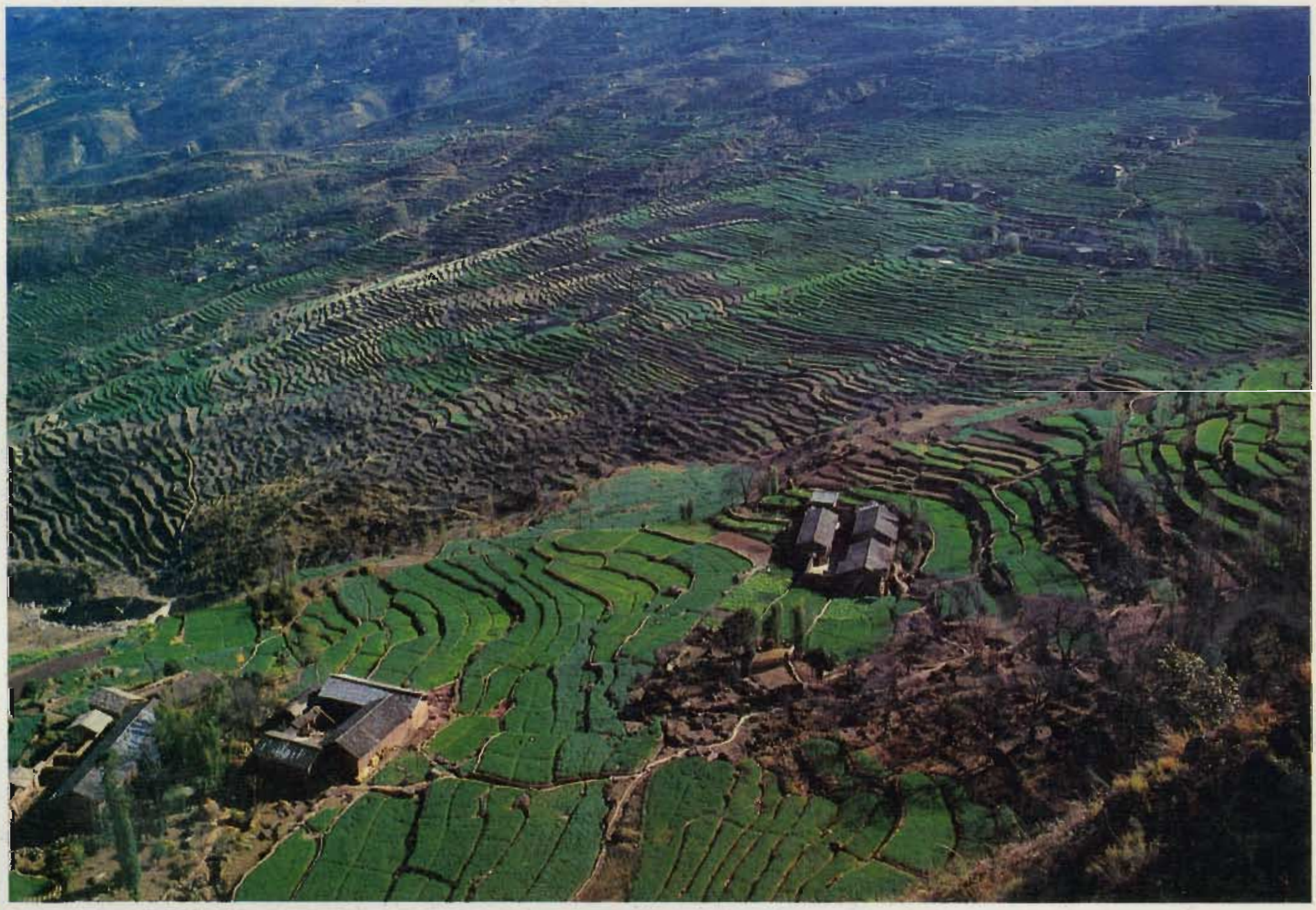
ICIMOD
International Centre for Integrated
Mountain Development

Commission for
Integrated Survey of
Natural Resources
The Chinese Academy
of Sciences

WATERSHED MANAGEMENT

Proceedings of The International Workshop on Watershed Management in The Hindu Kush Himalaya Region



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Organized by

International Centre for Integrated Mountain Development

in collaboration with

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The Chinese Academy of Sciences

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WATERSHED MANAGEMENT IN MOUNTAIN REGION OF SOUTHWESTERN CHINA

Collected Papers from the

International Workshop on Watershed Management in the Hindu Kush-Himalaya Region

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Foreword

ICIMOD is a newly established International Centre focusing on the issues of integrated mountain development in the Hindu Kush-Himalaya Region. Its first priority has been to review the current state of knowledge and of field experience on selected topics, by organising International workshops to bring together leading professionals from the countries of the Region, and international agencies and organisations.

An International Workshop on Watershed Management in the Hindu-Kush Himalaya Region was held in Chengdu, China in October 1985. It was organised by ICIMOD, the International Centre for Integrated Mountain Development in collaboration with CISNAR, Commision for Integrated Survey of Natural Resources, Chinese Acadeny of Sciences.

The conclusions are summarised in the Workshop Report published in 1986.

This is a volume of Collected Papers on Watershed Management in Southwestern China, addressing major issues of natural resources management in Hengduan and Himalaya Mountain areas of China. A volume of the same papers in their full text version is available in the Chinese language.

ICIMOD and CISNAR would like to express their warmest thanks to all the Chinese professionals who contributed to this volume.

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WATERSHED MANAGEMENT IN MOUNTAIN REGION OF SOUTHWESTERN CHINA

Collected Papers from the

International Workshop on Watershed Management

in the Hindu Kush-Himalaya Region

ICIMOD PHASE I Workshop Series

The International Centre for Integrated Mountain Development began professional activities in September 1984, with the first objective of reviewing development and environmental management experience in the Hindu-Kush Himalaya Region. An International Workshop was planned for each of four major fields to review the state of knowledge, and practical experience, and to provide an opportunity for the exchange of professional expertise with regard to integrated mountain development.

ICIMOD completed Phase I activites in June 1986, having held:

- o the International Workshop on Watershed Management in the Hindu-Kush Himalaya -- Chengdu, China, 14 to 19 October 1985
- o the International Workshop on Planned Urbanisation ;and Rural Urban Linkages in the Hindu-Kush Himalaya Region -- Kathmandu, Nepal, 25 to 29 March 1986
- o the International Workshop on Distric6t Energy Planning and Management for Integrated Mountain Development -- Kathmandu, Nepal, 3 to 5 May 1986
- o the International Workshop on Off-Farm Employment Generation in the Hindu -Kush Himalaya -- Dehradun, India, 17 to 19 May 1986.

These Workshops were attended by over two hundred experts from the countries of the Region, and concerned professionals and representatives from international agencies. A large number of papers and research studies were presented and discussed in detail. With the permission of the authors, copies of papers in full will be supplied on request, with a charge to cover reproduction and postage costs.

In September 1986, ICIMOD published four summary Workshop Reports. Each is intended to represents the conclusions reached at the Workshop and does not necessarily reflect the views of ICIMOD or other participating institutions.

Copies of the reports are available upon request from:

The Publications Unit
ICIMOD
G.P.O. Box 3226
Kathmandu
Nepal

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

Li Wenhua and Zhang Mingtao

(Commission for Integrated Survey of Natural Resources, Academia Science)

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	Altitude (m.a.s.l) 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 coniferous 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 (1000 Km^2)	Average Silt Content kg/m^3	Annual Silt Transportation (mio t)	Erosion Modulus (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. Inter-connecting 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 30^0N), the rivers run roughly northwest to southeast with slight gradient. Fluvial terraces and flood lands occur in a number of broad valleys. Southwards from 30^0N, 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 $10^{0}C$ 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. (^{0}C) annual	the coldest	the warmest	Annual precipitation (mm)
HIMALAYAS								
southern flanks	Kathmandu	$27^{0}42'$	$85^{0}20'$	1324	18.7	10.2	24.6	1427
	Bhojpur	$27^{0}11'$	$87^{0}03'$	1667	17.1	10.6	21.0	1192.3
	Pagri	$27^{0}44'$	$89^{0}05'$	4330	-0.1	-8.8	7.8	412.7
northern flanks	Lhunze	$28^{0}25'$	$92^{0}28'$	3990	5.0	-4.6	13.0	276.1
	Tingri	$28^{0}38'$	$87^{0}05'$	4300	2.7	-6.8	11.9	322.1
HENGDUAN MOUNTAINS southern section	Baoshan	$25^{0}07'$	$99^{0}10'$	1653	15.5	8.2	21.0	966.4
	Jianchuan	$26^{0}32'$	$99^{0}55'$	2191	12.8	4.6	19.7	747.5
middle section	Jinchuan	$31^{0}29'$	$102^{0}04'$	2169	12.2	1.8	20.6	616.2
	Zhongdian	$27^{0}50'$	$99^{0}42'$	3276	5.4	-3.8	13.2	619.9
	Litang	$30^{0}00'$	$100^{0}16'$	3949	3.0	-6.0	10.5	785.8
northern section	Aba	$32^{0}54'$	$101^{0}42'$	3275	3.3	-7.9	12.5	712.0
	Seda	$32^{0}17'$	$100^{0}20'$	3894	-0.1	- 11.3	9.8	643.8
	Shiqu	$32^{0}59'$	$98^{0}06'$	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 Chengiaa*, 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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ANIMAL HUSBANDRY AND GRASSLAND RESOURCES

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ANIMAL HUSBANDRY AND WATERSHED MANAGEMENT IN HIMALAYA-HENGDUAN REGION

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INTRODUCTION

The Himalaya-Hengduan region situated in the south-western part of China is the largest mountain region in the world. The Himalayan range known as "The Roof of the World", has numerous ice pinnacles and rugged peaks. Mount Qomolangma (Mount Everest) is the highest peak in the world.

The Himalaya region includes the valleys of Yarlungzangbo, Pum-Qu, Luo-Qu, Ma-Jia Zang Bu, and Lang-Qin Zang Bu. The Yarlungzangbo river is the worlds highest.

The natural landscape of the southern Himalayan slopes differs from the northern slopes and the physical phenomena vary within short distances.

The Hengduan ranges situated to the east of the Himalaya are oriented north to south. The range includes the Boshula, the Thaniantaweng, and the Nigjing. In between are the gorges of Nu-Jiang, Lancung-Jiang, and Jinsha-Jiang. Peaks on the range rise to 5500-7000m and the climate is moist.

At the source of Himalaya-Hengduan valleys, topography is gentle with good vegetation and light erosion. Tibetan sheep and yak find excellent pastures on the plateaus, mountains, and lacustrine flats. The precipitous mountain zone with sparse vegetation is not good for livestock farming. Gorges alternate with depressions on river courses. The elevation is not high and terracing occurs in the depressions. The climate is good for farming, particularly in the main urban centers and areas of concentrated population. The region is rich in agricultural by-products, for example fodder.

ANIMAL HUSBANDRY

Types and Charactersitics of Animal Husbandry

The Himalaya-Hengduan region, with complex prevailing conditions, is rich in natural resources and domestic animals. It is a typical region for mountain animal husbandry studies as it has a vertical distribution of the various types: sheep, goat, horses, donkeys, swine, yak, cattle, buffalo and zebu.

Animal husbandry production is restricted by the natural conditions due to the changes in rising elevations (See Table 1).

Range lands and Animal Husbandry: The region is composed of various types of rangeland. The main types are alpine meadow, mountain shrub, mountain sparse wood, and mountain desert.

Alpine animal husbandry: The elevation for this form is the highest in the region, as most parts are over 4500 m, including areas at the top of the Himalaya, the source of Yarlungzangbo river and the northern part of the Hengduan range. The cold climate is not suitable for farming, so the rangelands are not cultivated, creating a pastoral region. The domestic animals reared, such as yak, sheep and goat, are native breeds with a great capacity of survival in this environment. The management of animal husbandry is extensive and most animals are free-range grazers.

Owing to the variances in natural

conditions between the western and eastern parts, alpine animal husbandry is sub-divided into three parts.

In the east Himalaya and northern part of Hengduan, the altitude is lower, annual precipitation is about 650mm, the vegetation of the rangeland is mainly alpine meadow and shrub, and the animals mainly yak and sheep. Yak form 25-45% of the total animal population.

In the Western Himalaya, the altitude is in excess of 4500 m, climate is semi-arid,

Table 1. Vertical Distribution of Animal Husbandry

Altitude	Topography	Climate	The Type of Rangeland	Type of Economy	Main Animal
>4500m	Alpine Plateau	Cold Sub-humid	Alpine meadow and Alpine steppe	Pastoral regions	Yak and sheep
3500 - 4500	Plateau Valley	Cool Semi-arid	Mountain Steppe and Mountain shrub	Semi-pastoral regions	Sheep, Yak and Cattle
2500 - 3500m	Valley	Warm Semi-arid	Mountain shrub	Semi-agricultural regions	Cattle,Goat and Swine
<2500 m	Valley	Hot Humid, Semi-arid	Mountain sparse wood	Agricultural regions	Buffalo and Swine

precipitation is 300-350 mm, vegetation is mainly steppe, and sheep form 40-60% of the total animal population.

In the far western end of the Himalaya, climate is arid, precipitation is less than 100 mm, vegetation is mainly desert, and goats form 45% of the total livestock population.

Plateau lake-basin area: This form is practised at the second floor of vertical distribution, generally at an elevation of 4200-4500 m. The climate is not too cold, and vast natural grasslands exist. Animal husbandry is the main component of the economy. The area is self-sufficient in animal products. Some cold-resistant crops, i.e. highland barley (naked barley), are planted in some areas.

Species of livestock are more numerous and include sheep, goat, yak, cattle, hybrids, horses, donkeys and swine. Sheep form 60% of the total animal population. The management of animal husbandry is extensive. Herdsmen are settled and most animals penned.

Plateau-valley area: The elevation is generally between 3000-4000 m, where the warmth is good for farming. Forests, rangeland and cropland are distributed across the slopes of the mountains. Agriculture plays an important role in the economy, and the areas are self sufficient in agricultural products, particularly supplementary fodder. Animals are mainly cattle and goats.

Low elevation-gorge area: In the south-eastern parts of Hengduan and southern slopes of the east-Himalaya, altitude is lower than 2000m, climate is hot and humid, agriculture is developed, and the crops grown include rice, wheat and maize. Animal husbandry is a part of the agricultural ecosystem. In addition to cattle and goats, there is a large number of other animals living in the tropics and sub-tropics. For example buffalo and zebu. Cattle form 25-30% of the total animal population.

DEVELOPMENT OF ANIMAL HUSBANDRY AND THE MANAGEMENT OF VALLEYS

Direction of the Development of Animal Husbandry

Because the region has wide rangelands, rich farming by-products, a high population of domestic animals and a long history of animal husbandry, it is expected to continue as a prime area for animal husbandry. General development direction will be towards a stable base for animal husbandry. Management will change gradually from extensive to intensive.

Animal husbandry practices are expected to concentrate on oxen, which are an important division of animal husbandry in the region. The oxen population is 40% of the total livestock. The ox species are yak, hybrids, cattle, buffalo and zebu. These animals adapt to various environments and form a good foundation for animal husbandry development in the future. The beef/milk ox population will be increased, and programmes for the improvement of meat/milk ox, draught animals, and wool stocks will be initiated.

Sheep: Sheep development is important in a division which invariably produces large quantities of wool and mutton, and sheepskin. Sheep will be developed for wool and mutton, and goats for wool, milk and skins.

Transportation is difficult in the region. For short distances horses that suit the mountain environment are required. Other animals, and poultry, should also be developed to maximize available resources.

Management Methods: In the region, rich in grasslands, animal husbandry has had a long history. However use of natural resources has been irrational, with excessive use of grassland which has damaged the development of animal husbandry and valley management. The following suggestions are made:

The full rangelands should be used during the warm periods (summer and autumn), and protected during the cold winter and spring. The animal carrying capacity of the rangelands is seasonally unbalanced. An estimate is that the animal carrying capacity during the cold season is 40% less than in warm seasons. Analysis indicates that in periods of warm weather alpine meadow (40% of rangelands) is utilized.

The rangelands of alpine meadow are the best of the high mountain lands and have palatable and nutritious grasses, with a high content of crude protein (16%). Alpine meadow in warm seasons when the climate is cooler and water sources plentiful, are ideal. Additionally, the root systems of the herbage are concentrated within the surface layer of the springy soil, that is resistant to erosion. This rangeleand, with altitudes generally of 3600-4800 m, and sometimes 4700-5200 m has a climate that is cold and stormy in winter and spring, preventing grazing. A rational plan is required to increase the animal population and grazing time during the warm seasons.

Lake-basin meadow is also found in the region. Topography is low-lying and surrounded by hills, climate is not too cold during winter, and the yield from grasses is high. It is suitable for the grazing of animals during the cold season. 70% of the animal population graze here during winter and spring. A 5-7 month grazing season has resulted in overgrazing causing damage to pastures and soil. A grazing plan must be developed to decrease animal grazing times.

Degraded rangeland can be improved by cultivating artificial grassland. In the region, most herbage is too short to cut and stores of hay are insufficient for winter feed - only 0.5-1 kg being stored per animal. To achieve a stable system of fodder production, with rational use of natural rangeland, the improvement of degraded rangeland, the cultivation of aritifical grasslands, and the increase of fodder production during winter and spring should be energetically persued. Irrigating, applying fertilizer and sowing seed can all raise the productivity of rangelands. After improving rangelands, yields at 4000m elevation are 300-400 kgs hay per Mu, 7-10 times greater than the yields of degraded rangeland, and 3-5 times greater than natural rangeland yields.

Also shrubby rangeland can be grazed. Shrubby rangelands situated on gentle slopes can generally be grazed leaving time available to sow herbage. Shrubs growing on steep slopes and banks should be not grazed in order to avoid soil erosion.

In the foothills of the river sides in the Himalaya (4200 m) and the Hengduan (3500 m), there are large areas of steppe rangelands which have been exploited, thus creating serious soil erosion and threatening valley bottom croplands. Exploited rangelands, especially slopes exceeding 25°, should return to animal husbandry activities in order to enhance vegetation growth and to preserve both soil and water. In addition, the land should be cultivated with herbage. Stall-feeding of stock should be prolonged to reduce free range grazing. Agricultural by-products and fodder should be increased.

Efficient animal production: Creating efficient animal production is an important link in animal husbandry management. In the region, animal breeding levels, including breed selection from native and imported breeds, should be enhanced. Correct breed selection and improvement can raise productivity by 30%. Seasonal animal husbandry must be developed to decrease usage of the rangelands in the cold seasons. Measures that eliminate inefficient animals thereby structurally improving animal groupings can increase animal productivity. For example, in a countryside area the rate of inefficient animal elimination has been raised to 18% from 13%. Total animal production has not decreased but animal grazing has been reduced by 10%, thus protecting the rangelands.

Rational distribution of husbandry to suit local conditions: The interdependent relationships between various ecological factors and the comprehensive characterstics of production should be considered when using rangeland resources in harmony with the need to preserve ecological balances for the future. The region is sub-divided into four management districts.

Southern slopes of the Himalaya and the Southern part of the Hengduan: This district includes the southern slopes of the middle-east Himalaya and the south-eastern sections of the Hengduan. The climate is hot and humid, rich in precipitation, the forest resources are plentiful, natural conditions provide good farming of two or three crops per year, and natural rangelands mainly consist of alpine and sub-alpine throughout the forest belt.

Although the livestock population is low, its origin is complex. The main groups of domestic animals are goat, sheep, cattle, buffalo, and zebu. Many are the best breeds of the country. With regard to the prevailing ecological conditions and animal species, animal husbandry should be directed mainly towards meat/milk and draught animals. The main animal groups that require development are cattle, buffalo, goat and pig. Rearing methods should rely mainly on stall-feeding, with limited summer grazing.

Valley of the Yarlungzangbo (mid-section), and the central Hengduan: The elevation of this area is high, annual precipitation is low, 400 - 650mm, and one crop only per year is cultivated. It is rich in grazing rangelands and agricultural by-products. The area is developing mixed activities, farming, forestry and animal husbandry.

It is a transition district varying from agricultural to pastoral areas. Animal husbandry should be focussed on milk and meat producing cattle, and also sheep and horses should be suitably utilized.

The district is important for the development of seasonal animal husbandry. The animal population should be controlled to prevent overgrazing and to protect the ecological balances.

Northern Section of Hengduan Range: In the northern part of the Hengduan, topography slopes gently, elevation is higher, growing period of grass is short, and farming/cultivation is minimal. Animal husbandry development depends mainly upon the availability of natural rangelands. Rangelands where the animals are reared and grazed are mainly alpine meadow. Livestock development should be concerned with yak and sheep. Cold season rangeland grazing should be controlled to prevent the degeneration of the rangelands.

Plateau lake-basin of the Himalaya: This includes vast plateau with the lake-basins of the northern slopes of the Himalaya. Elevation is generally 4300-4500m, climate is semi-arid and arid, annual precipitation is 230-410mm, and only cold-resistant crops can grow. Rangeland vegetation is alpine steppe. The natural conditions and characteristics of the resources are good for sheep rearing.

The rangeland has been overgrazed and is degenerated. In order to increase stall-feeding and decrease free range animal grazing, artificial grass and fodder crops should be grown.

EXPLOITATION OF THE MARSHLANDS AND MARSH MEADOWS AND RATIONAL USE OF THE GRASSLAND RESOURCES IN RUOERGAI REGION

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INTRODUCTION

Ruoergai region, (32°20'-34°10' N 102° 15'-103 50'E) belongs to Ruoergai and Hongyuan counties of Aba Tibet Autonomous Prefecture, Sichuan. The grassland here, distributed over a large area of plentiful water and luxuriant grass, is an important base for the plateau animal husbandry. The marshlands and marsh meadows (informally called by the local people and including marsh vegetation and marsh meadows, as well as some joined meadows) have also been developed well and play an important role in the region, covering an area about 30 million ha (including part of the adjacent Aba county) and accounting for 10.59 % of the total area and 14.66% of the total grass-land area of the three counties. The major plants of the marshlands and marsh meadows are the Carex and Kobreasia of the Cyperaceae. A lot of surface water accumulates seasonally, so the areas are not easily accessible and have low useful value. Attention is now focussed on how to improve and use the marshlands and marsh meadows. This paper, based on the many-year vegetation surveys of the region, presents suggestions for the exploitation of the marshlands and marsh meadows, and the utilisation of the pasture resources of the region.

CHARACTERISTICS OF THE NATURAL ENVIRONMENT OF RUOERGAI REGION

Landform characteristies

Ruoergai region is a part of the Yellow River source on the north of the Bayankela Mountains, which belong to the east margin of the Qinghai-Tibet Plateau. Based on the structure, it belongs to the Ruoergai-Jingchuan Synelinovium in the Western Sichuan geosyncline, running from northeast to southwest. The rock layers mainly consist of sandstone, plate, phyllite and flag limestone of the Triassic period. The rock formation is covered with the Quaternary sediments made by the alluvial, diluvial, slope and iceborne deposits. There are few rocks without earth cover.

Based on the vast plane formed in the peneplain stage during the middle Triassic period, the basic outline of the region's plateau landform was formed with the strong uplift of the Qinghai-Tibet Plateau during the end of the Triassic period and the beginning of the Quaternary period. The edges of the plateau became warped because of the intermittent and different uplifts of the neotectonic movement. On the plateau there are wide valleys and gently sloping hills. It is a hill - like plateau, the south part being a little higher than north part. It is surrounded by the mountains: the Mountain land is in the north; Min Mountains are in the east and Qionghai mountains are in the south. Those mountains are often 4000 m high. In the middle of the plateau, there are valleys with wide floors and low hills. The relative height between the hill tops and valley bottoms is over 50-200 m. The Black River and White River run through the region from south to north and empty into the Yellow River. Those river valleys are open and several kilometers wide; in some places they are more than 20 kilometers wide. Many well-developed meanders, river forks and oxbow lakes are spread all over the region.

The gently sloping hills, broad valleys and meandering rivers are useful for collecting and keeping water in the region. The Quaternary sediments widely distributed in the valleys and especially, the silt and light clay of the lake facies deposits, have poor permeability and have formed a layer which easily prevents water from permeating the terrene. The accumulated water on the surface has provided the conditions for the development of the marshlands and marsh meadows.

Climate characteristics

Ruoergai region belongs to the frigid climatic zone of the Qinghai-Tibet Plateau. The main characteristics are frigid, humid, and long frost season, with relatively large precipitation and much drizzling rain. The major climatic factors of Ruoergai and Hongyan counties are shown in Table 1.

Table 1: Major climatic factors of the two counties (1957-1974)

Counties	Annual mean precipitation (mm)	Annual mean temperature °C	Annual mean relative humidity (%)	Annual accumulated temperature (°C)
Ruoergai	641.9	0.69	68	306.9
Hongyuan	700.3	1.1	72	322.0

Water is the main influence, on the formation of the marshlands and marsh meadows, and precipitation is the major source of water of the area. Table 1 shows that precipitation in the Ruoergai region is relatively high. The climatic data between 1957-1974 also indicate that in the region, the precipitation from May to September each year accounts for 80% of the total annual rainfall. Overcast and rainy days are many, and continuous rain can last as long as 25 days a month. Due to such rainfall density, and soil permeability, the surface runoff is small. The annual mean evaporation is only 450 mm, which is smaller than the precipitation of Ruoergai region. The surplus water is drained away by surface runoff and underground streams.

Heat not only influences plant growth, but also the decomposition and accumulation of the organic remains. It can promote the development of the marshlands and marsh meadows if the accumulation of the organic remains is faster than decomposition. Generally speaking, when the temperature is below 5° C, the activity of micro organisms is very weak. In the region there are 7 months a year when the mean temperature is less than 5° C. Under such a long and low temperature period, the docomposition of the organic remains is greatly inhibited (by microorganisms) and peat accumulateds in large quantities.

To sum up, precipitation is higher than the evaporation capacity and the extended, low temperatures create favourable conditions for the formation and development of the marshlands and marsh meadows, as well as deeply influencing the composition of the region's vegetation types.

Hydrological characteristics

The discharge of the Black River and White River, running through the region, is large but stable year after year. The two flow in the same valley. The rivers' valleys are relatively wide and flat, without terraces. Particularly in the middle and lower reaches, there is little difference between hill slopes and valley floors. The rivers therefore, are so meandering in many places and flow so slowly with a specific drop of only 0.002-0.003 %, providing the marshlands and marsh meadows with plentiful water by permeation.

It is the underground water that greatly influences the marshlands and marsh meadows. The underground water mainly consists of the slope underground water, alluvial underground water, and crack underground water. The slope and alluvial underground waters are usually found at the foot of the hills and spill out onto the surface, but this varies greatly. In winter (after November) the water is frozen and stored in its solid state. When the warm season comes, it melts and flows into the areas. However the discharge of crack water is great and stable, and usually converges into streams. The streams flow into the marshlands and trunk rivers. The different underground waters are highly influential on the formation and development of the marshlands and marsh meadows.

Vegetation characteristics

Due to the effect of the frigid and wet environment, the growth of some forest species has been inhibited. The small-size coniferous forests of *Picea asperata, P. wilsonii, P. purpurea, and Abies faxoniana* are scattered on the north-facing slopes. In addition, scrub is also usually distributed on the north-facing slopes, as well as on the river banks. The major plants are *Salix spp; Spiraea alpina, Sibiraea angustata, Lonicera thibetica, Rhododendron nitidum, Potentilla frunticosa and Hippophae rhamnoides.*

Besides the small-size coniferous forests and scrubs meadows and marsh vegetation is widely distributed. The meadow vegetation mainly consists of *Clinelymus nutans, Roegneria nutans, Koeleria litwiniwii, K. cristata, Poa pratensis, P. pachyantham Festuca ovina, Agrostis scgneideri, Deschampsia caespitosa; Kobresia setcwanensis, K. humilis and Potentilla anserina, P. bifurca, Anemone rivalaris, A. geum, A. trullifolia var,. Linearis, Anaphalis flavescens, Polygonum viviparum, Leontopodium logifolium.* The marsh vegetation is mainly composed of *Carex muliensis, C. atrofusce, Cremanthodium lineare, C. plantagineum, Caltha scaposa, Sanguisorba filliformis, Chamaesium paradox, Potamogeton pusillus,. Mengathens trifcliata, Utricularia vulgais, Batrachium trichohyllum* and so on.

Meadow vegetation and marsh vegetation is widely distributed over large areas. The meadows have many types and various species, which are luxuriant and grow relatively high. This is the most distinguishing feature of the natural vegetation of the region.

The natural factors of Ruoergai region, such as the land - form, climate and hydrology, create favourable environmental conditions for the formation and development of the marshlands and marsh meadows. Due to the high elevation and severe climate, plantation and forestry have been inhibited, but meadow vegetation and marsh vegetation has been widely developed in the region. Therefore, the pasture land of the region is vast and productive for animal husbandry. The pasture land can produce more than 100 kilograms per mu and sometimes even 1000 kilograms, of dry grasses. The rich meadow vegetation provides animal husbandry with liberal resources. Thus animal husbandry has become the basic production in Ruoergai region.

Drainage of the marshlands and marsh meadows

With the development of the animal husbandry, the pasture lands are in great demand. In order to expand pasture land and the problem of the use and improvement of the marshlands and marsh meadows has been raised. The excessive water is the key factor. Thus, based on the many-year vegetation surveys in the region, the marshlands and marsh should be drained. There have however, been different opinions about it.

Drainage of the marshlands and marsh meadows will destroy the balance of the hydrological cycle.

Due to the environmental conditions in Ruoergai region such as high elevation and harsh climate, the main vegetation there is meadow and bushland, as well as large areas of marshland and marsh meadow. The interception of water and the transportation of vapour in the hydrological cycle is largely done by these vegetation types. Although the marshlands and marsh meadows are smaller than meadows, they have a higher water content and larger water-storage capacity, and in some places they are even covered with water. Therefore, through evapo-transpiration they play an important role in the transportation of vapour into the air, maintenance of the hydrological cycle, and stabilization of the atmospheric and soil humidity and the ground water level in the region.

Based on the climatic data, the annual precipitation of Ruoergai region is 50-80 mm more than that of Shiqu and Seda counties which are at the same latitude. The atmospheric circulation is the main influence on precipitation levels. One of the reasons for the large amount of precipitation in the region is that the marshlands and marsh meadows transport a lot of vapour into the air. During our surveys, it was found that Ruoergai region has developed a large area of meadow vegetation and not grassland vegetation, especially the quantity and growth of *the Gramineae*, as well as the grass yield of the various pasture lands there, are better than those of Shiqu, Seda and Ganzhi counties. The forests on the north-facing slopes are multilayer forests, where growth and natural regeneration is also better than that in Ganzhi county; even the soil of the so-called dry grassland is wet below 5 mm. Besides the influence of latitude, elevation and atmospheric circulation the large area of the marshlands and marsh meadows is important to stabilize the atmospheric and soil humidity of the region.

If the marshlands and marsh meadows are drained dry, the natural reservoir of the region will be destroyed, vapour reduced, ground water level will drop, and the so-called arid grassland become real arid grassland. Futhermore, due to the fall in the ground water level, some sand dune pastures developed from the sand sediments of the ancient rivers, will be affected.

If the marshlands and marsh meadows are drained over a large area, the environment of the region will tend to be arid; and meadows will gradually evolve into grassland vegetation. Thus the productivity of the pasturelands will be reduced and the development of animal husbandry will be inhibited.

It is difficult to plant trees on the plateau and forests cannot be used to regulate the environmental water balance. Due to the harsh natural environment of the pastoral areas, and an elevation beyond the tree line in many places, it is difficult for trees to grow there and very difficult to plant trees. Therefore, it is unrealistic to use forests to regulate climate and maintain the hydrological balance of natural ecology. Forests cannot replace the marshlands and marsh meadows in the natural ecological equilibrium of the region. Drainage of the marshlands and marsh meadows is not the key to increasing the animal husbandry production of the region. It is severely cold in Ruoergai region with a long winter and short spring, summer and autumn.

The growth of grass is different in different seasons; and quantity and quality of forage available vary. Between April and September the grass productivity is high and rich in nutrients. The plentiful regenerated grass is of a fine quality. Between October and March grass productivity and nutrients decrease sharply because of the cold weather. Also, because of the bitter cold and strong winds, the winter and spring pasturelands require good environmental conditions, and are generally distributed on the leeward, south-facing river terraces and on the foot of the hill. Those areas are very limited. During summer and autumn with the temperature rise, the pasture land is more than enough. The pasture areas in winter and spring are not proportional to those in summer and autumn, which causes a disequilibrium.

In winter and spring the pasturelands are over used, but during summer and autumn they are not effectively used. Ineffective use is also a limiting factor in animal husbandry development in the region. The drainage of the marshlands and marsh meadows is not the key to resolving the disequilibrium between forage supply and pastureland use in animal husbandry production. Since the marshlands and marsh meadows are wide spread in the broad valleys, with bitterly cold and strong winds in winter and spring, they are not suitable to be used as the winter and spring pasture. They are also not suitable for mowing, because the grass layer of the Cyperaceae is short and productivity is low. The best time for mowing grass is the rainy season, but it is difficult to dry and store the grass collected.

On the low-temperature terrain of the region it is not easy for the plant residues and the organic matters in the soil to decompose. After the drainage of the marshlands and marsh meadows, though the hydrothermal conditions could be improved to some extent, peat decomposition will still be limited. The mineral nutrients released by the decomposed peat hardly meet the demands of the growth of fine grasses, making it difficult for them to invade the region naturally. Good results will be hard to get even if the region is seeded with fine grasses.

If deep tillage and seeding are used to speed up vegetation regeneration, substrates should be added to the deep peat layer. If the drained marshlands and marsh meadows are not deeply tilled in time, these areas will be covered with water again and there will be no way for the vegetation to regenerate.

It is difficult to drain the marshlands and marsh meadows using common methods. Their relief is generally high, and the river bed runs almost flat. Some central areas are submerged or covered with many deep pools. The peat is generally one meter thick but can be as thick as several metres. The water -absorbing capacity of peat is very strong, making it very difficult to drain the areas with rich peat, leaving aside the landform conditions. If drainage is carried out under the specific drop less than 0.003% of the rivers, the drainage quota must be raised and complex engineering and machines would be needed. The common drainage methods such as digging pitches, and burying water-storage tanks can do nothing. The relations between drainage and the water requirement of the plants should also be considered. It would also be inhibiting to raise the drainage quota.

To exploit the marshlands and marsh meadows, it would not be good to drain the areas if only to increase the pasturelands to meet the demands of animal husbandry production. But multi-purpose use of the rich peat is another possibility. There are other problems that must be considered, such as the reserves of the peat resources, and the economic benefits of exploitation. Furthermore, the exploitation of the areas needs not only the latest in technology and equipment, but also a labour force, energy, and some public utilities, such as a food supply, transportation and housing.

SUGGESTIONS FOR THE RATIONAL USE OF THE PASTURELAND RESOURCES

As stated above, the limiting factors for animal husbandry production in the region are the different levels of forage supply in different seasons and the disequilibrium between winter-spring and summer-autumn pasture areas and uses. The latter is the major reason that animal husbandry has been unstable for so long. In order to obtain high and stable production, the use, improvement and construction of the pasturelands must be centered on the problem of disequilibrium. To resolve the problem, different methods should be used on different kinds of pasturelands. The pasturelands of Ruoergai region can be roughly divided into hilly pastureland, valley pastureland and the marshlands and marsh meadows, based on the landform characteristics. Some ideas for using and improving the three pastureland types are discussed below.

Rational use of the valley pastureland and establishment of artificial forage-bases:

The valley pastureland is the largest and most valuable of the Ruoergai region. It is mainly distributed in the valleys, on the terraces along river banks and on the flat and gentle hills. The relief of the valley pastureland is relatively high, soil is thick and fertile, and humidity is moderate. The drainage conditions and aeration of the soil are good. Besides natural precipitation, there is plentiful underground water in this area. Because the environmental conditions of the valley pastureland are better than those of the other two, the grass species are many and various. The dominant plants are the Gramineae. This pastureland has been unevenly used in the past. Some places have been overgrazed, particularly on some leeward and gentle south-facing slopes and valley bottoms, the areas along each side of roads and rivers, and the residential areas nearby, but the remote areas and some northern slopes have not been fully and rationally used. Some plots of pasture have even degenerated. The valley pastureland is predominant in the region and has a great influence on animal husbandry development.

The residential areas are distributed over the valley pastureland. In order to use and construct the valley pastureland rationally, attention must be paid to the lay-out of the residential areas. The pasture should be divided for rotational grazing. Its grazing capacity has to be controlled and grazing technologies improved to make full and rational use of it. The degenerated pastures should be raked and scarified in time to improve soil aeration. In the meantime, irrigation, fertilization and reseeding of fine grazing grasses should be applied to change the composition of the grass population and increase yield. While improving the degenerated pastures, plans should be made to till the soil deeply and establish some artificial forage bases. The valley pastureland has many advantageous conditions for the establishment of artificial forage bases, such as its large area, relatively flat relief, fine drainage possibilities, and moderate humidity.

The artificial River Daba Pasture (about 10,000 mu) in Ruoergai county has been established by the deep tillage method and can produce 1968 kilograms per mu, which is about 10 times more than that of the pasture prior to deep tillage. Deep tillage, reseeding and the establishment of artificial forage bases are not only useful methods to improve the degenerated pastures, but are also effective in resolving the shortage of the winter fodder.

The Hilly Pasturelands and Artificial Reseeding

Strict control of the grazing capacity of the hilly pastureland and transformation of the sandy grazing pastures; The hilly pastureland is located on the low mountains, the upper parts of the plateau hills, and the watersheds of small and large rivers. Drainage of this pastureland is good and the source of water is mainly the natural rainfall, so the soil is generally moderate or a little dry. Because of the freezing and melting interractions, the physical weathering is serious and soil layer is thin and contains much gravel.

The major plants of the areas are the mosophilic perennial grasses, and among them there are a few xerophilous and mesophilic grasses. Because of the relatively steep slope of the hilly pastureland, its thin soil layer, and rough soil structure, if it is over grazed the grass cover can easily be destroyed, the soil is liable to be eroded, and the destroyed vegetation is very difficult to recover. Especially on some hills made from sand sediments of the ancient river courses, once the vegetation is over-nibbled and trampled by animals, the sand dunes become exposed and become sand drift under wind erosion. At present, although this hilly pastureland is not large and has little influence on the animal production, it should be transformed in time to prevent the movement of the drift and extinction of this kind of pastureland. The land should also be rationally grazed and the grazing capacity controlled, to keep the grass cover from being destroyed. The hilly and sandy pasturelands which are already without vegetation and seriously degenerated should be closed to grazing, and be artificially reseeded to speed up vegetation recover.

Maintenance of the hydrological cycle and limited drainage of marshlands and marsh meadows

Although the marshlands and marsh meadows have a little value for animal husbandry production, they have a great effect on the hydrological cycle balance of the region.

The main grasses of the marshlands and marsh meadows are the hydrophilous Cyperaccac which need few mineral nutrients. With sufficient water, the grasses turn green earlier than those in other areas. They are soft, tender and palatable for animals. But after spring, with the increasing precipitation and temperature, parasites grow fast and infect the animals. After summer the grasses become rough and indigestible. Anyhow the surface water cuts off the area from people and animals. Therefore, the marshlands and marsh meadows have a little useful value, except for their influence on regulating the climate of the region. It is better to select some uplands and low terraces in lake basins and wide valleys to drain within limits and control the ground water level properly.

The vegetation of the region is on the transition zones from forest to meadow and from meadow to grassland. The natural ecosystem formed on the transition zones is generally fragile and unstable. The destroyed forests easily evolve into meadows, and the degenerated meadows evolve into grasslands. Once this takes place, it is difficult to reverse. Therefore, when considering the use of existing pastures, attention must be paid to the influence on the environment. The opinions in this papers remain to be further deliberated and confirmed.

FOREST RESOURCE MANAGEMENT

PRESENT SITUATION OF FOREST ADMINISTRATION IN SOUTH-WEST REGION OF CHINA AND ITS ROLE IN RIVER BASIN MANAGEMENT

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INTRODUCTION

The focus of this paper is on the Himalayan and the Hengduan mountain regions. This is a place of difficult accessibility and is economically underdeveloped. The population of this region, mainly Zang nationality, is 3.67 million, among which agricultural population is 3.15 million. The labour force is about 39% of agricultural population. Arable land in this area is 5.081 mio ha. The mode of production is quite primitive, the yields per unit area are very low, about 0.75-tons per hectare. Grain production is inadequate in most of the areas.

This region was considered as an individual unit in "Divisions of China Forestry", and named "South-west High Mountain and Deep Valley Water Resource and Timber Forest Division". It is located between latitudes 26° to 36°30'N and longitudes 92°35' to 105° E. Administratively the region forms the south-east part of Quinghai Province, and the south-west part of Gansu Province, the west part of Sichuan Province, the north-west part of Yunnan Province, and the eastern part of Xizang Autonomous Region (Tibet). It covers 79 counties in the five provinces and the total land area is 64.515 million ha.

The region is characterised by high peaks and deep valleys is mostly at high altitude. For example, in the two districts of Ganzi and Aba in the eastern part of Sichuan Province, 93.4% of the land is over 2400 m and 31.1% is over 4200 m.

These mountain regions are in the Sub-tropical Zone, part of which is the South Sub-tropical Zone. The climate of this area is influenced by monsoons of Indian Ocean and Pacific Ocean and the circulation of west wind. The moisture comes mainly from the Indian Ocean monsoon, that moves northward along the valleys which run north-south direction and influence large area. The Pacific monsoon brings rainfall to the eastern part of this area.

The circulation of west wind is limited to the northern part of this area. In winter, it's cold, dry and windy. Due to these three factors, the moisture and thermal conditions, as a whole in this region, worsens from South-East to North---west, geomorphologically, the conditions of high mountains and deep valleys, give arise to a highly complex and variable local climate. Without exception, it expresses a characteristic of multiple vertical zonality.

In the past thirty years or so, wood processing industries, hydroelectric power stations, woolen textile industry, paper mills, match factories, animal products and dairy industry, etc., have been gradually established. While livestock industry is fairly important to the region, the forest industry is undoubtedly the most significant, having played a key role in promoting the development of transport and other industries in the area.

FOREST VEGETATION

The forest vegetation is mainly coniferous. is mainly conferious. The lowest area has dry, hot river valleys where there is widespread growth of thorny and succulent bush. The next belt above consists of evergreen broadleaf forests with a variety of deciduous broadleaf trees. In the area from 3500-3000 m, there are mainly temperate coniferous forests. In the lower part there are mainly alpine pine and Chinese pine on south slopes, and mixed forests of Chinese hemlock, maple and birch on north slopes; the higher areas have cold-temperate coniferous forests including pure forests consisting of fir, and mixed forests.

The area above 3000 m is covered by cold-temperate coniferous forests, the most wide-spread being Minjing fir. There are mainly pure forests on north slopes and mixed forests on the south slopes. Sometime bushes and alpine oaks grow. Above 4000 m there are bushes or meadows. The more southern the location the higher the relative forest zone. In the south part of Chayu Motuo and Dawang there are tropical rain forests and monsoon rain forest in valleys and low hills, where the lower limit of alpine bushes rises up to 4400 m.

The role of forest in the river basin management

This is an important region for supplying water to the upper reaches of Changjiang, Honghe Mekong River, Saewangjing, Salween, and the Brahmaputra Rivers. The basin management of this area is important for river control not only in the middle east & Yunnan province, but also for Vietnam, Laos, Kampuchea, Thailand, Burma, Bangladesh and north-eastern India. In this area there is frequent earthquake activity, heavily weathered basic rock, steep deep valleys, and snow cover on top many mountains, and bare rocks on others.

With abundant rainfall, soil erosion and mud-rock flows occur easily. These factors increase the difficulties of the river management, and it is practically impossible to rely on engineering practices alone in so large an area. As forests have multi-layer construction both under and above ground, they have strong ability to conserve water & soil, and check materials falling from above. Sufficient forest cover is therefore critical in river control of this area. The following examples are given to illustrate the point.

Observations in the upper reaches of the Minjiang in 1959 regarding a small river basin with 70% forest cover and a rainfall of 678.5 mm (within 81 hours) showed a water retaining rate of 66.3%. Miyaluo a small river basin covered with 80% bush, and a rainfall of 676.3 mm (within 68.7 hours), the retaining rate was 51.8%. An area of original coniferous forests in the upper reaches of Uingiang, under conditions of moderate rainfall showed that 20% of the rainfall was retained by the crown of trees, 20-40% by litter layer, and the rest permeated the soil, with almost no surface flow.

Liusahe river basin in Hanyuan county, has high mountains with long slopes. Lack of forest cover has allowed heavy rain floods to bring down sand and stones, that have submerged the fields, destroyed houses and caused enormous losses . They have distroyed more than 600 ha of farm land, and 700 farmer houses, killed 500 people in the past 100 years. In a few years in the 60's, the area was afforested by pines. Young trees have grown covering more than 13,000 ha. The conservation conditions have been improved substantially. Comparing 1975-1979, when the forest was still young, with 1964-1968, the runoff had been reduced by 25%, and silt content had declined by 39%.

Observations made in Dingxihe basin in Xichang County, show that in the past 100 years there have been frequent occurrences of mud-stone flows and floods causing 3000 erosion gullies and many earth slides. A flood in 1893 submerged 5 streets in Xichang town, and killed 1000 people. Afforestation was carried out in 1958, on 26,000 ha and the erosion in the area has decreased by 80% including a reduction in silt content of 77%. In spite of many heavy rains, there has been no damage caused by floods and mud-stone flows.

Heishahe basin in Xichang County has an area of 2000 ha. This area used to be bare land, suffering from severe erosion. There were 180 earth slides and more than 200 mud-stone gullies. Afforestation from the air and by hand began on 1300 ha in 1967 including engineering activities that took place in 1971. All these measures have improved the environmental conditions. According to an observation on the 15th September, 1976, under a rainfall of 50.1mm, the rate of runoff in waste land was 0.52, and in the fields of young trees was 0.12. The beginning of the runoff all over the area was delayed by 85 minutes as compared to the waste land. The erosion index was 64.2 ton/km^2 in the waste land but 8.7 ton/km^2 in the fields of young trees.

Bailongjiang, which is located in the north of this area, used to have clear water and stable flow. There was a coverage of dense forests in the catchment of its upper reaches. Just before the forests were exploitated, the area looked like the "white dragon" after which it was named. With the exportation of trees, the forest cover was reduced, soil erosion has been getting more serious, the variation of river flow has become big and in the rainy season, flood mixed with sand and stones submerged villages, silted up the river bed, and brought great damage to the people in the low lying areas.

However, in some small river basins where forest have not been cut, environmental condition remain good and the river flow is clear and stable. All examples mentioned above show clearly the importance of forest in river basin management of this area, but the present forest resources in this region, when compared to its needs, is far from adequate.

The present forest resources and their characteristics

Forest occupies 11.42 million ha with a coverage of 17.7%, but many slopes have no forest cover. Rain causes severe erosion and mud-stone flows. Also snowfall and stonefall from upper parts of the mountains roll to the bottom, damaging animals and crops, and blocking roads and rivers. The stock in this area is about 2.57 billion of mainly natural, overmature forest. The stand is about 200 years old and the constitution of forest is as as follows: area: young forest 3.8%, moderate mature forest 6.2%, overmature forest 90%; stock: young forest 0.5%, moderate mature 2.8%, overmature forest 96.7%.

The stock per unit area is 252 m^2/ha which is the highest in the county-375 m^3/ha in Banma of Qinghai, 285 m^3/ha in the west part of Sichuan, 255 m^3/ha in south-east Tibet. The density is many times higher in specific places, for example in Yunnan where pines over 130 years have a volume of 990 m^3/ha, and spruce forest in Bomi has a volume of 385 m^3/ha.

The problem is that the mature and overmaturee forest is too widespresd, the growth rate is too slow, and the productivity of the stock is very low: In West Sichuan the figures are 0.68% for firs and 0.75% for spruce and east Tibet they are 1.49 for spruce and 0.79% for firs. Even negative production appears in some places. Limitation of Local native conditions limit forest regeneration. It takes decades for natural succession. The present forest resources can not meet the needs of both conservation requirements and timber production.

Present administration and problems in this area

There are large areas of forest producing a high volume of timber, with huge potential for the development of forest industry. 100 million m^3 of logs have been produced in the past 30 years. Now there are 25 wood processing industries, under which there are 100 lumbering fields, producing 628 million m^3 of logs.

Forest protection and prevention of fire is done mainly through the local people. There was forest protection by air in the 60's which had been cancelled. Now, this system is being rebuilt once again. There are eight nature preservation areas, mainly protecting panda, golden monkey, antelope, and special natural landscapes, among which the Wolong and Jinzhaigou nature preservation areas are the most famous.

Certainly remarkable achievements have been made in the past 30 years, but characteristics such as the long periods required for growth and beneficial results that imply easy to destruction but difficult afforestation, have not as yet been fully understood. Administration of the forest industry has not conformed to natural and economic principles.

Few lumbering and processing industries in Aba, Ganzi, north east of Yunnan and Geng Zhang, are in-sufficient in such a large area with mainly mature and overmature forest. As a whole, there has not been any attempt to manage the forest. It is estimated, that the losses from rotting and fire were more than 3600 m per year, and worth 2 billion dollars on the international market. On the other hand, regeneration cannot be carried out in time for the maturé and overmature forest, with the forest quality getting poorer. The effectiveness of conservation measures is reduced and such losses can not be valued in terms of money.

Although exploitation of forest was carried out in parts of this region, lack of finance has limited the road system and , lumbering fields are concentrated and clearfelled. This has all damaged the ability of the environment to regenerate.

Another problem is the imbalance between cutting and planting. Because the wood processing industry is administered in the same way as mining, there is no regulation for regeneration, tending and resource management. Contrary to the principle of forest production, too little emphasis is placed on the planting and tending of seedlings. For example, only 13.6% of the labour force in forest industry work in forest management and planting, whereas the desirable figure should be 30-40%.

Forest cover has decreased because regreneration is not keeping up with felling. According to the survey in the upper reaches of Minjiang, the forest cover in Heishui Songpan, Lixian, Mouwen, and Jinchuan, has fallen from 30% in the early 50's to 18.8% thereby increasing the environmental degradation due to higher wind speeds, more servere drought, less snow, and a shorter frost-free season.

Most of the felling area has been changed to lush meadow with patches of forest, particularly in Songan and Heishui. One third of the river valleys have become semi-deserts. In addition, their boundaries have extended even to the upper reaches of the tributaries.

The ability to retain water resources has also been reduced. The annual, mean river flow in Minjiang was 14.7 million m^3 in the 40's and 50's, but it has reduced to 14 million m^3 since 1970.

Severe soil erosion, earthslides, rockfalls and mud-stone flows always occur in this area.

The rapid reduction of forest cover in the Chongjiang basin and the Renhehe basin of Lijiang county, in the north-west of Yunnan, the rate of river flow increased by 27.3% in the rainy season from the 60's to the 70's in the dry season it decreased by 13%.

THE FUTURE OF THE FORESTRY

The present management of available forest resources do not meet the practical needs of this area. The situation must change. In order to produce more wood and forest products, there should be, promotion of local economy and protection of water resources in low lying areas, by carrying out and maintaining maximum afforestation in this area. In order for the conditions of a stable forest eco-system to develop, forests must be regarded as the key factor, and development of forestry, animal husbandry and agriculture should be well coordinated, including the exploitation of hydroelectric power resources.

Hillsides should be closed to livestock grazing and fuel gathering, to facilitate afforestation. In suitable areas with proper conditions of soil, moisture and temperature, and a small population, sealing off hillsides is probably the best way to raise the forest cover and build up the water resource base. Under 4400 m in the south , and under 3400 m in north on all wasted hills, except bare rock, on which it is possible to grow mixed forests of trees and bush, it can be expected that two thirds of the new forest will originate from these loose hillsides.

Plantation of high growth rate and high productivity forest is feasible in those places where there is proper soil and optimum moisture, temperature and man power. In other places with optimum moisture and temperature, but poor soil, afforestation must be economically appraised. There is a need to build up the road system and increase management of the forest industry. First, the scale of clear felling has to be controlled and gradually a scientific way to obtain wood should be introduced in order to ensure that forest resources increase overtime. The role of conservation must be stressed and forest products should be diversified.

Scientific management of afforestation should be extended over an increasing area with coordination in the development of animal husbandry, agriculture and hydro-power resources. For example, animal husbandry can be organized by forest enterprises. Mixed forest grazing and forest industry can be run in partnership with electricity generation. All of these help to increase the value of forest conservation works. If the measures mentioned above are implemented, the forest cover will increase. Every place where trees can grow, will be covered with dense forest except the land necessary for agriculture, animal-husbandry and other use. If scientifically managed, it is possible to produce 50 million m^3 of logs and plenty of forest products, and at the same time, carry out effective conservation. No soil will go down. Clear water will flow in rivers. The damage caused by flood, drought, frost, hail, eathslides, mud-stone flows and soil erosion will be reduced, bringing beneficial results for the low lying areas through the development of water transport and irrigation.

These measures are the only way to raise forest resources and strengthen forest administration, but unless present conditions change, it will be very difficult to implement them.

First the local herdsmen and the residents who practice husbandary and agriculture, burn the trees to maintain grassland and practice shifting cultivation, must change their ways. Under these conditions, it is difficult to protect any young trees.

Gansu, Qinghai, Sichuan, Yunnan and Xizhang need to increase local supply of wood. With limited transportation, the present methods of clear felling and overfelling will be continued. The most difficult thing is the lack of finance. For maximum effect, 11.72 million ha need to be forested.

In order to carry out proper management in all areas the following should be noted:

There is a need to build 220,000 km of road and railway lines 10000 km. This will cost 100 billion yuan, and 22 billion yuan for main and secondary networks in the felling area. For management, if a worker manages 50 ha, the costs of house construction will be 9 billion yuan.

Altogether, the total cost is about 134.4 billion yuan and there is no easy way to mobilise resources of this scale to carry out all these projects.

All the problems mentioned above are key issues but the work will be organized and carried out by government, gradually overcoming the difficulties.

Recommendation and popularization of improved agriculture and animal husbandary technology has already been carried out and the present primitive form of production is beginning to change.

The scale of clear felling in exploited areas has to be controlled. Regeneration must be carried out in some places. As soon as possible a road system must be built. For developing resources, selective cutting should be introduced except in places where the stand type is unsuitable.

Forests should not be opened up in the areas along both sides of Jinshajiang and the area to the west for some years, except for local needs. Gradually scientific management should be conducted in an integrated manner with the accumulation of capital and modernization of production.

It is necessary to study the management methods of the wood processing industry and adopt the new management system suitable to forestry.

In brief, the forest management in this area must be improved and strengthened. This policy must be firm and unshakeable. The forest ought to make its proper contribution to river basin management. No matter how many difficulties there will be, this policy must be carried out continuously generation by generation. The area will be developed in such a way that no hill is without green cover, all water is clear and the beneficial results of conservation of forest are available to all areas and counties in the low reaches.

RUNOFF EFFECTS OF THE CUTOVERS IN ALPINE FOREST AREAS

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INTRODUCTION

The runoff effects of forest have become a matter of general interest of late. Some people, however, deny the positive effects of forest on river flow keeping in view the fact that forest retains quantities of water. They advocate cutting down all forests where there is shortage of water resources. Others hold the view that forest is a factor in water conservation which inturn helps precipitation, the reduction of evaporation and flood, and the aggregation of silt - with the result that high quality-and-quantity runoffs are maintained.

With the economic development of China and the growing standard of living of the people, the forest cut in mountainous areas especially in the areas of Hengduan mountain ranges - is increasing with each passing day. The forest consumption in the Province of Yunnan averages 27 mio m^3/y. In Sichuan Province the area of forest cover has decreased from 19 percent to 13.3 percent. In the county of Yuexi located in Western Sichuan the lower limit of forest cover has risen from 1,400 m to 2,700 m. In the Lijiang Prefecture on the Jinshajiang River the area of forest cover has fallen from 36.7 per cent to 27.9 per cent in the past ten years with an annual lapse of 0.52 percent in the average.

Hengduan mountain ranges, characteristic for their steepness and loose geological structure with great potentialities in water loss and soil erosion, are the upper reaches and the water sources of the principal rivers of this country, where drastic weather phenomena predominate. What will happen if one keeps cutting down the forest? Quite a few scholars and experts hold the view that the Yangtze River will become a second Yellow River if one keeps on doing so. There is, however, no agreement upon the above argument for lack of conclusive evidence. Based upon our firsthand long-period surveys and observations from the fixed stations, this paper presents some ideas concerning the runoff effects of forest, namely, flood runoff, flow of solid matter and runoff of low water.

SEDIMENT CONTENT OF RIVER AND STREAMS

Records from the lower Hydrological Station on the Dadu River show an average sediment concentration of less than 0.5 kg/m^3 on a yearly basis whereas in recent five years it has exceeded 0.6 kg/m^3, with a maximum of 1.16 kg/m^3 in 1981. The erosion modulus of the Small Jinchuan River - a tributary of the Dadu River - increases from an average of 90 $t/km^2.y$ during 1965-1978 to 118.6 $t/km^2.y$ for the period of 1971-1978. It is 1.31 times as many as that for the first eight years. Observations during the period of 1978-1982 from the Zhaojue Hydro-logical Station, located in the upper reaches of the Zhaojue River - (an affluent of the Jinsha River), show the total sediment discharge in 1982 to be 1.7 times greater than that for the year of 1978 (Table 1).

Table 1: The Annual Sediment Discharge and Erosion Modulus for the Upper Reach of the Zhaojue River

Year	Total sediment discharge (mio t)	Increase (%)	Erosion modulus (t/km^2y)	Growth (%)
1978	0.546	100	839	100
1979	0.631	116	970	116
1980	0.813	149	1250	149
1981	1.020	187	1570	187
1982	0.930	170	1430	170

The erosion modulus in 1981 is equivalent to three times the sediment discharge of the Yellow River's reaches up Lanzhou which is 518 t/km^2.y. The soil erosion is rather considerable.

The rise in sediment concentration is responsible for the continuous rising of the beds of medium and small rivers. For example the Yongchun River, a tributary of the Lancang River and the Ninglang River, an affluent of the Yalong River in Northewestern Yunnan have been silted up to different extents in recent years.

Moreover, the Qinglong River in Northern Yunnan had become a surface river. A huge amount of expended labour force was in every year to clear away the silt, in order that flood might be prevented. For example one may cite a reach of it which is only 150 metres long but 327 workdays were spent in 1976, 430 in 1978, 1237 in 1979, and 3560 in 1980. The workdays expended increased with each passing year.

In the meantime a large number of storage reservoirs were silted up, quite a few of which were reported to have been abandoned. In the county of Huidong in Southwestern Sichuan 103 reservoirs have been completed since 1950. But the irrigated area decreased by 44 per cent until 1979. Another cistern, completed in 1979, and named as the Xinwen Reservoir, is located in the affluent areas of the Yalong River. During its construction the forest cover in this region accounted for 60 per cent or so. But in recent years trees have been felled in large quantities. The forest cover in this region had decreased to 25 per cent or so until 1981, so that the silt charge in the river had kept growing. In 1982 the silt layer of the reservoir greatly exceeded the dead storage level. Almost half of the reservoirs in the whole region of Hengduan mountains seem to be severely threatenend by silt accumulation. The situation may worsen in future if proper attention is not paid to this fact.

Increased Frequency of Floods and Debris Flows

There had been no severe floods in the earlier history of the Hengduan mountain region. There were only 9 inundations during the period of 783 years from 1191 through 1974 in the whole province of Sichuan. The average interval was 87 years. The trunk stream of the Yalong River, however, was flooded nine times during the 88 years from 1896 through 1984, with a recurrent period of nearly ten years. The Anning River overflew three times during the 69 years from 1891 through 1960.

Debris flows often occurred in the history of the Hengduan mountain regions but far less frequently than nowadays. There were 14 catastrophic debris flows in the Heisha River of the Liangsnan Prefecture during the 90 years from 1874 through 1964, with an average interval of 7 years. Four catastrophic debris flows took place in the East Xide Stream of the Prefecture of Liangshan during the 50 year period from 1901 through 1951. The calamity recurred every 12 to 13 years on the average.

But in recent years calamitous floods and debris flows have been more and more frequent with shorter and shorter intervals, thereby causing great harm to the people. The Province of Sichuan was stricken by five calamitous floods during the 30 years from 1950 through 1981. The interval averaged out to 6 years. The July flood of 1981 was a fierce natural calamity in the history. In the eighties alone, the Prefecture of Liangshan has been hit by two catastrophic floods namely, the June flood of 1981, which struck 319 townships of the 17 counties of the Prefecture in question resulting in a direct loss of 17 million Yuan or more, and the May flood of 1984, which broke with still more tremendous force than the June flood of 1981. Moreover, small mountain torrents were more frequent. These happened quite a few times a year. Mud rock flows accompanying mountain torrents occurred incessantly.

Take the Heisha River of the Liangshan Prefecture, for example. Three catastrophic mud rock flows took place successively in 1967, 1968 and 1970. In the section of the Cheng-Kun Railway (a railroad from Chengdu to Kunmin) through the Prefecture of Liangshan a total of 110 big or small alluvial channels were caused by mud rock flows. The flows have buried seven railway stations since their opening to traffic in 1970, causing 40 traffic interuptions, totalling 1300 hours or more. The debris flows have occurred so frequently during these years in the areas where few or no debris flows had ever happened in the history, e.g., on the Xin Zhunag River of the County of Huaping and the Shuoduogang River of the Zhongdian county - where the phenomenon has developed so rapidly that it is really most harmful and pernicious.

Runoff of low water kept decreasing and droughts aggravated

Monsoon prevails in the region of Hengduan mountains, where the dry and wet seasons are sharply contoured. The wet or rainy season ranges from May to October. In this season the precipitation accounts for more than 80 percent of the annual (Table 2). In the dry season, however, the rainfall amount is small and the precipitation phenomena are temporally scattered; therefore it is hard to produce surface and subsurface runoffs through precipitations. In this season low water is maintained through the modulation of a part of the rainwater of the wet season by vegetation and soil.

Table 2: Distribution of the Precipitations Recorded at the Principal Meteorological Stations in the Region of Hengduan Mountains.

Station	Annual (mm)	May to Oct. (%)
Xiaojin	614	86
Maowen	492	83
Ganzi	636	89
Batang	474	96
Xichang	1013	93
Yuexi	1113	89
Huidong	1056	94
Dukou	761	96
Binchaun	573	93
Lushui	1185	79
Lijiang	955	94

In recent years such a modulation effect has been reduced. Continuous observations for the past decades at the Zinpingpu Hydrological Station show that the monthly mean of the runoff in the dry season has been obviously decreasing (Table 3). If the data are averaged on a ten-year basis, then we have the ratios of the mean runoff volumes in the driest month (February) of the thirties to eighties. They are as follows:1.46:1.22:1.16:1.14:1.03:1. In other words, the average runoff volume in the driest month of the eighties only corresponds to 68 percent of that of the thirties. It also shows that the ratio of the mean runoff volume (Table 3) of the maximum month to the minimum month has been increasing from decade to decade. If that of the thirties is set at 1, then we have 1.32 for the eighties. The growing amplitude of the runoff volume explains from another point of view the fact that the modulation power of nature has been reduced.

Table 3: Runoff Data Recorded at the Zipingpu Hydrological Station.

Decades	Annual Mean (m^3/s)	Ratio[1]
30	541.0	6.2
40	466.4	6.1
50	467.2	6.3
60	477.7	7.3
70	431.8	7.0
80	447.0	8.1

[1] Ratio of mean runoff volume of the max. month to min. month.

It is a common phenomenon that electricity from the medium and small water power plants all over the region of Hengduan mountains was in short supply as a result of the decrease in runoffs of low water. Quite a few power plants had to be reconstructed or closed down for lack of water sources. The benefit from diversion works also decreased owing to the reduction in low water. The Yongli Diversion Canal, a comparatively large diversion work on the Dazao River was completed in the fifties. When it started working, it was capable of diverting

0.8 m^3/s of water because there were sufficient headwaters. In the early sixties the river water could be diverted to Heshangtou. But in the late sixties it could only be diverted to Xinhuawanzi; in the mid- seventies merely to Datong; and in the year of 1983 simply to Baofuluo with a real diversion of only 0.2 m^3/s. As the diversion canal could not guarantee irrigation in the dry season, pumping works or stations had to be built in the low reaches. Seven pump stations have been completed since the sixties.

The reduction of low water means the aggravation of droughts. The period from April to June is the season in which winter crops are maturing and the spring crops are greening for transplanting. In this season the crops absorb the maximum of water and the water budget is unbalanced due to low river discharge. There used to be one or two drought years out of ten. The continuous reduction of the runoffs of low water greatly aggravated the circumstances, so much so that only a certain part of the irrigated area in the region of Hengduan mountains could be ensured. By the end of 1983, the ensured irrigation area of the six prefectures and one municipality in the region of Hengduan mountains only accountd for 28 percent of the cultivated area (Table 4).

Table 4: The present condition of the irrigation in the region of Hengduan mountains

Items / District names	Cultivated area (CA) (10^4 mu)	Irrigated area (IA) (10^4 mu)	Ensured irrigation % of CA	Ensured irrigation % of IA
Ganzi	128	41	23	73
Aba	80	30	25	67
Liangshan	460	168	30	82
Dukou	48	27.4	44	77
Lijiang	167	72	31	72
Diquing	58	14	21	85
Nujiang	76	14	17	92
Total	1017	366.4	28	78

Droughts have become an obstacle for the people to improve their standard of living.

INVESTIGATION OF THE RUNOFF MECHANISM

The experimental area was located on the plateau of 3,100 m in the upper reaches of the Jinsha River in Northwestern Yunnan.

The effect on flood runoff

The three-year observations show that the forest area is a relatively perfect system of water circulation.

In the process of water circulation the forest area has a huge invisible reservoir while the slash area has not. Such an invisible reservoir no doubt has a modulation effect on water flow. It reduces the precipitation amount that can reach the ground surface and the falling speed, causing time lag, and weakens the lashing effect of rain water upon the ground surface - thus affecting the runoff and the flow of solid matter. Such an effect mainly depends on the cutoff and storage of crown cover and dead twigs and leaves which constitute a humus layer.

In the condition of much shower and little rainstorm the cutoff and storage effect of crown canopy is rather considerable (Table 5).

It is seen that the annual precipitation amount inside the pine forest only corresponds to 60-70 per cent of that outside the forest. The crown cover cutoff is not a constant. It is closely related to the kind

Table 5: Comparison Between the Annual Precipitation Amounts inside and outside the Pine Forest

	Precipitation (mm) outside forest	inside forest	outside the forest %
1983	740.5	476.9	64
1984	999.7	667.6	66

of forest, precipitation amount and precipitation intensity. The experiments in single dragon spruce tree and pine tree show the following cutoff effects respectively. The cutoff rates of dragon spruce and pine are over 90 per cent and 70 per cent respectively, when precipitation amounts to 1-2 mm. They are 50 and 30 per cent or so, respectively, when precipitation exceeds 10 mm. The greater the precipitation amount, the smaller the cutoff rate. Observations show that the cutoff rate is 20 per cent or so when the precipitation amount of a rainstorm exceeds 30 mm. Cutoff process is, in a sense, a process of flood reduction. For this reason the canopy cutoff of the primitive forest in a mountainous area can reduce a flood by more than ten per cent. Generally speaking, such a reduction also applies to the flood peak.

When the precipitation reaches the ground it permeates the humus layer, a layer of dead twigs and leaves first, and then causes the forest system to work. In the experimental area thickness of this layer varies from 5 to 20 cm by and large.

In the dry condition a humus layer of 1 cm thick can modulate a percipitation amount of 0.5-1 mm. With the increase of the precipitation the modulation weakens. Nevertheless, the modulation capacity is considerable in the case of a rainstorm. The Daoban stream, i.e., the stream in the forest area, has a modulation effect of invisible reservoir, and therefore greatly differs from the stream in the slash area in creating a flood.

Let us first analyse the hydrograph of the daily means of the flow quantity in 1984: The peak flow in the stream of the forest area only accounts for 85 per cent of that of the cutover area. This means that the flood peak in the stream of the cutover area is greater than that of the forest area. If the process curve is cut with a flow quantity of 0.035 m^3/s, then the number of the runoffs of 0.035 m^3/s in the stream of the cutover area is 1.6 times that of the forest area. In the last days of the flood period, namely, from July to August the maximum amplitude of the daily means of the flow quantity arises in the stream of the slash area. It is 0.065m^3/s. In other words, it is 23 per cent greater than that of the forest area.

Then we analyse the runoff modulus in 1984. In the dry season the monthly runoff modulus in the stream of the forest area is mostly greater than that of the slash area. In the wet season, especially in the period when flood prevails, however, the runoff modulus of the stream of the cutover area is much greater than that of the forest area. The ratio of their average values in the period from July to August is 1.6:1. Such a high ratio means that the runoff during short-period flood peak in the stream of the slash area is greater than that of the forest area (Table 6). That's why the floods in slash areas are so frequent and harmful.

Table 6: A Comparson of the Maximum Flow during Flood Peak (m^3/s)

	Day 1	3	5	7
stream of the slash area	0.078	0.187	0.267	0.326
stream of the forest area	0.067	0.161	0.238	0.315

In order to show further the effect of invisible storage reservoir upon the flood we have made an analysis of the flood process in roughly the same precipitation condition.

- The flood broke with a greater force in the stream of the cutover area.
- At eleven forty on the 31st of June 1983, a torrential rain broke simultaneously over both the areas. The rainfall and flood were roughly synchronous for the stream of the slash area and were characterized by a high speed. At 12:10 p.m. the flood reached its peak value with a rising slope of 0.0005. But there was atime lag of 20 minutes for the onset of the flood in the stream of the forest area. The flood rose to the maximum within one hour and thirty minutes with a rising slope of only 0.00003.
- The flood receded at a quicker tempo in

the stream of the slash area.

- The curve of the rising process of the stream of the slash area was in sawtooth shape because of the inhomogeneity of the precipation. At 12:10 the precipitation intensity began to decrease and so did the flood runoff of the stream of the slash area. What a sensitive reaction it was! What happend in the stream of the forest area was quite different. The process curve sloped up smoothly and slowly. It didn't react to any small change in the precipitation, and began to stop until 1:05 p.m.

- The flood had a higher peak in the stream of the slash area.

The stream of the cutover area during the peak flood had a maximum flow quantity of 0.0045 m^3/s and runoff modulus of 0.00563 $m^3/s\ km^2$ whereas the stream of the forest area during the peak flood had 0.0029 m^3/s and 0.0025 $m^3/s\ km^2$, respectively, i.e., the total flood runoff and the flood runoff modulus of the stream of the cutover area were 1.6 and 2.25 times that of the stream of the forest area, respectively.

From the above differeneces, a few conclusions can be drawn as follows:

- The stream of the forest area has an obvious modulation effect upon the flood produced by a rainstorm. Generally speaking, the modulation effect is in the affirmative. Moreover, it is especially worth noting that the forest also has a lagging effect upon the flood peak.

- How to deal with the modulation effect of forest upon the flood created by successive rainstorms is a relatively complicated problem. But the stream, of the slash area always has a greater sum of the superposed peak floods than the stream of the forest area, in which case the greater the peak floods the smaller the reductions.

- Anomalous phenomena can occur only if successive torrential rains fall where the invisible reservoir is too saturated to give a modulation effect.

Torrential rains or successive rainstorms with short intervals are usually responsible for a catastrophic flood in the transverse mountain region. Nevertheless, forest plays a positive role in preventing or controlling floods. In any case it would not play a negative role. Some people compare forest to reservoir, which would be still more harmful should the dam of the reservoir collapse. Such a point of view, however, does not hold water.

The effect on the flow of solid matter

Soil conservation has become the most important problem of environmental protection in the world. Denudation will inevitably lead to losses of water and soil.

There is no sediment on the whole in the stream of the forest area where no trees have been felled, i.e., the yearly mean of the sediment concentration in the stream is nearly zero. The stream water only becomes a bit turbid even if there is a torrential rain with a daily precipitation of 30 mm or so. In this case the water turbidity is 25 or so, the sediment concentration being less than 0.06 kg/m^3. The duration of such a phenomenon is very short. The stream water turns clear shortly after the rain. But what happens in the stream of the slash area where quantities of forest have been felled is totally different. The stream water is very clear in the dry season or in fair days of the wet season. However, sediment always follows rain when the rainy season comes. During the period from May to September in 1984, some 134 sediment processes were recorded, i.e., 4 times in 5 days on the average. There was a loss of 353 tons of sediment in suspension, the average erosion modulus being 441 t/km^2. Supposing that there is a slash of 10,000 km^2, the total loss of sediment within a year will be 4.41 million tons. The sediment processes had various durations. The longest duration was 33 hours while the shortest was 3 hours. The usual durations were 2 to 6 times as great as those of the usual precipitations. The total time for the sediment loss processes in 1984 accounted for 14 per cent of the whole year and 30 per cent of the whole rain season.

The average sediment concentration greatly varied in different sediment processes. On June 24, 1984 there was a precipitation of 1.3 mm with a duration of 30 minutes, of which 1.1 mm was precipitated within 10 minutes. The sediment concentration in the stream increased from zero to 0.476 kg/m^3. It is found that a precipitation of less than 1 mm was unable to produce sediment in the stream.

The mean sediment concentration in 1984 is 4.23 kg/m^3, which is greater than that recorded at the principal hydrological stations in the region of the Hengduan mountains. If the measurements in 1984 are graded, then we have the sediment discharge mechanisms of various grades, shown in Table 7.

Table 7: Discharging Mechanisms of Sediment for Various Grades of Sediment Concentration

Grade	Frequency	% of the total	Mean concentration (kg/m^3)	Weight (kg/m^3)
0-1	63	46	0.4	27.8
1-2	20	14	1.4	28.7
2-3	12	8	2.4	28.9
3-4	8	6	3.3	26.4
4-10	15	11	5.9	89.5
10-20	9	7	14.5	130.5
20-50	7	5	33.6	235.2

The observations show that the sediment concentration mainly depends on the precipitation amount, precipitation intensity, initial runoff and maximum flow quantity. There are also some correlations. That is to say, the greater the precipitation amount and initial runoff, the greater the soil loss.

The effect on low water runoff

It is well known that forest has an effect upon low water. But, for lack of comparative studies, nobody knows how strong the effect is. In this paper we have mentioned the modulation effects of the invisible reservoir in the region of the Hengduan mountains. The essentials of such a modulation are to store up in the rainy season to make up for the dry one. That is why the low water in the stream of the forest area is more than that of the slash area. In 1984 the minima of low flow and runoff modulus were 0.002m^3/s and 0.0017m^3/s. km^2 in the stream of the forest area while they were 0.0009 m^3/s and 0.0011 m^3/s km^2 in the stream of the slash area. According to the minimum of low runoff modulus, a forest area of 10,000 km^2 would mean increasing the least low runoff by 6m^3/s. The monthly mean of the flow quantity in the stream of the forest area was 0.00825 m^3/s while that of the slash area was 0.00375 m^3/s. The stream of the forest area had a runoff modulus of 0.00717 m^3/s. km^2. In other words, if there are 1,000 km^2 of forest, then some 2.5 m^3 /s of water will be produced. If such an amount of water is used to fight a drought it can meet the need of 50,000 mu of rice. If it is used for a water power plant it can generate more than 100 KW of electricity. What an economic benefit it might be !

FOREST FELLING AND REGENERATION IN THE SOUTHWEST MOUNTAINOUS DISTRICT OF CHINA

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INTRODUCTION

The range of the southwest mountainous districts includes Tibet, three prefectures: Liangshan, Ganzi and Aba in the west of Sichuan Province, and three prefectures: Nujiang, Diquing and Lijiang in the northwest of Yuannan Province. The total area is 158.6 million hectares.

CHARACTERISTICS OF THE FOREST RESOURCES

State of the Forest Resources

There are abundant forest resources in China's southwest mountainous district. The region has one of the best preserved virgin forests presently in China and is also an important base of timber production in the country. The forests cover an area of 14 million hectares (13.9%) in this district, with the timber stock of 2,71 mio m^3 (Table 1), which is 29.5 per cent of the store capacities of all the forests of the country.

Most of the forests in the southwest mountainous district are virgin forests, mature stands constitute and respectively make up 68.1 and 92 per cent of in the whole district.

The store capacities of mature and overmature forests holds the majority, in which, The timber stock of mature and overmature forests in Tibet accounts for 95 per cent of the total store capacity. The west of Sichuan Province and northwest of the Yunnan Province, have about 90 per cent, coniferous tree species predominating. The common coniferous tree species *Picea, Abies, Tsuga, Larix, Pinus yunnanensis, P. tabulaeformis, P. armandi, P. griffithii* and *Cupressus funebris.*

Table 1: The Forest Areas and Store Capacities of the Southwest Mountainous District

	Total Forest Areas (mio ha)	Total Timber Stock (mio m^3)	Mature Stock %	Mature Forest Area %	Coniferous Forest Area %	Coniferous Stock %
Whole districts	11,78	2,715	92	80	74	79
West of Sichuan Province	3,88	1,010	90	80	90	96
North-west of Yunnan Province	1,77	315	90	70	83	77
Tibet	6,13	1,390	95	85	61	66

Among the coniferous trees, *Picea* and *Abies*, are extensively distributed, widely utilised and of excellent quality. They occupy an area of 457000 hectares, with store capacity of 1,550 mio m^3. These respectively amount to 32.6 and 57.2 per cent of the total areas and store capacities in the whole district.

Due to the high elevation, steep slopes and the lack of transportation in the district, forest felling and use meet with great difficulties. Only 15 per cent of the forest in Tibet is accessible, while in the west of Sichuan Province and in the northwest of Yunnan Province, it is 50 per cent and 70 per cent. Forest enterprises are sometimes excessively concentrated in some areas, which results unavoidably over-cutting. Three or four times more than the amount specified by the government has been cut. Most of the timber served as an energy resource, such as for heating, cooking, making charcoal, and the brick industry. More forest areas will be used as the local economy develops. The improvement of transport conditions and the rising of technical level of the forest industry will also heighten the ratio.

At present not only the ratio of accessible forest is very low in the district, but also the rate of utilisation is disappointing. The data from various regions in this district show that the utilisation ratio is merely 50 per cent. The multipurpose application of the remains of cuttings have not been paid attention to at all, which has led to a severe waste of the resource.

Growth Characteristics of the Forests

One of the prominent characteristics of forest growth in the southwest mountainous district of China is that the forests have abundant biomass. For instance, dense *Picea* forest in Tibet holds a store capacity as high as 2,300 m^3/ha, and enjoys its position as the finest in the world compared with the other coniferous forests. The biomass can sometimes reach 1,200 t/ha, three times more than that in Taiga, and in the northwest of Yunnan Province one can easily find biomass over 1,000 m^3/ha. By analysing numerous data of forest surveys, it is known that forests in Tibet grow much quickly and have the highest productivity. The average timber store per ha in Tibet is 260 m^3. That in the west of Sichuan Province of 225 m^3 comes second, followed by the northwest of Yunnan Province, with 180 m^3. But it must be pointed out that though the store capacity per ha is two or three times the average store capacity of the whole country, the age of the trees turn out to be all above 100 years. Some are 150 to 200 years or even more. Decayed timber appears everywhere in the forests. In some regions, 90 per cent of the trees in overmature *Abies* forest are decayed. The other characteristic of the forest growth is that the trees have much longer periods of growth. Many trees can grow into big trees. This phenomenon appears particularly in Tibet. For instance, some big trees can, provided with better conditions of water and temperature, reach a height of 80 metres with 2.5 metres diameter and 40 cubic metres volume for a single tree in the tall and straight forests of *Picea* and *Abies*.

Serving as an ecosystem, the biomass and leaf index of these forests far exceed other vegetation types. People must not only acquire timber and other byproducts from forests to meet their material needs which are increasing constantly, but they must also attach importance to bringing the forests into full play in conserving water, preserving soil, regulating climate, cleaning air, reducing pollution and protecting and beautifying the environment.

DISTINGUISHING FEATURES OF THE FOREST DISTRIBUTION

Uneven Distribution of the Forests

Of forest area, the vegetal cover is 8 per cent in Tibet, 13.3 per cent in the west of Sichuan Province and 26.8 per cent in the northwest of Yunnan Province. Present situations of forest distribution are closely related to the economic activities of mankind. To use unsuitable felling measures and violently destructive action will bring about a continuous reduction and eventual disappearance of the forest resources. The forests nowadays are distributed mainly over the upper hills and branch gullies far from mainstreams. The elevation may be high and the slopes steep. According to the data from the west of Sichuan Provincce, the slopes of forest lands above 35^0 make up 55 per cent, 25 to 35^0, 35 per cent and those below 25^0 , only 10 per cent.

The upper limit of the forest distribution is mostly restricted by conditions of water and temperature. Generally, the elevation of the upper limit of forests may be 3,850 m in the south of the district 4,100 m in the middle, in moist conditions, and 4,300 m in the north, in semimoist and semidry conditions. Because most of the regions of the Qinghai-Xizang Plateau have an elevation above 4,000 m, the growth and distribution of the forests are limited. The high elevation also means that the forest cover ratio cannot rise greatly. Especially in Tibet, only 12 per cent of the land area is located below 4,000 m.

Rich and Varied Distribution of Vertical Belts

The southwest mountainous district occupies a major part of the Qinghai-Xizang Plateau. This region has a broad and undulant landscape. It can be celebrated for its unique and varied natural conditions. Along 2,400 km of the grand Himalayas, over 5,200 m, snow is covers the land throughout the year. There is a glacier. Under the impact of the violent action of running water, many deep gorges have been developing. Also, owing to the influence of warm airflows from the Indian Ocean, precipitation abounds in this region, providing favourable conditions for variant forest types to grow. There is an obvious vertical pattern of distribution. Furthermore, the composition of tree species in the forests appear to be rather complex. Different vegetation types, from the torrid zone at low elevation to the frigid zone at high elevation, can be seen easily.

The tree species of the forests in Tibet have a high economic value. There are quantities of coniferous tree species there, such as *Picea* and *Abies, Pinus griffithii, Tsuga, Cupressus, Amentotaxus argolaenta.* These species have many merits, i.e. straight stems, good growth, smooth grain, convenient to process and a good compressive strength, and have been used as the superior material in construction, furniture, sleepers and poles. Meanwhile, the figure and grain of the broadleaf trees like *Cinnamomum Phoebe*, and *Toonasinensis* are very clear and colourful and the wood has a protection effect against insects and therefore acts as an important material for furniture and construction.

Some species of Quercus have crooked stems, many branches, tensil wood, and a beautiful grain and grow no more than thirty metres high. But since it is difficult to process and the wood easily cracks, they can only be used in heating, cooking and making charcoal.

The famous Hengduan mountain chain is composed of a series of high hills and deep gorges from north to south. The elevation of the valleys can be 1,000 to 3,000 m, reaching 5,000 to 6,000 m at the top of the mountain. Most of the eastern and southeastern parts of this region are affected by the southeast monsoon. The precipitation varies in the southeast monsoon, so it varies in the region. In the eastern and southeastern parts, the annual rainfall may reach 1,200 to 1,600 mm in other parts, it changes from 500 to 900 mm. As a result, the tree species and forest types of the Hengduan mountains are much fewer than those in southern Tibet. From the south to the north, the terrain rises and turns into a plateau. Forest vegetation is simpler and the tree species poor. The *Picea* forests are distributed unevenly and species of *Abies* are thinly scattered.

In southern and southeastern areas, that have better conditions of water and temperature, some evergreen broadleaf forest still remains. Of the dominant tree species in the stands there are *Fagaceae, Lauraceae, Magnoliaceae* and *Theaceae*, among which again, the species and genus of *Fagaceae* is most frequently seen. Also often seen are the species of *Pinus, Yunnanensis, P. bensata, P. tabulaeformis, Abies, Picea, Tsuga, Keteleeria, Larix* and *Cupressus.* There exist some secondary forests of *Betula* and evergreen forests of *Quercus semecarpifolia*, of which the latter are more widely distributed, but have not been put into full use and suffer from a severe waste of resources.

FOREST FELLING AND REGENERATION IN THE SOUTHWEST MOUNTAINOUS DISTRICT

The southwest mountainous district is the only virgin forest region well-preserved in the country, attracting more and more attention from forestry researchers. Outstanding results have been reached especially in the selection of measures of forest cutting and in practical approaches to regeneration, based on years of experiment and research work done by the institutes concerned.

This achievement provides a further rational utilisation of the forest resources in the region and significant experience in regenerating cutting-blanks. Forest felling and regeneration are two elements closely linked in forestry. The former strongly restricts the latter and, on the other hand, depends on the efficiency of the latter. For this reason, a suitable strategy for felling and regeneration must be formulated on the basis of a full understanding of the local natural conditions and the biological and ecological characteristics of the tree species. This should be combined with the protective performance of forests, the existing technical level, the requirements of the nation and the local economic conditions. Coniferous trees are mainly cut and used both now and in the past, in this district. They can be divided into two catagories: the light coniferous forests consisting of *Pinus yunnanensis* and *P. densata*, and the dark coniferous forests consisting of *Picea* and *Abies*. The two categories, either in the context of geographical distribution, ecological environment, or regeneration peculiarity and utilisation value, differ from each other. The following sections offer further discussions on the felling and regeneration of these two kinds of forests.

Felling and Regeneration of the Light Coniferous Forests

The light coniferous forests consists of *Pinus yunnanensis* and *Pinus densata*, are dispersied fairly extensively. *P. yunnanensisis* are concentrated in the southern mountainous area, which is 1,600 to 3,000 m, while *P. densata* appears in farther north at a higher elevation, from 2,500 to 3,500 m. It is the sole *Pinus* species scattered at such a high elevation in the country. These coniferous species all have the distinguishing features of strength, short viability of seed with a flying wing favourable for dispersion, the capability of natural regeneration and drought resistance. Therefore, the distribution of the forests seems to extend continuously. It has been proved in practice that afforestation through naturally flying seeds is possible and safe on condition that fifteen to twenty mother-trees per hectare are retained after clear-cutting. Furthermore, if some measures for afforestation through artificial spreading or direct seeding are adopted after clear-cutting, the results will be even better. Usually, the artificial measures are needed only in areas of bad natural conditions, to promote natural regeneration and satisfy the requirement.

The natural regeneration under the crown of *Pinus yunnanensis* and *P. densata* usually proceeds much better at the gap, sparse woodland and fire-slash. But fire greatly affects the regeneration of saplings, particularly those under 10 years old which are sometimes burnt completely. Attributed to the *Pinus yunnanensis* and *P. densata* is light-demanding and not shade enduring. Regeneration is closely related to canopy density. Where the canopy density is below 0.4 with sparse undergrowth, regeneration goes on well and produces the normal number of saplings. However, if the canopy density is high and the shrub thick, the number of the saplings, and their growth, will be limited.

In order to speed up afforestation in the large areas of the cutting-blanks and waste lands aircraft sowing has been applied since the end of the 1950's. From that time on, the remaining *Pinus yannanensis* forest not only has long been closed by crowns, but has also produced ecological and economical benefits.

The importance of establishing seed plantation must be stressed. It has a profound significance in afforestation over a short time, of the waste lands and the realisation of the regeneration of the cutting-blanks.

Felling and Regeneration of Dark Coniferous Forests

The dark coniferous forests composed of *Placea* and *Abies* served for a long time as a subject for cutting and utilisation in the southwest mountainous district. For many years cutting and exploitation of the forest have caused concern and different ideas have been put forward. Some examine from the angle of utilisation and lay emphasis on clear-cutting, for mechanical operations, reducing investments, decreasing expenditure and making a good use of natural resources. Others place stress on selection cutting from the viewpoint of forest management and further elaboration of the varied profits of the forests. Most of the forests in the district are usually scattered on the upper reaches of rivers, for example, the watershed of Minqiang river covers twenty-five counties, among which the areas of forests at the upper reaches of the river make up 64 per cent and the store capacities 73 per cent of that of the whole watershed. But the problem remains that the overmature forests account for 80 to 90 per cent of the forest with increasing withered trees and decreasing products. Still some others take the view that consideration should be given to general factors, such as the natural conditions, stand character, economic value and technical level of the foresters and stress the principle of suiting measures to local conditions, and combining clear-cutting with selection cutting. Concerning the selection of a felling pattern for subalpine dark coniferous forests, lots of discussions and rules have been made by forestry research projects up to 1977. The idea of taking a slope as an integrated unit then come out where the cutting intensity varies from the foot to the top of the slope, with clear-cutting at the lower part and 70 per cent of the cutting at the middle, applied to the sectors of better regeneration. On the upper slopes, owing to the bad conditions that result is difficult forest restoration of the stands, high rates of disease and decomposition, sharp trunks and low economic ratios of cut-turns, the method of stipulating not more than 30 per cent cutting intensity and of combining clear-cutting with selection cutting has been widely applied.

The size of clear-cut areas differs from place to place. As the data of the year 1984 by the Forest Department of Sichuan Province shows, all the 364 cutting sectors in 14 forests in the west of Sichuan Province are in following proportions: those less than ten ha make up 50.55 per cent, those between eleven and twenty ha, 32.42 per cent, and those larger than twenty-one ha, 17.3 per cent.

Experience has already been accumulated for forest felling in the mountain valleys, and regulations been put into practice. But crossing through the high mountain valleys from the south to the north, gradually turning into mountianous plateau zones, the terrain changes little with little variance of altitude. The forest distribution is markedly restricted by topography. Most of the forests distributed on shaded and semishaded slopes present a discontinuous belt or a patch, where *Picea* dominate. After being cut, the forests have difficultly in natural restoration, and selected cutting must be adopted under these circumstances as a main felling method, with exception that a few areas small size, are up to clear-cutting.

It has been proved by a great deal of data that the fragility of dark coniferous forests are affected by outside fluctuation. If the forests are cut or destroyed and not afforested by artificially cultivated seedlings in time, they are often reduced to shrubbery or meadow. Therefore, forest protection belts of different kinds must be strengthened by means of reinforcing the protection to those forests at the upper limit, on both sides of rivers, roads, and ridge of hills, or on steep slopes and bareland so as to, through forest reservation, conserve water, preserve soil and reduce landslides in the regions. As for the loss of water and erosion of soil after felling, it might be incorrect to attribute the problem simply to the cutting pattern, on the basis of data from surveys at an established station. Vegetation is restoring quickly and grass growing thickly after the forest was cut with a cover ratio, retaining from 70 to 90 per cent. Although this creates unfavourable elements for regeneration, the ability of damming precipitation is thus raised and waterflow on the ground turned underground. That is the reason why serious soil erosion does not occur in many forest cutting regions. In some sectors the phenomena of soil erosion and collection of sands in rivers does take place, but it is mainly on the account of the transportation of timber from one slope to another along little gullies. It has little to do with felling. So in order to prevent the loss of water and soil erosion, the means of collecting timber must be improved first of all.

The Regeneration of Dark Coniferous Forests

Using data acquired from many standard plots, the effects of natural regeneration of *Picea* and *Abies* forests is proved to be unsatisfactory, but it does not mean that there are no regeneration seedlings at all to be found under the canopy of *Picea* and *Abies*. A considerable number of one-year-old seedlings can be found: about one hundred thousand or more per hectare, but it is hard to find seedlings of two years old, especially in conditions where the ground under the canopies is nearly covered by liver mosses. Apart from mortality caused by lack of sunlight, most seedlings are hung in the upper layer of liver mosses and cannot touch the soil. Also, because of their short growing period, (45 to 60 days) and a low extent or an inability to grow into xylem, the seedlings can hardly endure the impact of the cold climate in winter and drought in spring, and they almost all die.

Picea and *Abies* by nature belong to shade-enduring species, but beginning from the seedling, their ability to endure shade weakens step by step and their light demand may increase the net assimilative rates of a one-year-old seedling of Abies under the condition of full sun shine do not come high. They reach the highest value under the condition of 30 per cent intensity of natural sunlight. As the seedlings grow their requirements of light intensity increases. Meanwhile, the light intensity and temperature are the two principal factors that influence the rate of photosynthesis. Obviously, the surveys of this kind are significant in guiding growing seedlings of *Picea* and *Abies* in the mountains.

Alongside the success of growing seedlings on high moutains, the possibilities to realise regeneration over a large area through artificial afforestation has arisen. Also only by that success, can the policy of relying chiefly on artificial regeneration be put into practice. But there still exist some problems. First, no afforestation plan exist that meets the ecological requirements of the tree species and the principles of suiting measures to local conditions, which often leads to unhealthy growth of some afforested trees, or even to failure. Secondly, the quality of the seedlings is not good. Afforestation demands planting seedlings over two years old and to substandard and eliminate mechanically damaged seedlings. But the seedlings are not carefully selected and some place and planting technicalities are not strictly implemented. Thus the survival ratio remains low. This seriously impairs the preservation rate of regeneration. According to statistical data from the forestry department in Sichuan Province, since the beginning of 1950's, only thirty per cent of the afforested areas are retained and produce a marked effect on regeneration. Thirdly, the tending and managing of the woods is badly carried out. There is a shortage of labour which leads to each year's tending of afforested areas being left incompleted which affects the survival and preservation rates after afforestation.

The application and popularisation of container planting in the west of Sichuan Province possesses a profound significance. Container planting is not limited by the afforesting season and it mitigates the problem of labour shortages in afforesting periods. In regions with bad conditions for silviculture, the utilisation of container planting strikingly raises the survival ratio. Owing to the limitation of existing conditions, however, container planting is only popular in some regions. Along with the development of seedling planting it will certainly play an important part in the future.

It must be pointed out that research is being carried out into growing seedlings with nodule bacteria. Success in this will add impulse to the growing of seedlings in the high mountains, especially of the coniferous species. Also it is helpful to improve the quality of the seedlings and raise the survival ratio of afforestation. Using the principle of giving priority to artificial regeneration while advancing natural regeneration, the probability of making full use of natural regeneration in better areas will not be excluded. Under natural conditions, *Picea* and *Abies* are developing continuously through gaps, patches and margins of forest. So the speed of regeneration is continuative but slow. But on the other hand, these are certainly some merits for those regions which are short of labour and seed resources.

FOREST CUTTING AND SOIL CONSERVATION IN ALPINE FOREST OF WEST SICHUAN

(with special reference to Minjiang River)

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INTRODUCTION

Many scientists are concerned with the felling of forest trees and its repercussions. A lot of papers are written about the conservation and rational management of the forest in the upper reaches of Minjiang River, which plays an important role in the supply of water for industries and agriculture in Sichuan basin. In the last 30 years, due to irrational cutting of the forest, very serious deforestation occured. It is now not easy to find a good forest stand. Large areas of mountains lost the protective cover of forest and plants, which caused an imbalanced water source and very serious soil-water erosion. Land slips and mud-debris flows occur frequently and block the transportation on highways and in river courses. This paper deals with the hydrological data and the variation in the forest resources over many years in the upper reaches of Minjiang river, and suggests approaches and research needs.

Located on the periphery of Qinghai-Xizang plateau, the topography of the upper reaches of Minjiang River is by no means even. The average gradient is over 30°, many are 45°-60°. The relief is high cold mountains and deep valleys inclined towards the southeast from the northwest. The Songpan Aba plateau in the north is connected with Min mountains with an elevation over 4000 m. The main stream of Minjiang River flows through Songpan, Maowen and Wenchuan, then enters the valley flowing south through Guanxian into the Chengdu plain. Minjiang meets the Heishui River in Maowen, then the Zagunao River in Wenchuan. Heishui and Zagunao rivers all have their sources in the north end of Zhegu mountain in the Qionglai mountain range and are the large tributaries of Minjiang River. The topography of high mountains and deep valleys with very different elevation formed the evidently vertical climate belt. Between 1400-3000 m the climate is subtropical to temperate. Above 3000 m, it is cold temperate to frigid. In summer this region is cool and there is no severe winter since the area is at high elevation but low longitude.

Heavy rainfall in summer, due to the impact of a southeast, southwest monsoon and the circulation of a west wind, gives an annual precipitation of 500-1300 mm, gradually decreasing from southeast to northeast. The dry season and rainy season are distinct; in the rainy season rainfall is even and not intensive.

On the whole, there are good hydrothermal conditions in all of the forest areas. Rain comes in the growth season of the trees and is moderately humid and evenly distributed. It is very suitable for the growth of many kinds of plants.

Vegetation and soil are various at different elevations. At 2600-3000 m, mainly mid-mountain mix forests of conifer, and broad leaved forests grow. The soil is the dark brown forest soil of the mountains. At 3000-3800 m, there are the sub-alpine conifer forests and the soil is brown. At the elevation of 3800 to above 4100 m, there is the alpine shrub open forest belt, the soil is alpine meadow soil, the stand type is mainly fir and spruce forest and the age of the all stands is over 200 years. They consist of mature and overmature forest and the structure of the stands is multilayer uneven-aged forest of many generations. The material rock for soil genesis is mainly schist and phyllite, which are very easily weathered. The soil layer is between 0-100 mm in depth with good structure and high infiltration capacity. Its ability to resist erosion is also good.

CUTTING AND UTILIZATION OF THE FOREST RESOURCES IN THE UPPER REACHES OF MINJIANG RIVER

The forest in the upper reaches of Minjiang river is an important component of alpine forest resources in southwest China. The stock of the forest is about 150 mio m^3, or 12% of the total stock of the forest in Sichuan. Distributed mainly in the large tributaries of the upper reaches of Minjiang River, the forest industries are divided according to the catchment area of the rivers. The tributaries there are: the Minjiang River, Heishui River, Zagunao River, Yuzixi River. These rivers belong to Songpan forestry bureau, Heishui forestry bureau, Chuanxi forest bureau and Hongqi forest bureau respectively.

All the timber cutting areas of this region are based upon the distribution characteristics and physical conditions of the forest. Besides a certain amount of trees preserved on the upper part of the mountain ridge near the upper limit of the forest fringe, all timber was clean cut from top to bottom; some places are clear cut by plots and some places are cut in strips; some places are cut by intensive selection. The timber transportation and skidding systems are established according to the large and small rivers in the natural catchment. Either the wood is skidded down slides on slopes or simple sliding-tracks are used based upon the relief. To transport the timber, the lock gate on the river is opened and the wood is floated, or is transported by canal. These methods very easily induce soil erosion and increase the silt content of the river.

Among them, the Chuanxi forestry bureau in Zagunao river basin and the Heishui Forestry Bureau of Heishuibe river basin suffered the largest volume of felling. The yield exceeded the increment. Regeneration could not keep pace with cutting. Consequently the stock of the forest decreased rapidly. Yield from felling eventually decreased by about 50%. The timber from Heishui Forestry Industry Bureau decreased from 406,345 m^3 in the 70's (Table 1). From some basins of the tributaries of the Minjiang River the total yield from felling was increased to some extent, because the number of forestry industries were increasing and the cutting area was therefore enlarged. Forest cover decreased to 10-20%. It is evident that continued cutting gives less and less economic returns seriously destroying the environment. The protective function of the forest will then be weakened considerably.

Table 1: The Yield from Forest Felling in Upper Reaches of Minjiang River

Forest Industry Bureau (River)	Felling Period	Yield from Felling Annual	Yield from Felling Total (m^3)
Sichuan (Zagunao River)	1950s	267977	2679776
	1960s	220965	2209656
	1970s	121563	1094073
Heishui (Heishui River)	1950s	406345	1625383
	1960s	289942	2899422
	1970s	249067	2241606
Maoergai River	1971-1978	147623	1180989
Hongqi (Yuzixi River)	1950-1959		3236
	1965-1969	10869	54347
	1970-1974	58215	291079
Songfan (Minjiang River)	1975-1978	8451	33806

MAIN FACTORS THAT INFLUENCE RIVER DISCHARGE

River Discharge and Rainfall

The annual rainfall in Minjiang river basin is about 500-1300 mm. There is less rainfall in the north near Songpan where it is about 450-600 mm, while in the east part near Guanxian, rain falls in abundance and in Pitiao River and Yuzixi River the annual rainfall is 840-1200 mm. The rainy season is from May to September and is followed by the dry season October to April. No heavy rain falls in the rainy season; mostly moderate and light rain which make 70-80% of the rain days. The maximum rainfall is in June gradually decreasing until September. The river discharge is closely connected with the rainfall distribution in the year i.e., the river discharge is increased when the rainfall is increased. The hydrological data of 1956-1978 indicated that from January to March is the dry season. Minimum flow in June or July, and a little bit decrease in August, increase in September.

The water source of the rivers in Minjiang river basin are mainly supplied by rainfall which makes up 75-80%, of which 5% is from melted snow. The ground water recharged to the river is about 20-25%.

Forest Cover and River Discharge

The forest has a positive function in regulating the river discharge. It can decrease the surface runoff into underground flow. Alpine forest has an important role in retarding the flood volume in flood season and increasing the low water volume in the dry season.

It is difficult to assess the relationship between forest cover and river discharge accurately since the factors that influence river discharge are various and complicated. Two conclusions were drawn from related observational data of several countries in the world:

Increasing the forest cover in catchment areas can increase the annual runoff and decrease the flood volume.

Increasing the forest cover can result in a decreased river flow.

IMPACT OF CUTTING FOREST ON RIVER DISCHARGE AND SILT CONTENT

Annual Variation of Runoff

The origin of Minjiang River is in Minshan range. It flows through Songpan to Zhenjiangguan. The catchment area above Zhenjiangguan is about 4486 km^2; the forest cover is about 40%. The impact of cutting forest on river discharge can be explained by the variations in mean annual runoff over many years. In the' 60's the mean annual runoff and annual runoff depth was the highest of many years (20.33 mio m^3, and 453.18 mm), while in the' 70's they reached 1760 mio m^3, and 392.23 mm, and the minimum was in the' 50's (17.28 mio m^3, and 385.19 mm). Table 2 shows the variation of annual runoff is mainly influenced by rainfall.

Beyond Sangping, the catchment area is about 4629 km^3, and before 1950, the forest cover was 56%; after cutting the forest till 1977, the cover decreased to 47%. The annual variation of mean runoff is similar to Minjiang River. In the' 60's the figure is the highest 3547 mio m^3, while in' 70"s it was 3353 mio m^3 and the' 50's the mean runoff reached a minimum of 3340 mio m^3.

There are two tributaries in the upper reaches of Heishuihe River namely: Mao'er Gai River and Dagu River. When they join together, the river is called Heishuihe River. By Shaba, it flows into Minjiang River. Above Shaba, the catchment area is 7231 km^2. Prior to 1956, the forest cover was 57%; after cutting forest till 1977, it dropped to 41%. The variation of annual mean runoff is similar to Minjiang River and Jagunao River- the highest figure is appeared in 60's (4655 mio m^3), the 70's rank second (4279 mio m^3), while the minimum appears in 50's (4089 mio m^3).

The upper reaches of Minjiang River with a catchment area of 22,664 km^2, is the joining place of several tributaries.The forest cover dropped from 30% to about 20%. The annual variation of runoff is similar to other tributaries. In '60's it was 15060 mio m^3, '50's it was 14739 mio m^3 '70's it was 13212 mio m^3. If compared to the '40's when the rainfall was similar to the '60's the annual runoff increased by 342 mio m^3 (Table 2).

It is evident that in the watersheds of Zagunao River, Heishuihe River, the annual river flow showed no remarkable decrease causd by the cutting of the forest, but on the contrary, it even increased (Table 2). The increase of the annual river flow was not only closely related to the annual rainfall, but also caused by the larger volume of surface runoff in cutting banks than in the forest. A spot observation in west Sichuan in 1961, in the same rainfall conditions, the surface runoff in the cutting blank was 0.02 - 0.13% larger than that of the forest. With the rehabilitation of the vegetation in the

Table 2: Statistics of Discharge of Tributaries in Upper Reach of Minjiang River

River	Catchment Area	Forest Cover		Mean Annual Runoff Rainfall	Runoff	Modulus	Depth
(Station)	(km^2)	%	Decade	(mm)	($mio.m^3$)	($min.m^3/s.km^2$)	(mm)
Minjiang River		41	50'	569	17.3	12.2	385
(Zhengjiangguan)	4486		60'	622	20.3	14.3	456
		40	70'	567	17.6	12.4	392
Zagunao River		56	50'	499	33.4	22.9	721
(Sangping)	4629		60'	536	35.4	24.3	766
		47	70'	469	33.5	22.9	724
Heishui River		57	50'	569	40.9	17.9	565
	7231		60'	603	46.5	20.4	643
		41	70'	564	42.8	18.7	591
Yuzixi River		67	50'	880	19.8	36.1	1141
	1740		60'	1303	20.8	37.9	1195
		66	70'	1226	16.7	30.4	959
Upper Reach of		30	40'	1551	147.2	20.6	649
Minjiang River	22664		50'	1495	147.4	20.6	650
Zipingpu)			60'	1551	150.6	21.0	664
			70'	1367	132.1	18.5	583

cutting blank, the annual runoff will decrease.

Annual Runoff Modulus and Annual Runoff Depth

Annual runoff modulus means the minimum water yield in unit period per unit area (min. $m^3/s.km^2$). The annual runoff depth is the depth of the water. The variation of these two items is similar to annual runoff (Table 2).

Flood Discharge and Low Water Flow

What kind of forest cutting brings on the flood discharge and low water flow of the rivers? Based upon the comparison between maximum and minimum discharge of tributaries in the upper reaches of Minjiang River (Table 3), and the continuation of forest cutting year on year enlarging the cutting area, obviously the flood discharge increased (monthly mean discharge), and low water flow (monthly mean minimum flow) appeared in several tributaries of the upper reaches of Minjiang River. The flood dischargeeached a maximum in the '60's. Compared to '50's, the '70's showed a small increase; the Zagunao River increased 13.80 m^3/s. Heishuihe River increased 31.3m^3/s. The upper reaches of Minjiang River increased 8.27 m^3/s. Only the Yuzixi River decreased. Compared to '50's, the low water flow in the upper reaches of Minjiang River and its tributaries in '70's, the Zagunao River decreased 0.64 m^3/s., Heishuihe River decreased 1.20 m^2/s., the upper reaches of Minjiang River decreased 10.8 m^3/s. Water source conservation practices in the forest are to evenly distribute and stabilize the river discharge in a year. This can be explained from the ratio of the maximum and minimum monthly discharge in many years. A high ratio means uneven distribution in the year and brings difficulties in using water for agriculture and industries. With the cutting of the forest and the use of the timber, the ratio increased gradually. From the '50's to '70's, the ratio of Zagunao River increased from 7.6 to 8.24, Heishuihe River increased from 8.04 to 9.79 and the Minjiang River increased from 6.68 to 7.72 (Table 3). The forests have a function to convert the surface water into ground water runoff. The cutting of the forest

Table 3: Comparison Between Maximum and Minimum Discharge of Tributaries in Upper Reach of Minjiang River.

		Discharge (m^3/s)	
	Year	Max. Flow	Min. Flow
Minjiang River	50'	107	22
	60'	138	21
	70'	114	20
Zagunao River	50'	236	31
	60'	247	30
	70'	249	30
Heishui River	50'	284	35
	60'	355	36
	70'	316	34
Yuzixi River	50'	152	18
	60'	165	17
	70'	117	15
Upper Reach of Minjiang River (Zipingpu)	40'	987	142
	50'	916	137
	60'	1055	136
	70'	924	126

decreases this effect. The ratio of surface water to ground water in the upper reaches of Minjiang River and its tributaries was 7:3 before, but is now 8:2.

Impact of Cutting Forest on Seasonal Variation of Silt Suspended Load

There was an obvious difference of river discharge in the rainy and dry seasons of Minjiang River and its tributaries, caused by the distribution of rainfall in a year.

In the rainy season, the average silt content in the rivers is high; in the dry season it is low. The difference is obvious. In rainy season, the monthly mean silt content over many years, of Minjiang River in the '70's is 0.25 kg/m^3. In the dry season it is 0.092 kg/m^3. At the same time the monthly mean silt content over many years of Zagunao River is 0.367 kg/m^3, while in the dry season it is 0.015 kg/m^3. In the rainy season it is about 24.4 times as much as in the dry season. The monthly mean silt content Heishuihe River in the rainy season is 0.255 kg/m^3, and in the dry season is 0.016 kg/m^3, about 15.93 times as much.

MANAGEMENT OF NATRUAL RESOURCES

THE MANAGEMENT OF NATURAL RESOURCES IN DRAINAGE AREAS

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INTRODUCTION

To help a developing country or backward area in the development of its national economy and to achieve equilibrial development in industry and agriculture, it is necessary to control drainage systems and to give massive support to the mountain-area economy. Basically this involves the rational utilisation and exploitation of the multifarious mountain biological resources and the protection of the complex and variable mountain ecosystems. It is the key link between territorial renovation and the development of a national economy, and the way to develop agriculture, in its broadest sense; i.e. coordinating and developing farming, forestry, fisheries, animal husbandry and sideline production, in an all-round way.

China is a model among developing countries. On her 9.6 million km^2 of land, there are ten thousand crags and torrents; the mountainous areas (including plateaus) over 500 m, occupy 86% of this land surface, while areas over 1000 m, occupy 64%. The southwestern provinces are typically alike in this regard. If the mountain economy does not progress to a higher level, it will be a drag on the national economy. Since the revolution, China has been improving the conditions for farming, using technical equipment and getting bumper harvests for years running, especially in her flatlands area. These go some way towards solving the problems of feeding a billion people and putting an end to the large numbers of peasants engaged only in food production. However, in the mountainous regions particularly, destruction of natural resources continues, creating more and more new problems:

- areas of soil erosion are increasing and the erosion is serious;
- the silting up of rivers, lakes and reservoirs is severe, and the mileage of inland navigation has been reduced;
- destruction of forests has occured on a large scale, steadily worsening the conditions for fauna and flora;
- decreases in soil fertility and in the physical and chemical properties of the soil are a great hindrance to raising the unit area yield; now more than one third of the cultivated land is low-yield montane land;
- large quantities of natural resources are not yet fully utilised so the mountain and hill people are mostly still living in poverty;
- rural energy resources are under a heavy strain, thus forming a limiting factor for forestry and other industries.

ECO-SYSTEMS

River Drainage Systems

As a result of the situation described above, the Yellow River drainage system has fallen into a vicious circle: in the middle reaches, the principle of "the more reclaimed the more impoverished; the more improverished, the more reclaimed" is becoming common. At the thousand "li" dyke of the lower reaches, the principle of "the more reinforced, the more dangerous" seems to apply.

In addition, the Yangtze River which formerly had a silt quantity one third (5 billion tons) of that of the Yellow River, has become a muddy stream. This phenomenon led to the fierce flood of 1981 which smashed 1470 thousand "mu" of cultivated lands, reduced the grain yield to around 30 billion "jin", halted the production of more than 3000 industry and communication units, and caused direct economic losses of about 25 billion Yuan for the entire province.

Integrated Eco-systems

Irrespective of the size of the river, a drainage area is an integrated, unified and huge ecosystem, and its various filial systems are all interdependent, mutually conditioned and mutually complemented by "feedback". When a river originates in a mountainous region or plateau, it will erode the rock stratum. Due to the transport of soil and the multiplication of many living organisms, various biological resources gradually develop. The variable ecosystems, with different productive abilities are dominated by plants which capture solar energy more and more effectively, covering the hills and peaks with green. The surface runoff and underground water, flow together, forming rivers. These accelerate the normal circulation of energy and matter, irrigating and moistening the lower and middle reaches and forming a dendritic drainage system. The resulting drainage areas extend across the horizontal and vertical zones but they still organise into mutually connected and conditioned systems in the upper and lower reaches.

The upper reaches, if "there are green hills and green water", could follow the descendence of altitude layer by layer intercepting and conserving the water-head. The lower reaches could then not only gain the benefit of the inundation of fertile soil, and water, at regular intervals, but could also avoid the danger of unstable discharge, either through flooding and water-logging or by being cut off from the flow after it dries up. On the contrary, if the headwaters of Mekong River and Salwin River were destroyed, the lower reaches of several countries in the Indo-Chinese Peninsula and Burma would become submerged and human beings would become the fishes and turtles. In short, the good and bad of the mountain environment must affect the lowland and valleys of the lower reaches, and also the flood plains, which are densely populated. Although this is a simple and obvious fact, owing to the division of nations into different administrative areas, unified planning and control often cannot be easily achieved.

Mountain Eco-systems

Within the mountain ecosystem, as against the ecosystem of the plains, complicated and variable filial systems are provided for. Generally speaking, because of the influence of wet monsoon, trade winds and oceanic current in the continental zones, and owing to better and more advantageous natural conditions, the mountain regions, can mostly be developed into various types of forest ecosystems. Yet these ecosystems are likely to be complicated and variable, often restricted by the natural conditions of different altitudes. Thus they form various types of filial forest ecosystems.

Inside the forests and above their upper limits there are several different types of meadow, swamp, and scrub. The zonal range is narrow and relationships within it are close. The successional changes are rapid, and the diversity of microniches is obvious. Agricultural production and utilization of this land shows:

- the stereoscopism of the agricultural structure, its diversity, its decentralization, and the seasonal continuity of the agricultural resources;
- the numerous and manifold local varieties of superior quality but that are hard to introduce anywhere; and
- the profound influence of such factors as slope, orientation, and land vulnerability, on agriculture.

Full recognition of these characteristics and a thorough application of drainage control as well as the exploitation of montane biological resources, may have a far-reaching significance.

RELATIONSHIP BETWEEN RESOURCE USE AND DRAINAGE CONTROL

Where rational exploitation and utilization of biological resources and drainage control are concerned, close attention ought to be paid to the very important relationship between the economic development of the big city and that of the middle and small cities together with villages and towns. Urbanization is already a world-wide phenomenon on an unprecedented scale. The rural population is pouring into the urban areas in large numbers, but at the same time, those cities need more and more natural resources, including fuel, food, industrial raw materials, and even water, soil and fresh air. Urbanisation begins with a surplus of agricultural products. Then the cities, especially those situated on the middle or lower reaches, or the mouth, of a river, become necessary for the provision of material resources and manpower, for the development of industry and farming in the small cities, villages and towns.

In the development of a national economy, the largest and most important basis for economic production is agriculture in the widest sense. The words "no stability without agriculture, no richness without industry, no vitality without commerce", are meaningful in this context. Only in such a way can the healthy and rapid forging of new cities, towns and villages in both the upper and lower reaches of the rivers, be successful. As a result of energy and material input combined with an improved network, a state can be reached where the best use is made of everything and there is demand for the goods produced. It is not only that a human, in order to become "Homo energetica", is enthusiastic to take part in the cosmic ecosystem, but also because that human is the dominator of Nature and the composer of the cosmic ecosystem. Humans and Nature could and ought to gradually attain a lofty harmony. This is especially important for city dwellers in developing countries because the power for construction can easily change into a tremendous power for destruction and extermination. This can lead to the exhaustion of energy supplies and natural resources, which, when combined with population inflation, results in food shortages, the degeneration of the environment and the dislocation of the ecological equilibrium. In the end this means the destruction of human beings themselves.

Yet, what are the tools that people can use to regulate Nature? We face the problem of rational exploitation and utilization of various natural resources, especially botanical and biological resources. In nature, only biological resources are "renewable"; including different kinds of animals, plants, micro-organisms and various ecosystems in combination with the surrounding environment (within biosphere), such as farmlands, forests, and meadows. In a suitable natural environment, and under a rational exploitation system and good management and administration, they can regenerate successively and reproduce in a large numbers, thus everlastingly to be utilized by human beings.

As long as humans recognize and protect the basic ecological conditions that are their life blood, the evolutionary process inside the ever-changing and developing ecosystems will continue.

Biological resources possess five distinguishing features:

- The entirety of resources; between each kind of resource and their environment there are mutual connections and conditioned relationships which form them into interrelated layers and filial systems. A change in any one factor, any one resource, or any one filial system, may affect the whole. Comprehensive research leading to multiple exploitation is necesary to maintain this entirety.

- The regionality of resources; the distribution of natural resources is restricted by regional regularities. This is most obvious with botanical resources. Measures to exploit, protect and reproduce these resources must "suit....local conditions", and should "be restricted only by the natural region and not the administrative region".

- The limited resources; natural resources are often exhaustible and their load capacity and structure are limited under certain conditions. There are ways of resolving this; reproduction, economization or substitution, but all are dependent upon science and technology.

- The changability of resources; ecosystems are constantly evolving both through self-induced change and through interference from humans. This is especially so with renewable resources. The threshold value of the different resources should be assessed seperately and thereafter, the degree of exploitation and utilization of each can be determined. During the course of resource change, it should be noted that when exploiting them, "the most diversified measures are the most stable".

- The multiple uses of natural resources; there is an economic benefit, a social benefit and an ecological benefit in the utilization of most resources. To concentrate on one aspect only, violates the optimisation principle.

Botanical Resources

Botanical resources occupy a central position in the ecosystem because they have the function of directly transforming solar energy into food and fuel energy. Added to this is their regeneration ability allowing them to be used and then renewed.

Plants are present in every environment of human life and are a basic material for the environment. Plants link "Man and Biosphere", atmosphere and lithosphere. They influence the formation and evolution of water, soil and climate, and certain species are valuable in the preservation of water and soil reserves. Therefore, vegetation is a key element in the substratum, and various plant cover, especially different kinds of forest vegetation, have a stabalizing effect on the water-heat balance, creating good conditions for agricultural production.

In any environment, plants are almost the only primary producer, while microbes and animals, (including humans), are just the decomposers. The consumers, sometimes secondary producers, also take their raw materials from plants. Materials that humans use for clothing, shelter, transport, utensils, and especially food, are directly or indirectly taken from plants. Today, humans even need plants to monitor the dynamic changes in the quality of the environment. Provided the growth rates of plants and human population are harmonised by carefully increasing quantity and quality of plant yield per unit area, and administering birth control for humans, there should be few problems.

As previously stated, drainage control is crucial, especially in the upper reaches of a mountain river, where continuous utilization of the mountain forest ecosystems and the rational exploitation of biological resources have proved to be the key to the problem. Here a common difficulty arises; that is the contradiction between utilization and protection. In the longrun, exploitation and conservation should be completely consistent and their ecological, economical and social aims should be unified. People must realize that the ecological benefit of natural resources is the assurance of economic benefits in the longterm. These may sometimes contradict each other, but when this happens man should start from the standpoit of coordinator inside the ecosystem. It is up to him to create the technology and science and find a feasible and reasonable way to solve the contradiction, thereby promoting social productivity. Otherwise, he leaves a legacy of trouble for coming generations.

Resource Conservation

Conservation is for the purpose of protecting the regeneration ability of the biological resources and the ecological environment, so that they can continue to be used for a long time to come. It simply implies more rational utilisation of those resources for long lasting stability. This is the scientific method of management, and has nothing to do with passive attitudes that attempt nothing and therefore accomplish nothing. Some suggestions regarding the relationship between conservation and utilization of resources are given below, for discussion:

- Dependence upon green plants for full use of solar energy. In the mountainous upper reaches of a drainage system, especially in tropical or subtropical regions with wet or damp climates, various types of multi-storeyed forests should be encouraged to grow. Solar energy is the richest and most constant natural resource on this planet, and yet historically very little use has been made of it; less than 1%. There are still large areas of bald land (especially under xerophytic conditions or where it has been mismanaged), with a lack of grasses or tree species, either original and protected, or exotic and introduced. Vegetation cover should be developed on such land, so as not to waste the rich light-energy resource of the sun.

Planting trees and plants also beautifies the environment. Furthermore, if forestry can be correctly integrated with agriculture, animal husbandry and sideline productions, the deficit caused by human over-occupation of land surface, induced by the development of industry and population inflation, can be made up.

- Multi-layered utilization of the food-chains in different ecosystems. To build up an efficient artificial ecosystem, nurturing self-regulated forest types such as mixed forests and multi-storeyed forests, has the advantage of low investment with fast results. However, in not so few developing countries, the waste of these resources is astonishing, especially in tropical and subtropical mountain areas. The practice of shifting cultivation is widespread, as is forest burning that destroys huge quantities of trees and herbs. There is waste even in the agricultural regions of the lower reaches, where hard-working labour intensively farms the land, meticulously pouring large amounts of fertilizers to get the maximum yield. Less than one third of the products of photosynthesis are used; two thirds of the resulting straw is burned for fuel which is a waste of its nutritive elements. Only 10% of its energy content is used in this way.

If, according to the demands for prolonging the food-chain, some intermediate links (a new composition) are added, it is possible to change existing practices into an optimized utilization model. For example, straw should be given as fodder for the domestic animals and fowls, which uses only a part of its nutritive elements; the excrement of the animals can then be used as fertilizer for growing mushrooms, thereby using more of the nutritive elements; then the methane gas generated from the fermentation of marsh bacteria can be burned, which brings the utilisation of the nutritive elements of the original fodder up to 60%; the residue inside the marsh gas generator may be used as food for the earthworms, carrying the remaining nutritive elements back to the soil as nitrogen, phosphorus, and potassium inside the marsh gas medium, and organic material retained inside the residue; finally, any nutritive deficiency can then be supplemented by chemical fertilizers, thereby attaining a new equilibrium. Some farmers already feel strongly about these kinds of optimization models, but in other localities, situations may still be created that suit measures to local conditions.

In China, a few advanced areas of agriculture such as, the "mulberry base and fish pond", and "sugarcane base and fish pond" systems in the Pearl River delta, the "mulberry tree, silkworm, rice and fish" complex rotation system in Taihu Lake region, and the rotation system of "Sassafras forest, mulberry fields, and paddy" in the hilly region near Lou-shan on the Chengdu Plain, have improved the ecological circle and accelerated agricultural yield, with good economic and social effects.

- Building up a vegetation cover management system. Particularly those people in tropical and subtropical mountain areas should build up intensive, multi-storey, polyspecific farming management. Woody crops (tea plantation under para-rubber plantation, tea plantation under cinnamon or alder forest plantation, etc) should be cultivated; in forest production, the fast growing tree species should be selected (*Leucaena leucocephala, Anthocephalus chinensis*, etc), using rotation lumbering and thinning-out lumbering methods that prolong the life of the forest; on meadows inside the forest areas, grassy slopes, and even the high alpine and subalpine shrub land, a system of pastureland vegetation should be encouraged, artificially cultivating the high yield, best quality fodder crops and forage trees. This allows for the development of animal husbandry and prevents the degeneration of the pasturelands' ability for soil and water conservation. In general, this ought to raise the production ability of different types of vegetation, as well as shortening the production period.

- Sufficiently developing the biological resources with emphasis on botanical resources. Living organisms are richly diverse: there are more than 230 thousand species of higher plants and more than one million species of insects. They are important in the development of mountain area economies. Biomass (particularly plants), provides the raw materials of agriculture, industry, commerce and medicine, and also create a good environment for human beings. The basis of biological resources is the fauna and flora in a certain geographical area, being composed of thousands of living things. Unitary economic practices may damage other biological resources when man attends to one thing and losses sight of another. But in this case, it is not an obstruction for man to reinforce the dominant position of a certain biological resource while forming the basis for agricultural management, to gain a large quantity of products to be manufactured into commodities. For example, to develop para-rubber as the dominant plantation in a tropical region, but to develop tea in tropical mountain regions.

- Protection of the regeneration ability of biomass as a renewable resource. Considering the level of intensity appropriate in the utilization of biological resources, the recovering and regenerating abilities of every species and the self-regulation and feed back function of every ecosystem, should be taken into account. One should not "drain the pond to get all the fish", or "kill the hens to get the eggs". Urgent attention is required owing to the daily decrease of some natural resources, and the steadilty increasing demand for them. If strict conservation is not adhered to and renewable resources are not extensively developed, then the fundamental sources for the development of certain countries, such as, farming, forestry, animal husbandry, fisheries and sideline production, will be eroded.

- Active promotion of multiple utilization, due to the peculiarities of the various biological resources. Although there are many biological resources that can be directly utilized as raw materials, there are still a large number that do not provide commodities for man. They are only protected because of their special ecological functions to other living organisms or their environmental contribution to industrial production, communication safety, and sanitation, i.e. the conditions necessary for survival and living. Examples include, antipollution plants, wind breakers, sand-binding plants, watershed forests, landscape forests, ground cover plants forming protective belts along river banks and roadside slopes. and the very diverse biological gene resource ("gene pools" or "gene banks"). Although these have a direct ecological or social benefit only, due to the multifaceted nature of biological resources, they often indirectly are of economic benefit to man. For example, one river, when its banks are secured by forest belts, combined with a dyked reservoir, can provide an electricity supply, gravity irrigation for agriculture, an economic method of transportation, a good environment for residents and beauty to attract tourists. Also, the river can supply fishery products, acquatic fodder for animals, timber and various forest by-products for sideline production.

CONCLUSION

When tackling the contradiction of conservation and exploitation of natural resources, the characteristics listed above should be taken into consideration to develop their complex benefits. Although the metabolic and accumulated elements in any biological species in the same polygenetic period are useful, many are valuable as whole units. Whole trees are of value, as use can be made of the stems, roots, twigs, and leaves, to be processed into sawdust, wood pulp, fibre-boards, paper, and even wood sugar and wood alcohol. All the by-products, such as the resin, gums, essential oils and pharmaceutical raw materials can be fully extracted.

Living organisms are present in different combinations in different localities and one kind of biological resource is frequently complemented by another. Only comprehensive use of them will raise the productive ability of a unit area in the longrun.

EXPLOITATION AND UTILIZATION OF NATURAL RESOURCES IN THE HENGDUAN MOUNTAINS

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INTRODUCTION

The Hengduan Mountains cover an area of 376,000 km^2 and display a range of climatic conditions from Asian tropic to frigid. This variety of climate is suitable for the development of agriculture, forestry, and animal husbandry. Although 18.5% of the total land area is under forest, and 42.5% is grassland, up to three crops can be harvested every year from the region.

The main crop is grain, occupying 91.5% of the cultivated land. Average yield is 2.65 m ton/ha which makes up 52.3% of the total output, industrial and agricultural, of the region.

Some areas of forest have been overfelled. Trees are not yet an economic commodity here, but the forests have that potential.

There are 19.94 million head of livestock in the region, a large proportion of which are old, sick animals. The population is unevenly spread over the grassland, so some areas are overgrazed particularly in the winter and spring.

There are several kinds of mineral deposits to be found in the Hengduan Mountains but they remain to be exploited. The area also ranks fourth in the country for water resources and only 0.7% of the water power has been exploited. Environmental protection must be taken into consideration however, as the mountains are prone to earthquakes, mud-rock flows, drought, and hail.

The area includes eight prefectures, administrative divisions, and cities. There are about 9.93 million people living in the Hengduan Mountains who can be divided into more than ten minority nationalities. The development of the economy is still in the early stages and is reflected in the mean output per capita from the agriculture and industry sectors which makes up only 57.6% of the country average.

RECOMMENDATIONS

To allow the economy to flourish, and to raise the living standards of the local people by improving the interaction of the people with their environment, the structure of production and distribution of products must be adjusted. The rational utilization of resources will depend on the stabilization of grain production and the distribution of the surplus grain to deficient areas. Steep slopes, high, cold areas, and other land with low productivity should be withdrawn from crop cultivation and used for grazing or forest. A food base should be established in the fertile middle reaches of the Anning River.

Existing forest areas could be utilised selectively as against clear cutting. Tree planting should be increased. Preventative measures should be taken against forest fires and available timber should be utilized on an integrated basis.

The carrying capacity of the grassland has decreased to 2.9 adult sheep per ha, so there is a need to improve the grass yield through selective use and the establishment of artificial grassland, to reach 20-30 tons per ha output. This can then be used as winter and spring fodder source. The structure of the animal community must be improved; fine breeds should be popularized, and weaker animals eliminated.

The development of cash crops such as sugar and tobacco, forests of walnut, tung, and the Chinese prickly ash, and fruit orchards including apple and pear trees, would be of great economic benefit to the region.

More use could be made of the rich, wild biological resources -- there is a host of medicinal herbs and flowers, as well as a wide collection of birds and animals.

Efforts should be made to exploit metals and other mineral resources. There is the potential for a diverse energy resource base through the development of water power, coal, peat, geotherma, biogas, solar energy, wind energy and firewood.

When further advances have been made in processing the products of improved agriculture, forestry, and animal husbandry, the price of production can be raised. To take advantage of the festival of minority nationality groups, the market should be opened and the interflow of commodities encouraged. This could be aided by making modifications to the Cheng-Kun railway, building the Kunpa-Da railway, and developing a highway network for the transportation of products.

Such improvements in the communications network would allow the development of Jui Zhai Guo, Huang Long Si, Gong Ga Shan, Lu Gu Hu, Cang Shan Er Hai, and Yu Lang Shan as tourist attractions.

All these suggested changes will require capital input, and the introduction of technology, partly through foreign specialists who could visit the region to advise, educate and train local professionals.

The Hengduan Mountains may be divided into ten regions according to resource conditions and systems of resource exploitation:

- Forest, agriculture, and mineral resources of mountains and valleys in the middle reaches of Nujinang River, Lancangjiang

- Agriculture, forestry, and mineral resources of the middle reaches of Jinshajiang River

- Animal husbandry, forestry, agriculture, and mineral resources in the Shaluli and Yunling Mountain ranges

- Industry, agriculture, forestry, and mineral resources of the inter mountain basin of Erhai

- Industry, mineral resources, and agriculture in the lower reaches of Jinshajiang River

- Forestry, agriculture, animal husbandry, and mineral resources in the mountains and valleys of the middle reaches of Yarlongjiang

- Agriculture, industry, forestry, and mineral resources in the broad valley of the Anning River

- Forestry, animal husbandry, agriculture, and mineral resources in the Liangshan mountains

- Forestry, agriculture, and industry in the Dadu River, Min River and Bailungjiang River regions

- Animal husbandry, forestry, agriculture, and mineral resources in the region of plateau and mountains in northwest Sichuan

ECONOMIC PLANTS OF HENGDUAN MOUNTAINOUS REGION

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INTRODUCTION

The Hengduan Mountainous region is located on the transition zone from the Qinghai-Tibet Plateau to the Yuan-Guizhou Plateau and Sichuan Basin, includes western Sichuan, northwestern Yunnan and eastern Tibet. It covers an area of about 400,000 km^2. In the region there are many deeply-incised valleys with great difference in height between valleys and ridges. Vertical distribution can be easily found on the mountain slopes. The rivers valleys run from north to south, and the influence of the horizontal zone is clear. Various vegetation types, such as tropical, subtropical, temperate and alpine frigid, (going from south to north), are distributed from foot of mountains to their summits. Despite incomplete statistics the region is considered rich in alpine plants.

MEDICINAL PLANTS

There are more than 1500 species of medicinal plants in the region, and they play an important economic role. There are 400-500 kinds that make up the The staple Chinese medicines. Well-known ones include:

Asparagus cochinensis
A. filicinus
Astragalus ernestil
A. membranacus
Adenophora potaninii
Amomum villosum
Aradia cordata
Arctium lapps
Arisaema consanguineum
Aucklandia lappa
Codonopsis pilosula
Dendrobium nobile
D. moniliforme
D. hancockii
Fritillaris chinensis
F. unibracteata
F. przewalskii
F. delaviyi
Gastrodia elata
Gebtiana macrophylla
Hedysarum potybotrys
H. chinensis
Heracleum hemsleyanum
Ligusticum sinense
Lilium brownii
Notoplevygium forbesii
N. incisum
Nardostachys chinensis
N. jatamansi
Peucedanum praeruptorum
P. medicum
Polygonatum odoratum
P. sibiricum
Pinellia ternata
Rheum offininale
R. palmatum
Sesili delavayi
Typhs orientalis
Vladimiria muliensis
V. berardiodea
V. souliei
V. tsoultei
Veratrum mentzeanum
V. nigrum
V. stenophyllum

The region is a multinational area. The medicine of each nation has a long history and is a component part of the Chinese medicine. The Tibetan people use *Meconopsis quintupli*, *M. horridula*, *M. punicea*, *M. integrifolia*, as analgesics and antidiarrheals; *Rhododendron cephalantum* to treat asthma; and *Logotis ramalana*, *L. brevitula*, *L. integra*, *L. yunnanensis*, to treat hepatitis and nephritis. Some local people use the roots of *Berginea purpurascens* as antidiarrheals; *Peoromia reflexz*, *Sedum lineare* to treat carbuncles, nail-like, deep-rooted boils and burns; *Arenania kansuensis* to treat gynopathy; *Atylosia scarabeoides* to treat ulcers; *Cassiope selaginoides* to treat neurasthenia; *Lysimachia christinae* to treat cholecystitis, cholelithiasis, urolithiasis and icterus hepatitis.

All these plants have good curative effects and are widely distribution over the region.

The most commonly used, local medicinal plants are:

Acorium szechenyanum
Acorium tanguticum
Caragana erinacea
Chrysosplenium nudicaule
Corydalis adunca
Delphinum densiflorum
Dracocephalum tanguticum
Loydia serotina
Phadiola spp.
Pholomis younghushandii
Pterosephalus kookeri
Saussurea spp.
Saxifraga pasumensis
Solms-lanbachia pulehrrima
Thlictum spp.

Many of these plants are important for the extraction of various alcaloids for the production of many new drugs. Berberine and geranniol are extracted from *Berberis spp.* and *Mahonia spp.*; the *Aconium* with many species can be used to extract aconitic acid; and atropine is extracted from *Anisodus spp.* and *Scopolis spp.* Some species of the Stephania are the raw material for rotundine, and the roots of *Dioscorea spp.* contain yam sapogenin, which is used to synthesize hormonal drugs.

ESSENTIAL OIL PLANTS

There are at least 400 species of plants in the region that contain volatile oils in their roots, stems, leaves and flowers. These oils have many uses in light industry, the food industry, the chemical industry, and for medicines. The plants belong to families such as:

Apocynaceae	*Lauraceae*
Aristolochiaceae	*Loganiaceae*
Betulaceae	*Oleaceae*
Cercidiphyllaceae	*Orchidaceae*
Chloranthaceae	*Pinaceae*
Compositae	*Rutaceae*
Cupressacea	*Santalaceae*
Diapensiaceae	*Symplocaceae*
Ericaceae	*Umbelliferae*
Franimeae	*Verbenaceae*
Magnoliaceae	*Valerianaceae*
Labiaceae	*Zingiberaceae*

Subgen and *Lepidorrhodium* of the *Rhododendron* family have more than 100 species and are distributed over a large area with great exploitation potential. The volatile oils are terpene oxygen compounds. Along the river valleys of the Anning River, Yalongjiang River, and Nujiang River. Cymbopogon jwarancusa and C. distans are widely distributed. The citronellol and piperitone contents of the plants accounts for over 80% of the volatile oils. Both of them are the important raw material for the essential oil industry. The flowers, leaves, and fruit coats, of the *Litsea cubeba* are used to extract citral. *Euerina mesormepha*, which was found recently grows up to 3000 meters. The essential oil plants of the Hengduan Mountain region are in aboundance, with various species and great exploitation potential.

OIL PLANTS

The oils extracted from oil plants are widely used in the food industry, machinery, light industry and chemical industry. There are about 250 species of oil plants and more than 100 species with an oil content over 39%, such as:

Amygdalus tangutica
Corylus chinensis
C. yunnanensis trema orientalis
Camellia yunnanensis
C. oleifera
C. pitardii
Cinnamomum gladuliferum
C. pittosporoides
Cephalotaxus fortunei
C. wikonii
Elsholtzia ciliata
E. densa
Galeopsis bifida
Jatropha curcas
Juglans cathayensis
Koelreutria paniculata
Lindera glauea
L. chunii
L. communis
Litsea cubeba
Neocinnamomummdelavayi
Machilus yunnanensis
Osyris wightiana
Pinus aramandii
P. densta
P. yunnanensis
Phoebe forrestii

Prinsepia utilis
Schoepfia jasminodora
Taxus yunnanensis
Thlaspi arevense
Trema Orientalis
T. levigata

Among the various fatty oils of the Cinnamomum, capric acid accounts for 49 - 60% of the total. Of the Litsea and Lindera, lauric acid accounts for 60 - 80%. Of the seed oils of *Xanthium sibiricum* and *Phlomis umbrosa,* linoleic acid accounts for 70 - 85 %. Of *Elsholtzia ciliata* and *E. densa,* linolenic acid accounts for 55 - 65 %. Of *Camelllia oleifera,* oleic acid accounts for about 80 %. The fatty acids mentioned above have many important uses. Capric acid is decane acid. Caprin is used to treat the disorders of lipodystrophy. Lauric acid is dodecylic acid. Lauric acid and laurin, are the raw materials for medicine and light industry, and are in great demand. Linoleic acid is linolic acid, which is a fatty acid needed by the people as a nutrient and it is effective in preventing coronary heart disease. Inside the body it is transformed into arachidonic acid, which is a precursory matter used to synthesize prostaglandin in the body. Prostaglandin is spread over various parts of the body. It is the necessary material for cell membranes and can regulate blood pressure, lipometabolism, etc. Linolenic acid is an octadecatrienoic acid, which can prevent irregular blood coagulation and can treat chronic heart diseases to some extent. It is also a fine drying oil and ideal for use in the painting industry. Oleic acid is also an important industrial material.

STARCH AND GELATINOUS STARCH PLANTS

250 species of starch and gelatinous plants come from the following famillies:

Alismataceae	*Gramineae*
Angiopteridaceae	*Leguminosae*
Amaryllidaceae	*Liliaceae*
Araceae	*Musaceae*
Blechaceae	*Orchidaceae*
Convolvulaceae	*Polygonaceae*
Cucurbitaceae	*Polypodiaceae*
Cycadaceae	*Pteridaceae*
Cyperaceae	*Rosaceae*
Dioscoreaceae	*Ulmaceae*
Fagaceae	*Urticaceae*

Some of the plants are of edible value, such as *Dioscorea opposita, D. japonica, D. alata, Cardiocrinum giganteum, Lilium davidii, L. brownii var. viridulum, Amorphophallus rivieri, Colocasia esculenta* and *Pteridium aquilinum var. catiusculum.* Most of them are energy plants and can be used to make wine, such as *Quercus, Castanopsis, Lithocarpus, Cyclobalanopsis, Pueraria, Potentilla, Osteomeles, Pyracantha, Woodwardia* and *Smilax.* The seeds and roots of *Bletilla* and *Sesbania* are rich in mannose and semi-mannose. These are the fine wash liquid used in mine drilling.

FIBRE PLANTS

Fibre plants are distributed widely and have large reserves of high quality fibre. There are 300 species; the main ones are:

Apocynaceae	*Palmae*
Asclepiadacea	*Pinaceae*
Cupressaceae	*Salicaceae*
Cyperaceae	*Sterculiaceae*
Gramineae	*Taxodiaceae*
Iridaceae	*Thymelaeaceae*
Juglandaceae	*Verbenaceae*
Moraceae	

There is great potential in the use of their branches and tops, in combination with timber, in the paper-making industry.

TANNIN PLANTS

Tannic acid is an important material in tanning, machinery, removal of scale in boilers and light industry. The major tannin plants are:

Anacardiaceae	*Juglandaceae*
Betulaceae	*Leguminosae*
Euphorbiaceae	*Pinaceae*
Fagaceae	*Rosaceae*
Geraniaceae	*Salicaceae*

There are more than 200 species with widely distributed in the region. Rich in tannin of fine quality are the shells of *Fagaceae*, the root and stem skins of *Rosa, Rubus* and *Phyllanthus emblica*, the fruit of *Platycarys strobilaceae*, the galls of *Rhus chinensis, R. potaninii, R. punjabensis var. sinica*, are rich in fine quality tannin. The barks of *Pinus, Picea, Abies, Larix*, and

Tsuga, also contain tannin. Greater economic results will be obtained if the tannin plant resources are used in combination with felling. The germplasm resources mainly refer to the wild original species of the cultivated plants. They have better characteristics and more advantages than the cultivated species. They are an important raw material for breeding the finer varieties.

The germplasm resources have gradually been understood. Because of unreasonable production activities, a large number of species have been stamped out in the world. Owing to the sparse population and poor transportation facilities of this region, the damage at present is not too serious. Some places are still in their original state and many wild original types of the cultivated species have been preserved. The wild, or inbreeding species of the cultivated legumes are *Clycine ussurriensis, Phaseolus mungo, P. trilobatus, Vigna vexillata, Stizolobium basszoo, Vicia tetrasperma*, and *V. unijuga, Citrus, Morus*, and *Eriobotrya*, also have their wild original species and so do *Rosaceae, Rubus, Fragaria* and *Prunus* of *Rosaceae, Ribes* of *Saxifragaceae, Tamarindus indica* of *Leguminoseae, Phyllanthus emblica* of *Euphorbiaceae, Vitis* of *Viteceae, Actinidia* of *Actinidiaceae, Elaeagnus* and *Hippophae* of *Elaeagnaceae, Psidium guajava* of *Myrtaceae, Hippophae rhamnoides, Psidium guajava, Rosa roxburghii, Myricanana.* The latter four are relatively concentrated distribution, large reserves and therefore great exploitation potential.

ORNAMENTAL PLANTS

The ornamental plants are in extremely rich abundance. Besides the three well-known flower plants, *Rhododendron, Primula* and *Gentiana* in the alpine zone, there are also many others of exploitation value in the region, such as:

Calanthe	*Lycoris*
Caltha	*Magnolia*
Cardiocrinum	*Meconopsis*
Crinum	*Nomicharis*
Cymbidium	*Notholirion*
Cypripedium	*Paeonia*
Dendrobium	*Pecteilis susannae*
Detzia	*Pedicularis*
Dipelta	*Petrocosmea*
Dysosma	*Philadelphus*
Epipactis	*Pleione*
Geranium	*Rosa*
Habenaria	*Saxifrage*
Hemerocallis	*Speraea*
Hydrangea	*Stranvaesia*
Incarvillea	*Trollius*
Iris	*Tupistra*
Lilium	*Vanda*

OTHERS

The host plants of lac insects and white-wax insects, are *Cajanus cajan, Eriolaema malvacea, Trema orientalis, Engelhardtia spicata, Dalbergia obtusifolia, Fraxinum chinensis, F. chinensis var. rhychophyllus* and *Ligustrum lucidum.* The leaves and branches of *Indigofera bungeane, I. pseudotinctoria* and *Saussurea graminea* and the seeds of *Caragana franchetiana, Amaranthus caudatus* and *A. paniculatus* are rich in protein and complex amino-acids. Furthermore, there are plentiful plant resources of resin, gum, and pigment.

To sum up, the Hengduan Mountain region is one with a large variety of plant species, and great reserves. It is also an area of treasure land to be exploited.

RIVER BASIN MANAGEMENT AND RESOURCES EXPLOITATION IN HENGDUAN MOUNTAINS

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INTRODUCTION

This paper is limited to a discussion on the west part of Sichuan, the north part of Yunnan Province and the east part of Xizang Autonomous Region only. It is an area of 416000 km^2, including 69 counties and cities with a total population of 7.59 million. Within the region there are parallel mountain ranges and big rivers which flow from north to south. The river basins are, Nujiang, Lancangjiang, Jinshajiang, Yalongjiang, and Doduhe. This region is famous for its very highmountains and deep valleys.

Situated in the southwest part of China, the region is remote and the mountains and and gorges signify the intense variations of the land, rendering all transportation difficult. It is very backward in culture, education and scientific technology, with a low level of economic development particularly in the west and north. The east and south have a long history of development in Sichuan and Yunnan, where the climate is warm, the valleys are not so deep and the altitude is less.

Table 1: The Economic Development Level of River Basins.

River Basin	Cereal production per capita	Livestock* Unit per capita	Industry & Agriculture output Yuan per capita	Industry & Agriculture output Yuan per km^2
Whole Region	311	1.00	479	8741
Nujiang	259	1.63	269	1628
Lancangjiang	209	1.81	246	2310
Jinshajiang	289	0.77	623	17133
In the basin north of Shigu	195	3.16	297	1875
South of Shigu	305	0.37	678	42618
Yalongjiang	347	1.03	362	6312
Daduhe	361	1.14	414	8182

*Livestock unit: 1 cattle = 5 sheep = 10 goats

ECONOMIC DEVELOPMENT

In north part of the Nujiang, Lancangjiang and Jinshajiang basins (north of Shigu) is a vast land area, with low population and a backward economy (Table 1). The mean population density is 6.9 persons/km^2; the mean industry and agriculture output per capita is 237 Yuan, and the total industry and agriculture output per km^2 is 1890 Yuan. In the east part of Doduhe, Yalongjiang and Jinshajiang basins the population density is 27.4 person/km^2, the mean industry and agriculture output per capita is 521 Yuan, and the total industry and agriculture output per km^2 is 14,299 Yuan.

In this region, there is only one rather large newly developed industrial city; that is Dukuo. Based upon the local resource of iron the Panzhihua Iron and Steel Company was established. Besides industries of building materials, chemicals and machinery were also developed. About 64% of industry output of the whole region was concentrated in Dukuo city. Some limited mining and agriculture processing industries are distributed in the adjoining regional centres. Basically there are no industries in the rest of this vast area. Abundant water energy and mineral resources exist but are not being exploited due to the blocked transportation and lack of funds. Of the total output agriculture occupies about 70 % (excluding Dukuo city).

There are only high mountains and plateaus with very broad natural grassland

and forest land, and limited cultivated land, which only occupies 1.8% of the total land area. The forest land makes up 17.5%, the sparse wood and shrub: 15.8%, and the several kinds of natural grassland: 48.1%.

In north and central part, animal husbandry is the main economic activity, although also with extensive management, but due mainly to the large number of livestock, a certain amount of livestock, meat, fur and skin can be supplied to other regions. This is the second natural forest region of China and occupies 6.2% of total forest of China. The timber volume occupies 14% of the total timber volume. Some timber enterprises were established and the main felling areas become Daduhe river basin and east part of Jinahajiang river basin. But over the years, there has been a trend to move the felling area further to the west and north parts. Regeneration of the cutting blanks and the afforestation effects are not evident. The forest resource was destroyed very seriously and the area of sparse wood and shrub is continuously enlarged. In east and south part of this region, where the elevation is low and the climate is warm, the irrigation assurance level for drought is rather high, so the cultivation predominates. In Daduhe river basin, the east part of Jinshajiang river basin and the basin of Anning river which is a tributary of Yalunjiang river, the arable land occupies 52% of the total land in these basins. The production of grain makes up 74% of that of the whole region and rice and economic crops also have high proportions. These basins are the main cultivation base of this region.

In general, in the north and west parts of the region, vegetation cover is still fairly extensive and there is not much environmental change. However in the east and south, where widespread forest cutting has occured for cultivation, the ecological disturbance, soil erosion and increased silting of the rivers, is very serious. One of the most affected areas is Batang-Pengshan (including the north part of Yunnan Province), where erosion reaches 725 tons/km^2, and is much higher than the upper reaches of Yellow River (above Lanzhou). Where the destruction of forest has caused serious mass movement, erosion levels can reach 1900 tons/km^2.

It is imperative that the following action is taken to improve the quality of the environment:

- rational forest cutting

- improved stocking and transportation of timber

- readjustment of the structure of the agricultural economy in the mountains areas

- rahabilitation of slopes

These are the important ways to control the exploitation and management of the resources of these rivers basins.

ENERGY SOURCES IN THE TENGCHONG COUNTY YUNNAN PROVINCE, CHINA

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INTRODUCTION

The Tengchong county of Yunnan province is located on the western slope of Geoligong - the southern section of the Hengduan Mountains, between parallels 24°38' and 25°51' N and 98°05' and 98°45' E. Its total territory covers an area of 5692.86 km^2, with a maximum altitude of 3780.2 m in the north and the minimum altitude of 930 m at its south end. As a result, the relative disparity of the heights within Tengchong's territory can be up to 2850 m, while the county seat is only 1640 m above the sea level. The Longchuan, Daying and Bingland rivers, with their numerous tributaries within Tengchong which develop along the fault zones, cut the plateau surface, according to the trend of the mountains and rivers, into varied and colourful geomorphological forms. Twenty per cent of the whole territory of Tengchong is made up of river-valley and intermontane basins. The remainder is composed of mountainous districts. While the cultivated area of Tengchong accounts for only 16.1 % of the whole Territory, the percentage of forest (including both natural and the artificial) is 34.6 % and vegetation cover is as high as 59.5 %. The dense forest and vegetation are obviously dominant natural resources of Tengchong county.

There are two large drainages named Longchuanjiang and Dayingjiang and both of them are the tributaries of Irrawady River, which flows through the territory of Tengchong from north to south. The runoff of these two covers a total area of 5690 km^2 and their maximum annual production of water is as high as 8.04×10^9 m^3. The plentiful flow-off and the hydropower are other dominant factors among the natural resources of Tengchong.

The Gaoligong Mountains provide a natural barrier for Tengchong, which consequently displays an Indian Ocean monsoon climate dominated by the moist-warm air-flow from the Bay of Bengal, and possesses the characteristics of a low-latitude mountainous monsoon climate. Here the latitudinal differentiation of climatic zones are overruled by the differentiation of the vertical mountainous climatic zone. Thus the climatic conditions in Tengchong are varied and strongly sterioscopic. The majority of Tengchong country belongs to the northern subtropics or medium subtropics, and the minority, to the southern semitropics and temperate zone. The pluri-annual mean air-temperature is 14.7°C, and the pluri-annual mean rainfall is 1425.4 mm. Annual precipitation is highly concentrated, thus the dry and rainy seasons are quite distinct. The annual sunshine is 2176 hours. The annual radiant heat off Tengchong groundsurface is 13.6 kcal/cm^2. The yearly frost-free period lasts 239 days. Thus, it can be reasonably concluded that Tengchong is also rich in climatic resources.

According to 1983 statistics, Tengchong had a population of 461,476, consisting of 8 nationalities, with a density of 81 people per km^2. The peasants accounted for 93 % of the total population. and there were tens of thousands of overseas Tengchong Chinese or foreign citizens of Tengchong origin, of which the majority are living in southeastern Asia, Japan, United States and Canada. All of them would like to promote the economic construction of their homeland.

But all the advantages mentioned so far have not yet been realized. Tengchong's commodity economy is not well developed; in other words, the economy of Tengchong county remains in a self-sufficient or semi-self-sufficient state. The annual per capita income of the peasant population was only 93 Yuan in 1982. This is mainly a result of the past policy, which gave importance only to the river-valley and intermontane basins, and over a long period of time neglected the comprehensive development of the vast mountainous region that makes up 80 % of the whole territory. According to 1980's statistics, the total output value from forestry that year was only 5.90 mio Yuan, equivalent to only 2 Yuan per mu, and occupied only 4.6 % of the gross output value of agriculture and industry in 1980. It is clear that policy is to blame for the insufficient development of the natural resources in the mountainous district of Tengchong.

LOCAL ENERGY SOURCE

The problems with the local energy-source, and communication with hinterlands, are the other two important factors which hinder the development of the productive forces in the mountainous districts of Tengchong. This paper will only deal with the former.

The crux of the rural energy resource problem is that 93 % of the total population of Tengchong county are peasants currently moving from a self-contained economy to a commodity economy. It is reported that until 1984 rural areas all over China were short of energy resources. 40 % of peasant households seriously lacked cooking fuel. Recently, the rural transport service, building materials and various processing industries have been developing rapidly and consequently the consumption of energy resources in rural areas is also increasing sharply. It is estimated that the shortage of convenient energy resources such as coal, oil and electric power is between 40 - 50 %.

Given this serious situation, there are however, peasants in Tengchong who are not lacking in cooking fuel, but this non-shortage is gained at the expense of enormous consumption of the valuable forest resource. Tengchong is a county with neither coal nor oil. Consequently both household and industry basically depend upon the forest. The Diantan Iron Factory of Tengchong, for example, uses charcoal for smelting. Thus 9000 tons of charcoal are consumed every year, which is equivalent to 30,000 m^3 of timber. According to the statistics from Tengchong Forestry Bureau, the consumption of timber in 1979 was about 521,584 m^3 in all, of which 87 % was burned up entirely for domestic cooking, food processing, wine distilling, sugar and tea refining and brick kilning etc. Such a huge consumption of forest inevitably resulted in the following disastrous effects:

The percentage of forest cover decreased from 48.1 % (1952) to 34.6 % (1974);

The timber reserve (accumulation) of the forested areas dropped to 2,076,669 m^3;

The forest quality changed substantially. The mature timber is reduced and the seedlings grow slowly, although the percentage of the forest cover only dropped by 13.5 % since 1952. The density of the forest also changed considerably. About 30000 - 35000 mu of thick forest have been turned into sparse woods each year. Consequently the sheltering and water-conservative functions of the forest have decreased significantly.

The constraints of forest on the ecological environment of a certain region are extremely important. Within the Tengchong mountainous district, there are numerous high cliffs and steep slopes. Therefore, due to the destruction of the forest and mal-practised animal husbandry, the loss of water and erosion of the soil have continuously intensified, mud and rock-flows have occurred repeatedly in many places, some streams have dried up, the periods of time between the calamities have shortened considerably, and the disasters have increased in severity.

HYDROPOWER

What is mentioned above must seriously affect lots of small hydropower stations - the energy source of Tengchong.
The national and the regional electric networks have not covered Tengchong in the past and may well not in the future, for the place is very remote and separated from the heartland by numerous mountains and rivers and its economy is not well-

developed. Fortunately, both the Longchuanjiang and Dayingjiang in the Tengchong county have the type of rivers which are rich in hydropower reserve. It is thought feasible to produce 126 MW or more. The construction of small hydros started in 1954. To-date, the operating hydropower stations with small installed capacity total 85, composed of 111 units producing 20.11 MW in all. These mini-hydros are the only source of the electric power in Tengchong, and in fact shoulder the heavy loads of agricultural, industrial, cultural and educational, and health undertakings. About 90 % of the capital for building these mini-hydros was provided by the peasants. This shows the great enthusiasm and high expectations the peasants have for constructing electropower establishments in the rural areas.

Unfortunately, the worsening of the ecological environment of Tengchong decreased the runoff volume of the river-courses. Take Dieshuihe for example; it is the backbone of Tengchong's ministrations, and is a run-off-river plant with an installed capacity of 3.25 MW, and a drop as high as 46 m. The runoff volume is 12 m^3/sec, but was reduced to 4 m^3/sec recently and only 1 - 2 m^3/sec during the dry season. The change in runoff-volume of the channel necessarily affects the output from this hydrostation because it is unable to self-regulate. Thus the Dieshuihe station has to be shut-down for half the year. According to statistics, the miniplants which can not operate normally, or can not operate at all during dry season, make up 60 % of the total hydrostations in Tengchong. The peasants make fun of these miniplants, calling them "thundering plants" because they operate only when the rain falls and thunder roars. And yet, even the effect of rainstorms on the miniplants is extremely limited due to the decrease of the water-conserved forest area. The effect of heavy rains, lasts only 3 days, and then the runoff volume returns to its original status. There are 8 miniplants in the Puchuan district of Tengchong county with a total installed capacity of 0.541 MW, among which 7 plants are the so-called "thundering" ones. In 1983 only 0.1778 MW were produced which was 32.9 % of the total installed capacity in Puchuan district, while the remainder (67.1 %) was untapped all the year round due to the insufficient volume of river water.

There are many factors responsible for these problems, but this paper will only deal with those concerning the comprehensive development and utilization of the natural resources in Tengchong. There are two factors in this regard, the first, hydropower usage, in fact conflicts with the second, the water-conserves in the forest areas, which have fallen sharply over the last few decades.

WATER RESOURCE

The first contradiction is a common problem world-wide nowadays, although in principle the hydros only utilize hydropower rather than consume water volume. The annual precipitation in Tengchong is more plentiful than in other areas of China, and has remained essentially stable for the past 70 years. Furthermore, the degree of exploitation of hydropower in Tengchong is not very high, so there shouldn't be much shortage of water. The actual situation is quite different. The water resources within the territory of Tengchong county are not easily utilized due to extensive relief of its topography with high mountains and deeply cut river valleys, and also because the precipitation is not distributed evenly over the different areas and seasons of Tengchong. There are 399,000 mu of paddy field and 223,000 mu of non-irrigated farmland. But the farmland and paddy fields able to maintain stable yields despite drought or excessive rain only account for 22 % of this total. The hydrostations will have to make way for irrigation when conflict between them occurs. The Dieshuihe hydrostation generates electricity with the water of Dayingjiang river, but that also has 44 irrigation ditches with a total length of 263.4 km and a total runoff volume of 19.6 m^3/sec around its upper reaches. Therefore it is not hard to imagine that these irrigation ditches located in the upper reaches of Dayinjiang river must interfere with all the hydrostations sited in the lower reaches. The cropland has expanded with the increasing population during the last two decades - paddy field area has increased by 101,314 mu. Their annual consumption of water was 638 m^3 per mu on average.

Following the increase of farmland, the area of barren hills has also increased. The mature coniferous forest has been reduced by 49 %, and the young growth increased only by 13 %. The gravity of the problem lies also in the fact that the evergreen broadleaf forest has turned into coniferous forest, the aged forest has changed into young growth, primeval forest has turned into seedling and shrub grassland. These variations have naturally resulted in the worsening of agricultural ecology and have significantly weakened the ability of the forested areas to conserve water. According to hydrological data, the lowest runoff volume of Dayingjiang river has been reduced from 1.67 m^3/sec (1957) to 0.98 m^3/sec. In 1979, a total of 1302 streams were cut out entirely and a total of 128 ponds dried up. Shandieshui (installed capacity 0.3 MW) and Wanyao (0.12 MW) hydrostations in Gudong district provide another two typical examples in this respect. At present, the outputs of these two hydros are only 0.06 - 0.07 MW and 0.03 - 0.04 MW respectively because the Dahe Forest Center, which was set up in 1973, has removed a large stretch of forested area through unreasonable opening-up.

EXPERIENCE OF TENGCHONG

To sum up, Tengchong has to pay a heavy price for its energy source problems in the past. What happened in Tengchong is typical of all the mountainous areas of western China. The experience of Tengchong shows that the development and utilization of energy-sources in the mountainous areas must be considered in connection with resources and ecological environment conservation at the same time. All the developments of agriculture, industry, forestry, animal husbandry, hydropower and irrigation must be considered comprehensively, otherwise a difficult situation in which "one careless move jeopardizes the whole game" will probably arise. Now Tengchong is undertaking the transition from a natural economy to a commodity one. We believe that a comprehensive solution to the energy-source problems is urgent and propose two measures to cope with this matter: rapid development of the quick-growing fuel forest and development and utilization of the local high-temperature geothermal resource. These two measures taken together may well contribute not only to the improvement of the local energy-resource constitution, but also to reducing the heavy burdens on the local water and forest resources, which then could regenerate gradually.

Techtonically, Tengchong is located in the junction zone between the Eurasian and Indian continental plates. There are more than 50 late-Genozoic volcanoes and 58 active hydrothermal systems, among them the Hot Sea geothermal field (only 11 km southwest of the county seat) and the Ruidian system (about 60 km north of the county seat) may have great exploitation potentials for power generation. According to the geochemical estimation, the subsurface temperature of the Hot Sea could reach 200°C and the hydrothermal energy reserve may well meet the heat needed for a 10 MW magnitude geoplant. The preliminary surface-investigation shows that due to its shallow burial the hydrothermal reservoir of the Hot Sea is more convenient for both exploration and exploitation.

To construct a 10 MW magnitude demonstration geoplant may have the following advantages:

- To provide large quantities of inexpensive electric power for the economy of the Tengchong county;

- To help achieve the ambitious goal of substituting electricity for firewood because the geoplant could bear the basic load;

- To share the original load of the hydrostations and then to provide an opportunity for the rehabilitation of both the hydropower and water resources;

- Combined with the development of fuel forest, the geoplant would significantly contribute to the conservation of the forest resource. Consequently the renewing and expanding of the forest area would certainly improve the present status of numerous minihydros;

- To provide Tengchong with an extremely valuable tourism resources;

- To provide experience for the development and utilization of geothermal resource throughout China;

- To provide valuable scientific data for advancing geoscience in China.

Finally the authors also appeal to ICIMOD to pay attention to the respects mentioned above, and earnestly hope that the solution of the energy-source problems could be beneficial to all the developing countries of the world.

BASIN DEVELOPMENT AND INTEGRATED MANAGEMENT OF THE ERHAI REGION, YUNNAN PROVINCE

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INTRODUCTION

The Erhai Lake is the largest remaining ancient lake in the Transverse Mountain District. It lies in the east, at the foot of the Cangshan mountains of which the main peak is about 4122 m high above sea level. The elevation of the water surface of Erhai lake is 1973.5 m. It has an area of 255 κm^2 and maximum depth is 22 m. The water storage is about 2900 mio m^3 and the average long-term inflow amounts to 813 mio m^3.

The Erhai Region consists of a series of roughly parallel northwest-southeast mountains divided by open valleys of different sizes.

The Dali valley, where the Erhai Lake is located, lies in the center of the Erhai Region. Other main valleys are Shanglan, Jianchan, Eryuan, Weishan, Midu, Huangping, Binchuan and Xiangyuan. The principal topographic feature of the region is the descending altitude of the mountains from the northwest to the southeast. Along this direction the main mountains and open valleys drop away step by step.

The Laojun mountain, belonging to Yuling mountain range and located in the northwestern corner of the District, is 4247 m. The Yuling mountains stretch and connect with the Cangshan. The Jizu mountain, located in the east of Erhai Lake, is 3276 m high. Further east, the elevation of the mountain decreases to 3000 m or less. The Shanglan valley, located at the foot of Laojun mountain, is the highest valley, in this district, with an elevation of 2400m, while the Binchuan valley, located in southeast part of the region, . is the lowest with an elevation of 1200-1450 m.

The complex river system in Erhai Region consists of three rivers: The Jinsha river, Lancang river, and Yuan river. They belong to the three well-known river systems of the Yangtze River, Meigong River, and Red River respectively. The headwater of the Erhai Lake is called the Mizao River, which originates from the mountains north of the Eryuang valley and pours through the Xiashankou gorge into the Erhai Lake. The Xier river, the outlet of Erhai Lake, is located in the south of Erhai and is a tributary of the Yongbi river. The Yongbi river has two headwaters. The east one is called Heihui river, which in turn originates north of Jianchuan valley; the west one is called Misha, and it originates from the west foot of Laojun mountain, runs through the Shanglan valley, and then joins the Heihui River at Hejiang City, where the Youngbi River starts. The Yongbi river runs southward along the west foot of the Cangshan mountain. After combining with the Xier River, it flows to the Lancang River. The Yuan River also has two headwaters. The east one originates from the Xiangyun valley, located in the southwest corner of the district. It flows southwest at first, then turns southeast and finally enters into the Midu River. The west one comes from the north of the Weisha valley, flows southeast and joins with the east headwater, finally forming the Yuan River. The Dadan River, a tributary of Jinsha River, is located in the far east of the district. It originates from the south of the Haishao valley, flows through the Binchuan valley and then enters into Jinsha River. The Yonggong River rises from Yulong Snow Mountains, which are 5596 m above sea level. After flowing southward through the Lijiang valley and Heiqing valley, it turns northeast and pours into the Jinsha river. The Erhai Region is substantially a dividing area of those three well-known Asian river systems.

NATURAL RESOURCES

The large valleys in Erhai Region are

flat, and have plenty of land resources, but the climatic conditions which are required for agricultural production vary greatly with the different elevations and the geographic localities of these valleys.

Heat resources are abundant in the Erhai Region. Active accumulated temperature increases strictly with the increase of elevation. Most of the valleys belong to the central subtropical climatic zone, while the Shanglan valley belongs to the tepid temperate climatic zone. Comparing the average temperature of the coldest month and the hottest month, it is apparent that most of the valleys at the middle attitude have a typical high plateau climate, with a warm winter and a cold summer.

The maximum precipitation in this region occurs in the Dali valley at middle altitude. Precipitation apparently decreases when the elevations of the valleys are higher or lower than that of the Dali valley, but especially in the latter case resulting in a serious inbalance of heat/water resources.

The temporal distribution of precipitation in this region is uneven. More than 80 per cent of the annual precipitation is concentrated in the wet season from June to October, particularly in those valleys with lower elevation. Although in general, the processes of water and heat in the atmosphere are seasonally synchronous, precipitation during the spring is very scarce and the spring drought constitutes the greatest threat to agricultural production in the Erhai Region.

The main problems in the development of water resources in the Erhai Region occur in the Bai Autonomous Prefecture of Dali, Yunnan Province. The Dali district was the communication link between China and the South-Asian countries in ancient times. It is the birth place of the Bai and Yi cultures. Some 1000 years ago, during the Tang dynasty, the Nanzhao and Dali countries were established one after the other and since then, they have kept close cultural contacts with China. Because of their relatively advanced production technology they had been the political and cultural center of the southwest boundary of China. Now, Dali City is situated by the Erhai Lake and is one of the 22 historically famous Chinese cities under special protection. Therefore, the Erhai Region has a long history in economic development. Recently, however, the value of agricultural production has declined from a rank of the third in Yunnan province in 1950's down to the seventh or eighth at present. The reason for this lies in the insufficient utilization of the water resources in terms of hydroelectric energy, irrigation and the preservation of a balanced eco-system during the developing process of the Region. Following the construction of Xier river water power station at the outlet of Erhai Lake, the water level of Erhai Lake has fallen down greatly. This is not only caused by abnormal operation of the power station itself, but also by the imbalanced eco-system around the Lake. In the meantime, those valleys which are situated southwest of Erhai lake and have suffered from the threat of drought for a long time would not be able to get water supply from the Erhai Lake. The result would be a slow rate of development of agriculture in these valleys. As a whole, agricultural production on which the Erhai Region is based will further decline along with the living standard of people.

Problems of the Xier river water power station

Dali City, on the shore of the Erhai Lake, is a newly developed industrial city and a communication center for the west part of Yunnan province. The Erhai Region is rich in mineral resources of nonferrous metals. Hence, accompanying the development of industry, mining and agronomy, an increasing demand for energy has emerged.

Unfortunately organic energy sources such as coal, gas and oil are very scarce in the Region. Although hydroelectric energy in the main region of the Jinsha river and the Langcang river is plentiful, it is constrained by the enormous investment a and long construction period required.

By utilizing the natural drops of about 600 m of the Xier river, a chain of four water power stations was built in the early 1970's. The total installed capacity of the four stations is 255 MW and three of them already have lines in operation. With the

Erhai Lake as a natural regulation reservoir, the Xier river power station has become a key project in the local electric network. It is certain that the Xier river water power stations have played an important role in improving the energy supply conditions of the Yunnan province as well as the Erhai Region. However, the designed annual water use of the station is equal to the annual inflow of the Erhai Lake and the maximum drop of the Erhai lake is 4.5 m, several conflicts of water usage have appeared in the quantity of water as well as in the elevation of water surface of the lake. Recently, the Erhai Lake has been the source of a water supply for the pumped irrigation water needs of about 10,000 ha of farm land around the Lake, the industrial and domestic water users of the Dali City, and the water consumption by evaporation of the lake surface. The total amount of water use has already been greater than the mean annual inflow of the Lake. Furthermore, some years of low precipitation have occurred in this region recently. As a result, the water level of the lake has decreased by 2.78 m. Accompanying the drop of the level of the lake, the surrounding environment has been degraded, and farm lands whose production depends on the lake have been threatened. Meanwhile, other deterioration has also occurred. In view of all of the above, the Xier river water power station was forced to close down in 1984. Since then, not only has the energy supply been in a tense state and the development of production been affected, but this has also resulted in a corresponding rise in the cost of production due to the long-distance transfer of electricity.

Farmland Irrigation problems of the varied valley in the southeast of the Erhai Lake.

East and south of Erhai Lake, there are several large, flat, open valleys such as Binchuan, Weishan, Midu, Xiangyun, and Huangping. The total farm land of these valleys is 50000 ha. Because the elevation of most of these valleys is rather low, heat resources are abundant but precipitation is scarce. In addition, since all of these valleys are situated in the uppermost part of the river, surface runoff is deficient. This constitutes an apparent imbalance of heat/water resources in the valleys, and particularly in the Binchuan valley.

The Binchuan valley, located the east of the Erhai Lake, and with an elevation of about 1450 m has yielded more than 2000 ha of arable land. It is separated from the Lake by a mountain and because of the burning-wind effect (i.e., a falling downward effect), the accumulated temperature (average daily temperature 10° C) has exceeded that of Dali valley by 22.9 per cent. Rice can be harvested twice a year. Under conditions of guaranteed irrigation, the rice production on an experimental plot reached 15.84 t/ha in 1982, the highest recorded in China. Furthermore, the land is suitable for growing economic crops such as sugarcane, cotton and oranges. Nevertheless, the precipitation of Binchuan valley is only 559.6 mm, 51.7 per cent of that of Dali valley. A Spring drought occurs almost every year, and serious drought occurs once in 3-5 years. However, since 1981, there has been a succession of serious droughts. Serious drought causes a significant depression in crop production; trees die and there is a drinking water deficit for man and livestock. This valley has become one of the three well-known arid centers in the Yunnan province. The Binchuan valley is located in the upper part of the Sangyuan river where the average annual run off is only about 107 mio m^3. In the last 30 years, about 1600 water work sites were developed in this region, but majority of them cannot be fully utilized due to the water deficit. Only 26.6 per cent of the total area of farmland in the region, has a sufficient irrigation water supply. It is estimated that to provide the water requirement of the total arable land, 180 mio m^3 of water should be transferred from the watersheds outside of the region.

Except for the Xiangyun valley, the Erhai Lake has a potential superiority in elevation to the other four valleys. That means, if the water from the Lake is trans ferred eastward, the required irrigation water for those arid valleys can be provided and the hydroelectric resources will be developed at the same time by utilizing the drops of 700 m or more between the Erhai Lake and Binchuan valley, and then the Jinsha river.

Unfortunately, since the Erhai water power station was built, this plan cannot be realized further.

Because of the depression of the level of Erhai Lake, the inlets of many irrigation pump stations around the Lake are already above, or will soon leave, the lake surface, threatening directly the irrigation water supply for more than 10,000 ha of farmland on the lake-shore. Either to reconstruct the existing pump station or to build new ones would require further investment and increase the operating costs of irrigation. Besides, because the newly exposed beach of the lake is rather soft, it is difficult to construct any new pumps on it.

Bow fish used to grow in the rock holes under the waters along the shore of the Erhai lake or by migrating to the upper streams of the receiving tributaries. Since the stage of the lake was deplessed, the rock holes have been exposed, the gradient and velocity of the water flow of those tributaries have become steep and fast respectively, and a series of water drops has appeared along the longitudinal section of the tributaries. Owing to all the lake shore and river channel modifications, the Bow fish have lost their breeding place and are approaching extinction.

Accompanying the depression of the level of the lake, an upward scour has occurred. From the incomplete census of more than 100 rivers, the total length of scour amounts to 23 km; 45 structures of bridge, culvert, barrage, and dam along the river have been severely damaged, or destroyed, due to degradation, and 15 km of dike have also been damaged.

The groundwater level around the lake has also been reduced, with the depression of the level of the lake. This has caused half of the domestic wells along the lake to dry up and the other half to become semi-dry or polluted. Consequently, the water supply for man and livestock has become a very difficult problem. Many of the people have to draw water from the lake, by boat.

About a million people have suffered from these adverse conditions. Meanwhile, the water requirements of the double crops have increased by 20 per cent due to the depression of the groundwater level and its results and additional water consumptions, thereby raising cost of agricultural production.

The water body of the Erhai Lake has a obvious regulatory effect on the surrounding climate. For example, the mean temperature in the coldest month along the shore of the lake was generally higher than that of neighbouring areas with similar elevation.

DESIGNS FOR INCREASING WATER RESOURCES IN ERHAI DISTRICT AND THEIR EVALUATIONS

The unfavourable effects of the falling water level are so great that various measures should be taken to control the steady decline of the environments, both for agricultural and industrial production. A lot of money has been invested in the building of a power station in cascade. It is almost complete and has begun to have a beneficial economic impact and so no closing down now, as a remedial measure would be helpful in modifying the present problems. New water sources beyond the Erhai river-basin must be found and tapped by cross-basin diversion. That is the only way to solve the series of contradictions that are a result of water shortages in Erhai district.

The design of the cross-basin diversion project must follow comprehensive analysis of demand for water utilization as well as some technological and economic comparisons:

- Providing the necessary irrigating stream for dry basins in Erhai district. Making sure that the Erhai power station in cascade is running normally.

- Maintaining the normal water level of Erhai lake to recover the ecological balance in Erhai Lake surroundings.

- Meeting the demand for water resources by the ever - increasing population and expanding agricultural and industrial production. For this, as an estimation, at least 600 mio m^3 water should be diverted to Erhai Lake every year.

To tackle the serious water shortage in Erhai district, government department has put forward various proposals for increasing water resources, for example, diversion or pumping from Jingsha River, diversion from Yanggong River, or opening up the ground water in Binchuan county. etc. All of designs have their inevitable disadvantages as well as advantages.

Pumping of Jingsha River Water

Jingsha River flows through the north part of this district, an abundant water source, but its valley sides are very precipitous, and its nearest point to Erhai Lake is at Shigu, where the river's surface elevation is 1810 m and lower than Erhai Lake water level by 163.5m, and Jiuhe Basin, which is to the south of its first watershed, by about 500 m. In order to build the extraordinarily high dam on the Jingsha river, a structure which is indispensable if water self - reversion is to be realized, great amounts of labour and finance are needed. Moreover, the losses caused by the reservoir's water back-flowing will be tremendous. If a water raising station established at Shigu were used to divert the necessary 600 mio m^3 water every year, the power plant's consumption of it would be equivalent to that generated by the west Erhai power plant. In addition, the horizontal distance between Shigu and Erhai Lake is 120 km. Regardless of diversion or lifting water from Jingsha River, a long canal and two long tunnels would have to be constructed. All these disadvantages have made the realisation of this design impossible in recent years.

Diversion of Rivers

Another proposal for diverting water from Jingsha River with a 400 m pumping head should be installed near Jingsha River Bridge to the north of Binchuan Basin; then, a 80 km long canal is dug along Daden Valley which will provide the necessary water resources for irrigating Binchuan Basin. Profit from this design would be small as its power consumptions is also very great.

Yanggong River is a branch of Jingsha River. If a diversion site on it is selected at Shimenkan below Heing Basin, there is only 470 mio m^3 runoff which could be diverted annually. Besides, the topographical conditions here are not suitable for water storage, and a large section of the necessary 12 km long canal would have to lie on the topographically and geographically acrid mountain areas composed of carboniferous limestones, so lack of water volume, a complex constructon project, make this design are unreasonable.

Heihuei River is the east source of the Yangbi River and is part of the Lancang River system. Key factors in the design to divert water from the Heihuei River is to dam the river in the lower reaches of Shaqi Basin and to divert water into Erhai Lake through Luoping Mountain with a 11 km long tunnel. Due to the lack of water-regulating requirements, only 250 mio m^3 of water could be diverted annually.

Exploiting the ground water of Binchuan Basin in recent years has, to some extent, alleviated the drought threat there. However, the ground water resources of the Basin are very limited, and after several years they would be gradually exhausted. So exploiting ground water resources cannot be the main way to solve the water shortage problems of Erhai district in the long-term view.

Use of Yangbi River Water

Diverting Yangbi River's water across the river-basins to Erhai Lake is a reasonable way to solve the water shortage problems in Erhai district.

From 1982 a two-year field survey was made, comparing and analysing the different diversion designs. In the end a design to exploit Yangbi River's water resources and divert them into cross-over basins to Erhai district, was put forward, and it was seen to be the only reasonable way to solve the water shortage problems in Erhai river-basin and adjacent areas.

Yangbi River runs along the west foot of Canshan Mountain and it is divided into west and east; both sources in upper Heijang, in Eryuang county. The east source, called the Heihuei River, originates from Lijiang River and runs through several basins including Jiuhe, Jianchuan and Shaqi. Its river valley first narrows then widens. The west source, called the Misha River, originates from Laojun Mountain, which has an elevation of 4247m. Running through the narrow Shang Lan basin, it converges with Kaster springs, and then gets into gorge (mainly composed of crushed rocks of the tertiary system) and at last joins Heihuei River at Hejiang. The watershed area of upper Hejiang is 2639 km^2 and the annual runoff there is more than 900 mio m^3. Both the watershed area and the water from it are not less than in the Erhai river-basin. To realize the exploiting of Yangbi River's Water resources across river-basins, there are two basic plans to choose from when deciding project layouts, which include water source regulating projects and water transfer projects.

Converging Plan: the two sources of Yangbi River converge near Heijiang, and the valley base there is 1940 m above sea level. In the east it is separated from Cibi Lake by Luoping Mountain, which is the northwards extending ridge of Canshan mountain. Cibi Lake is 2055m, 115m higher than the valley base of Heijiang. If a high dam was built at Heijiang and a 13 km long tunnel through Luoping mountain, water sources may flow automatically from Cibi Lake into Erhai Lake, and the water diversion volume every year would not be less than 600 mio m^3. One prominent advantage of the plan is the simplicity of the project layout. However, its disadvantages are (1) the dam project is too huge; (2) the valley base width exceeds 250 m and loose Quaternary sediments are deep; (3) the valley base-strata are very fragmented due to the influences of structure-breaking; (4) the faults on the Heihuei valley base are active. All these unfavourable factors are latent threats to the extra - high dam at Hejiang.

In order to modify the influence of these unfavourable factors, the dam height must be reduced and the corresponding diversion projects must be combinations of storing and lifting projects. In a whole year the conversion ratio must be near 20 m/sec., the reservoirs regulating storage cannot be less than 180 mio m^3, and the corresponding dam height must be not less than 94 m. A pump-station with delivery over 25 m should be constructed. To further reduce the dam height to eliminate the latent threats of the high dam, the reservoir's regulating storage must be reduced, and the lifting station's delivery lift and installed capacity must be raised. All these mean increases in both the power consumption of the water lifting station and Erhai Lake's regulating-storage.

Diverging plan: the principle of this plan is to transfer water from Heijiang to upper places on the Heihuei River and Misha River.

Misha River runs into a gorge near Dunhuo mountain. The gorge's cross-section is V-shaped and its basal width are just over 10 m in some places. Its lateral slopes are composed of Mesozoic broken rocks and mud-ash rocks, providing suitable conditions for dam building. The wide gorge near Yanqu village, above the dam site is an ideal place for building a reservoir. If the dam height is 50m, the corresponding reservoir storage may exceed 101 mio m^3 and the effective water would be about 410 mio m^3/annum. Water is diverted to Heihuei valley through canal extended along the right side of the valley. There are two suitable sites for building a dam on Heihuei River, upper Heijiang: one is near Chunjian; although its neighbouring areas are geologically suitable for dam building, the dam site is too low. For automatic diversion, a dam of over 82 m high must be built. The other site is at Miziping, upper Chuniam. It is located at the upper breaking point of the river, and its valley base elevation is about 2030 m. Based on regulated calculations; when the dam height is 60 m, not only can gravity diversion be realized, but also the Heihuei River's flowing-ration can be regulated every year by the corresponding reservoir storage.

Suppose that two reservoirs alone, were built at Dunhuoshan on Misha River and Miziping on Heihuei River, adopting the combination-regulating system of the two reservoirs, the converged water sources could be then diverted to Erhai river-basin through Luoping Mountain's tunnel. This plan has the following advantages:

- The adjacent areas of Hejiang not suitable for projects are avoided.

- After the height of the regulating-poundage is raised, gravity diversions are possible, thus freeing the demands of water-lifting establishments, power consumptions, post-repair and management costs.

- Fundings, project and profit can be obtained stage by stage, mollifying the difficulties of collecting funds brought about by centralized investment.

- The falls between the upper surface and the lower reaches of the reservoirs can be used to build two hydraulic power stations, whose total installation capacities may reach to 20 MW, and this would make up for losses in tapping water power due to the water reduction in branches of the Yangbi River, below Hejiang.

There are also some disadvantages with the diverging plan, when compared with the converging plan:

- On one side of Heihuei River, the reservoir protrudes somewhat into the Shaqi basin, and the south tip of the basin submerges.

- The total watershed area near Hejiang, controlled by the two reservoirs is reduced by over 130 km^2 more than in the converging plan.

The water tunnel through Luoping mountain is a key factor in the diversion system. Most of the sites for the tunnel may be composed of dolomitic limestone, and broken strata are rarely seen. Moreover the tunnel's longitudinal line is almost vertical to the rock strata, and this is good for the tunnel's stability. But attention must be paid to the development of Karst phenomena and the local hydrological and geological conditions. It should be also taken into consideration that of the tunnel's total lengths about 8 km would be under the depth of 500 m, and 1 km under the depth of 1000 meters, implying that the tunnel roof must sustain huge Rock bursts in some places where rocks are hard and fragile, while the tunnel is being cut. In addition, on the east and west sides of Luoping mountain there are many places where low hydrothermal processes are active, and under the influence of the carboniferous limestones' high thermal-conducting ratio, high temperatures may be encountered during the cutting process.

The mouth of Luoping Mountain's tunnel is at Cibi lake, whose east tip joins with the Miqie River, through the Haiwei River. The Haiwei river's cross-section should be enlarged to adapt it for the increased water flows due to the diversion. The Miqie river then runs through Xiashankou gorge, its descending grade suddenly becoming lower and lower, and the river bed there has been higher than the surrounding ground because of years of sediment accumulation. In recent years some measures, such as cleaning and diversion, have been taken, and the river's safety discharge has reached 120 m^3/sec. and will be raised to 130 m^3/sec in the near future. Based on the years' statistics, gathered by Liangchen Hydrographic Station on Miqie River, a maximum discharge of 118 m^3/sec occurred in 1955. So if the diversion's constraints are dealt with in the flood season, the present river course can sustain the water-flow burden after the diversion has been built.

The annual diversion volume from Yangbi River to Erhai Lake can be over 600 mio m^3, ensuring the maintenence of the water level of Erhai Lake. Nearly half of the diversion volume, can be used to feed Xier River power station, and the other half to irrigate the dry basins of Binchuan, Xianun and Mido, etc. all situated to the East of Erhai Lake. Water can be provided for the industrial bases dominated by the refining of nonferrous metals, and these bases will soon be developed in Erhai river basin.

The water tunnel through Erhai Mountain is a strategic passage for the eastward diversion of water resources of Erhai Lake. The tunnel's total length is 7.73 km, of which over 500 m at its mouth,had been completed in 1958 at Diantuo village Binchuan county. The tunnel line extends over rocks that are composed of sand stone, shale, limestone and basalt. Their properties are complex, and fractured strata may be met. The rocks' maximum thickness on the tunnel top is less than 500 m., so during the cutting process, rock bursts or high temperatures may be avoided, and one or two more working faces may be opened so as to raise cutting efficiency.

After the tunnel is built, the water can flow into the upper reaches of Daxi river, which belongs to the Jingsha river system, and then be divided into two branches: the north branch flows into the Dayingdian reservoir on Daying river to irrigate the farm lands on the west bank of Sanyuan river in Binchuan county; the east branch joins with the completed "Binhai" canal and flows into the Haishiao reservoir on the upper reaches of Sanyuan river. Haishiao reservoir's present dam height and storage volume are 28 m and 43 mio m^3, respectively. When the dam is raised by 5 m its total effective storage may reach 100 mio m^3 which is enough to regulate and store the water resources diverted from Erhai lake and to control the irrigation of the farm lands and cultivating wastelands along or to the west of Shanyuan river, from the north tip of Yongsheng county to the sides of Jingsha river. If the annual diversion to Binchuan basin is 150 mio m^3, added to the present hydraulic facilities, 20000 ha, may profit.

As part of the future Hangbi river diversion system, 7-8 medium or small water power stations can be built or enlarged by utilizing falls in the diversion line. Of these station two can be located at the foot of Dunda mountain reservoir on Misha river, and their installed plant capacities together would be 20 MW. After water flows into the Erhai river-basin, the present Xiashankou power plant on Miqie river can be enlarged so that its installed capacity reaches 20 MW. In the irrigated areas below the mouth of Yinger tunnel, at least 4 power plants can be built and their total installed capacities may be about 25 MW. In other words, in the diversion system's newly tapped generating capacity may amount to 63 MW which is 3.5 times the total installed capacities of the present middle and small water power stations in the Dali prefecture.

The project layouts of the described Yangbi river diversion system can be divided by the watersheds of Luoping mountain and east Erhai mountain into three sections: Water sources, Xier power station and the water systems for controlling Erhai Lake's water level and agricultural water demands in the dry basins. In this paper several designs and tentative plans are proposed to expand the choice of project surveys and designs, for diverting water in the most economic, effective and safe way, and with minimum engineering costs.

Economic and Ecological Benefits

The Yangbi river diversion project is cross-basin diversion system linking the Lancan, Jingsha and Yuan river systems. It agrees with the diversion principle of transfering water from water-rich areas to water-poor areas, and can make many contributions towards improving the ecological balance, increasing water utilization in power generating, developing agricultural irrigation systems, and providing water resources for cities and industrial bases.

- When the diversion takes place, the fluctuating water level of Erhai Lake can be controlled, and the environment would proceed towards a cycle. Direct profits include increasing aquatic product resources, improving conditions for navigation, meeting the water demands of local inhabitants, reducing the irrigation costs of farm lands and lessening risks and losses brought about by river floods. Indirect benefits include strengthening and expanding the climate regulating - capacity by the lake to its surrounding areas and further improving tourists attraction.

- From calculations based on the premise that Xier power station can get 300 mio m^3 water annually from the diversion project, the generating capacity per year of this power station may be raised by 4.10^8 Kwh more than twice as much as its present generating capacity. By utilizing falls on the line of the diversion project, 7 or 8 water power station can be built or rebuilt, and 3.10^8 Kwh more electric energy can be gained annually. In this way, the power demands for developing agricultural and industrial production in Erhai district can be met, and the power required for tapping mineral resources in adjacent areas and building the big hydraulic power system on Lancan River, can also be realised.

- Irrigation for about 30000 ha of farm land can be provided or improved due to the increased water supply in the dry basins of Erhai district. It is estimated that 10-15000 tons more grain and about 3.10^5 tons more sugarcane can be harvested every year, and the output of other economic crops including tea, oil crops and fruits, can be greatly increased. Forestry and stock raising can also be developed and improved.

- The dry basins in Erhai district will be gradually transformed from the present areas that rely on state subsidies, to agricultural bases that provide grain, and other sideline products for the development of industrial and mineral production.

- The diversion project will provide enough water to meet the production and water demand in the developing Dali City, which will become an industrial and mineral base in near future.

PREVENTION OF DEBRIS FLOWS

DEBRIS FLOWS AND THEIR PREVENTION AND CONTROL IN JIUZHAIGOU SCENIC SPOTS OF HENGDUAN MOUNTAINS REGION

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INTRODUCTION

The Jiuzhaigou drainage area, of the Hengduan Mountainous Region, is beautiful. Its beauty is due to the rapids and waterfalls in the forest, the colourful lakes surrounded by dense woods, and the surrounding high mountains. Debris flow disasters pollute the lake water, make inroads on the blue lake, destroy the wonderful forest, block roads to scenic spots, endanger giant panda, and threaten the safety of tourists. If the disasters are not prevented, the lake in this area will be gradually silted up.

There are large natural debris flow gullies within the Jiuzhaigou area and also large and small artificial ones. Therefore, it is of great significance for the prevention and control of debris flows to safeguard the forest eco-system and natural enviornment.

Jiuzhaigou is one of the debris flow areas in the northeast part of Hengduan Mountainous Region. The drainage area covers 650.4 km^2 and its main gully is more than 50 km long in south-north direction. According to the physical geographic structure and scenic characteristics, the area is divided into six scenic spots (Shuzheng, Changhai, Rizhe, etc.).

There are 114 lakes (Haizi) in this area, and the largest and deepest one is named Changhai (long lake). The biggest waterfall is 130 m wide and more than 20 m high. There are also thick forests with more than 150 species of trees, mainly, fir and dragon spruce as well as Chinese pine, birch, oak, larch, maple, etc, and including the rare economic tree Chinese plumeyew.

THE DISTRIBUTION OF DEBRIS FLOW

Debris flows are widely distributed over this area, from the north Heye Gully, southeast to Changhai, and southwest to Xuanya-jianquan. There are 27 disastrous debris flow gullies. The distribution characteristics are as follows:

Topographically, most debris flows in this area developed in rocky mountains and on steep hillslides above the forest line. The ridge 4000 m above sea level, with exposed bed-rock and active soil slip and collapse, having been strongly weathered, becomes the original place of debris flow.

A rainstorm concentrates the distribution. For instance, there was a storm centre in Wesikahuang mountain range, 4192 m above sea level, on July 7, 1984. The fierce storm caused 3 debris flows on the west slope and four on the east slope, resulting in the most centralized distribution of debris flow in the region.

The debris flow mostly covers the forest cutting area, especially as some slope debris flows are formed by wood collecting.

The main debris flows occur between 2000 - 3000 m above sea level, and particularly between 2600 - 2800 m where there are two thirds of the total of 27 debris flow gullies.

In brief, the debris flows over the Jiuzhaigou region appear in belt-like distribution along the gully, and some in slice-like or dot-like distribution because of the effect of storms or human activity.

THE CAUSES OF FORMATION AND TYPES OF THE DEBRIS FLOW

Causes of Formation

The causes of formation of debris flows in Jiuzhaigou display a regular pattern; there must be abundant solid materials, a steep landform and plentiful rainfall. In addition, man's irrational economic activities also promote formation and activity.

Abundant materials: The mountain range in the Jiuzhaigou drainage area has great altitude differences. The exposed mountain body of weathered rock above the 3800 m forest line is mainly limestone, which has many joints and cracks. Where it is heavily exposed there often occur collapses and debris slips, providing abundant solid materials for the occurence of debris flows. On the forest belt below 3800 m, the thick brown earth and drab soil of the hilly area are developing into residual hillside deposits which become the material source of slope debris flows. Generally speaking, the abundance of solid materials in this area is favourable for the occurrence and development of debris flows.

Steep landform: This is an area of complex topography - steep slopes and big altitude differences (1500 - 2000 m) especially in the limestone area, where knife-back form or saw-tooth form ridges tower above hanging valleys. This is due to steep dip angles, flourishing cracks, frost weathering, eroding and denuding. The slope in the formation area is either between 60^0 and 70^0 or a sheer precipice with overhanging rocks. The gradient of gully beds is 200-600% and most of them appear steep in the upper reaches and gentle in the lower reaches with a broken-line form. Such features create favourable conditions for the formation and activity of debris flows.

Strong storm: No practical observation information on this area has been gained until now. Observations made by the meteorological office in Nanpin County and Pinwu County, show plentiful rainfall and frequent strong storms in parts of the area which promote debris flows. As the dense forest regulates the rainfall, this factor is influential in causing debris flows, so the frequency of large scale debris flows is low and that of small ones higher in recent years.

Artificial factors: The formation of debris flows in Jiuzhaigou is strongly linked to the economic activities of the people. With the growth of population in this area, wood cutting and clearing for cultivation, livestock over-grazing, and excessive fuel collection have all increased. The results are exposed hillsides and gullies, and active collapse which promotes the occurrence and development of debris flows.

Types and Features of Debris Flows

In terms of the causes of debris flows in this area, they can be classified as either natural or artifical.

In the light of landform features they are classified as gully and slope types. Most natural ones are the gully type, while most artifical ones belong to the slope type. According to its own characteristics a debris flow can be classified as either thin viscous or low-viscous.

THE HARMFUL ACTIVITIES OF DEBRIS FLOWS

There is a long history about the activity of debris flows in Jiuzhaigou. Judging from their depositional fans in some branch gullies, several large-scale debris flows have occurred in the past. The extent of tree growth on the depositional fans, shows a history of more than one hundred years. For example, an investigation in 1983 indicates that Shuzheng, one of the branch gullies, once suffered a large-scale, disastrous debris flow which destroyed the village that was there at that time digging house foundations have uncovered clay basins and bowls, and a man's skull, etc.

Although debris flows occur more and more frequently in Jiuzhaigou, they are often on a small-scale with a volume of only several dozen cubic metres. A large one will have a volume of several thousand cubic metres and some more than ten thousand.

Jiuzhaigou is praised as a pearl on the plateau of Hengduan Mountainous Region for its mirror-like lakes, quiet and secluded mountains and dense forests. It not only has high value for viewers and admirers, but also is the field in which to do scientific research. The mountains, lakes, forests, and ecological environment remain a profound mystery for scientists.

Nevertheless, the debris flows strongly affect the lakes and forests. The main harm is that a great amount of silt and debris falls into the lakes and accumulates there, which reduces the lake area polluting the transparent lake water at the same time. Debris flows cause considerable damage to forests, threaten the safety of tourists and also block transportation routes.

The Prevention and Control of the Debris Flows

As the Jiuzhaigou scenic spots have won fame as "pearls","treasure places" and "some of the finest scenic spots in the world", the control of debris flows, protection of the natural ecological environment and the promotion of tourism must be the priorities.

In order to protect the natural environment and prevent the disasters, any scheme in this area, must stress the main points to avoid the strong debris flows and control the weak, and must be carried out in stages. The principles of a control scheme lie in: prevention combined with control, making a comprehensive list of key points, carrying out engineering works first, and combining short-term measures with long-term measures, debris flow control with environment beautification and nature protection. Using control measures, we hope to basically reduce the pollution of scenic spots and protect the environment. Short-term engineering, vegetative, and social measures should be determined according to the cause and formation conditions, and the type, pollution and damage extent of debris flow so that it can be controlled and the harm to environment and tourism can be reduced.

Engineering measures are very important and must be taken in the short-term. Vegetative and social measures are fundamental in debris flow control, and are also important in nature protection. However they are long-term, and therefore slow to take effect. This has been taken into account in the planning of a comprehensive scheme to control debris flows in scenic areas.

Engineering measures: Because formation conditions are complex in this area, variety of features, types and advantageous dynamic conditions are exhibited by debris flows. Many debris flow gullies have a much larger starting flow and longitudinal slope than the common one. The debris flows have a strong effect, with rapid motive speed and short, steeply sloped gullies. The large falling difference, short flow process and narrow deposit area bring about some difficulties for the arrangement of the control engineering. So, the type in the engineering project design widely adopts the advanced one in and out of our country, especially the Sabo Project against debris flow in Japan's national parks. The adaption of these measures to the features of debris flow must be considered, attention paid to their appearance and viewing value, while protecting the original natural environment. Main measures are:

- Blocking project: To avoid polluting, and silting up lakes and destroying tourist attractions, by intercepting a debris flow in the gully, reducing the longitudinal slope and stabilizing the slope bottom on both banks, blocking partial solid materials of debris flows, and decreasing sand quantity, various measures have been taken: stone dams, iron rail dams, concrete rail dams, and gravity dams constructed with stone and concrete.

- Leading the debris flow: Although a dam can intercept a partial discharge from a debris flow, it is still possible for debris to flow into lakes and tourist spots, so a project has been adopted to guide the discharge which is not blocked, into a designated area.

- Sandpocket project: The combination of a leading project and a sandpocket in engineering, can silt up the discharge of the debris flow at the designated place, to prevent its overflow.

- Discharging project: Considering that some large gullies have had flowing-water all the year round, a discharging project must give the way to the discharge of the debris flow, so discharge channels are built to avoid flooding tourist areas. The project will be carried across highways, using surface water-flows and small bridges.

- Stabilization of gully and slope: The formation and activity of a debris flow is always related to the development of an unstable slope. Therefore, small-scale, low cost and effective measures to stabilize the slip at the foot of the slope can be used, such as building retaining and supporting walls, and slope projection.

Vegetation measures: Being a comprehensive control system in Jiuzhaigou drainage area, the forest vegetation has the functions of protection, recreation, sanitation and hydrology, water and soil conservation as well as the function to improve the local micro climate. For instance, it is common in this area that each type of debris flow formed above the forest line, stops and silts up along the gully due to inadequate water, which demonstrates the importance of water conservation by the forests. Therefore, expanding forests and strengthening their renewal has an important role in debris flow control.

- Plantation: Plantation on hillslides can bring slope debris flows under permanent control, and also reduces hydraulic waste. Larger saplings within the project should also be planted to block sand and debris in the gullies and on hillsides and the green tree variety can beautify the project and add to the scenic value of Jiuzhaigou.

- The tending of woods: Strengthening artificial and natural woods, flowers and plants, and promoting their growth, can increase water conservation and flow regulation.

- Closing-off hillsides: Every blade of grass and every tree in Jiuzhaigou must be protected and hillsides must be closed to facilitate afforestation and bush growth and to promote their renewal in order to maintain a balanced of ecosystem that is unfavourable for debris flow formation.

- Returning cultivated land to forest: The cultivated land near the lakes and on hillsides must be allowed to return to forest, bush and grass. Woods for protection and economy (the local tree varieties in this area) may be planted.

- Forbidding tree-felling: Timber used for building in Jiuzhaigou should not be cut from this area, especially in the debris flow gullies. Only sanitary lumbering (cutting down sick and indecorous, withered trees) can be permitted.

- Forbidding free livestock grazing: The young trees in Jiuzhaigou, and the flowers and plants along the roads have been seriously gnawed and trampled by livestock. The eight hundred or more head of cattle and more than one thousand goats must be kept in pens by local people and free and rotational grazing must be forbidden on hillsides. In addition, the development of stock-raising must be controlled and the number of cattle and goats must be decreased. There can only be decorative livestock around villages in Jiuzhaigou.

Social control measures: With the growth of population in Jiuzhaigou, economic activity has increased. If there were no measures to control it, the forest would gradually decline, and the beautiful lakes would be in danger of disappearing, so some social control measures are needed.

Control of the growth of agricultural population and migration: Jiuzhaigou got its name from the nine stockade visages in this area. With the growth of the agricultural population, the area of farmland has gradually expanded, but the 640 km^2 area of Jiuzhaigou is unable to expand. This inevitably causes a serious problem. Timber for building and cooking is increasingly needed, and the quantity of trees falls far behind the quantity consumed, which results in the slow destruction of the natural vegetation and wonderful scenery. So this problem cannot be neglected and it is necessary to control the growing agricultural population. Farmers living in debris flow gullies who are unable to change the direction of their production should be relocated.

The previous economic structure should be changed and agriculture rationally change its direction: 805 people, 2000 mu land under cultivation, no less than 800 head of cattle and more than one thousand goats bred in Jiuzhaigou represent great danger to the woods and plants. Therefore, the farmers and herdsmen urgently need to change the direction of their production to forest protecting, and economic wood, fruit tree and medicinal material planting, or to gardening and tourism services.

Strengthening administration and guaranteeing the implementation of control schemes: Debris flow control in Jiuzhaigou should be combined with nature protection and be guaranteed by strong administrative measures. In addition, a unified administration organisation should be set up to strengthen the protection of natural environment.

Increasing scientific research on debris flows in Jiuzhaigou: Because these are the first debris flow control measures to be taken in this area and owing to the limitation of time, the research lacks systematization and depth, only part of the programme has been designed in this tentative scheme. To draw up a comphrehensive and rational control programme, it is necessary to do further scientific investigation and observation on the basic features of debris flows.

DEBRIS FLOWS AND THEIR PREVENTION

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INTRODUCTION

The Hengduan Mountain Region is located in the trasitional belt between Qinghai-Xizang Plateau and the Eastern hilly land. It is characterised by peculiar natural environment, complex geological structure, frequent earthquakes, steep topography and varied climate. Development of resources disturbed the mountain stability and ecological balance, facilitating the occurrence and increases of debris flow. In recent years debris flows have been becoming remarkably active and destructive, and have obstructed the economic development of the mountain region. Effective measures must be taken to control or restrain the occurrence and development of debris flow, and to facilitate the economic development in the mountain region.

DEBRIS FLOW DISTRIBUTION AND ACTIVITY CHARACTERISTICS

Distribution of Debris Flow

The Hengduan Mountains are one of the China's areas where debris flows are widely developed and distributed. The distribution characteristics are:

- Debris flows are concentrated in fracture zones, especially in seismic activity belts, such as the Anning River Fracture zone, the Heishui River Fracture Zone, the Jinsha River Fracture Zone, the Xiaojiang River Fracture Zone and the Xuanshui River Fracture Zone.

- Debris flows are largely distributed in river valley zones with 600-1000 mm of annual precipitation.

- Debris flows are largely distributed in deep-cut high mountain and middle mountains zones at 700-3500 m above sea level.

Activity Characteristics

- Debris flow activity fluctuates, sometimes strong and sometimes weak. For example, there are 40 or more debris flows in the Liusha River Basin, a tributary of the Dadu River. Debris flow activity since 1748 can be obviously divided into 4 active periods and 3 relatively quiet periods. The former occurred in 1819-1840, 1876-1894, 1922-1934, 1971-1974. Since 1980 debris flows have entered a fifth active period. In 1981 40 debris flows occurred in more than 30 ravines. There are 160 or more debris flow ravines along the Nujiang River (from the Nujiang River Bridge to the Gongshan). Since 1946 three active periods have occurred in 1947-1951, 1961-1966, 1967-1983. Activity in even one debris flow ravine fluctuates. In the Luhua Ravine of the Heishui River, since 1930, three active periods have occurred in 1930-1934, 1958-1969, 1976-1980. The active periods of debris flow are closely related to periodical changes in atmospheric circulation, the periodical activity of earthquakes and human economic activity.

- Obvious regional difference in Debris flow activity: Owing to the varied environment of the Hengduan Mountain Region, the formative factors of debris flows differ from place to place, and from ravine to ravine. Therefore, there is no correlation between the activity and scale of debris flows. Debris flows are very active in some sections of the Nujiang River, the Jinsha River, the Anning River and the Dadu River, including Gingshan, Fugong, Dequin, Dongchuan, Dukou, Xide, Hanyuan, Ganlo and other counties. As for each debris flow ravine, more than 10 debris flow occur in the Jiangjia Ravine of the Xiaojiang River every year; one debris flow occurs in the Luhua Ravine, Heishi every six years.

Recent strong and frequent debris flow activity: Recent debris flow activity has been strong in the Hengduan Mountain Region. During the middle 70's and early 80's, debris frequently occurred in the vast area east of the Minjiang River and west of the Nujiang River. Not only are they widely distributed, but also concentrated in stretches and zones, and in great numbers. For example, in 1983 a rainstorm simultaneously caused ten or even one hundred debris flows in the lower reaches of the Sunshui River of the Anning River, the Heishui River of the Jinsha River, the upper reaches the Xiaojiang River, of the Dadu River (Dajinchuan), and the Nujiang (Njiang River Bridge-Gongshan). In 1981, 381 ravines gave rise to debris flows in 29 counties, in western Sichuan. In 1976 and 1979 debris flows took place in more than 100 ravines of 5 counties in the Nujiang River Basin. Large-scale debris flows from some of these ravines caused great disasters. Eamples include the 1976 debris flow in Lishadi, Fugong, Nujiang; the 1981 debris flow in the Liziyida Raivine, Ganlo, Dadu River; the 1983 debris flow in the Baishui River, Heishui River; the 1982 debris flow in the Hunshui Ravine, Anning River; and the debris flows the took place in the Guanmiao Ravine, the Bola Ravine, and the Zuoji Ravine of the Baishui River, the Luhua Ravine of the Heishui River, and the Ravine of the Zagunao River in 1984.

- Strong seasonal activity of debris flow: Most debris flows are caused by rainfall with obvious seasonal activity in May to October. Because there are double-humped rainfall and drought in the summer half season, two high tides can be found in debris flow occurrence in the summer half season, i.e. June, july and September.

HARMFULNESS OF DEBRIS FLOW

Numerous debris flows are distributed in the Hengduan Mountain Region, mainly concentrated in the valley zone in front of the mountains, which are densely-populated urban areas, so they are very harmful.

Since 1970, debris flows have occurred more and more frequently. There are many large or middle scale viscous debris flows of high velocity and large volume, with plenty of boulders, and a great impact force. The damaging pattern includes siltation, dash, impact, course change due to damming, bank denudation, upward breach of the natural dam. The most serious are the disasters caused by siltation, dash, breach of the natural dam and upward moves at the bend.

Siltation

This is the most common damage caused in the Hengduan Mountain Region. Its harmful affects cover wide areas, including farmland, villages, roads, water conservation and hydroelectric power works, cities and towns, as well as rivers and lakes. For example, in 1983, a rainstorm caused debris flows in 27 ravines of the Back Mountains, Xide County, Sichuan, burying more than 1000 mu of farmland, and a 4 km long section of highway. In 1972, a debris flow from the Hanlo Ravine, Mianning County, Sichuan buried the Xintiechuan Station of the Chengdu-Kunming Railway (four tracks), more than 100 mu of farmland and dozens of houses.

Dash

Debris flows have great dash power. When a large or middle scale debris flow occurs, all the facilities, roads and farmland in its path will be swept away, giving place to a rock sea. The following are two examples.

- On July 9, 1981, a disastrous debris flow occurred in the Liziyida Ravine which was bridged by the Chengdu-Kunming Railway. With velocity up to 13.2 m/s., volume weight 2.32 T/m^3, and tens of big boulders 8 m in diameter, this debris flow had great dash power. The bridge platform of the right bank was dashed, the pier No. 2 was sheared, and two beams were damaged, wrecking the train No. 422. This is a rare debris flow disaster in Chinese railway history.
- On July 18, 1984, a debris flow burst out

from the Guanmiao Ravine, Nanping County. This powerful debris flow had a velocity of 9.2 m/s., volume weight of 2.22 T/m^3, 430 boulders 2-5 m in diameter and 60 boulders 5-10 m in diameter. It cut away part of a three storey building. Big boulders smashed into the cemented-brick buildings and breached a 1 m thick concrete wall. As it came out of the ravine mouth, a highway was destroyed, pushing away the 1 m thick retaining wall on the left bank, and damaging a 14 m long opening.

Damming

When a debris flow occurs, if it is relatively large and crosses the main flow at right angles, the river is often dammed. Usually, the damming does not last long; with the rise of water level, overflowing will occur. Sometimes a lake may form and inundate farmland, villages and roads. If the dam breaks down, a more serious disaster will happen.

- Inundation: On July 18, 1984 a disastrous debris flow occurred in the Zuoji Ravine, Nanping County. Because the debris flow ravine crossed the main river at the right angles, the Baishu River was suddenly dammed, and the increased water volume and water level upstream resulted in the inundation of farmland and roads.

- Scour: On September 2, 1982 a debris flow from the Hunshui Ravine, Mianning county blocked the Anning river, strongly scoured the banks and channel, and formed high and steep slopes up to above 35°. On May 22, 1983 a debris flow from Geerzhai, Jinchuan County straight dashed to the Dadu River, and strongly scoured the valley. In addition the scouring of the opposite bank caused a new landslide.

- Breach: This is the most serious and damaging disaster in damming. The common mountain event affects wide areas and often brings about disaster. For example, on July 18, 1984 in the Guanmiao Ravine, Nanping county, the firest debris flow wavefront dashed into the Baishui River, and formed a dam. After about 30 minutes, the dam collapsed, creating a powerful special flood, which destroyed houses, farmland and roads downstream causing damage of more than 10 million Yuan. The sediment discharged into the river by the debris flow raised the river bed and changed the river course, bringing a damage to the production and construction on the river banks.

COUNTERMEASURES AGAINST DEBRIS FLOW

The occurrence of debris flows in the Hengduan Mountain Region has its internal natural factors. Their recent frequency and destructive capacity is mainly due to the irrational economic activity of man. For example, forcible deforestation, grass and shrub clearing for cultivation, road and canal construction, and excessive exploitation of bilogical energy resources will lead to the occurrence of debris flows which can destroy building construction, endanger cities and towns, bury farmland, damage industrial, agricultural, and hydroelectric facilities, stop transportation and communication, pollute rivers, and cause casualties.

The occurrence and development of debris flows in the region has a long history. The recent activity is so strong and frequent that it is very difficult to control. Furthermore, the debris flow areas are densely populated and economically developing. Accordingly, the control principle should be combined with the economic development, people's interest, and ecological and social benefits in the region. Debris flow countermeasures should include three compoenents: prevention, averting the hazardous area, and overall treatment.

Prevention

Protect the forest ecological system, strengthen artificial renewal and green the bare hills. Control the intensity of logging, improve logging patterns, facilitate natural renewal, recover the natural ecological balance, control the occurrence conditions and restrain debris flows.

- Sensitively develop and utilise natural resources, ensure the rational development of agriculture, forestry and animal husbandry, prohibit random reclamation, overgrazing and steep slope cultivation, and solve the contradiction between agriculture and animal husbandry to reduce the factors for debris flow occurrence.

- Improve the backward farming patterns, and give special attention to the irrigation canals that pass landslide zones or broken mountains so as not to add to the solid materials in debris flows. s flow occurrence.

- Proper measures should be taken in road construction, mining and waste disposal to prevent collapse, landslide and debris flow.

- In the densely populated areas with serious debris flow disaster and energy shortage, biological energy, such as successive fuel tree species, or water energy should be developed.

Averting the Hazardous Area

Most towns and villages of the Region are built on the old debris flow deposits, so they often suffer from the revival of debris flow. Averting disastrous debris flows and delineating the hazardous zone is necessary until debris flow countermeasures take effect. New villages, industrial facilities and the enlargement of towns should avert the debris flow hazard zone so as not be attacked by a debris flow.

Overall Treatment

Overall watershed treatment must be carried out in the towns, main roads and important factories and mines where debris flows are destructive. According to the formation, nature, activity characteristics and damage degree of debris flow, engineering measures with emphasis on checking, discharging and stabilising should be adopted for the present time; biological measures with emphasis on closing mountains to livestock grazing and fuel gathering, and on afforestation should be adopted in the long run. An overall treatment combining short-term and long-term measures, and engineering and bilogical measures could control debris flows and prevent disasters happening.

CONCLUSION

The natural environment of the Hengduan Mountains favour the activation of debris flows. In particular, mans' over-use and development of the rich natural resources (forest, mineral deposits, water energy and land, etc.), added to improper measures, and massive exploitation to obtain biological energy, have disturbed the natural ecological balance, which has led to the degradation of mountain ecological environment and the increasing frequency of debris flows. It is noted that since 1980 the activities of debris flows have been at a new high tide.

DEBRIS FLOWS AND THEIR COMPREHENSIVE CONTROL IN HEISHA RIVER, LIANGSHAN, SICHUAN, CHINA

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INTRODUCTION

The Heisha River is known as a catastrophic debris flow gully in the mountainous region of southwest China. It originates in the Luji Back Mountain Region, Liangshan, Sichuan, passes through the Luji Basin and the Qingtang Front Mountain, and empties into the Anning River. The whole course is 12.6 km, and the watershed has an area of 22.7 km^2. The River is composed of three gullies -- Heisha (main gully), Maidi and Madu, which join eachother at the col.

Before the programme was implementated, debris flows in the Heisha River were frequent. Debris flows of different scales took place almost every year, and a catastrophic debris flow occured every 8-10 years. During the last century debris flows have submerged five villages, and 3000 mu of farmland. A dispositional fan 3 km wide was produced. The Chengdu - Kunming Railway and the Sichuan - Yunnan Highway run through the middle of the fan. The communication and transport lines, factories, villages, and farmland, on the lower reaches, were often subjected to debris flow demage.

The Heisha watershed has a high and precipitous relief and deep-incised gullies. The relative height difference is 200 m; the hills slope at about 40^0. Weak Jurassic, black and purple shale, mudstone, and siltstone, interbedded with smut, predominates. Rocks have numerous joints and fissures due to the effects of faulting, folding, seismicity, and fossil landsliding. The loose soil material is more than 60 m thick as a consequence of heavy weathering. The dry and wet seasons are distinct. 93% of precipitation is concentrated in the rainy season between late May and early October. There are many rain storms in this period and the total rainfall of one event can exceed 160 mm. Forest cover has been lost leaving sparse grass cover.

The above-mentioned precipitious relief, loose soil material, and plentiful heavy rain provided favourable conditions for debris flow formation. The destruction of vegetation intensified soil and water loss through gully erosion, and accelerated the activity of landslides and the gully development. There are 180 landslides, slumps and falls, 135 debris flow branch gullies, and more than 26 million m^3 of loose materials. A powerful debris flow could burst out whenever the next heavy rain falls. The maximum debris flow discharge could reach 300 m^3.

PROCESS OF DEBRIS FLOWS

Types of Formation

There are two types of formation processes in the Heisha River: hydraulic and soil-mechanical (Tian, 1981). The former is due to the scouring of sloped surfaces, and eroding of the gully bed and loose deposits along gully banks by the forceful runoff. Such debris flows in the main gully of Heisha River resulted from the erosion of gully bed deposits, bank colluvial deposits, and slope wash on the middle reaches, added to debris flow deposits from branch gullies, that were initiated by floods originating in the Luji Basin on the upper reaches. A flow formed soil-mechanically occured when saturated slide deposits and other loose materials entered the gully under the stimulus of a rain storm. There have been many such debris flows in the branch gullies of Heisha River.

Types of Debris Flow

Debris flows in the Heisha River are of different types and have typical flow regimes, manifold effects and patterns.

According to the character of the flow, they can be further subdivided into: viscous, fluid, and plastic flows. The viscous type is the most characteristic debris flow. It has elements of both soil and water flows, as well as its own peculiar mechanical properties and movement laws. The specific gravity is 1.8-2.3 t/m^3; the viscosity and incipient static shear of slurry are 0.8-8.0 P and 0.2-100 mg/cm^2 respectively. The fluid debris flow is the transitional flow between sediment-laden water flow and viscous debris flow. It resembles a water flow in character. The specific gravity is 1.2-1.8 t/m^3; the viscosity and incipient static shear are 0.02-0.8 P and 0.2-100 mg/cm^2 respectively. The plastic debris flow is the transitional flow between viscous debris flow and sliding soil material. It has similar character to mass movement. The specific gravity is above 2.3 t/m^3; the viscosity and static shear are more than 8 P and 500 mg/cm^2 respectively.

Most of the debris flow slurries of the Heisha River belong to Bingham fluid (Wu, 1981). Like debris flows, debris flow slurries can also be divided into fluid, viscous and plastic with different contact variabilities and laxation phenomena. All debris flow slurries have net-shaped textures. According to their character, they can be divided into four types: extremely close, close, relatively close, and loose. Debris flows may by considered as slurries containing a large number of rock fragments, and most of them belong to the pseudo-Bingham fluid with a lattice-like texture. There are four types: star-like suspended, supported, overlapped, and mounted.

Debris Flow Movement

The moving process of debris flows in the Heisha River varies with fluid properties. Generally, there are three categories: continuous, continuous-pulsating and pulsating. Usually, fluid debris flows are in the pulsating form. Debris flow regimes change with fluid properties and boundary conditions. Flow regimes can be classified as turbulent, disturbed, creeping, sliding, or waving. Debris flows of different regimes have different resistance laws and velocity formulae.

Debris flows of the Heisha River have a distinct impact that is abrasive and scouring, and they have deposition effects far more intense than that of floods with the same velocity. The flows not only have the capacity to cause major damage, but are also a great sculptural force. They can finish the morphodynamic process in hours, or even minutes, where it would take tens or hundreds of years for a water flow.

CONTROL OF DEBRIS FLOWS

A control programme was devised taking into account the formative mechanisms, activity laws, and damage patterns, of debris flows in Heisha River (Wu, 1983). Debris flows that occured in the main gully were the hydraulic type. They resulted from the powerful floods that originated in the Luji Basin on the upper reaches, scouring the loose deposits on the gully bed and banks, and receiving debris from branch gullies. The debris flows cut a course through the mountains and spread violently over the 3 km wide deposition fan with disasterous results. Therefore a control programme was devised: "A combination of engineering measures and biological measures, unified planning of the upper, middle, and lower reaches, and comprehensive management of mountain, water, forest and grassland" (CIG, 1981).

Concrete measures taken include:

- a flood control reservoir with a 22 m high dam, 540,000 m^3 capacity, and 12,000 mu of conservation forest on the upper reaches, to regulate floods and weaken the flood peak, to increase control of the hydrodynamics - the leading factor in hydraulic debris flow formation

- 7 silt arrest dams and 5 check dams

- 7 revetments and longitudinal dikes, backed by 6000 mu of soil and water conservation forests on the middle reaches, (Zhang, 1983) to arrest sediment, stabalize slopes, and weaken gully erosion in order to control the soil materials that gather to form debris flows

- a 5 km director dike, a drain ditch and 39 protecting forest belts to stabalize the gully bed and drain the floods, thereby reducing debris flow hazards.

All the properties and effects of the debris flows were taken into consideration in the design of each corrective engineering project. For example, the section, structure, and energy dissipation device of the silt arrest dams adopted, were a completely different form from the hydraulic check structures.

All the control measures were completed by 1978, and have successfully decreased the hazards of debris flows, and assured safety downstream. Since then the main gully has not seen a debris flow, withstanding the test of a rain storm with a 50 years recurrence. The amount of sediment transported out of the mountains after the treatment has been less than a quarter of what was transported out before under similar conditions. The peak discharge induced by a rain storm of 10 years recurrence has been one fifth of that before the treatment; in the main gully the peak discsharge induced by the same rain storm has been only one twentieth of that before. Not only have 2000 mu of farmland been recovered but crop yields have also increased. However, in recent years the reservoir and the director dike have had some siltation problems. In order to increase the effectiveness of the control programmes, aided by closing off the mountains to facilitate afforestation, management of the area must be strengthened.

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SOIL AND WATER CONSERVATION

THE PROBLEMS OF SOIL AND WATER CONSERVATION IN SOUTHWEST CHINA

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INTRODUCTION

Hengduan Mountain, Bayankala Mountain, the Yungui Plateau, Washan Mountain. and the parts beyond Qingling Mountain are all called the High Mountain and Gorge Area of Southwest China, which includes the Nujiang, the Langchangjiang, the upper middle Changjiang, and the upper Xijiang, which is a tributary of Pearl River.

Changes over the last 400 million years have been determined on the basis of scientific research over many years. The tectonic movement in the Silurian of Palaeozoic did not greatly affect the landforms of China, when Kangdian old land was mountains. The land Southwest China was submerged in the sea during the iddle and later Carboniferous and afterwards it was raised. So the land had been denuded for a long time and had formed a plain. The whole of this area had been submerged in the sea during the Permian. During the Indo-china movement in later part of Triassic, 200 million years ago, the large area of south China expanded beyond the east part of Kangdian and the Sichuan Basin was formed.

Cretaceous in China was an unstable period, particularly due to volcanic eruptions and folding, i.e. Sichuan Movement. During the latter period of cretaceous, Dabashan Mountain in the north of Sichuan Basin, Daliangshan Mountain in the west, Daloshan Mountain in the south, and Hyingshan Mountain in the east were formed. The inner Sichuan Basin remained stable.

Up to Tertiary of Cenozoic, especially at Miocene 10-20 million years ago, the Himalaya movement reached a higher level. The old Mediterranean Sea trough disappeared and the folding, swelling, and faulting occurred strongly, and as result peaks were raised over 8000 m., which formed the Himalaya Mountain. New tectonic movement has been continuing. In Yunnan, Sichuan and Guizhou Provinces, these has been strong swelling along the western and southern border of Chengdu Plain resulting in the present formation of the high mountains and gorges in the southwest of China.

When Qingzang Plateau appeared on the earth, it may have influenced or even controlled the climatic conditions in Southwest China. It is also a screen which protects the Northwest from the continental monsoon.

The formation of the Hengduan Mountain range has forced the summer monsoon of Indian Ocean inland and it's influence has reached Southeast Tibet. The distinction between the dry season and the damp season is very clear and the vertical change of climate is obvious, from the cold, icy, and snowy world of the mountains to the tropical rain forests. Annual rainfall is about 336-1764 mm.

In order to get an ideal description of the vertical changes of climate, we need to consider the influence of altitude besides the latitude and longitude of geographical location.

SOIL AND WATERSHED LOSS

The principal forms of soil and water loss and their control in Southwest China:

- Plant nutrients and leaching loss

These are the result of the corrosion, soil acidation, and it's latosolization under the rainy and megathermal climatic condition.

- Squamose erosion

This has been caused by extensive cuttin of trees and vegatation on non-farmland.

- Gravity erosion

After original forest has been destroyed, various forms of gravity erosion may occur when soil is saturated by rain on steep slope. One important form of gravity erosion are landslides.

- Torrential erosion

This is one kind of flood which has not reached satuation state in solid materials. The frequency and area covered by torrential erosion is higher than with debris flow.

- Debris flow

The soil and water loss due to debris flows is an obvious cause of destruction of production and construction in the mountain areas. It can be divided into mud flows, mud-debris flow and water-debris flow. The debris flow will be detailed as follows.

DEBRIS FLOW FORECAST

Debris flow

There are many classifications of debris flow. The debris flow which is discussed in this paper is oversaturation of solid load. It usually occurs in mountain area.

The oversaturation load is when solid is mixed with water. The level of oversaturation of solid load is expressed in terms of the mass of solid materials which flow through a given cross per unit time (kg/sec.). The oversaturation of solid load means, the kinetic energy of the moving solid mass including not only hydraulic power, but also the influence of gravity.

There is one essential difference between the debris flow & soil erosion. The characteristic of the debris flow are that it happens abruptly, flows rapidly and can destroy any thing in general.

If the debris flow forms, there are 3 essential conditions:

- Rapidly gathered surface flow: It is formed by melting snow, lakes and other sources of water. The main meteorlogical condition conducive to debris flows is that there are enough rainfalls before storm rain.

- Having steep slope (>23°), funnel-shaped basin and gradient ratio of the valley (0.14-0.22-0.40).

- There are a lot of solid loads which flow into the valley. Forming oversaturation is a determinal condition.

Although debris flow only happens in vallies, the vallies have the 3 conditions listed above which cause debris flow. However, these vallies are only a small part of the mountain area.

Prediction of Debris Flow

Formation of debris flow makes the oversaturation of solid load as a basic. Most of the materials come from slopes, especially a great deal of solid materials that cause by gravity erosion. These materials are usually the main resource of debris flow's development.

The gravity erosion on slopes is determined by the following condition:

$$Z > p.\ f + c$$

Where: Z --- sheer stress on unit area,
p --- pressure per unit area;
f--- friction factor,
c --- cohesion.

In the equation, "p" "f" and "c" are determined by the slope, materials that it consists of (stands for fine and coarse soil), the depth of soil body, bedrock, vegetation and land uses.

Let "L" stand for the slope and the material it consists of "E" stand for the depth of the soil and bedrock, "F" stand for vegation and land uses, "K" stand for potential intensity of gravitational erosion, then we have:

$$K = f.(L,E,F)$$

The classification of valley's character for the prediction of debris flow is shown in Table 1.

Table 1: Classification of the damage's intensity

Condition of debris flow's valley			C_3 (over-saturation of debris flow)	C_2 (over-saturation of debris flow)	C_1 (slight oversaturation of debris flow)
Time of occurrence & date of heavy rainstorm		Times of debris flow and Peak flood	___	___	___
		Time of rainstorm and rainfall intensity (mm/h).	> Hmax	= Hmax	< Hmax
Debris Flow Fan	Data of slope	Surface slope of sediment,	> 13°	13° -- 8°	< 8°
		Bottom slope of sediment,	___	___	___
		Site of sediment's top valley's mouth	below or equal to mouth	flowing into valley's	flowing into valley's
		Volume of sediment (m^3)			
	Futures of quality	Surface roughness of sediment,	High levels of sediment along water course	relatively flat/ plain	flat plain
		Water course on the sediment,	obvious turblence uncertain water course	water course relatively stable	water course stable and cutting down, having sediment at the bottom
		Skirts of sand	no sediment in skirt of sands	obvious skirt of sands	having sediment of skirt of sands
Analysis of solid load (Soil, Sand, Debris and Rock		Average maximum length of solid load b	> 50 cm	50 - 15 cm	< 15 cm
		Vertical and horizontal distribution of b	no rule on length, due to vertical rise	slight b// direction direction of water course	b// have a wide water course
		Chosen situation of solid load	chosing not obvious	not distributed obviously in parts, but as a whole the sand's volume is decreased	large size sands having fine sand's sediment
		Consistency of solid load	___	___	___
		Rock future of solid load	___	___	___
		Future of filling materials	mud as filling materials	lose and unbroken sand as filling materials	the materials by torrent as filing material
		Roundness of solid load	not similar but to be similar	small roundness obviously	roundness

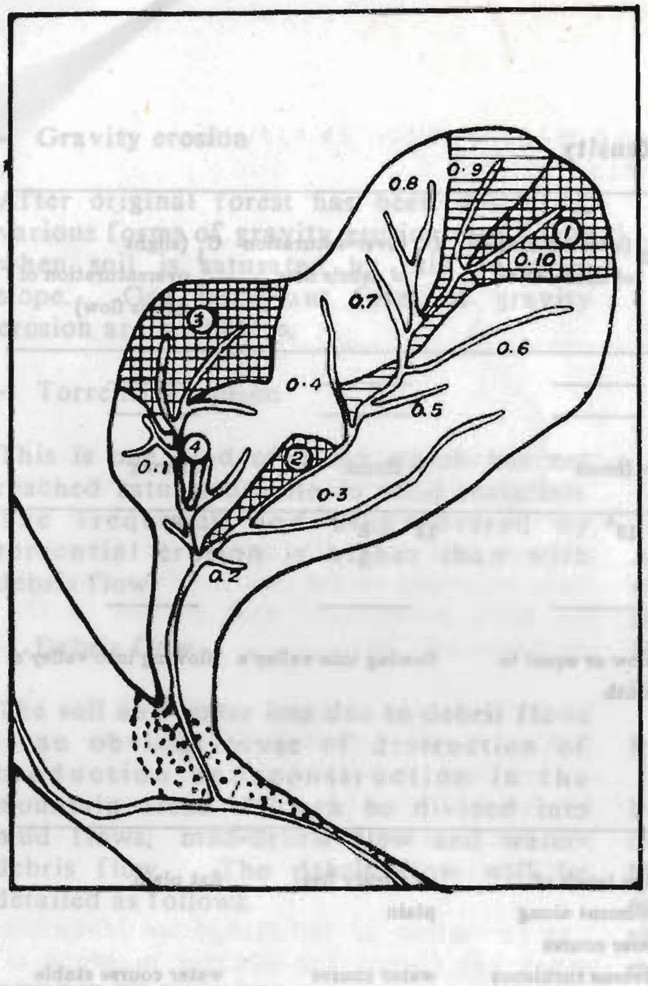

Fig. 1 The dynamic calculating of debris flow

①-④ Gullies

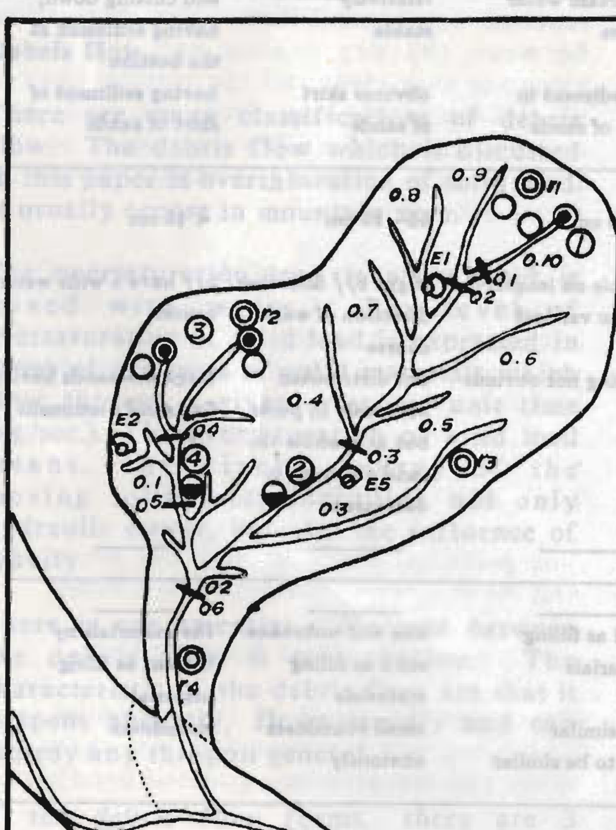

Fig. 2 The desposition picture for debries flow forecast and monitoring

OBSERVATION SPOT

- Dynamic pressure
- Rain gauge
- Tersio metre
- Soil pressure
- Trailing Shooting
- —Qn Weir dam

The basis of the forecast

The debris flow will be forecast according to the varying rainfall level (Fig. 2) at r_1,r_2,r_3,r_4, and rate of flow at Q_1, Q_2, Q_3, Q_4, Q_5, Q_6. If each r and Q are recorded continuously, the varying of rainfall level, rate of flow and runoff coefficent of the subgully will be forecast, as well as the main gully.

The time lapse from the beginning of the rainfall to the occurance of gravitational erosion and debris flow, r_1-r_4, directly depends on Q_1-Q_4. If r_1 and Q_1 vary regularly, the unexpected reduction of Q_2 would mean the occurance of gravitational erosion or debris flow in sub-gully No. 0-10, and if Q_1, Q_2 vary regularly as well as r_1, the unexpected reduction of Q_3 would mean that the debris flow occurs at same time in sub-gullys No. 0-9 and No. 9-10. If r_1, r_2, r_3, r_4 increases regularly, (Q_3 fluctuates) Q_4 is disturbed and Q_6 unexpectedly decreases as well as Q_5, that means there is a serious debris flow in the gully according to the order 4-3-2-1 (Fig. 1 and Fig 2).

As mentioned above, the direct basis of the debris flow forecast is the dynamic prediction, but the basic data of the forecast is the continuous measurement of the rainfall, the rate of flow and the runoff coefficient. There may also be an unexpected case, for example: if variance of Q_1-Q_5 is regular as well as r_1-r_4, but the Q_6 unexpectedly decreases or fluctuates, that means the debris flow would occur in sub-gully No. 0-3, where a safe gully was predicted. So it is necessary to study the debris flow forecast further. The debris flow forecast mainly depends on the oversaturation of the solid load.

An important factor that often is cause of the gravitational erosion and debris flow is excessive rainfall but that is not the only one. If there is not enough solid matter, the rainstrom only forms torrential flood. The debris flow can also be formed by melting snow, melting ice or by if a dam bursts. Further more, apart from the increasing of solid matter, the deceasing of rate of flow also form the oversaturation of solid load. So it is more correct that the forecast mainly depends on oversaturation of solid load.

Suppose the unit weight of debris flow is 1.6, according to the dynamic rate of flow at each rate of flow point, the quantity of solid load matter, which is needed to form debris flow was given as follows:

$$r_o = r.x + r'(1-x)$$

here r_o = unit weight of debris flow
r = specific gravity of water
r' = specific gravity of solid load matter

x = the volume proportion of water in debris flow

$1 - x$ = the volume proportion of solid load matter in debris flow

So the base debris flow forecast is dynamic monitoring with reference to the maximum of solid load matter. In order to avoid error, the minimum of unit weight of debris and maximum of solid load matter are used. The torrential flood which contains a lot of sediment may be regarded as a debris flow.

RAINSTORMS AND THEIR RUNOFF OVER THE HIMALAYAS AND THE TRANSVERSE MOUNTAINS

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INTRODUCTION

Rainstorms can cause severe natural disasters. Runoff from them quickly causes damage through floods of mud-rock flow, stopping transport, destroying highways, bridges and buildings, and silting up reservoirs. As a result, many people and livestock may die and farms and towns suffer heavy losses from rainstroms. Therefore, a study of them should be a priority, not only for meteorologists and hydrologists, but also in civil engineering and river valley harnessing projects.

The Himalayas stretch along the south border of the Tibetan Plateau. They are a strong climatic barrier between the Plateau and the southern slope area. The Transverse Mountains (Hengduan Shan) are located on the east of the Himalayas and run from south to north. They can be considered a climatic barrier between Tibet and the areas to the east of it. The climates of these two regions are quite different from others in Asia.

The climatic characteristics of rainstorms and their runoff in these two mountain areas have not been studied in depth due to lack of data. The authors have collected data both from meteorological stations and through scientific investigations, on the characteristics and formation causes of rainstorms in this region.

RAINSTORMS AND THEIR CLIMATIC CHARACTERISTICS

Definition

In China, when the rainfall reaches 50 mm or more during 24 hours, it could be generally defined as a rainstorm or "hard rain". Similarly, "heavy rain" in these areas implies rainfall of 25 mm or more during 24 hours. However, in defining rainstorms on the Tibetan Plateau, a diurnal rainfall of 25 mm or more, instead of 50 mm, is often adopted as the criterion. The reason is that the rainfall there is much less; diurnal rainfall of 50 mm has never been observed. Even the annual rainfall is only about 50mm.

Considering its relationship with floods and mud-rock flows, heavy rain (> 25 mm) is also discussed in this paper. It should also be mentioned that data on rainstorms and heavy rain are often concerned with annual rainfall on a site.

Spatial Distribution of Rainstorms

Heavy rain and hard rain are comparitively less in the Himalayas and the Transverse Mountains than on the east plain, except for a few sites in the southern part of the mountains, such as Xia Zayu, Huili, and Tengchong. For example, the annual rainfall in Xia Zayu, which is a small town on the southern slopes of the Himalayas, has been near 1000 mm and the number of days of heavy rain and hard rain has been 8.5 and 4.3 respectively. The average annual hard rain there is higher than in many sites on the east plain.

The annual rainfall is less than 400-600 mm on the vast plateau, including the Himalaya-Transverse Mountains. The annual rainfall in the west Himalayas is seldom over 100 mm, and the number of days of heavy rain is between 0-3 each year; there are no rainstroms over the plateau. However, on the southern slopes of the Himalayas and south Transverse Mountains the annual rainfall is more than 800-1000 mm. On the southern slopes of the East Himalayas it can reach 4000-5000 mm per year; and heavy rain for 8-10 days, hard rain for 2-4 days per year. Certainly, the rainfall level increases as it moves closer to the Chinese border.

There are three centres of rainstorms: the lower reaches of the Yarlung Zangbo River and the western slope of Gaoligong Mountain; around Mi-Huaping areas of the southeast Transverse Mountains; and Yaan County of the northeast Transverse Mountains, i.e. in the east and southeastern parts of the Himalaya-Transverse Mountains.

The moisture of the area comes up mainly from the Bay of Bengal. A great quantity of moisture runs along the Irrawaddy River and the Brahmaputra River with the southeast monsoon flow. When the moist air masses are stemmed by the Himalayas and Gaoligong Mountain, they cool and condense causing rainstroms and heavy rain. Baxika is a border town at the end of the Yarlung Zangbo River with an altitude of 157 mm. Its annual rainfall reaches 4495 mm and the mean diurnal rainfall in June and July is over 46-48 mm.

However, in the west rainfall is not high. In Shiquanhe (32°29'N, 79°45'E), at an altitude of 4200 m, the maximum recorded diurnal rainfall is only 24.6 mm.

Rainfall density in the southern Transverse Mountains is higher, especially in Tengchong and Gongshan (Gaoligong Mountain) and in Miyi and Huaping (Jingping-Mianmian Mountains). They have, on average, 12-15 days of heavy rain and 2-4 days of hard rain per year. This decreases as it moves northward, to only 1 day per year and no rainstorms on Garze, Qamdo and other places in the Transverse Mountains.

Temporal Distribution of Rainstorms

There are distinct dry and wet spells in the Himalayas-Transverse Mountains. The dry spell starts in May, except in the lower reaches of the Yarlung Zangbo River and parts of Gaoligong Mountain, where it starts in March. The spell ends in September or October. Rainstorms are concentrated mainly in June and July over the northern Himalayas and the North Transverse Mountains. The maximum diurnal precipitation has reached 55.1 mm in Lhasa. Rainstorms occur almost every month in the south of the area; for example hard rain was recorded in January or December in some sites: Nyalam, Gongshan, Dali and Tengchong.

Rainstorms in the southern Himalayas and South Transverse Mountains are not only frequent but also high-density. Based on observations made in Baxika in 1954, the rainfall in June, July, and August was 1645 mm, 2137 mm, and 1347 mm respectively. That means the average diurnal rainfall was 54.8 mm, 68.9 mm and 43.5 mm correspondingly. The maximum rainfall in Nyalam (102.3 mm) and Pagri (89.4 mm) was in October and caused by the Bengal storms. In Huili and Dali a rainstorm of more than 100 mm was recorded during one summer and autumn, but in Gongshan nothing was recorded in July and September; only once a level of 116.4 mm was recorded in October, caused by the Bengal Low. In sum, rainstorms in the Himalayas-Transverse Mountains could be observed each month, but are mainly during the summer and autumn.

The Weather Systems which form Rainstorms

Rainstorms in East China during the summer season are usually formed in two kinds of weather systems: typhoon, or stationary front, shear line and vortex, (Tao Shiyan, 1980). However it is a little different in the plateau and mountain areas where the main systems are shear line, vortex, and Bengal storm. The frequence of occurrence of each low-pressure weather system during the summer half years between 1969 and 1976, was surveyed. Shear line systems totalled 247, vortex 71, and westerly 97, making a total of 415, (JGTMR, 1981).

Rainstorms caused by Shear Line or Vortex

An example of precipitation caused by shear line occured in July 1974. The rainfall was defined as heavy or hard, at this time, in the Yarlung Zangbo River Basin.

There was a transversal shear line stopped near 32°N on July 10. A long-wave trough was formed to the east of the plateau on the next day. The trough was favourable for the invasion of cold air masses and made the shear development. Three days later, an inverted trough formed by an Indian Low extended into the plateau on 500 mb contour chart. Meanwhile, the West Pacific Subtropical High intensified and its ridge moved westward. The convergence of the flow around the transversal trough line became stronger with intense southwest flow. Then, the cloud masses in front of the Bengal Low stretched to 30°N. The cloud system developed very fast and the precipitation process began over the Yarlung Zangbo River Basin.

As a result, the maximum diurnal rainfall in Xigaze was 30.3 mm, in Zetang it was 42.9 mm which created a new record. On 16th, the shear line faded away with the weakening subtropical high in the West Pacific and inverted trough in the Bay of Bengal. The precipitation then stopped.

Another example of a shear-line rainstorm happened around the Nujiang River Valley, South Transverse Mountains in October, 1979. The synoptic situation on October 2 was as follows: on the 500 mb chart -- a long wave trough by 115°E, a high ridge near the Lake Baykal, a cold trough in Western India, covered low-pressure circulation through the Bay of Bengal to India with a high centre in the Indo-China Peninsula; on the 700 mb chart -- the positions of the trough and ridge are similar to those on the 500 mb chart, but there was a high near Hezuo, Gansu Province, and a strong shear convergence belt between the Hezuo high and the Peninsula high. The synoptic regime did not show any distinct variation on the 500 mb chart except that the cold trough in Western India moved eastward on October 3. But something was different on the 700 mb. The Hezuo high moved into Chengdu (it can be called Chengdu High) and became stronger. The Peninsula high moved southward a little. These two highs played important roles in keeping and intensifying the shear of the convergence belt. Meanwhile, a southeast-northwest strong front was forming over the Nujiang area and there was precipitation on the westward moving cold front.

The process was keeping heavy rain or hard rain on October 4-5, because the synoptic situation was the same as before except for a little move of the westerly trough on 500 mb chart. The long wave trough which was located on 115°E moved nearer 135°E on October 6, and the Indian cold trough moved near 88°E. That means the Nujiang area was in front of the cold trough. Thus, a second rain peak occurred over the area. This process ended on October 8 when the trough passed over the area. It had lasted for five days from October 3-7. The hard rain was observed in some counties of the Nujiang area during the whole five days. The maximum diurnal rainfall in Fugong was 121 mm and the process rainfall was 419 mm. All caused a maximum flood peak in the Nujiang River.

Vortex is also an important weather system causing heavy or hard rain over the Himalayas-Transverse Mountain area. An example of heavy rain happened over the northern Himalayas in July, 1962. There was a shallow trough near Nagqu on the 500 mb chart, on July 25. The southwest flow in southeastern Tibet coincided with the wet tongue on the 500 mb chart. Then the shallow trough developed into a vortex and extended. At the same time, the Subtropical High of the west Pacific stretched westwards near the plateau and stopped the vortex moving eastwards. With the southward upper trough and the northward inversed Bengal trough, the cold and warm air masses met and formed a rain area over the Lhasa River. The maximum diurnal rainfall was over 44 mm.

The well-known "81.7" (July, 1981) rainstorm was caused by a vortex under special atmospheric circulation. The eastern Transverse Mountains are located on the border of the rainstorm area (Zhang et al, 1981).

Since the West Pacific High extended into Southwest China along 24-26°N, there was a strong stationary south flow over Yunnan and Guizhou. It was sure to transport the warm moisture. The southwest vortex was developing fast. The vortex was quite deep and thick (over 10 km). Since the atmospheric barocline became strong with the deepening westerly trough, the vortex still intensified and developed. The high over North China was steady and favourable for the transportation of moisture and for the development of the vortex over the Sichuan Basin. The Bengal

Low was developing and coincided with south flow from the west part of the West Subtropical High. A lower jet was found over the Guizhou plateau and causing a lot of moisture to enter Sichuan Basin.

Under the coaction of these factors, successive rainstorms were observed over west Sichuan and the east Transverse Mountain on July 12-13. With mud-rock flows in hundreds of sites, an exceptionally serious flood was caused in the area resulting in extensive damage.

Bengal Storm

When the Bengal storm influences the Tibet plateau, a rainstorm or snowstorm could be produced. However, there would have to be a strong typhoon near the coast.

A tropical cloud mass was found on the Bay of Bengal based on a satellite cloud picture taken on October 4. It could not be considered a tropical storm till October 7. While the storm moved northward the south branch of a westerly trough developed and moved southeast. The cloud systems between the storm and the trough gradually closed together. They combined on October 11 and snow began to fall on the south slopes of the Himalayas. As the storm became stronger, the snow belt, extended north. The next day, it was over northeast India and the cloud system made a snowstorm over the Himalayas stretch into the Tanggula Range (the total area is several hundred thousand km^2). In Pagri, the maximum diurnal snowfall broke the historical record and set a new record of 120.6 mm. Such a rainstorm or snowstorm not only depends on these weather systems (shear line, vortex and Bengal storm) but on the coaction of another. Sometimes, the construction process of a rainstorm (or snowstorm) is quite complicated.

Rainstorm and Topography

A rainstorm is always produced in a warm wet flow with strong ascending movement, and belongs to a convective kind of weather system. It also needs a stable synoptic situation to retard the process of the rainstorm system, and favourable topographical conditions.

It has been mentioned before that rainstorms on the south slope of the Himalayas happen more often in sites at the same latitude as the plateau. The lower reaches of the Yarlung Zangbo River is one of the moisture passageways to enter the plateau. More rainstorms can be observed there. Medog is a county located in the southern slope of the Himalayas. Based on observations made in the county seat from October 1973 to September 1974, six rainstorms occurred in May, June and July. Another temporary observational site is close to the county seat and its topography is shaped like a horse's hoof. The result of a one year observation (February 1983 - January 1984) showed total rainfall over 200 mm and 10 rainstorm days most of which were in June and July.

One thing that should be mentioned is the "maximum precipitation height". Rainfall generally reaches a maximum near the height and reduces with the increased distance from the height. Figure 11 shows the distribution of the maximum precipitation height for annual rainfall around the whole plateau (4) mention. The height over the Himalayas-Transverse mountain area is about 2-3 km. Three sites, Baiben, Hanmi and Nage, were chosen for rainfall observation during the scientific investigation around Mount Namjagbarwa, in the summer of 1983. Their locations are not far apart and they all face southeast.

The heights of the locations are 780, 2100 and 3200 m respectively. Some observed data from July 11 to 31 is listed in Table 5. It is obvious that the total rainfall increased fast with the increased height during each period: July 11-21, July 11-31 and August 1-31. So did the heavy rain. For example, during July 11-21, the heavy rain was recorded once in Nage and the diurnal rainfall was 31.9 mm on July 15. On the same day, the rainfall in Hanmi, which is lower than Nage, was only 2.8 mm, there was no rainfall on the lowest site, Baiben. The maximum precipitation height on one slope could be distinct from that of another slope. Based on observation around the Mount Baimaxueshan from 1982 to 1984, the maximum precipitation was found to be at 3760 m. altitude, over the eastern slope of the mountain. Almost all rainstorms around this area were recorded near this level. However, rainfall always increased with height over the western slope. The maximum precipitation height might be higher than the peak height, and there was no rainstorm on the western slope. The quantity and density of the precipitation on the eastern slope was more than on the western slope except at the foot of the mountain (Table 6).

The reason might be the action of a lee wave. So it is not difficult to see the siutation: rainfall on the peak of the hill and floods at the foot of it.

The Runoff Caused by a Rainstorm

The runoff caused by rainstorms over the Himalayas-Transverse mountain area is very little, and the water-collecting area controlled by one hydrological station is quite big. It is difficult to calculate the results of the runoff. In this paper, authors will try to give a preliminary analysis on it based on some observed facts and hydrological data.

Some Characteristics

The characteristics of the runoff produced from a rainstorm varies with geographical environment. The flood discharge of most rivers over the Himalayas-Transverse mountain area is caused mainly by rainfall; only a few rivers near glaciers or snowfields can get much water from the melting ice or snow rather than from precipitation. Since the area of runoff concentration in larger rivers is big, the maximum peak discharge and the maximum rainfall density are not synchronous.

The storage ability of some smaller river beds in the mountain area is limited. When a rainstorm occurs, the surface runoff into the river happens very fast because of steep slopes. The discharge and level of the river increases in a short time. When the rain stops, the flood disappears equally quickly.

Concerning rainstorm occurrence, the runoff in the south part of the area begins earlier than that in the north part. The flood period in the Zayu River Basin, the Nujiang River Basin and the Duolong River Basin, occurs in March (it is also called "the flood with peach blooming"), and occasionally in May. The maximum flood discharge over the west and north parts of the area often occurs in July to September.

In some rivers, the proportion of the maximum diurnal runoff of the whole annual runoff is larger, generally as 1.2% or more, with a maximum of 4%. The maximum diurnal runoff modulus is about four times as large as the yearly mean runoff modulus, sometimes over 14 times more. The ratio of the maximum to the minimum is 200:20.

Distribution

The geographical distribution of the runoff over the Himalayas-Transverse mountains coincides with that of rainstorms. The runoff in the southern part of the area is much higher than that in the western and northern parts.

If the water-collecting areas are similar, the maximum diurnal runoff and flood peak discharge in the southern part of the Himalayas or the Transverse mountains is larger than those in the western and northern parts. Table 7 shows an example for comparison. Hydrological indices in the station Gyangze, the Nianshu River, Tibet are smaller than those in other hydrological stations. The average maximum diurnal runoff moduli for other sites are 15 or more times as large as those in Gyangze.

The maximum diurnal runoff modulus over the northern part of the Himalayas is near 70 l/s. km^2. Than means the area is a low value region. However, the southern Himalayas and the east and south Transverse mountains are high value regions. Their moduli in some rivers are more than 200 l/s. km^2.

The peak discharge in the many rivers over the area is quite huge because of the concentrated rainfall over a few months and the big water-collecting area. The mean flood peak discharge in the station Nuxia, where the water-collecting area is near 190,000 km^2, is 8090 m^3/s, but the maximum reached was 12,700 m^3/s on August 31, 1962. There was an exceptional rainstorm over the middle reaches of the Nujiang River in October, 1979. Rainfall in Fugong was 419 mm, and in Liuki 355 mm. A maximum flood peak discharge, 10,400 m^3/s, was observed on October 8 in station Duojieba, where the water-collecting area in near 119,000 km^2 and the mean flood peak discharge was 6470 m^3/s. The maximum discharge was nearly twice the mean.

The Damage and a Prevention and Control Approach

The serious weathering and developing joint are distinct features along some rivers over the Himalayas-Transverse mountain area. The slides and mud-rock flows are frequent here in the rainy season. The damage, can be on a large scale destroying transportation facilities and agriculture.

In the lower reaches of the Yarlung Zangbo River, the surface horizon has been scoured off and the rock is bared in many places on the banks. The reason is the strong runoff caused by rainstorms. According to the survey of the well-known "July, 1981" rainstorms, the mud-rock flow gully was found over 150 sites in five counties of east Transverse-Mountains. The damage to local houses, agricultural fields and livestock is difficult to count. There was another rainstorm in the Nujiang River Basin in October, 1979. The damage again was serious: 180,000 mu (1,200,000 ha) inundated fields; 10,000 destroyed houses; 41 broken bridges; 1020 slides on the highway; 230 people hurt of killed. In a few places, the slides and mud-rock flows are frequent during the rain season, even though the rainfall has not reached the criterion of rainstorm. One such site is around Tongmai located on the highway from Chengdu, Sichuan to Lhasa, Tibet. Road blocking is a major problem there. The following approaches could be adopted for preventing or reduces the damage caused by the runoff from rainstroms:

- Afforestation of the area. Large-scale forests are effective stores of soil and water and can reduce the flood peak discharge. They may also improve the ecological environment.

- Constructing or reconstructing flood control installations. The capacity of reservoirs should be enlarged; the ability of civil engineering to store flood should be enhanced; the river course should be unblocked.

- More research on the rainstorm and its runoff is required. Prediction especially should be reinforced, including long-, medium- and short- range forecasts.

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RESEARCH AND TECHNOLOGY

GUIDELINES FOR FIRST-STAGE RESEARCH OF WATERSHED MANAGEMENT IN THE DRY VALLEYS OF THE HENGDUAN REGION

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INTRODUCTION

A multidisciplinary reconnaisance was carried out in 1984 throughout the dry valleys of the Hengduan Mountains, by the Commission for Integrated Survey of Natural Resources. A number of natural scientists participated including physical geographers, pedologists, plant ecologists, geomorphologists, hydrologists, climatologists and one economist. We were asked to offer a general comment with research guidelines for further investigation concerning the management of the dry valleys which are considered to be a special kind of watershed in these particular areas.

The dry valleys within the Hengduan area along the three gorges of Nujiang (Salween), Lancangjiang (Mekong) and the upper reaches of Changjiang (Yangtse) and its tributaries (the Jinshajiang, Taiduhe and Minjiang), and the Yuanjiang (Red) in the southern Yunnan. They are not only of academic interest but also of great importance to agriculture due to the better water resources and the concentrated terrace farmland there which hold about 90% of the total farmland, and are the most populated settlements of the area.

According to Wagner's theory of Berg-und Talwinde (1932) and Flohn's review of local wind system (1968), Schweinfurth (1981) pointed out that the phenomena of "Local dryness" in the valley bottoms observed in the Hengduan region were comparable to what had been reported from parts of the Himalayas. In the Hengduan, they were developed on a much grander scale. The vegetation area has been drawn out through almost all the gorges from about 31^{0}N to about 22^{0}30'N at the south border (Wu, 1980). In most of the valleys, the farmland suffers frequently from water shortages because of the climate and other environmental conditions as well as a drastic, unfulfilled irrigation requirement. It seems somewhat of an oversimplification to treat the dry valleys as a single type of landform because the great latitudinal and longitudinal breadth of their distribution gives considerable variation in physical environment as well as in agriculture systems.

DRY VALLEYS

Classification:

For the purpose of dry valley management, it is necessary to identify them on the basis of climatic criteria. Using the aridity index of Penman (1962), the data from 58 meteorological and hydrological stations, was analysed and the result shows that the dry valleys of the area belong to the semi-arid category and can be subdivided into three patterns according to the degree of dryness which varies locally, e.g. tending to semihumid, normal or arid. The temperature index is taken as the criterion for the climatic regionalization on a large scale. The combination of the two climatic indices give three major types : hot-dry , warm-dry and temperate-dry; and seven subtypes illustrate the vegetation diversity and the regional variety of farming in general (See Table1). Furthermore, each type and subtype is characterized by distinct upper natural zones of predominantly wet vegetation.

Distribution

There are nineteen sections corresponding to the semi-arid climatic type, in the seven rivers mentioned above. They are distributed discontinously and occupy about 11,403 km^2 in total. The most widespread type is the hot-dry followed by the warm-dry and the temperate-dry (Fig. 1). It is not suprising that this result is not in agreement with the previous vegetation map which is based on the

Table 1: Criteria for the Classification of Dry Valleys in Hengduan Area

	Annual T. July T. Jan. T.	Aridity (Semiarid)	Annual rainfall (mm)	Extant Vegetation (Original vegetation)	Cropping	Yield without irrigation
Dry-hot	20° 24°-28° 12°-7°	Tending Semi-humid[1] 1.5-2.0(2.2)	800-900	Shrub-grass with trees scattered (Dry monsoon forest)	3	rather good(I)
		Normal (II) 2.0(2.2)-3.4	800	Small-leaved mesoshrub (Pine or oak forest)		not bad(II)
Dry-warm	14° 22°-24°	(I)	800-900	Shrub-grass with trees (Pine or oak forest)		(I)
	5°-7°	(II)	600-700	Small-leaved deciduous shrub (Pine or oak forest)	2	(II)
Dry Temperate	10°	(I)	600-700	Broad-leaved deciduous shrub (Pine or oak forest)	2 almost	(I)
	18°	(II)	500-600	Small-leaved thornlet shrub (Pine Juniper forest)		(II)
	0°	Tending arid (III)	300-450	Small-leaved thornlet shrub (Open pine-Juniper forest)		unstable (III)

1 Flohn, 1968

extant vegetation only, because without the help of climatic data, it is difficult to dintinguish the natural vegetation forms from the secondary savanna-like grasswood in such an enviornment degraded by long-term human activities. In the great mountain chains ranging in different geographical positions and with abrupt and complex topography, there are enormous regional and local changes of such dry areas. Nevertheless, the valley bottoms of the gorges can never be replaced by the wetter vegetation which appears constantly at a certain altitude above.

It is interesting to point out that most of the dry valley sections are located within the regional centres of lowest rainfall. These centres are situated in geographical positions that are subjected to the effects of rain-shadow in the area. It is reasonable to suggest that the local dry phenomena occurring on such a scale may be the result of the interaction of climatological factors, although the local wind system could play the most important role, including those of the circulation system, regional climatic system and local current system. All the factors may strenghten or weaken the development of valley dryness in a given period of time, as shown in Fig. 2.

MANAGEMENT OF DRY VALLEYS

The classification of dry valleys may contribute as an indicator to show the possible potentional for environmental improvement and agriculture development in different sections unclassified areas with aridity indices less than 1.5, are known by the local people as a kind of dry valley with scant vegetation, serious soil erosion and irrigation shortage. But, those sections are better characterized by climatic conditions when they show a surprising potential for tree growth and incidentally provide evidence that most of those sections must once have been natural forests of subtropical evergreen trees.

Under a semiarid climate, dry agriculture can exist, so in the mind of local farmers and even officers of the local governments, the land of dry valley has high potential. During the past decades, the policy of the government has prompted the farmers to enlarge cereal crops to increase food production. Because of that the limited terraces in the valleys have been farmed exhaustively; expansion of cultivation could only be onto the steep slopes. This led to accelerated forest clearing and soil erosion, damaging downstreams and reservoirs. In addition, the deforestation on the high slopes, regular removal of firewood near the settlements, and road cuts or other misplanned construction in the area have facilitated slope instabilization, sometimes with cataclysmic results.

The deforestation in the dry valleys produced a vast range of pasture which can only support poor grazing of goats because of the adaptability of the goats to low quality feed, drought and rugged terrain. A misleading policy was established in the last decades to promote goat pasture which resulted in overgrazing, especially preventing growth of plants and compacting the soil, despite the limited economic value of goats products on the market.

Man-made factors intensified the deterioration of the ecological environment in the dry valleys. It is almost impossible to find any ecosystem without intensive and direct human influence in the whole area, but, many people attribute the deterioration to unchangable natural factors. So, making a scheme to show the whole picture including all the factors and their interrelationship may generate further understanding (Fig. 2).

With the practise of Four Modernizations, a basic principle of the policy for mountain agro-system reform is to emphasize increasing the income of the local farmers and in the meanwhile to improve the degraded ecological enviornment. For a long time people know that the diversity of the mountains environment has resulted in a wide range of subsistance resources. This is considered to be a strong support for the strategy of reform to develop a multiple cropping-system, replacing the former single-cropping of cereal, based upon the discussion above, and taking a more realistic attitude, the first step in the management of the dry valleys should focus on the conversion of the misused lands, especially the steep slope farmland, to land available to plant perennial, noncereal crops or to abandon for regreening in order to minimize, at least by degrees, the serious extent of ecological deterioration. For that further investigation should be concentrated on the following:

a. Analysis of basic data provided by the local government (environment and its vertical variation, landuse patterns and their distribution, the dynamics of shifting cultivation in the hot-dry areas, local economic activities, national economic priorities).

b. Assessment of the extent of landuse

   - classification of actual misuse of agriculture land based on standard criteria (slope gradient, soil quality)

   - quality of grazing slope (vegetation cover, abundance of palatable plants, soil)

   - habitat of silviculturing slope (soil, microtopography available and its plant percent)

c. Suggestion of farmland conversion and land protection.

   - the sites for conversion, based upon the degree of their deterioration.

   - alternative uses of the converted land (following crops or the kinds of regreening)

   - the land which should be prohibited from goat-grazing

   - which forest should be prohibited from cutting.

d. Based on the experiences of dry valley management of the local governments, to develop the three types of dry valleys respectively.

All the studies suggested above should be paralleled by studies of socio-economic aspects of the minority. The best way is to organize integrated research with the participation of experts of natural, social, and economic sciences and the officials concerned from the local governments, because the primary and final objective of watershed management in the dry valleys should not only benefit the local people but also contribute the resources to national modernazation, and minimize the negative effect downstream. The government should pay attention to the management and make an effort to get a compromise between national or regional priorities and the local goals, although, to reach a compromise in some cases might be difficult; for example, the forestation needed by the national government in certain places would be unacceptable in terms of the interest of local people.

For the first stage of dry valley management, the decision makers of the local government must consider relying on national and regional policy and common engineering works to promote reform on the one hand, and to fit the development of the so-called third and fourth industries, inside or outside, on the other hand, which may be a decisive influence on the reform undertaking. Figure 3 shows the three major systems (Administrative, Agro-ecological, Economic) in the overall framework of the dry valley management. It is not a working model but gives comprehensive concepts for the decision makers and is a scheme for the continued refinement of further research projects.

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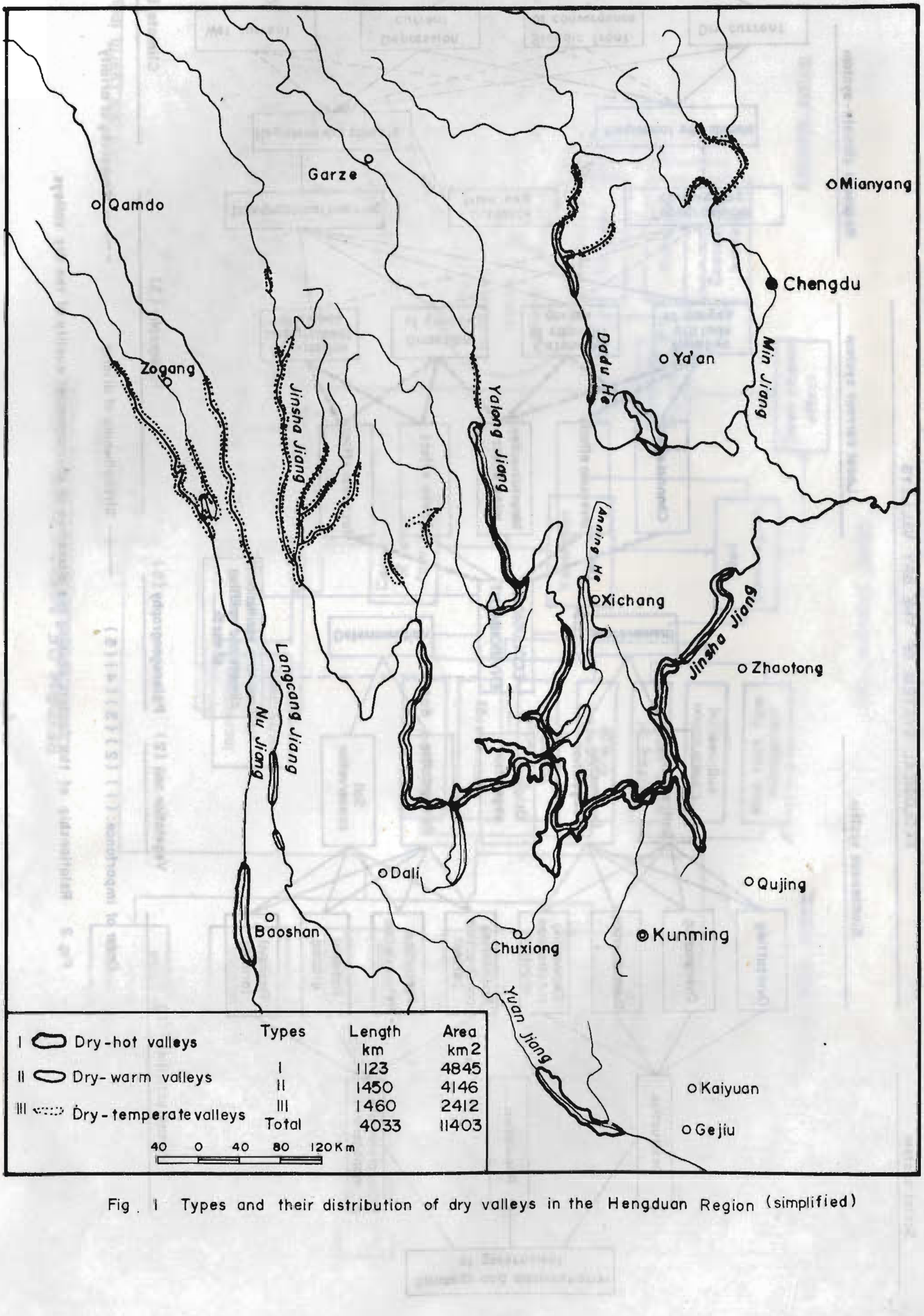

Fig. 1 Types and their distribution of dry valleys in the Hengduan Region (simplified)

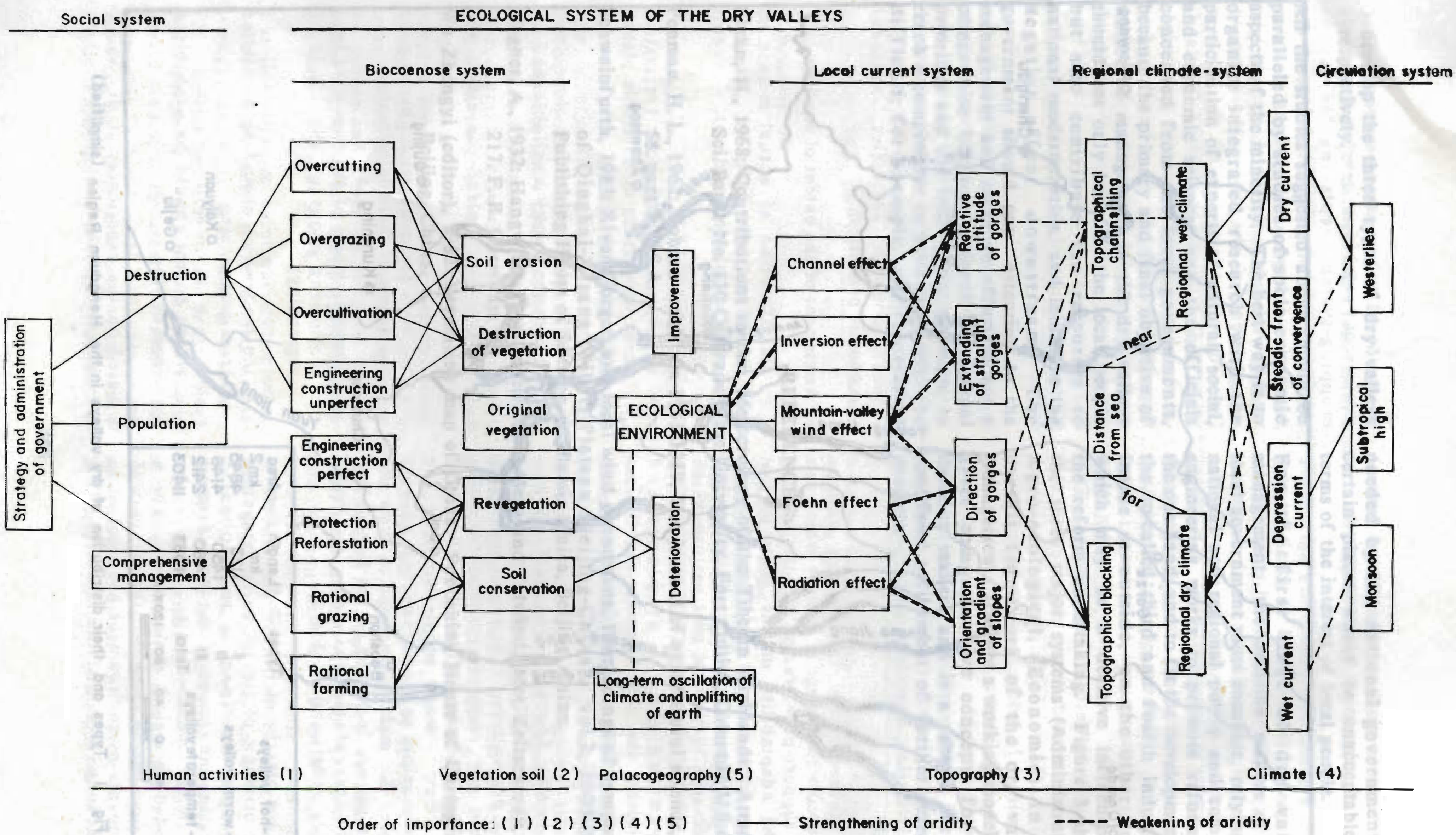

Fig. 2 Relationship of the factors causing the alteration of environmental quality of the dry valleys.

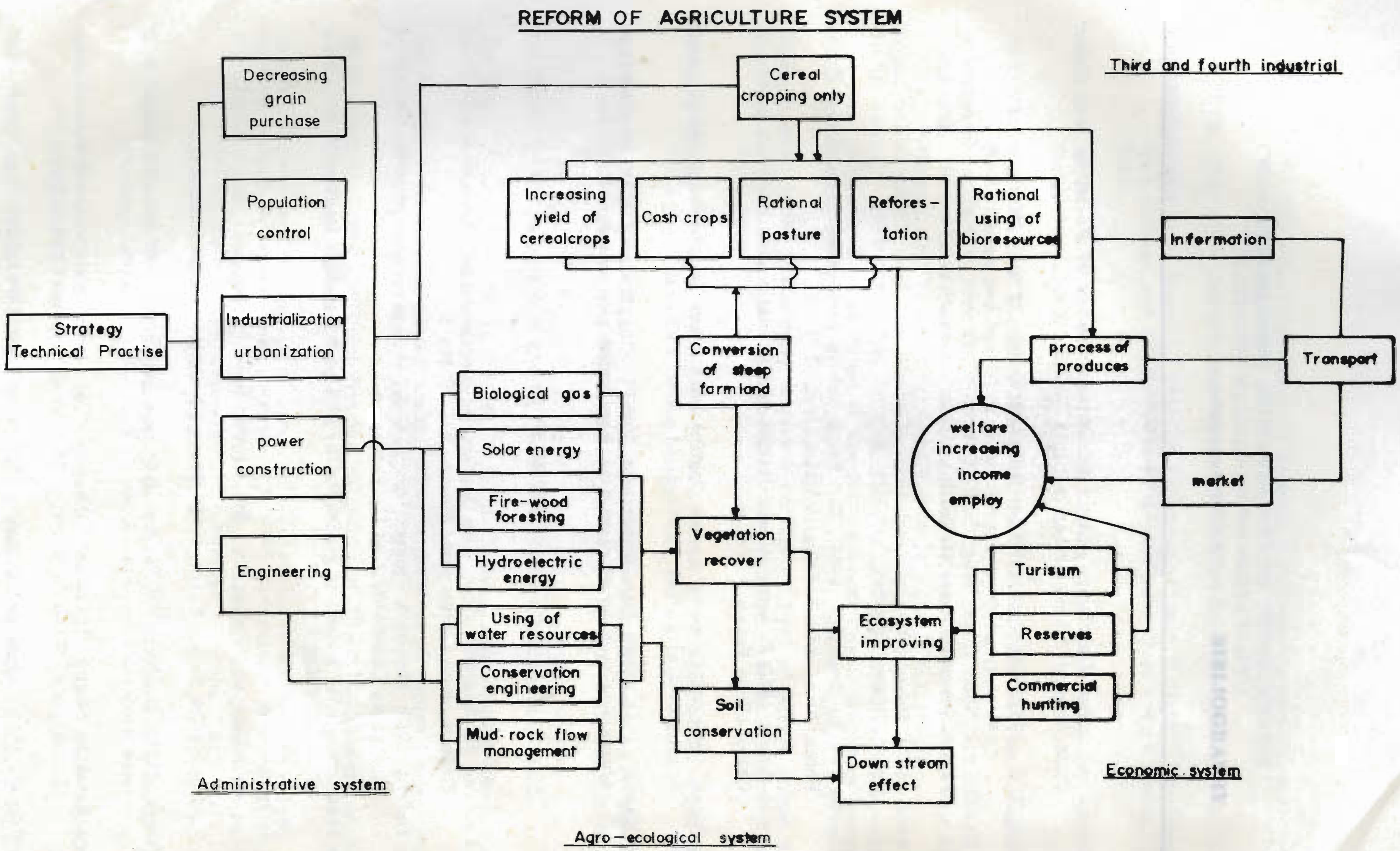

Fig .3 A general scheme for comprehensive management of the dry valleys in Hengduan region

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