Japan International Cooperation Agency
State Forestry Administration,
People's Republic of China

Study on Reforestation in Anning Watershed in Sichuan Province in the People's Republic of China

Summary Report

July 2002

Joint Venture to Conduct a Study on Reforestation in Anning Watershed in Sichuan Province in the People's Republic of China

Japan Overseas Forestry Consultants Association
Aero Asahi Corporation

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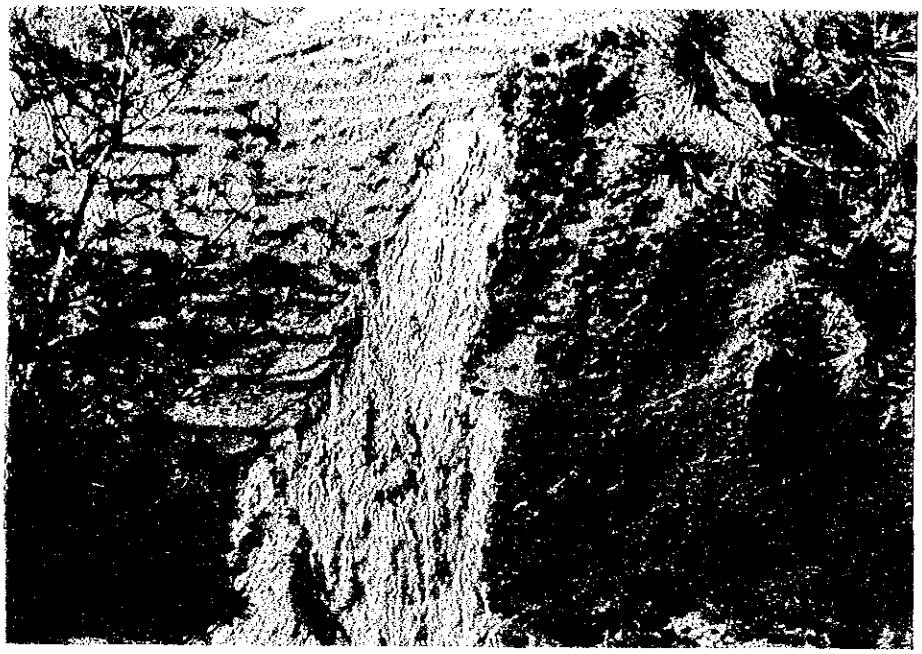


1. Slope failure in the high-altitude zone (About 2,700 m above sea level) (Xide-xian)

2. Gully in the high-altitude zone (About 2,700 m above sea level) (Zhaojue-xian)

3. Small-scale slope failure (Xichang-shi)

4. The turbid waters of the Anning River
The clear stream is a tributary.
(Xichang-shi)

5. The turbulent flow of the Anning River
(Xichang-shi)

6. Siltation in a tributary
(Xichang-shi)

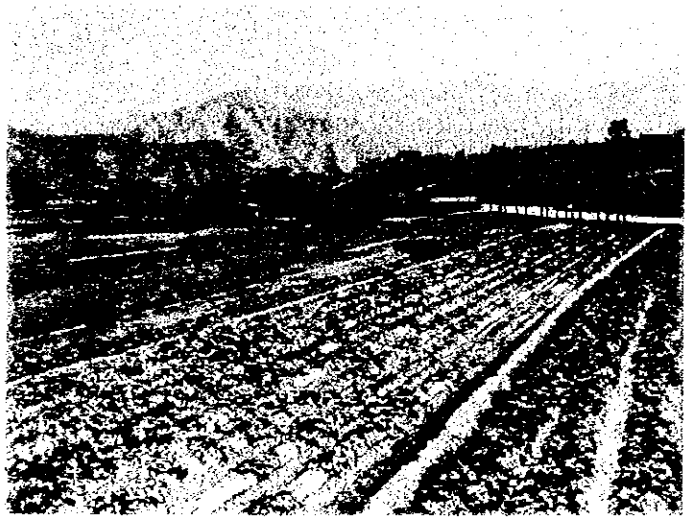
7. Natural open forest in the high-altitude zone (About 2,800 m above sea level)
(Xide-xian)

8. An area afforested with *Pinus yunnanensis* using aerial seeding
(Zhaojue-xian)

9. A grove for eucalyptus oil production
(Xichang-shi)

10. Farmland in the high-altitude zone (About 3,000 m above sea level) (Xide-xian)

11. Parent and her children carrying firewood on their back (Dead *Pinus yunnanensis* trees) (Zhaojue-xian)



12. Farmland in the flat basin (Dechang-xian)

13. A meeting with the Chinese counterparts (At an office)

14. The Study Team looking at a map during a field survey (Dechang-xian)

15. Research area for trial afforestation (Miyi-xian)

Contents

Tables

Figures

1. Background to the Study

China is facing increasing deforestation and forest degradation due to the overuse of forest resources over its long history, resulting in a large area of land becoming devastated and denuded. Although China boasts the largest area of plantation forests in the world, a large area of forestland remains severely degraded. There is also a problem with forests in China in relation to soil and water conservation. Moreover, rapid economic development under China's policy of reform and liberalization has been exerting further pressure on the already vulnerable forest ecosystem, having a significant impact on the natural environment.

The basin along the upper reaches of the Yangtze River, which encompasses many high mountains and a small area of flatland, constitutes one of China's largest forest belts with a diverse ecosystem. Still, this part of the basin has been undergoing increasing soil erosion due to long term deforestation, excessive cultivation on steeply sloping land, and grassland deterioration caused by overgrazing. Soil erosion has also been intensifying in the basin along the middle reaches of the river due to the excessive conversion of forestland and grassland to farmland. As a result, the incidence of natural disasters in the basin along the middle and lower reaches of the Yangtze River has been increasing in both number and intensity in recent years.

To rectify the situation, the Chinese government has taken a number of steps, including a project to build a shelter belt forest along the upper and middle reaches of the Yangtze River. Following a major flood disaster in 1998, the government launched a national project to protect natural forests in September of the same year. In January 1999, the Chinese government put the National Ecological Construction Plan in place as a plan to administer these projects. Under the plan, the basin along the upper and middle reaches of the Yangtze River, including Sichuan Province, was designated as a priority area for ecological restoration. In response to this national initiative, the Sichuan provincial government formulated a plan for ecological restoration in Sichuan Province in March of the same year, designating western Sichuan, including the Anning River basin, as a key area for priority ecological restoration.

As part of these forest conservation efforts, the Chinese government asked Japan for assistance in the implementation of two undertakings in December 1999. One was the Model Afforestation Project in Sichuan (MAPS) -- a project-type technical cooperation scheme aimed at the development and dissemination of, and training in, afforestation technology. MAPS has been in place since July 2000. The other was a development study, covering five city/counties in the Anning River basin, for the formulation of a reforestation plan in the basin.

These two cooperation schemes came after Chinese President Jiang Zemin and the then Japanese Prime Minister Keizo Obuchi agreed on the need for cooperation in the reforestation field as part of environmental conservation initiatives at the summit meeting in November 1998.

As part of the development study requested by the Chinese government as discussed above, the Japan International Cooperation Agency (JICA) dispatched a mission to China for the period between May 15 and June 3, 2000, to conduct a preliminary study and scope of the work (S/W) consultations for a reforestation project in the Anning River basin in Sichuan (S/W Mission). The study mission, headed by Mr. Yukihide Katsuta, confirmed China's intentions of the background and details of the request from China, consulted with the

Chinese side regarding the policy and procedures for the full-fledged study, and decided on the S/W for the study.

2. Study Region

This study covers an area of 500,000 hectares in the Anning River basin, including five cities/counties in Sichuan Province, namely Xide-xian, Zhaojue-xian, Xichang-shi, and Dechang-xian in Liangshan Yi Autonomous Prefecture as well as Miyi-xian in Panzhihua-shi. After conducting an aerial photographic survey of the area, the Study Team selected an area of 10,000 hectares or smaller for each city/county as a key study area.

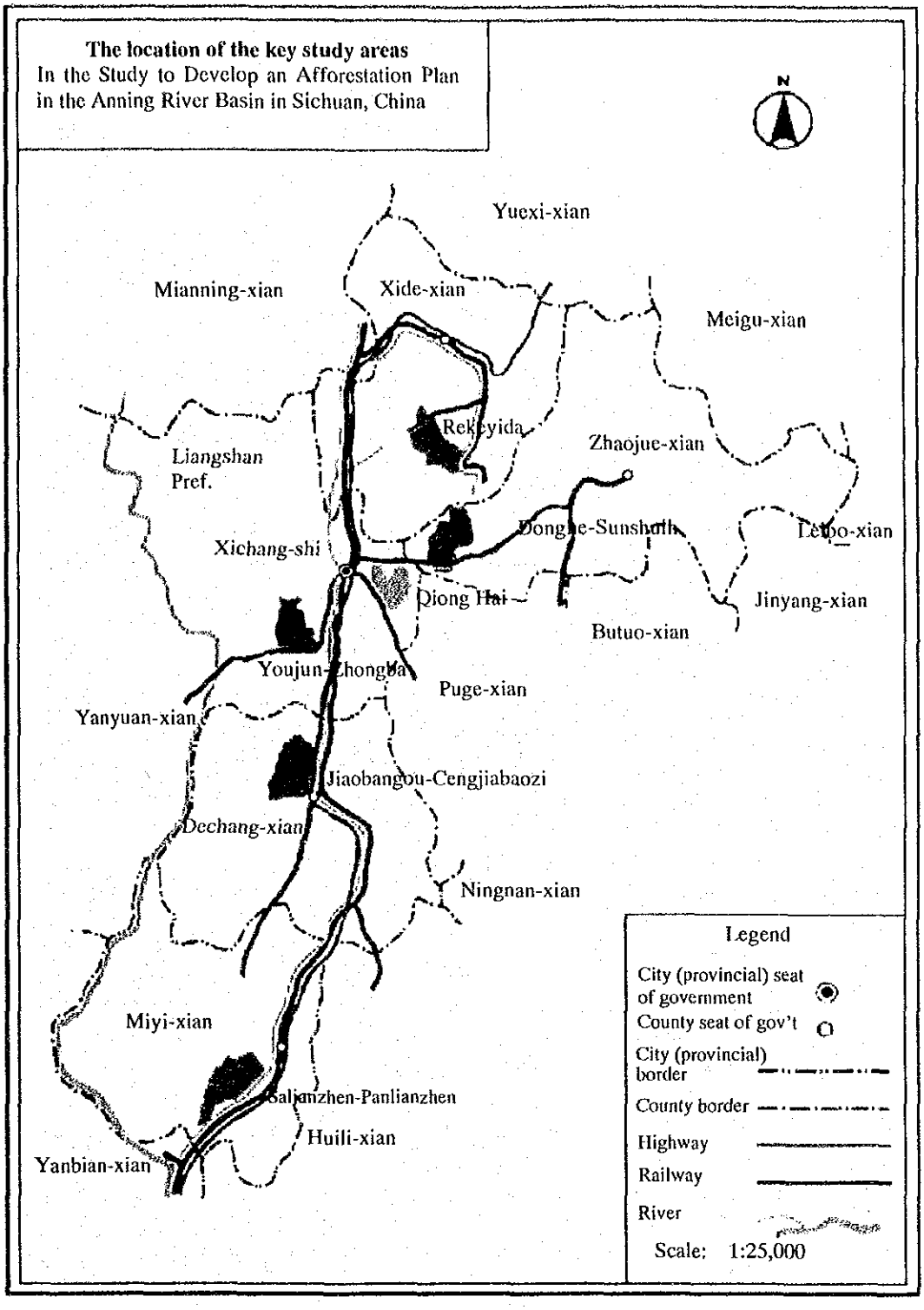


Figure 1 The study region and the key study areas

3. Objective of the Study

The main objective of the study, called the Study to Develop a Reforestation Plan for the Anning River Basin in Sichuan, China, is to develop a reforestation plan designed to enhance the soil and water conservation functions of the region, including an erosion control plan.

To this end, this Study includes:

(i) Aerial photographing the study region the Anning River basin with an area of about 503,000 hectares, selecting a key study area for each of the five city/counties in the basin, preparing a topographic map of each area, and conducting a soil survey, a land use and vegetation survey, and a socioeconomic survey in each area.
(ii) Drawing up a reforestation program for each key study area, including a project to build simple structures for erosion control and a seedling production plan.
(iii) Conducting reforestation trials in the hot and dry valley zone in Miyi-xian, and then making recommendations on such issues as the planting methods to be used and what species to plant, based on the findings of the trials.
(iv) Developing a guideline for formulating a reforestation plan, and transferring the technology to the Chinese counterparts through on-the-job training (OJT) concerning the planning procedures and the survey method for each item.

4. Why was This Study Necessary?

The Anning River basin, located in the southwestern part of Sichuan Province and situated in the Hengduan Mountain Region, abounds in faults and is geologically vulnerable. The flatland region of the basin is thickly populated and well developed. In the mountain region, on the other hand, the infrastructure is underdeveloped. Even steeply sloping land is used as farmland. Slope failure, landslides, and traces of mudflows can be seen everywhere in the basin. The mountain region abounds in devastated and denuded land, with grassland, bare soil, and open forest occupying large areas. Heavy rain therefore triggers mudflows on the sloping land, turning the rivers muddy and causing flood disasters downstream.

It is therefore essential to reforest such denuded forestland while taking into account the livelihood of the local residents; this helps improve the local forest ecosystem. To this end, it is necessary to gain the cooperation of local communities in the conservation of the forest ecosystem. Reforestation and erosion control measures prevent mudflows, promoting the welfare of local residents. Such measures also help mitigate flood disasters downstream. Although the main objective of this study is to formulate reforestation and erosion control plans, identifying the benefits of these plans in the formulation process is also important. The benefits thus identified, as well as the achievements of MAPS in terms of technical development, constitute key elements for a model plan designed to conserve the forest ecosystem in the basin as a whole. This study also serves as important preparatory work for the implementation of the reforestation and erosion control plans developed under this study.

5. Considerations in Implementing the Study

1) Selecting key study areas

As discussed above, the Study Team has selected a key study area in each of the five city/counties--Xide-xian, Zhaojue-xian, Xichang-shi, Dechang-xian, and Miyi-xian in the Anning River basin. The Study Team prepared a topographic map of each zone, conducted a soil survey, a land use and a vegetation survey, and a socioeconomic survey for each zone, and then developed reforestation and erosion control plans.

Each key study area, measuring 10,000 hectares or smaller in area, consists of one or more watershed units that have the largest area of devastated land and slope failure, and therefore require reforestation as a matter of urgency. The Study Team selected these key study areas with full respect for China's intentions.

The key study areas are listed in Table 1 below. The geographical locations are shown in Figure 1 above.

Table 1 Key study areas

City/county	Key study area	Area (ha)	Purposes
Xide-xian	Rekeyida	9,970	Reforestation plan for the acid purple soil zone
Zhaojue-xian	Donghe-Sunshuihe	9,500	Reforestation plan for the high altitude zone
Xichang-shi	Youjun-Zhongba	9,900	Reforestation plan for the deeply weathered granite zone
Dechang-xian	Jiaobangou-Cengjiabaozi	9,980	Reforestation plan for the mountainous, yellowish brown soil zone
Miyi-xian	Salianzhen-Panlianzhen	9,910	Reforestation plan for the hot and dry valley zone

2) The study's course of action

The study took the course of action described below:

(1) The study was conducted in line with the Scope of the Work (S/W) and the Minutes of Meeting (M/M), which were agreed upon, signed, and exchanged with the Chinese government on May 30, 2000. The actual study work conformed to the Terms of Reference of JICA and a number of materials were drawn upon, including the findings of the S/W Mission, the MAPS Preliminary Study Report, the National Ecological Construction Plan, and the Ecological Construction Plan of Sichuan. The Study Team maintained close contact with experts involved in MAPS and exchanged the findings of each other's studies.

(2) The study was conducted in coordination with the study review committees established within the Forestry Department of Sichuan Province and the forestry bureau of

Liangshan Prefecture.

(3) After completing the study, the Study Team transferred technology through OJT to the Chinese counterparts while seeking their active participation, with an view to the implementation of the reforestation and erosion control plans.

(4) The study fully assessed the general socioeconomic situation, the degree of dependence of the local communities on forest resources, and the intentions and needs of these communities concerning the management and conservation of forests in the study region. Then the study reflected these assessments in the reforestation plan.

(5) The study did not consider afforestation of farmland on the slope in formulating the reforestation plan since it is an obligation under a national program called the "Conversion of Croplands to Forests". As for the afforestation of grazing land, the study took the intentions of the parties concerned fully into account.

(6) The study went into the type of operation so that the reforestation plan can be operationally viable.

6. Relationship with MAPS

1) Summary of MAPS

The Model Afforestation Project in Sichuan (MAPS) has two main objectives. One is to build model nurseries and establish model reforestation projects in Xichang-shi, Xide-xian, and Zhaojue-xian in the Anning River basin so as to develop and demonstrate nursery and reforestation technology suitable for the natural and social conditions of the region. The other is to train engineers and disseminate technology to the local communities so as to establish a basis for self-supported reforestation activities there.

Since MAPS aims to develop technology both on drylands at relatively low altitudes and on highland at an altitude of 2,500 meters or above, the technology to be developed there will have wider applications to cover many parts of the Anning River basin. In addition, it is expected that the technology to be developed in the nurseries will improve the existing plant nursery system, leading to the production of high quality seedlings.

Zhaojue-xian and Xide-xian, where the reforestation model areas have been established, are populated with many Yi people as is the case with key study areas. Likewise, these two counties are socioeconomically similar to the mountain areas covered by this study.

2) Relationship between this study and MAPS

Taking into account reforestation technology and socioeconomic conditions, it is highly possible that the reforestation plan, the seedling production plan, and forest protection plan developed in this study will be able to make use of technology to be developed in MAPS, except for the reforestation program in the hot and dry valley zone in the lower reaches of the Anning River basin.

Therefore, this study is closely related to MAPS technically. It is important that the technology that is developed and disseminated in MAPS is utilized in the implementation

process of the reforestation plan developed in this study.

In fact, the study has already made use of the achievements that MAPS has made in reforestation and nurseries, although technical development under MAPS is at the early stages.

3) Key study areas and model areas

It is preferable that the key study areas in this study should match the model areas in MAPS. In reality, however, they did not match except for the key study area in Zhaojue-xian due to differences in the main objectives and the sizes of the reforestation areas between this study and MAPS, as well as China's intentions. Nevertheless, technology developed in MAPS will likely be applicable except in the hot and dry valley zone.

7. Specific Activities of the Study

1) Chronological account of the study

The first year phase of the study included preparations in Japan and other work in China - briefings on the inception report, a general survey, aerial photography, the selection of key study areas, the preparation of topographic maps, a soil survey, a land use and vegetation survey, and other basic surveys. The findings of these surveys were compiled into the Progress Report I and Progress Report Update.

The second year phase centered on a field survey conducted between October 28, 2001 and February 12, 2002. The field survey included the selection of reforestation areas, the development of reforestation and erosion control plans, assessment, and trial reforestation management. The results of these works were compiled into the Progress Report II.

The third year phase started in April 2002. After monitoring the trial reforestation, the Study Team drew up a draft final report and held briefings and consultations on the report in the study review committees. In Chengdu-shi, the Study Team held technology transfer seminars with the participation of the parties concerned. Since the Study Team and the Chinese government had already reached an agreement on the contents of the report, the Study Team compiled the final report, completing this study.

2) Basic survey activities

The basic survey activities of this study are described below:

(1) General survey of the Anning River basin

The Study Team conducted a general survey of the whole of the Anning River basin, extending from the headwaters of the river to the area where the river joins the Yalong River. This survey was designed to assess a number of items, including the topography and geological features of the mountainous region, rivers, forests, distribution of vegetation, the extent of forestland degradation, the extent of grazing, and the distribution of villages and farmland.

(2) Aerial photography and plotting

The Study Team aerially photographed the study region, conducted a ground survey of the key study area in each of the five city/counties, and then subcontracted to local enterprises the production of a topographic map on a scale of 1:25,000 and the plotting of the key study areas on the map.

The Study Team also subcontracted the production of thematic maps and image digitization of the key study areas, totaling about 50,000 hectares, with the help of digitization software.

(3) Selection of the key study areas

As discussed in 5. 1) above, the Study Team selected a key study area in each of the five city/counties and conducted a field survey of the five key study areas to assess the general situation there. These key study areas are shown in Table 1.

(4) Land use and vegetation surveys, etc.

After reading the aerial photos of the key study areas and conducting a field survey, the Study Team produced land use and vegetation maps and compartment maps, measured the area of each compartment, and compiled a forest area inventory data describing the general conditions of forests under a subcontract to a local enterprise. The land use and vegetation maps and compartment maps were produced based on the topographic maps produced for this study on a scale of 1:25,000.

Table 2 shows the land use and the percentage of forestland in each key study area based on the land use and vegetation survey.

Table 2 Land use and the percentage of forestland in the key study areas

Unit: ha, %

Key study area	Xide-xian	Zhaojue-xian	Xichang-shi	Dechang-xian	Miyi-xian
Populated zone	0.9	17.0	22.3	39.0	97.2
Rice paddies	0.0	0.0	68.5	136.8	0.0
Dry farmland/fruit orchards	2,515.9	2,141.1	2,500.2	2,107.3	3,468.3
Slope failure	14.0	10.6	0.0	17.5	3.3
Devastated and denuded land	4,277.8	3,898.0	1,695.6	1,387.7	2,665.8
Forest land	3,217.1	3,338.0	5,582.7	6,509.7	3,702.3
Other land uses	24.1	95.6	42.1	3.1	275.2
Total	10,049.8	9,500.3	9,911.9	10,201.1	10,194.1
Percentage of forestland	32.0	35.1	56.3	63.8	36.3

Forests in the key study areas consist mostly of artificially regenerated *Pinus yunnanensis* and natural evergreen broad-leaved trees, except for the key study area in Miyi-xian, where artificially regenerated *Pinus yunnanensis* forests are small and deciduous broad-leaved forests, included in the category of "Other forests" in Table 3, constitute a large percentage, which is a reflection of the local weather conditions.

Table 3 Percentage of artificially regenerated *Pinus yunnanensis* forests, natural evergreen broad-leaved forests, and other forests

Units: ha, %

Classification		Xide-xian	Zhaojue-xian	Xichang-shi	Dechang-xian	Miyi-xian
Pinus yunnanensis forest	Area (ha)	669.1	1484.4	1,269.1	2,480.6	236.2
	Percentage	20.8	44.5	22.7	38.1	6.4
Natural evergreen broad-leaved forest	Area (ha)	2,440.2	1742.1	3,729.9	3,766.1	1,310.1
	Percentage	75.9	52.2	66.8	57.9	35.5
Other forests	Area (ha)	107.8	111.5	583.7	263.0	2,156.0
	Percentage	3.4	3.3	10.5	4.0	58.2
Total area of forest land	Area (ha)	3,217.1	3,338.0	5,582.7	6,509.7	3,702.3
	Percentage	100.00	100.00	100.00	100.00	100.00

Notes:
1. Due to rounding, the sum of individual figures may not add up to the total.
2. Data from the land use and vegetation survey.
3. "Other forests" includes deciduous broad-leaved forest, natural coniferous forest, and mixed forests.

(5) Soil survey

After carrying out a land classification based on the general survey of the key study areas of around 50,000 hectares, the Study Team carried out a soil survey and collected soil samples. Then the Study Team conducted laboratory analyses of the samples, produced soil maps using the topographic maps produced for this study on a scale of 1:25,000, and compiled a soil report under a subcontract to a local enterprise.

Major types of soil distributed in the key study areas, based on the findings of the soil survey, are shown in Table 4.

Table 4 Soil types in the key study areas

City/county	Key study area	Major types of soil
Xide-xian	Rekeyida	Plateau aquent soil (plateau riverside sedimentary soil), acid purple soil, yellowish brown soil, brown soil, brown dark soil, and subalpine meadow soil
Zhaojue-xian	Donghe-Sunshuihe	Plateau aquent soil (plateau riverside sedimentary soil), acid purple soil, and subalpine meadow soil
Xichang-shi	Youjun-Zhongba	Alluvial soil, red soil, and yellowish brown soil
Dechang-xian	Jiaobangou-Cengjiabaozi	Paddy soil, red soil, yellowish brown soil, brown soil, brown dark soil, and subalpine meadow soil
Miyi-xian	Salianzhen-Panlianzhen	Alluvial soil, dry red soil, red soil, and stony purple soil

Xide-xian and Zhaojue-xian has an abundance of acid purple soil, which consists mainly of aqueous rock and is vulnerable to erosion, while Xichang-shi and Miyi-xian has an abundance of red soil. Dechang-xian has many types of soil.

(6) Socioeconomic survey

It is necessary to assess the socioeconomic conditions in local communities to develop a viable reforestation plan. The Study Team, under a subcontract with a local enterprise, conducted a socioeconomic survey to assess a number of aspects of the local communities, including the land use, income levels, means of livelihood (farming, stock raising, etc.), living standards, and dependency on forest resources, especially fuelwood. In the survey, two villages in each key study areas were chosen as sample villages for the survey. Then 100 households were sampled at random from each of these villages. In all, 1,000 households were surveyed.

These households were interviewed based on a questionnaire. Data collected from such interviews were input into computers, analyzed, and then compiled into a report.

Table 5 shows the distribution by altitude zone of the townships (xiang-zhen) from which the ten sampled villages were selected.

Table 5 Sampled villages by altitude zone shown with the names of the townships (xiang-zhen)

Mid-to-high mountainous zone	Mid-to-low mountainous zone	Flat basin zone
Zhaojue-xian: Nidi	Zhaojue-xian: Pushi	Xichang-shi: Junyou
Xide-xian: Rekeyida	Xichang-shi: Mopan	Dechang-xian: Ayue
Xide-xian: Luoha	Dechang-xian: Qianshan	Miyi-xian: Salian

Notes: 1. The mid-to-high mountainous zone is at an altitude of 2,700 meters or higher. The mid-to-low mountainous zone is at an altitude of between 2,000 and 2,700 meters. The flat basin zone is at an altitude lower than 2,000 meters.
2. The top to bottom order of city/counties and townships (xiang-zhen) in the table is from upstream to downstream of the Anning River basin.
3. In Miyi-xian, two villages have been selected from Salianzhen.

The survey showed that higher altitude communities have a closer relationship with forests, as had been expected. The following are the selected findings of the survey. Please note that the figures shown below represent average values.

Higher altitude communities tend to have a smaller area of paddies and a larger area of fallow rotation fields. They have less forestland and grassland than expected, although it was thought that they privately own a large area of forestland.

It is expected that higher altitude communities would have a lower average income. In any case, the survey showed that a significant source of income for higher altitude communities is stock raising. Agricultural income is greater in terms of both absolute value and percentage for lower altitude communities. The proportion obtained from forestry income is less than expected. Forest income for alpine communities is particularly low due to the difficulty of managing forests for producing non-wood forest products (commercial forests) in the alpine zone. The average income of the surveyed households is shown Table 6 below.

Table 6 Average income of surveyed households

Classification		Total	Agriculture	Forestry	Stock raising	Wages	Other income
Mid-to-high mountainous zone	Amount (yuan)	2,834	798	171	1,835	6	24
	Percentage	100	28	6	65	0	1
Mid-to-low mountainous zone	Amount (yuan)	4,233	2,030	430	1,466	209	97
	Percentage	100	48	10	35	5	2
Flat basin zone	Amount (yuan)	6,038	3,766	3	972	716	581
	Percentage	100	62	0	16	12	10

Notes: 1. Data from the questionnaire survey in April 2001.
2. Other income comes mainly from trading, but inland water fisheries are also included for some villages.
3. Forestry income comes mainly from pepper trees, walnuts, chestnuts, pears, and pine resin.

The main crops in mountain areas are potatoes, buckwheat, oats and corn. These crops are for personal consumption as well. On the other hand, the main crops in flat basin areas are paddy rice, wheat and corn. These crops are for personal consumption as well. Important cash crops include buckwheat and potatoes in the mountain zone and rice and wheat in flat basin zone. In flat basin zone, vegetables are also traded.

Table 7 Main crops for surveyed households

Units: kin (about 600g), %

Classification		Paddy rice	Buck-wheat	Corn	Oats	Wheat	Potatoes	Pulses
Mid-to-high mountainous zone	Production (a)	14	1,680	278	394	1	2,554	96
	Consumption (b)	14	1,248	187	302	1	2,046	31
	Ratio (b/a)	100	74	67	77	100	80	33
Mid-to-low mountainous zone	Production (a)	309	884	1,540	97	181	2,589	229
	Consumption (b)	294	772	1,070	85	158	1,772	127
	Ratio (b/a)	95	87	69	88	87	68	56
Flat basin zone	Production (a)	3,427	9	407	27	482	3	201
	Consumption (b)	2,609	9	343	12	340	3	60
	Ratio (b/a)	76	100	84	44	71	77	30

Note: Data from the questionnaire survey in April 2001.

Table 8 shows the percentage of the households using each type of fuel. Please note that in this questionnaire survey, households were asked to mark all the types of fuel they use, even if the level of consumption was low. Communities in the mid-to-high mountainous zone depend heavily on firewood, while those in the mid-to-low mountainous zone depend on pine needles as well as firewood. Fuels used by communities in the flat basin zone include briquettes, electricity and coal in addition to firewood and pine needles. It should be noted that communities in the flat basin zone also use straw as a fuel. The higher the altitude of communities, the more fuel they need to use. They use an unexpectedly large amount of fuel for boiling livestock feed. In addition, as the altitude of the communities becomes higher, they search for firewood in larger areas.

Table 8 Fuel consumption by the surveyed households

Unit: %

Classification	Coal	Briquettes	Firewood	Straw	Weeds	Electricity	Methane	Pine needles
Mid-to-high mountainous zone	1	0	100	0	10	0	0	14
Mid-to-low mountainous zone	1	0	100	31	23	0	0	60
Flat basin zone	6	81	35	49	28	13	24	17

Note: Data from the questionnaire survey in April 2001.

3) Reforestation and other plans, etc.

The reforestation plan, the erosion control plan, assessment, and trial reforestation are discussed in the following chapters.

8. Summary of the Reforestation Plan

1) Basic survey for developing the reforestation plan

China has taken a number of steps to restore its forest ecosystems, including the National Ecological Construction Plan (NECP), a project to build a shelter belt forest system along the upper and middle reaches of the Yangtze River, and a national project to protect natural forests. In this study region, the Sichuan provincial government has implemented a plan for ecological restoration in Sichuan Province, the Sichuan version of the NECP. However, more reforestation is needed, since forest restoration is still insufficient.

With a variation of more than 2,000 meters in altitude, the Anning River basin has diverse climates, ranging from the subtropical climate in the flat basin to the subarctic climate in the alpine zone. For this reason, the basin also has a wide variety of tree species, including evergreen species, subtropical species in the flatland, deciduous species in the montane zone, and subarctic species such as *Picea* spp. and *Tsuga* spp. in the alpine zone.

2) Procedures for the development of the reforestation plan

(1) Policy for selecting the proposed reforestation areas

Reforestation should be conducted to avoid affecting the livelihood of local residents. For this reason, the Study Team held consultations with representatives of the Liangshan Provincial offices concerned, including the forestry bureau, the national land bureau, the agriculture bureau, the livestock bureau and the water resources bureau, to develop a policy for selecting areas where reforestation was possible. The Study Team then explained this policy to the Forestry Department of Sichuan Province and obtained their approval.

(2) Confirmation of the proposed reforestation areas

Before selecting the proposed reforestation areas, the Study Team conducted a full, on-site investigation to deal with the local land use situation: firewood is commonly used as domestic fuel in the high altitude zone, and stock raising by grazing is an important source of income.

3) Considerations in selecting reforestation areas

According to the forest area inventory, the devastated and denuded land to be reafforested is managed mainly by city/counties or collectively. Private management is rare.

The land use situation in the key study areas is diverse. For example, grazing land includes forest managed by city/counties, as well as forest and grassland managed collectively.

The devastated and denuded land registered in the forest area inventory cannot be reafforested as a whole, since it includes farmland, crop rotation fields and grazing land. It is necessary to secure some pieces of land that are needed to maintain the livelihood of local farmers.

4) Classification of reforestation areas and measures for such areas

(1) Land use classification of the key study areas and measures for soil and water conservation

In consultation with the Forestry Department of Sichuan Province, the Study Team classified the land use of the key study areas and decided on measures for soil and water conservation for each classification as shown in Table 9.

Table 9 Water and soil conservation measures by type of land use

Classifications	Land use classification	Management classification	Measures	Symbol
Farmland	Stable farmland (inclination: below 6°))	Farmland I (A)	Maintenance of the present status	A
	Farmland subject to soil runoff (inclination: 6°-25°), including fallow fields	Farmland II (B)	Eco-farming	B
	Farmland (inclination: 25° to below 36°)	Farmland III (C)	Conversion of Croplands to Forests	C
High altitude pastures	Altitude of 3,400 m or above	Alpine vegetation (D)	Maintenance of the present vegetation	D
Devastated and denuded land	Treeless forestland (crown density: below 0.2)	Devastated and denuded land (E)	Ecosystem conservation forest (protected forest)	E1
			Eco-type commercial forest	E2
			Eco-type fuelwood forest	E3
			Eco-type timber forest	E4
			Eco-type grazing forest	E5
Forestland	Forestland (crown density: below 0.20-0.39)	Open forest (F)	Prohibition of entrance (*Pinus yunnanensis*), and supplementary planning	F
	Forest land needing improvement	Mid-density forest (G)	Tending or application of other silvicultural technique	G
	High-density plantation forest land (*Pinus yunnanensis*)	High-density forest (H1)	Density control, pest control, and fire prevention	H1
	Dense forest excluding high-density forests (H1)	High-density forests (H2)	Fire prevention and pest control	H2

(2) Course of action in developing the reforestation plan

The Study Team, taking into consideration the natural and socioeconomic conditions in each key study area, took the following course of action in developing the reforestation plan:

(i) For the zone at an altitude of 3,400 meters or above, the Study Team planned to use the land for grazing, since reforestation is difficult in these altitudes.
(ii) For the zone at an altitude of below 3,400 meters, the Study Team planned reforestation that is centered on ecosystem conservation forest, but also included eco-type commercial forests, eco-type timber forests, eco-type fuelwood forests and eco-type grazing forests.
(iii) For the high altitude zone, where firewood is commonly used as a domestic fuel, the Study Team decided that fuelwood forests needed to be established in areas where fuelwood resources are scarce.
(iv) For the high altitude zone, where grazing is an important source of income, the Study Team decided that certain areas of eco-type grazing forests needed to be established.
(v) The Study Team decided that the establishment of commercial forests was difficult in the high altitude zone, where the infrastructure is insufficient and the climate is cold. Instead, the Study Team planned a small area of eco-type commercial forests in the low-altitude zone, since commercial forests are feasible there.
(vi) The hot and dry valley zone, with a large area, is concentrated in the Hengduan Mountain Region, especially in the basin along the upper reaches of the Yangtze River. Since this zone is one of the most difficult zones for reforestation, the achievements of the trial reforestation in this zone in this study are significant. The Study Team took advantage of such achievements to formulate a reforestation program in Miyi-xian.

Eco-type forests are intended to contribute to the conservation of the local ecosystem as a basic objective, as well as for the original objective of reforestation. As an example, a schematic diagram of an eco-type grazing forest is shown below:

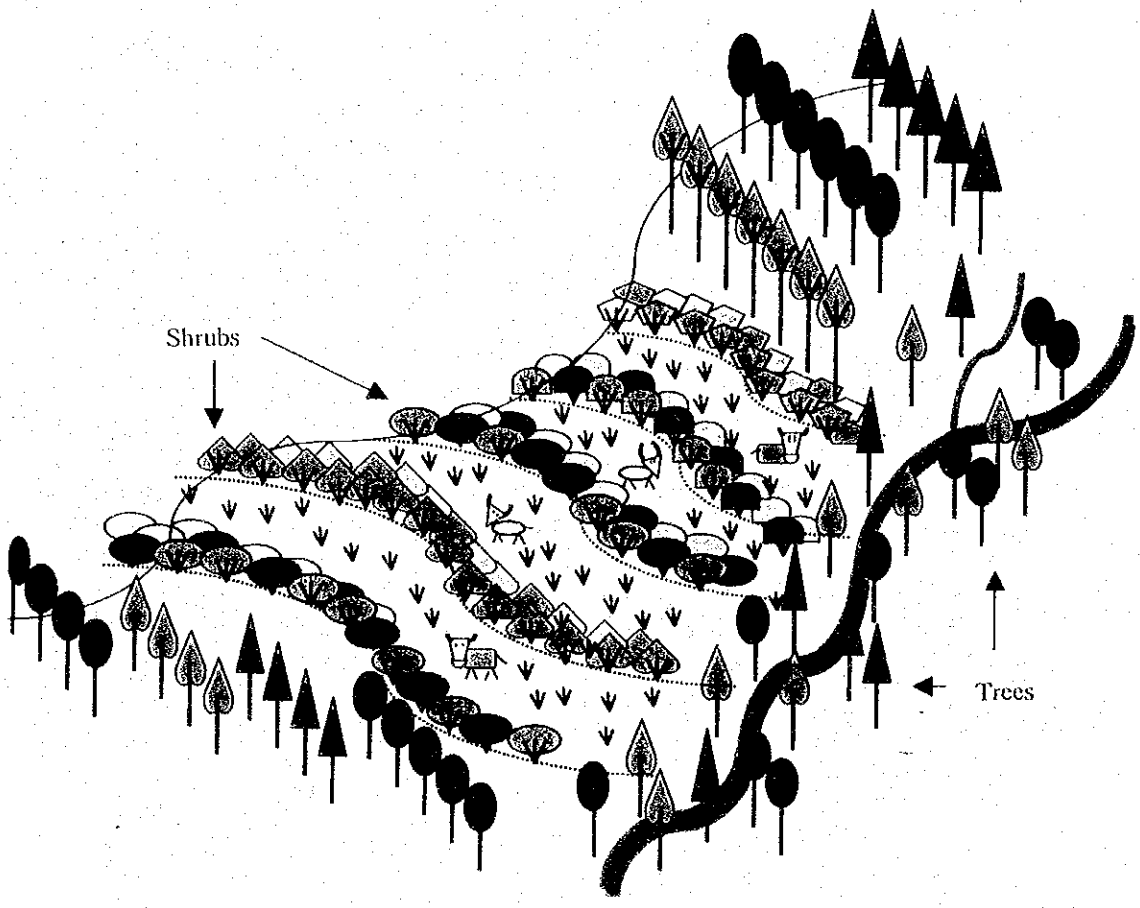


Figure 2 Schematic diagram of an eco-type grazing forest

5) Reforestation technology for each measure to be taken

In accordance with the course of action in developing the reforestation plan, the Study Team decided on the course of action in developing the reforestation program as detailed below for each key study area.

(1) Reforestation planning

(i) Planting methods for each reforestation area

The Study Team established reforestation areas (in hectares) for each type of measures for reforestation—an ecosystem conservation forest, an eco-type commercial forest, an eco-type fuelwood forest, an eco-type timber forest, and an eco-type grazing forest—for every key study area, in accordance with the zoning of the key study areas, the land use policy, and the course of action in developing the reforestation program for each key study area.

The reforestation area in the key study areas consist of sub-sections classified as "devastated and denuded land" in the forest area inventory. Since these sub-sections include fallow rotation fields, it is impossible to reforest all the "devastated and denuded land." Therefore, the Study Team took the local farming situation into account in zoning reforestation sub-sections and in selecting tree species for each section.

(ii) Reforestation area (hectares)

The reforestation area (hectares) for each key study area is shown in Table 10.

Table 10 Reforestation area (hectares) for each key study area

Unit: hectares

Classification	Xide-xian	Zhaojue-xian	Xichang-shi	Dechang-xian	Miyi-xian	Total
Ecosystem conservation forests	1,647.7	2,132.4	1,647.5	960.8	1,831.5	8,219.9
Eco-type commercial forests			24.4	99.4	98.9	220.7
Eco-type fuelwood forests	509.5	452.8		2.1		964.4
Eco-type timber forests		36.7			62.8	99.5
Eco-type grazing forests	551.7	301.1		133.9	57.2	1,043.9
Total	2,708.9	2,923.0	1,671.9	1,196.2	2,050.4	10,550.4

(2) Reforestation technology

Even within the same type of reforestation area, the species, the planting density, the planting method, and the type of silvicultural technique applied all vary according to the altitude at which reforestation is conducted. Since the planting methods for ecosystem conservation forests need to be diverse to match the variation in zones—ranging from the hot and dry valley zone to the alpine zone, the Study Team devised a zoning

classification and established a standard reforestation method for each zone. Table 11 shows the zoning and major planting species for ecosystem conservation forests. Please note that although the Study Team set the planting density at 3,300 seedlings per hectare for ecosystem conservation forests, it applied different planting densities for other types of reforestation.

Table 11 Zoning and major planting species for ecosystem conservation forests

Zone	Altitude and direction of slope	Planting species
(i) Alpine zone	Altitude: 2,600 - 3,400 m	(i) Mixed planting of *Pinus yunnanensis var. pygmaea* and *Quercus monimotricha*; (ii) mixed planting of *Pinus armandii* and *Larix kaempferi*, and planting of *Abies* spp. and *Picea* spp.; (iii) Mixed planting of *Betula albo-sinensis* and *Rhododendron*, etc.
(ii) Subalpine zone	Altitude: 2,000 - 2,600 m	(ii) Mixed planting of *Pinus armandii* and *Larix kaempferi*; (ii) Mixed planting of *Pinus yunnanensis* and *Coriaria sinica* ; (iii) Introduction of *Illicium simonsii*, etc.
(iii) Montane zone I	Altitude: 1,600 - 2000 m; north facing slopes	Mixed planting of *Pinus yunnanensis*, *Alnus cremastogyne*, *Cupressus funebris*, *Quercus* spp., etc.
(iv) Montane zone II	Altitude: 1,600 - 2000 m; south facing slope	Single or mixed planting of *Robinia pseudoacacia*, *Pyracantha fortuneana*, *Pinus yunnanensis*, *Coriaria sinica*, *Dodonaea viscosa*, and *Cupressus funebris*
(v) Hot and dry valley zone I	Altitude: 1,600 m and below; north facing slope	The same as the species for the montane zone II
(vi) Hot and dry valley zone II	Altitude: 1,600 m and below; south facing slope	Mixed planting of *Acacia confusa*, *Leucaena leucocephala*, *Jatropha curcas*, *Bombax malabaricum* , etc.

6) Seeds and seedlings planning

The Study Team assumed that all the seedlings to be planted under this reforestation plan would be purchased. Table 12 shows the number of seedlings required, including those for supplementary planting.

Table 12 The total number of seedlings required for the five city/counties

Unit: 1,000

City/county	Ecosystem conservation forests	Eco-type commercial forests	Eco-type fuelwood forests	Eco-type timber forests	Eco-type grazing forests	Total
Xide-xian	6,966		3,531		4,634	15,131
Zhaojue-xian	8,307		3,138	158	2,529	14,132
Xichang-shi	6,516	113				6,629
Dechang-xian	3,798	172	689		1,121	5,780
Miyi-xian	9,514	87		269	469	10,339
Total	35,101	372	7,358	427	8,753	52,011

Note: The required amount of seeds for direct sowing is excluded.

Abies spp., *Picea* spp., and other conifer species, which will be planted in the high-altitude zone, grow slowly at their early stages of growth. It takes about five years for them to reach a height of 25 centimeters. Therefore, seedlings of these species should be procured under well organized schedule before the implementation of the reforestation program. Given their physiology and transportation requirements, the seedlings should preferably be propagated as near to the planting area as possible. This is particularly true of bare rooted seedlings, which should be particularly near to the planting ground since their roots dry quickly. For potted seedlings of *Pinus* spp., it is preferable to use seedlings sown the previous year rather than to plant three-month-old seedlings.

Nursing conifers entails the use of seedlings grown by farmers in the high-altitude zone. At the initial stage, it is preferable to purchase two-year seedlings from other counties for nursing.

Seedlings should preferably be produced by farmers in the key study areas. The production of such seedlings will be a source of cash income for them.

7) Forest protection and management planning

Newly reforested areas needed protecting from livestock and fire by prohibiting the entrance. To this end, the Study Team decided to assign watchmen to patrol such reforested areas.

Because overstocked stands are vulnerable to pests and wind damage, thinning for tending purpose is necessary to prevent the stands from being overcrowded. Such thinning helps preferable undergrowth to develop, which serves as a good source of feed for grazing animals.

8) Annual reforestation operation planning

Although the total period for the planting operation plan was set at five years, the Study Team planned to complete the development of ecosystem conservation forests in four years. Each reforested area requires weeding, and the Study Team set the period for such work at two years from the time of planting, or three years where necessary. The Study Team planned to prohibit the entrance into the reforested areas for protection for five years after planting. Please note that smaller areas were allocated for reforestation using the measures other than the ecosystem conservation forest, so the reforestation period was shortened accordingly.

9) Reforestation costs

(i) Unit cost of reforestation

The Study Team established a standard mix of planting species, planting methods, planting density and work procedure for each reforestation type. After compiling materials on the existing reforestation processes, the unit cost of labor, the unit price of seedlings, transportation costs and other factors, the Study Team calculated the unit cost for each type of reforestation.

(ii) Project cost

The project cost was estimated by multiplying the above-mentioned unit cost by the area of each type of reforestation zone. Please note that this project cost represents direct expenses only, excluding indirect expenses. The reforestation costs by city/county are listed in Table 13. The total reforestation cost was estimated at about 198 million yuan, with a total reforestation area of 10,550 hectares.

Table 13 List of estimated reforestation costs by city/county

City/county	Reforestation area (ha)	Reforestation costs (1,000 yuan)
Xide-xian	2,709	51,826
Zhaojue-xian	2,923	56,529
Xichang-shi	1,672	29,715
Dechang-xian	1,196	22,361
Miyi-xian	2,050	37,624
Total	10,550	198,054

Notes: 1. Due to rounding, the sum of individual figures may not add up to the total.
2. The figures represent direct expenses only, excluding indirect expenses.
3. The costs are estimated on the assumption that all seedlings will be procured by purchasing.

Figure 3 shows relation ship between the percentage of the forestland to the total area and the reforestation costs by city/county.

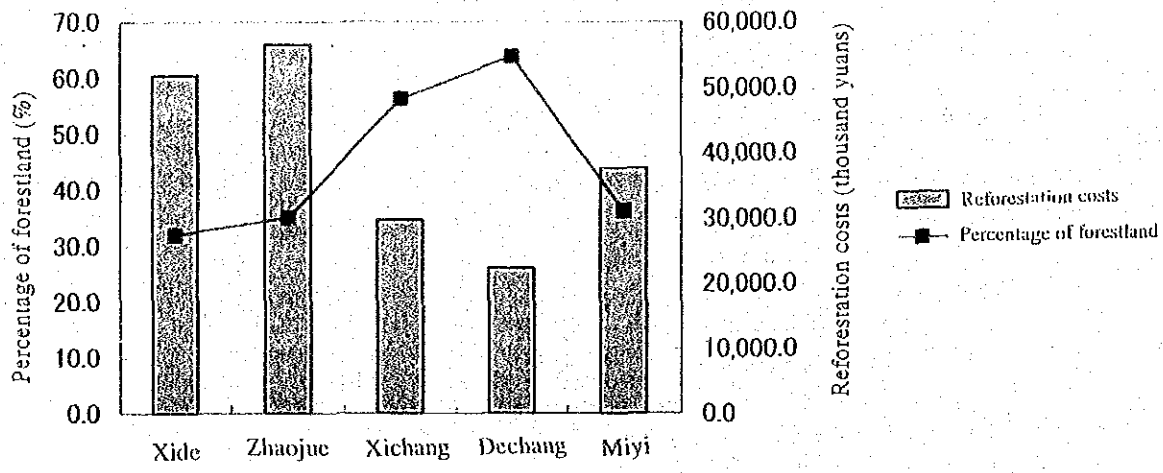


Figure 3 Relationship between the percentage of the forestland to the total area and the reforestation costs by city/county

10) Implementing bodies

As part of the administrative reform in China, the Liangshan provincial government has established a foreign project implementation office (Foreign Exchange Coordination

Office) within its forestry bureau. The office has jurisdiction over forestry-related projects in which foreign parties are involved. Currently, projects financed by domestic funds are supervised by the section(s) concerned within the forestry bureau, while projects supported by foreign countries or international institutions are implemented by the foreign projects implementation office.

11) Forest management and utilization planning

This reforestation plan aims primarily to develop ecosystem conservation forests, and does not regard the utilization of planted trees in the form of timber as its major objective. Even in eco-type commercial forests, the plan does not include the objective of felling dominant trees, but the intention is instead to use their fruits and leaves. As for the eco-type grazing forests, the planned use centers on the undergrowth. The use of the branches and leaves of shrubs is limited to under branches, and there is no intention to cut dominant tree. In eco-type timber forests and eco-type fuelwood forests, felling should be limited to one strictly limited area at a time. Also, cutting regulations should be imposed to ensure that cutting blocks are not adjacent to one another.

12) Considerations

Only a few reforestation projects have been implemented so far in the alpine zone, where the climate is severe. In this sense, the achievements of MAPS are significant. The achievements of the trial reforestation in Miyi-xian can be applied to reforestation in the hot and dry valley zone. For conifer reforestation, seedlings older than three-month-old seedlings should preferably be planted. Weeding and cleaning are important to improve the performance of the reforestation. Thinning for tending is necessary to protect reafforested areas. In this connection, local communities should be actively involved in forest protection and management.

9. Summary of the Erosion Control Plan

The erosion control plan developed in this study is designed to arrange for the simple, small-scale erosion control works required for reforestation. The plan does not consider rehabilitation and erosion control works for large-scale slope failure, works for landslides, stream works, or works for slope failure on farmland.

1) Selection of simple, small-scale erosion control works

Since there are many small-scale slope failures in the proposed reforestation areas in the key study areas, it is impossible to formulate a detailed erosion control plan for each example of slope failure or gully erosion within the period of this study. Therefore, the Study Team categorized slope failure and gully erosion based on the field survey and interpretation of the aerial photos, and classified them according to their scale, and selected those for which erosion control works are applicable. The number and total area of such slope failure and gully erosion areas are shown in Table 14.

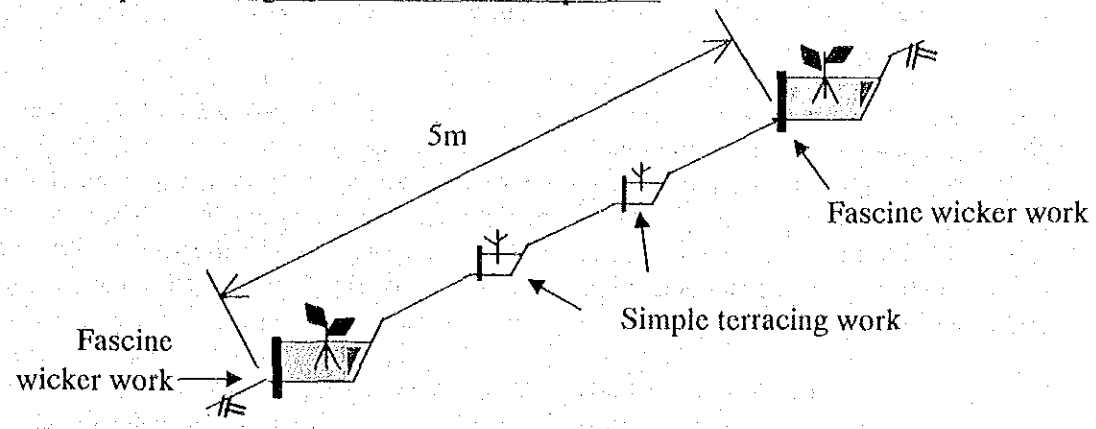
Table 14 Slope failure in the key study areas

Classification	Hillside slope failure		Gully erosion		Total	
	No. of locations	Area (ha)	No. of locations	Area (ha)	No. of locations	Area (ha)
Total number	2,081	277.21	671	329.78	2,752	606.99
Works planned	1,958	85.07	390	23.48	2,348	108.55

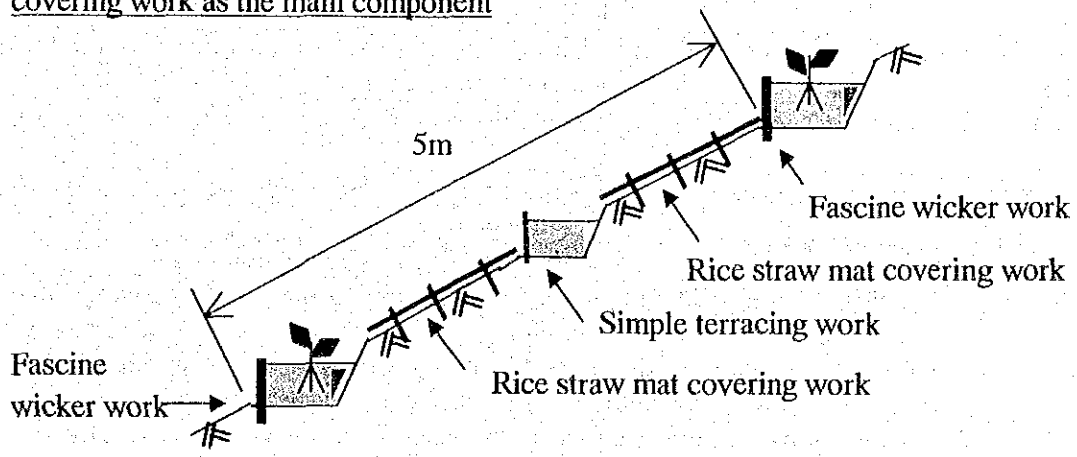
2) Simple hillside works

Under the erosion control plan, mixes of a number of types of hillside works—grading work, fencing work, simple terracing work, seedling propagation work, mat covering work, and planting work—will be used to deal with slope failure. Soil bag work, gabion work, and soil bag channel work will be applied to gully erosion. Figure 4 is a schematic diagram of these hillside works.

Hillside work method using fascine wicker work and simple terracing work as the main components



Hillside work method using rice straw mat covering work as the main component



Gully control work

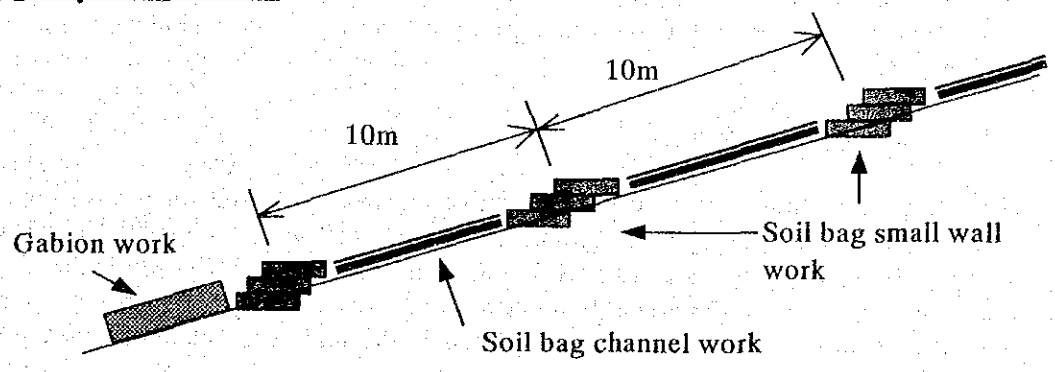


Figure 4 Schematic diagram of major hillside work methods

For these hillside works, locally available materials will be used as far as possible. For example, wooden piles and bamboo will be used for fascine wicker work and simple terracing work. For rice straw mat covering work, mats made of straw produced in the Anning River basin will be used.

Apart from those works that are designed to stabilize the ground surface, trees will always be planted where fascine wicker work or simple terracing work with bamboo are to be buried. Herbage will be introduced together with trees. For such herbage, pasture plants are appropriate as they germinate well even where the climate is severe. It is preferable to include a wide variety of different tree and herbage species with various characteristics. Recommended mixes of types of work, planting trees, pasture plants and other herbage are shown in Table 15.

Table 15 Trees and herbage for each type of hillside works

Type of hillside works	The recommended mix of trees and herbage
Fascine wicker work (i), (ii)	Planting trees, seeds of pasture plants (stocks of herbage), and cuttings
Simple terracing work with bamboo (i)	Planting trees, seeds of pasture plants (stocks of herbage), and cuttings
Simple terracing work with bamboo (ii)	Seeds of pasture plants (stocks of herbage), and cuttings
Rice straw mat covering work	Sowing mixtures of seeds of trees and herbage (pasture plants)
Soil bag channel work	Herbage seeds (pasture plants)

Notes:
1. Regarding herbage, the plan is for mainly sowing the seeds of pasture plants that can thrive under different conditions. It is preferable, however, to sow seeds of indigenous herbage in the form of sowing mixtures, where possible. Stocks of herbage, if they are available locally, will be used instead of herbage seeds.
2. For rice straw mat covering work, the seeds of trees will be sown directly. It is therefore necessary to select species suitable for direct sowing.

Since these types of erosion control works are relatively new to the Anning River basin, field engineers and contractors require training to acquire the basic skills for carrying out these works.

3) Unit cost of each method

The Study Team first calculated the amount of materials required for the selected work methods— fascine wicker work, simple terracing work with bamboo, rice straw mat covering work, soil bag small wall work, etc. —by developing a figure for the cost of a model structure. Then the Study Team developed an account of unit prices based on the pre-surveyed unit prices of materials and labor in the region to calculate a unit cost for each method.

Furthermore, the Study Team developed separately several model work methods for slope failure and gully erosion according to their scale and then calculated the average construction costs.

4) Calculation of the total cost of erosion control works

(1) Direct construction costs

The Study Team calculated the construction costs for each section by multiplying the average unit cost discussed in 3) by the total area of slope failure in each section. These calculations were broken down according to the type of slope failure. Then the Study Team added up the construction costs for all sections with slope failure to calculate the total cost of the erosion control works. This total cost represents the direct construction costs only.

(2) Calculation of the cost of materials transportation

Since the reforestation areas are located in remote areas, the costs for transporting the materials for the erosion control works are considerable. The Study Team calculated the materials transportation cost by multiplying the average weight of the materials by the unit transportation cost. In the process of this calculation, the average weight of the materials was calculated for each compartment, and the unit transportation cost was calculated for each type of transportation—transportation using manpower or transportation by vehicle.

(3) Calculation of other costs

Apart from (1) and (2), which represent the direct construction costs, the Study Team calculated the cost of overheads by summation or allocation according to a ratio of each cost item to a total. The cost of overheads includes engineering management costs, safety costs, repair costs, and the cost of installing facilities designed to control turbidity in the streams caused by these works.

Table 16 shows the cost of erosion control works by type of cost and city/county.

Table 16 The cost of erosion control works by cost type and city/county

Unit: 1,000 yuan

City/County / Breakdown Of the cost	Xide-xian	Zhaojue-xian	Xichang-shi	Dechang-xian	Miyi-xian	Total
Direct construction cost, including the cost of materials and labor (A)	3,845.5	5,569.1	4,199.0	460.9	3,322.1	17,396.6
Transportation costs (B)	1,874.4	1,023.3	469.4	67.2	224.3	3,658.6
Cost of overheads (C)	1,144.0	1,318.5	933.7	105.6	709.3	4,211.1
Total	6,863.9	7,910.9	5,602.1	633.7	4,255.7	25,266.3

Note: (C) = (A+B) × 0.2

10. Production of Reforestation and Erosion Control Planning Maps

The Study Team first produced a draft land management classification map that classifies the land according to each type of management to be applied. The Study Team then produced a draft reforestation planning map that was based on the land management classification. These drafts were examined and revised for the final versions.

Meanwhile, the Study Team drafted a map for an erosion control plan. The draft was then finalized after the plan was fixed.

11. Assessment

The reforestation planned in this study is aimed primarily at establishing ecosystem conservation forests, contributing to the restoration and conservation of the local ecosystems. The trees to be planted are either indigenous species or those that have already been introduced and do not have the potential to disrupt the local ecosystem.

The reforestation and erosion control planned in this study will boost the water holding capacity of the local forests, mitigating soil runoff. This will enhance the conservation of the headwaters and improve the function of the forests in recharging ground and surface water and therefore increase the base flow discharge during times of water scarcity and reducing the peak discharge at times of flooding. Mitigation of soil runoff will reduce the loss of soil nutrients. This will in turn increase the capacity of the forests for photosynthesis, thus extending their capacity to absorb carbon dioxide and produce other external economic benefits. The reforestation will promote the growth of wild grass on which livestock feed. Commercial forests will produce economic benefits in the form of firewood and timber.

Table 17 shows estimated increases in water recharge rates over a period of 50 years in the key study areas due to the reforestation and erosion control plans developed in this study.

Table 17 Estimated increases in water recharge rates in the key study areas

Units: tons (for annual discharges per hectare)
yuan (for annual economic benefits per hectare)

Key study area	Xichang-shi	Xide-xian	Zhaojue-xian	Dechang-xian	Miyi-xian
Discharges from plantation forests	4,219	2,801	5,349	2,957	3,230
Discharges from devastated and denuded land	7,287	10,786	7,378	6,362	8,818
Difference in the discharge rates (recharging)	3,068	7,985	2,029	3,405	5,588
Storage after deducting evapo-transpiration	1,040	809	688	1,154	870
Annual economic benefits gained by using the discharge for irrigation and city water per hectare (yuan)	2,277	1,990	1,507	2,424	2,140

Source: Findings of the on-site artificial rainfall test performed by the study team

Note: The annual economic benefit is calculated based on the assumption that 20% of the recharge is lost, 30-40% is used for irrigation, and 40-50% is used for city water supplies. In this case, the economic benefits gained by using the discharge for irrigation is calculated as the estimated increase in income if rain-fed fields are irrigated. The discharge used for city water is calculated as the amount of water that runs into rivers from common lands where water intake for irrigation is difficult.

Table 18 shows the total financial cost of the planned reforestation and erosion control work developed in this study.

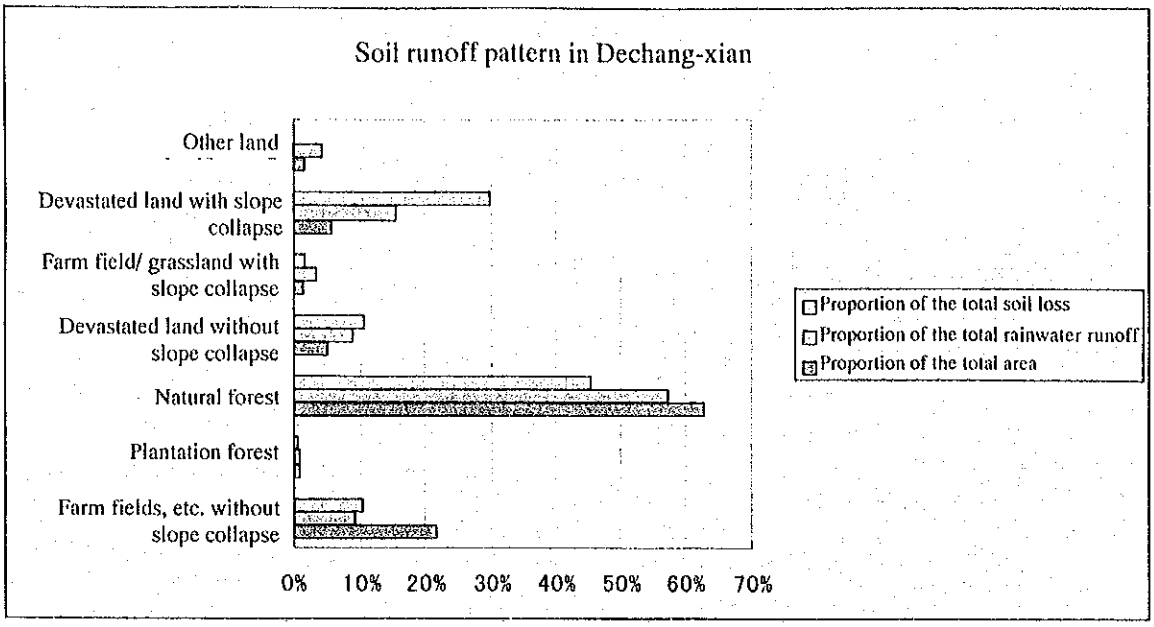
Table 18 Total financial cost and the breakdown

Unit: 1,000 yuan

Key study area	Direct reforestation costs	Erosion control construction costs	Construction-related miscellaneous expenses	Total financial cost
Xide-xian	51,826	6,864	10,289	68,979
Zhaojue-xian	56,529	7,911	10,949	75,389
Xichang-shi	29,715	5,602	5,943	41,260
Dechang-xian	22,361	634	4,470	27,465
Miyi-xian	37,624	4,256	7,524	49,404
Total	198,055	25,267	39,175	262,497

Measurable economic benefits include disaster prevention effects (flood control and farmland conservation), ecological conservation effects (silt control, groundwater recharge, global warming mitigation, the prevention of runoff of soil nutrients, etc.), and benefits gained from physical production (production of firewood, grazing forest products, commercial forest products, timber, etc.).

Figure 5 shows soil runoff patterns in Dechang-xian and Xide-xian. The figure demonstrates that landslides on waste land with slope failure account for a large proportion of the total soil loss compared with their proportion of the total area. The situation is quite the opposite for forestland. This proves that reforestation reduces soil runoff.



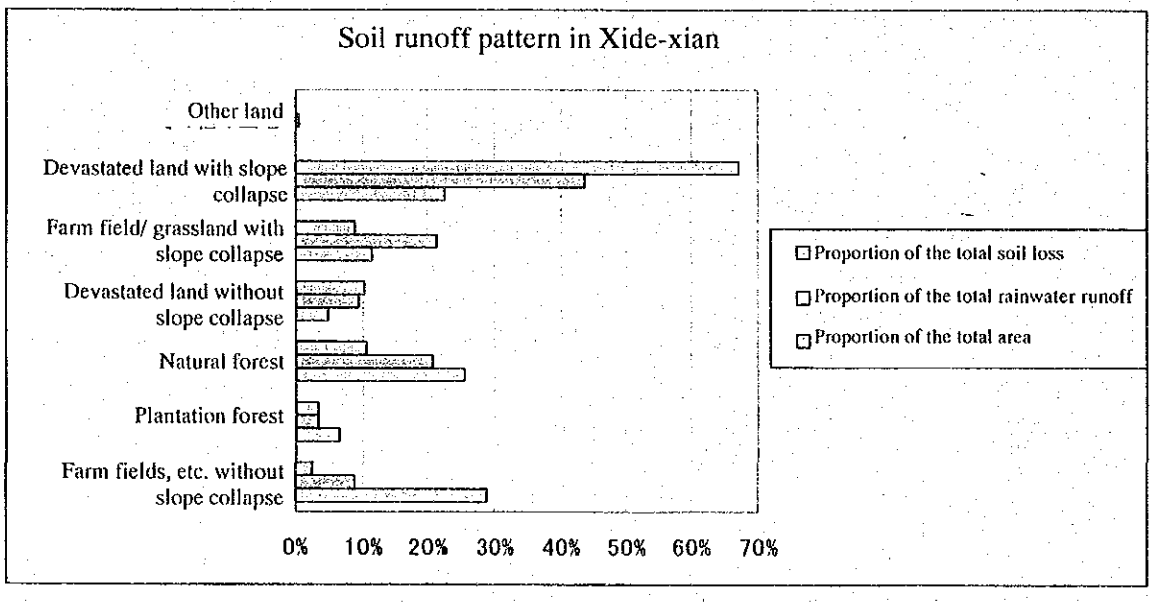


Figure 5 Proportion of the total soil loss, total rainwater runoff, and total area by type of land use

Table 19 shows the project costs and benefits and the results of a financial analysis of the reforestation and erosion control plan. The internal rate of return (IRR) is slightly more than 8%, indicating that the plan is feasible. Please note that even if the cost increases by 20% and/or the benefit decreases by 20% due to unpredictable factors, both the resultant cost benefit ratio and IRR will be within a range in which the plan is feasible.

Table 19 Project costs and benefits and financial analysis results

Key zone	Financial cost (1,000 yuan)	Measurable economic benefits (1,000 yuan)	Cost benefit ratio	IRR (%)
Xide-xian	68,979	592,784	8.59	8.9
Zhaojue-xian	75,389	435,131	5.77	6.8
Xichang-shi	41,260	419,191	10.16	10.0
Dechang-xian	27,465	252,468	9.19	8.9
Miyi-xian	49,404	278,094	6.63	7.2
Total	262,497	2,027,071	7.72	8.1

12. Results of the Trial Afforestation

The objective of the trial reforestation was to lay the groundwork for improving the performance of reforestation in the hot and dry valley zone, where the dry season lasts for about six months. In Miyi-xian, Panzhihua-shi, the Study Team selected two forestland consolidations suitable for demonstrating reforestation techniques that could be widely applied in the zone. The first consolidation (trial reforestation site) is 5.7 hectares in area, and its soil is mountainous, dry red soil. The second consolidation is 4.3 hectares in area, and its soil is mountainous, dry red soil rich in sand.

Species planted included *Acacia confusa*, *Bombax malabaricum*, *Dodonaea viscosa*, *Jatropha carcas*, and *Leucaena leucocephala*. In addition, *Agave sisalana*, a perennial herb species, was planted where the soil layer was thin and on the border of the trial reforestation sites. *Bombax malabaricum* was planted in places where water conditions were favorable, such as in small valleys and hollows. For *Acacia confusa* and *Leucaena leucocephala*, current year potted seedlings (three-month-old seedlings) were planted. As for *Bombax malabaricum* and *Jatropha carcas*, two-year-old bare rooted seedlings were planted. *Dodonaea viscosa* was sowed directly. The planting density was 4,995 trees per hectare (1 m x 2 m).

For land preparation, the Study Team prepared a terrace-shaped ground 80 centimeters along the contour lines that were set at an interval of ten meters in distance. Then the Study Team prepared planting holes at each planting point. The standard for land preparation with planting holes was 60 cm x 60 cm x 40 cm. To promote the initial growth of the planted trees, the Study Team treated the soil with 150 grams of compost mixed with chemical fertilizer per tree before planting. The appropriate planting time was when the cumulative precipitation reaches 100 millimeters after the rainy season set in, and the planting work began on June 21, 2001. In that year, the rainy season began about one month earlier than usual and the precipitation was 47% higher than the average year. For this reason, the hardening of the seedlings was insufficient. As an emergency measure to cope with the situation, the Study Team conducted trimming for *Leucaena leucocephala* seedlings and removed leaves of *Bombax malabaricum* at the time of planting. As tending for the first year of planting, undergrowth cutting was carried out in August and November. The second-year tending—fertilizing and weeding—was completed by June.

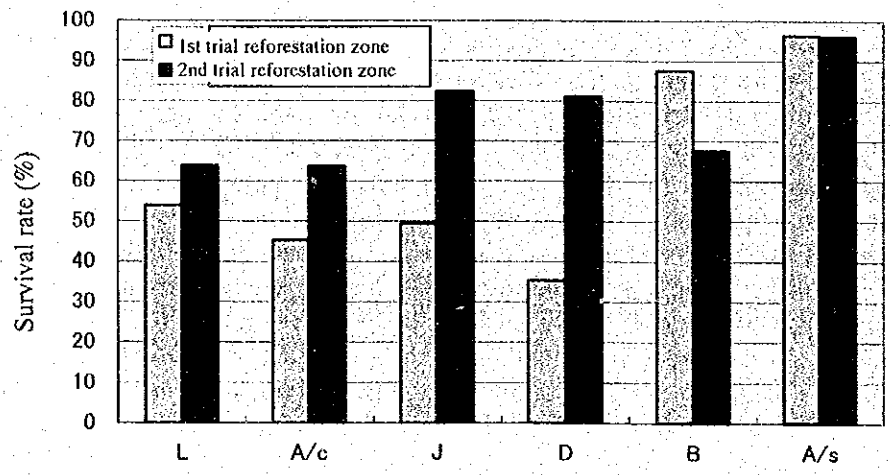
The afforestation performance as of April 25, 2002, is shown in Figure 6 (survival rate) and Table 20 (growth).

In the past, *Leucaena leucocephala* and *Acacia confusa* were planted in the region. Yet the survival rate of these species stood at less than 40% in the first year of planting and went below 20% after a few years. There has been no precedent for full-fledged plantation using *Bombax malabaricum, Dodonaea viscosa* or *Jatropha carcas.*

In this trial reforestation, the average survival rates for *Acacia confusa* and *Leucaena leucocephala* were more than 50% at the end of the dry season in the second year of planting. The survival rates for *Jatropha carcas* and *Dodonaea viscosa* stood at more than 80% in the second trial afforestation zone. The survival rates in the first trial afforestation zone were relatively low, due to smothering by the weeds that grew vigorously with the unusually high precipitation in the first year of planting. Damage due to weeds was relatively small in the second trial slope failure zone because the ground consisted of sandy soils.

In average weather, the major factor that substantially affects the survival rate of the planted trees is soil aridity in the dry season. Even at the driest season, soil 60 centimeters below ground maintained water conditions that guaranteed the survival of trees in the trial afforestation sites. Therefore, saplings whose roots reached 60 centimeters underground had little chance of wilting due to aridity. In fact, some 80% of the saplings that survived at the time of an April survey had extended their roots to 60 centimeters underground. During the rainy season between May and October, most of the remaining saplings are expected to extend their roots 60 centimeters underground as well. Therefore, it is predicted that the survival rate in the trial afforestation sites will not decrease significantly in the future.

On the whole, the performance of this trial reforestation far exceeds the previous attempts at afforestation in the region. The Study Team is confident that the model for this afforestation can be practically applied in the hot and dry valley zone in the Anning River basin to establish ecosystem conservation forests.



L: *Leucaena leucocephala,* A/c: *Acacia confusa,* J: *Jatropha carcas,* D: *Dodonaea viscose,* B: *Bombax malabaricum,* A/s: *Agave sisalana*

Figure 6 Survival rates of species in the trial afforestation

Table 20 Growth of major species in the trial afforestation

Species	Average size of seedlings (cm) planted on June 25, 2001		Average growth found in the survey of November 25, 2001 (cm)						Average growth found in the survey of April 25, 2002 (cm)					
			Trial reforestation site I		Trial reforestation site II		Total average		Trial reforestation site I		Trial reforestation site II		Total average	
	Height	Stem base diameter	Height (max.)	Stem base diameter (max.)	Height (max.)	Stem base diameter (max.)	Height	Stem base diameter	Height (max.)	Stem base diameter (max.)	Height (max.)	Stem base diameter (max.)	Height	Stem base diameter
Leucaena leucocephala	27.5	0.5	87.4 (215.0)	1.1 (2.4)	123.4 (250.0)	1.2 (2.5)	103.9	1.2	97.5 (282.0)	1.7 (3.4)	132.8 (270.0)	1.7 (3.2)	113.8	1.7
Acacia confusa	28.3	—	42.8 (103.0)	—	42.8 (120.0)	—	42.8	—	66.0 (149.0)	—	54.8 (130.0)	—	60.4	—
Jatropha carcas	12.6	1.6	34.2 (80.0)	2.8 (4.8)	45.7 (104.0)	3.1 (5.2)	38.7	2.9	36.1 (82.0)	3.1 (5.4)	47.4 (113.0)	3.4 (5.7)	40.48	3.3
Bombax malabaricum	Direct sowing	—	23.2 (55.5)	—	40.4 (82.5)	—	34.4	—	33.6 (72.0)	—	48.6 (100.0)	—	43.3	—
Bombax malabaricum	38.1	1.2	72.3 (152.0)	2.4 (4.3)	75.8 (140.0)	2.5 (4.8)	73.9	2.4	87.9 (170.0)	2.5 (4.3)	84.9 (156.0)	2.5 (5.2)	86.5	2.5

Note1: The November survey omitted the measurement of the stem base diameter as far as *Acacia confusa* and *Dodonaea viscosa* were concerned, since the lignification of the stems was not completed and the individual differences were small.

Note 2: The April survey omitted the measurement of the stem base diameter of each tree as far as *Acacia confusa* and *Dodonaea viscose* were concerned, since the stem base thickening growth was one centimeter or less.

13. Guidelines for Formulating the Reforestation Plan

After some progress in formulation of the reforestation plan, the Study Team discussed a policy for developing a guideline with their Chinese counterparts. Based on this discussion, the Study Team came up with the Guidelines for Formulating the Reforestation Plan in the Anning River Basin.

Theses guidelines made it possible to formulate the reforestation plan for the area that had been aerially photographed. Likewise, the guidelines will make it possible to formulate reforestation plans for other areas after they are aerially photographed.

14. Conclusion

In this study, the Study Team aerially photographed a total area of about 500,000 hectares of the five city/counties in the Anning River basin—Xide-xian in Liangshan Yi Autonomous Region, Zhaojue-xian, Xichang-shi, Dechang-xian, and Miyi-xian in Panzhihua-shi. The aerial photographs show the degradation of the forest vegetation due to overuse of forests and expansion of farmland on the slope in the mountain region of the Anning River basin, indicating that the region is quite vulnerable to erosion. The photographs also show large-scale slope failure, gully erosion, and traces of debris flows throughout the basin. On the riverbed, a large amount of unstable silt has accumulated. This makes not only the basin but also the lower reaches of the Yangtze quite vulnerable to flooding. In this connection, flood control is important.

An effective measure to control the runoff of mud and sand from the mountain region is the rehabilitation of devastated forestland that is designed to restore the forest ecosystem. This will boost the soil infiltration capacity and decrease the overland flow of rainfall, mitigating topsoil runoff. The root system of the forest plants will solidify the ground. This will prevent the landslips and the runoff of mud and sand. It will also contribute to headwater conservation and water recharge improvement.

The Model Afforestation Project in Sichuan (MAPS) is underway to develop and disseminate reforestation and nursery techniques designed to accommodate areas in the Anning River basin where reforestation is considered to be difficult. This study took advantage of the expertise and experience gained under MAPS. The reforestation plan developed in this study should make use of further achievements of MAPS.

Although this study is limited to reforestation in the key study areas, the cooperation of local communities over a wider area is essential to the actual reforestation. Fire prevention, prohibiting the entrance into the reforested areas, and voluntary restraint with regard to grazing, which are some of the important elements of the management of reforested land, require cooperation from the local communities. Such cooperation is also necessary for the reforestation work itself and seedling production. To gain such cooperation, dialogue with the local communities is essential. In the process of formulating the reforestation plan, it is necessary to consider the impact of the plan on local communities. For example, the plan needs to incorporate the establishment of forests that will help increase the income of local residents, although the main objective is to establish ecosystem conservation forests.

In fact, this study encompasses eco-type commercial forests, eco-type fuelwood forests, eco-type timber forests, and eco-type grazing forests. Here, "eco-type" implies the development and management of forests that not only serve the original purpose of each type of forest, but also contribute to ecological restoration. The Study Team has been making arrangements so as to realize ecological restoration while helping increase the income levels of local residents. It is undeniable that at the early the stages of the reforestation plan, the interest of local residents will be affected to a certain extent by such aspects of grazing and firewood collection. Yet the Study Team is confident that the plan will gain the cooperation of local communities since it will help increase the income of local residents in the long term.

The reforestation plan will improve the ecosystem in the key study areas. Specifically, the plan will contribute to headwater conservation and recharge improvement, control the runoff of mud and sand, and mitigate or even prevent flood disasters in the lower reaches of the Anning River basin. This in turn will improve agricultural productivity in the lower reaches. It can also increase the income of local residents in the key study areas, as a result of the establishment of eco-type commercial forests, eco-type timber forests, eco-type grazing forests and other types of forest.

Although the reforestation areas under the plan are limited in area compared with the Anning River basin as a whole, the reforestation plan, especially erosion control projects under the plan, in these areas (key study areas) will serve as a technical model not only for the basin but also for other basins in the Hengduan Mountain Region that have similar topography and geology and are devastated in a similar way to the Anning River basin.

Finally, the Study Team would like to take this opportunity to express its heartfelt gratitude to the following: the State Forestry Administration and the Ministry of Science and Technology in the State Council of the People's Republic of China, the offices concerned and the Forestry Department of Sichuan Provincial People's Government, the Forestry Bureau and other offices concerned of Liangshan Yi Autonomous Region, the Forestry Bureau and other offices concerned of Panzhihua Municipal People's Government, the Model Afforestation Project in Sichuan, the forestry bureaus and other offices of people's governments of the five municipalities/counties, operation supervisors, the secretaries concerned of the Japanese Embassy in China, JICA Headquarters and the JICA China Office. Their support was invaluable.

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