# INTRODUCTION

ICIMOD collaborated with CISNAR in the organization of an International Workshop on Watershed Management in the Hindu-Kush Himalaya Region which was held in Guanxian and Chengdu, Sichuan Province, October 14-19, 1985.

ICIMOD considers it important to conduct such workshops in its member countries, which makes it possible to focus on the ideas, activities and experiences of each host country, on particular subjects. It also enables professionals from outside the host country to share experiences with a large group of the host professionals. Another important result of such workshops is that it provides the opportunity for a fairly large group of host professionals to contribute on different aspects of the workshop subject.

The Workshop's objective was to review and evaluate progress and constraints in the field of Watershed Management, to identify priorities and to promote regional cooperation in the Hindu Kush-Himalaya.

The Chengdu Workshop was especially important in that it was able to solicit contributions from more than 30 leading Chinese professionals.

This publication of Collected Papers from the Chengdu Workshop is unique in that, for the first time 20 very important papers addressing the issues and aspects of watershed management, covering the Himalaya and Hengduan Mountains, in Southwest China, have been put together in one volume. It offers the readers the opportunity to know the approach and priorities of the watershed management activities of the Chinese professionals.

Although the some of the papers are only extended summaries of the original papers in the Chinese language, they nevertheless, reflect the depth and degree of investment in research and development works by Chinese professionals in the management of natural resources. A full text version of this volume is also available in the Chinese language.

This volume of Collected Papers is divided into three theme groups:

- A review of fundamental aspects of watershed management, from the historical perspective to the present issues of natural resource management in the Mountain Region of Southwestern China and a comparative analysis of conditions in Hengduan and Himalaya mountains.

- Present constraints and potentials of natural resource management for the economic development of the mountain regions, covering such aspects as forest, animal, grassland, energy and waterbodies.

- Geo-ecological conditions and environmental problems, and debris flow phenomena, as well as guidelines for research in the dry valleys of the Hengduan Mountains.

A comprehensive bibliography on the exploitation, Management and Utilization of Natural Resources in the Hengduan Mountains, prepared by the Chinese Academy of Sciences, is presented at the end of the book.

# WATERSHED MANAGEMENT IN MOUNTAIN REGION OF SOUTH WESTERN CHINA

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## INTRODUCTION

Watershed management is a key to successful integrated mountain development. This is particularly true while considering such fragile ecosystems as the Himalaya Hengduan Mountain areas.

The physio-graphical and socio-economical conditions of this region are characterized by their diversity and complexity. A large number of highly differentiated ecosystems occur within a small geographical area. Despite the diversities, there are a number of common problems in watershed management of the region. The population has increased rapidly during the last few decades. The impact of population has led to increased use of marginal, easily eroded lands and overgrazing of fragile upland pasture areas. Forests are being cleared at an ever increasing rate for firewood, timber and additional grazing lands. When the forest disappears and environmental deterioration begins, great relief and steep slopes accelerate rapidly, aggravating the process of site destruction, such as soil impoverishment, massive erosion and frequent landslides.

For the purpose of solving these problems we need to develop a new balance, which will be consistent with the socio-economic needs of the people who live there, and with the reasonable and sustainable carrying capacity of the land and its resources. During the last years it appears that solutions were not being reached by individual sectoral efforts or isolated measures. What is needed is a comprehensive approach to development that encompasses the many complex factors involved in the functioning of the man-environment system of the Hindu Kush-Himalaya-Hengduan regions. This integrated approach should also be adopted by watershed management (WSM).

The term "watershed" is normally used to indicate the area of land that drains into an individual stream or lake. Thus a watershed may only be a few hectares in area or may consist of a drainage tens of thousands of square kilometers in area. Rational WSM means the management of land and resources within a watershed in such a manner as to obtain the optimum economic, social and ecological benefits.

An integrated approach to watershed means that the development of a watershed must take into account environmental conservation. The development of an individual watershed must be linked with regional and national planning. The development of agriculture in watersheds should be linked with energy, transport, construction, industrial and commercial sectors. In addition, integrated development plans for watershed management must take into consideration the social issues, policies, legislation and prevailing education system. Finally, integrated WSM plans will never be successful without the joint efforts of three groups: policy makers and advisers; scientists and technicians; and the local people.

During the last few decades considerable efforts have been made by the countries of the Hindu Kush-Himalaya region. In spite of this increased attention being paid to WSM in the region, deterioration of resources and degradation of the environment do not appear to have been arrested.

In order to exchange experiences, identify existing problems and future prospects in the field of WSM, and to explore the possible solutions to the identified problems this country review paper has been prepared.

WSM is an important problem in China. Considerable work has already been carried out in the different regions. The area discussed is confined to the Himalaya and the Hengduan Mountains located in the southern part of the Xizang Autonomous Region (Tibet), and the western section of the provinces of Yunnan and Sichuan.

## GEOGRAPHICAL SITUATION AND PHYSIOGRAPHICAL CONDITIONS OF STUDIED AREAS

### Geographical Situation and Topography

The mighty Himalaya range, 2,400 kms long and 200-300 kms wide, with a mean elevation at the central axial ridge of 6000 m extends from the west to the east on the southern rim of the plateau, and is by far the youngest and most lofty of the world's mountain systems.

The Himalaya system consists of several parallel ranges, for example, the Siwalik, the Lesser Himalaya, the Great Himalaya and the Tibetan Plateau to the north.

The Great Himalaya, 50-90 km wide with a mean elevation at the ridge of about 6000m is characterized by snow-covered lofty peaks. There are more than 50 peaks with an altitude of above 7000m and 11 peaks above 8000m towering to the highest peak - Mt. Qomolangma or Sagarmatha with an altitude of 8848m in the Central Himalaya.

Based on the results of multi-disciplinary expeditions undertaken in the last decade, it is confirmed that the Himalaya and the Quinghai-Xizang Plateau is the product of a collision between the Indian and the Eurasian Plates.

Under the control of the geological structure and topographical configuration a series of deep transverse gorges were cut into the Himalaya range, forming a considerable number of natural channels within China, India, Nepal and Bhutan, which indicates the importance of cooperation in WSM of the Himalaya-Hengduan region.

The topography between the northern and southern aspects of the Himalaya is fully asymmetrical, especially in the Central Himalaya. In the south, the main ridge of the Great Himalaya rises abruptly to 6000 m above the Ganges Plain and forms steep slopes having strong fluvial erosion. In the upper reaches of the rivers and their tributaries, U-shaped glaciated valleys are well developed. As a result of recent river- sculptures, the valley forms change from wide trough to typical V-shaped valleys. In some cases there is an uplifting of the mountain systems and the landform "valley-in-valley" may occasionally be seen throughout the whole region. Settlements, such as Chentang and Xiebugang, are normally located on the level shoulders, above the knick point in their transverse profiles.

In contrast with the montane region of the southern flanks, the topography of the northern Himalaya consists of gently descending slopes with a relative elevation of 1200 - 1500m. Skirting the northern slopes of the Himalaya is a series of platform-like remnants of the peneplain, moraine platform, with broad basins and valleys separated by lower montanes and hills with relative elevations of 200 - 500 m.

The plateau of South Xizang is located to the northern side of the Himalaya with broad valleys and basins, with extensive piedmont depositions. With cold-dry conditions, sand dunes and drifts are created alongside the rivers providing a sandy phenomenon.

The Hengduan Mountains "Traverse Block Mountains", located in southwestern China, are composed of a series of high mountain ridges sandwiched between deep river gorges. The main mountain ranges, from west to east, are the Boshula, Taniantaweng, Mingjing-Mangkang Shan, Chola Shan-Shalulu Shan, Daxue Shan-Zhedo Shan, and the Qionglai Shan, with the Nu-jiang, the upper reaches of the Salween River, and their numerous tributaries between. All cut deeply as parallel gorges, hence the region of the Hengduan Mountains is topographically well known as the "River Gorge Country" or "Meridional River Gorge". In the northern section, from 30°N, the rivers run in a northwest-southeast direction with

some slight gradients. Fluvial terraces and flood lands occur within a number of broad valleys. South from 30°N, the rivers are north-south orientated and are characterized by deep cut gorges with narrow river beds, steep valley walls, swift torrents and large gradients in the rivers. Terrace and flood lands almost disappear at the base, however mudflows, debris-flows, landslides and slope-slips occur frequently.

The northern section of the Hengduan Mountain Region is characterized by a slightly dissected plateau with gentle slopes. The altitudes of the plateau surface descend from 4500m in the west, to 3500m at the eastern edges. In the middle section of the Hengduan Mountains the plane of the plateau, elevation 4000-4500m is seen in the Shaluli-Shan Region. Broad valleys of gentle relief occur, with relics of former glacial caps and well developed landforms resulting from glacial erosion. Above the plane of the plateau there are several peaks with an elevation of more than 6000m, for example Mt. Gongga Shan (7556m), Mt. Chola Shan (6168m) and Mt. Genie (6240m). The snowline is at 4900-5500m. Generally the snowline inland is higher than in the lower margins. The area of recent glaciation in the Hengduan Mountains is only 1456 $km^2$, less than generally found in the Himalaya.

The southern section of the Hengduan Mountain region consists of series of lake basins, middle mountains and plane of plateau with an elevation varying from 3000 to 2000m. The combination of landform types includes: mountain- plane of plateau, undulating plain; fluvial plains and lacustrine plains. The topographic characteristics of the region are similar to those of the Yunnan Plateau.

Also in this section basins with lower altitudes and with gentle relief favourable for cropping have created an important agricultural region in the Province of Yunnan.

The intensive neo-tectonic movement plays a significant role in land formation. The divided area of the northern section of the Hengduan Mountains, with broad plane of plateau, is conserved with a relative dissected depth of 1000-1500m. The middle and southern sections as well as the marginal area of the region are characterized by the intensive fluvial process with deep cut gorges, narrow divides, steep valley slopes and a relatively dissected depth of 2000 - 2500m.

At base of the gorges, because of steep slopes, intensive physical weathering, and instability of slope surfaces a variety of deposited landforms occur such as debris cone, and debris avalanche. Landslides, slope-slips, mudflows and debris flows occur frequently, especially in the rainy season.

**Thermal-Moisture Regimes**

Located in the middle and lower latitudes both the Himalaya and the Hengduan Mountains, in the tropical fringe and subtropical zone, are influenced by the Asian monsoon climate.

During the winter period from November to April, both these mountainous regions are influenced by the south-westerly jet stream. It has abundant sunshine, dry and rare precipitation, especially to the northern face of the Great Himalaya. The winter precipitation, derived from disturbed westerlies, has significance- particularly in the Western Himalaya.

In the summer half-year from May to October, the southwesterly jet stream withdraws northwards. The southern moisture-laden monsoon reaches from the Indian Ocean to the Himalaya and Hengduan mountains, bringing heavy rainfall on the southern. flanks of the Himalaya and on most areas of the Hengduan Mountains, particularly from June to September.

The eastern foothill zone of the Himalaya is the most humid area, with an annual rainfall of 2000-4000mm; the rainfall decreases to the west with an annual precipitation of 1000-2000mm on the southern flank of the Central Himalaya. In the western Himalaya the precipitation is 500-1000mm. The Himalaya, extending along the southern rim of the Plateau, is an effective climatic barrier. On the

northern side of the Himalaya is a rain shadow area with an annual precipitation of 200-300 mm. Further westward the annual precipitation is lower than 200 mm.

The seasonal distribution of precipitation in the studied area is clearly seen. 90% of the total precipitation falls in the period from June to September on the northern face of the Himalaya, with 80% of the total precipitation, during the same period, being registered on the southern flanks of the Central Himalaya. In the inner area of the Great Himalaya snowfalls occur during winter and spring. The percentage of precipitation during monsoon (June to September) is lower on the southern flanks of the East and West Himalaya.

In the Hengduan Mountain Region the precipitation regime is distinctly different to that of the Himalaya. The eastern side of the Qionglai Shan and western edges of the Gaoligong Shan receive an annual precipitation of 1200-1600mm. The majority of meteorological stations in the region record a mean annual precipitation of 500 - 900 mm, with 80 - 95% of the fall during the period from May to October. Due to the disturbing trough of westerlies with copious convections, the western edge of the Hengduan Mountains has significant rainfall during spring. A distinct difference in precipitation is recorded between the Luv and the Lee slopes, e.g. Baoshan and Tengchong, located on the east-facing slopes and the west-facing slopes of the Gaoligong Shan, receiving annual precipitation of 966mm and 1464mm respectively.

At the bases of the gorge sections of three rivers, the Nu Jiang, the Lancang Jiang and the Jingsha Jiang, inland of the middle section of the Hengduan Mountains, located at 28-30°N, is climatically a centre of rare precipitation, due to topographic configuration and atmospheric circulation. Perhaps this results from the foehn effect of dry valleys with an annual precipitation of 300 - 500 mm only. The dry valleys occur extensively in the Hengduan Mountains with examples also in Bhutan and Nepal in the Central Himalaya area.

The temperatures in the Hengduan Mountains are lower than those in the Himalaya, and temperatures in the humid region are lower than in the arid regions. Temperatures drop according to the latitudinal situations from south to north (Table 1).

**Table 1: Thermal-Moisture Regimes of Hengduan Region**

| Type | Altitude (m.a.s.l) West | East | Mean (°C) Temp. (of Warmest month) | Accumu-Temp.(°C) (during 10°C period) | Main Crops and Cropping System | Main Livestock | Main Vegetation Type |
|---|---|---|---|---|---|---|---|
| Cold | | | | | | Yak, sheep, horses | Alpine meadow |
| Cool | 4300 | 4100 | 10 | - | Spring highland barley spring wheat (single crop) | Cattle, yak, sheep | Montane dark coniferous forest |
| Temperate | 2800 | 2600 | 16 | 2000 | Spring wheat, winter wheat,potato,buck wheat (single crop) | Cattle, Sheep, goat | Montane conife-rous forest |
| Warm | 2400 | 2100 | 20 | 4000 | Maize, winter wheat (double crop) | Cattle, goat, pig | Mixed needle and broad leaved forest |
| Hot | 1200 | 900 | 24 | 6000 | Rice,maize, (double crop) | Cattle,Buffalo, goat, pig | Evergreen broad leaved forest |
| Very Hot | | | | | Rice, sugarcane (double crop) | Buffalo, goat, pig | tropical forest |

**The Altitudinal Belts and Regional Variations**

In comparison to the base and prevailing belts, the spectrum in the altitudinal belt between the flanks of the Himalaya is quite different. The spectrum in the southern flanks of the Central and Eastern Himalaya, consisting mainly of montane forest belts, is of the maritime system. It comprises chiefly of two types:

- Base-belt of tropical evergreen and semi- evergreen rainforest,
- Base-belt of lower montane tropical monsoon decidious forest.

The evergreen rainforest consists chiefly of *Dipterocarpus tubinatus, D. macrocarpa, Mesuaferrea, Artocarpus chaplasha, and Tetrameles nudiflora.* The upper storey is of semi- evergreen rainforest dominated by deciduous trees, *Terminalia myriocarpa, Altingea excelsa, Lagerstroemia minuticarpa and Homalium zeylanicum,* including *Castanopsis indica, and Talauma hodgsonii.* The lower storey consists of evergreen trees, including *Castanopsis indica* and *Talauma hodgsonii.* In the valley of the Yarlung Zangbo the tropical evergreen rainforest reaches to the north as far as *Siging* (450m) and the semi- evergreen rainforest to the north of Medog (1000m, 29°N).

The lower montane belt of evergreen broad-leaved forest consists of evergreen *Fagacea*, among which the genus of *Castanopsis and Cycloblanopsis,* characterized usually by the mossy forest, being the prevailing belt of the spectra. The montane needle-and broad-leaved forest belt and the montane coniferous forest belt are respectively dominated by hygrophilous forest of *Tsuga dumosa and Abies delavayi.*

On the southern flanks of the Central Himalaya the base-belt of tropical monsoon deciduous forest is dominated by *Shorea robusta,* with upper limits of 1000-1200m. The mixed coniferous and broad-leaved forest belt consists of *Tsuga dumosa* on the shady slopes, and *Pinus griffithii and Quercus semecarpifolia* upon the sunny slopes.

The southern flanks of the western Himalaya, located in northerly latitudes of semi-arid climate, possess a base-belt of spectra composed of forest, *Pinus roxburghii,* and dense scrub growth of *Acacia and Zizyphus.* At higher elevations forests of *Pinus gerardiana* and oak are present. This type of spectra seen in the altitudinal belt may be considered to be of a transitional type ranging between maritime and continental systems.

In contrast to the spectra on southern flanks, the altitudinal belt of the continental system is present on the Tibetan plateau situated on the northern flank of the Himalaya. The base-belt and the prevailing belt of the spectra on the alpine steppe is composed of *Stipa purpurea, Artemisia wellbyi, and A. younghusbandii.* In the arid region of the northern flanks of the western Himalaya, the montane desert, and the desert-steppe, growth consists chiefly of *Ceratoides latens and Stipaglareosa,* which are the base-belt of spectra within the altitudinal belt.

The spectra on the altitudinal belt vary in the Hengduan Mountains from south to north. In the southern section of the Region the montane evergreen broad-leaved and coniferous forest of *Pinus yunnanensis* compose the base-belt of the spectra. In the hot and warm-dry valleys shrub- grassland, *Phyllanthus emblica, Jatropha curcas, Euphorbia antiquorum, Bauhinia faberi, Heteropogon contortus, Cymbopogon distans*, is present.

In the middle section of the region the mixed coniferous and broad-leaved forest belt is composed of the montane *sclerophilous* evergreen broad-leaved forest and montane coniferous forest. The former, consisting of *Quercus aquifolioides*, plays a significant role in the landscape of the Region. The latter is composed of *Pinus densata, Tsuga dumosa and T. chinensis.* At the base of temperate and cool-dry valleys the thorny shrub consists chiefly of *Sophora vicifolia, Bauhinia faberi, and Sageretia phenophylla.* The upper montane coniferous forest, consisting of *Picea balfouriana, Abies squamata, A. georgei and A. ernestii*, prevails in the spectra of the altitudinal belt.

A base-belt of the alpine shrub and meadow occurs widely in the northern section and gentle relief area. Generally the shady slopes are covered by alpine shrubs, consisting chiefly of *Salix spp., Rhododendron nivale, R. Spp., Sibiraea angustata, and dasiphora fruticosa.* On the sunny slopes occur the shrubs of *Sabina pingii* and the alpine meadow, dominated by *Kobresia pygmaea, K. setchwanensis, K. spp., Polygonum macrophylla, P. viviparum, Festuca ovina, ·Anaphalis flavescens* and *spenceria ramalana,.*

The altitudinal variation of the natural environment gives rise to corresponding variations in the distribution of crops and livestock.

## THE GENERAL STATUS OF THE ECONOMIC DEVELOPMENT IN THE STUDIED REGIONS

The Himalayan-Hengduan Mountains are remote areas with extremely limited access to transportation, education possibilities and scientific technologies resulting in slow economic development. The gross industrial-agricultural output accounts for just about 4.8% of that of Sichuan, Yunnan and Tibet. Development of economies relates directly to regional differentiation. In general, the economies of the eastern section are more developed than those of the western section.

The Daduhe basin, in close proximity to the Sichuan basin, with a favourable geographical position, convenient transportation and rich agricultural resources, has become one of the most developed areas of the region. The predominant economic activities are forestry, industry, mining, textiles and crop farming.

Jinshajiang River basin as a whole has a rather low level of development. The industrial city of Duko is situated in the middle reach of the basin. The gross industrial-agricultural output is higher than that of other river basins. The population of Duko is 15% of the total population of the basin. It provides 59% of the gross industrial and agricultural output of the basin. In the upper reach of the basin the major economic sector is animal husbandry, while in the lower reach the major economic sectors are metal, mining and forest industries, and crop farming.

Located on the western border of the Hengduan Mountains, the Nujiang and Lancangjiang River basins have limited transportation facilities and slow economic development. Existing is a rich forest and nonferrous metal reserve, which remains to be exploited. The major production sectors are animal husbandry, crop farming and a limited timber industry.

The development level within the Yarlunzangbojiang River basin is comparatively low. In the upper reach animal husbandry is the major economic activity with crop farming and forestry in the middle and lower reach.

### Crop Farming

Many parts of this region have a very long history of cultivation. Approximately four-fifths of the population are involved, directly or indirectly, in agriculture. Despite this, the cultivated rates of this region are very low (0.5 - 2.5%), as almost all the land suitable for farming has been cultivated. The arable land per capita only amounts to 0.1 - 0.16 hectares. Agriculture in this region is self-sufficient. Cereal crops yield 90% of the total crop from cultivated land. In general, naked barley, wheat, rape, peas and potatoes are the five staple crops widely grown in the high altitude areas. The higher the elevation, the greater the percentage of spring naked barley and wheat grown. In the sub-tropical and tropical areas the main crops are rice and maize. Cultivation is extensive and irrigation assurance level low. Shortages of fertilizer and natural disasters are common events for the whole region. In certain limited areas cereal crops can yield high productivity. Overall the crop yield in the region is rather low, and is only 73.8% of the average yield of south western China. Although per unit yields have increased, population growth has kept pace, resulting in a per capita cereal production of approximately 350 kg.

Owing to population pressure, lands have

extended to the steep slopes. It is estimated that crop lands on slopes, with a gradient of more than 25°, are 25-30% of the total arable land area. In the Jinchuan County 7% of the total croplands are distributed on slopes with a gradient of more than 30°. The phenomenon of cleared forests for land cultivation is conspicuous in the marginal areas neighbouring the montane forest belt. This process leads to an ecological imbalance, soil erosion and landslides.

**Forestry**

The forests of this region are characterized by a rich floristic composition, wide diversity of vegetation, and relatively high productivity. According to a forest survey, in the region of Xizang the area covered by different types of forest total 6.3 mio ha with a timber stock of 1.4 billion $m^3$. In the Hengduan mountain region the total afforested area consists of 7.3 mio ha with a timber stock of 1.3 billion $m^3$.

For 30 years the process of deforestation has been wide spread, and clearing of forests for grazing, cultivation, and firewood has rapidly depleted the forest cover.

In the upper reach of the Minjiang basin, located in the northeastern part of the Hengduan Mountains, the forest cover decreased from 50% in the Yuan Dynasty (1271 - 1368 AD) to 30% in 1949. Since then it has reduced to 18.8%.

In Western Sichuan 160 mio $m^3$ of timber, 1/5th of the total forest resource stock was consumed in the last 30 years. Forest exploitation is 2.3 times more than the forest productivity.

Demand for firewood continues to be a major problem for the environment, and is closely correlated to deforestation, leading to the heavy depletion of natural vegetation. In general, forest resources consumed for cooking and heating are greater than the demand for timber. In Liaoshan county, Yunnan Province, 0.46 mio $m^3$ of timber were consumed in 1979, 3/4 of which was used for cooking and heating.

The most significant feature of the mountains in southwestern China is the rich composition of flora and fauna. 10,000 varieties of higher plants have been recognized. Many of them belong to *endemic* threathened species with high value for economic and scientific uses. More than one third of the fauna species of the country are clustered in the region. An estimated 50 vertebrata and birds are threatened with extinction. The representatives of them are Ailuropeda melanoleuca, Rhinopithecus bieti, Cervus alherostris, and Grus nigricullis. Deforestation in company with over-exploitation of wild life leads to degradation of the environment, destruction of the life support system, and extinction of valuable species.

Since the founding of the People's Republic of China, efforts to plant trees and enclose forest areas for natural reproduction have achieved successful results. Relatively successful programmes have achieved the reforestation of sub-alpine coniferous forests. Aerial seeding has also been introduced in this mountainous region. The effectiveness of this reforestation method is now being verified. Especially effective has been the aerial seeding of pine forests in Xichang, Sichuan Province.

**Animal Husbandry and Grazing Land**

The Himalaya-Hengduan Mountain region is a vast deposit of natural grazing land suited for the development of animal husbandry. The region is also rich in livestock species.

The domestic animals, such as yak, sheep, goat and horse reared mainly in rangland ecosystems, are eurochoric species. They are widely found in pastoral and semi-pastoral areas. The domestic animals in the agricultural ecosystems, i.e. cattle, donkey, buffalo, zebu and swine are stenochoric, being mainly distributed in the agricultural and semi-agricultural regions.

Although animals and livestock easily adapt to natural environments, the cold resistant livestock, i.e. yak, sheep and goat total 96% of the herds on the plateau. Yak is mainly found in the sub-humid regions.

There are various types of grassland: Cold

alpine meadow, alpine meadow, alpine steppe, lake basin meadow, mountain shrub, mountain sparse woodland, and alpine desert. Amongst them the cold alpine meadow is the predominant one. The production from meadow land is low (400-1000 kg/ha dry matter), 4-6 times lower than Inner Mongolia. However herbage is richer in nutrition.

The number of domestic animals has increased very rapidly in the last decades. The camping time of alpine meadow is 150 - 240 days if the warm season pasture land is fully utilized to develop livestock. The pasture will lack 20.1% of herbage in the cold season. As the pressure on pasture is heavy, there is a constant danger of overgrazing. Overgrazing can take place in two ways, either by grazing too many cattle or allowing them to remain at one place for long periods.

**Industry**

Industrial production is 53% of the total for the region, 64% of the industrial output is from Duko City. If the output of Duko is excluded, the industrial output value of the whole region consists of 30% of the total.

In accordance with the conditions of the region, there are two promising industrial sectors:- metallurgy and the agricultural processing industry.

The agricultural processing industry includes cigarette, wine and liquor, and tanning industries.

## POLICY AND LEGISLATION CONCERNING WATERSHED MANAGEMENT

Soil erosion is a serious environmental problem in the mountain regions of China. In order to improve the situation the government has enacted several policies and provisions.

The Chinese government attaches great importance to WSM, and has in fact issued a series of legislations and policies relating to this.

The government considers protection and environment improvement to be an important issue and includes within the constitution of the country provisions relating to these.

In September 1979, a trial Environment Protection Law was ratified. This enactment was designed to guarantee a rational utilization of natural resources, to prevent environmental pollution and violation of ecological balance, and to create clean living and working environments to protect health and stimulate production.

**Forest Law**

In 1979 the First Law concerning forestry was introduced. Based upon experiences since 1949, it indicated a direction for forestry development. The law provides for forest management regulations in respect of forest planting, increase of forest cover and stock; strengthening of forest protection, rational logging methods, regeneration, construction of forest areas, improvement in forest management; raising forest productivity, rational use of forest resources; enhanced education in forestry science, training of qualified forestry technicians, strengthening of forest research, and acceleration of forestry modernization.

The Forest Law regulates that the percentage of wooded space over the whole country should reach 30%, and in the mountain area 40%. Production teams are encouraged to plant trees and shrubs for fuel wood if natural conditions permit. National wilderness suitable for forest growing ought to be reforested within a fixed time. The reproduction of forest in cutting areas should be replanted in the following or subsequent year. Forest harvesting is to be carried out according to forest logging regulations. In the environment protection forest, i.e. forest for water conservation in the upper reaches of the river forest, cutting is allowed when selection systems with long cutting cycles are used. In the forests of nature reserves and other protected areas, cutting is strictly prohibited.

In order to assist in the implementation of the Forest Law, a system of rewards and penalties has been instituted.

**Grassland Act**

In 1980, the government issued details of a Tree Planting Drive. The nation was encouraged to plant trees. Recently, the government has issued the Grasslands Management Act, with a purpose to ensure the sustainable utilization of natural resources, and to maintain the ecological equilibrium in grasslands. Included within this act are provisions for:

- the building of artificial meadows of high yields and high quality grass;
- establishment of forage bases to meet the needs of livestock during winter and spring;
- enclosure of livestock with planned fencing;
- achievement of rotational grazing at regular intervals;
- loosening of soil;
- sowing seed to fill gaps in vegetation cover;
- applying fertilizer;
- irrigating and weeding out poisonous weeds;
- rational distribution of livestock according to the carrying capacity of the different grasslands.

Serious grassland damage caused by burning, cultivating and overgrazing is a punishable offence.

**Conservation Strategy**

In 1957, a Strategy of Water and Soil Conservation was introduced for trial implementation. This was formalized in 1978. A Commission for Water and Soil Conservation was established and local governments involved. The stipulated guiding principles for water and soil conservation are:

- to combine prevention with maintenance and management;
- to combine conservation with utilization;
- to combine biological and engineering measures; and
- to emphasize the importance of natural conservation.

The "Strategy" prohibits cultivation on steep slopes above 25° and cutting of forest for farming and shifting cultivation. The strategy suggests that water and soil conservation should utilize watersheds as a fundamental unit and should involve upper and lower reaches of rivers. WSM implementation is directed by the Ministry of Water Conservation and Electric Power in cooperation with Departments of Agriculture, Forestry, Animal Husbandry, Transportation, Industry, Mining, Education and Scientific Research.

In order to promote the work of WSM, a special regulation was issued by the Ministry of Water Conservation and Electric Power in 1950. The aim of WSM is to control soil erosion; to improve the productivity of impoverished land; reduce sedimentation; improve the ecological environment; promote integrated development of agriculture, forestry, animal husbandry, and fishery production, and to achieve sustainable development by means of resource conservation. For small WSM, an overall development plan is necessary. In the plan, the land area within watersheds should be rationally apportioned for agriculture, forestry and animal husbandry. To facilitate recovery of grasses and trees biological measures ought to be combined with engineering, grass and tree planting and use of hill sides for livestock grazing and fuel gathering.

In order to account for long term and immediate interests of the local population, the regulations stipulate a series of policies to encourage rational WSM.

Based on the stipulations, producers of new arable land made available through use of rational measures of soil and water conservation will be free from grain tax for 3-5 years following the first profit-producing year. In sparsely populated

areas or in areas where people suffer from shortages of fuel, fodder, fertilizer and timber for buildings, it is suggested that local governments will freely distribute wilderness land for planting of trees, shrubs and grasses. Products from the wilderness will be eventually owned by the land users. Reclamation is however not permitted. If the regulations are not followed and the environment becomes harmed the distributed land will be taken back.

While considering integrated mountain development, one cannot avoid current rural economic policies as well as public health and population policies. The policies which are designed to change the poverty and backwardness of rural areas and to boost agricultural production as soon as possible, the policies may be summarized as;

- Safeguarding the right of ownership and the decision-making power of the collective economic unit.
- Implementing the policy of "To each according to his work" and establishing all farms within a production responsibility system.
- Encouraging and developing (household sidelines) cottage industries and free market enterprises.
- Diversifying the rural economies.
- Increasing state aid to agriculture.

Although the studied region is sparsely populated (1-28 people/$Km^2$) the arable land per capita is very low. Since the economy of this region is based on agriculture and most of the reclaimable land has been developed, the declining man-land ratio is perhaps the most fundamental problem of development. Since the 1970's, families have been encouraged to have only one child. Many places have issued honor certificates to reach the goal of zero population growth by the year 2000.

Although the above-mentioned policies and regulations have, to a certain extent, promoted the work of WSM, the problems of environmental degradation still remain in mountainous regions. This is due mainly to the following reasons:

- Until recently, policies and legislations concerning WSM have been fragile and marred by gaps, duplication and even conflicts.
- WSM is the responsibility of several different agencies. There is not a special organization strong enough to assume cross-sector coordinating work.
- One of the major constraints in WSM is the lack of knowledge. Although there will always be a need for more knowledge, it is most important that the considerable body of knowledge, as already exists, is used.
- Another constraint upon the implementation of policies and measures is the lack of trained personnel and adequate information. Interdisciplinary courses are required for generalists. Individuals require a broad sense of theory and practice in WSM, either within sectors or cross sectors with an overall understanding of the disciplines involved.
- Public participation in WSM is not adequate. An awareness of the benefits from WSM relevant to daily life should be created.

Priorities in WSM research include: integrated surveys of watersheds to include resource, inventories, prevailing socio- physiographical conditions, location mapping, extent of erosion, natural hazards and control measures, multiple utilization of rural energies, and ecological farming.

Great hydropower potential exists in the mountainous region of the southwest China. In Yarlunzangbyo River of Tibet the potential hydropower could reach 470 $kw/km^2$, 2-3 times of that of Changjiang drainage. On the sharp turn in the lower reaches of the Yarlungzangojiang River, a hydropower station could be built to obtain 27 Giga Watt. Due to the remoteness and isolation from major industrial centres, it is doubtful that this

will be built. In the Hengduan Mountains, the hydropower potential consists of more than 1/3 of the total hydropower potential of China. Although the current level of development is extremely low, in the future, together with the metallurgical industries and timber industry, the hydroelectric industry could become one of the three most predominant industrial sectors of the region. At present small hydropower stations play a crucial role in providing energy.

In general, the average silt content and erosion modulus of rivers in Tibet are much less than those of Hengduan areas. Erosion in the northern and western parts of the Hengduan Mountains is less than in the eastern and southern parts. These phenomena correspond with the development levels in different areas of the region. In brief, the erosion modulus is no greater than 100 tons/km$^2$ in the upper reaches, 100-300 tons/km$^2$ in middle reaches, and 300-500 tons/km$^2$ in lower reaches. For example, Yarlungzanbojiang river in Tibet has very low silt content (0.28-0.73 kg/m$^3$) and erosion modulus (85-93 tons/km$^2$) while in the eastern part of the Hengduan Mountain the silt content reaches 1.6 kg/m$^3$ and the erosion modulus reaches 434 tons/km$^2$ (Table 2).

**Table 2: Average Silt Content of Rivers in China**

| | | Silt content in main rivers | | | |
|---|---|---|---|---|---|
| Name of River | Station | Area of Drainage Silt (1000 Km$^2$) | Average Silt Content kg/m$^3$) | Annual Modulus Transportation (mio t) | Erosion (Ton/Km$^2$) |
| Dada River | Tongjiezi | 76 | 0.69 | 33.0 | 434 |
| Yalong River | Kiaodeshi | 118 | | 25.8 | 218 |
| Anning River | Wantan | 11 | 1.08 | 3.8 | 341 |
| Jingsha River | Batang | 188 | | 15.7 | 84 |
| | Pingshan | 485 | 1.60 | 231.0 | 476 |
| Lancang River | Jiuzhou | 84 | 0.65 | 20.7 | 246 |
| Nu Jiang River | Daojieba | 113 | 0.36 | 19.6 | 164 |
| Yarlung River | Nugasha | 189 | 0.73 | 16.1 | 85 |
| | Yangoun | 153 | 0.46 | 13.4 | 88 |
| | Nuxia | 190 | 2.55 | 0.1 | |
| Xijiang River | Wuzhou | 330 | 0.34 | 69.2 | 210 |
| Yellow River | Lanzhou | 975 | 14.00 | 632.5 | 1023 |
| | Lijin | 752 | 24.70 | 1150.0 | 1530 |

The silt content is one of the many indicators of soil erosion. According to estimates, the silt washed into rivers consists of 1/10th of the total soil eroded from the surface. Although the process of silt movement is caused partly by natural factors, human activities - especially steep slope cultivation and deforestation - have strongly accelerated the process.

## HISTORICAL RETROSPECT OF STUDIES ON WATERSHED EXPLOITATION AND MANAGEMENT IN SOUTHWEST CHINA

In a very broad range of nearly 3,000 kilometres, mountains and rivers are the background to a structurally complicated group of nationalities. Cultural origins, historical traditions and processes in social development vary greatly among the differing nationalities. Methods of WSM and characteristics of agricultural production are confined to specific nationality areas. This is important and needs to be confronted in discussions concerning WSM.

Tibetans, previously called Tufans, - a nomadic people - have inhabited the areas north of the Himalayas to the Songpan grassland of north Hengduan for many centuries. According to historical records, primitive farming and cultivation activities started during second and third centuries A.D. in eastern Jinshajiang with seeds introduced from Sichuan or Yunnan provinces. Following the marriages of Princess Wen Cheng and Princess Jin Cheng of the Tang Dynasty with Kings of the Tufan Dynasty in the seventh and eighth centuries, considerable quantities of seeds as well as farming skills were brought in or introduced to the Tufan from the hinterlands, thereby starting the farming practices and the construction of water conservancy projects in broad valleys of the middle reaches of the Yarluzanbujiang River. In the seventeenth century, cultivation activities were expanded to the high altitude interior drainage basin of north piedmont in the Himalaya. During this time, a pattern of production, with agriculture as the dominant factivity enclusure of animal husbandry, was formed in the river valleys of South Xizang. Cultivated land was concentrated in the bottom valleys of the Yarluzanbujiang River. Valley slopes were devoted to fuelwood collection, cultivation and stockbreeding.

Desertification was caused in the valleys due to extensive farming and removal of vegetation. Agricultural and animal husbandry practices were scattered throughout the valley slopes of the main river courses and tributaries of three rivers in the Hengduan Mountain Region. The major effect of soil erosion, caused as a consequence of vegetation loss from the valley slopes, was mudflow. Centres of various Tibetan tribal groups were formed in the seventh century. Presently, Lhasa is a city with a population of over 100 000 with 106 other cities and towns throughout the country. The increasing activities of gathering grass and bush from thinly stocked primitive forest tree felling ecological settings of adjacent basins are rapidly aggravated.

The southern part of the Hengduan Mountain Region is an area inhabited by numerous minority groups of various nationalities. Influenced by the policy of advocating and promoting farming and cultivation pursued by Zhuge Liang, the Prime Minister of the Kingdom of Shu Han, at places he visited in the third century, systems of slash-and-burn cultivation were replaced by ploughing with cows, paddy cultivation was commenced, and domestic animal rearing practised. This policy was certainly progressive and favourable to WSM. In the eighth century, the Kingdom of Nanzhao and Kingdom of Dalia, dominated by Yi and Bai nationalities were founded in the Erhai Lake Region of Yunnan Province. They established friendly relationships with Central (comprising the middle and lower reaches of the Huanghe) and introduced advanced farming techniques.

Unification of Yunnan Province was realized in the thirteenth century and the policy of opening up wastelands, reclaiming Bazi (intermontane plain), and developing water conservancy projects was pursued in areas east of Erhai Lake. Large scale reclamation began in the fifteenth century, and wasteland opened by garrison troops, peasants or merchants who migrated from the hinterlands. This replaced, to a large extent, the previous slash-and-burn cultivation. However, the production and development levels in the various inhabited areas of the minority groups were extremely uneven. In the Southeast Hengduan Mountain Region, where the climate is warm, the flat intermontane basins mostly inhabited by Han, Bai, Naxi and Dai whose technique of farming are comparatively well advanced. In the Dai inhabited areas in particular, there has been a long history of awareness

in the protection of mountain forest. The water resources in the catchment areas of the surrounding mountains were also conserved and these alleviated, to some extent, the effect of natural disasters. Following the Opium War (1840-1842), the economies in these areas were impacted, and opium became a special form of exchange. Uneven development caused by the destruction of forests in order to plant opium in the remote mountain regions was not arrested until the middle of the twentieth century.

In the recent 30 years, an unprecedented advance in the development of agricultural production has been achieved in the southern Hengduan Region. Partially the increased production was achieved at the cost of forest damage and by reclamation. The increasing requirement for energy to support production and to satisfy the growth in population caused rapid depletion of forests around the various basins. In addition, slash-and-burn cultivation practices in parts of the remote areas have aggravated the situation. The steadily deteriorating environmental quality of watersheds has become a pressing and critical issue for the southern part of the Hengduan Mountain Region.

During the last fifty years various departments, approaching from differing viewpoints, have conducted WSM projects or related activities in the Himalaya-Hengduan Mountain Region.

**Watershed Management Projects/Activities**

In the 1930's, a meteorological station was established in Lhasa by a Chinese geographer Xu Jinzhi, thus initiating one of the earliest meteorological observation posts in the Chinese Himalaya Region. He compiled "Physical Geographic Data of Qinghai-Xizang" - the first book which systematically introduced the landform, climate, vegetation, and data of the Himalaya- Hengduan Mountains.

Forest inventory of the east Hengduan Mountain Region was compiled in the 1930's.

The first large scale integrated survey on the Himalaya-Hengduan Region, conducted in 1951, included aspects of geology, geography, meteorology, hydrography, vegetation, soil, agriculture, animal husbandry, medicine and social science.

In 1951, work commenced on utilisation of the sub-alpine dark needle-leaved forests upstream of the Mingjiang River in the West Sichuan Province. Subsequently, regulations have been introduced to control such activities - thus indicating the need for forest conservation and regeneration.

Artificial regeneration experiments in alpine forests started in Miyalu Forest Farm, West Sichuan, in 1955.

A survey of growing conditions, distribution, types and tending of alpine forest in the east Hengduan Mountains was conducted during 1958 and 1959. The survey team, "China-Soviet Union Joint Survey", produced a "Report on Integrated Survey of Forest in Southwest Alpine Forest Area".

An Integrated Survey Team, concerned with Water Transfers from the South to North, conducted for the first time an overall and comprehensive survey from 1959 to 1962. The survey was concerned with hydrography, run-off characteristics, water resources, hydroelectric potentials and energy resources in mainstream and tributary areas of three rivers. The feasibility of diverting water from these three rivers in the Hengduan Mountain Region to arid areas of Northern China was investigated. Following the survey "Hydrography of West Sichuan and North Yunnan Region" was published. The survey also aided in setting up an increased number of hydrologic stations (68 to 120) in the basins of the three rivers, thus forming a network for hydrologic observation. In addition, the monographs "Forest of West Sichuan and North Yunnan" and "Agricultural Geography of West Sichuan and North Yunnan" were prepared. Special topic reports relating to wasteland reclamation in Garze and Aba prefectures, pastoral resources, and marshland stocks, were produced by the team. These documents provide a basis for watershed exploitation and management in the Hengduan Mountain Region.

Since 1959, four runoff fields of inner

forest have been under observation in Miyaluo and Markhang. The observations were concerned with soil erosion measurement in various runoff fields - clear felled, selectively felled, and slash burned. This activity continued until 1967, and it proved from a scientific point of view that the role of forest in conserving water supplies and protecting the ground surface in small catchments of the alpine region is one of prime importance.

From 1960 until 1961, the Integrated Survey Team of Xizang carried out an integrated survey to the south of Xizang. The investigation concentrated on the arable wastelands of the mainstreams and tributaries of the Yarluzanbujiang and the Nianchu river.

Aerial seeding was repeatedly undertaken over the Anninghe and Tangyuanhe river basins and the Jinshajiang River Valley in the ,vicinity of Duko, Sichuan Province during 1958-1977. The seeded area then covered 333,000 ha, now it has a stock of closed stand area of 133,000 ha. Practice has proved that aerial seeding provides an effective measure for WSM in mid-latitude mountain regions, but not in dry-warm valleys of the Jinshajiang River.

In 1965, various exploitation schemes for the Anninghe River Valley and for the management of the Yuanmou Basin were prepared by the Chinese Academy of Sciences.

During 1964 to 1966, a survey of the evergreen broadleaf forest in Xiaoliangshan Mountain region was underkaten and the results published during the period of 1964 to 1966.

Debris flow studies, dealing with their control and prevention, were undertaken in the Heishahe drainage basin of the Hengduan Mountains from 1976 to 1978 by the Chinese Academy of Sciences.

From 1973 to 1980, a comprehensive survey on Xizang was undertaken. The area studied included the Chinese Himalaya and the West Hengduan Mountains. Topics covered included landforms of the major exterior and interior drainage basins of the Yarluzanbujiang River in South Xizang, exploitation and utilization conditions of water resources, hydroelectric systems, and energy resources. "Rivers and Lakes of Xizang" was subsequently published. While inventoring the forest resources of Xizang, the team proposed an afforestation project for the Lhasahe River Basin. Studies of geothermal, hydroelectric potential and available support by exploratory activities, and energy resources demonstrated that the expansion of energy construction services was an important channel in reducing fuel wood consumption - thus protecting the forests and preventing the deterioration of watershed environments. Prevention and control measures for debris flow were also proposed.

Studies of change in river runoff and suspended upstream loads of Minjiang, West Sichuan, were undertaken in 1980. The relationships between the changes, cutting, methods of logging and transportation and other human activities were also analyzed. Reasons for soil erosion in the high mountain region were summarized in a relatively systematic manner.

Six Nature Reserves were established in Nanping, Zaige, Wenchuan, Meigu, Mabian, in east Hengduan Mountain Region from 1963 to 1978.

A forum on soil erosion in the Changjiang (Yangtze) River Basin was convened by the Chinese Forestry Society in 1980. Special reference were made to increased sedimentation of the Changjiang River and flood frequency caused by soil erosion as a result of forest and vegetation destruction in the Jinshajiang River Basin. The potential threat to a future macro hydro-electric project was also discussed.

An investigation of soil and water conservation measures in the Changjiang River area was organized in 1981. Again it was highlighted that the over-consumption of forest resources was endangering the Middle and Lower Reaches of the Changjiang.

From 1980 until the present, the focal point of the Integrated Survey Team on Qinghai-Xizang Plateau, CAS, has been directed towards the Hengduan Mountain

Region. The purposes of the survey related to felling and regeneration practices in the sub-alpine dark needle-leaved forest of the Hengduan Mountain Region and to combine a regional survey with static field experiment in order to provide a scientific base and to identify effective technical measures for future artificial regeneration of *Picea* and *Abies*. Experimental fields to measure run-off effects after felling and slashing were also established at the Hangshan Forest Farm of Xiaozhongding. Four experimental fields were established; these composed of standing forest felled and slashed forest. Two pairs of drainage basins of different sizes were chosen in order to demonstrate by means of scientific analysis the hydrological effects of forest felling. Special topics, i.e., local energy resources, were also studied as a means to inventory the number of traditional and non-traditional energy sources available in the Hengduan Mountain Region for subsequent programmes of exploitation and utilization. The aims included an examination of traditional energy structures, promotion of forest regeneration and reproduction, and improvement of the environmental quality of watersheds. Investigations relating to debris flows were also conducted in the east Hengduan Mountain Region. Active debris flow areas were selected and focal investigations conducted. Engineering and biological measures for debris flow control and prevention were elaborated. Studies of dry valley transformation and utilization were conducted to enable solutions to be found for the weak links in management of the Hengduan Mountain Region watersheds.

A joint survey on man's impact on changes occurring in mountain ecological environments and on soil erosion was undertaken in Yulongxue Shan of Yunnan Province in 1985.

## LEGISLATION AND POLICIES CONCERNING WATERSHED MANAGEMENT IN SOUTHWEST CHINA

The Himalaya-Hengduan Region, the highest mountain system in China and also in the world, is situated at the headwater or upper reaches of many famous Asian rivers. Since the region is located in a complete watershed ecosystem, it occupies a position of crucial significance. Watershed Management in this particular mountain region has been a matter of great concern to China and the neighbouring South Asian countries.

In recent years, the increased activity of man has constantly disturbed and shaken the vulnerable ecological balance, causing some quite serious results. Moreover, the close and complicated relationship between different ecosystems - forest, grassland, farmland and soil - and the constitutional components of mountain ecosystem, require the establishment of a co-ordinated relationship between the satisfaction of man's economic requirements and the improvement of environmental quality. Watershed management policies should be formulated on the principles of suiting measures to local conditions and tackling in a comprehensive and early step-by-step manner the problem of the repeated practices of watershed exploitation during the past 30 years in association with an understanding of the prevailing natural conditions of the Himalaya - Hengduan Mountain Region. Consideration of the present uneven economic development is also important. The relevanc of specific and isolated solutions is to be regarded as applicable in the particular situations only. Each measure is important in itself and can be comprehensively interwoven to achieve long-term ecological, social and economic balance. With a background of varied natural conditions and forms of watershed, the principal policies and ligislation concerning watershed management may be expressed as follows:

### Rational Cutting and Regeneration of Forest

Forest has a multi-layer structure, bushes, grass, moss, humus layer and tree root systems. These reduce surface runoff coefficients and erosion modulus by means of interception, storage and impediment. Hence forest ecosystems play a leading role in stabilizing mountain ecosystems.

Constrained by the upper forest limits , the southeast part of the Himalaya - Hengduan

Region, located below 3900-4300m, receives concentrated precipitation with intense scouring on the steep slopes. It is also a region that is subject to serious soil erosion. Forest areas in the southeast Himalaya - Hengduan Region are the best preserved primary forest area of China and the second largest timber production base. Whether viewed from the point of national requirement for timber and forest by-products, or from the point of need for mature forests as a source of parent stock, it is necessary to engage in cutting. We should also be aware that forests not only provide timber but have significance as environmental and genetic resources. For this reason, felling methods must be favourable to regeneration, and should be regarded as the focal point for forest management.

The lower limit of subalpine dark needle leaved forest dominated by Picea and Abies is at 3100m. Due to high timber quality, and stock volume these trees have been rapidly felled. Restocking has not been undertaken; neither have the new trees been planted at the correct times. By identifing the relationship between felling, regeneration, management and investments of the past 30 years, the felling methods, and taking a slope area as unit, it has been possible to combine clear felling with selection felling. The order of felling defined for the lower to upper slopes complies with both the regulatory laws and the character of the altitudinal belts. The order provides for clear felling only on the lower slopes. Where regeneration has been undertaken on middle slopes, 70% of stock may be selectively felled. As it is difficult to plant trees on upper slopes felling is not to exceed 30%. Shelter belts should be reserved at key positions i.e. dividing ridges, steep slopes, upper forest limits and where soil is impoverished. An important characteristic of dark needle leaved forest is its vulnerability to external disturbances. Slashing may convert the areas into bush or meadow if only natural regeneration is depended upon. The crucial factor for artificial regeneration of dark needle leaved forest is correct sapling cultivation, particularly for *Abies*. A report concerning experiments at the Xiaozhongdian Forest Farm of Yunnan indicated that better results in Abies regeneration can be achieved in respect of sapling cultivation if sowing is started early, kept under shelter for a certain period of time during winter and if the saplings are planted at the correct time.

Bright needle leaved forests, composed of *Pinus yunnanensis and P. densata* , are situated on mid-altitude slopes of 1000-3000m. Bright needle leaved forest has strong seed-forming ability. *Pinus yunnanensis* is draught resistant and tolerates poor soil. Forest can normally be formed by flit-seeding if 15-20 parent trees are reserved on the slash where clear felling has been practised. On the slash where clear felling has been entirely done, the result of forestation by means of artificial seeding and direct seeding is better than by reserving parent tree. Air-seeding of slash slopes suitable for forest and abandoned arable land is a low-cost high-efficiency method. In the dry-warm valleys, irrespective of whether artificial seeding or air-seeding is applied draught-tolerant and nitrogen-fixing pioneer species should be used.

The water conservation ability broad leaved forest is better than that of needle leaved forest. Generally speaking, intense selective felling adopted for evergreen broadleaved forest would be more favourable to natural regeneration. In the case of clear slash felling, artificial regeneration is preferable to relying upon natural regeneration, which takes a long time.

The effect of logging and transportation methods upon soil erosion in forest areas is not negligible. At present, backward slide logging is still used in forest areas. This usually results in the formation of deep gullies on the slopes which become hotbeds of erosion, landslides and debris flows. Rafting in small rivers by means of opening sluice gates damages the edges of banks causing them to be dashed or washed away, thus causing an increase in river sedimentation. The most suitable method is to substitute slide logging with cableway and capstan machines.

**Rational Utilization of Improved Grazing Lands**

The proportion of natural grazing land to

total land area is at the highest in the Himalaya-Hengduan Region, especially at high altitudes above the forest line. Grassland ecosystems predominate in watershed ecosystems of mountain regions.

In the plateau lake basin region of the north piedmont of the Himalaya, the climate is dry with sparse grass cover. Degradation of rangelands of varying degrees, caused by overgrazing, mainly accounts for the prevailing soil erosion and desertification.

Alpine meadow dominates the piedmont alluvial plains of north Hengduan Region. Since both the soil and moisture content are rich in organisms, a solid yet elastic soggy grass layer was formed. It possesses a dense root system of the surface which is tolerable to animal trampling and able to protect the ground surface; therefore soil erosion is not severe. In the Zoige area, (N.East Hengduan Mountain Region) swampy meadows prevail. The rangeland grass yield is comparatively high and the regeneration of dark needleleaved forest is effective as local precipitation and humidity are higher than in plateau areas of similar atitudes due to vast expanse of swamp meadowlands. In order to solve the problem of carrying capacity of winter pastoral areas, a proposal to dredge water from the meadows to enlarge the grasslands has been defined. The implementation of this programme will cause ecological imbalance. To maintain animal husbandry and protect the environment simultaneously, hay supplies can be established in the dry season and artifical forage bases slowly established.

The proportion of agricultural land of the middle and lower altitudes in the deep valleys and basin areas of the southern Hengduan Mountain Region is relatively high. Soil erosion caused by overgrazing exists on valley slopes in the vicinities of the agricultural areas. The upper parts of valley slopes have great potential as alpine meadow-rangeland for summer grazing. Efforts should be made to prolong the period of summer grazing on lands in order to reduce pressure upon winter grazing lands situated on lower slopes of the valleys. In addition, arable lands should be used for fodder bases to compensate for forage deficiencies.

Vegetation in the dry-warm valley of south Hengduan Mountain Region has been seriously damaged; hence grazing should be reduced and stockbreeding should be advocated.

**Rural Energy Resource and Protecting Watershed Forest**

According to estimation, 90% of the total volume of timber felled is consumed as fuelwood in the forested areas of southeast Himalaya-Hengduan Region while in the non-forested areas bush, even sod, has become one of the major energy resources locally. Therefore, exploring local diversified energy resources in line with local conditions is a strategic measure to reduce felling volume of forest.

Water storages of the Yarluzanbujiang, mainstreams and major tributaries of the three rivers in the Hengduan region is two-thirds of the nation's total storage ability. Since construction of mammoth hydroelectric power projects involves long periods of time, it requires cooperation with other services including transportation, activities in dangerous and difficult topographic conditions and it is impossible to solve energy issues with huge power networks. The density of medium and small rivers in the Hengduan region is very high, and rivers with a drainage area exceeding 100 $km^2$ do not normally dry up in winter. In most cases, the longitudinal gradient of river beds is over 10%. The total water storage of medium and small rivers can potentially supply 73 Giga Watt. The investment for constructing hydroelectric schemes in such locations is lower than that of the normal national level. Rural energy plans for the region should include extensive development of medium and minihydropower stations. These schemes would replace the need for firewood by electricity, with the added advantage of assisting in development. In Garze prefecture of Sichuan Province, 19,000 electric cookers are in domestic use, hence nearly 100,000 $m^3$ of timber can be saved each year.

The Himalaya-Hengduan Region has the strongest geothermal belt in China. There are more than 1000 geothermal areas of hydrothermal types. Recently about 30

geothermal fields have been identified in the vicinity of county-level settlements as having power generation and exploitation value. Now the installed capacity of Yangbujing geothermal power station of Xizang has reached 10 Mw which can satisfy 50% of the power requirement of the city of Lhasa; this greatly lessens the dependence of Lhasa on fuelwood in east forest area. Since energy is inadequate in South-Xizang, geothermal resource has been designated as a focal energy to be exploited in near future.

Developed agricultural production and concentrated populations are discernible in the lower altitude valley basins of the east Hengduan region. A yearly increasing radius of forest felling is encroaching upon the surrounding areas of the basin. Biogas is suitable for development in the region due to favourable temperature conditions and rich material sources. It is particularly true of the dry-warm valleys. Where fuel wood is deficient less hydropower resources are available and temperature conditions can satisfy the biogas digestors for an opearting period of 300-365 days each year.

No coal resources have so far been discovered in the Himalayan Region whereas in the Hengduan Region coal reserves are limited and mining sites scattered. In areas where conditions permit, small scale mining may provide a solution to the energy issue. In high altitude areas of south Xizang and north Hengduan where exploitation potentials of medium and small rivers are not good, whereas geothermal, wind and solar energy resources could be tapped.

**Developing Water Conservancy Projects and Bringing Farmlands Under Irrigation**

The dry season is long in the Hengduan Mountain Region and serious spring and summer droughts regularly occur. Droughts occur frequently in the Lijiang area of Yunnan Province (68.9 - 81.1%). Serious drought frequency is 17.2 - 30.,7%. Estimations reveal that the area of irrigated farmland in the Hengduan Mountain Region only reaches 20-30% of the total arable land with mostly concentrated in the warm flat southern valley basin. In respect of slope lands and dry-warm valleys, the crop yield is very low due to inadequate water conservancy projects and deficits in soil moisture. With an increasing population the solution seems to lie in the expansion of cultivated land and the practice of extensive farming. As a consequence the ecological environment of slope lands and dry-warm valleys has steadily deteriorated.

Development of water conservancy projects provides a guarantee for constructing sustainable farmland, creates suitable conditions for conversion of arable slope land into forest, and prevents deforestation for reclamation. In view of irrigation requirements on terraces they are also helpful for soil and water conservation. This also offers an effective measure for promoting arable slope land improvement. In the hot and dry warm valleys where WSM is difficult to implement, huge water conservancy projects will be beneficial for the overall improvement of soil and air moisture conditions, and for rapid restoration of vegetation.

**Developing Diversified Economies and Increasing the Economic and Ecological Benefits of Mountain Production**

Unitary, self-sufficient economies have dominated the Himalaya- Hengduan Region for long periods of time. Sown area of grain crops occupies over 90% of the total cultivated area. The idea of solely seeking grain output in terms of management will inevitably cause steep slope cultivation and deforestation for reclamation. To change this tendency it is necessary to turn the closed unitary management system gradually into multipurpose open management; to make use of arable lands where conditions are suitable to build grain bases; and then to develop fruits and oil-bearing cash crops which will attain both economic and ecological benefits from surplus arable slope lands and barren hill slopes with measures suitable to local conditions. In regard to animal husbandry in agricultural areas, grazing animal species such as sheep should be properly reduced whereas domestic breeding of cows, pigs, chicken, ducks and rabbits should be advocated.

Intercropping of fruits and grain was introduced in the Yufengyan orchard of Lixian County, Sichuan Province. As a result,the sustained fruit yield was 18 tons/ha for the period 1981 to 1983, grain yield was 6 tons/ha, and income increased 3-4 times above that of the unitary economies.

**Preventing Non-Agricultural Engineering Activities From Damaging Slope Surfaces**

More and more problems relating to watershed management will occur with the operation of engineering activities in the mountain regions, e.g. mining, road construction, housing, geological prospecting, smelting and slag removal. The Hengduan Mountain Region is a well-known multi-metal formation zone in China; mineral resources have been discovered in each county of the region. Therefore, development of mineral resources has become important and an economic mainstay in the mountain regions. However, geologic trench projects and slags produced from pit, especially extensive strip mining caused arbitrary sliding of slag heaps, which often bury farmland. In association with other engineering projects mining accounts for a significant increase in river bedloads. Sliding, destruction of ground vegetation and surface soil erosion are also considerable.

Results of engineering activities in mountain regions i.e. those of road construction and house building are similar to those of mining activities.

In view of the above-mentioned fact, the necessary rules for engineering operations on sloped surfaces should be defined as early as possible. Firstly, specific schemes for the disposal of waste material and slag, filling of trenches and pits, and trees are required to be included in each specific project design. After approval, they are to be implemented under the supervision of the authorized organizations. Then, the various engineering projects within mountain regions should be continued under unified guidance and in a planned and orderly manner.

## WATERSHED MANAGEMENT IN SOUTHWEST CHINA

**The Role of Irrigation Projects in Managing Hot and Dry Warm Valleys of Yuanmou Basin, Yunnan Province**

Yuanmou Basin is located in the lower reaches of Longchuanjiang River, about 30 km in length and 5- 7km in breadth. Interconnecting diluvial aprons are accumulated in the basin by the 10 small rivers originating from the Dongshan Mountain Region. Topographically, it is high in the east and low in the west with an altitude of 1350m. Yuanmou Basin is the centre of the hot-and warm-dry valleys of the Yunnan Province. Accumulated temperature 10°C may reach 7996°C with three crops per year. Annual precipitation is 614 mm and 62.6% concentrates in June-August. Long dry spell is unfavourable to crop and vegetation growth in the area. Natural forests in surrounding areas have been exhausted due to long-term reclamation activities, giving an appearance of a sparse tree-bush-turfy slope landscape. Grass and bush coverage is very low because of animal foraging. Its dry red earth is a reflection of the dry basin. It is characterized with vertical joints, coarse grains, calcium content, wetness, and stickiness.

Floods created during the rainy season act strongly upon the diluvial fans with steeper slopes. Since the 1950's, the cultivated area of the basin has been increasing rapidly, the total arable land being 10,000 ha. With soil erosion developing quickly, the most serious cases are in the Qinglinghe Basin in the west and Bingxianghe Basin in the east. Cultivated land and barren slopes have been swallowed up by criss-cross ravines. Earth pillars are standing in great numbers on the broken ground surface, resulting in land devaluation or loss. Afforestation directly on the hot-and warm-dry valleys achieves little, making it necessary to improve site conditions by planting drought-enduring pioneer species in the succession stage. It, therefore, takes a long time for the ecological environment to be improved. Afforestation period cannot be shortened unless soil moisture is artificially increased.

The Longshuanjiang Drainage Basin, upstream on the Yuanmou Basin is 3,400 $km^2$ in area and the annual runoff is 600 mio $m^3$. Large reservoirs have been built in the upper reaches of the mainstream in the 1960s with a total effective storage capacity of 150 mio $m^3$. In addition to agricultural and power generation purposes for the middle and upper reaches, a dry season runoff of 5 $m^3/s$ for the lower reaches needs to be ensured. Dengshan Canal in Yuanmou was completed in the 1960s for the Longchuanjiang water diversion. It is 84 km long, and the inlet flow is 5 $m^3$ which ensures 3,500 ha of farmland to be irrigated. This accounts for 35% of the total cultivated land. In the mid-1960s, the Integrated Survey Team of Southwest China, CAS, investigation proposed that an additional mitigated regulation system centered with two reservoirs should be built by using flood water as well as water in the Dengshan Canal system during off-season. Of these two, the Bingjian Reservoir was completed in 1982 which ensures that irrigated area will increase to 6,500 ha, or 65% of the cultivated area. As soil moisture has been increasing and air humidity has been rising, vegetation in the basin is now undergoing restoration. Direct forestation has succeeded around the reservoir area. Different varieties of trees, bushes and grass are now growing luxuriantly in the irrigated areas. Along the fields and on barren slopes, tropical fruits with high economic value have been successfully trial- planted, and soil erosion in southern part has been basically controlled.

The benefit of the Dengshan Canal began to be apparent in 1964 and the desired results achieved by 1977. The Bingjian Reservoir was completed ahead of schedule in 1982, although a complete irrigation system was not formed until then. Increases in grain and sugar cane yields at three stages of the Dengshan Canal construction and at the preliminary stage of the Bingjian Reservoir are given in Table 3.

Yuanmou Basin has become a base for exporting commercial grain and sugar instead of an area which relied on grain and sugar resold by the state. Local producers receive additional incomes from the rapid development of fruit and winter vegetable production.

**Table 3: Increase in Producation due to Dengshan Canal**

| | Grain | | Sugar Cane | |
|---|---|---|---|---|
| | Yield ($10^4$ ton) | Increase (%) | Yield ($10^4$ ton) | Increase (%) |
| 1964 | 2.868 | | 1.797 | |
| 1977 | 3.309 | 15.3 | 3.008 | 61.0 |
| 1982 | 5.603 | 95.4 | 7.000 | 289.0 |

Simawing Reservoir, which is currently under construction, is a third phase project of the Yuanmou Irrigation System. It is capable of storing 34 mio $m^3$ annually, and may reach up to 140 mio $m^3$ with effective storage. After the completion of the water conservancy project system Yuanmou Basin can receive about 300 mio $m^3$ each year, which will thoroughly change the moisture condition of the hot- and warm-dry valleys. This is not only a prerequisite for agricultural development but also an important guarantee for ecological equilibrium improvement and soil erosion control. Irrigation of nearly all the cultivated land will be guaranteed when the project is completed. New arable land can also be increased which will become an important base for commercial grain, sugar, vegetable and fruit production in the Hengduan Region.

**Comprehensive Control and Prevention of Debris Flows in Heishahe Drainage Basin, Sichuan Province.**

Heishahe River is a tertiary tributary of the Jinshajiang River and a branch ravine of Anninghe River. The Anninghe Valley is flat in terrain and mild in climate. It receives an abundant rainfall and it is the biggest granary in the Hengduan Region.

The Heishahe originates from the Lujihoushan Mountain with a total length of 12.6 km and a drainage area of 22.6 $km^2$. Dense forest was found in

Lujihoushan more than 100 years ago. The military operation provoked by the Qing Dynasty in 1870 and a subsequent tribal dispute resulted in serious damage of the forest. Its vegetation cover of burn and slash, having been reclaimed and grazed again, was only 40-60%. Catastrophic debris flows occurred 14 times from 1874 to 1964, and almost once every other year at the end of the 1960's. 35 villages or stockaded villages and more than 300 ha of farmland were silted up successively and another 430 ha of cultivated land was affected. Roads and irrigation canals and ditches were damaged and the railway was threatened. A black debris-flow accumulated fan as wide as 3 km was formed in the west flank of the Anninghe Valley.

The mountain slope in the upper reaches of the Heishahe is 40°, ravines and gorges are deep dissected, and the longitudinal gradient of main valley is above 100%. The principal lithological characteristics of the drainage basin are: comparatively loose sand, shale and mud stone, fragmented rock formation is discernible due to the effect of faulting, folding and recent earthquake activities. Annual precipitation is about 1000 mm, having 93% concentration in May to October. In one storm, on-the-spot measurement was above 160 mm. In any storm, debris flows would occur. The maximum flow would be 200 $m^3$, the total runoff volume of debris flow at one time is about 308,000 $m^3$. Different varieties of debris flows with typical flow morphologies and various forms are recognized in Heishahe. A scheme on "combining engineering measures with biological measures, planning upper, middle and lower reaches in uniform and tackling problems concerning mountains, rivers and farm land in a comprehensive way" was worked out according to studies on the occurrence mechanism of debris flows, law of their activities and way of damage.

The major measures identified were to build flood regulating reservoirs with a capacity of 640,000 $m^3$ at upstream of the main valley; to plant 800 ha of forest for conservation of water supply in order to mitigate peak flood; to construct seven silt trap dams at middle reaches, five check dams, seven longitudinal dams and embankments; to afforest 400 ha for soil and water conservation for the purpose of retaining sediment and controlling the loose soils; and to build 5.8 km-long diversion dam, dig a drainage channel and construct 3% shelter belts for the purpose of stabilizing the valley.

Debris flow control and prevention work in Heishahe was completed in 1978. Its afforested area consists of 85% of the total drainage area. A storm event of 169 mm took place on September 11, 1972; no flood and debris flows occurred. Debris flows in the Heishahe Drainage Basin has disappeared since 1972. Erosion control results by means of biological measures in the Heishahe Basin are given in Table 4.

**Table 4: Result of Erosion Control**

| | Barren Land | | | Plantation of Pinus Yunnanensis | |
|---|---|---|---|---|---|
| Time of observation | Precipitation per day (mm) | Runoff coefficient | Erosion modulus (ton /$km^2$) | Runoff coefficient | Erosion modulus (ton /$km^2$) |
| 1975.9.1 | 29.5 | 0.82 | 11,900 | 0.44 | 3,800 |
| 1976.9.6 | 50.3 | 0.72 | 30,502 | 0.11 | 34 |
| 1977.7.17 | 45.2 | 0.74 | 285 | 0.01 | 16 |
| 1978.7.12 | 60.2 | 0.79 | 18,002 | 0.01 | 211 |

The direct economic results from permanent control and prevention of the Heishahe drainage basin are identified in follows:

- Grain output increased 1.93% whereas cultivated land decreased 30% as a consequence of cultivated land and forest abandonment in the upper reaches;
- Grain output increased 100% as a result of improvement of 140 ha of strip farmland and reclamation of 140 ha of wild land in the agricultural area of the lower reaches;
- Economic value of the existing forest has now become 14% of the cost of afforestation as a result of 10 years of forestation.

# A COMPARATIVE STUDY OF GEO-ECOLOGICAL CONDITIONS AND ENVIRONMENTAL PROBLEMS BETWEEN THE HIMALAYAS AND THE HENGDUAN MOUNTAINS

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## INTRODUCTION

The Himalayas, the highest and the youngest mountain system in the world, is one of the key-areas for mountain development. It has long since drawn the attention of scientists from various fields, especially from geo-science and biology. The Chinese Academy of Sciences has been sponsoring, since the 1950, a number of expeditions to the Qinghai-Xizang (Tibet) Plateau-known as the "Roof of the World" - and its southern fringe, the Himalayan region. The international symposium on Qinghai-Xizang (Tibet) Plateau in Beijing, 1980, provided an opportunity for both Chinese and foreign scientists to summarize and exchange scientific results on the Plateau and the Himalayas. The symposium is a milestone for international cooperation in the research on mountains areas. After the symposium, the Integrated Scientific Expedition Team to the Qinghai-Xizang (Tibet) Plateau of the Academia Sinica has been sponsoring another expedition to the southeastern part of the Plateau-the Hengduan Mountains - since 1981. Special attention has been paid to some of the problems of mountain development, such as: evaluation of the renewable natural resources and their rational development and utilization", "geo-ecological conditions of the dry valley, their utilization and management" and "regeneration of the montane coniferous forests".

Because of intensive uplifting since the late Tertiary, the Himalayas and the Hengduan Mountains pertain to the marginal areas of the Plateau. Located in the middle and low latitude levels and influenced by the Asian Monsoon, both the Himalayas and the Hengduan Mountains are characterized by the monsoon climate with alternate wet and dry seasons. A more detailed description and comparison of the two mountain regions would be of special interest. Therefore a comparative study in the geo-ecological conditions, the types of spectra of the altitudinal belts, land utilization and human impact on the environment would be helpful to explain the experiences of watershed management and to make effective decisions on countermeasures to be implemented.

## GEOGRAPHICAL SITUATION AND TOPOGRAPHY

### The Himalayan Region

The Himalayan range, 2400 km long and 200-300 km wide, with a mean elevation of the central axial ridge of 6000 m, extends from west to east at the southern rim of the Plateau, and is by far the youngest and lofties mountain system in the world.

The Himalayan system consists of several parallal ranges, such as the Siwalik Ranges, the Lesser Himalayan Ranges, the Great Himalayas and the Tibetan Plateau of the Northern flanks. The Great Himalayas may usually be divided into three sections: the Western Himalayas, lying between the Nanga Parbat and Namunani (Guerla Mandatasha), comprising the Kashmir Himalayas and the Kumaon Himalayas; the Central or the Nepal Himalayas, located between the Namunani and the Chamo Lhari; and the Eastern Himalayas including Bhutan and the Assam Himalayas which end in the Namcha Barwa.The Western Himalayas stretch between 30-36$^0$ N,from northwest to southeast, while the Central and the Eastern Himalayas turn to extend from west to east in the region between 27-30$^0$N.

Controlled by geological structure, the Himalayan ranges emerge with a completely developed valley system, cut through by very deep transverse gorges such as the Yarlung Zangbo, the Indus, the Sutlej and the other tributaries of the

Ganges and Brahmaputra. This circumstance of antecedant drainage of the Himalayas explains the peculiarity that the watersheds of the chain extend not along its highest peaks but a great distance to the north of them.

The snow-line, the lowest limit of perpetual snow on the southern flanks of the Himalayas, varies from 4500-5000 m in the east to about 5500-5800 m in the west. On the opposite northern side the snow-line is about 600-900 m higher, owing to the desiccation of that region caused by the absence of moisture-bearing winds. The Great Himalayan Range is a gathering ground for snow, nourishing a multitude of glaciers. The sum total area of the recent glaciers is 33,200 $km^2$ in the region of the Great Himalayas. In the northern side of the Central Himalayas, the glaciers pertain to the continental type with the glacial tongue at about 5000m. The main range of the Eastern Himalayas is remarkably lower, towering up in Namcha Barwa to 7782m, with a few glaciers round about. Eastwards there are a number of glaciers belonging to the maritime type in the Kangrigarbo Mountains, the most famous one being the Abzha glacier that runs through the montane coniferous forest belt and ends with a glacial tongue in the montane evergreen broad-leaved forest belt at about 2500 m.

The topography between both northern and southern sides of the Himalayas is fully asymmetrical, especially in the Central Himalayas. In the south, the main ridges of the Great Himalayas rise abruptly to about 6000 m above the Ganges plain, forming steep slopes with strong fluvial erosion in the gorges. In the upper reaches of the rivers and their tributaries, glaciated U-shaped valleys are well developed. As a result of recent river-sculpturing the valley form changed from a wide trough to a typical V-shape. In some cases the hanging valleys may be developed in several tributaries. Owing to the uplifting of the mountain system the landform of "valley in valley" can be found here and there in the region. Settlements such as Chengtang and Xiebugang are located on the level shoulders, lying above the knick point in their transverse profiles.

The Mountainous region, about 150 km wide, between the Great Himalayas and the Siwalik, constitutes the intricate system of the Lesser Himalayan Ranges. In this region there are broad valleys and basins, such as the Kathmandu basin, and the Pokhara valley. It is characterized by fertile land and intensive farming, being the most populous region in Nepal.

In contrast to the montane region of southern flanks, the topography of the northern side of the Himalayas is more gently descending step by step, with a relative elevation of about 1500 - 2000 m. Skirting the northern slopes of the Himalayas a series of platforms stretch that are remnants of the peneplain, the moraine platform, and broad basins and valleys are separated by lower montanes and hills with a relative elevation of 200-500 m. The plateau proper of South Xizang is located in the northern side of the Himalayas with broad valleys and basins, where the piedmont depositions are very extensive. Under the cold and dry conditions a lot of sand dunes and sand drifts lie along the river.

**The Hengduan Mountain Region**

The Hengduan Mountains (literally, the "Traverse Block Mountains"), located in southwestern China, are comprised of a series of high mountain ridges sandwiched between deep river gorges. The main mountain ranges, from west to east, are the Boshula, Taniantaweng, Ningjing-Mangkang Shan, Qiaoer-Shaluli Shan, Daxue Shan-Zhedo Shan, and the Qionglai Shan. And they are respectively separated by the Nu Jiang (the upper reaches of the Salween River), the Lancang-jiang (the upper reaches of the Mekong River), the Jinsha-jiang (the upper reaches of the Chang Jiang) and their numerous tributaries. All of the rivers cut deeply in parallel gorges; therefore the region of the Hengduan Mountains is topographically well known and is termed the "River Gorge Country" or the "Meridional River Gorges" in the World. In the northern section (northwards from $30^0$N), the rivers run roughly northwest to southeast with slight gradient. Fluvial terraces and flood lands occur in a number of broad valleys. Southwards from $30^0$N, the rivers turn to be the north-south oriented, characterized by deep cut gorges with narrow river beds,

steep valley walls, swift torrent and high gradient of the river. The terrace and flood land almost disappears at the bottom, but mudflows, debris-flows, landslides and slope-slips occur frequently.

In the Hengduan Mountains the mountain crests may be considered as a plane of mountain plateaus with gentle relief. They are the product of a former peneplain that has been up-lifted and dissected.

As a whole, the Hengduan Mountain Region tips from northwest to southeast and from north to south, with altitudes from 4500 m to less than 3000 m. The topography of region is mountains, plateaus, valleys and basins, extending from north to south, interlaced and separated with distinct relief.

The northern section of the Hengduan Mountain Region is slightly dissected plateau with gentle slopes; the altitude of the plateau surface descend from 4500 m in the west to 3500 m on the eastern edges. In the middle section of the Hengduan Mountains a plateau with an elevation of 4000-4500 m may be seen in the Shaluli-Shan region, where the broad valley occurs with gentle relief, and there are relics of the former glacial cap with the well developed landforms of glacial erosion. Above the plateau there are several peaks with an elevation of more than 6000 m, such as Mt. Gongga Shan (7556), Mt. Qiaoer Shan (6168m) and Mt. Genie (6240m). The snowline is estimated at 4900-5400 m. Generally it is higher inland of the region and lower in the margin of the region. According to Shi Yafeng and Li Jijun (1981), the total area of recent glaciers in the Hengduan Mountains is only about 1456 $km^2$ , much less than that in the Himalayas.

The southern section of the Hengduan Mountain region consists of lake basins, middle-altitude mountains and plateaus, with an elevation varying from 2000 to 3000 m. The landform types include mountain-plane of plateau, undulating planes-pluvial fans, and lacustrine plains. The topographic characteristics of the region are similar to the Yunnan plateau. In this section a number of basin with lower altitudes and gentle relief are favourable for crop growing, making this an important agricultural region in the Yunnan Province.

Intensive neo-tectonic movement plays a significant role in the landforms. In the divided area of the northern section of the Hengduan Mountains the broad plateau is conserved with a relatively dissected depth of about 1000-1500 m. The middle and southern sections and the marginal area of the region are characterized by intensive fluvial processes with deep-cut gorges, narrow divides, steeply sloped valleys with a relatively dissected depth of 200-500 m.

At the bottom of the gorges, because of steep slopes, intensive physical weathering, instability of slope surfaces, a variety of deposited landforms such as debris cone and debris avalanche, forming abundant loose materials of tills and debris, landslides, slop-slips, mud flows and debris flows occur frequently, especially in the rainy season.

## CLIMATIC CHARACTERISTICS AND THERMAL - MOISTURE REGIMES

Located in the middle and low latitudes, both the Himalayas and the Hengduan Mountains pertain to the tropical fringe and subtropical zone and are therefore influenced by the Asian monsoon with alternate wet and dry seasons.

During the winter period, from November to April, the climates of both mountainous regions are controlled by the southern jet stream of westerlies. There is abundant sunshine and dry weather with rare precipitation , especially on the northern side of the Great Himalayas. The winter precipitation derived from the disturbed westerlies plays a significant role in the Western Himalayas.

In the summer half year, from May to October, the southern jet stream of the westerlies withdraws northward, and the southern moisture-laden monsoon from the Indian Ocean reaches up to the Himalayas and the Hengduan mountains. The monsoon brings heavy rainfall on the southern flanks of the Himalayas and most of the areas of the Hengduan Mountains, especially from June to September, while the southeastern monsoon prevails in the

eastern and southeastern parts of the Hengduan Mountains, reaching as far as the ridges of the Daxie Shan and the Ailao Shan.

**Precipitation**

The eastern end of the Himalayas and its foothill zone is the most humid area, with annual rainfall as high as 2000-4000 mm; decreasing westward, the annual precipitation drops to about 1000-2000 mm on the southern flanks of the Central Himalayas; further westward the region receives only about 500 - 1000 mm.

The lofty Himalayas, extending along the southern rim of the plateau, are an effective climatic barrier. On the northern side of the Himalayas there is a rainy shadow area with an annual precipitation of about 200-300 mm. Further westward the annual precipitation is much less than 200 mm, for example, Skardu and Leh in the West Himalayas have a mean annual precipitation of 162mm and 83mm respectively.

In the Central Himalayas the maximum precipitation belt is generally found at altitudes of 2000-3000 m with an annual rainfall of about 2500-3000 mm, while in the eastern and western Himalayas the maximum precipitation belt descends to altitudes of about 1500 - 2000 m.

The seasonal distribution of precipitation is obvious in the studied areas. More than 90% of the total precipitation falls in the period from June to September on the northern side of the Himalayas. About 80% of the total rainfall is registered in the same period on the southern flanks of the Central Himalayas. In the inner area of the Great Himalayas snow also falls during the winter and spring months. The percentage of the rainfall in the monsoon season (from June to September) is lower on the southern flanks of the East Himalayas and the West Himalayas.

The precipitation regime of the Hengduan Mountain Region is distinct from the Himalayas. On the eastern side of the Zionglai Shan and western edges of the Gaoligong Shan annual precipitation as high as 1200-1600 mm has been observed but most of the meteorological stations register a mean annual precipitation of about 500 - 900 mm, 80-90% of which falls in the period from May to October. Owing to the disturbance of the southern trough of the westerlies with strong convections, the western edge of the Hengduan Mountains has significant rainfall in the spring. There is a distinct difference in precipitation between the luv-and the lee slopes, for example, Baoshan and Tengchong, located respectively at the east-facing slopes and the west-facing slopes of the Gaoligong Shan, receive an annual precipitation of 966 mm and 1,464 mm.

The bottom of the gorge section of the three mighty rivers (the Nu Jiang, the Lancang Jiang and the Jinsha Jiang) in the inland of the middle section of the Hengduan Mountains located at about 28-30$^0$N, is climatically a centre of rare precitation, controlled by the topograpic configurations and atmospheric circulation. This is perhaps a result of the foehn effect and the valley- and mountain-wind systems, which form a number of dry valley with an annual precipitation of only 300-500 mm. Dry valleys occur widely in the Hengduan Mountains and may be occasionally seen from Bhutan to Nepal in the Central Himalayas.

**Temperature**

The temperature and precipitation conditions in the Himalayas and the Hengduan Mountains are shown in Table 1. Barakshetra, located in the foothill zone of the southern flanks of the Central Himalayas, has a mean annual temperature of more than 24$^0$C,and is absolutely frost-free, approaching strict climatic criterion for the tropics. Because its mean temperature in the coldest month is lower than 18$^0$C, the base-belt of the Central and Eastern Himalayas may be considered the northern fringe of the tropics.

The thermal condition of Bhojpur and Baoshan, at a comparable altitudes, shows the similarity between the southern flanks of the Himalayas and the southern section of the Hengduan Mountains: equal in the mean temperature of the warmest month, but with a variation of more than 2$^0$C in the mean temperature of the coldest month. This shows that the Himalayas and the

plateau, being an effective climatic barrier, stop the northern cold air masses invading southward. Therefore the southern flanks of the Himalayas are especially well sheltered. The temperature regime of Baoshan indicates that the climate of the southern section of the Hengduan Mountains is essentially subtropical. Due to a high elevation and unfavourable thermal conditions, the southern Tibetan plateau on the northern flanks of th Central Himalayas belongs to the Temperate Zone of the Qinghai-Plateau. Because of the heating effect of the uplifting plateau, it is temperate in summer. For example, in Tingri, at an elevation of 4300 m the average period with a daily mean temperature above 10°C is more than 50 days, enabling the local people to grow crops such as highland barley, peas, and rape with one harvest in a year. Compared to the meteorological station at the southern flanks of the inner Himalayas, at a similar altitude, the temperature condition of the northern flanks is more favourable, with a difference of 3-4°C in the mean temperature of the warmest month.

Table 1. Comparison of Temperature and Precipitation - the Himalaya and the Hengduan Mountains

| Region | Station | Latitude N | Longitude E | Altitude m.a.s.l | Mean Temp. (°C) annual | the cold est | the warm est | Annual precipitation (mm) |
|---|---|---|---|---|---|---|---|---|
| HIMALAYAS | | | | | | | | |
| southern flanks | Kathmandu | 27°42' | 85°20' | 1324 | 18.7 | 10.2 | 24.6 | 1427 |
| | Bhojpur | 27°11' | 87°03' | 1667 | 17.1 | 10.6 | 21.0 | 1192.3 |
| | Pagri | 27°44' | 89°05' | 4330 | -0.1 | -8.8 | 7.8 | 412.7 |
| northern flanks | Lhunze | 28°25' | 92°28' | 3990 | 5.0 | -4.6 | 13.0 | 276.1 |
| | Tingri | 28°38' | 87°05' | 4300 | 2.7 | -6.8 | 11.9 | 322.1 |
| HENGDUAN MOUNTAINS | | | | | | | | |
| southern section | Baoshan | 25°07' | 99°10' | 1653 | 15.5 | 8.2 | 21.0 | 966.4 |
| | Jianchuan | 26°32' | 99°55' | 2191 | 12.8 | 4.6 | 19.7 | 747.5 |
| | Jinchuan | 31°29' | 102°04' | 2169 | 12.2 | 1.8 | 20.6 | 616.2 |
| middle section | Zhongdian | 27°50' | 99°42' | 3276 | 5.4 | -3.8 | 13.2 | 619.9 |
| | Litang | 30°00' | 100°16' | 3949 | 3.0 | -6.0 | 10.5 | 785.8 |
| | Aba | 32°54' | 101°42' | 3275 | 3.3 | -7.9 | 12.5 | 712.0 |
| northern section | Seda | 32°17' | 100°20' | 3894 | -0.1 | - 11.3 | 9.8 | 643.8 |
| | Shiqu | 32°59' | 98°06' | 4200 | -1.6 | - 12.7 | 8.4 | 569.0 |

The divided area and valleys with higher elevations in the northern and middle section of the Hengduan Mountains, belong to the plateau-temperate zone also. Because of different moisture regimes, the temperature condition is not as favourable as on the northern flanks of the Himalayas. For example Litang and Lhunze, at

comparable altitudes, have different thermal regimes: a difference of more than 2°C in the mean temperature of the warmest month. The average period with a daily mean temperature above 10°C is quite different: Litang, 27 days, while Lhunze, 133 days. Litang lies nerly at the upper limit of the highland barley and has an unstable yield, while in Lhunze the highland barley and wheat are successfully grown.

The effect of the latitudinal situation on the thermal regimes becomes apparent in the Hengduan Mountains Region, especially for winter temperatures. For instance, Zhongdian and Aba, at a similar altitude with a difference in latitude of 5°C, have different thermal conditions: a difference of more than $4^0$C in the mean temperature of the coldest month and a difference of more than 55 days in the average duration with a daily temperature above 10°C. This fact plays an important role in cultivation planning.

According to differences of thermal regime, the dry valleys in the Hengduan Mountain Region may be divided into 4 types, generally occurring in the following succession: hot dry valleys, warm-dry valleys, temperate-dry valleys and cool-dry valleys, being correlated with an increasing elevation of the valley bottom.

In addition to regional differentiation, an enormous altitudinal range over a short distance contains obvious differences in thermal-moisture conditions, creating a great variety of altitudinal belts.

## THE ALTITUDINAL BELTS AND THEIR REGIONAL VARIATIONS

### The Range of the Altitudinal Belt

The range of the altitudinal belt between the base - belt and the prevailing belt of the Himalayas is wide. The southern flanks in the Central and Eastern Himalayas consisting mainly of montane forest belts, are of the maritime system. This is chiefly comprised of two types: tropical evergreen and semievergreen rainforest, and lower montane tropical monsoon deciduous forest (Zheng Du and Chen Weilie, 1981):

The former of the two types exists on the southern flanks of the eastern Himalayas. The evergreen rainforest consists predominantly of *Dipterocarpus turbinatus, D.Macrocarpa, Mesua ferrea, Artocarpus cheplasha,* and *Tetrameles nudiflora.* The upper levels of the semi-evergreen rainforest are dominated by deciduous trees, such as *Terminalia myriocarpa, Altingea excelsa, Nagerstroemia minuticarpa* and *Homalium zeylanicum.* The lower levels consist of evergreen trees, including *Castanopsisindica, Talauma hodgsonii.* In the valley of the Yarlung Zhangbo the tropical evergreen rainforest reaches as far north as Siging (450 m) and the semi-evergreen rainforest, to the north of Aedog (1000 m, $29^0$N).

The lower montane belt of evergreen broad-leaved forest consists of *Fagacea,* among which the genus of *Castanopsis* and *Cyclobalanopsis,* characterized usually by the mossy forest, prevail. The montane needle- and broad-leaved forest belt and the montane coniferous forest belt are dominated by hygrophilous forest of *Tsuga dumosa and Abies delavayi.*

On the southern flanks of the Central Himalayas the base-belt of the tropical monsoon deciduous forest is dominated by forests of *Shorea robusta,* reaching its upper limit at an elevation of 1000-1200 m. The range of the montane evergreen broad-leaved forest belt may reach 1500 m. The mixed coniferous and broad-leaved forest belt consists of *Tsuga dumosa* on the shady slopes, and *Pinus griffithii* and *Quercus semicarpifolia* on the sunny slopes. On the southern flanks of the western Himalayas, located in northerly altitudes with semiarid climate, the base-belt of the spectra is composed of *Pinus roxburghii* forest and the dense scrub of *Acacia* and *Zizyphus.* Further up are forests of *Pinus gerardiana* and *oaks.* This type of spectrum on the altitudinal belt is transitional between the maritime and the continental systems. In contrast, the altitudinal belt of the continental system appears on the Tibetan Plateau in the northern Himalayas. The prevailing belt is alpine steppe, composed of *Sipa purpurea, Artemisia wellbyi,* and *A. Younghusbandii.* In the arid region of the northern flanks of the western Himalayas the montane desert and desert-steppe, consisting chiefly of *Ceratoides latens,* and

*Stipa glareosa*, are the base-belt of the spectra of the altitudinal belt. The spectra of the altitudinal belt vary from south to north in the Hengduan Mountains. In the southern section of the region the montane evergreen broad-leaved forest and the montane coniferous forest of *Pinus yunnanensis* comprise the base-belt of the spectra. In the hot-and warm-dry valleys the shrubgrassland, consisting mainly of *phyllanthus emblica, Jatropha curcas, Euphorbia antiquorum, Bauhinia faberi; Heteropogon contortus, Cymbopogon distans*, etc.

In the middle section of the region the mixed coniferous and broad-leaved forest belt is composed of montane sclerophilous evergreen broad-leaved forest and montane coniferous forest. The former, consisting of *Quercus aquifolioides*, plays a significant role in the landscapes of the region; the latter is composed respectively of *Pinus densata, Tsuga dumosa* and *T. Chinensis.* At the bottom of temperate- and cool-dry valley the thorny shrub is mainly *Sophora vicifolia, Bauhinia faberi, Sageretia pycnophylla* . The upper montane coniferous forest, of *Picea balfouriana, Abies squamata, A. georgei* and *A. eernestii*, prevails in the spectra of the altitudinal belt.

A base-belt of alpine shrub and meadow occurs widely in the northern section of the Hengduan Mountains Region with higher elevation and gentle relief. Generally the shady slopes are covered by alpine shrubs, mainly *Salix spp., Rhododendron nivale, R. spp. Sibiraea angustata, Dasiphora fruticosa.* On the sunny slopes the shrub of *Sabina pingii* and alpine meadow, dominated by *Kobresia pygmaea, K. setchwanensis, K. ssp., Polygonum macrophylla, P.viviparum, Festuca ovina, Anaphalis flavescens* and *Spenceria ramalana*, grows extensively.

**Limits and Type-Combinations of the Altitudinal Belt**

In the Central and Eastern Himalayas as well as the southern section of the Hengduan Mountains the montane evergreen broad-leaved forest belt with a range of 1000-1500 m, reaches up to limit to 2200-2300 m in the humid region of the eastern Himalayas, 2500 m on the southern flanks of the Central Himalayas and 2700 m in the Hengduan Mountains Region.

The district Zayu is a transitional area of montane evergreen broad-leaved forest, dominated by *Cyclobalanpsis oxyodon*, and appears on the north-facing slopes at an elevation of 2000-2600 m , while the south-facing slopes are covered by the forest of *Pinus yunnanensis* reaching up to 2700-3000 m. The type-combination of the montane coniferous and broad-leaved forest belt is complex. The hygrophilous forest of *Tusaga dumosa* prevails in the Central and Eastern Himalayas as well as in the southern marginal land of the Hengduan Mountains. Towards the interior, where there is an unfavourable moisture regime, the south-facing slopes are covered with pine forests: *Pinus griffithii* in the Himalayas, and *Pinus densata* in the Hengduan Mountains. An Asian montane variety of the sclerophilous evergreen broad-leaved forest is widespread. The forest is mainly of *Quercus semicarpifolia* in the Himalayas, while in the Hengduan Mountains it is dominated by *Qercus aquifolioides, Q. longispica.* The altitudinal range of this forest belt varies from 2500-4000 m. In some places a variety of Quercus shrubs reaches as high as 4200-4500 m.

In both regions the montane coniferous forest is dominated by *Abies* and *Picea.* The montane coniferous forest belt occurs over a range of 800-1200 m in altitude, while in the interior and the north-western part of the Hengduan Mountains the montane coniferous forest is composed of *Picea* on the north-facing slopes, and the open forest of *Sabina tibetica* on the south-facing slopes. The total range of the belt decreases to 400-500 m, the forest grows in patches. Northwestwards the range of the coniferous forest belt narrows and disappears gradually.

The upper forest limit varies obviously in different regions. On the southern flanks of the Eastern Himalayas the upper forest limit is between 3700 - 3900 m ; in the inner part of the Central section it is 3900-4100 m while in the Western Himalayas it reaches 3800-4000 m. In the Central and western Himalayas the stunted forest of *Betula utilis* and the dense shrubs of a special ecological type *Rhododendron campanulatum* grows near the upper limit,

benefitting from the geo-ecological effect of snow drifts in the winter half year.

In the peripheral area of the Hengduan Mountains the upper forest limit is lower, 3700-3800 m, and less than 3500 m on the eastern slopes in the JiaJin Shan and the Qionglai Shan areas. In the inland of the Hengduan Mountains, the forest section, and descends to 4000-4200 m in northern section, corresponding to the latitudinal effect.

The type and limit of the scrub belt of the dry valley varies from the margin to the interior in the Hengduan Mountains Region. In the south it consists chiefly of *Acacia, Bauhinia faberi, Phyllanthus emblica, Heteropogon contortus* and *Cymbopogon distans*, with montane red-drab soils. In the north the dominating species are *Sophora icifolia, Sageretia pycnophyulla, Caryopteris forrestii* and *Artemisia vestita*, with montane drab soils and drab carcareous soils. The total range of the scrub belt of the dry valley varies from 300-600 m. The upper limit of the belt controlled, to a certain extent, by the moisture regimes, may be considered as the lower limit of the montane forest. In the middle section it increases from 1600 m in the eastern margin, to 3100 m, in the interior. Corresponding with an increasing elevation of the bottom of dry valleys, the lower forest limit ascends from south to north. For example in the Dadu River valley, it is 1600 m at Luding in the south, while 2400-2600 m at Jinchuan in the north; in the Lancang Jiang River, it is 3100 m at Yanjing in the south, and 3600-3800 m at Qamdo in the north.

## LAND UTILIZATION AND HUMAN IMPACT ON THE ENVIRONMENT

In the mountain region the altitudinal belt is the background for rational utilization of the renewable natural resources and the plannin of agriculture, forestry and animal husbandry. It deserves sufficient attention that the long-term impact of humans on the fragile mountain environment has given rise to variations of type and limit of the altitudinal belt and a lot of environmental problems.

### Main Features of Land Utilization

Altitudinal belts are economically important in delineating different areas for agriculture, animal husbandry and forestry. Yak and sheep are grazed on the alpine belt, croplands are located in the valley belt, and the montane forest belt, being an interlinked zone for grazing and cultivating, supplies timber, for fuel and other things. The regional differentiation of geo-ecological conditions is reflected in the structure of land utilization.

The plateau region with lake basins and broad valleys is an agriculture-pasture interlinked district. About 2/3rd of the total area is covered by natural pasture, consisting chiefly of alpine steppe. The cropland is located at lower elevations only. The valleys and basins lower than 4300 m, are favourable for growing *Qingke* (highland barley), pea, spring wheat and rape, *Qingke* takes up more than 60% of the sowing area of the region. The upper limit of *Qinke* is 4750 m; rape, 4600 m; pea, 4500 m; and spring wheat, 4400 m. The district, at an elevation of 4300 - 4500 m, is an interlinked zone for agriculture and pasturage and the district, 4500 m, is used for animal husbandry, grazing, herds of Tibetan sheep and an increasing proportion of yaks in wetter locations (Cheng Hong and Ni Zubin, 1984). Forested land makes up the bulk of the total area on the southern flanks of the Himalayas. In Bhutan the forested land covers about 67% of the country (ICIMOD, Nepal). In Nepal the forested land accounts for 27% of the total hill and mountain area. In the Medog and Zayu districts of Tibet, located in the Eastern Himalayas forest coverage may reach about 40%. There is little cultivated land on the southern flanks of the Himalayas. About 72% of the total cropland of Nepal is located in the Terai, and the rest lies in the hills and valleys of the middle region ranging between 300-3,000 m. The cultivation ratio may reach about 7.7% in the region. Approximately 69,000 hectares are under cultivation in the mountains, above 3,00 m. In the Great Himalaya, the cultivation ratio reaches 1.96% only. The upper limit of crops in Eastern Nepal is as follows: 4300 m for highland barley, potato and buckwheat;

2800 m for maize; 2500 m for millet and 2100 m for wet rice (Haffner, 1979 & 1984).

The main features and structure of land utilization correspond to the geo-ecological conditions of the Hengduan Mountains. Owing to high altitudes and cold climate, the valleys above 3500 m in the northern section are too cold for crop growing. *Qinke* and wheat may be locally grown in valleys at lower latitudes only. The alpine shrubs and meadows which are favourable for grazing yak and sheep, cover most of the region. In Shique and Seda the yak and sheep make up about 48% and 40% respectively of the total livestock. In the middle section with lofty ridges and deep gorges, the altitudinal belt plays a significant role in land utilization.

In the Prefecture Ganze Zhou of west Sichuan the available area of pasture accounts for 29.6% of the total land area and forested lands, 9.8%. Due to the topographic conditions the cropland is restricted mainly within certain limits in the valley bottoms; the cultivated ratio is only 0.6% in the Prefecture. The upper limits of cultivation vary with the different crops: 3000 m for maize; 3000 - 3600 m for wheat; for highland barley, 3 3500 - 3700 m in the middle section and 3900 - 4000 m nearby Qamdo in the interior. The upper limit of cultivation, which lies usually at an elevation under the upper forest limit, is considerably higher in the interior than in the margin areas.

In the southern section of the Hengduan Mountains the cultivated land is located in the broad valleys and basins, where the leading crops are rice, maize and wheat. The upper limit of rice may reach 2600 - 2700 m, much higher than that on the southern flanks of the Central Himalayas.

**Environmental Problems**

Historically human activities have been insignificant in both regions. In comparison to the Sichuan Basin the impact of human activities on the environment of the Hengduan Mountains was also insignificant, similar to the Great Himalayas.

However, since the beginning of the twentieth century, and especially since 1950, the political and social conditions of the two mountain regions have been subjected to great changes. Because of the introduction of technology from neighbouring areas, the increasing need for economic development, the improvements in transportation and the pressure of population growth, human mismanagement and overuse of natural resources, such as cultivating steep slopes, clearing forests, gathering fuelwood, overgrazing, etc., bring about a lot of environmental problems,for example the instability of slopes, accelerated soil erosion and gradual expansion of the scrub belt of dry valleys.

In the Great Himalayas most of the permanent settlements are located at an elevation of less than 2800 m. As a case study, in the Khumbu region of Nepal, located on the southern side of Mt. Qomolangma or Sagarmaṭha, although the land above 3500 m is considered unfavourable for crop growing, croplands still appear up to an elevation of 4300 m. The mean area of cropland per capita is 0.15 hectares only. In Chengtang district of the Dingjie County in the upper reaches of the Arun River the mean area of croplands per capita is less than 0.7 hectares, while in Zham, located at the gorge section of Po Q 0,03 hectares per capita.

A decrease of cropland is closely linked with a rapid growth in the population. During the period of 1951-1981, the expanded croplands of the Prefecture Ganze Zhou reached to 4,562 hectare and due to a rapid growth of the population with an increase of 255, 293 persons at the same period, the mean area of croplands per capita decreased from 0.17 to 0.11 hectares. Owing to the pressure of population growth in the mountainous area the people have to expand croplands and cultivate on steep slopes. In the Prefecture Ganze and Aba, although there is a lower ratio of cultivation (0.6-1.1%), the cropland on slopes with a gradient of more than 25% makes up about 20-30% of the total area . In the Jinchuan County about 7% of the total croplands is distributed on slopes with a gradient of more than 30%. The phenomenon of expanding cultivable land by clearing forests is conspicuous in marginal areas neighbouring the montane forest belt. It gives rise to the deforestation

and a serious loss of water and soil.

In the upper reaches of the Min Jiang, located in the north-eastern part of the Hengduan Mountains, forest coverage decreased from about 50% in the Yuan Dynasty (more than 600 years ago) to 30% at the founding of New China. And since then it has fallen to 18.8%.

In west Sichuan 160 million cubic metres of timber, about 1/5 of the total stores of the forest resources, were consumed in the last 30 years. The total exploitation of the forest is about 2.3 times more than the productivity of the forest.

Fuel demands and firewood collection, a major problem to the environment, are closely correlated with the deforestation, which has led to the depletion of the natural vegetation.

In Baoshan County at the southern section of the Hengduan Mountains, about 0.46 million cubic metres of the timber were consumed in 1979, 3/4 of which was used for cooking and heating. There are a number of factories which still use timber an energy resource for production. Around the Jinchuan County in the valley of the Dadu River were many forest stands consisting of *Cupressus Chengiaà*, but now there are only a few left due to overcutting for fuel producing calcined lime.

To sum up, the expansion of cultivable lands and deforestation are problems in mountain development. Overuse and mismanagement of the renewable natural resources has brought about environmental problems such as soil erosion, water shortage, forest destruction and damage of the biological resources. The expansion of the scrub belt of dry valleys and the variation of the upper-and lower-forest limits are inevitable results, and reflections of the environmental problems.

In addition, the phenomena of landslides, slope-slips, mud-flows and debris-flows as natural hazards, occur frequently in the two comparable mountain regions. They deserve attention in the watershed management of the mountainous areas.

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