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

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

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	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

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 km^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 rive. 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.