Chapter 2
Water Harvesting in the South Western Mountains of China

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1. Overview

Water harvesting plays a vital role in mountainous areas, especially in the alpine regions where mountain inhabitants live on sloping lands and have agricultural land at higher elevations where water supplies a are less than required. In this situation, people have to travel long distances to fetch limited amounts of water. In many cases, water scarcity is widespread in the high mountains because poor water retention capacity. Hence, water harvesting is necessary to provide sufficient water for people, livestock, and agriculture in the mountain regions.

In order to provide water to people dispersed over difficult terrain for their animals and crops, water harvesting has been promoted rapidly in arid and semi-arid mountains of China and has also been actively promoted in the alpine regions of southwest China. For example, the southwest mountain areas in the middle reaches of Yaluzangbu River in Tibet have more than five thousand storage structures for water harvesting. Notwithstanding, there are still 250,000 people for whom water supplies are insufficient and for whom none of these structures are in place.

On the other hand, water harvesting has been successful in the Hengduan Mountains of Yunnan and meets the needs of 98,100 people and 69,000 animals in Nujiang county. However, another 58,400 people and 40,100 animals still do not have sufficient water.

In the alpine regions of southwestern China, water harvesting practices consist of collecting rain water runoff from very small or small catchments, the extraction of subsurface flows or interflows, digging of superficial wells to draw infiltration rain water or spring water, and roof rain catchment. In the absence of conventional irrigation systems, rain water is used to irrigate farmlands and ranches.

The mountainous regions in China account for 70% of its territory, and water harvesting is both very useful and also holds promise for the future. Besides the alpine areas, all the arid and semi-arid regions, which occupy two thirds of Chinese territory, including the rain shadow belt of the Himalayas and 6,600 or more islands along the sea coast, are introducing water harvesting to overcome water shortages.

2. POLICY AND PLANNING

Policies on water harvesting

According to the Chinese constitution, water resources, like other resources, belong to the state. Without water harvesting, high mountain areas would suffer from water shortages. This would result in loss of productivity and immense difficulties in developing and managing mountain areas; in addition to insufficient water. Hence, the Chinese government has promoted water harvesting and introduced many relevant policy measures and codes with the following six characteristics.

The Chinese government advocates water harvesting in the mountains, and gives priority to investments in water-harvesting projects. For example, the government offers more than 70 million yuan annually to develop **"One Jiang Two He"** regions: the Yaluzangbu River, Lhasa River, and the middle and lower reaches of the Nianchu River. These regions cover eighteen counties and cities. Out of the total investment, 50% is used to build water facilities to provide Tibetan counties and townships with engineering facilities to establish water-harvesting structures. Up to the end of 1996, the total fixed assets of irrigation works in Tibetan project areas was 12.9 billion *yuan*, and two hundred irrigation areas had been established. These areas have 5,000 or more water storage projects, 34 reservoirs with capacities greater than 100 thousand cubic metres, and 14 thousand water extraction projects. Owing to such water harvesting installations, two thirds of the cultivated land along with some grasslands are irrigated properly and urban water supplies are sufficient. On the other hand, water supplies are insufficient in some farming areas, and 250,000 people are still short of water.

Water harvesting and poverty alleviation

The harsh natural environment exacerbates poverty in these regions. The Hengduan Mountains are a prominent example. Blocked by high mountains and deep canyons and situated in a remote belt where the upper reaches of the Nujiang River, La-chang River, the Jinsha River, it contains more than 40 underdeveloped counties where 20 minority groups live. Insofar as harsh natural conditions prevail on the Qingzang (Qinghai-Tibet) plateau, poverty also prevails here: for instance there is no electricity in 21 countries, a situation that prevails in only 28 counties in China as a whole.

The most effective way to alleviate poverty is to build irrigation systems and roads. Therefore, the Chinese government drafted a notification about how to eradicate poverty from poor and disadvantaged regions in September 1984 and has been carrying out a plan for replacing aid with labour since that time. The plan includes building roads and irrigation works and developing water resources and so on. To improve the living conditions of mountain inhabitants is seen as the ultimate policy and aim of the government. Nowadays, the plan has promoted seven projects, all of which have a connection with water harvesting. Five of them are in quite similar and involve establishing water-harvesting facilities.

The funds for water harvesting come not only from the government's poverty assistance programme and the appropriation of small irrigation works, but also the aid donor's consortium. Since the inception of China's 'open door' policy, the total amount of international loans directly used by poor and underdeveloped regions in China is approximately 1.5 billion U. S. dollars, most of which has been spent for water-harvesting systems. For example, the World Bank loaned 0.25 billion U. S. dollars to assist the southwestern poor mountainous regions of China.

From the report of World Bank and its subsidiary, IDA, people in the poor regions of developing countries can benefit most from assistance for water harvesting, transport, education, and hygiene.

In China, local governments and water users conjoin to draw up extended plans for water harvesting, and these are supported by local government finance and to a certain extent from the consumers themselves. Local governments provide most of the funds especially if a plan is for poverty eradication, while local people mainly provide labour to build the system. Because water supplies can lead to improvement in local economies and increase in local living standards, there has been an increase in systems built on a voluntary basis by local people. MangKang County, located in the southeast of Tibet in the parallel flow belt of three rivers (Jinsha River, La-chang River and Nu-jiang River) in the Hengduan Mountain region has had a water-harvesting policy based on its needs and conditions since 1965. Different methods are followed and, depending on diversion projects, indigenous methods and miniature hydraulic works were used involving voluntary labour. These have irrigated 1,380 hectares of farmland, built 84 pools with a total capacity of 35,600 cubic metres and improved a further 4,000 hectares of land by controlled irrigation.

Increasingly, provincial governments and many local governments in mountain regions have encouraged households to construct water harvesting systems for drinking water supplies and to develop yard economies.

In 1995, Ganshu Province government began its rain water catchment policy to put its **'1-2-1 rain water harvesting project' into operation**. This means that **each household** in the project area makes use of the house, roof, and yard to catch rain water by forming a **one hundred square metre compressed surface** with poor permeability to collect rain water. The collected rain water is stored in **two cisterns or tanks** separately for drinking and production uses. **One** of them is projected to supply water for **one *mu* (15 *mu* per hectare) of land so that cash crops can be planted in the yard around the house. So** this is called a **'1-2-1 project'**. Up to the end of 1996, rain water cisterns reached 525,600 and the total area of yard economies extended to 7,813 hectares and 11,700 or more yard economy units were involved in livestock breeding and processing. At the same time, the project provided drinking water for 267,300 households with 1,310,200 people and for 1,187,700 livestock. Now, in the Ninth Five-year Plan (1995-2000), Ganshu Province has planned to expand water-harvesting areas to 266,667 hectares. Obviously, this illustrates the important role government policy plays in developing water harvesting.

Taking advantage of water cisterns, Shanxi Province started to implement a so-called 'nectar project' to encourage water harvesting in all the mountain areas of the Province in 1996.In accordance with the project proposal, Hengshan County in the Province proposed a **'21211** project' to carry out the 'nectar project'. The **'21211** project' means **two cisterns, one 'mu'** (0.0667 ha) of garden, **two mu (0.1334** hectares) of water-saving cropping, **one thousand 'Jin'** (500g) **per capita** with earnings of **one thousand 'yuan'**. Counties like Hengshan and Wuqi have achieved **21211**'s aim initially and made appreciable progress in agricultural development by using rain water cisterns.

Combining rain water catchment systems with other miniature water development projects, the water-harvesting policy for southwestern China has adopted an integrated approach. In the mountain areas of this region, the high mountains and deep canyons hinder movement of local commodities and, as a result, the local economy. Additionally, both the predominant natural economy and bad infrastructure (facilities) make the economic basis weak and productivity low. Furthermore, cultural diversities also make local management complex. All these factors augment the disadvantages from which the area suffers. Although sources of water are plentiful enough in the mountains, cultivated land is impoverished and cereal production limited, making it difficult for people and their livestock to survive let alone develop the economy. Only by conserving water can the current situation be improved. As everyone knows, besides illumination, hydropower can be used to process grain, feed stuff, and food, employ labour off-farm, and provide alternatives to herding in industry and associated sectors. Moreover, since firewood can be replaced with hydropower, forest and grass can be protected, conserving an environment that is conducive to agriculture and animal husbandry by preventing soil and water loss.

A demerit of hydropower establishment is the substantial investment needed for construction and the amount of time it takes compared to thermal power plants. However, when hydropower is associated synthetically with flood control and water supplies for irrigation, the investment is worth carrying out with higher benefits compared to costs. Therefore development of miniature water structures should be encouraged, so that water resources can be exploited in an integrated manner to provide a big economic benefit from such policy.

Water-harvesting planning

Sustainable development must be considered as the final goal. So far as water resources exploitation are concerned: firstly, the development and use of rain water should support water resource systems to be continuous and sustainable; secondly, the developm.ent and use of rain water resources should be associated with meeting the requirements of social and economic development at local level. These two factors are mutually dependent, so that rain water harvesting is of great significance and must be integrated with sustainable development.

Harmonious development of human activities, rain water resources, ecology, and the environment should be the principle for planning. It is well known that water is one of the most important resources for human survival. This resource has two attributes. While the positive attribute of water is that it is a useful natural resource essential for human production and survival, the negative attribute is its association with disasters that threaten and harm human beings such as floods, water logging, and drought. Rain water harvesting should be organised in such a way that water can be supplied to people who are living on high mountain slopes away from streams.

Based on the hydrological cycle, rain water should be seen as an original source transforming into surface water, soil water, groundwater, and water contained by vegetation. So harvesting rain water involves integrated development of all water sources for use.

Priorities for increased water-harvesting activities are planned over the long term in accordance with objective of meeting the growing needs of the population growth and increased production by mountain inhabitants. Water harvesting has to be planned in accordance with the availability of rain water in time and space through careful investigation and survey. This work requires technical assistance from government and relevant institutions.

Planning for water harvesting should follow the sequence outlined below.

- Analysis of basic conditions such as the rainfall regime, topographical conditions for water harvesting, and the socioeconomic situations

- Planning objective, necessity and feasibility analysis for harvesting water, its storage, and use
- Determination of the demand for water for drinking, livestock, and agricultural use in terms of water needed for field crops based on water-saving farming techniques
- Place and scale of water collectors (water harvesting, place and scale) should be planned on the basis of analysis of the balance between water demand and water supply
- Planning of storage techniques by establishing storage structures for water harvesting and storing according to water requirements in mountain communities
- Planning water supplies according to irrigation needs and optimum use of water by proper selection of irrigation systems and facilities
- Budgetary planning and cost-benefit analysis so that funds can be provided to build storage facilities.

The investments for construction should be shared by national and local governments, and water users should provide the labour to implement the plan, to provide water harvesting facilities, and to manage water-harvesting systems.

Four case studies from different mountain regions of China are discussed briefly to illustrate the impacts of water-harvesting policies on the lives of local people.

Case 1: Water harvesting in the southern high mountains of Tibet

Background information

The rain shadow area of the southern high mountains of Tibet, the southern area of Lhasa City, Shanpan prefecture and some counties of Xigaze prefecture are the main agricultural areas; population density in these areas is greater than in other parts of Tibet. Unfortunately, precipitation is only between 300 and 400 mm and the climate is semi-arid. Influenced by the monsoon, about 80% of the annual precipitation is concentrated in the summer season from June to September. Shortage of water is a serious problem in these regions.

Policy and development of water harvesting

In order to solve the problem of the shortage of water for drinking and irrigation, people are usually organised into natural village units to build ponds and storage for harvested water. Methods used include the tapping of subsurface water, the storage of cataracts, the collection of rain water, and diversion of water from storage and creeks, ponds, and others. Such sources are important areas of supply in the dry season.

Mainly, along the banks of creeks and at elevations between 3,500 and 4,200 m, these ponds have different sizes, from tens of cubic metres to millions of cubic metres. Almost every village possesses one or several ponds. In some cases, the ponds are distributed along the low-lying slopes or at the foot of slopes to collect the intermittent flow from gullies and sub-surface water. In such situations, they usually do not dry-up, but it is difficult to fetch water from them due to their distance from the village. In other cases, the ponds are located on the plains to collect cataracts and rain water for people and livestock. However, the quality of the water is poor and the ponds often shrink after the rainy season.

There are nearly sixty small ponds in the five administrative villages lying along the Zhanang channel in Zhanang County, Shannan prefecture. The biggest one can supply water for fifty households, about 300-350 people. However, the ponds are small, and can only supply water for three to five households with about 20-35 people. Owing to the collection of subsurface water and rain water, and even some collection from cataracts, the ponds upstream of the Zhanang channel do not dry up in a normal year. In the dry season, water can only be collected during the night. These ponds can only supply drinking water for people and livestock with a little water for irrigation. On the other hand in the downstream areas of Zhanang channel, the ponds collecting rain water and cataract water are only sufficient for drinking water not for irrigation. They usually dry up in the dry season. In such case, it is difficult to get sufficient drinking water, and furthermore, the quality of water is relatively poor.

Water harvesting and hydropower development

With the improvement of small hydropower schemes in recent years, the government has developed successions of wells for drinking water supply in association with these. Zhanang channel, for example, has twenty wells, but some of them, such as those in Shajia in Xigaze prefecture and others in counties in the Xietongmen region have water that is not suitable for drinking. So there is still a long way to go for drinking water as these wells need to be checked and the water analysed. Nevertheless, water harvesting is still an efficient way of supplying water for rural farmers and herdsman.

Case 2: Water harvesting in the Hengduan Mountains of Yunnan

Background information

The West Hengduan (Traverse) Mountain areas of Yunnan are unique geographically. There are three mountain range systems, viz. , the Gaoligong, Nushan, and Yunling mountains. They extend from south to north and the highest peaks are all above 5,000 metres. Among the peaks, the elevation of the highest peak, Cagert Peak in Yunnan Province, is 6,740 metres high. From these high mountains and snow peaks, the Nu jiang (Salween), Langcang (Mekong), and Jinsha (upper part of the Yangtze) rivers flow southwards.

The Hengduan Mountain areas in Yunnan Province include Diqing Prefecture and the Lijiang area of Nujiang prefecture, accounting for a total land area of 38,000 sq. km. the population is 800,000 and the population density is 21/ km^2, differing widely between sub-areas, with a high of 62/ km^2 and a low of below 8/ km^2. Eighty-two per cent of the population are from minority ethnic groups such as the Tibetan, Lili, and Naxi.

Survey of water resources

The main source of water in Yunnan is rainfall and small amounts of snowmelt in the warm season. So the distribution of water resources in space and time is basically according to the rainfall distribution pattern. Consequently, water allocations throughout the year are in accordance with rainfall conditions. The weather conditions vary depending upon the south current of the dry-hot west wind from November to April; and the weather is mainly sunny with strong sunshine and few clouds. However, when the warm-moist Bengal air current influences conditions from May to October, there is plentiful moisture and thick cloud, causing abundant rainfall on the windward slopes of the three mountain ranges. The densest annual precipitation, for example, reaches 4,000 mm on the leeward slopes and valleys. Because of the orographic influence and rain shadow effect, rainfall decreases gradually from the western to the eastern slopes, and the rainfall increases from the valley bottom to the mountain peaks. Since the river courses are long, the runoff waters from the Nujiang, La-chang, and Jinsha rivers are very plentiful. On the headwaters of these rivers, the flows mainly come from snowmelt and groundwater, and, in the lower reaches, the flows mainly come from rainfall recharge. Furthermore, there are many tributaries and stream networks, with almost one tributary every two to four kilometres.

Development of water-harvesting projects

In the Hengduan Mountains, the rainfall reaches even the highest peaks, but because of the topography and the neglect the area has suffered throughout history, there is a perennial shortage of drinking water for both people and livestock For example, drinking water was provided for 98,100 persons and 69,000 head of livestock by the end of 1988; 58,000 people and 40,100 draught animals in Nujiang Prefecture are without water. There is also another problem in terms of water quality. In this area, water is deficient in iodine and contamination has caused endemic diseases; and these cause serious health problems. Although there are plentiful hydro resources, the current water conservation projects can only control 200 million cubic metres and only 150 million cubic metres are used: about 6.9% of the total water, available (below 0.14% if all available water resources are taken into consideration). The established hydroelectric capacity is 31.9 MW (16.9 MW from the Nujiang River and 15 MW from the Diqing River). Moreover, each county has a mainstay hydropower station, and the townships have mini-structures and small hydropower stations.

Existing problems in technology and institutions

Water harvesting is a very old method of resolving the shortage in supply of drinking water for people and livestock. The technology needs improving, but this is not a major problem. There have been quite a few good examples of yard-economy development through use of water-saving technology. Sufficient input and good instruction are the essential conditions. In the mountains, additional attention must be paid to the hydrologic complexity and adequate policy measures for water harvesting management must be established.

Challenges for water-harvesting technology

Hydrologic characteristics in mountain areas differ greatly from those in the arid and semi-arid plains. The main arguments are as follow. The immense difference in precipitation on windward slopes compared to leeward slopes is caused by the topography and by the rain- shadow effect. The rainfall on the leeward slopes is quite sparse. For example, the annual rainfall in the middle reaches of the Yalu River is only from 300-600mm. Only a small amount of the rainfall converts into river runoff and supplies groundwater, most of the rainfall is lost by evaporation. The evaporation and stream water that flows out can cause a shortage of water. If 10% of the water lost were to be collected, it would provide benefits for 33,682 sq. km land. For windward slopes, the rainfall is plentiful. For example, the annual rainfall on the windward slopes of three mountain ranges (Gaolingong, Nushan, and Yunling) in Hengduan Mountain areas can reach 4,000mm, while precipitation in the arid and semi-arid areas is too low, from 300-600mm. However, because the area has a monsoon climate, precipitation is concentrated between July and September. In addition, on the high mountains and steep slopes, rainfall runs off rapidly. Flooding in the valley-belts provides abundant water in the rainy season. So, these areas are not suitable for habitation and people in this region live on the slopes away from water courses and hence drinking water supplies are short during the dry season. Furthermore, geological formation in these mountain areas is very intense, and the rock patterns are crushed and folded. All these serious conditions have restricted the efficient use of water-harvesting technologies.

Examples of the above problems can be seen in the parallel belts of three rivers (the Nujiang, Langlang, and Jinsha) where as a result of insufficient hydrological investigation by certain gravity flow water projects, site selection was not optimum and resulted in excessively circular channels; and thus water supplies could not be assured. An added problem was serious leakage. All this and bad maintenance have resulted in many projects being out of order. In short, the utility of the projects is poor. In another example, paucity of large storage projects along the Nu-jiang River in Diqing Prefecture, has led to extraction of water by pumping it out from hydroelectric stations. The stations are, however, short of regular supplies of water and the output of hydropower is poor and generation of electricity unstable. A lot of water is wasted during the seasons of abundance, whereas power generation is poor during spate. This has resulted in widespread shortage of electricity. Shortage of electricity consequently affects the development of agriculture and industry in mountain regions. So, water harvesting should be an engineering system based on adjustment of water storage and collection of surface runoff.

<u>General problems in managing water harvesting</u>

Water-harvesting management consists of designing, implementing, and operating activities as well as their social implications. Hence, water-management problems should be considered in an integrated context. Generally, the first problem is that each office for managing water resources does things in its own way and takes little care of the mutual relations and cooperation among government organisations and administrative divisions. For example, separate departments administrate water supply, irrigation, hydroelectricity, aquatic ecology, and transportation. Water quality, quantity, and the environment of water bodies are the responsibility of different offices or agencies. So, comprehensive planning of water development does not take place.

The second problem is lack of systems supporting maintenance supporting. In general, after a mainstay project is finished and some irrigated areas begin to profit from a project, the project is no longer listed in the budgetary plan associated with maintaining project structures. The maintenance of structures and associated project systems are neglected for a long time because of the poverty of the local people who are unable to bear the costs of irrigation. In the end, many irrigation systems cannot attain their projected goals Furthermore, after the irrigation systems are transferred to the administrative office, water fees are needed to operating it. This includes the costs of salaries and welfare of the administrative staff. Therefore a certain subsidy should be provided to mountain people by the government. The third problem, however, is that the project, when combined with poverty alleviation, is less concerned with the costs of water. Thus projects emphasise the economic benefits and ignore the accounting aspects, assigning a lower price for water than its actual economic value. The direct results are insufficient maintenance and poor service; insufficient measures to ensure sustainable development. The fourth problem is that water quality and water-related environmental management are not considered to be critical issues and the end result is endemic diseases.

Case 3: Harvesting rain water in eastern Qinghai Province

Background information

The Qinghai Province is a part of the Qing-Zang Plateau and is located in north Tibet. It has a total area of 720,000 square kilometres. The average annual precipitation is 286 mm.

About 350 mm of precipitation occurs in the eastern area of Qinghai; a semi-arid mountain area There is a population of almost four million people, mainly living on cistern water. Most of these cisterns are clay-cisterns, and the rain water collection system uses natural ground or yards, resulting in poor hygiene, contaminated water, and bad construction causing seepage and even collapse of the cisterns.

Development of rain water harvesting

Since August 1996, a rain water harvesting project for 2,300-2,700 metre high mountains in eastern Qinghai has been constructed by rebuilding and replacing old clay-cisterns with brick-cisterns. Each house built two 30-cubic metre round brick-cisterns and 100 square metres of brick-catchment to collect water in every yard. One cistern collects rainfall from the roof and yard for drinking water. Rain water harvested from the road and ground outside is stored for irrigation. At present, this kind of structure can be found in Huangzhong County, Pingan County, Ledu County, Minhe County, and Hualong County in Qinghai Province. The structures serve 190,000 households reaching nearly one million people, if one estimates five persons per house. At the same time, some old clay-cisterns were lined with brick inside, to establish 400,000 brick cisterns that collect up to 11 million cubic metres of water. Nearly eight million cubic metres of harvested water were stored after autumn in 1998 and were ready to provide drinking water during the winter and water for irrigation the following spring.

Experience in institutions and diversified use

During implementation of structures, the government was responsible for providing cement and a subsidy of 1,000 yuan per one household as well as transportation costs. In addition, counties were provided with technicians to guide construction work. The beneficiaries prepared the sand and stone, and built the cisterns themselves. After one year of operations, the water of these new cisterns provided drinking water of relatively good quality in terms of PH value, total amount of bacteria, colicin count, and so on. Now, have an assured supply of drinking water and furthermore they have been able to grow vegetables in gardens and irrigate some of their fields since 1997.

Along with the building of plastic greenhouses, vegetables are grown in gardens using drip irrigation and micro-spray irrigation. Water is extracted by electric pumps, hand pumps, and manually from the cisterns.

Use of harvested water for irrigation through financing schemes

Field irrigation mainly depends on pressure in drip irrigation and seeping irrigation. Using a drip irrigation system introduced by the Luyuan Company in Beijing along with plastic film, wheat and corn were planted in strips at regular intervals in Zhongbao Haiyugou village, Huangzhong County in 1998.Drip irrigation was carried out six times and the amount of water was 534 m^3/ha. A bumper crop was seen that year. Planting only corn from the Corn Department of the Chinese Ministry of Agriculture, up to 6,667.5 kg was produced per hectare. It was the first time in record that a yield such as this was harvested in the high, frigid (reaching an elevation of 2650 m) and arid mountains.

Using perforated pipes from Huayuan Henan, a seeping drip irrigation test for spring wheat was carried out watering the crops three times and using 370.5 cubic metres of water per hectare. As a result, 4,470 kg of spring wheat per hectare was harvested. Neighbouring lands without seeping drip irrigation produced only 3,045 kg per hectare, hence seeping drip irrigation can increase production by 46.8%.

Today, facilities for field irrigation are financed mostly by the government and are usually managed by water stations in each county. Some of them are administered by the farmers themselves. In 1999, beneficiaries were provided with facilities for field irrigation, aided partly by the government and paid partly by the farmers themselves in order to extend the scale of rain water harvesting. According to the funds budgetted, 20-25 thousand households will benefit, which means about 100-120 thousand people.

Case 4: Water harvesting in the southwest mountains of Sichuan Province

Background information

This is a case study from Liangshan Yi Autonomous Prefecture in the southwestern part of Sichuan Province. The Prefectures covers a territory of 61,000 square kilometres and has a population of 3.8 million. About 40% of the population belong to the Yi minority ethnic group. The prefecture is a typical mountain region and mountains account for 91.7% of its total area. The high mountains are cut deeply by the Jinsha River and its tributaries. Elevations in the prefecture vary from 305 to 5,958 masl. Most of the areas in the Liangshan Prefecture lie in the subtropical zone. Climatically it has a wet season from June to October and a dry season from November to May. Annual precipitation is about 1,000 mm, of which 90% is concentrated in the wet season. Annual pan evaporation is much higher than precipitation. For example, in Ningnan County, annual pan evaporation is 1,939.6 mm while precipitation only amounts to 960.5 mm. In the dry season in April and May evaporation is twice precipitation. In the dry and hot valley of Jinsha River the lowest yearly precipitation and the highest yearly pan evaporation are 600 and 3,000mm respectively.

Presently, in Liangshan Prefecture, 592,000 ha of cultivated land are under irrigation. The rest is rainfed land and prone to drought. Since 1952, a number of water conservation projects, such as reservoirs, irrigation canals, and ditches, have been constructed in the prefecture. The irrigated land has increased by 6,440 ha. Most of the land in the prefecture has no irrigation facilities. Four hundred and twenty-five thousand people and 913,000 cattle are short of drinking water. It is difficult to construct water conservation structures to provide sufficient water to all the mountain regions in Liangshan. The landscape is deeply dissected and people live in scattered settlements. Since 1983, micro-engineering work has been carried out to provide water storage facilities in areas suffering from drought.

Development of water harvesting

In Tongkuan village, Huidong County, Liangshan Prefecture, water-harvesting techniques have been introduced to provide sufficient water in times of drought. In the history of the village, there are even stories about residents fighting with wolves over drinking water. In 1983 people dug a few simple water storage ponds to collect runoff. The ponds had no sedimentation hollows or covers. The walls were not lined with concrete or brick and by Spring of 1984 one third of the collected water was remaining in the ponds. This was due to heavy water losses caused by seepage and evaporation. Such problems should be taken care of in future because, after 1983, a lot of ponds were built in the village. Only with proper care can people harvest water efficiently.

Experience in managing water harvesting ponds in Tongkuan Village drew the attention of leaders and engineers from both the county and prefecture. They realised the significance of the village's experience for the county and the prefecture. The simple ponds needed to be improved to overcome shortcomings such as heavy losses of water through evaporation and seepage, sedimentation, and collapse of the earthen walls of the ponds. A research project on water-harvesting techniques supported by the government of Liangshan Prefecture and the Bureau of Water Conservancy and Electricity of Liangshan Prefecture was carried out in the middle of the 1980s. Huidong and Huili counties were selected as experimental regions for demonstrating water-harvesting techniques. Great improvements have been made in water-harvesting techniques and in applying and transferring the experience from these counties to other counties. A simple ground pond has been converted into a standard underground cistern. In the winter of 1991, a regional working meeting on micro water conservancy works in Sichuan Province was held in Huili and Huidong counties. Since then, water-harvesting works have been applied and have spread widely.

Progress and problems to be solved

Up to August 1996, 163,854 underground cisterns had been built with a total storage volume of 594 million cubic metres in Liangshan Prefecture. Water from the cisterns had irrigated 1,530 ha of farmlands. Drinking water was supplied to 60,000 people and 90,000 cattle in the during dry season. Thanks to the establishment of water harvesting works, the value of agricultural output from the Prefecture had increased by 89 million yuan. The farmers' yearly income totalled 64 million yuan (about 8 million U. S dollars).

Through water harvesting, great changes have taken place in a number of villages in the Prefecture. Tongkuan Village has 450 underground cisterns for drinking water. The area irrigated has reached 100 ha. In 1995, per capita grain productivity was 544 kg and the per capita income averaged 2,921 yuan. The village has become rich thanks to water harvesting. Chanxian village of Huidong County is a typical mountain village which in the past frequently suffered from drought. Although farmers worked very hard, the yearly grain production was no more than 1,350 tonnes before 1991. The poor harvest was because of water shortage. Since 1991, water harvesting has led to a yearly grain production increase to 1,600 tonnes. Farmers have produced more than 400 kg of grain per capita per annum. There was an increase in per capita income of 402 yuan on an average in 1992. In 1995, 1,210 underground cisterns were constructed and now each household has its own cistern. Farmers produced 450 kg of grain and earned 900 yuan in cash per capita in 1995.

Lessons from water harvesting

The above case studies have shown that water harvesting has made three principal breakthroughs, has three criteria for suitability, and provides three benefits. Firstly, as a strategy micro water harvesting can be carried out in association with large water conservation projects. Secondly, it can be carried out easily by local people. Thirdly, the underground cisterns only lose a little water through evaporation, transportation, and seepage.

As to the three criteria of suitability, firstly, the underground cisterns are suitable in the climatic conditions in terms of overcoming the problems of uneven distribution of water between the wet and dry seasons. Secondly, the cisterns are suited to the scattered farm lands and households, because underground cisterns can be set up almost anywhere. Thirdly, support is easily found because construction costs can be borne locally.

In terms of the three benefits, firstly, water harvesting is a convenient way of providing irrigation in the mountains. For example, one underground cistern can serve one or two *mu* of dry farmland. During sowing in Spring water is available from the cisterns when it is needed. Secondly, water from cisterns is reliable as drinking water during the dry season. Thirdly, water cisterns are ecologically compatible as they do not take up space on the surface of the land.

3. SUGGESTIONS FOR DEVELOPING AND MANAGING WATER-HARVESTING SYSTEMS

The importance of water supplies cannot be overestimated in terms of long-term development of agriculture and a sustainable increase in productivity in mountain areas. Hence the importance of water harvesting and a long-term plan to develop and manage water harvesting and auxiliary systems. A comprehensive strategy that takes ecological and environmental conditions, socioeconomic implications, user participation, water prices, and cost recovery into consideration is essential. The objective is to assure sustainable development of water harvesting.

Systematic and intensive studies on water harvesting development should focus on the features of mountain hydrology. Perhaps water harvesting can be used as a supplementary technology for irrigation in mountain areas? Can an optimum system of technology and management that will ensure water balance and water and soil conservation be found? What are the economic benefits of water harvesting in the mountains? Only by answering these questions can the position and function of water harvesting in mountain areas be assessed. Such answers can help determine national investment and design for water technology and management.

An integrated management framework should be worked out based on a series of laws: Water Law, a Law for Water and Soil Conservation, and so on. Measures for a permit system for water extraction should be strictly implemented. At the same time, by using economic, legal, and administrative measures, integrated management to assure scientific allocation of water resources should be implemented. Administrative integration for planning, maintenance, operation, permission for water extraction, levy of water fees, and quality and quantity control should be ensured.

Proper budgetary allocation for investment in poverty alleviation in the mountains is necessary. This means rational pricing and a policy for cost return and cost recovery. In turn this will lead to efficient use of water. Otherwise, wastage will continue.

Training officials and technicians in good water-harvesting techniques is advisable. Such knowledge should be passed on locally as soon as possible to raise consciousness about the importance of water harvesting. It is more important to train administrators who can comprehend water harvesting policies and who have a long-term view of sustainable development as they will be instrumental in promoting and developing water harvesting.

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