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 hydropower 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
Diqing	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 $0.002 m^3/s$ and $0.0017 m^3/s. km^2$ 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 FϼREST 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	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					Mean Annual Runoff		
	Catchment	Forest		Rainfall	Runoff	Modulus	Depth
	Area	Cover					
(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.**

	Year	Discharge (m^3/s) 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.