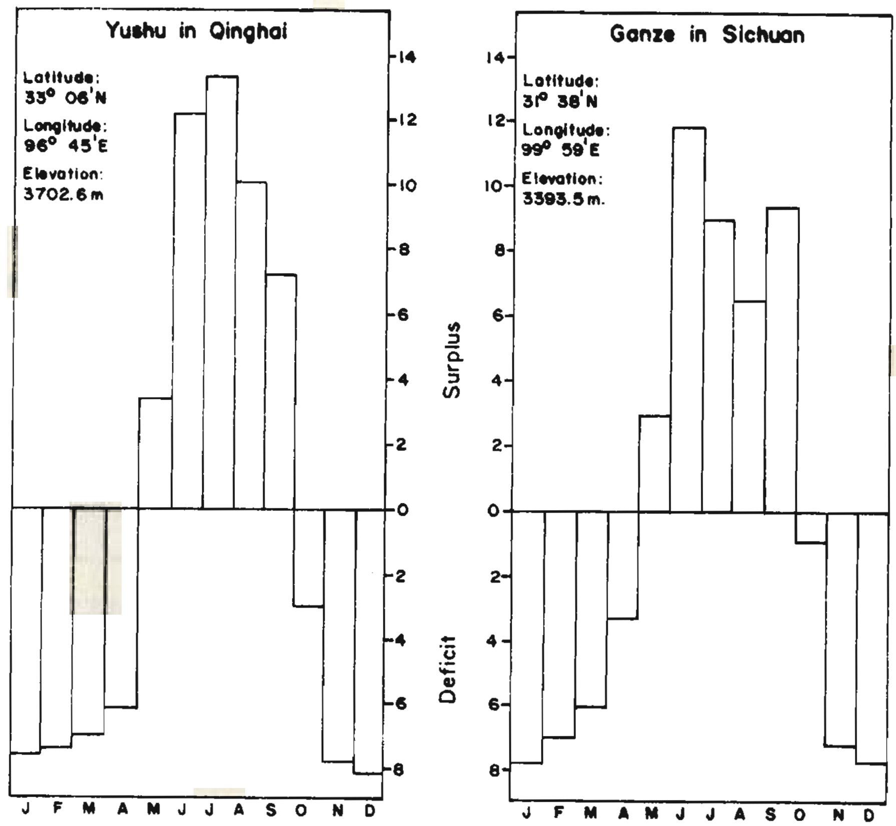


Figure 2.11a

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

Source: State Bureau of Meteorology 1980

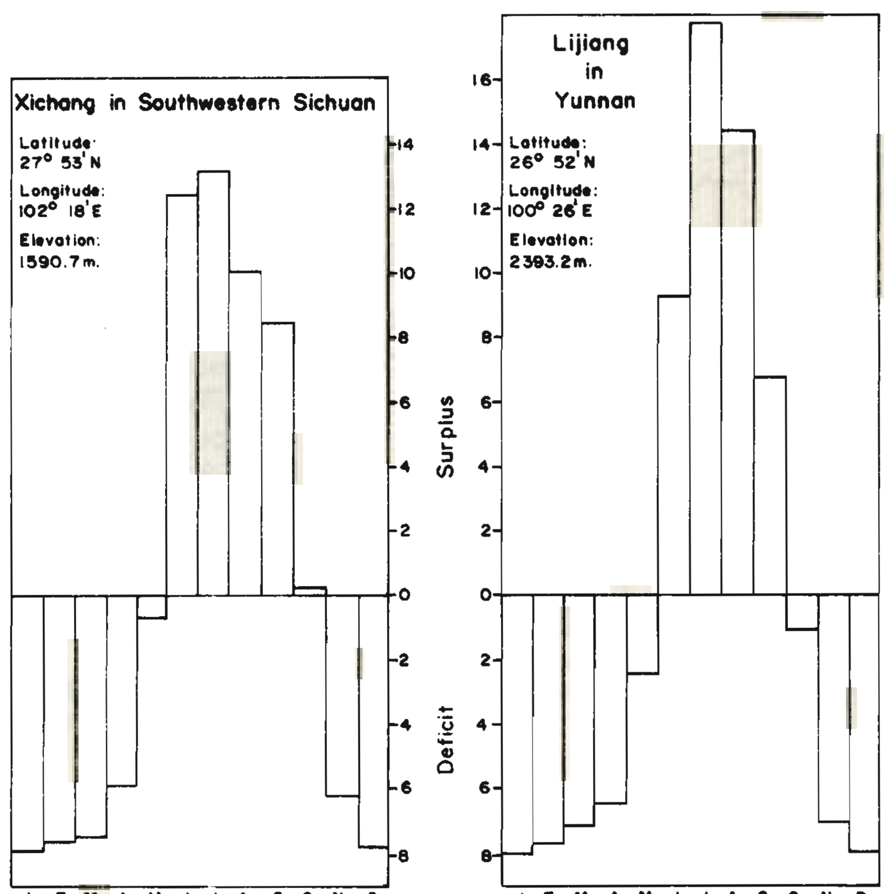


Figure 2.11b

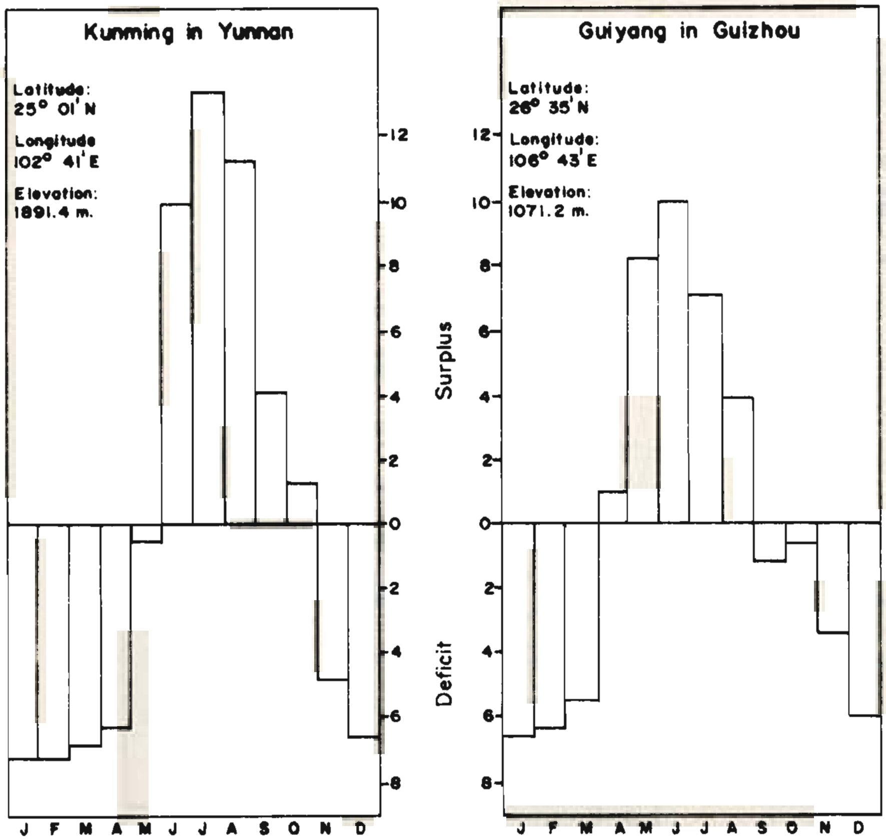


Figure 2.11c

Source: Ibid

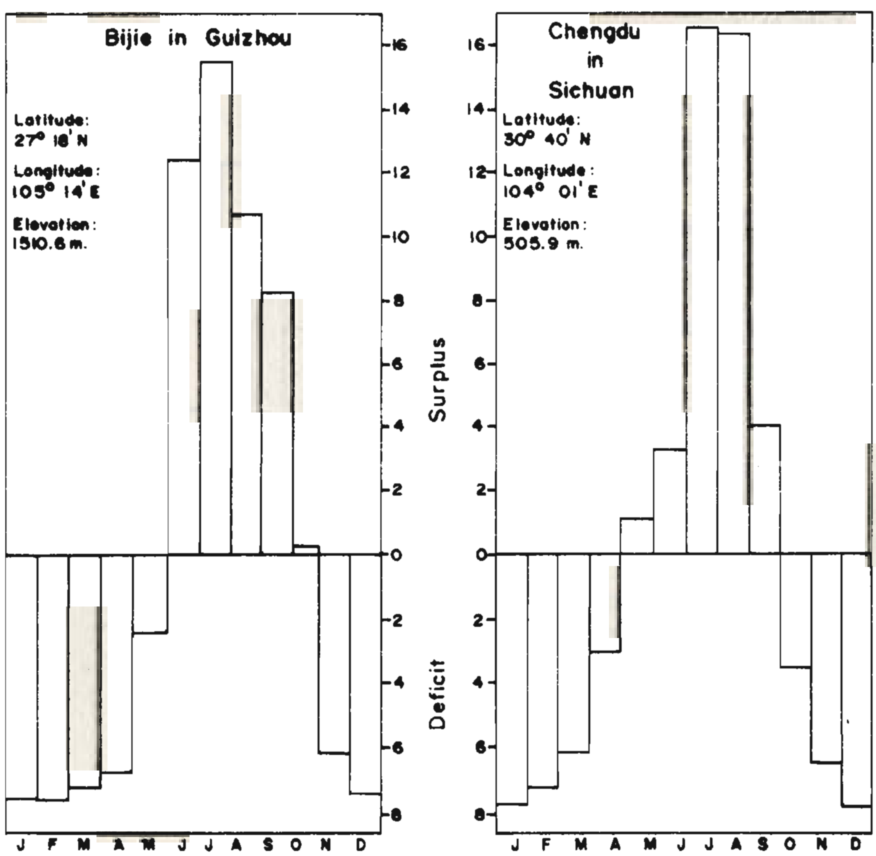


Figure 2.11d

Source: Ibid

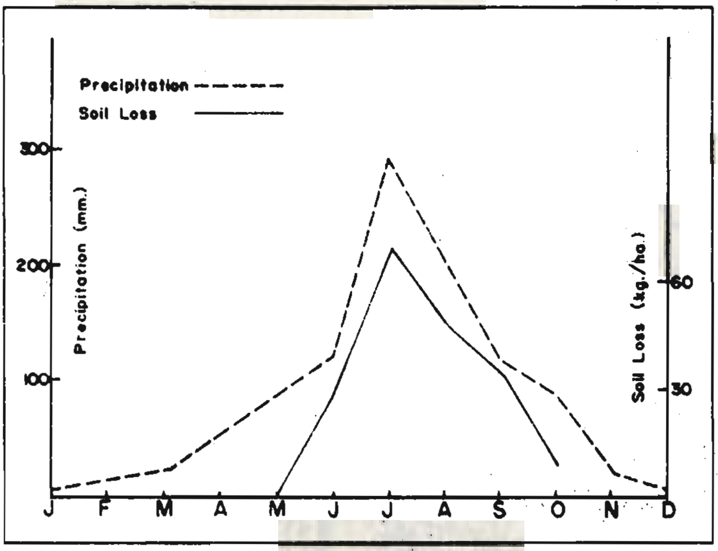


Figure 2.12: The Relationship between Annual Precipitation and Variations in Annual Soil Loss Variation

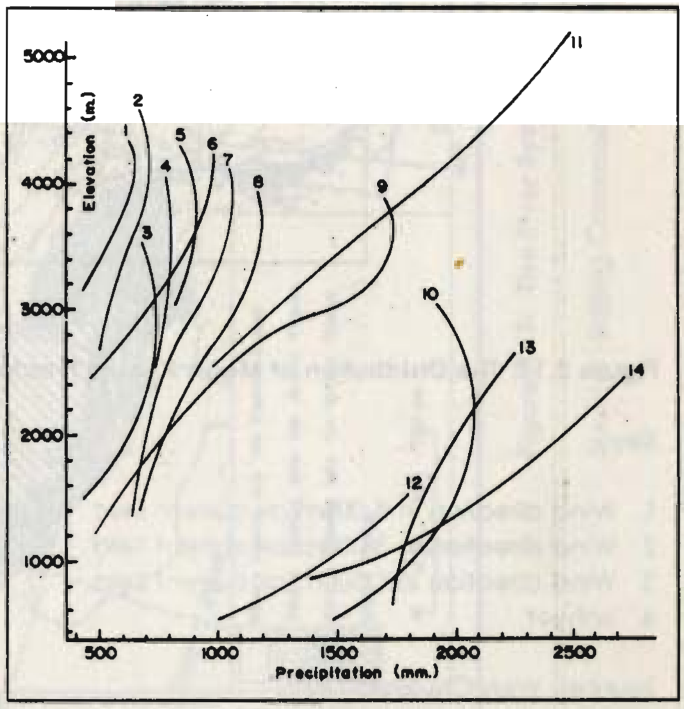
Source: Soil-Water Conservation Office of Sichuan 1986

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



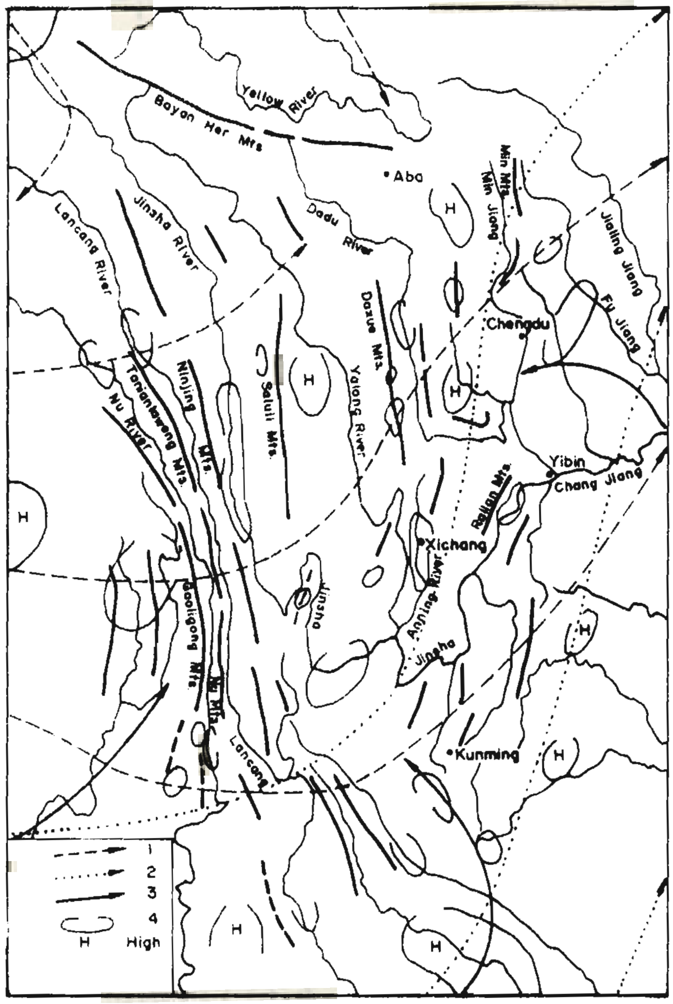


Figure 2.14: The Distribution of Mean Annual Precipitation in the Hengduan Mountains

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

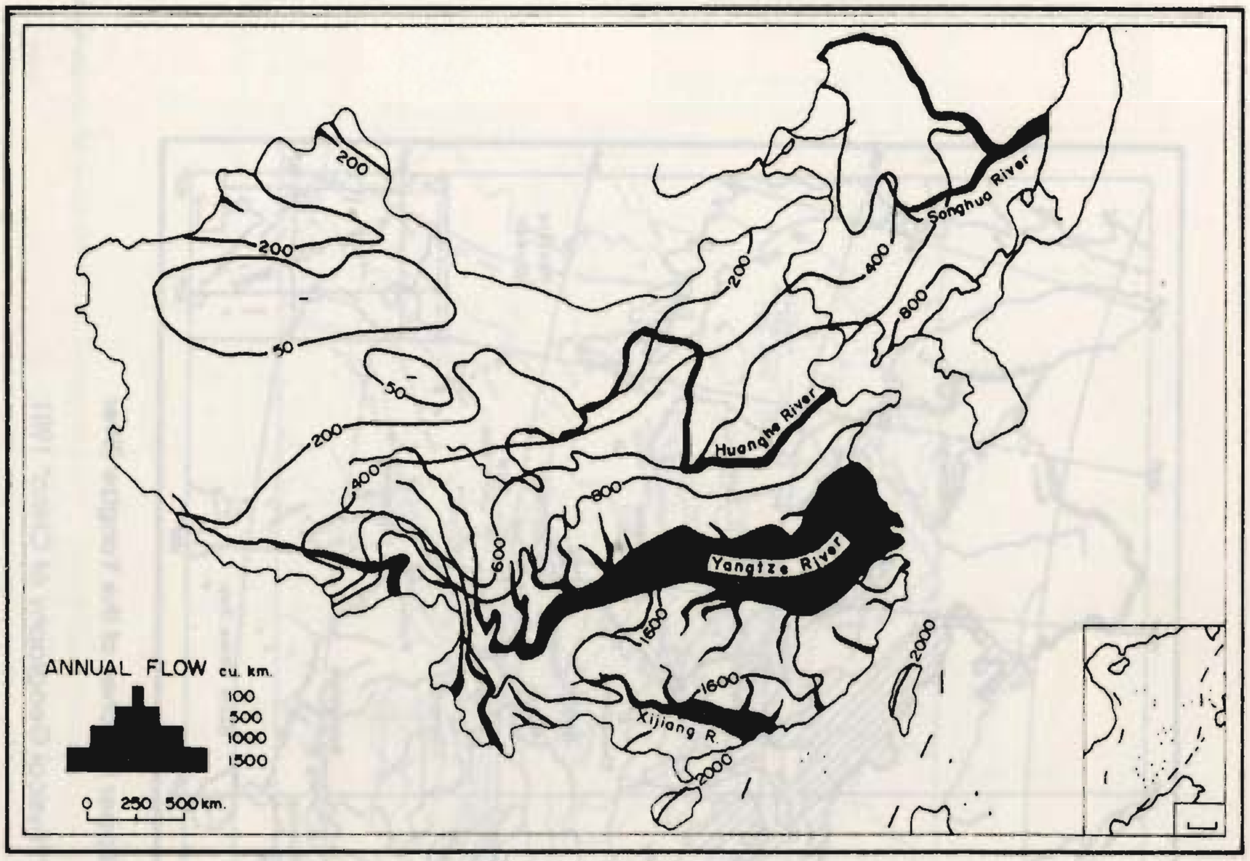


Figure 2.16: The Flow of Rivers in China

Source: After Liuchang Min 1990

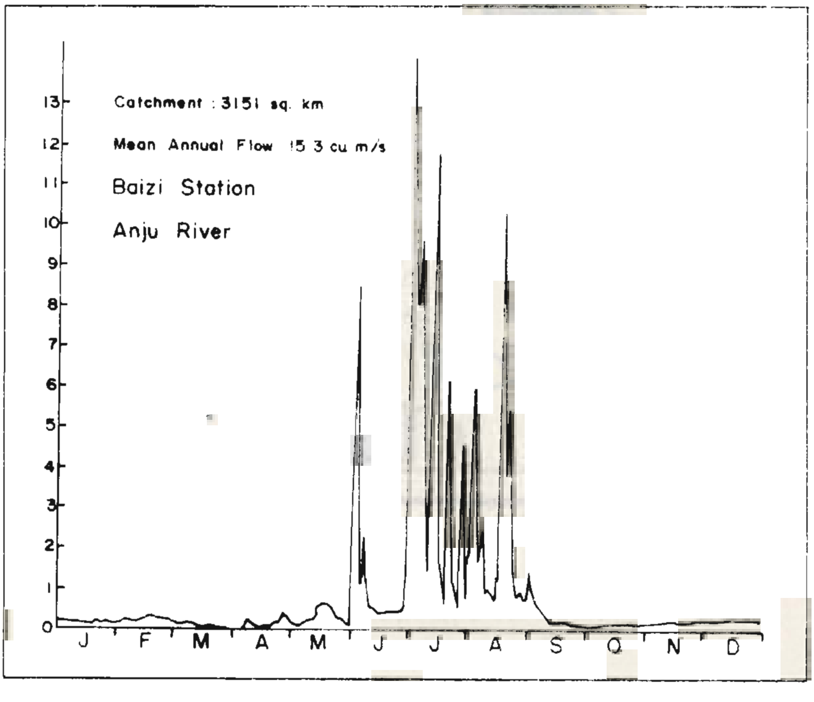


Figure 2.17: Mean Relative Discharge Hydrograph of the Sichuan Basin Type

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

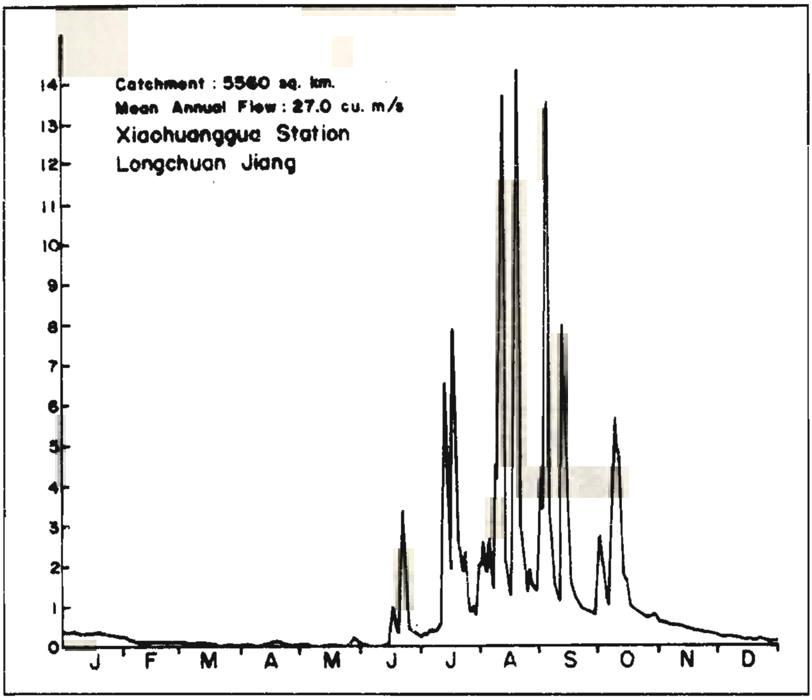


Figure 2.18: Mean Relative Discharge Hydrograph of the Dian-Guo Type

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

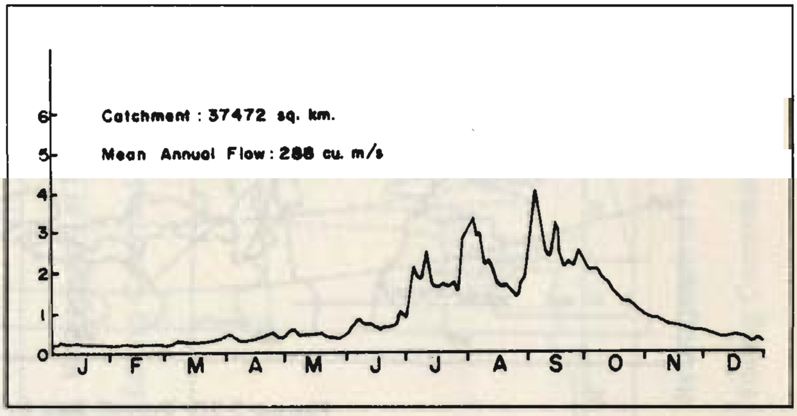


Figure 2.19a: Mean Relative Discharge Hydrograph of the Ganzi Type

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

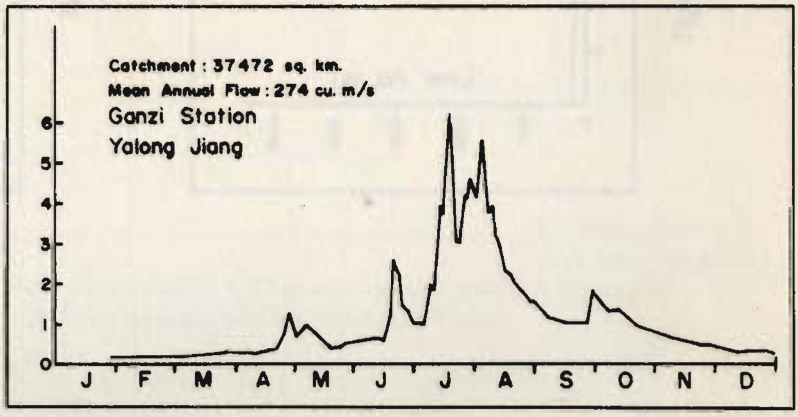


Figure 2.19b: Mean Relative Discharge Hydrograph of the Ganzi Type (based on 1970 data)

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

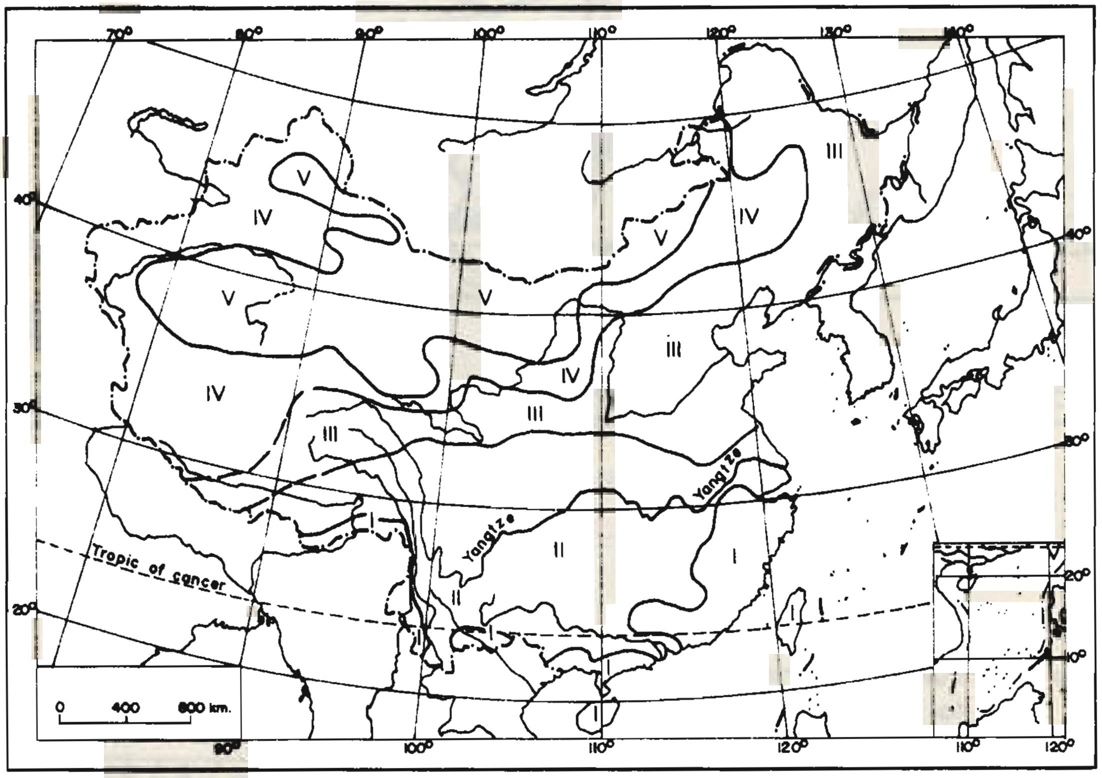


Figure 2.20: Runoff Belt in China

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

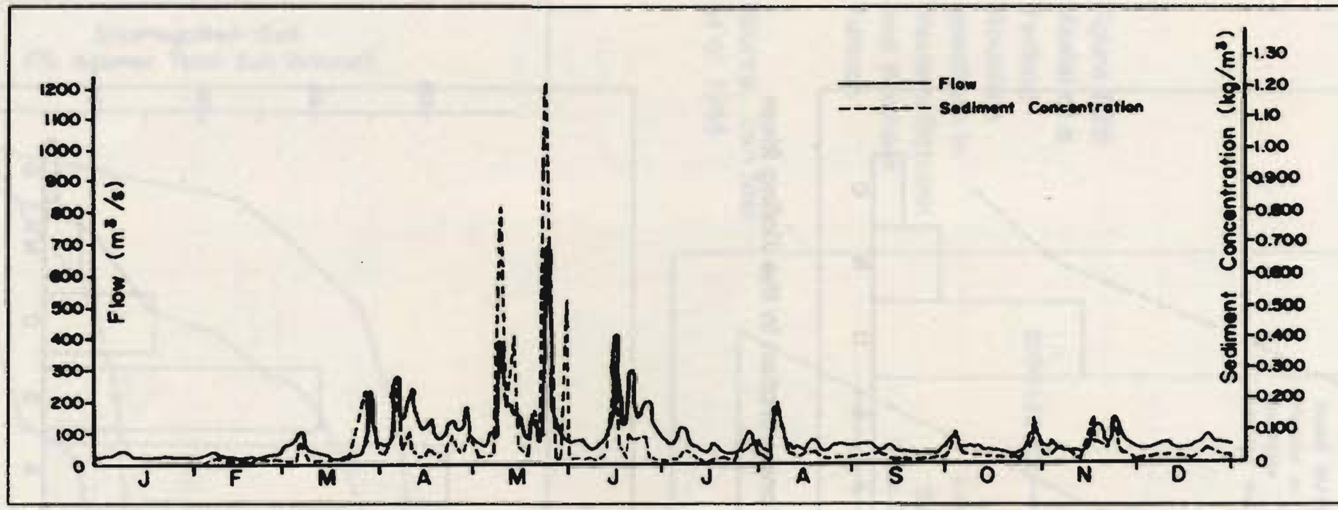


Figure 2.21: Hydrograph of Flow and Sediment Concentration in the Lei River

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

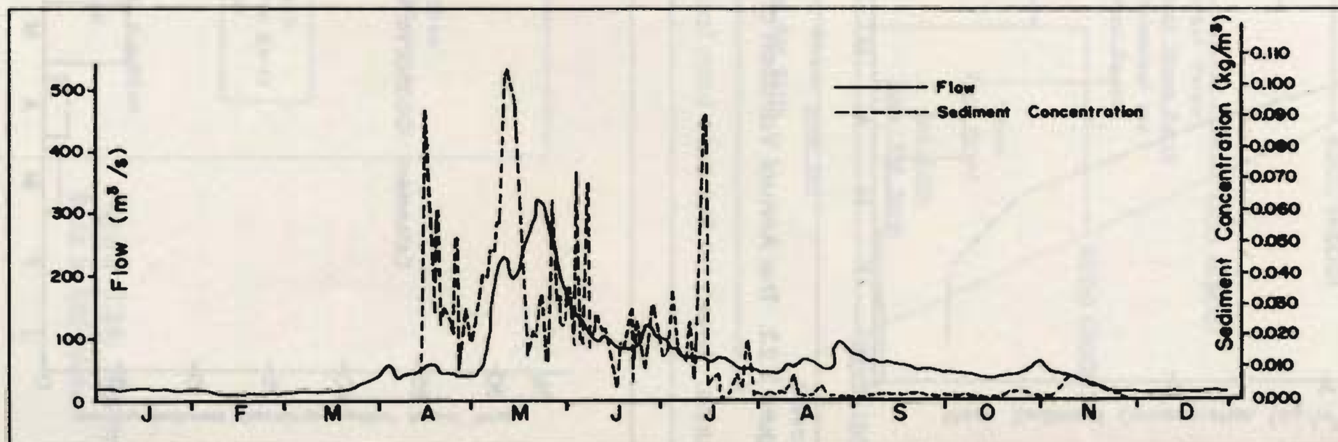


Figure 2.22: Hydrograph of Flow and Sediment Concentration in the Eergisi River

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

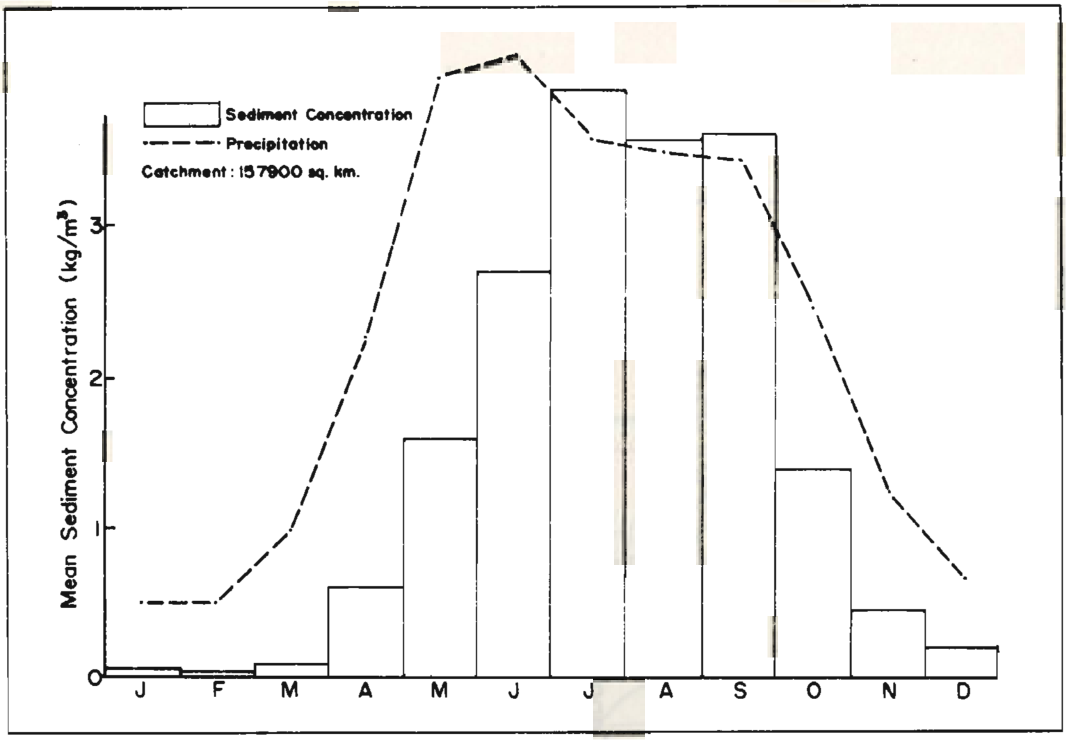


Figure 2.23: The Annual Variation of Sediment Concentration in the Jialing River

Source: Based on the data from Table 2.19

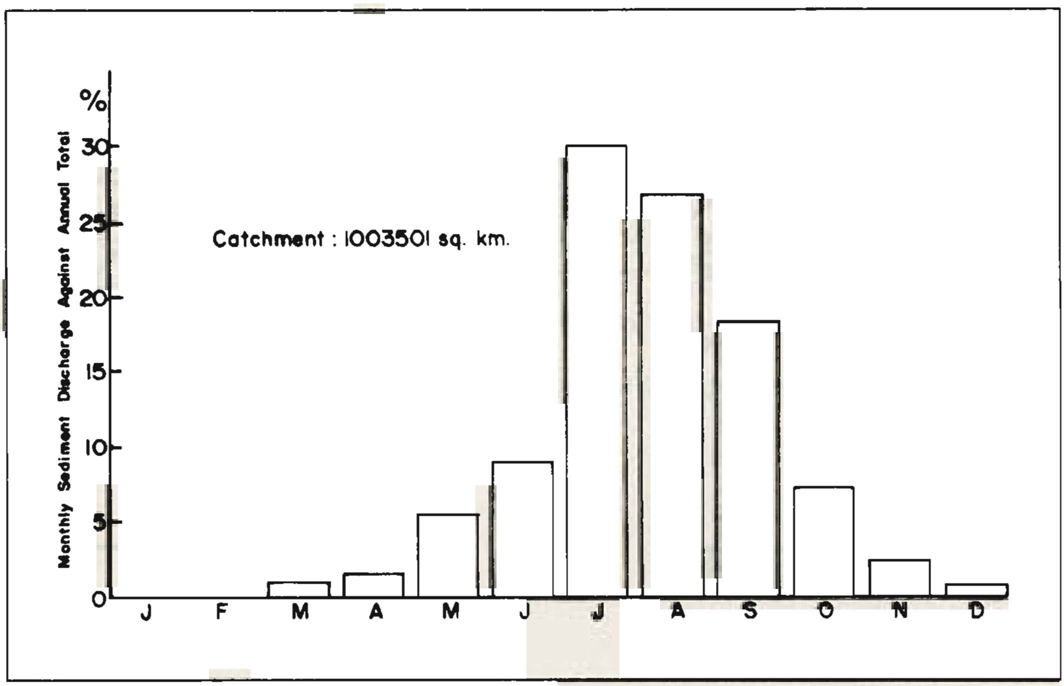


Figure 2.24: The Annual Variation of Sediment Discharge in the Upper Reaches of the Yangtze River at Yicheng Station

Source: Based on the data from Table 2.20

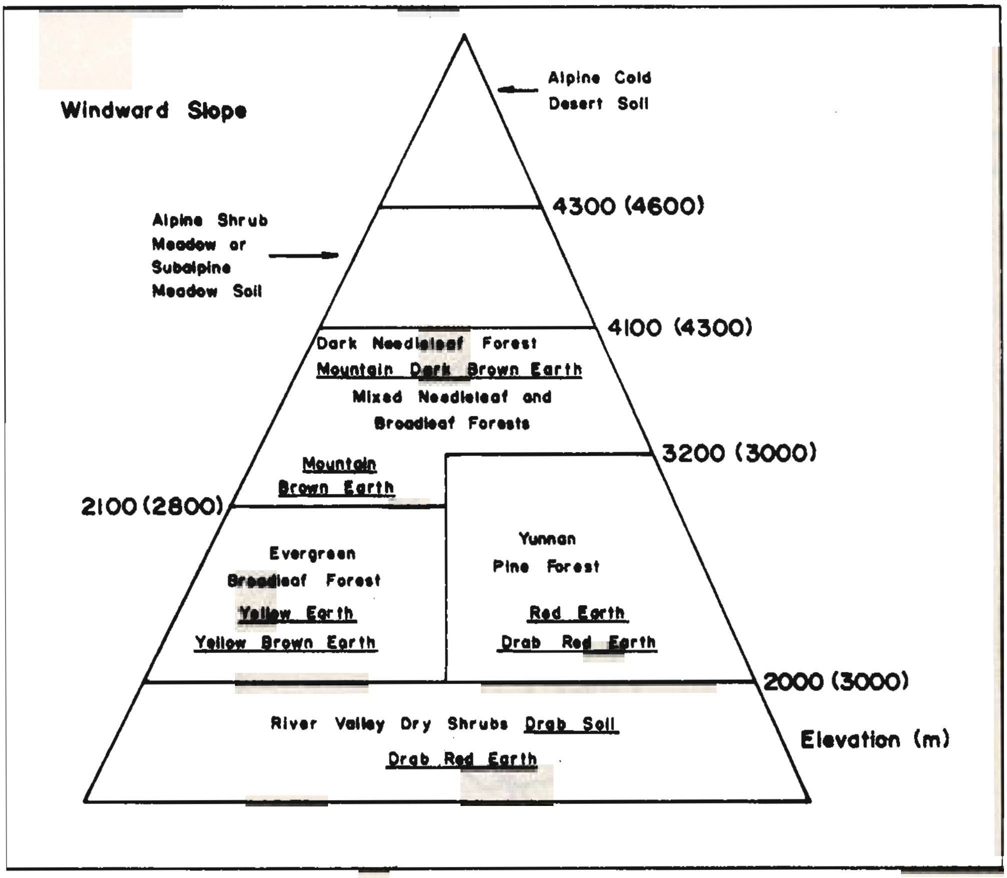


Figure 2.25: Model of a Vertical Mountain Spectrum in Western Sichuan and Northern Yunnan

Source: Ren Mei et al. 1985

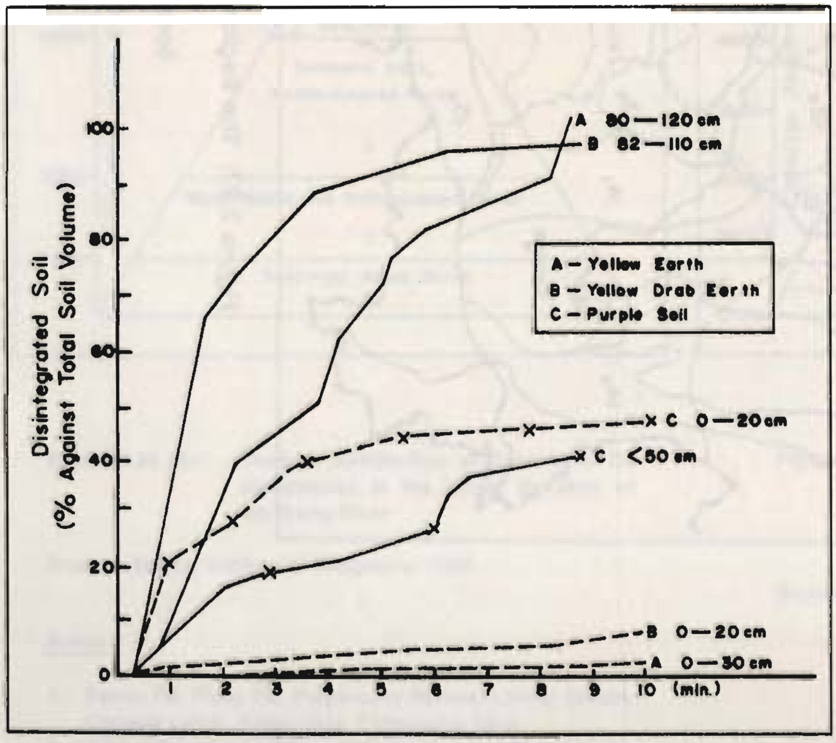


Figure 2.26: Disintegration of Soils in Still Water

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

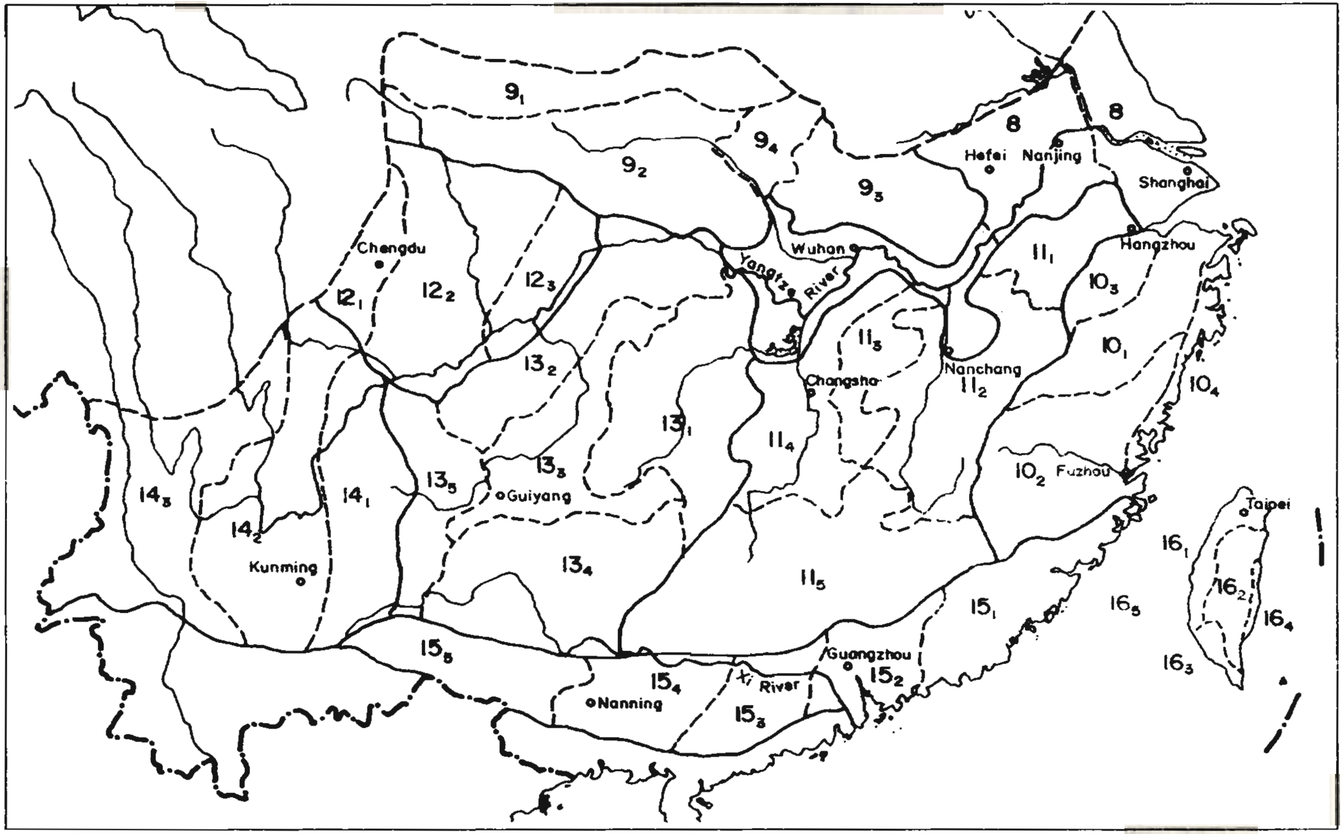


Figure 2.27: The Regions of the Upper Reaches of the Yangtze River

Source: Zhao Songqiao 1986

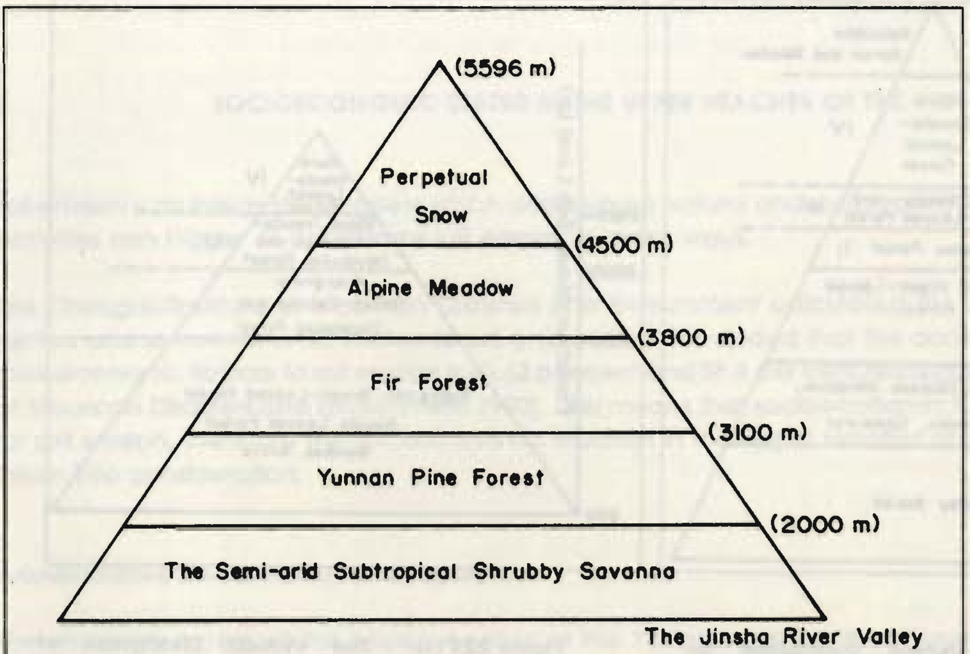
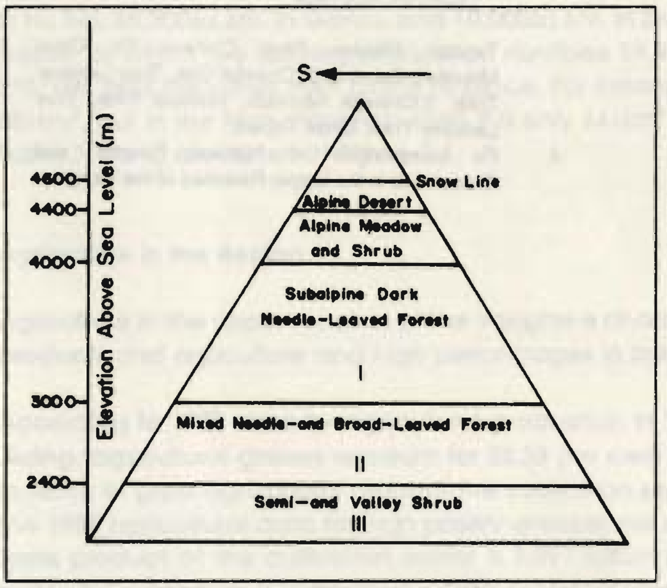


Figure 2.28: Vertical Distribution of Vegetation on Yulong Mountain

Source: Beijing Institute of Geography 1983



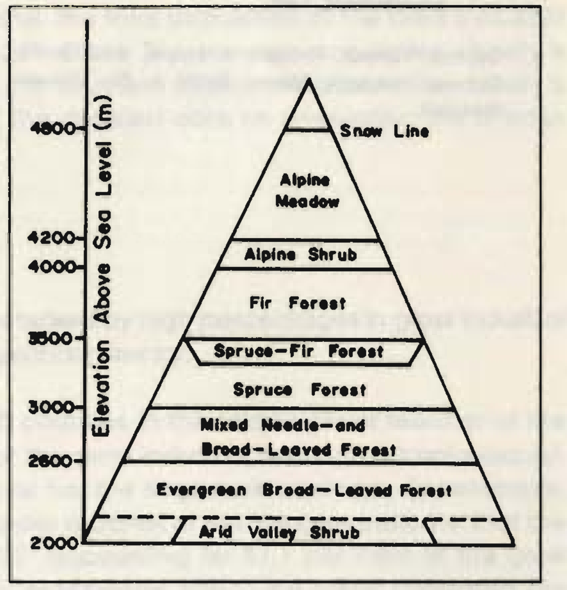


Figure 2.29 (1): Vertical Distribution of Forests in Da Xiaojinshan in the Upper Reaches of the Dadu River

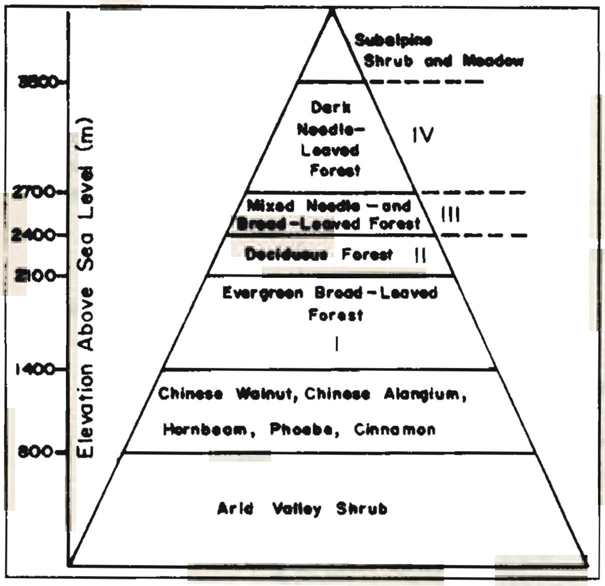
Source: Beijing Institute of Geography 1983

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



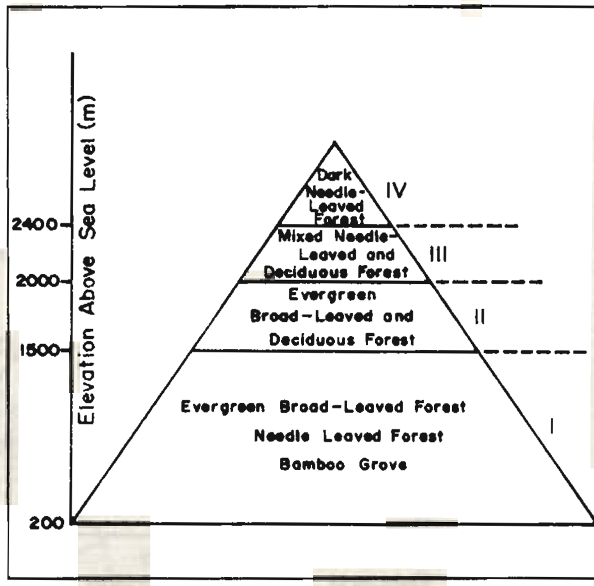


Figure 2.29 (3): **The Vertical Distribution of Forests On Xiaoliang Mountain**

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.

3

SOCIOECONOMIC STATUS IN THE UPPER REACHES OF THE YANGTZE

Soil erosion is an integrated process which depends on natural and socioeconomic conditions. Human activities can trigger or accelerate soil erosion in many ways.

The Chengdu Institute of Mountain Disasters and Environment calculated the contribution of natural factors and socioeconomic factors to soil erosion and concluded that the contribution of natural and socioeconomic factors to soil erosion is 40.62 per cent and 58.8 per cent respectively (Chengdu Institute of Mountain Disasters and Environment 1990). This means that socioeconomic factors are more critical for soil erosion, therefore the socioeconomic situation in the upper reaches of the Yangtze should be taken into consideration.

Administrative Demarcation and Population

The drainage system of the upper reaches of the Yangtze covers Tibet, Yunnan, Sichuan, Guizhou, Hubei, Gansu, Shanxi. The high priority area for water-soil conservation in the upper reaches of the Yangtze covers 152 counties administered by 25 prefectures (cities), accounting for 304,000sq.km. of which 65,900sq.km. is in Yunnan Province, 25,600sq.km. in Guizhou, 158,700sq.km. in Sichuan, 5,600sq.km. in Hu Bei, 38,200sq.km. in Gansu, and 10,000sq.km. in Shanxi. The total population of the area is 65.3393 million, of which the farming population numbers 59.3526 million. The average population density is $215/km^2$ and this varies from place to place. For instance in Southern Shanxi, the population density is $68/km^2$, but in the high mountain area it is only $34/km^2$. The detailed data on population are listed in Table 3.1 and are noted in Figure 3.1.

Agriculture in the Region

Agriculture in the upper reaches of the Yangtze is characterised by high percentages in gross industrial products and agriculture and high percentages in the planting sector.

According to 1988 data for agricultural production in 15 counties, in the middle-lower reaches of the Jialing, agricultural grasses account for 58.38 per cent of the gross industrial and agricultural product. In terms of gross agricultural product the cultivation sector has the largest percentage. For example, the 1988 agricultural data for high priority areas in the upper reaches of the Yangtze indicate that the gross product of the cultivation sector is 3.397 billion US$[1] accounting for 57.1 per cent of the gross agricultural product (Commission Office for Soil-Water Conservation 1990). The crops cultivated are mainly food species. The area under food crops accounts for 80 per cent of the total area sown and only 20 per cent of the area is used for cash crops. The commercialisation of crops like tobacco is low. The constraints to cultivation are outlined below.

The paddy and terrace areas are small, and the dry sloping farmland area is large. In most of the rural areas about 60 per cent of the land is subjected to extensive farming, land is left fallow, and slash-and-burn cultivation is still carried out in some localities. In some mountainous areas, extensive cultivation is still practised. When disasters occur, the harvests are poor and do not meet the demands of the local people for food.

---

[1] In 1988 there were 3.45 *yuan* to the U.S. Dollar.

Table 3.1: **Population in High Priority Areas for Water - Soil Conservation in the Upper Reaches of the Yangtze (based on 1988 data)**

High Priority Area	Province	No. of counties	Population (10^4)		Agricultural labour force (10^4)	Population density (per km^2)
			Total	Agricultural population		
Lower-reaches of the Jinsha and Bijie district	Yunnan	36	914.67	824.03	370.81	139
	Guizhou	8	542.64	513.34	203.79	212
	Sichuan	13	262.31	228.21	94.13	96
Subtotal	3	57	1719.62	1565.58	668.73	145
Southern Gansu & Southern Shanxi	Gansu	15	266.11	249.58	112.12	70
	Shanxi	6	63.02	56.72	18.76	63
Subtotal	2	21	329.13	306.30	130.88	68
Middle-lower reaches of Jialing	Sichuan	47	3662.08	3378.08	1593.64	325
Subtotal	1	47	3662.08	3378.08	1593.64	325
Three Gorges' District	Sichuan	22	740.51	607.32	289.32	394
	Hu Bei	5	82.59	77.98	34.51	148
Subtotal	2	27	823.10	685.30	323.83	338
Total	6	152	6533.93	5935.26	2717.08	215

Source: Commission Office for Soil-Water Conservation 1990

Population

There is an uneven distribution of population. For example, in the Wu Basin, the population density decreases in line with the middle reaches (average density: 233/km^2) > upper reaches (average density 204.6/km^2 > lower reaches of Sichuan province (average density 167.1/km^2); and it is a minority area settled by more than ten minorities (mainly *Yi, Miao, Hui, Tibetan*, and *Naxi*).

The educational level is lower than in the coastal areas of China. Three educational indicators are taken into consideration.

The illiteracy rate in the Wu Basin is 31.2 per cent, which is 50 per cent higher than the average in junior secondary school (grades 6 to 9). Enrollment ranges from 10 to 20 per cent and the average educational level (schooling years) ranges from 2.3 to 5.2 years.

There is quite a large labour force, but absorbing the surplus labour is an urgent concern. According to the second census of Guizhou Province (1982), the working population in the province accounts for 51.09 per cent of the total population (Table 3.2).

Another example is that, in the Wu Basin, the rural labour force roughly accounts for 33.8 to 44.9 per cent of the total agricultural population. The variations in terms of specific area are 38 to 44 per cent for the upper reaches of the Wu, 33.8 to 43.7 per cent for the middle reaches, and 40 to 44.9 per cent and 40.1 to 44.5 per cent for the lower reaches of the Wu in Guizhou and Sichuan respectively (Chengdu Institute of Mountain Disasters and Environment 1990).

Table 3.2: Population Breakdown by Age Group

Age Group	1964 Census		1982 Census	
	Total population (10^4)	% of total population	Total population (10^4)	% of total population
Total	1714.05	100	2855.29	100
Under one year	83.48	4.86	76.69	2.69
Preschool (1-6 years)	406.61	23.72	415.15	14.53
7 - 14 yrs	339.37	19.79	675.47	23.68
18 - 22 yrs	154.71	9.02	215.53	7.54
Females of child bearing age 15 - 49 yrs)	298.14	23.22	635.13	22.24
Active labour force males 16 - 59 yrs females 16 - 55 yrs	922.94	53.84	1458.96	51.09
Retired males > 60 females > 55	146.55	8.55	229.64	8.88

Source: Population Census Office of Guizhou Province 1990

The farming population is much larger than the urban population. For instance, the urban population in the Wu Basin is only 11.3 per cent and the agricultural population accounted for 88.7 per cent (1986 Census) and 86.8 per cent (1988 census) of the total population in two consecutive census reports.

Economic and Living Conditions in the Upper Reaches of the Yangtze

Some economic indicators are selected and given in Table 3.3 which gives a general analysis of the rural economy and living conditions in the region.

In the vast rural area of the region some constraints to socio-economic development still persist. Low per capita grain output is, for example, in the Wu Basin 31.2 per cent of the counties' per capita grain is less than 200kg, which is far lower than the level of sufficiency - 300kg. Poverty is another constraint in 61.9 per cent of the total counties in the Wu Basin. The per capita net income of the agricultural population is about 191 *yuan*, or approximately 55.36 US$, which is lower than poverty line - 200 RMB or (57.97 US$) (Chengdu Institute of Mountain Disasters and Environment 1990).

Table 3.3: Selected Economic Indicators

(based on 1988 data)

Area of water and soil conservation	Province	# of County	Total Area (sq.km.)	Area of Farmland (10^{4*})	Per capita farmland in agricultural sector (ha/capita)	Total output of grain (10^4 kg)	Unit output of grain (kg/ha)	Per capita output of grain in agricultural sector (kg/capita)	Gross value of agricultural output (10^4 US$*)	Per capita net income in agricultural sector (US $/capita*)
Lower reaches of the Jinsha and Bijie district	Yunnan Guizhou Sichuan	36 8 13	65921.80 25607.00 27223.65	110.98 120.14 18.41	0.135 0.234 0.081	217246.0 107300.0 86035.0	2175 2310 4665	264 209 4665	67145.41 29034.78 20321.16	75.36 52.75 73.91
Subtotal	3	57	118752.45	249.53	0.159	410581.0	2340	262	116501.35	67.83
Southern Gansu and Southern Shanxi	Gansu Shanxi	15 6	38199.50 10039.00	66.29 9.30	0.265 0.164	58790.0 21610.0	1635 2325	236 381	22227.04 5426.55	53.33 72.75
Subtotal	2	21	48238.50	75.59	0.247	80400.0	1710	262	27653.59	56.81
Middle-lower reaches of the Jialing	Sichuan	47	112674.40	225.74	0.067	1501500.0	6645	444	360521.74	78.55
Subtotal	1	47	112674.40	225.74	0.067	1501500.0	6645	444	360521.74	78.55
Three Gorges	Sichuan Hubei	22 5	18777.40 5589.67	42.69 6.16	0.070 0.079	200060.0 25770.0	4680 4185	329 330	79699.96 9760.12	57.39 81.74
Subtotal	2	27	24367.07	48.85	0.071	2225830.0	4620	330	89460.08	60
Total	6	152	304032.42	599.72	0.101	2218311.0	4110	374	594136.76	72.17

* The exchange rate between US$ $ and the *yuan* in 1988 was 1 US$ = 3.45 *yuan*

Source: Commission Office for Soil-Water Conservation 1990

Natural Resources

The Upper Reaches of the Yangtze are rich in natural resources, providing a good foundation for development agriculture, forestry, husbandry, and diversifying the economy. There is a variety of climates which are favourable for agricultural development.

Forest resources are insufficient but vast mountainous areas with good thermal and water conditions can provide for the development future of forestry.

There are large areas of natural pasture land but they are degraded by overgrazing.

Land Use

According to data collected from 152 counties in the upper reaches of the Yangtze, the total farmland area is 7.830 million ha, accounting for 25.75 per cent of the total land, of which 2.161 million ha are paddy land accounting for 27.60 per cent of the total farmland. Terraces occupy 10.23 per cent of the 0.801 million ha. Sloping farmland accounts for 62.17 per cent of the farmlands or total farmland.

Forest land occupies 43.65 per cent of the total land, pasture land, 12.88 per cent, water 3.01 per cent, barren land 6.10 per cent, waste land 8.61 per cent. Detailed data on land use in the region can be found in Table 3.4. The constraints to land use in the region are:

- the land is not fully used; and
- the sloping farmland areas are not improved; thin topsoil, low capacity to withstand drought, and low unit outputs make harvests unstable.

A high percentage of forest land is secondary forest, young plantation, and overmature forest with almost zero growth. Pasture land is being degraded and because of poor quality grasses the use value is low.

Land use in the region varies from place to place (Beijing Institute of Geography 1983).

a. The Qinghai-Tibetan Plateau. In pastoral areas, animal husbandry is prevalent in areas where the vegetation coverage is about 90 per cent. In the valleys, forestry and animal husbandry are prevalent. Maize, wheat, beans, highland barley, potatoes, rice, and radishes are cultivated at the rate of one crop per year, but two or three crops every two years are common in some places.

b. The Hengduan Mountains. The Hengduan Mountains are rich in forest resources and pastoral land, and the prevalent activities are forestry and animal husbandry. Agriculture only accounts for a small proportion of the total economy. The farmland is mainly distributed throughout the valleys and intermontane basins. In the warm valleys, two or three crops a year are produced with intensive cultivation, whereas, in mountainous areas, one crop a year is usual and highland barley, oats, and potatoes are cultivated extensively.

c. The Yunnan - Guizhou Plateau. On high mountainous pastoral land, animal husbandry is prevalent and, in mountain areas > 2,200masl, forests account for a large proportion of the total land. The land between 2000m to 2200masl rarely has vegetation and most of the forests have been cleared for farmland, most of which are cultivated extensively. Most land areas below 2000masl are used as farm-land. In the valleys below 1,200masl, double crops of rice and some tropical cash crops, for example, rubber trees and coffee, can be cultivated. Forested land accounts for 20 per cent of the total area on the Yunnan-Guizhou Plateau.

Table 3.4: The Current Status of Land Use in the Region (unit: 10^4 ha)

Area	Province	Total land (area *)	Farm Land (a) Area	Farm Land % of total land	Of Farm Land: Paddy	Of Farm Land: % of farm-land	Of Farm Land: Terrace	Of Farm Land: % of farm-land	Of Farm Land: Sloping farm land	Of Farm Land: % of total farm-land	Forest Land Area	Forest Land % of Total Land	% of Forest Land: Forested land	% of Forest Land: % of total forest land	Pastoral Area	Pastoral % of total land	Waters Area	Waters % of total land	Barren Land Area	Barren Land % of total land	Non-productive Land Use Area	Non-productive Land Use % of total land
Total		3040.325	782.969	25.75	216.121	27.60	80.093	10.23	486.755	62.17	1327.177	43.65	841.706	63.42	391.581	12.88	91.383	3.01	185.551	6.10	261.663	8.61
Lower reaches of the Jinsha & Bijie district	Subtotal	1187.525	267.965	22.57	40.773	15.21	34.558	12.90	192.655	71.89	575.113	48.43	351.876	61.18	228.463	19.24	21.911	1.85	23.203	1.95	70.783	5.96
	Yunnan	659.218	110.980	16.84	23.069	20.80	11.296	10.18	76.595	69.02	367.855	55.80	201.87	54.88	124.185	18.84	18.019	0.68	n.a.	n.a.	18.952	8.09
	Guizhou	256.07	120.145	46.92	9.969	9.31	17.257	13.34	92.932	77.85	67.872	26.51	55.313	81.50	47.353	20.91	4.145	1.52	22.669	8.55	11.652	4.28
	Sichuan	272.237	36.861	13.54	7.694	20.88	6.039	16.38	23.128	62.74	139.285	51.20	94.693	67.93	56.925	20.91	4.145	1.52	22.867	5.67	40.084	8.31
Southern Gansu & Southern Shanxi	Subtotal	482.385	81.161	16.82	0.781	0.96	11.879	14.64	68.501	84.40	258.458	53.58	210.329	81.38	66.819	13.85	12.330	1.87	26.867	5.67	40.084	8.31
	GanSu	381.995	66.289	17.36	n.a.	n.a.	10.038	15.14	56.251	84.86	182.600	47.80	158.138	86.60	63.607	16.65	7.802	2.04	26.867	5.03	34.830	9.13
	ShanXi	100.390	14.872	14.81	0.781	5.25	1.841	12.38	12.250	82.37	75.858	75.56	52.191	68.80	3.211	3.20	1.195	1.19	n.a	n.a.	5.254	5.24
Middle-lower reaches of the Jialing	Subtotal	1126.744	327.328	29.10	156.793	47.90	24.549	7.50	145.985	44.60	433.658	38.50	238.539	55.0	74.674	6.60	54.505	4.80	107.747	9.60	128.835	11.40
	Sichuan	1126.744	327.328	29.10	156.793	47.90	24.549	7.50	145.985	44.60	433.658	38.50	238.539	55.0	74.674	6.60	54.505	4.80	107.747	9.60	128.835	11.40
Three Gorges	Subtotal	243.671	106.494	43.70	17.775	16.69	9.107	8.55	79.613	74.76	59.948	24.60	40.963	68.33	21.626	8.89	5.373	2.45	27.667	11.35	21.961	9.01
	Sichuan	187.774	99.449	52.96	16.873	16.97	8.91	8.06	73.665	74.04	39.872	21.23	25.162	63.11	17.627	9.32	4.671	2.49	12.373	6.59	13.783	7.34
	Hubei	55.897	7.046	12.61	0.901	12.79	0.197	2.79	5.948	84.42	20.076	35.92	15.801	78.70	4.000	7.15	0.703	2.33	15.295	27.36	8.178	14.63

Source: Commission Office for Soil-Water Conservation 1990

(a) and (b). The total land area and farmland in the table is a little different from those in Table 3.3, because of a difference in coverage of study area

* 1 ha = 15 *mu*, the *mu* is a farmland unit in China. 1 *mu* = 666.66 sq.m.

The barren land accounts for 50 per cent of the total land area and is mainly covered with grass and shrubs following the disappearance of other vegetation-leading to the possible intensification of soil erosion. Farmland accounts for only 10-15 per cent of the total area, and one crop a year is prevalent in mountainous areas where maize and potatoes are cultivated. On the intermontane basins and flatlands, two crops a year are grown, e.g., rice, wheat, broad beans, cole, etc. Cash crops, for example, tobacco, sugarcane, wood oil trees, timber stock, tea, and some fruit trees, are grown extensively in this area. The irrigated farmland area is larger than the dry farmland area and irrigated farmlands are mainly distributed throughout the intermontane basins, along the banks of rivers, and along lake-shore lowlands with high and stable agricultural outputs. Dry farmlands are mainly found on the slopes of hills and on low mountains where soil erosion is intensified.

d. The Sichuan Basin. The Sichuan Basin, in the foothill areas, is an agricultural area and has a high multiple crop index of about 175-250 (Figure 3.2). Farmland area accounts for 40-50 per cent of the total area although this varies from place to place. More than 70 per cent of the farmland is situated in the lowlands and hills and 10-20 per cent is situated in the mountains.

Mountain Agriculture. Most of the Upper Reaches of the Yangtze are mountainous areas. Table 3.5 shows the different mountains in China.

Table 3.5: Morphological Classification of Selected Provinces (Number of County and Prefecture)

Selected provinces	High mountains	Middle and low mountains	Hills	Plateaux	Plateaux plains	Plains
Qinghai	3	13	--	21	3	--
Tibet	53	--	--	19	--	--
Yunnan	6	108	15	--	--	--
Guizhou	--	35	48	--	--	--
Sichuan	8	75	74	21	-	17
Total	70	231	137	61	3	17

Source: Chengdu Institute of Mountain Disasters and Environment 1983

From Figure 3.2 (2.47) and Table 3.5, it can be seen clearly that mountain agriculture plays an important role in the socioeconomic development of the upper reaches of the Yangtze.

Vertical Distribution of Agriculture in Mountainous Areas in the Upper Reaches of the Yangtze

At present, agricultural production in the mountainous areas of the region generally follows the vertical distribution of climate and land use (i.e., "stereo-agriculture). This can clearly be observed in the Hengduan Mountains. From the valleys of the Jinsha (< 1,000masl), up to the western plateau of Sichuan Province (> 4,500masl) the climatic regime is: subtropical valleys (lower part), subtropical valleys (upper part), warm temperate, cool temperate, cold temperate, alpine, and cold alpine, and farming systems vary accordingly (see Table 3.6).

This vertical distribution of farming systems can be found in southwestern Sichuan Province. Taking Xichang District as an example, different farming systems have been classified.

Table 3.6: Vertical Distribution of Agriculture in Western Sichuan Province and Northern Yunnan Province

Climatic regime	Accumulated temperature (> 10°C)	Growing period in days (> 5°C)	Average monthly temperature of hottest month	Crops	Crop system	Animal husbandry
Cold alpine	--	--	< 10°	No crops No trees	--	Yak and domestic sheep
Alpine sub-cold	About 300°	< 130	10-11	Food crops do not mature, vegetables, linen, and sugar beet are planted locally	One crop per annum	Husbandry dominated by cattle, *pien-niu**, goats and pigs
Cold temperate	900-1800	170-210	12-15	Spring wheat	One crop per annum	Agriculture and husbandry are practised equally; diversified livestock
Cool temperate	2300-3000	220-270	16-17	Spring wheat, early maize, and middle maize	One crop per annum dominated	Animal husbandry
Warm temperate	3200-4000	280-310	18-20	Winter wheat, middle-late maize	Two crops per annum	No yak and *pien-niu* buffalo
Subtropical valley (upper part)	4200-6000	300-365	21-23	Rice, middle late-maize	Two crops per annum locally	Buffalo
Subtropical valley (lower part)	6600-7700	365	24-25	Double cropping rice, cotton, sugarcane, coffee, maguey, hemp, bananas	Three crops	Buffalo

* *pien-niu*, offspring of a bull and a female yak

Source: Chengdu Institute of Mountain Disasters and Environment 1983

Dry and Hot Valleys

The dry and hot valleys include valleys in the lower reaches of the Anning River (below Miyi County), the lower reaches of the Yalong and the Sanyuan River valleys, and the Jinsha valleys.

These valleys have good thermal conditions (accumulative temperature >10°, ranges 6,800° to 7,500°C and less precipitation (annual precipitation is from 600mm to 1,100mm), and, on irrigated farmland, three crops can be harvested.

Wide Valleys and Basins

The wide valleys and basins include the wide Anning River Valley, Huili Basin, Huidong Basin, Ningnan Basin, and Yanyuan Basin. The growing period lasts up to 10 months. The multiple cropping index is about 170 per cent.

Middle and Low Mountains

The middle and low mountainous areas are large and most of the farmland is dry sloping farmland. Paddy fields are located at the base of the mountains. One crop per annum is prevalent but, in the lower area of the zone, two crops per annum can be grown.

High Mountains

The high mountainous areas of the cool temperate zone produce one crop per annum. The major crops are potatoes, beech wheat, and highland barley. At lower elevations, early maize and middle maize are planted. The multiple cropping index is 138 per cent.

The vertical distribution of farming systems, described above, is shown in Table 3.7 (Chengdu Institute of Mountain Disasters and Environment 1980).

Table 3.7: Vertical Distribution of Farming Systems in the Xichang District of South Western Sichuan Province

	High mountains, > 2400masl	Middle and low mountains, 1200-2400masl	Wide valleys and basins, 1200-1800masl	Dry and hot valleys, 600-1300masl
Climatic conditions	Annual average temp.: < 13°C; accumulative temp > 10° < 3,600°C; frost-free period <210 days; annual precipitation < 900mm	Annual average temp. : 15 to 13°C; accumulative temp. > 10°C: 4,800 -3,600°C; frost-free period: 240 to 210 days; annual precipitation: 900 to 1200mm	Annual average temperature: 19 -15°C; accumulative temperature > 10°C : 6,800 to 4,800; frost-free period: 290-240 days; annual precipitation: 900 to 1200mm	Annual average temperature: 21° to 19°C; accumulative temperature > 10°: 7,500 to 6,800°C; frost-free period: 320 to 290 days; annual precipitation: 600 to 1,100mm
Land use	Forest, grassland dominated, a few farmlands	Forest dominated, some farmlands	Farmland dominated	Farmland dominated
Cropping system	One crop per annum	One crop or two crops per annum	two crops per annum	Three crops per annum
Crops	Potatoes, beech, wheat	Maize, rice, potatoes	Rice, wheat, cole, tobacco, sugarcane	Double cropping rice, sugar cane, tropic crops
Livestock	Yak, domestic sheep	Goats, cattle	Buffaloes, pigs	Buffaloes, pigs, goats
Forests	Mixed needle and broad-leaved forests, needle-leaved forests	Deciduous forests, Yunnan Pine forests	Evergreen broad-leaved forests, Yunnan Pine forests	Shrubs, tropical trees, shellac

Source: Chengdu Institute of Mountain Disasters and Environment 1980

Mountain Agriculture and Soil Erosion

In the Upper Reaches of the Yangtze River, soil erosion on the slopes mainly occurs on dry sloping farmland where protection measures have not been taken. Food crops and cash crops on sloping farmland in the region have no dense coverage, especially in the early strong seedling period. Crop coverage is 50 per cent in the young seedling period, and the crop coverage scant meaning that, with heavy rain, the soil is subject to serious erosion.

In the hilly areas of the Sichuan Basin, dry farmland areas produce two crops per annum. The rotation system is simple: wheat - sweet potatoes, wheat - peanuts, wheat - sorghum, peas - sweet potatoes, peas - cotton peas - maize. In these areas, the rainy season starts in late May or early June, when the crops are in the budding or young seedling stage, loose soil and low crop coverage (< 20 %) does not preserve the soil from erosion. Work in this area points out that the soil loss on fallow land after the wheat is harvested in May accounts for 20 per cent of the annual total soil loss, in some places up to 50 per cent. July is the peak month for precipitation in the hill areas of the Sichuan Basin with high precipitation intensity, while 50 per cent crop coverage is less. Therefore, soil erosion is extensive (see Table 3.8).

Table 3.8: Precipitation and Soil Water Losses on Dry Farmland

Item/ Month	Precipitation (mm)	Precipitation of runoff (mm)	Yield against total precipitation	Runoff (m^3/ha)	Sediment discharge (kg)
May	264.0	216.7	82	12.3	101.2
June	166.5	81.6	49	3.15	1.6
July	246.7	201.3	82	133.5	467.0
August	125.0	87.8	70	33.0	15.9

Source: Experimental Station of Water and Soil Conservation, Suining County, Sichuan Province, 1986

Here along the mountainous borders of the Sichuan Basin in the west of the province (> 1000masl) only one crop per annum, such as maize or potatoes, is planted on sloping farmland.

From the work carried out on agriculture and soil erosion, a number of points have arisen.

Soil erosion on farmland is related to crops, crop combinations, and sowing time. Table 3.8 lists information and data concerning this relationship which were obtained from Neijiang County in Sichuan.

From Table 3.9 it can be observed that water and soil losses are ranked in descending order as follows: fallow land > maize + peas > sorghum + peas > peas + cole > grassland.

Root System in Grassland and Soil Erosion

The laboratory data on soil disintegration in still and flowing water are listed in Table 3.10. The soil samples are from pea fields, wheat fields, and barren land without crop cover From Table 3.10 it can be seen that the disintegratiòn of soils sampled from pea fields in still water and in flowing water and from wheat fields are lower than ones from soil sampled from new barren land without crop cover. Because there are fewer roots in the soil samples taken from new barren land, they have lower disintegration rates than the samples from pea and wheat fields, because these latter tend to have more roots in the samples, most being found in the samples taken from pea fields. Barren land should be quickly revegetated.The water-stable granular structure of purple soil varies under different kinds of vegetation, including crops.

Table 3.9: Soil and Water Losses on Farmlands with Different Crop Combinations and with Grass Cover

Item	Annual runoff (m^3/ha.)		Annual soil loss equal to soil depth (mm)	Note
Fallow land	2445.0	167.41	11.0	12° slope for all pilot plots
Maize + peas	2142.0	87.06	5.7	
Sorghum + wheat	----	75.71	5.1	
Peanuts + cole	1968.0	53.74	3.6	
Grass cover	1525.3	23.59	1.1	

Source: Neijiang County, Sichuan Province, 1986

Table 3.10: Soil Disintegration and Crop Roots in Soil

Crop	Soil sampling depth (cm)	Soil disintegration in still water (% against total volume of soil sample)	Soil disintegration in flowing water (% against total volume of soil sample)	Roots (g/kg)	Note
Pea fields	0 - 5	10	10	5.39	Yellow-drab soil developed on quaternary deposits
Wheat fields	0 - 6	15	20	1.28	
Barren land with no crop cover	0 - 5	30	35	a few	

Source: Northwestern Institute of Soil and Water Conservation 1986

From Table 3.11 it can be observed that the portion of water-stable granules of > one mm in soil with perennial herbs is 66.0 per cent. for mixed Alder and Cypress forest it is 57.7 per cent, and in maize fields it is only 5.6 per cent to 5.8 per cent. This means that perennial herbs function well in conserving the soil.

Therefore in agricultural areas in the hills and lower mountains, the land use systems for agriculture, forests, and animal husbandry should be reasonably proportioned and husbandry should be developed along scientific lines.

Forestry in the Region

In areas where there is high priority for water-soil conservation the forested land is 8.147 million ha, but the forest resources are not abundant. For example, in the lower reaches of the Jinsha, the forested land covers 2.966 million ha with 98.864 million cubic metres of living timber stock. The per capita average living timber stock is 7.6 cubic metres and 1.56 cubic metres in the lower reaches of the Jinsha and Bijie district respectively. These figures are lower than the per capita average of 10 cubic metres for China as a whole.

Among the problems are uneven distribution of forest resources. Forests are mainly found in the lower reaches of the Jinsha and the upper reaches of the Jialing. Some forests are situated in inaccessible high mountain areas, therefore they are not easy to harvest.

Table 3.11: The Water-Stable Granular Structure of Purple Soil under Vegetation

Vegetation										
		> 5	5-3	3-2	2-1	1-0.5	0.5-0.25	> 0.25	> 1	> 3
Mixed alder and cypress forest	Topsoil	31.42	14.08	5.95	6.27	8.94	3.92	70.58	57.72	45.5
	Sub-soil	7.79	4.55	2.30	3.34	8.49	6.47	32.94	17.98	12.34
Lalang grass	Topsoil	29.57	20.34	3.43	7.67	8.05	2.47	76.53	66.01	49.91
	Sub-soil	26.73	17.69	7.56	6.93	9.53	4.79	73.23	58.91	44.42
Maize (I)	Topsoil	1.43	2.12	1.25	2.00	4.82	4.75	16.37	5.80	3.55
	Sub-soil	1.19	1.65	0.98	1.82	5.78	5.44	16.86	5.64	2.84
	Topsoil	1.75	1.13	0.96	1.75	10.20	11.03	26.82	5.59	2.88
Maize (II)	Sub-soil	0.00	0.64	0.99	2.61	14.71	11.56	30.51	4.24	0.64

Source: Chengdu Institute of Mountain Disasters and Environment 1983

The composition of forests generally is not the best. Timber forests account for 80 per cent of the total forested area, with commercial forest, firewood, and protective forest covering 20 per cent of the area. Coniferous forests are of low quality and there are too many middle-aged and young trees.

Most forests are subjected to unbalanced cutting and planting. In most cases plantation does not keep up with cutting.

Table 3.12 gives an example of forest composition in the lower reaches of the Jinsha.

Table 3.12: The Composition of Forests in the Lower-Reaches of the Jinsha

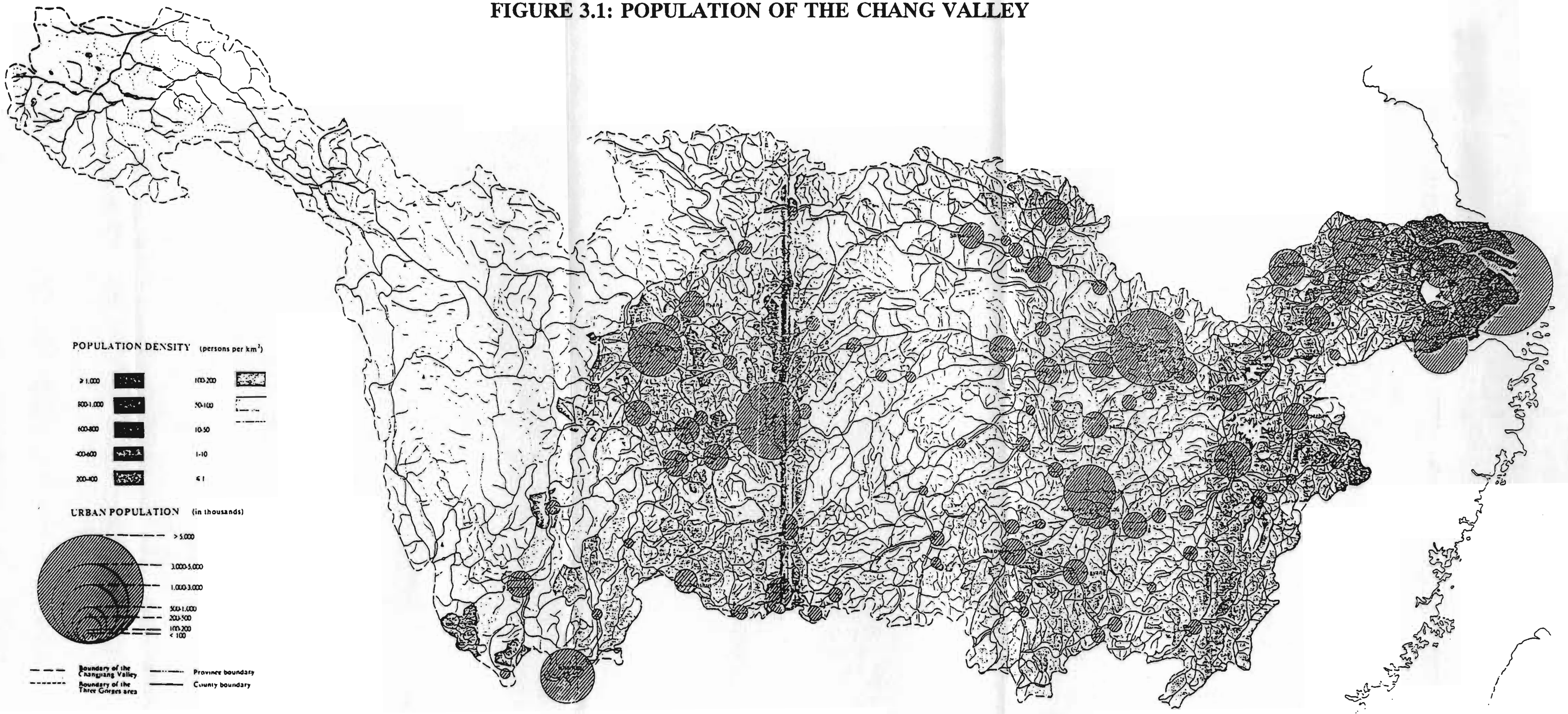
District	Forested land (excl. bamboo forest	Timber forest		Protective forest		Cash forest		Firewood forest		Forest for specific purposes	
		Area	% of forested land	Area	% of forested land	Area	% of forested land	Area	% of forested land	Area	% of forested land
Sichuan	54.923	43.080	78.4	6.639	12.1	3.134	5.7	0.910	1.7	1.160	2.1
Yunnan	96.647	6.120	91.8	4.371	4.5	2.6545	2.7	0.867	0.9	0.055	0.1
Total	151.570	131.790	86.91	11.009	7.3	5.779	3.8	1.777	1.2	1.215	0.8

Source: Commission Office for Soil-water Conservation 1990

Animal Husbandry in the Region

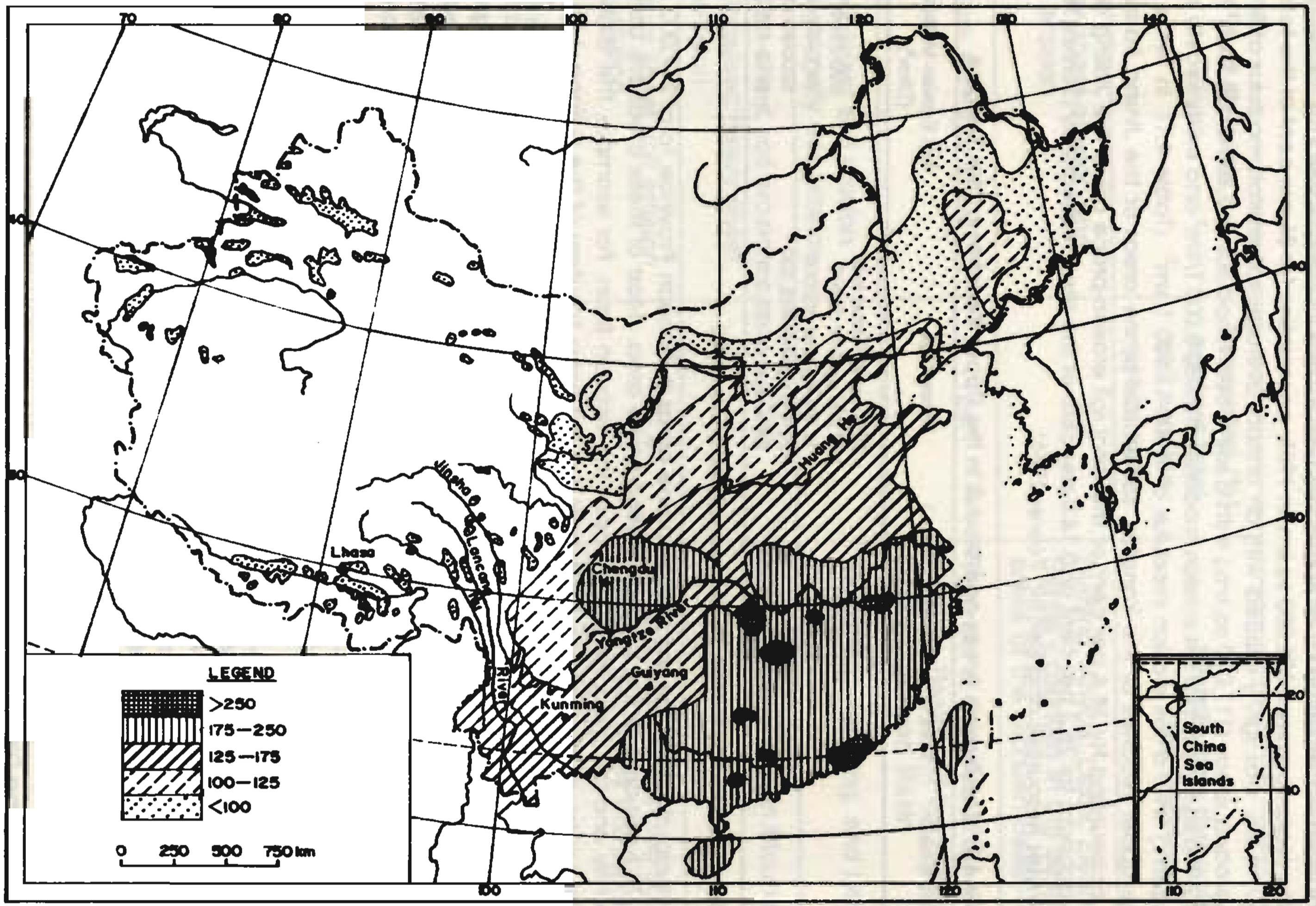
Pig raising and sheep raising are major sectors in animal husbandry in the region. Large-sized livestock include cattle and horses. At present, animal husbandry is basically reliant on natural conditions. Degradation of pasture land, overgrazing, and short supply of winter hay constrain development of animal husbandry in the region. In Liangshan Prefecture, livestock productivity per hectare is 5.043 US$ (Commission Office for Soil-Water Conservation 1990).

FIGURE 3.1: POPULATION OF THE CHANG VALLEY



Source: Zhao Songqiao 1986

Figure 3.2: Multiple Crop Index in China



Source: Beijing Institute of Geography 1983

RECENT STATUS AND CHARACTERISTICS OF SOIL EROSION IN THE REGION

Recent Status of Soil Erosion

Data on water and soil conservation in the upper reaches of the Yangtze indicate that the soil erosion-prone areas in the region covered 352,000 sq.km. in 1985, accounting for 35 per cent of the total area of which 133,000 sq.km. was lightly eroded with an annual average soil erosion modulus of 500-2500 T/km^2; medium-eroded areas (111,000 sq.km.) with a soil erosion modulus of 2,500-5,000 T/km^2 heavily eroded areas (72,000 sq.km.) with a soil erosion modulus of 5,000-8,000 T/km^2 and extra heavily eroded areas (10,000 sq.km.) with a soil erosion modulus of 8,000-13,500 T/km^2 (Table 4.1). In terms of the tributaries of the upper reaches of the Yangtze, soil erosion-prone areas of the Jinsha Basin cover 135,400 sq.km., accounting for 38.4 per cent of the total soil erosion-prone area. The Jialing and the Min River areas account for 26.3 per cent and 14.0 per cent of the area respectively (Survey Team of the Ministry of Water Resources and Electric Power 1986).

Table 4.1: Soil Erosion Areas and Moduli in the Upper Reaches of the Yangtze

Classification of Soil Erosion	Area of Soil Erosion (sq.km.)	Percentage	Soil Erosion Modulus (T/km^2)
Total	352000	35% against total area	
Light	133000	37.8% against 35200	500-2500
Medium	111000	31.5% against 352000	2500-5000
Heavy	72000	20.4% against 352,000	5000-8000
Extra Heavy	10000	2.8% against 352,000	8000-13500

Source: Survey Team of the Ministry of Water Resources and Electric Power 1986

In terms of provincial statistics, the soil erosion-prone areas in Sichuan Province total 247,000 sq.km., accounting for 70.1 per cent of the total soil erosion-prone area. Most of these areas are distributed throughout the hilly and low mountainous areas of the Sichuan Basin. For example, the Giong River which drains the centre of the Sichuan Basin and is a first order tributary of the Fujiang, had 4329.2 sq.km. of drainage area and 3277.8 sq.km. of soil erosion-prone area in 1983, accounting for 75.7 per cent of the total drainage area in 1983 and being 40.4 per cent over the total area recorded in 1957. The annual average soil erosion modulus is 4335.2 T/km^2 in the basin. Sichuan Academy of Agriculture Sciences has carried out work on the regionalisation of soil erosion in the province and this is summarised in Table 4.2 (Sichuan Academy of Agricultural Sciences 1980). Detailed data on the status of soil erosion in the high area of soil-water conservation in the upper reaches of the Yangtze are given in Table 4.3.

Soil Erosion on Dry Sloping Farmland

The plains in the upper reaches of the Yangtze are small. About 80 per cent of the total farmland is situated on the slopes of the hills, low mountains, and middle mountain areas, and 70 per cent of farmland is on slopes that do not have any protection. The slope gradient for most of the sloping farmland in hilly areas in the Sichuan Basin ranges from 5°-20°. A considerable amount of sloping farmland is found on slopes with a > 25° slope gradient. In Sichuan Province, eight districts have farmland on > 25° steep slopes, accounting for 10-20 per cent of the total area of each prefecture. They are Yibin District (12.1%), Da County District (12.3%), Fulin District (15.3%), Yaan District (15.6%), Ganzi District (15.8%), Aba District (16.6%), Guangyuan District (17.7%), and Xichang District (18.2%). In some counties (cities), farmland on steep slopes accounts for > 60 per cent of the total area. For example, farmlands on steep slopes in Jin Kou, a district administered by Leshan City, and Chengkou County administered by Wanzian District, account for 71.7 per cent and 66.4 per cent of the total area respectively.

Table 4.2: Distribution of Different Types of Soil Erosion in Sichuan Province

Soil Erosion Type	Presented (%) against total soil erosion-prone area	Distribution throughout the Province
Heavy sheet erosion and gully erosion	2.9	Suining, Anyue, Lexhi, Ziyang, and Santai - counties in the central hilly areas of the Sichuan Basin
Medium and light sheet erosion	24.1	The rest of the area of the Central Sichuan Basin and the mountains in the eastern Sichuan Basin
Heavy sheet soil erosion and light gully soil erosion	1.0	Mingshan, Jianjiang, and Leshan Counties
Medium sheet soil erosion and localised heavy sheet soil erosion	23.5	Daba Mountains, Min Mountains
Medium sheet soil erosion and solution	23.4	Fringed mountains in the southern Sichuan Basin and the Daliang Mountain Area
Light sheet soil erosion	2.1	Lushan, Tianquan, Baoxing counties in the upper reaches of the Qingyi
Soil erosion by wind erosion and by collapse	1.3	Valleys in the upper reaches of the Min Dong River and Xi River Basin in the Tibet District and in the Liusha River Basin in Hanyuan district
Light sheet soil erosion and medium gully soil erosion	14.3	Tibet District
Soil erosion by wind and glaciation	7.3	Western Mountains of Sichuan Province
Erosion in paddy	0.1	Western Plain of Sichuan Basin

Source: Sichuan Academy of Agricultural Sciences 1980

Table 4.3: Status of Soil Erosion in the High Area of Soil-Water Conservation in the Upper Reaches of the Yangtze

(Area: sq.km./Unit : Erosion loss: 10^4 T erosion modulus T./km^2 annum)

Region	Province	Area of Land	Soil Erosion Prone Area and Erosion Loss											
			Total				Light				Medium			
			Area	% of total land area	Average annual erosion loss	Average erosion modulus	Area	% of total soil erosion-prone area	Average annual erosion loss	Average erosion modulus	Area	% of total soil erosion prone area	Average annual erosion loss	Average erosion modulus
Total		304030.42	170544.90	56.09	77250.88	4530	56600.16	33.19	8702.77	1540	57634.77	33.79	21737.94	3770
Lower reaches of Jinsha and Bijie district	Subtotal	118752.45	63498.30	53.47	27692.65	4360	25526.65	4360	25526.98	1580	20350.32	32.05	7766.00	3820
	Yunnan	65921.80	33671.00	51.08	12175.10	3620	16162.08	48.00	2585.93	1600	11010.42	32.70	4183.93	3800
	Guizhou	25607.00	13310.00	51.98	8032.20	6040	4260.00	32.00	690.12	1620	3460.00	26.00	1377.08	3980
	Sichuan	27223.65	16517.30	60.67	7485.35	4530	5104.90	30.91	765.74	1500	5879.90	35.60	2204.96	3750
Southern Gansu and Southern Shanxi	Subtotal	48238.50	22774.78	42.21	9705.26	4260	8113.11	35.62	1216.97	1500	7928.17	34.81	2963.33	3740
	Gansu	38199.50	18152.26	47.52	7924.55	4360	6507.59	35.85	976.14	1500	5981.17	32.95	2242.94	3700
	Shanxo	10039.00	4622.52	46.05	1780.71	3850	1605.52	24.73	240.83	1500	1947.00	42.12	720.39	3700
Middle-lower reaches of Jialing	Sichuan	112674.40	70096.66	62.21	31674.96	4520	20436.89	29.16	3065.53	1500	25032.85	35.71	9387.32	3750
Three Gorges	Subtotal	24367.07	14175.16	58.17	8178.01	5770	2523.18	17.80	378.48	1500	4323.43	30.50	1621.29	3750
	Sichuan	18777.40	11118.93	59.21	6556.29	5900	1892.07	17.02	283.81	1500	3256.32	29.29	1221.12	3750
	Hubei	5589.67	3056.23	54.68	1621.72	5310	631.11	20.65	94.67	1500	1067.11	34.92	400.17	3750

Soil Erosion Prone Area and Erosion Loss											
Heavy				Extra Heavy				Serious			
Area	% of total soil erosion prone area	Average annual erosion loss	Average erosion modulus	Area	% of total soil erosion-prone area	Average annual erosion loss	Average Erosion Modulus	Area	% of total soil erosion prone area	Average annual erosion loss	Average erosion modulus
38068.66	22.32	24635.66	6470	13782.20	8.08	14781.4	10700	4459.11	2.62	73933.30	16580
10350.91	16.30	6640.33	6415	5283.75	8.32	5804.93	10990	1986.34	3.13	3439.60	17320
4511.91	13.40	2797.38	6200	1447.85	4.30	1665.03	11500	538.74	1.60	942.80	17500
2396.00	18.00	1605.00	6700	1996.00	15.00	2300.00	1152	1198.00	9.00	2060.00	17200
3443.00	20.84	2237.95	6500	1839.90	11.14	1839.90	10000	249.60	1.51	436.80	17500
4577.06	20.10	2953.88	6450	1700.82	7.47	1819.31	10707	455.62	2.00	751.77	16500
3870.06	21.32	2515.54	6500	1337.82	7.37	1438.16	10750	455.62	2.51	751.77	16500
707.00	15.30	438.34	6200	363.00	7.85	381.15	10500	n.a.	n.a.	n.a.	n.a.
18462.89	26.34	12000.88	6500	4402.03	6.28	4402.03	10000	1762.00	2.51	2819.20	1600
4677.80	33.0	3040.57	6500	2395.60	16.90	2754.94	11500	255.15	1.80	382.73	15000
3805.96	34.23	2473.87	6500	1912.53	17.20	2199.44	11500	252.05	2.26	378.08	15000
871.84	28.52	566.70	6500	483.07	15.81	555.53	11500	3.10	0.10	4.65	1500

Source: Commission Office for Soil-Water Conservation 1990

In Bijie District, Guizhou Province, farmland on > 15° slopes accounts for 50 per cent of the total farmland. In Hezhang County District, the soil erosion from farmland on > 25° slopes accounts for 70 per cent of the total soil erosion.

Low Frequency of Soil Erosion and Short Duration of Rainy Periods

Some field work on soil erosion carried out in Suining County, Sichuan Province, suggests that the precipitation intensity - 10mm/h can be used as the critical precipitation intensity in Sichuan Basin at the point where soil erosion begins. According to weather data on the precipitation regime, the number of rainy days with a 10mm/h precipitation intensity coincides with a precipitation rate of >25 mm/day and the number of heavy soil erosion days coincides with the number of rainstorms (>50 mm/day).

Table 4.4 lists data from the Anning Basin on annual precipitation, runoff, and sediment discharge (Chai Zong Xin 1985).

Table 4.5 lists data from the Qiong Basin on precipitation, runoff, and sediment discharge (Commission Office for Soil-Water Conservation 1988).

Jinsha River has the highest annual erosion rate of up to 466 million tons, accounting for 33.2 per cent of the total. Next comes the Jialing River accounting for 27.1 per cent of the total, then the Min River, and a section of the mainstream of the Yangtze Jiang in eastern Sichuan Province account for 13.8 per cent and 12.8 per cent of the total respectively.

Characteristics of Soil Erosion in the Upper Reaches of the Yangtze Jiang

There is a pronounced seasonality in soil erosion. There are variations in annual precipitation and soil erosion. Accordingly, the annual precipitation in the region is concentrated in the period ranging from May to September. Therefore, soil erosion caused by water takes place mainly in the same period; especially from June to August. For example, in the Anning River area of the Xichang Prefecture of Western Sichuan Province, annual precipitation, runoff, and sediment discharge are variable and mutually effective. This is shown in Table 4.4 and in Figure 4.1.

The variation in soil erosion has seasonal characteristics, depending upon the natural conditions as well as upon anthropogenic activities. The variations have been divided into four stages.

1) In the dry season - a period of light soil erosion.

2) In the early rainy season - a period of heavy soil erosion. This is because soil erosion occurs on the farmlands in hilly and mountainous areas that are exposed to precipitation, therefore the soil erodes easily. The soil loss in this period accounts for 50 per cent of the total annual amount. According to Chonging's data on water and soil conservation, soil erosion on the uncultivated and open land in May accounts for 58 per cent of the total annual amount in the region.

3) In mid-rainy season - a period of medium soil erosion. Rainy season means the maximum precipitation months, and this varies from place to place, although, in general, it ranges from the final ten days of June to the final ten days of August. The soil erosion is comparatively less than in previous periods because of the dense coverage by crops.

4) End of the rainy season - a light soil erosion period. From September to October, precipitation is characterised by a long rainfall duration and a low precipitation intensity. In addition, with a high average of mature crops, the soil does not erode so easily.

Table 4.4: Variations in Annual Precipitation, Runoff, and Sediment Discharge in the Anning River Basin

Item	Month\Data	January	February	March	April	May	June	July	August	September	October	November	December	Annual
P	Amount (mm)	2.5	4.0	7.7	28.1	110.8	195.5	213.2	163.4	185.7	113.9	24.1	10.2	1059.1
	Percentage against total	0.2	0.4	0.7	2.7	10.5	18.5	20.1	15.4	17.5	10.7	2.3	1.0	100.0
Runoff	Amount $10^8 m^3$	1.9	1.4	0.7	0.9	1.0	7.2	11.3	10.7	14.3	12.7	5.0	3.1	70.2
	Percentage	2.7	2.0	1.0	1.3	1.4	10.3	16.1	15.2	20.4	18.1	7.1	4.4	100.0
Sediment discharge	Amount $10^4 T$	0.55	0.31	0.20	0.63	17.05	129.81	192.48	110.99	191.26	79.19	4.59	1.77	728.83
	Percentage	0.08	0.04	0.03	0.09	2.34	17.81	26.41	15.23	26.24	10.86	0.63	0.24	100
Sediment Concen-tration	g/m^3	28.0	23.9	26.4	54.7	635.4	1829.81	1617.49	999.81	1285.4	565.8	87.6	59.9	1024.6

* Precipitation data are based on records from Anning Bridge, Xichang, and Hetan Stations on the mainstream of the Anning River. Runoff sediment and sediment concentration data are based on records from Lantan Station located at the mouth of the Anning River.

Source: Chai Zong Xin 1985

Table 4.5: The Variation in Annual Precipitation, Runoff, and Sediment Discharge in Qiongjiang Basin

Item	Month Data	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Maximum Month		Max. three months		Max. five months	
															Months	Amount	Months	Amount	Months	Amount
P	Amount (mm)	15.7	16.3	26.7	70.7	112.5	1248	179.9	157.2	152.0	79.3	36.2	15.6	986.9	P	Amount (mm)	15.7	16.3	26.7	70.7
	Percentage against total	1.6	1.7	2.7	7.2	11.4	12.6	18.2	15.9	15.4	8.0	3.7	1.6	100		Percentage against total	1.6	1.7	2.7	7.2
Runoff	Amount (10^8 m^3)	0.1483	0.2835	0.3430	0.5705	0.7444	1.3839	2.8024	2.0664	1.8103	1.0600	0.5050	0.1918	11.91	Runoff	Amount (10^6 m^3)	0.1483	0.2835	0.3430	0.5705
	Percentage	1.25	2.38	2.88	4.79	6.25	11.62	23.52	17.35	15.20	8.90	4.24	1.61	100		Percentage	1.25	2.38	2.88	4.79
Sediment discharge	Amount (10^4 T)	0.23	0.034	0.045	0.721	2.812	6.013	43.768	41.741	16.203	1.013	0.394	0.033	112.6	Sediment discharge	Amount (10^4 T)	0.23	0.034	0.045	0.721
	Percentage	0.02	0.03	0.04	0.64	2.32	5.34	38.87	37.07	14.39	0.90	0.35	0.03	100		Percentage	0.02	0.03	0.04	0.64

Source : Commission Office for Soil-Water Conservation 1988

The number of rainy days (> 25 mm/day) varies from place to place. Generally in the mountainous areas of western and northeastern Sichuan Province, the number of rainy days varies from 10 and 18 days (e.g., in the Wu Basin). In northwestern Yunnan Province, the number ranges from three to 8 days, and hence the number of days when soil erosion is heavy is less and the frequency of soil erosion occurrence lower than in other areas described.

The days when daily precipitation is > 25 mm mainly occur from May to October and are concentrated in July and August. For example, in the Emei Mountain Area, the days with precipitation of > 25 mm fall in July (4.76) and August (6.8). The total number of days in July and August account for 62.5 per cent of the total annual number of days when precipitation is > 25 mm. In Yibin District, the days in August having a precipitation of > 25mm account for 33 per cent of the total number of days, indicating that soil erosion occurrences are concentrated in the rainy season (Chengdu Institute of Mountain Disasters and Environment 1988).

Regionalisation of Soil Erosion in the Upper Reaches of the Yangtze Jiang

The regionalisation of soil erosion programmes are meant to help in water and soil conservation. The soil erosion process, as a whole, involves many factors and their interactions, producing certain types of soil erosion at specific locations. The factors affecting soil erosion are climate, topography, soil, vegetation, and human activities (Integrated Survey Team for Soil-Water Conservation in the Yangtze River Basin 1986).

Principles of the Regionalisation of Soil Erosion

In programmes dealing with the regionalisation of soil erosion, five principles should be considered.

1) The natural factors contributing to soil erosion should basically be the same.
2) Types of soil erosion should be similar.
3) Socioeconomic development differences should not be too disparate.
4) The ways in which water and soil conservation and natural resource uses are handled should basically be the same.
5) Administrative and physical boundaries should be taken into consideration (Integrated Survey Team for Soil-Water Conservation in the Yangtze River Basin 1986).

Criteria for Regionalisation of Soil Erosion

A lot of work has been carried out on the regionalisation of soil erosion. Because the Yangtze is a system, the regionalisation of the basin should be considered first.

The Northwest Institute of Water and Soil Conservation has carried out some work on the regionalisation of soil erosion in the Yangtze Basin by using a three-level regionalisation system. The first level in the system is known as the collective belt, then the belt is divided into small areas called zones, then further into sub-zones.

The area of a soil erosion belt is based on topography, climate, vegetation, soil, land use, and impacts of land use on soil erosion. According to these factors, the Yangtze Jiang Basin can be divided into eight belts.

(I) The Yunnan - Guizhou Plateau Belt.
(II) The Sichuan Basin Belt.
(III) The hill and mountain areas south of the Yangtze.
(IV) The Qin Ba Dabie Mountain Belt.
(V) The Wuling Mountains.
(VI) The Plains' Belt in the middle-lower reaches of the Yangtze
(VII) The Hengduan Mountain Belt.
(VIII) The Qinghai-Tibetan Plateau.

The second level in the context of regional soil erosion is the "zone" and is based on soil erosion intensity. To determine the soil erosion intensity of each particular type, both the soil erosion-prone area and the modulus of soil erosion have been taken into consideration. Soil erosion intensity is classified into five categories; namely, extra light, light, medium, heavy, and extra heavy.

The "sub-zone" is the lowest level of the system and it is based on the combination of major types of soil erosion in each "sub-zone". There are usually not more than three major types of soil erosion.

Figure 4.2 and Table 4.6 shows the regionalisation scheme for the Yangtze Basin.

The Commission Office for Soil-Water Conservation (1990) has divided the region into four areas.

1) **Extra Light Soil Erosion Region**

The upper and middle reaches of the Jinsha, Yalong, and Dadu, the upper reaches of the Min, Bailong, and the Chengdu Plain falling into this region, accounting for an area of 0.4742 million sq. km. In the high mountains of the region, natural soil erosion is prevalent because of the low population and good vegetation.

2) **Light Soil Erosion Region**

Mountains on the northeastern and northwestern fringe of Sichuan Basin, the middle and lower reaches of the Wu, and the upper reaches of the Ji are in this region and cover a total area of 0.1762 million sq. km. The annual surface erosion is 209.15 million tonnes.

3) **Medium Soil Erosion Region**

The middle-lower reaches of the Jialing, lower reaches of the Min and Yalong, the upper reaches of the Wu, the Chishui River Basin, the Niulan River Basin, the Huang Basin, and sections of the basin of the Upper Reaches of the Yangtze from Chongqing to Yichang are in this region. The total coverage of the region is 0.24131 million sq.km. with annual surface erosion of 769.94 million tonnes.

4) **Heavy Soil Erosion Region**

The region covers the upper reaches of the Jialing, the middle and lower reaches of the Bailong, the lower reaches of the Yalong Basin with a total area of 0.1120 million sq.km. The annual surface erosion is 383.52 million tonnes of which 120.23 million tonnes are a result of gravitational erosion.

Table 4.6: The Soil Erosion Regionalisation Scheme in the Yangtze Basin

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
I. Yunnan-Guizhou Plateau	Jinsha Valley	Extremely heavy soil erosion	Zhaotong	High mountains and deep valley; yellow mountain soil and red soil; one crop per annum; dry farmland accounts for 85% of the total farmland.	Squamose erosion on barren land; sheet erosion on farmland.
			Yongren	Purple soil, hot and dry.	Squamose erosion on barren land; gully erosion on forest land.
			Dayao	Purple soil with shallow topsoil.	Squamose erosion and gully erosion.
			Weixin	Yellow mountain soil; secondary forests dominate in the foothills and low mountains.	Squamose erosion on barren and forest land; sheet erosion on farmland.
			Bijie	Limestone is prevalent; purple stone can be observed in the mountain basins.	Squamose erosion on forest land and sheet erosion on farmland.
			Hezhang	Red soil.	Squamose erosion on forest land and barren land; rill erosion on farmland.
			Heishuitou	Red soil; mountains and hills.	Squamose erosion on barren land; gully erosion on forest land.

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

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
I.	Eastern plateau of Yunnan Province and southwestern mountains of Sichuan Province	Heavy soil erosion	Kunming	Major agricultural area in Yunnan Province; most of the area has no natural forest.	Concealed erosion; squamose erosion on barren land.
			Wuding	Most of the farmland is dry and has little paddy land.	Sheet erosion on farmland; squamose erosion on forest land and barren land.
			Chuxiong	Purple entisol and real entisol; topsoil less than 50cm.	Sheet erosion on dry farmland; concealed erosion on paddy; squamose on forest land.
			Binchuan	Purple stone and limestone; red soil and paddy soil; dry and warm.	Squamose erosion on barren land; gully erosion on farmland in the foothills.
			Xichang	Mountain red soil; deforestation and overgrazing are serious; steep slope cultivation is popular; one of the rainstorm centres in China.	Gully erosion and sheet erosion on sloping farmland; concealed erosion on paddy; squamose erosion on forest land.
			Huili	Low mountains and foothills; outcrop of purple stone; low natural vegetation coverage; popular steep slope cultivation.	Sheet erosion and gully erosion on steep farmland; squamose erosion on forest land.
			Liangshan	Mountains and valley; forest distributed on high mountains and farmland in valleys and hills.	Squamose erosion on barren and forest land in high mountains; sheet erosion and gully erosion on farmland in valleys and foothills.
			Shuimian	Mountain area in Dadu River Basin; dry and hot in valley; 30% of the total farmland is on slopes of > 30°.	Gully erosion on farmland; squamose erosion on forest land.
			Daxiangling	2,000 masl with natural forest, few human activities.	Squamose erosion on forest land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
	Central mountains of Guizhou Province	Medium erosion	Guiyang	Foothills with small plains.	Squamose erosion on barren land; concealed erosion on paddy land.
			Zunyi	Purple stone is distributed throughout the foothills, no natural forest.	Squamose erosion on barren land; sheet erosion on farmland; concealed erosion on paddy land.
			Meitan	Mountains with large forest areas.	Sheet erosion and gully erosion in purple stone mountains; squamose erosion on barren land; sheet erosion on sloping farmland.
	Northern mountains of Guizhou Province	Light erosion			
II. Sichuan Basin	Central hills of Sichuan Basin	Extremely heavy erosion	Nanchong Ziyang	Agricultural area	Sheet erosion and gully erosion on farmland.
				Agricultural area	Sheet erosion on farmland; concealed erosion on paddy land; squamose erosion on barren land.
	Eastern low mountains and hills of Sichuan Basin	Heavy erosion	Wanxian	High anticlinal mountains and hills	Sheet erosion on farmland; squamose erosion on forest land.
			Chonqing	Low mountains, foothills with wide valleys;	Sheet erosion on farmland, concealed erosion on paddy land; squamose erosion on forest land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
			Xishui	Fold zone in northwestern part; anticline in southwestern part; low mountains and hills in eastern part.	Sheet erosion on farmland; concealed erosion on paddy land.
			Wusheng	Foothills and wide valleys; farmland accounts for 35-45% of total area.	Sheet erosion on farmland; concealed erosion on paddy land.
			Quixian	High hills and narrow valleys; farmland accounts for 16-26% of total area; vegetation coverage 60%.	Sheet erosion on dry farmland; squamose erosion on forest land.
Hills	Central low mountains hills of Sichuan Basin	Medium erosion	Nan Bu	Middle hills and wide valleys; farmland accounts for 40% of total area.	Sheet erosion on dry farmland; concealed erosion on paddy land.
			Zigong and Lezhi	Foothills and wide valleys; high reclamation ratio; 60-70%.	Sheet erosion on dry farmland; concealed erosion on paddy land.
	Fringe low mountains and hills of Sichuan Basin	Light erosion	Tongjiang	Extended range of Daba Mountains; rich in forest with 80% coverage.	Sheet erosion on dry farmland; squamose erosion on forest land.
			Mianyang	Hills; high reclamation ratio.	Sheet erosion on dry farmland; concealed erosion on paddy land; gully erosion on steep slope farmland.
			Yaan and Muchuan	Rich in natural vegetation with 80% coverage.	Sheet erosion on dry farmland; squamose erosion on forest land.
			Leshan	Foothills; rare natural vegetation and forest on small scale; high reclamation ratio.	Sheet erosion on dry farmland; concealed erosion on paddy land; squamose erosion on forest land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
	Chengdu Plain	Light erosion		Rare natural vegetation; dense population; high reclamation ratio; two crops or three crops per annum; annual average temperature: 17°C; annual precipitation about 1,000mm.	Concealed erosion on paddy
	Southern mountains and hills of Jianxi Province	Extremely heavy erosion	Ganzhou	Red soil with shallow topsoil.	Sheet erosion on dry farmland; gully erosion on steep slopes.
			Guangchang and Ningdu	Red soil and purple soil; rare natural vegetation.	Gully erosion and squamose erosion on barren and forest land.
			Dongxiang	Red soil developed on red stone of tertiary period, shallow topsoil.	Sheet erosion on dry farmland; squamose erosion on barren and forest land; gully erosion on hill tops.
			Nanchang	Red soil developed on red stone of tertiary period.	On hills, squamose erosion on barren land; gully erosion on hilltops; sheet erosion and rill erosion on cash crop land; concealed erosion on paddy.
	Hills of Hunan and Jiangxi provinces	Heavy erosion	Guoan	Foothills; red soil developed on red stone of tertiary period; rare natural vegetation.	Squamose erosion and gully erosion on barren land; sheet erosion on dry farmland.
			Jian	Red soil.	Sheet erosion on dry farmland; squamose erosion on forest land.
			Hengyang	Hills; rare natural vegetation.	Squamose erosion on barren land; gully erosion on steep slopes; sheet erosion on dry farmland.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
			Changsha	Red soil.	Squamose erosion and gully erosion on barren land; concealed erosion on paddy land.
			Pingjiang		Squamose erosion on barren and forest land; gully erosion on small scale in some locations.
			Shaoyang		Squamose erosion on barren land; sheet erosion on forest land; concealed erosion on paddy land.
			Tongsha and Yangxin	Mountains; rich in natural vegetation with 60-80% coverage.	Squamose erosion on barren and forest land; sheet erosion on dry farmland; gully erosion on steep slopes.
			Jianxin	Hills in northern part of the region; low mountains in southern part of the region.	Squamose erosion on forest land; concealed on paddy land; gully and sheet erosion in some locations.
			Tianmu and Wuyi mountains	Brown soil, grey-brown soil, red soil and yellow soil, rich in natural forest.	Squamose erosion on forest land and barren land; sheet erosion and ripple erosion on cash crop land.
			Yihuang	Brown soil, red soil, and purple soil; higher forest coverage.	Squamose erosion on forest land and barren land; sheet erosion on dry farmland.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
	Southern fault mountains of the Yangtze River Basin	Medium erosion	Xiushui	Mountain areas with altitudes ranging from 600 to 1000 masl; brown soil, grey-brown soil, yellow soil, red soil, and purple soil; rich in natural vegetation.	Squamose erosion on forest land and barren land; gully erosion on cash crop land.
			Luoxiao Mountain	Brown soil, red soil, and yellow soil; purple soil in scattered locations; rich in natural vegetation.	Squamose erosion on forest and barren land; Gully erosion in some low mountains and hills.
			Daoxian	Hilly area.	Squamose erosion on barren and forest land; sheet erosion on dry farmland.
IV. Qin-BaDabie moun-tains	Valleys, low mountains, hills in Hanshui River Basin	Extremely heavy erosion	Hanzhong and Ankong	Agricultural area.	Sheet erosion on dry farmland; Squamose erosion on barren land; concealed erosion on paddy land.
			Zhenan	Deforestation is serious.	Squamose erosion on barren land; sheet erosion and sheet erosion on dry farmland.
			Guangyuan and Huicheng	Loess; less precipitation.	Squamose erosion on barren land; gully erosion and sheet erosion on dry farmland.
	Dahong-Dabie Mountains	Heavy erosion	Yuexi and Yingshan	Deforestation is serious.	Squamose erosion on forest land; gully erosion on barren land.
			Hongan and Macheng	Low mountains and foothill area; large amount of sloping farmland.	Sheet erosion and gully erosion on dry farmland.
			Suixian and Anlu	Hilly area; red soil; higher reclamation ratio.	Sheet erosion on dry farmland; concealed erosion on paddy land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
			Dahong-shan	Low mountain and hill areas.	Squamose erosion on forest and barren land; sheet erosion on dry farmland.
			Wanyuan		Squamose erosion on forest and barren land; sheet erosion on dry farmland.
	Daba Mountains	Medium erosion	Wushan and Zigui	Low mountain and hill areas; purple stone is predominantly distributed; deforestation is serious.	Sheet erosion on dry farmland; squamose erosion on barren land; denudation on outcrops.
	Northern Qingling Mountain and Motianling Mountains	Light erosion	Fuping	High mountain area; farmland accounts for 3% of total area; rich in natural vegetation.	Squamose erosion on forest and barren land; sheet erosion on dry farmland.
			Xigu	Higher forest coverage in southern part.	Squamose erosion on forest land and barren land; sheet erosion on dry farmland.
			Motianling mountains	Mountain area with altitudes ranging from 500 to 2,300 masl; annual average temperature ranging from 14°C to 15°C; annual precipitation 700-900mm; rich in natural vegetation; farmland accounts for 10% of total area.	Squamose erosion on forest land; sheet erosion on dry farmland.
	Nanxiang Basin	Extremely light erosion		Agricultural area with high reclamation ratio.	Sheet erosion on dry farmland.
V. Wuling Moun-tains	Hills and low mountains of Western Hunan Province	Heavy erosion	Yanling	Purple stone is widely distributed.	Sheet erosion on dry farmland and cash crop land; squamose erosion on barren land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
			Sangzhi		Squamose erosion on forest and barren land; sheet erosion on dry farmland.
	Northern part of Wuling Mountain	Medium erosion	Qianjiang	Deforestation is serious.	Squamose erosion on barren land; sheet erosion on dry farmland.
			Lichuan	Mountain area; rich in natural forest with 80% coverage.	Squamose erosion on forest land; sheet erosion on dry farmland near settlements.
	Wuling-Xuefeng Mountain	Light erosion	Hafeng	High mountain area; rich in natural forest.	Squamose erosion on forest and barren land; denudation on outcrops.
			Bajing	Shallow topsoil; Karst well developed.	Squamose erosion on forest and barren land; sheet erosion on dry farmland.
			Jinping	Mountain area; rich in forest.	Squamose erosion on forest and barren land.
VI. Plain in middle and lower reaches of the Yangtze River	Lacustrine plain and alluvial plain	Medium erosion	Nanjing	Foothills; yellow-cinnamon soil; yellow-brown soil, and paddy soil.	Squamose erosion on barren land; sheet erosion on dry farmland; concealed erosion on paddy land.
			Hefei		Sheet erosion on dry farmland; concealed erosion on paddy land.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
	Jianghan Plain, Boyang lacustrine plain and Boyong alluvial plain	Light erosion	Jianghan Plain	Total lake surface accounts for 20% of the total area.	Concealed erosion.
			Wishui and Wangjiang		Concealed erosion on paddy; sheet erosion on dry farmland.
			Lacustrine plain and alluvial plain by Boyang Lake	Red soil.	Concealed erosion.
	Yangtze River Delta	Extremely light erosion			
	North-western mountains of Yunnan Province	Medium erosion	Zhongdian		Natural erosion on grassland; sheet erosion on dry farmland.
			Lijiang		Squamose erosion on forest and barren land; sheet erosion on sloping farmland.
			Jinkuang		Squamose erosion on barren land; gully erosion on forest land.
VII. Hengduan Mountains	Jiajinshan Mountain	Light erosion		Altitude ranging from 400 - 4000 masl; yellow soil, mountain brown soil, and mountain meadow soil; annual precipitation is from 700 to 1,000mm mainly falling during June, July, and August.	Squamose erosion on forest and barren land; sheet erosion on dry farmland.
	Kandian, Daocheng and Batong	Extremely light erosion		Altitude ranging from 2500 - 7000 masl.	Squamose erosion on grassland; sheet erosion on farmland.

Zone	Sub-zone	Soil Erosion Intensity	Region	Major Natural Environmental Conditions	Soil Erosion Type
VIII. Qinghai-Tibetan Plateau	Maowen Mountain	Medium erosion	Wenchuan	Less precipitation with low intensity and even distribution.	Sheet erosion on farmland.
			Jiuding Mountain and Tiancheng Mountain	Altitude is more than 2,000 masl.	Squamose erosion on forest land and grassland, sheet erosion on farmland in some locations.
	Aba high mountains, deep valleys, and plateau	Light erosion	Aba	Annual precipitation is about 1,000mm with 50% falling in June through August; acid humus soil, rich in natural vegetation.	Natural erosion.
			Marerkan	Rich in natural forest and grassland.	Natural erosion.
	Ganzi, Yushu Plateau	Extremely light erosion	Head of the Yangtze River	High mountains, alpine desert, glacier; altitude is more than 5,000 masl.	Natural erosion.
			Yushu	Grassland, glacier, and alpine desert; animal husbandry area.	Natural erosion.
			Ganzi	Grassland, glacier, and forest land; podzolic soil, bog soil.	Natural erosion.

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

Work on regionalisation of soil erosion in Sichuan Province has been carried out by the Commission for Soil-Water Conservation 1988, and it points out that the total erosion in Sichuan Province amounts to 1,207 million tonnes; the annual erosion modulus is 2,133 T/sq.km./annum. Detailed data are in Table 4.7.

Table 4.7: Regionalisation of Soil Erosion in Sichuan Province

Soil Erosion Region	Soil Erosion-Prone Area			Soil Erosion Loss		
	Area (sq.km.)	% of total land area of Sichuan	% of total erosion area	Average (T/sq.km.)	Total amount (10^4T)	% of total soil erosion loss
Extra light (a)	316,904.02	56.0		250	7.922	6.6
Light	73,904.61	13.1	29.7	1,500	11,086	9.2
Medium	91,178.23	16.1	36.6	3,750	34,192	28.3
Heavy	59,485.24	10.5	23.9	6,500	38,665	32.0
Extra Heavy	21,568.37	3.8	8.7	11,500	24,804	20.6
Serious	2,680.40	0.5	1.1	15,000	4,020	3.3
Total	248,816.49	44.0	100		120,689	100

Source : Commission Office for Soil-Water Conservation 1988

Note that the total soil erosion area does not include the extra light soil erosion area.

The Chengdu Institute of Mountain Disasters and Environment has divided the Wu Basin into three soil erosion intensities according to the guidelines laid down by The Ministry of Water and Energy of the People's Republic of China, which stipulate six categories as follows:

extra light soil erosion	< 500 T/sq.km./annum,
light soil erosion	500-2500 T/sq.km./annum,
medium soil erosion	2500-5000T/sq.km./annum,
heavy soil erosion	5000-8000T/sq.km./annum,
extra heavy soil erosion	8000-15000T/sq.km./annum, and
serious soil erosion	> 15000T/sq.km./annum.

1) **Heavy-Medium Soil Erosion Region**

The plateau and mountains in the upper reaches of the Wu cover a total area of 20,130.123 sq.km., accounting for 23.26 per cent of the total basin area. The average erosion modulus is 4,499.4 T/sq.km./annum; surface erosion and gully erosion are prevalent in the region.

2) **Light Erosion Region**

This region is in the middle reaches of the Wu and covers an area of 25,001.65 sq.km., accounting for 28.89 per cent of the total Wu Basin. The soil erosion-prone area in the region covers 1,16,030.0 sq.km. accounting for 46.41 per cent of the total regional area. Most of the counties in the region have an average modulus of 2,300 T/sq.km./annum. Squamose erosion is prevalent in the region with gully erosion in a few localities.

3) **Heavy-Medium Soil Erosion Region**

This region is located in the lower reaches of the Wu with a total area of 4,14,206.61 sq.km., accounting for 47.85 per cent of the total Wu Basin. In this region, the soil erosion-prone area covers 20,709.1 sq.km. The average erosion modulus in the region ranges from 6,086.0 sq.km./annum to 5,000.0 T/sq.km./annum. Squamose erosion is prevalent in the region. Sloping farmlands are prone to surface erosion, and, in some localities, gully erosion can be seen.

The Hengduan Mountains

The Hengduan Mountains are latitudinally located between 27° to 31°N and longitudinally between 98° to 103°E. They are bordered by the Qianghai (Tibetan) Plateau to the north, the Sichuan Basin to the east, the Yunnan-Guizhou Plateau to the south, and the Lancang River to the west.

A vertical distribution of climate, vegetation, soil, and human activities is distinctively observed in the Hengduan Mountains. Annual average precipitation in this region ranges from 700 to 1,100mm. The rainy season is from June to September, and the region experiences pronounced wet and dry seasons.

Most of the region is still in the natural erosion stage because of its inaccessibility, scarce population, and comparatively little human activity. Nevertheless, in devegetated areas and on steep sloping farmlands, soil erosion is heavy, especially in the valleys and inter-montane basins. Medium to heavy soil erosion is widespread because of extensive cultivation and deforestation. In this region, soil erosion varies both vertically and horizontally.

Vertically, alpine desert and glacial erosion can be found in places more than 4,300masl, and, in places below 2,500masl, sheet erosion on farmlands and scale erosion on forested lands occur. Horizontally, in the northern and northwestern parts of the region, natural erosion is prevalent on grasslands. In northern parts of the region, forested lands and grasslands are subject to natural erosion and scale erosion and gully erosion can be found locally.

Qinghai-Tibetan Plateau

The elevation of the headstream of the Yangtze River is more than 5,600masl where frost cleft and wind transportation are prevalent and the secondary factor is glacial erosion. In the valleys, soil erosion is not obvious because of the dense vegetation cover.

The upper reaches of the Dadu River and the Min River flow throughout the high mountains and deep valleys, where light scale erosion on grazing lands and light sheet erosion on farmlands occur, but generally natural soil erosion is prevalent. In the Yalong Valley, soil erosion is not obvious because of the dense vegetation cover and fewer farmlands.

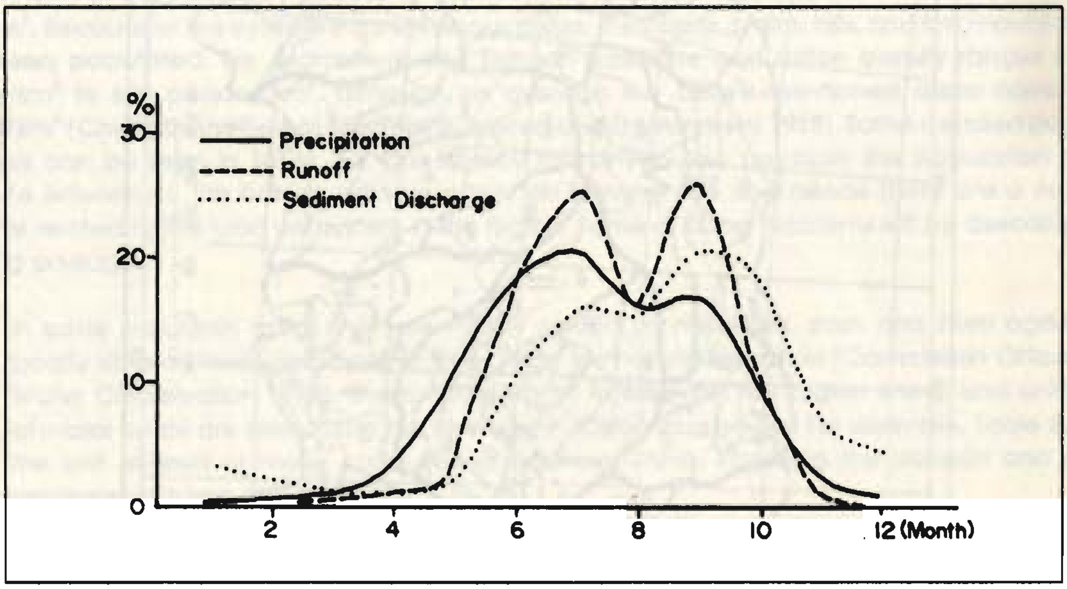


Figure 4.1: **Graph Depicting Annual Precipitation, Runoff, and Sediment Discharge Variations in the Anning River Basin (based on Data in Table 4.4)**

Figure 4.2: Regional Map of Soil Erosion in the Upper Reaches of the Yangtze

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

FACTORS BEHIND SOIL EROSION AND THE IMPACT OF SOIL EROSION ON SOCIOECONOMIC DEVELOPMENT

Soil erosion can be caused by many factors, including natural factors and man-made factors. Studies on soil erosion in the upper reaches of the Yangtze River suggest that water and soil losses in the region basically fall into the category of man-made accelerative erosion. Therefore, man-made factors behind soil erosion will be examined in the following passages.

Rapid Population Growth and Scarcity of Skilled Human Resources

Rapid population growth in the area has direct influence on soil erosion in the region. The total population in the region amounts to 146 million, having doubled in the period dating from the establishment of the People's Republic of China in 1949. The average population density in the region is 146/km^2. Because of the extensive mountainous areas, the basins, plains, hills, and low mountain areas are densely populated. For example, in the Sichuan Basin the population density ranges from 700 persons/km^2 to 800 persons/km^2, although on average the above-mentioned areas have 400-500 persons/km^2 (Chengdu Institute of Mountain Disasters and Environment 1988). Some detailed population indicators can be seen in Table 3.1. The literacy rate is very low because the population has little access to education. This has an adverse effect on farming skills and hence there are a number of problems related to the land use system in the region. Some of these problems will be described in the following passages.

1. In some mountain areas that are mainly settled by minorities, slash and burn agriculture is locally still practised, destroying or degrading the natural resources (Commission Office for Soil-Water Conservation 1990). The productivity of farmland in the region is low, and unit outputs of major crops are lower than the average in China as a whole. For example, Table 5.1 shows the unit outputs of major crops in southwestern China, including the Sichuan and Guizhou provinces (Chang Hong 1990).

   In the mountains and hills of the region, the farming system is very simple, crops and livestock being the only components. The agrarian population constitutes the majority of the total population. For example, in Bijie District, in the upper reaches of the Wu, the agrarian population accounts for 95 per cent of the total population. In some counties, the proportion is 98 per cent, resulting in the unsustainability of mountain agriculture.

Table 5.1: Unit Outputs of Major Crops in Southwestern China

(based on 1986 data)

Item	Sown Areas (10^4ha)	Total Output (10^8kg)	Unit Output (kg/ha)	Compared With				
				China	Hubei	Hunan	Jiangsu	Shandong
Rice	741.65	377.1	5084.55	5340.00	6390.00	5700.00	7035.00	5910.00
Wheat	269.77	72.7	2695.75	3045.00	2925.00	1680.00	4140.00	3705.00
Maize	365.14	112.1	3070.05	3705.00	3030.00	2010.00	5010.00	4425.00
Potatoes	228.47	64.8	2610.00	2925.00	2865.00	2625.00	4830.00	5190.00

* Hubei Province and Hunan Province are located in the middle reaches of the Yangtze River; Jiangsu Province is located in the lower reaches of the Yangtze River.

Source: Cheng Hun 1990

2. Unreasonable land use structure and steep sloping cultivation in mountainous areas leads to unfeasible land use. The Qiong Basin, a tributary of the Fu, covers 4,329.2 sq.km. of agricultural land which is 57.7 per cent of the total area; forest land covers 9.4 per cent, transportation networks 8.9 per cent, and grassland only 0.9 per cent. In the Basin, low per capita forest coverage with less pasture land leads to serious soil erosion. In most mountainous areas, clearing of forests for agricultural production is the principal method used to meet the needs of the rapidly growing population. In Guizhou Province, the plains cover only three per cent of the total area and steep sloping land has to be cultivated as farmland. Farmlands on slopes of > 25° account for 25 per cent of total dry land in the province and some farmlands are even on slopes of > 35°. Some farmlands have been taken from deforested areas. In Bijie District of Guizhou Province, the population has doubled in three decades and the farmland area has increased from 0.43 million ha to 0.59 million ha (1980). Forest coverage declined from 17 per cent in 1957 to 5.8 per cent in 1975, and this decline has continued until the present. Table 5.2 lists population density, land available per capita, forest coverage, and water and soil losses in some selected counties of the central hills of the Sichuan Basin. From the table it can be understood that rapid population growth causes land scarcity, deforestation, and severe water and soil losses (Sichuan Bureau of Forestry 1988).

Deforestation

The forests in Western Sichuan and Western Yunnan contain China's second largest store of forest biomass. A rich variety of broad-leaved evergreens are prevalent in natural stands and their felling age is usually less than 30 years. In Sichuan Province, the forest coverage has declined from 19 per cent in the early 50s to about 13.3 per cent today and in Yunnan Province, from 28.4 per cent to 24 per cent. At present, in Guizhou Province, the forest coverage is only 12.6 per cent. In many places, the forests have completely vanished and in eastern Sichuan's 53 counties, 50 per cent of the counties have less than three per cent of forest coverage. The forest coverage in 20 counties in the Central Sichuan Basin is less than one per cent and, in western Guizhou Province, less than 10 per cent (for example, Bijie District, 5.6%; Liupanshui less than 5%; and in Yuanmou, Dongshuan, and Lijiang of Yunnan Province, forest coverage is only 5-6%).

Deforestation in the region is caused by many factors, some of which are summarised below.

a. All forests throughout China were subjected to severe damage owing to the large-scale iron-smelting campaign started in 1958, the so-called "Great Leap Forward". Much of the accessible timber around tens of thousands of villages and towns was cut to provide charcoal for primitive "backyard" furnaces producing useless pig iron. In less than ten years, the "Cultural Revolution" started and the general lawlessness of its first few years resulted in the destruction of natural resources, including forests, for short-term gains. By far the most important reason for accelerated deforestation in the late 60s and during most of the 1970s was another policy - "taking grain as the key link", the Policy Research Office of the Ministry of Forests states that the reclamation of forests for green fields and forest fires have destroyed at least 6.7 million ha since 1949.

b. Overlogging to fulfil high timber production quota and provide financial revenue. Illegal cutting, slash and burn agricultural practices in some minority settlements, poor management of forest regeneration and plantation, and forest fires are also responsible for deforestation in the region.

In the high mountains and deep valleys of the region, forest areas cover 8.667 million sq.km., forest coverage being 21.9 per cent and stand storage 1.35 billion cubic metres, accounting for five per cent of the total forest storage in the Yangtze Basin. Since the founding of the PDRC, more than 20 forestry enterprises have been established in succession in this area, and the total annual felling of timber amounts to from 15 million-20 million cubic metres. However, because most of the forests in this area mature and/or overmature, the total annual increment is only 6 million - 7 million cubic metres, therefore, the annual net loss is 8 million to 13 million cubic metres. In addition, regeneration is difficult and the population scarce in Western Sichuan where the forest coverage has decreased to 9.9 per cent. In Western Yunnan it has decreased to 16 per cent and large areas of forested land have become brushwood land. Local governments in some mountainous counties fell beyond the state-set quota. For example, a county-run forestry enterprise with 206 employees in Muli County fells 0.12 million cubic metres of timber annually.

Table 5.2: Population Density, Land Available Per Capita, Forest Coverage, and Soil Erosion in the Central Hills of the Sichuan Basin

Item County	Population Density (person/ km²)	Per Capita Land (ha)	Per Capita Land for Afforestation (ha)	Per Capita Forested Land (ha)	Per Capita Barren Land (ha)	Forest Coverage (%)	Soil Erosion Intensity	Soil Erosion-Affected Area (% against total area)
Suining	616	0.160	0.003	0.001	0.002	0.5	extra heavy	79.8
Shehong	609	0.153	0.153	0.012	0.002	7.8	heavy	
Shong-jiang	605	0.173	0.011	0.004	0.003	2.7	heavy medium	
Pengxi	563	0.180	0.002	0.001	0.001	0.8	extra heavy - heavy	79.8
Anyue	508	0.200	0.009	0.002	0.003	1.0	heavy - medium	71.4
Santai	596	0.193	0.059	0.007	0.23	3.5	heavy - medium	
Tong-liang	559	0.153	0.015	0.009	0.003	5.9	extra heavy - heavy	72.5
Yong-chuan	629	0.153	0.017	0.008	0.003	5.4	medium	
Long-chang	857	0.120	0.003	0.003	0.001	2.2	heavy - medium	
Rong-chang	831	0.140	0.004	0.001	0.001	1.1	medium - light	
Dazu	611	0.173	0.009	0.005	0.003	2.7	extra heavy	77.4
Ziyang	566	0.173	0.007	0.001	0.003	1.1	heavy - medium	
Wusheng	704	0.140	0.001	0.0001	0.0003	0.1	heavy - medium	
Quxian	598	0.160	0.29	0.001	0.008	11.7	medium	

Source: Sichuan Bureau of Forestry 1988

In the densely populated foothills, communities consume large amounts of wood for indoor heating, cooking, house construction and maintenance, and some for items of farm water projects. Some investigations point out that in areas where energy is in short supply, each farmer needs 2,000 to 2,500 kg of firewood annually to meet energy needs. In mountain valleys, each household needs 5,000 kg of firewood per annum. A large amount of firewood is obtained from illegal cutting. Table 5.3 lists the firewood deficit months in some selected counties in the Sichuan Basin, indicating a heavy impact on the forests in this area.

Table 5.3: Population Density and Firewood Deficit in Some Selected Countries

Item County	Suining	Shehong	Zhon jiang	Anyue	Santai	Tong-liang	Yong-chuan	Long-chang	Rong-chang	Dazu
Average Fire-wood Deficit (month/ house-hold)	3	3	6	3	2.7	11	4	2	8	11
Popu-lation Density (person/ km^2)	616	609	605	508	596	559	627	857	831	611

Source: Sichuan Bureau of Forestry 1988

Some surveys also point out that in Southern China (including the Sichuan, Guizhou and Yunnan provinces), the forest storage consumed as firewood annually accounts for 35-40 per cent of the total timber consumption, and, in some forest districts, even up to 60 per cent. A new development in firewood consumption in the region should be mentioned. In recent years the valley and township enterprises have mushroomed into rural areas resulting in rapid and vast increments in firewood consumption. For example, cured tobacco production, tea finishing, brick and tile production, and lime production are mainly dependent upon firewood as fuel. In the Aba, Ganzi, and Liansheng minority autonomous districts of Sichuan Province, the forest coverage has declined from more than 40 per cent in the 1950s to 14 per cent at the end of the 1970s, mainly because of slash and burn agriculture. It has been projected that the existing forest storage in Aba District could be exhausted in 13 years, based on the actual amount of timber felled in 1984.

Deforestation in the region is closely related to soil erosion - the soil erosion affected area is increasing in Guizhou Province. In 1964 it totalled 0.035 million sq.km.; but it had risen to 0.05 million sq.km., an increase of 42.9 per cent in 20 plus years. In Sichuan Province, the soil erosion affected area in the 1950s was 0.0946 million sq.km. and it is now approaching 0.0369 million sq.km., accounting for two-thirds of the total provincial area.

The strong linkage between deforestation and soil erosion in the mountains can be seen in Table 5.4 (He Ying Wu 1988).

Table 5.4: Soil Erosion in Selected Districts of the Jinshan Basin

Item/District	Diquing	Lijiang	Shaotong	Dongchuan
Precipitation (mm/a)	787	975	939	689
Area of slope > 25° (% against total area)	62.14	45.2	45.8	61.50
Forest coverage (%)	36.8	30.3	6.6	4.8
Soil erosion - affected area (% against total area)	19.05	23.33	58.93	53.55
Soil erosion area with medium intensity (% against total soil erosion area)	6.45	4.01	33.97	53.55

Source: He Ying Wu 1988

The same conclusions can also be drawn from the data on relationship between forest coverage and soil erosion which are listed in Tables 5.5 and 5.6.

Table 5.5: Forest Coverage and Soil Erosion in Bijie District in the Wu Basin

Item	Year	Erosion Area		Total Amount of Soil Loss (10^4 T)	Erosion Modulus (T/sq.km. annum)	Forest Coverage (%)
		Area (10^4 ha)	% of Total Area			
	1982	109.2	40.6	3166.63	2900	17.5
	1986	140.9	52.2	6945.6	4927	14.9

Source: Chengdu Institute of Mountain Disasters and Environment 1990

Table 5.6: Forest Coverage and Soil Erosion in Selected Counties in the Upper Reaches of the Wu Basin (based on 1988 data)

Item	County	Forest Coverage (%)	Annual Soil Loss (10^4T)	Erosion Modulus (T/sq.km annum)
Zhujin		3.5	909.2	6745
Neyong		3.6	820.0	6348
Jinsha		7.1	67.6	807
Weining		10.4	25.0	185

Source : Chengdu Institute of Mountain Disasters and Environment 1990

Unreasonable Use of Sloping Agricultural Land

Some aspects of land resource and land use in the upper reaches of the Yangtze have been mentioned. Two tendencies in land resource and land use should be pointed out.

a) Land resource and land use have certain characteristics that are attributable to the mountainous nature of the area; for example, 38 per cent of all farmland is in the plains, 42 per cent in the hills, and 20 per cent in the mountains. Table 5.7 lists the breakdown of farmland into morphological types in Sichuan Province.

Table 5.7: The Breakdown of Farmland into Morphological Types in Sichuan Province

Item/ Morphological Type	Reclamation and Cultivation Index	Percentage of Farmland against Total Land (%)	Percentage of Paddy land against Total Farmland (%)
Plains	> 60 %	15.4	> 80 %
Hills	Approx. 40%	62.5	Approx. 40%
Mountains	5 - 10%	20.7	Approx. 20%
Plateaux	< 1%	1.4	0.0

Source: Zhenglin et al. 1980.

From Table 5.7 it can be seen that, in Sichuan Province, farmland in the hills and mountains accounts for 83.2 per cent of the total farming area. Some data obtained in Southwestern China proved helpful because Southwestern China includes the Sichuan, Yunnan, Guizhou, and Guangxi provinces. Most of Sichuan, Yunnan, and Guizhou provinces fall in the upper reaches of the Yangtze River. In southwestern China, the mountain area covers 0.067 million sq.km., accounting for 50 per cent of the total area of the region. The mountain population accounts for 44.4 per cent of the regional total and the agricultural population accounts for 89.3 per cent of the regional total, indicating the important position of mountain agriculture in the regional economy.

Hilly and mountainous farmlands are subject to soil erosion. The data point out that annual soil erosion loss on sloping farmland of > 5° is 714 T/sq.km.; 9,260 T/sq.km. on sloping farmland of > 15°; 15,137 T/sq.km. on sloping farmland of > 20° and 21334 T/sq.km. on sloping farmland of > 25°.

b) The average area of farmland per capita available for the agrarian population is declining in the region because of rapid population growth and capital construction.

In Southwestern China, the farmland available per capita is 0.0978 ha; 71.53 per cent of the average throughout China. It has been projected that in 2000 A.D. the farmland available per capita will be 0.08 ha in Sichuan Province. The farmland available per capita for the agrarian population has declined from 0.13 ha in 1949 to 0.08 ha in recent years.

c) Marginal land reclamation and cultivation is the only way to meet the food demands of the rapidly growing population in mountainous areas. In the western part of Sichuan Province, which covers part of the Hunduen Mountains, nine counties in southwestern Aba District, eight counties in southwestern Ganzi District, Muli County in Xichang District, and Baoxing County in Yunnan District, most of the farmlands are on slopes. According to field data, farmlands on slopes of < 10° account for 10 per cent of the total sloping farmland, 10-20° sloping farmland - 23 per cent, 20-25° sloping farmland - 20 per cent, 25-35° sloping farmland - 20 per cent, and 21 per cent of sloping farmlands are on slopes of > 35°. Steep sloping cultivation is the main factor behind soil erosion.

In this region, areas lightly affected by soil erosion account for 25 per cent of the total farmland, areas affected by medium soil erosion 35 per cent, and areas affected heavily by soil erosion 40 per cent. In southwestern Sichuan Province, in a total area of 31,000 sq.km., farmlands cover 21,93,333 ha, accounting for seven per cent of the total land area, of which most is dry farmland on slopes. For example, in Liangshan District, 30 per cent of the farmland is on slopes of < 25°, and, in Mabain and Shimian counties, 30 per cent of the farmland is on slopes ranging from 45-50°. Farmland on steep slopes is called "hanged land" by the local people. Because of the degree of soil erosion, the unit output of farmland is very low.

Apart from the factors mentioned above, mountain infrastructure without proper measures to preserve the soil from erosion could also trigger or accelerate soil erosion. Unfortunately data on this are not available.

Impact of Soil Erosion on Socioeconomic Development

Soil erosion is not only a symbol of the degradation of the mountain ecosystem, it also constitutes a serious negative impact on environmental conditions and socioecoconomic development in mountain areas and in the lowlands.

Soil erosion could cause a loss of soil fertility and productivity. Topsoil is often made thinner by soil erosion. According to data on the Three Gorges' Dam District, land with 10-25cm of soil depth accounts for 52.1 per cent of the total land area and 36.5 per cent of the soil has a soil depth ranging from 25cm to 50cm. In the Qiong Basin, 40 per cent of the total sloping farmland has a soil depth of less than 30cm. In Bijie District, Guizhou Province, farmland with topsoil of less than 15cm accounts for 49.3 per cent of total farmland in the district (Commission Office for Soil-Water Conservation 1990).

Farmland with thin topsoil has low productivity, for instance in Suining, Tongling, the unit output of farmlands with 15-18cm soil depth is only 40 percent - 70 per cent of the average unit output (Chengdu Institute of Mountain Disasters and Environment 1988).

Soil fertility will be lost by soil erosion, and, in this case, large amounts of fertiliser have to be applied to maintain farmland productivity. In Sichuan province, 270 million tonnes of fertile topsoil are washed away each year, fertiliser application has increased 87.7 times from 69,000 tonnes in 1957 to 6.052 million tonnes in terms of an application level per hectare of from nine kg to 925.5 kg (Commission Office for Soil-Water Conservation 1988). In Bijie County, 37.4 per cent of farmland is deficient in organic matter and in nitrogen, 90.1 per cent of farmland is deficient in phosphorous, and 27.1 per cent is deficient in potassium (Chengdu Institute of Mountain Disasters and Environment 1990).

Table 5.8 gives the erosion loss on sloping farmland in the Wu Basin.

Table 5.8: Erosion Loss on Sloping Farmland in the Wu Basin

Reaches	Farmland area (sq.km.)	Total erosion loss (10^4 Tonne)	Erosion Loss							
			8 - 15°		15° - 25°		25° - 35°		> 35°	
			loss	% of total	loss	% of total	loss	% of total	loss	% of total
Upper	9016.75	4474.86		19.56	1758.27	39.12	820.52	18.25	1036.93	23.07
Middle	8723.25	2889.57	686.95	23.77	1134.02	39.25	567.02	119.62	501.58	17.36
Lower	5558.22	2294.16	229.28	9.99	1083.86	47.24	469.66	20.48	511.36	22.29

Source : Chengdu Institute of Mountain Disasters and Environment 1990

Damage to Rivers, Lakes, and Water Conservation Projects

The increment of sediment concentration in the rivers is closely related to soil erosion in the river basin. The areas affected by soil erosion in the Yangtze River Basin are increasing at a rate of 1.4 per cent per annum. The areas with an erosion modulus of < 1000 T/sq.km. cover Yuanmou, Dongchuan, and Shaotong in Yunnan Province, the upper reaches of the Jialing River, the border areas of the Sichuan Basin, the lower reaches of the Yalong River, the Min River, and the Dadu River, covering 15 per cent of the total area of the upper reaches of the Yangtze. The annual average sediment discharge totals 63.6 per cent of the total sediment discharged in the upper reaches of the Yangtze.

In the upper reaches of the Yangtze, most of the sediment is from the Jinsha and Jialing rivers. The average sediment discharged from each river accounts for 45.8 per cent and 27 per cent of the total sediment discharged from the Yangtze River above Yichang respectively. According to data recorded in a number of hydrometric stations, the sediment concentration of the Longshuan River is rising, e.g., it was 4,015 kg/m^3 in the 1960s, 5,348 kg/m^3 in the 1970s, and 8,427 kg/m^3 in the 1980s. The sediment discharged from the Xiao (data from Dongchuan) has increased with time; e.g., from 4.88 million tonnes per annum in 1960, 11.10 million tonnes per annum in 1966, and to 30.00 million tonnes per annum in 1986.

The off-farm economic losses caused by soil erosion are outlined in the following passages (Fang Zheng San 1987).

Aggravation of Flood Damage

Much of the sediment caused by soil erosion silts up the river beds and reduces the discharging capacity of the rivers. For example, the river bed of the lower reaches of the Yellow River increases 10cm each year because of silt. As a result, the river bed is three to five metres higher above ground level on average and in some sections, more than 10m. Therefore, the Yellow River is called the "suspended" river. Similar situations can be found in the Upper Reaches of the Yangtze and the Xi, which is a tributary of the Jialing River (its bed has increased by two metres from the 1950s to the 1970s). The river beds of the six tributaries of the Jialing River in Guangyuang County are 0.8-3.5m higher than they were in the 1950s and one section of the Yangmu River bed is 1.5m higher than the surrounding farmland. One of China's worst floods for decades was certainly aggravated by widespread deforestation, soil erosion, and silting of the river bed. The Yangtze flood in Sichuan Province in mid-July of 1981, the worst inundation since 1877, directly effected 119 counties and cities inhabited by 15.84 million people, out of which 888 people were killed and 13.010 people injured. It flooded 1.39 million dwellings, 26,000 factories, and 830,000 ha of mostly fertile, level farmland (destroying or badly damaging a potential harvest of some 1.5 million tonnes of grain) and caused damage to 38,000 water conservation works. Direct monetary losses were estimated at 2.5 billion. A consensus on "painful lessons" quickly emerged. Besides the uncontrollable natural factors - heavy rainstorms, during which more than 100mm of rainfall were recorded at 17 weather stations in 24 hours - the loss of 30 per cent of the province's forested land by blind conversion of slope land into grain fields causing soil erosion and silting of the river beds and improper construction of water conservation projects were clearly to blame.

The frequency of floods has also increased during recent years. Table 5.9 lists the frequency of floods in Sichuan Province.

Table 5.9: The Frequency of Floods in Sichuan Province

Period	1950-1960	1961-1970	1971-1980	1981-1986
Bad floods (Nos.)	3	5	6	6

Source: Chenghong and Zhangmintao 1990

Damage to River Navigation

The silting of river beds reduces the number and size of navigable passes. The mainstream and tributaries of the Yangtze River in Sichuan Province had 14,000 km of navigable passes in the early 1950s and these decreased to 7,000km by 1981. The expanse of locally navigable river decreased to 67 per cent of its former expanse between 1958 to 1981. Meanwhile the total length of navigable passes has decreased by 50 per cent. In Hubei Province, a similar situation can be found; the total length of navigable passes on the Yangtze mainstream and major tributaries was 19,330km in 1960 but only 7,879km in 1979.

Silting and Shrinking of Lakes

Soil erosion in the upper reaches of the rivers causes the silting and shrinking of lakes in the middle and lower reaches of rivers.

In the middle and lower reaches of the Yangtze, Huaihe, Zhujiang, and other rivers, numerous lakes are distributed, and their total area is 22,161 sq.km., accounting for 27.5 per cent of the total lake area in China. Poyang Lake is China's largest freshwater lake with an area of 5,050 sq.km. The Gan, Fu, Xishui, Po, and Xin rivers converge into this lake and merge with the Yangtze. During recent years the lake area has decreased to 3,583 sq.km. because of silt deposits and reclamation of land. Dongtin Lake is China's second largest freshwater lake. The Xian, Zishui, Yuan, and Lishui rivers converge into this lake and merge with the Yangtze River at Chenglingji in Yueyang County. From 1949 to 1976, the lake's area decreased from 4,350 sq.km. to 1,840 sq.km. owing to silt deposits carried by the rivers and reclamation of land. It is estimated that about 200 million tonnes of sediment silt each year result in an increase in the lake bed of four centimetres per annum. Figure 5.1 shows the variation of Dongtin Lake in area and water storage over time (Editing Commission for the "Physical Geography of China" 1981).

The Dongtin Lake plays an important role in regulating the river flow and peak flow of the Yangtze River. This role is being weakened, however, because of a decline in water storage caused by silting and shrinking of the lake. The lake is one of China's major freshwater aquacultural centres. Catches from the lake accounted for 80 per cent of the total fishing in Hunan Province in the past, but, in recent years, the fishing has declined sharply, especially the total catches of quality fish which have decreased to four per cent of the total catches in the whole province.

Silting of Water Conservancy Projects

According to survey data in Sichuan Province, the total annual siltation of 73,079 convervancy projects is 46.19 million cubic metres, which reduces the area irrigated by 8,186.67 ha each year. Reservoirs in the Tuo, Fu, and Jialing basins in Sichuan Province have average siltation rates of more than one per cent. (Commission Office for Soil-Water Conservation 1990). Gongzui Water Power Station, which is the largest in southwestern China with a 35 million cubic metres reservoir capacity, has 11.4 million cubic metres of silt 10 years after its construction, accounting for 30 per cent of the reservoir's total capacity - the average siltation rate being more than 3.5 per cent (Fang Zheng San 1987).

Data from the Soil-Water Conservation Office at Mianyang, Sichuan Province, in 1987, pointed out that the total annual siltation of water conservation works in the district was 7.90 million cubic metres of which 308 million cubic metres was in the reservoirs alone. There are 2,483 river weirs in the district and 1,100 weirs have serious siltation problems; 450 weirs have almost gone out of operation. From the beginning of operation to 1987, Longzu reservoir in the district has lost 210,000 cubic metres in capacity because of siltation, Beiping reservoir with 4,20,000 cubic metres live capacity has been silted to the extent of 210,000 cubic metres. In general, the annual total losses in reservoir capacity in Sichuan

Province amount to 100 million cubic metres which means the province lost one large-scale reservoir per annum.

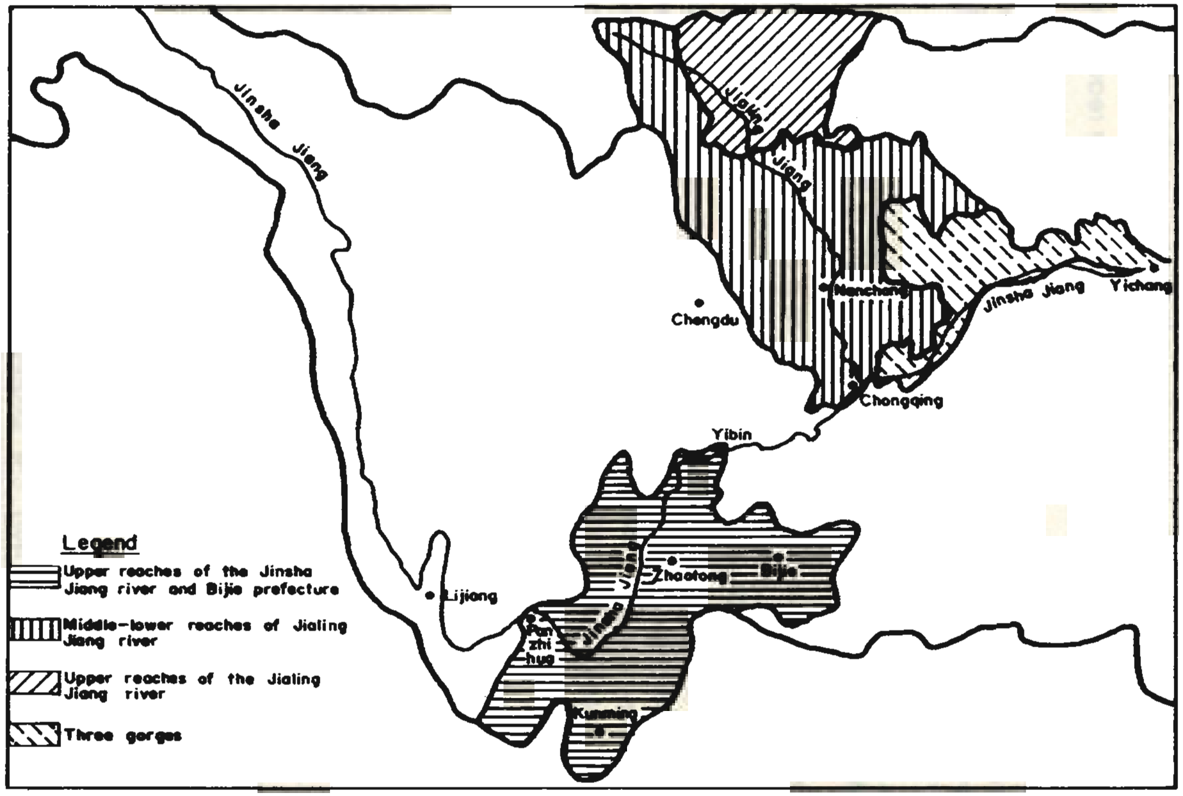
Reducing the Effective Use of River Flow

In China most of the rivers are fed by precipitation and the seasonal variation is uneven because of the monsoon. Soil erosion in mountain areas can aggravate the status of river flow. During peak periods, large amounts of water flow into the sea without effective use, thus reducing the use of runoff and river flow. For instance, in Minjiang River (the largest river in Fujiang Province), 57,000 million cubic metres flow is lost each year, accounting for nine per cent of the total flow, because of the lack of effective use.

Degradation of Eco-environmental Conditions and Poverty in Soil Erosion-prone Areas

Until now, some places in soil erosion-prone areas in the Upper Reaches of the Yangtze are operating at subsistence level. In Guizhou Province, there are 11 poor counties in the Yangtze Basin, of which 10 counties are prone to soil erosion. In Yunnan Province, 71.4 per cent of the poor counties are located in areas seriously affected by soil erosion. In the target area for water and soil conservation in Yunnan Province, deficiency of grain, fuel, and timber amounted to 32.57 million kg, 0.1138 million tonnes, and 18,900 cubic metres respectively in 1987; wells, springs, and ponds have dried up and it is difficult to irrigate farmland and for people and livestock to receive enough safe water to drink (Commission Office for Soil-Water Conservation 1990).

Figure 5.1: Variation of Dongtin Lake in Area and Water Storage Over Time



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

NATIONAL SOIL-WATER CONSERVATION PROJECTS IN THE REGION AND LESSONS FOR THE FUTURE

The Yangtze River Basin has an important strategic role in the social and economic development of China. Recent data on soil erosion point out that soil erosion-prone areas in the Yangtze River Basin total 5,62,000 sq.km. of which 3,52,000 sq.km. are located in the upper reaches of the river, accounting for 62.6 per cent of the total. Soil erosion causes constraints in socioeconomic development not only in the upper reaches of the Yangtze River but also in the middle and lower reaches of the river.

Since 1949, some local soil-water conservation projects have been carried out in the area and some of the experiences from these projects have been recorded. Based on old projects and the current situation, a new national project on soil-water conservation in the region was launched in 1988.

National Planning of Soil-Water Conservation in the Upper Reaches of the Yangtze

The upper reaches of the Yangtze River were demarcated as a priority soil-water conservation region in China by the State Council of China in 1988. The soil erosion prone region in the upper reaches of the Yangtze is divided into four soil-water conservation zones: 1) the lower reaches of the Jinsha River and the Bijie Prefecture; 2) the middle-lower reaches of the Jialing River; 3) the upper reaches of the Jialin River; and 4) the Three Gorges. The total area of land is 3,04,000sq.km. of which the Jialin River Basin occupies 1,60,900 sq.km.; the upper reaches of the Jinsha River and the Bijie Prefecture 1,187,005 sq.km.; and the Three Gorges 24,400 sq.km. The locations of the four key zones for soil-water conservation are shown in Figure 6.1 (Commission Office for Soil-Water Conservation 1990). The detailed areas of each of the four key zones are listed in Table 6.1.

Principles of Planning

Five points for planning soil-water conservation projects in the upper reaches of the Yangtze River are described below.

I The upper reaches of the Jiansha River and Bijie Prefecture
II The middle-lower reaches of the Jialing River
III The upper reaches of the Jialin River
IV The Three Gorges

a) Fundamental Planning Policy. The fundamental planning policy is a "combination between prevention and conservation with the priority being given to prevention; integrated management is carried out according to local conditions; high priority to four zones, extension to other soil-erosion prone areas".
b) According to local conditions and the socioeconomic development stage, under the leadership and coordination of the local government, rational land use in agriculture, forestry, husbandry, fishery, and infrastructure should be determined.
c) Three Combinations. (i) Ecological effect - economic effect and social effect, (ii) long-term effect and short-term effect, and (iii) management, exploitation and utilisation and anti-poverty should be considered simultaneously in planning for soil-water conservation.
d) Small-scale watersheds should be taken as units to control soil and water in a comprehensive way.

Table 6.1: The Area of Each of the Four Key Soil-Water Conservation Zones

Zone	Province	Prefecture	County	No. of Counties
Lower Reaches of the Jinsha and Bijie Prefecture	Yunnan Province	Chuxiong Yi Autonomous Prefecture	Mou Ding, Yao An, Yuan Mou, Dayao, Wu Ding, Yong Ren, Nan Hua, Chuxiong, Lu Feng	9
		Zhaotong Prefecture	Qiaojia, Zhao Tong, Yiliang, Yongshang, Suijiang, Nu Dian, Da Guan, Yan Jin, Heizi, Shui Fu, Zhen Xiong	11
		Dongchuan City	Suburb (county level)	1
		Quichien Prefecture	Dian, Huize, Malong, Xuan Wei, Quichien	5
		Kunming City	Panlong, Wuhua, Guan Du, Xishang, Jinning, Fumin, Chenggong, Luquan, Anning, Songming	10
	Guizhou	Bijie Prefecture	Hexhang, Weining, Bijie, Dafang, Jiasha, Qianxi, Zhijin, Nayong	8
	Sichuan	Liangshan Yi Autonomous Prefecture	Huili, Ningnan, Leibo, Jinyang, Huidong, Buge, Butuo, Zhaojue, Meigu	9
		Yi Bin Prefecture	Yibin, Pingshang, Yibin City	3
	Subtotal	9		57
Upper reaches of the Jialin (Longnan and Shan Nan)		Longnan Prefecture	Xihe, Lixian, Chengxian, Kangxian, Wudu, Wenxian, Dangchang, Liangdang, Huixian	9
		Tianshui Prefecture	Qincheng, Beidao	2
		Gan Nan (Tibetan) Zangzu Autonomous Prefecture	Zhouqu, Diebu, Mingxian, Luqu	4
		Hanzhong Prefecture	Lueyang, Ninqing, Zheg Ba, Nanzheng, Xixiang	5
		Baoji City	Fengxiang	1
	Sub-total	5		21
Middle-lower Reaches of Jialin	Sichuan	Guangyuan City	Suburb (county level), Qingchuan, Jiange, Wangcang	4
		Mianyang City	Suburb (county level), Pinwu, Jiangyou, Beichuan, Anxian, Santai, Yanting, Zitong	8
		Deyang City	Zhongjiang	1
		Aba (Tibetan) Zangzu Autonomous Prefecture	Nanpin	1
		Suining City	Shizhong, Pengxi, Shehong	3

Zone	Province	Prefecture	County	No. of Counties
Middle-lower Reaches of Jialin	Sichuan	Neijiang City	Anyue, Lezhi	2
		Nanchong Prefecture	Langzhong, Nanbu, Pengan, Guangan, Yuechi, Wusheng, Xichong Nanchong City (county level), Yilong, Yingshan, Cangxi, Huaying	13
		Daxian Prefecture	Tongjiang, Nanjiang, Bazhong, Pinchong, Daxiang, Xuanhan, Wanyuan, Dazhu, Quzian, Daxian City, Kaijiang, Baisha	12
		Chongqing City	Tong Nang, Tonglian, Heduan, Bishan	4
	Sub-total	9		43
		Fuling Prefecture	Fuling, Fengdu, Dianjiang, Wulong	4
		Daxian Prefecture	Kaijian (most of the county is located in the Jialing Basin)	1
	Sichuan	Qianjiang Prefecture	Shizhui	1
		Wanxian Prefecture	Lianpin, Kaixian, Wuxi, Zhongxian, Wanxian, Wanxian City, Yunyang Fengjie, Wushan	9
		Chongqing City	Jiangbei, Nanan, Shapinba, Jiulongpo, Baxian, Changshou, Jiangbei (district at city, county level)	7
Three Gorges	Hubei	Exi Tujia Autonomous Prefecture	Ba Dong	1
		Yichang Prefecture	Zigui, Xingshan, Yichan	3
		Shen Nong Jia	Forest area (county level)	1
	Sub-total	8		27
Total		29		152

Source: Commission Office for Soil-Water Conservation 1990

e) A combination of engineering-biological measures and conservative farming measures, slope management and gully management, revegetation (reforestation and grass plantation), and land closure should be considered.

f) The investments needed to meet the planned target should be met by the local government through mobilising local resources with some financial support from the central government.

Planning Procedure

Planning for soil-water conservation in the upper reaches of the Yangtze River is based on an engineering systems' theory, while considering the dynamic equilibrium of the population-environmental carrying capacity. Figure 6.2 shows the planning procedure.

Targets of the Soil-Water Conservation Project in the Upper Reaches of the Yangtze River

a) Population Projection. In China, the legal population growth rate is 0.9 per cent. Because most of the soil erosion-prone areas are in the mountains, the qualifications of the population are relatively low and the population proportion of the minorities is large, giving them a projection of a 0.10 per cent growth rate. The total population in this region in 2000 A.D. will be 73.7371 million, of which the agricultural population will account for 66.9846 million. The agriculture/population density will increase from 195 persons/km^2 in 1988 to 220 persons/km^2 in 2000.

b) Land Use Adjustment. The land use structure in this region should be adjusted according to the following aspects:
- the steep sloping farmland on gradients of more than 25° should be gradually turned into forest land or grassland;
- revegetation, which includes silviculture for soil-water conservation forests and non-timber product forests;
- greening of the barren land; and
- rapid growth of non-productive land use should be controlled and slowed down.

The adjusted land use structure for the soil-water conservation zones is given in Table 6.2.

Management of Sloping Agricultural Land. In the soil-water conservation project area, sloping farmland accounts for 62.17 per cent of the total farmland. Management of sloping farmland has two aspects.

1. Turning sloping farmland into terraced farmland (1.9629 million ha).
2. Conservative Farming. Agricultural technology, such as contour tillage, strip cropping, furrow and ridge tillage, plastic film covering, and fallow, should be used according to local conditions. At the end of the planned period, sloping farmland of 1.6679 million ha will be cultivated through conservative farming technologies.

Forest-Grass Measures for Soil-Water Conservation. The total afforestation and reforestation area will be 6.1787 million ha in the project area of which non-timber producing forests will cover 1.6499 million ha and firewood forests 2.2628 million ha. The grass plantation area will cover 1.2315 million ha.

Table 6.2: Land Use Change in Soil Erosion Conservation Zones (unit: million ha)

Item	Total Area	Farmland		Forest Land		Grassland		Others	
		Area	% against total	Area	% against total	Area	% against total	Area	% against total
Present Status	30.4032	7.8297	25.75	13.2718	43.42	3.9158	12.88	5.3860	17.72
At end of the planned period	30.4032	6.5689	21.61	14.9554	49.19	4.9596	16.30	3.9335	12.90

Source: Ibid
(Others: Water bodies, infrastructure, settlement, waste land, etc.)

Soil-Water Conservation Engineering. During the planned period, soil-water conservation engineering of 2,570 items (including sediment storage dam, check dam, and water pools will be constructed, drainage ditches along all slopes, diversion of water tunnels, and flood drainage works) in the project area covering 132.60 million sq.km. will be carried out.

Closing Land for Revegetation. The total land closed for revegetation in the project area will amount to 5.8667 million ha.

Management Aspects

Some of the management measures to be taken have been described below.

a) Establishing and Developing Institutions for the Project and Coordinating Concerned Agencies into the Project. The soil erosion conservation project covers many diverse socioeconomic sectors and is a comprehensive engineering system with social, ecological, and economic aspects. Therefore, in 1988, the State Council of China approved the establishment of "The Committee for Soil-Water Conservation in the Upper Reaches of the Yangtze River" to be responsible for both planning and implementing the soil-water conservation project. Committees at different levels for soil-water conservation in the project area have been established accordingly and this has been initiated by the principal local government leader.

b) Policy Formation to Mobilise the People to Work on the Project. Some policies have been formed to mobilise the local people to work on the project, and these vary from county to county in the project area. Some of the major policies carried out are described below.

A Contract Responsibility System was established whereby farmers have the right to contract and manage the new bench terraces built by them. This contract can be handed down to coming generations. Loans, relief, and supply of agricultural materials, such as fertilisers, plastic film, agricultural chemicals, and improved varieties of seeds, will be given to such farmers.

Preferential Support Policy, guaranteeing strong support from the government for people who work hard on the soil-water conservation project has been established.

In the project area, lack of family planning is one of the key constraints to soil-water conservation because of the rapid population growth. The environmental carrying capacity has an imbalance in terms of the local population. Therefore, family planning must be taken into consideration in implementing the project.

Training

Training soil-water conservation technicians and local farmers and involving the local people in decisions made by experts to ensure success of the soil-water conservation project.

Financial and Economic Aspects

The total investment in the project over the planned period is to be approximately U.S.$ 1.94280 billion of which 20.2 per cent (US$ 0.39251 billion) will be given in the form of subsidies from the Central Government for the construction of soil-water conservation engineering. Table 6.3 lists the subsidies for different soil-water conservation engineering projects.

Table 6.3: Subsidies for Soil-Water Conservation Engineering Projects (unit: U.S $/ha)

Item	Converting sloping farmland into terraces	Non-timber producing forests	Other forests	Grass plantations	Land closure for revegeta-tion	Inte-grated measures
Subsidy	115.1631	71.9770	20.1536	8.6372	3.4549	23.0326

Source: Ibid
(Exchange rate between US$ and RMB in 1990)

The local contributions will amount to US$ 78.5030 million, accounting for 4.04 per cent of the total. The investment of the local people in terms of labour will be US$ 1.47179 billion, accounting for 75.76 per cent of the total investment.

Soil-Water Conservation Benefits

The soil-water conservation benefits include economic benefits, ecological benefits, and social benefits. The ecological and social benefits are not easily quantifiable and are merely mentioned here.

Direct Economic Benefits

The direct economic benefits of the soil-water conservation project are generated by turning sloping farmland into terraces, soil-water conservation forest, and grass plantation. These are listed in Table 6.4.

Table 6.4: Breakdown of Direct Economic Benefits

Item		Area (10^4 ha)	Gain (based on average amount/ha)	Unit price (US$)	Benefits - starting year
Turning sloping farmland into terraces		196.2940	1125(kg)	0.0960/kg	1992
Soil-water conservation forests	Timber forests	226.5900	Stand growth 3.0m^3	47.9846/m^3	1994
	Non-timber producing forests	164.9920	Output *	0.1536/kg	1994
	Firewood forests	226.2840	6000kg	0.9597/10^{2}kg	1994
Grass plantations		123.1453	5025kg (hay)	0.0549/kg	1992
Total		937.3053			

* 262.50kg/ha for tea-oil, tung trees, Chinese tallows; 375.00kg/ha for tea; 12,000kg/ha for fruit; 150kg/ha for mulberries; 52.50kg/ha for Chinese prickly ash; 750.00kg/ha for Chinese chestnuts, walnuts; 112.50kg/ha for Chinese lacquer

Source: Ibid

Indirect Economic Benefits

The indirect economic benefits of the soil-water conservation project are described below.

Benefit of Water Storage. The water storage increment is calculated according to average annual precipitation, average annual runoff, and the type of soil-water conservation engineering.

Annual water storage by new soil-water conservation engineering methods is about 87,000 million cubic metres. The total benefit will be US$ 3.3391 million based on water costs at US$ 0.0038 per cubic metre.

Benefit of Soil Conservation. The synthesised data on soil erosion from a number of places in the upper reaches of the Yangtze River indicate that the soil-water losses will be reduced against the old level by soil-water conservation measures. The reductions are as follows:

- turning sloping farmland into terraces, 80 per cent;
- forests with technical soil-water conservation measures on slopes, 80 per cent;

- non-timber producing forests, 70 per cent;
- grass plantations, 60 per cent;
- conservative tillage, 60 per cent; and
- closing land for soil-water conservation, 60 per cent.

The value of soil conservation is based on the reduced capacity of reservoirs because of silting and the costs of unit reservoir capacity. According to the project target, the annual silting of reservoirs and other water projects could totally be reduced by 161 million cubic metres, the loss of reservoir capacity could accordingly be reduced by US$ 6.18 million per annum (at US$ 0.0384 cost of unit reservoir capacity) and these can be considered as economic benefits of soil conservation.

Benefit of Soil Fertility Conservation. This benefit is obtained from the quantity of equivalent fertiliser which is converted from N.P.K. contents in soil lost by erosion. The soil fertility conserved each year is equivalent to 6.7184 million tonnes of fertiliser at a cost of US$ 2.0845 billion.

Until the end of the project period, the soil-erosion prone area is projected to decrease from 1,70,544.90sq.km. in 1988 to 1,460.6sq.km., soil loss from 772.5088 million tonnes to 235.0392 million tonnes, and erosion modulus from 4,530T/sq.km. per year to 1,378T/sq.km. per year.

Increment of Vegetation Area and Coverage

In the project area, the forest land and pastureland will increase from 12.3329 million ha in 1988 to 18.4116 million ha at the end of the project period; vegetation coverage will increase from 28.4 per cent to 55.7 per cent.

Soil-Water Conservation Project

The soil-water conservation project can sustain the development of agriculture and other economic sectors and increase the anti-poverty capacity in soil-erosion prone areas because of the reasonable land use structure and improved eco-environmental conditions. At the end of the project period, the gross agricultural product will be U.S $ 11.4818 billion and it will be an increase of 192 per cent over 1988.

Case Study - The Project in Practice

Since 1989, 78 counties in the project area have started to implement the soil-water conservation project. Some progress has been achieved during the last two years (Sichuan Office for Soil-Water Conservation 1991).

(1) *Ningnan Case Study*

Ningnan County is located in southwestern Sichuan Province on the left bank of the Jinsha River and has a total area of 1,670sq.km. It has an area of 918.6sq.km. affected by soil erosion, accounting for 55 per cent of the total area. Until 1990, areas affected by soil erosion totalling 114sq.km. were brought under planned management and 957.6ha of sloping farmland were turned into terraces.

(a) Important Experiences. Some of the important experiences gained in implementing soil-water conservation projects are described below.

- Combining the conversion of sloping farmland into terraces and building water conservation projects, because water conservation is a major constraint to subtropical agricultural development in mountain areas. The benefit of converting sloping farmland into terraces is that irrigation systems are improved.

- Establishment of Demonstration Sites. Demonstration sites on the conversion of sloping farmland into terraces have been established. These need certain conditions such as easy access, a comprehensive management system covering the mountain area, water, forest, farmland, and infrastructure to a certain extent and with benefits of scale.

- System of rewards and penalties - the three points to be observed are given below.

  - The deadline is given to complete the conversion and this deadline should be kept, otherwise the farmers involved are fined.
  - Those converting the land will benefit from the new land for 30 years and will be given a land certificate to use the land.
  - Farmers who have fulfilled the contracted quota will be supplied with a certain amount of fertiliser at fixed government prices.

- Small-scale watersheds as basic units for soil-water conservation management.

b) Benefit of the Soil-Water Conservation Project. Huatan Township in Ningnan County received marked benefits from watershed management from 1989 to 1990. During these two years, sloping farmland of 225.6T/ha was converted into terraces. Ninety-six water conservation projects have been completed with a total length of 113km. A water pool containing 5,000 cubic metres of water has been repaired. In 1990, the total output of grain was 5.0150 million kilogrammes, and this was an increase of 20.2 per cent over 4.173 million kilogrammes in 1988. The average per capita grain output was 605kg; the total output of sugarcane was 613,000 tonnes, an increase of 46 per cent over 42,000 tonnes in 1988. The average per capita income in terms of selling sugarcane was US$ 94.8177. The total output of silkworm cocoons was 2,14,000kg, an increase by 188.6 per cent over 76,000kg in 1988. The average per capita income from the selling of cocoons was US$ 26.2956, and the total income was US$ 166.3628, an increase of US$ 124.7601 in 1988. Therefore, the living conditions of farmers have risen from "enough to eat and wear" to "well-to-do". The farmers in the township possess 916 bicycles, 14 motorcycles, 1,277 radio cassette recorders, 900 sewing machines, 1,513 colour television sets, 95 washing machines, and 19 vehicles. Their total savings' deposits are US$ 673,704.00.

The soil-water conservation project in the township has preliminarily functioned to attack poverty in areas affected by soil erosion to improve the local ecological conditions. For example, the area covered by vegetation accounts for 65 per cent of the total area.

(2) *Shizhong District of Suining City (County Level)*

The Shizhong district of Suining City is located in the central part of the Sichuan Basin on an area of 1,873.31sq.km. The total population is 1.29 million, out of which the agricultural population totals 1.16 million. The average per capita holding of farmland is 0.056ha. Since 1989, an area of 198sq.km. affected by soil erosion which contains 10 small-scale watersheds has been managed with preliminary benefits.

(a) Forest Coverage Increased. During the past two years, a soil-water conservation forest of 4,506.70ha has been planted. Non-timber producing and fruit forests account for 1,673.30ha, fuelwood forests 940.00ha, and 1,133.33ha have been closed to allow young plantations to develop. Forest coverage has increased from 6.6 per cent to 23.08 per cent.

(b) Soil erosion in the managed area has effectively been controlled. Integrated management of this area includes the following aspects:

- converting sloping farmland into terraces: 1,506 to 6,667ha;
- repairing old water pools: 349 items;
- constructing new water pools: 3,759 items;
- constructing sediment storage dams: 22,997 items;
- building flood drainage works and water tunnels: 1,408.00km; and
- conservative farming practised on 13,320.00ha.

According to a field survey of the managed area of 198sq.km., the total soil loss and erosion modules decreased from 1.7281 million tonnes and 8,728T/sq.km. per year in 1988 to 0.619 million tonnes and 3,116T/sq.km. per year respectively.

(c) Soil moisture increased. The field survey points out that, after converting sloping farmland into terraces during the rice-growing season, about 97 per cent of the total rainfall could be contained by the soil used. After afforestation on the wasteland in managed areas, runoff of about 0.5278 million cubic metres was held *in situ* during one year.

(d) Land carrying capacity improved. After converting sloping farmland into terraces, several changes could be observed:

- grassland on farmlands decreased by 13.5° on average; and
- the topsoil has increased, areas with topsoils of less than 30cm have increased by 79.9 per cent; areas with topsoil ranging from 30cm to 50cm increased by 54.9 per cent; and areas with topsoil of more than 50cm increased by 4.6 per cent.

(e) Grain output increased. In managed areas of 1,510.1333ha, grain output increased by 2.8003 million kilogrammes.

(f) Income increased in 1990, along with the agricultural income from grasslands in managed areas (US$ 18.7286 million), at the rate of 10.2 per cent over 1988. The average per capita income has increased from US$ 55.4702 in 1988 to US$ 71.7850.

(3) *Guangan County*

Guangan County is located on the western side of the middle section of the Huaying Mountains which stretch along the eastern borders of the Sichuan Basin. It has an agricultural population of 1.04 million. Areas affected by soil erosion total 1,019.9sq.km., accounting for 64.89 per cent of the total area with erosion modules of 7,351T/sq.km. per year.

(a) Progress. According to 1990 data on the project, since 1989 some achievements have been realised in the county. They are as follows:

- conversion of sloping farmland into terraces, 940.0ha;
- soil-water conservation forests, 1,486.6667ha;
- non-timber product forests, 7,600.00ha;
- grass plantations, 280.00ha;
- closing land for soil-water conservation, 820ha;
- conservation tillage, 5,926.6667ha; and
- water projects: 1,120 water pools, 192 small reservoirs, 16,075 silting basins, water diverting tunnels, 282km.

(b) Benefit from project progress. The landscape of some of the soil erosion-prone areas has changed. Nan Feng was at first a barren foothill. However, during the past two years, sloping farmland of 45.3333ha has been converted into terraced land of 80ha and this has been closed for reforestation - there is a peach orchard, a plum orchard, and a pear orchard of up to 20,000 fruit trees.

After converting sloping farmland of 940ha into terraced land, the topsoil depth on the new farmland of 40.67ha increased from 5cm to 50cm on terraces covering 540ha. The water-holding capacity also increased from 17 per cent to 20.5 per cent. Soil loss decreased by 69,100 tonnes and the contents of organic matter in the soil to 223.96 tonnes.

Terracing combined with a water conservation system on the slopes results in the runoff being conducted down the slope in a safe non-erosive manner.

In 1990, the grain output from the terraced area increased by 1.215 million kilogrammes being equivalent to the total grain output of one medium township. The per capita income increased by US$ 20.

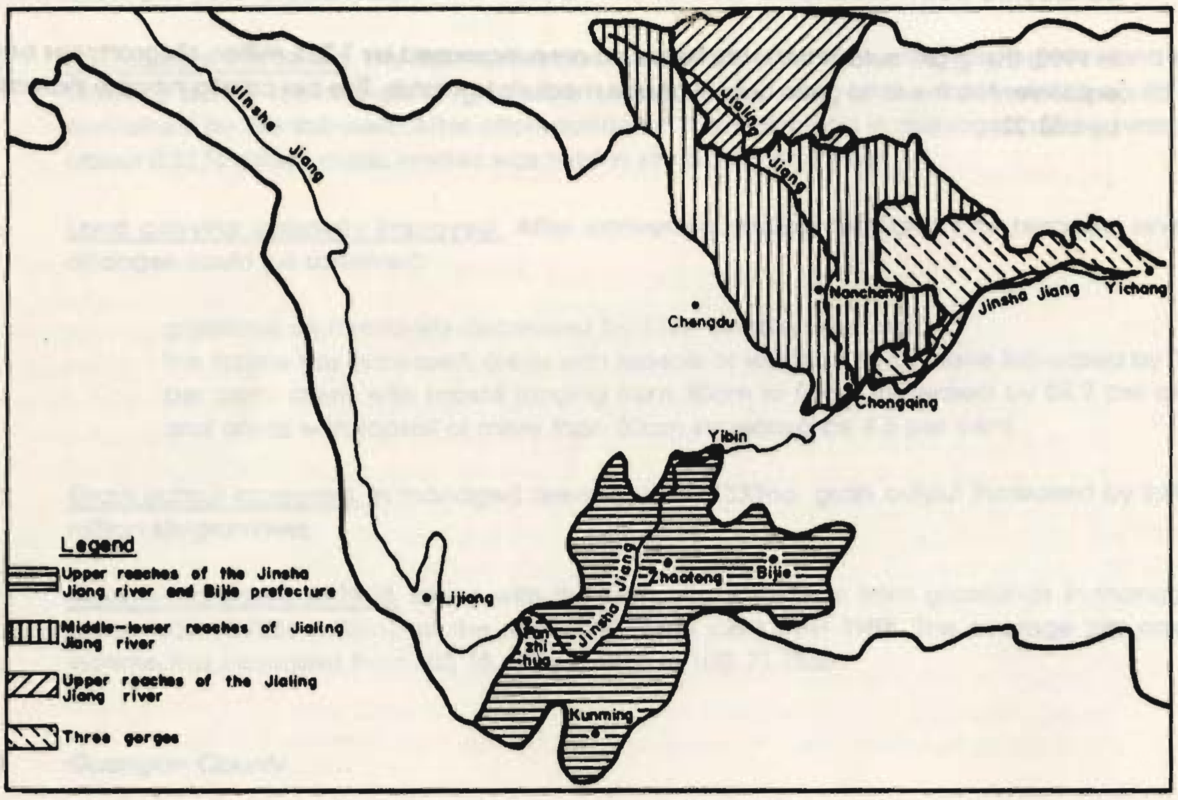
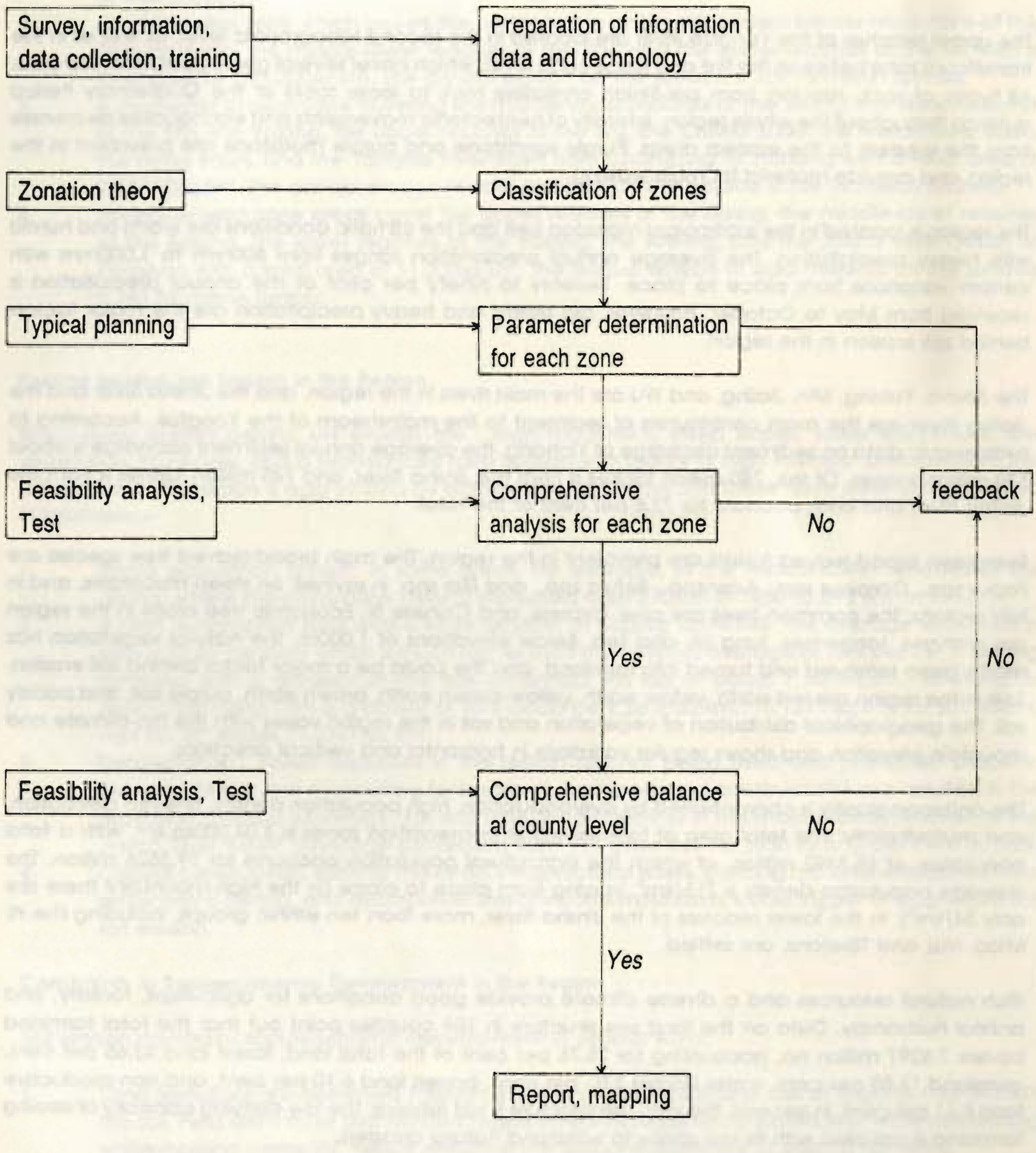


Figure 6.1: Sketch Map of the Four Key Soil-Water Conservation Zones in the Upper Reaches of the Yangtze River

Source: Commission Office for Soil-Water Conservation 1990

Figure 6.2: Flow Chart of Planning Procedures for Soil-Water Conservation in the Upper Reaches of the Yangtze River



Source: Commission Office for Soil-Water Conservation 1990

CONCLUSIONS

Environmental Conditions in the Region

The upper reaches of the Yangtze River are located in the second topographic level, as well as in the transitional zone between the first and the second levels which cover several geological structural units. All types of rock, ranging from pre-Sinian crystalline rock to loose rocks of the Quaternary Period outcrop throughout the whole region. Intensity of neotectonic movements and earthquakes decreases from the western to the eastern areas. Purple sandstone and purple mudstone are prevalent in the region and provide material for mass wasting.

The region is located in the subtropical monsoon belt and the climatic conditions are warm and humid with heavy precipitation. The average annual precipitation ranges from 800mm to 1,000mm with certain variations from place to place. Seventy to ninety per cent of the annual precipitation is received from May to October. However, big storms and heavy precipitation are the major factors behind soil erosion in the region.

The Jinsha, Yalong, Min, Jialing, and Wu are the main rivers in the region, and the Jinsha River and the Jialing River are the main contributors of sediment to the mainstream of the Yangtze. According to hydrometric data on sediment discharge at Yichang, the average annual sediment discharge is about 530 million tonnes. Of this, 240 million tonnes is from the Jinsha River, and 145 million tonnes is from the Jialing River and both account for 72.6 per cent of the total.

Evergreen broad-leaved forests are prevalent in the region. The main broad-leaved tree species are *Fagus spp., Carpinus spp., Acer spp., Betula spp.,* and *Tilia spp.* In ravines, on steep mountains, and in hilly regions, the common trees are pine, cypress, and Chinese fir. Economic tree crops in the region are oranges, tangerines, tung oil, and tea. Below elevations of 1,000m, the natural vegetation has mostly been removed and turned into farmland, and this could be a major factor behind soil erosion. Soils in the region are red earth, yellow earth, yellow-brown earth, brown earth, purple soil, and paddy soil. The geographical distribution of vegetation and soil in the region varies with the bio-climate and mountain elevation and shows regular variations in horizontal and vertical directions.

The anthropography is characterised by overpopulation, high population density, uneven distribution, and multiethnicity. The total area of four soil-water conservation zones is 3,04,000sq.km. with a total population of 65.3392 million, of which the agricultural population accounts for 59.3526 million. The average population density is 215/km^2, varying from place to place (in the high mountains there are only 34/km^2). In the lower reaches of the Jinsha River, more than ten ethnic groups, including the *Yi, Miao, Hui,* and Tibetans, are settled.

Rich natural resources and a diverse climate provide good conditions for agriculture, forestry, and animal husbandry. Data on the land use structure in 154 counties point out that the total farmland covers 7.8297 million ha, accounting for 25.75 per cent of the total land, forest land 43.65 per cent, grassland 12.88 per cent, water bodies 3.01 per cent, barren land 6.10 per cent, and non-productive land 8.61 per cent. In general, the land use structure is not rational. The low carrying capacity of sloping farmland is coupled with its low ability to withstand natural disasters.

Recent Status of Soil Erosion in the Region

Data on soil erosion in the upper reaches of the Yangtze River point out that the total area affected by soil erosion is 3,52,000 sq.km. accounting for 35 per cent of the total area of the upper reaches of the Yangtze River. The average annual soil loss is 1.568 billion tonnes. The region can be classified into four zones by taking erosion modules as the main classification index.

1. An indistinct erosion zone which covers the upper-middle reaches of the Jinsha, Yalong, and Dadu rivers and the upper reaches of the Min, Balong, and Chengdu Plains with a total area of 4,64,200sq.km.
2. A mild erosion zone which covers the northeastern and northwestern border mountains of the Sichuan Basin, the middle-lower reaches of the Wu, and the upper reaches of the Qi, with a total area of 1,76,200sq.km. The annual erosion on the surface is 209.15 million tonnes.
3. A moderate erosion zone covering the middle-lower reaches of the Jialing, the lower-reaches of the Min, the Yalong, the upper reaches of the Wu, the Chishui Basin, the Niulan River Basin, the Heng Basin, and the Yangtze River Basin from Changzing to Yichang with a total area of 2,43,100sq.km. The annual erosion of solid material on the surface is 769.94 million tonnes.
4. Several erosion zone areas cover the upper reaches of the Jialing, the middle-lower reaches of the Balong, the lower reaches of the Yalong, the Anning, and the Jinsha from Dukou to Pingshan with a total area of 11,200sq.km. The annual erosion of solid material on the surface is 383.52 million tonnes.

Factors behind Soil Erosion in the Region

The natural factors behind soil erosion are : high mountains, steep slopes, loose soil texture, low vegetation coverage, and a pronounced rainy season with plenty of high intensity precipitation. The soil erosion in the region is aggravated by anthropogenic factors and these have been recapitulated in brief below.

1. Rapid population growth in some areas. For example, in the middle-lower reaches of the Jialing, where the population density increased from 370km^2 in 1950 to 596 km^2 in 1987.
2. A high reclamation ratio and a large amount of sloping farmland. The average reclamation ratio is 32.46 per cent which is much higher than the national average of 10.4 per cent. Sloping farmland with a gradient of five has an annual soil loss of about 7,14T/sq.km., whereas for sloping farmland with a gradient of 10 it could be 9,260T/sq.km., 15,137T/sq.km. for 20° slopes, and for 25° slopes 21,334T/sq.km.
3. Deforestation. Forest resources in the region are not being used and protected properly. Excessive felling and overcutting for farmland, fuelwood, and construction have resulted in the reduction of forest coverage. For example, in 15 countries in the middle-lower reaches of the Jialing River, forest coverage decreased from 19.75 per cent in 1950 to 8.92 per cent in 1989.
4. Capital construction, such as mountain infrastructural works, building material enterprises, new settlements, mining, and hydropower stations in the mountains, could trigger or aggravate the soil erosion.

Constraints to Socioeconomic Development in the Region

Soil erosion constrains socioeconomic development in several ways.

1. Land resources are destroyed through the thinning of topsoil and loss of organic matter from the soil. Field data show that thinned topsoil could increase runoff coefficient while decreasing water-holding capacity, hence reducing the drought resistance of sloping farmland.
2. The silting of rivers and water projects.
3. Degradation of eco-environmental conditions and poverty.

Until now, people in many areas affected by soil erosion are living beneath the poverty line. In Guizhou Province, there are 11 counties in the Yangtze River Basin, of which 10 counties are affected by soil erosion. In Yunnan Province, 71.4 per cent of the poor counties are located in areas affected by soil erosion.

Soil-Water Conservation in the Region

How to make these normally productive? Some of the aspects that should be taken into consideration in the future are given below.

1. Promulgated laws and regulations concerning soil management and soil-water conservation such as "The Law of the People's Republic of China Conservation Environmental Protection" (September 13, 1991); "The Forest Law of the People's Republic of China" (September 20, 1984); "The Law of the People's Republic of China on Land Management" (June 25, 1986); and the "The Soil-Water Conservation Act" should be effectively enforced in soil management and soil-water conservation projects.

2. In China, many authorities are working on soil management and soil-water conservation because of their own concerns. This causes overlapping or gaps in soil-water conservation projects. Therefore, an authorised agency is needed to coordinate the work vertically and horizontally.

3. Full and rational use of local natural resources and disposition of conservative farming, biological measures, and engineering in line with local conditions.

4. Radical planning and integrated management with high benefits. Priority should be given to the following aspects.

   (a) Converting sloping farmland for agriculture into terraces in order to increase the unit output of farmland and solve the "eat and wear" problem of poor farmers. In the middle and lower mountain areas, the reclamation coefficient should be restricted from 0.3 to 0.5 for farmland in foothill areas with a population density of 700 km^2. Sloping farmland unsuitable for agriculture should be converted into forest land and grassland.
   (b) Soil-water conservation should be combined with market economy developments in order to increase the income of the local people in soil-water conservation areas. For example, in the middle-lower reaches of the Jialing River, mulberry plantations and sericulture should be developed; the lower reaches of the Jinsha River have good sunshine and thermal conditions for sugarcane and diverse fruits to grow.
   (c) Build small-scale water conservation projects and carry out soil-water conservation engineering. Form a water system composed of ditches, water pools, and sediment storage dams on the slopes.
   (d) Integral combination of conservative farming, biological measures, and soil-water conservation engineering.
   (e) Soil management and soil-water conservation on benefit-gains' scales. Soil-water conservation on odd areas of farmland should be changed to proper watershed management practices.
   (f) Family planning is a necessary measure for successful soil-water conservation and the education level of the local people also needs to be increased.

REFERENCES[1]

Academy of Survey and Planning of Forestry, 1981. *The Physical and Chemical Properties of Purple Soil*. Sichuan Province, China: Academy of Survey and Planning of Forestry.

Beijing Institute of Geography, 1983. *General Introduction to Agricultural Geography of China*. Beijing: Science Press.

Bureau of Hydraulic and Hydroelectric Engineering, 1981. *Selected Statistics*. Shanxi Province: Bureau of Hydraulic and Hydroelectric Engineering.

Carpenter, R.A., 1983. *Natural System*. New York: Macmillan Publishing Company.

Chai Zong Xin, 1985. "Preliminary Analysis of Soil Erosion in Panxi District". In *Sichuan Geography*, Vol.7. Sichuan: Society of Physical Geography.

Chang Hong, 1990. *Integrated Survey of Land Resources and Study on the Strategy of Development in Southwestern China*. Beijing: Science Press.

Cheng Hun, 1990. *Integrated Survey of Land Resources and Study on Stragegy of Development in Southwestern China*. China: no publisher given.

Chengdu Institute of Mountain Disasters and Environment, 1980. *Agricultural Geography of Sichuan Province*. Sichuan: People's Press.

Chengdu Institute of Mountain Disasters and Environment, 1988. *Integrated Analysis of Soil Erosion in the Upper Reaches of the Yangtze River*. Chengdu, Sichuan: Unpublished manuscript.

Chengdu Institute of Mountain Disasters and Environment, 1983. *General Introduction to the Agricultural Geography of China*. Chengdu: CIMDE.

China Handbook Editorial Committee, 1983. *Geography of China*. China: CHEC.

Chongquing Normal College, Department of Geography, 1987. *Chongquing College Field Survey*. Chongquing, China: Chongquing Normal College, Department of Geography.

Commission Office for Soil-Water Conservation, 1990. *Report on the Master Plan of Soil-Water Conservation in the Upper Reaches of the Yangtze River*. Beijing: Soil-Water Conservation Commission Office.

Commission Office for Soil-Water Conservation, 1980. *Soil-Water Conservation in the Upper Reaches of the Yangtze River*. Sichuan: Soil-Water Conservation Commission Office.

Domros, M. and Peng Gongbing, 1988. *The Climate of China*. Berlin, Heidelberg, New York: Springer - Verlag.

Dong Zhiyong, 1986. "Recent Situation of Forest Administration in the South-western Region of China and its Role in River Basin Management". In *Proceedings of the International Workshop on Watershed Management in the Hindu Kush-Himalayan Region*. Kathmandu: CISNAR and ICIMOD.

---

[1] Some references lack details because they were translations from the Chinese.

ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of envirornmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

Mountain Environmental Management constitutes one of the four thematic research and development programmes at ICIMOD. The programme is concerned with sustainable use and management of natural resources and the impact of development activities on the mountain environment. This programme is devoted to the scientific and technical understanding of biophysical aspects of mountain environment vis-a-vis traditional and modern human-use systems through appropriate research, state-of-the-art reviews, and field studies. Proper understanding of the functioning of natural systems and their interrelationships with the development needs of the people provides the basis for the sustainable development of mountain ecosystems.

Director General: Dr. E.F. Tacke

International Centre for Integrated Mountain Development

G.P.O Box 3226, Kathmandu, Nepal

Telex : 2439 ICIMOD NP   Cable : ICIMOD NEPAL

Telephone : (977-1) 525313   Fax : (977-1) 524509