Chapter 10

A Study on Species' Screening and Techniques for Afforestation in the Hot and Dry Valley of the Jinsha River

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Abstract

The hot and dry valley of the Jinsha River in southwest China is one of the most difficult regions for regeneration of vegetation. In the past, many attempts at afforestation ended in failure due to aridity and soil sterility. From 1980, extensive and intensive studies on species' screening, appropriate techniques for afforestation, and investigation of benefits have been conducted.

The results show that *Leucaena leucocephala, Eucalyptus camaldulensis, Acacia confusa, Acacia auriculaeformis,* and *Robinia pseudoacacia* are the most promising species for afforestation in the hot and dry valley of the Jinsha River. In accordance with the principle of specific species for specific habitats, the screened species should be characterised by fast growth and high generating capabilities. The soil layer should be no less than 60cm. Appropriate techniques for afforestation include: nutrient packages for growing seedlings, preparation of large holes or horizontal furrows, planting in rainy season, and other appropriate management measures. Management and modification techniques for current artificial forests are also discussed in this paper. These forests can provide fuelwood, fodder, green fertilisers, and timber as well as play an important role in water and soil conservation. The research programme has solved many technique problems which were prevalent in the hot and dry valley for a long time. It has filled gaps in the field of afforestation in the Jinsha River and enriched the knowledge of silviculture.

Key words: Afforestation species' screening; planting techniques; the hot and dry valley; the Jinsha River

Introduction

The hot and dry valley of the Jinsha River in the upper reaches of the Yangtze River is an arid centre of southwest China. It harbours one of the most fragile ecosystems in China and is classified as an important region in terms of water and soil conservation. It covers 40,000sq.km. of which wasteland accounts for 60 per cent of the total area. In recent years, under the pressures of rapid population growth and agricultural development, the hot and dry valley environment has become degraded. The main indicators of degradation include heavy water and soil erosion, increased aridity, soil sterility, and desertification. It is reported that soil erosion in the area is 4,624.8 tonnes/km ^{2}/ year^{-1} and total soil erosion in the Jinsha River is over 18 million tonnes/year^{-1}. Therefore, it is essential to establish multipurpose and high economic benefit forests in order to improve the environment and accelerate the socioeconomic development of this region.

In the past, several attempts at afforestation ended in failure as a result of the harsh environment. Before 1980, the dry valley of the Jinsha River was considered to be a 'forbidden zone' for afforestation by the local people. The main reasons for this are described below.

a. Trees did not grow well because of the hot and dry climate. Evaporation in this region exceeded rainfall by several degrees. Water shortage was one of the primary constraints to vegetation development and, thus, the main vegetation types were scrub and savanna.

b. In the dry season, plants remained dormant and their growth was restrained by aridity and high temperature. They had low biomass and productivity.

c. There was little leaf litter on the soil surface. The litter decayed rapidly due to the relatively high soil temperature. The humus layer developed poorly and had weak water and soil conserving capacities.

d. Most of the waterland belonged to steep slopeland. In a fragile ecosystem of this nature, soil loss and degradation by agriculture and livestock proved to be serious constraints to forestry development.

Thus, an extensive research programme –"A Study on Species' Screening and Techniques for Afforestation in the Hot and dry Valley of the Jinsha River" – was initiated with the support of the Sichuan Science and Technology Committee for the purposes of species' screening; formulating appropriate techniques for afforestation; and management and modification of low-benefit forests into high- benefit forests. As a result, successful techniques for afforestation in the hot and dry valley have been developed.

Site Description

Site location

The site is located at Hulukou, Huatan township, Ningnan county of Sichuan province, just near the Jinsha River, in the upper reaches of the Yangtze River. The site is situated at 102°54' E and 26°54'15" N. The elevation ranges from 710 to 820 masl.

Climate

Geographically, the site lies in the subtropical monsoon climate region. Because the landform is dominated by high mountains and deeply dissected gorges, the foehn effect is very apparent. The site is characterised by a typical hot and dry valley climate. The annual mean temperature is 22.2°C, with a maximum temperature of 42°C in July and a minimum temperature of 4°C in January. The monthly mean relative humidity is 57 per cent. The annual sunshine duration is 2,257.7 hours. The annual mean precipitation is 740mm and the minimum mean rainfall is 569.7mm. The rainy season lasts from May to October, during which the rainfall accounts for 90 per cent of the total annual precipitation. The annual evaporation is 2,168.8mm, 3.5 times as much as the precipitation. In the dry season, the land surface maximum temperature can reach 75°C and the maximum wind speed reaches 20m/s. In summer, the site is referred to as the 'Flame Mountain' because of the high land soil temperature and exposed dry red soil.

Soil

The soil of this hot and dry valley is comprised mainly of dry red soil which is formed from calcareous rock and dolomite rock. The physical and chemical characteristics of the soil of the site are listed in Table 1.

Table 1: The Physical and Chemical Properties of the Soil at the Experimentation Site

Types of soil	Texture	pH	Organic matter %	Total nitrogen N%	Total phos-phorus	Total potassium K_2O%	Quick-acting phosphorus ppm	Quick-acting potassium ppm	Alkalisa-tion nitrogen ppm
thin (<30 cm)	light soil	7.35	1.24	0.167	0.427	2.67	15	187	103
medium (30-90cm)	heavy soil	7.60	0.87	0.094	0.085	1.89	11	240	88
thick (>90cm)	sandy soil	7.25	1.01	0.074	0.057	1.58	32	51	50

Vegetation

The current vegetation is of secondary origin, consisting of scrubs and savanna. The main species found here are *Heteropogon contortus, Eulaliopsis binata, Cymbopogon distans, Phyllanthus emblica, Jatropha curcas,* and *Dodonaea viscosa*, etc.

Method

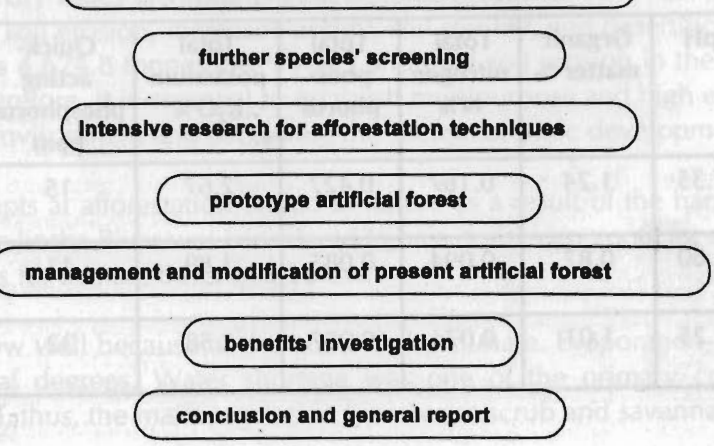
The principles for species' screening and afforestation were:

a. ecological principle
b. diversity principle
c. combination of trees, shrubs, and grasses
d. specific species for a specific habitat
e. species for afforestation in the hot and dry valley should have the following properties :

- fast growing
- fast-sprouting and high-generating capacity
- high biomass and productivity
- drought resistance
- deep root system
- low wilting co-efficient
- high survival and preserved percentage
- water and soil conserving capacities.

Technique Route

Before 1980, afforestation in this area usually ended in failure because of the lack of suitable species and inappropriate planting techniques. Keeping these mistakes in mind, the research programme undertook the following steps: First, about 40 species were put through experimentation. A few species which had adapted to the local habitat were screened. A set of techniques for afforestation were also developed. Second, these adaptable species were further tested and appropriate techniques were selected for afforestation for each year. Finally, the successful methods and plant prototypes were demonstrated and their use encouraged. In conclusion, the research achievements were demonstrated.



Data Analysis

Using the analysis of variance (ANOVA) method, it was determined whether there were significant differences in treatment and tests on the data distribution or whether they were in accordance with normal distribution.

Results

Screening of Suitable Species for Afforestation in the Hot and Dry Valley

The suitability or unsuitability of the species for the local environment is the key factor in determining success or failure of afforestation. Only the species whose physiological and ecological properties adapt to the climate and the soil of the hot dry valley can survive. Therefore a variety of species was tested to screen the suitable afforestation species. In 1980, nutrient package seedlings, naked root seedlings, and seeds of 18 species, including *Leucaena leucocephala* and *Eucalptus camaldulensis,* were planted on the experimental site. In the following year, a series of experiments on artificial forests, consisting of 27 species, including *Leucaena leucocephala, Eucalyptus camaldulensis,* seven other species of *Eucalyptus*, and others, were carried out. Trials with over 40 species were undertaken (see Annex to Chapter 9) and 17 species were found to be among the most suitable.

Seedlings of these screened species were planted with nutrient packages in 1984. The seedlings were raised in October/November 1983, except for seedlings of *Leucaena leucocephala* which were raised in March 1984. All the seedlings were planted in horizontal strip furrows. After afforestation, the height increment, survival percentage, and preserved percentage were investigated once a year and the data were analysed. The status of growth is shown in Table 2.

The species selected for afforestation in the hot and dry valley should manifest a high survival rate and high growth increment. To some extent, the survival rate represents the adaptability of the species to a harsh environment. It is the basis of species' screening. However, if the species have a high survival rate but low growth increment, it is difficult for timber forests to form. Only when the forests have been established can the stands have a good effect on water and soil conservation and good economic benefits. According to the comprehensive standards of a high survival rate and growth increment, *Leucaena leucocephala, Eucalyptus camaldulensis,* and *Acacia auriculaeformis* are the most promising species for afforestation in the hot dry valley; they have fast sprouting and high-generating capacities. Dense seedlings have been found in the *Leucaena leucocephala* forest. *Acacia confusa, Robinia pseudoacacia,* and *Casuarina equisetifolia* are bitter. They are drought resistant, sterility tolerant, and fast growing species. Although *Casuarina equisetifolia* has relatively low survival rates and growth increments on sloping wastelands, it grows very well along the river bank of the Jinsha River and has positive wind-breaking and sand-fixing effects.Consequently, the cultivated land and highway along the river bank have been well protected. Thus, it is a suitable species for river bank afforestation.

Cajanus cajan, Tephrosia candida, and *Albizia julibrissin* are nitrogen-fixing leguminous species. They have relatively high growth increment, survival, and preserved rates making them suitable species for afforestation. *Cajanus cajan* helps in improve soil fertility and is a host of the lac insect. It has good ecological and economic benefits. However, its average lifespan of about four years is short. *Tephrosia candida* can last for eight years. *Albizia julibrissin* grows fast in the the early stages but, after four to five years, the growth rate decreases rapidly.Furthermore, its sprouts and young branches are easily destroyed by the hot and dry foehn winds, resulting in low biomass productivity. These three leguminous species are good pioneer species. *Eriolaena malvacea* has a high survival rate and it is also an adaptable species. But it grows slowly and has a low increment, especially in the Jinsha River Valley. The foehn here is very conspicuous in the dry season and the newly generating branches are susceptible to drought and experience difficulty in resisting the dry season. Thus, this species is not suitable for afforestation at low elevations and in heavy foehn regions. *Cupressus decloxiana* is a potential species for afforestation by virtue of its ecological and physiological properties. However, the experiments showed that its survival and preserved rates were low because this

Table 2 : The Status of Growth of Preserved Species

Species	mean increment (cm/year)	diameter (cm)	survival percentage (%)	preserved percentage (%)	biomass production	adaptability to climate	lifespan	comprehensive characteristic
Leucaena leucocephala	184.8	1.84*	high	94.5%	high	very good	long	best
Eucalyptus camaldulensis	155	1.60	high	92.5%	high	very good	long	best
Trema augustifolia	127	1.142*	low	13.2%	low	not good	short	not good
Cajanus cajan	94	/	high	90.2%	medium	good	short	good
Albizia julibrissin	87.5	0.95	high	90.2%	low	not good	short	good
Casuarina equiselifolia	67.4	0.809	medium	32.0%	high	good	long	better
Tephrosia candida	67.2	0.687	high	79.4%	high	good	short	good
Acacia auriculaeformis	57.8	1.024	high	86.1%	high	very good	long	best
Robinia pseudoacacia	52.7	0.873	high	73.5%	high	good	long	better
Acacia confusa	49.8	0.951	high	82.7%	high	very good	long	better
Eriolaena malvacea	33.3	0.703	medium	72.2%	medium	good	short	good
Dodonea viscosa	28	/0.541	high	83.5%	low	very good	long	good
Platycladus orientalis	25.3	0.453	medium	75.0%	low	not good	long	not good
Cupressus duclouxiana	25.2	/	low	19.4%	low	not good	long	not good
Jatropha curcas	25	0.42	medium	43.5%	medium	good	long	good
Melia azedarach	24.5	/	medium	62.5%	low	not good	short	not good
Cassia siamae	5		medium	81.8%	low	not good	short	not good

* diameter at ground level

species is susceptible to damage by white ants. It was reported that about 60 per cent of the loss was caused by white ants. With regard to growth increment, it displayed an annual increment of 25cm only. Due to the above reasons, this species is not suitable for afforestation, especially in the harsh environment of the hot dry valley.

Platycladus orientalis has a higher survival rate than *Cupressus ducloxiana*. However, it grows better in more fertile environments as its physiological metabolism needs are better met. It is inclined to form low effect forests in hot, dry, and shallow soil environments making it an unsuitable species for afforestation.

Jatropha curcas and *Dodenea viscosa* are indigenous species of the hot dry valley. *Dodenea viscosa* is suitable for afforestation in the hot and dry valley environment but it lacks economic benefits. It can be selected as the first species to afforest in the wasteland where it is not easy to regenerate vegetation. *Jatropha curcas* is a kind of oil-bearing plant. It grows well in sandy soils as well as in more humid habitats. Elsewhere it has low survival rates. *Trema angustifolia* has a high height increment, but its survival rate is too low for the dry season. The growth rates of *Melia azedarach* and *Cassia siamea* are slow and they cannot adapt to the harsh environment of the hot dry valley.

A large part of the wasteland of the hot dry valley has low fertility. At present, it would be difficult to achieve success if arbors were selected for afforestation. But it is feasible to select a few adaptable shrubs of the leguminous species. Leguminous shrubs can fix nitrogen, increase soil fertility, and play an effective role in barricading water and soil erosion. They can also provide fuelwood for local farmers. On the experimental site, a few leguminous shrubs, such as *Tephrosia candida* and *Cajanus cajan,* were mixed in the forest and the results show that the roots of leguminous shrubs developed quickly and had high biomass, making them ideal species for afforestation.

Wilting Coefficient

In the Jinsha River Valley, the annual evaporation is three times more than the annual precipitation. The dry season lasts for over six months and, from March to June, the soil temperature is quite high. The soil moisture evaporates quickly. The soil moisture and the minimum moisture that the screened species can bear are key factors in determining whether afforestation is successful or not. The wilting coefficient is the level of soil moisture at which water becomes unavailable to plants and permanent wilting ensues. In order to reach scientific conclusions, not only on species' screening but also on the adaptability to water factor, and estimate the prospects of the afforestation species, soil moisture in the dry season and the wilting coefficient of the afforestation species were obtained in 1986. The minimum water contents of different soil types are shown in Table 3.

The results show that the water contents vary in soil types, but the water contents of the same soil type at different slope levels are not significantly different. The wilting coefficients of 14 species are shown in Table 4. It is obvious that the wilting coefficients vary from 1.593 to 1.897 in sandy soil to from 4.403 to 5.207 in dry red soil. The minimum water contents of the soil in the dry season are 1.941 in sandy soil and 5.272 in dry red soil. All these are higher than the wilting coefficients of the 14 species. Therefore, as far as water content is concerned, the needs of the above mentioned species can be met. The experiment also shows that screened species such as *Leucaena leucocephala, Eucalyptus camaldulensis, Acacia auriculaeformis,* etc are suitable for afforestation in the hot dry valley (see Table 4).

In the hot dry valley of the Jinsha River, the problems facing afforestation are not caused mainly by water conditions but by the over sterile soil. As already discussed, the minimum water content in the dry season is much higher than the wilting coefficients of the majority of species. For afforestation in the hot dry valley, the natural quality of the soil is the most important factor, given the fact that only when the soil has a certain humus layer can it support regeneration of vegetation.

Table 3. The Minimum Water Contents of Different Soil Types in the Dry Season

Number of soil profile	Slope	Soil type	Layer of soil profile	Monthly minimum water content							
				Date	Water content	Date	Water content	Date	Water content	Date	Water content
I	18.4	sandy soil	0	30/3	0.799	30/4	0.925	30/5	0.858	10/6	9.881
			30		1.941	10/4	2.725		2.875		5.436
			50		3.174		3.102		3.197		6.017
			70		4.077	20/4	2.834		4.160		8.267
II	17.8	dry red soil	0	20/3	0.671		0.908	30/5	0.986	10/6	9.596
			30	30/3	5.272		6.494		6.316		7.803
			50		6.781		7.232		7.707		8.116
			70		7.283		7.072		7.857		8.814
III	15	dry red soil	0	20/3	1.000	10/4	1.054	30/5	0.809	10/6	9.728
			30		6.516		7.567		7.077		7.843
			50		7.465		7.612		8.049		7.180
			70		6.357		8.462		8.879		8.123

Table 4: The Wilting Coefficient of Different Afforestation Species

Species	Mean Wilting Coefficient (WC) in Different Soil Types			
	Soil Type	Wilting coefficient	Soil Type	Wilting coefficient
Eucalyptus camaldulensis	Sandy Soil	1.873	Dry Red Soil	5.073
Zisyphus jujuba		1.815		5.185
Robinia pseudoacacia		1.864		5.207
Tephrosia candida		1.897		4.438
Leucaena leucocephala		1.629		4.455
Acacia confusa		1.680		5.151
Acacia auriculaeformis		1.695		4.590
Casuarina equisolifolia		1.844		4.458
Melia azedarach		1.759		4.879
Albizia julibrissin		1.736		4.778
Trema angustifollia		1.523		4.575
Cupressus duclouxiana		1.880		4.678
Cassia siamae		1.612		4.403
Eriolaena malvacea		1.593		5.100

Afforestation Techniques

Whether the afforestation techniques are correct or not also plays an important role in the success of afforestation. In the past, in addition to species' screening, inappropriate techniques for afforestation were also instrumental for failure. Consequently, a set of techniques were tested to establish the appropriate ones.

<u>The Effects of Different Seedlings on Afforestation</u>

The results of the tests showed that seedlings in nutrient packages have higher growth increments and survival rates than naked seedlings. Experiments with the naked roots of *Eucalyptus camaldulensis* showed that its survival rates decreased as follow: leave-pruned naked root seedlings > stem-cut naked root seedlings > non-treatment naked root seedlings.

<u>The Effect of Different Methods of Soil Preparation on Afforestation</u>

The tests proved beyond any doubt that the large hole (60*60*50cm) method is the best method of soil preparation for afforestation and the horizontal furrow (150*60*50cm) is better than the small hole method (30*30*30cm).

<u>The Effect of Different Soil Types on Growth Increment</u>

Leucaena leucocephala and *Eucalyptus camaldulensis* are two of the most promising species. In accordance with the principle of specific species for specific habitats, the effects of soil thickness and soil type on growth have been studied.

The results showed that a soil layer of less than 60cm is not suitable for afforestation. In the hot dry valley of the Jinsha River, especially at the Hulukou site, the soil layer (less than 60cm) tended to crack and gaps were also formed by soil tension in the dry season. The fine absorbed roots are prone to being broken into pieces and mostly die. The survival of the planted trees under physiological water shortage conditions caused by injured roots in the dry season is difficult. *Eucalyptus camalduensis* was found to be suitable for growing in sandy rather than in dry red soil. But difference in soil types had no significant effect on the diameter growth of *Eucalyptus camaldulensis*. The thickness of the soil also plays an important role in the height growth and diameter of the *Leucaena leucocephala* and *Eucalyptus camaldulensis*.

In general, in the hot dry valley, afforestation seedlings must be nutrient package ones. Although it is less expensive to use naked root seedlings for afforestation, rainfall in the hot dry valley is not significant and the rainy season is short, thereby necessitating nutrient packages. Even if the weather is suitable for afforestation, continuous drought days may follow after afforestation, rendering the attempt futile. Moreover, the naked root is susceptible to injury and loss of water during transportation. The naked root is difficult to restore to activity in a short time. So the root and height cannot increase considerably in the rainy season. In the following half year of dry climate, survival is uncertain. Nutrient package seedlings, on the other hand, overcome the above shortcomings. Therefore, for afforestation in low elevation regions, nutrient package seedlings are the most effective.

The quality of soil preparation is also very important. As far as soil preparation is concerned, large holes and horizontal furrows are better than small holes for seedling growth. The main reason for this is that the hot dry valley of the Jinsha River consists mostly of dry red soil. This kind of soil is characterised by sticky, heavy soil which is shallow and rich in gravel. In addition to the rare vegetation, water seepage and soil erosion are heavy. The subsoil is exposed. Using large hole or horizontal furrow methods of soil preparation would help accelerate the soil forming process. After soil preparation, a great deal of surface soil is filled back into the hole. Loose soil is favourable for root development and can block surface runoff. Simultaneously, weeds are also effectively controlled. The large hole method has proved to be the most economical and conducive to growth increment among all the soil preparation methods.

The soil layer thickness is one of the primary constraints to growth increment, and different kinds of soil types have varying effects on growth increment. In general, soil less than 60cm is not suitable for afforestation in the hot dry valley of the Jinsha River.

Management and Modification of Present Artificial Forests

Effects of Different Intensities of Thinning and Cutting on Growth

Thinning and cutting are favourable to plant growth because they can regulate light, heat, water, and nutrient allocation and improve the environment. Thinning and cutting must begin when obvious individual growth differentiation appears in the plant growth. The *Leucaena leucocephala* forest should be selectively cut five years after afforestation because the primary density (2,500-10,000 seedlings per hectare) begins to restrict plant growth. But on the middle or upper slopes, thinning may be delayed for six to seven years as there is relatively low growth due to shallow soil and sterility.

The intensity of thinning has a positive effect on *Leucaena leucocephala* growth but no significant effect on *Eucalyptus camaldulensis.* When the cutting intensity is above 50 per cent; the remaining *Leucaena leucocephala* grow fast and, when cutting intensity reaches 70 per cent, the individual growth rate is maximum. With regard to *Eucalyptus camaldulensis,* only when cutting intensity reaches 60 per cent is the diameter at breast height accelerated. However, no significant differences in the growth of cut and non-cut forests were noted.

With respect to biomass accumulation, a seven-year old *Leucaena leucocephala* forest is maximum when cutting intensity is 50 per cent. Whereas *Eucalyptus camaldulensis* is not sensitive to cutting intensity. Thinning and cutting helps the pure *leucaena leucocephala* to develop a high sprouting ability and generating capacity. The seedlings can cover forest land in a relatively short time, thereby enhancing water and soil conservation.

Management and Modification of Low Effective Forest

Mixing leguminous species with *Eucalyptus camadulensis* and regulating the nutrient area by using the selective cutting method have proved to be effective ways of managing low effect forests. Fertiliser application is not economical and has no significant effect on the modification of low effect forests. In general, for modification, pure *Eucalyptus camaldulensis* forests in the wetlands and their low effect forests should be mixed with leguminous species to increase soil fertility as the low effectiveness of *Eucalytus camaldulensis* is caused by malnutrition.

Leucaena leucocephala Forest - The low effectiveness of *Leucaena leucocephala* is caused by extensive afforestation, mismanagement, goat grazing, and insect problems. The first kind of *Leucaena leucocephala* low effect forest has no active growth point. This is caused just after cultivation because of extensive afforest-ation. Weeding and compost fertiliser application are the best ways of modification. Intercropping with crops is another effective way, but this method can only be applied in regions rich in manpower and on flat lands.

Another kind of *Leucaena leucocephala* low effect forest (over three years old) has no apical dominance and has a number of sprouting branches as a result of goat grazing and pests. The best ways of modification in this case are stem-cutting and fertiliser application.

The Benefits of Afforestation

Water Conservation

The experiments (see Table 5) show that the water runoff in the rainy season of a nine-year old *Leucaena leucocephala* forest is 1,017.04 cubic metres per hectare less than wasteland - accounting for US$ 0.063/m^3.

Table 5: The Water and Soil Loss of *Leucaena leucocephala* Forest and Wasteland Water runoff (m^2), soil loss (ton) runoff site area: 80 m^2

Time	annual rainfall	rainfall in rainy season	water and soil loss in $80m^3$				water and soil loss in one hectare			
			Forest land		Wasteland		Forest land		Wasteland	
			water	soil	water	soil	water	soil	water	soil
1990	793	611.4	1.9484	0.0066	9.9662	0.2646	243.08	0.83	1245.8	33.08
1991	952	884.8	2.7718	0.0049	11.1185	0.2993	346.49	0.61	1389.9	37.41
1993	893	815.9	2.0445	0.0005	10.0874	0.2726	255.58	0.06	1261	34.07
mean	880	769.9	2.2549	0.004	10.3907	0.2788	281.87	0.5	1298.9	34.85

Soil and Nutrient Conservation

A nine-year old *Leucaena leucocephala* forest can conserve soil 34.35 ton/year.ha, accounting for US$ 47.75 depending on the costs of local manpower and fertilisers (see Table 5).

Increasing Fertility

Table 6 shows that a nine-year old *Tephrosia candida* pure forest can account for US$4002.39/ha, mean annual US$444.71/ha/year. It is the most promising forest for increasing soil fertility. The abilities for increasing soil fertility of different forests are: *Tephrosia candida* pure forest > *Eucalpytus camaldulensis* and *T. candida* mixed forest > *Leucaena leucocephala* forest > *E. camaldulensis* and *L. leucocephala* mixed forest > *Acacia confusa* forest > *A. auriculaeformis* forest > *E. camaldulensis* forest (see Table 6).

Economic Benefits

Timber - 12-year old *Eucalyptus camaldulensis* forests can produce timber at the rate of $72.98m^2$/ha/year. The price of this timber is US$ $13.75m^3$ mean annual value, accounting for US$ 83.62/ha/year. Nine-year old *Leucaena leucocephala* forests can produce $40.1m^3$/ha. year, with a mean annual value accounting for US$61.26/ha/year. Ten-year old *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce 73. $41m^3$/ha/year, accounting for US$ 100.93/ha/year.

Fuelwood - 12-year old *Eucalyptus camaldulensis* forest can produce by-product fuelwood at the rate of $21.45*10^3$kg/ha depending on the local price of US$0.02/kg, accounting for US$35.75/ha/year. Nine-year old *Leucaena leucocephala* forest can produce fuelwood at the rate of $36.76*10^3$kg/ha, depending on the price of US$0.018/kg, accounting for US$ 73.5/ha/year.

Fodder - A nine-year old *Leucaena leucocephala* forest can produce $5.53*10^3$kg of leaves, accounting for US$73.73/ha/year, depending on the price of green fodder at US$0.12/kg. The *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce US$ 31.88/ha/year.

Green Fertiliser

The leaves of a nine-year old *Leucaena leucocephala* forest can produce green fertilisers at the rate of $5.53*10^3$, the price is US$ 0.04/kg, accounting for US$ 221.76, the mean annual is return is US$ 24.6ha/year. A 12-year old *Eucalyptus camaldulensis* forest can produce $6.13*10^3$kg of leaves, accounting for US$ 245.2, amounting to US$20.43/ha/year. *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce $2.31*10^3$kg and $4.48*10^3$kg of leaves respectively, accounting for US$271.6 mean annual US$ 27.2/ha/year.

Table 6: Increasing Fertility Effect of Different Stands

Type of Stand	organic matter %	total N %	total P %	quick-K mg/10g soil	fertiliser of 0-40cm soil OM* US$	NUS$	PUS$	KUS$	Total value US$/ha	increment US$/ha	mean annual US$/ha/yr
1 Eucalyptus camaldulensis	0.43	0.11	0.0021	1.51	569.81	2108.4	13.9	12	2704.1	147.84	12.3
2 Leucaena leucocephala	1.08	0.29	0.0034	1.94	1431.1	4419	22.5	15.4	5888	3331.8	370
3 Acacia confusa	0.79	0.16	0.0023	1.59	1046.8	2438.1	15.2	12.6	3512.7	956.44	95.6
4 Tephrosia candida	1.13	0.33	0.0021	2.36	1497.3	5028.7	13.9	18.8	6558.7	4002.4	445
5 Acacia auriculaeformis	0.71	0.15	0.002	1.47	940.8	2285.8	13.3	11.7	3251.5	695.23	69.5
6 Mixed forest of 1 & 2	1.01	0.24	0.0037	1.26	1138.3	3657.1	24.5	10	5030	2473.7	225
7 Mixed forest of 1 & 4	1.05	0.3	0.0027	2.22	1391.3	4571.5	17.9	17.7	5998.4	3442.1	382
8 Control	0.42	0.13	0.0017	0.94	556.53	1981	11.3	7.47	2256.3	0	/

* OM: Organic matter

* The price of different fertiliser: organic matter US$ 0.0125/kg: Nitrogen US$ 0.144/kg; phosphorus US$ 0.0625/kg; Potassium US$ 0.075/kg.

Climate and Social Benefits

Hulukou was referred to as the 'Flame mountain' and the 'Forbidden region' for afforestation by local people. Before afforestation, the mean annual temperature was 22.2°C, relative humidity was 57 per cent, and evaporation was 2618.8mm and 3.5 times that of rainfall. After afforestation, the climate has changed and improved. According to four years' meterological data from 1982-85, the mean annual temperature dropped to 21.7°C. From 1990 to 1993, the mean annual temperature dropped to 20.95°C, evaporation decreased to 1,604.73mm, and relative humidity was 70 per cent. Also, the response of the local farmers was favourable. In the past, mountain floods in the rainy season destroyed the crops. Afforestation has greatly reduced the occurrance of floods. The weather is no longer hot and arid. The forests have barricaded the wind and sand and the animal and bird populations have increased.

Conclusion

The hot and dry valley of the Jinsha River has rich heat and wasteland resources. But the soil is very sterile and has a low carrying capacity. Rainfall distribution is low and the dry season lasts for over six months. The weather is hot and dry in the dry season. Therefore, species and afforestation techniques are essential. Once close forests are established, good ecological and economic benefits will accrue as a result of a rapid growth rate under favourable climatic conditions.

Regeneration of vegetation, water and soil conservation, and provision of fuelwood are the tasks at hand. Therefore, the screened species must adapt to the special habitats of the hot dry valley and be characterised by fast growth; high survival rates; high biomass and productivity; high generating capacities; and drought resistance.

Afforestation should be carried out in accordance with the principle of specific species for specific habitats. The afforestation seedlings should grow in nutrient packages. In addition, the depth of the soil should be over 60cm. Large holes and horizontal furrows are the suitable methods for soil preparation. Mixing with leguminous species or intercropping with crops are effective ways of promoting growth increment and increasing soil fertility.

The low effect forests must be cut periodically.The thinning and cutting intensity should be 70 per cent for five-year old *Leucaena leucocephala* forests and 50 per cent for seven-year old *Eucalyptus camaldulensis* forests. Mixed forests are suitable for accelerating growth. *Leucaena leucocephala* and *Eucalyptus camaldulensis* are the most promising species for water and soil conservation and for solving the fuelwood shortage problem in the hot dry valley. They provide green fertilisers, fodder, fuelwood, timber, and other ecological and economic benefits.

For afforestation in the hot dry valley of the Jinsha River, *Leucaena leucocephala* and *Eucalyptus camaldulensis* should be selected as planting species and mixed with other adaptable leguminous species. *Tephrosia candida* is the most suitable pioneer species as it helps to increase soil fertility. Forestry development in the hot dry valley must keep the above measures in mind in order to be sustainable.

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Annex 1 to Chapter 10

1. List of species used for screening in Hulukoku, Ningnan County.

*	1.	*Eriolaena malvacea*
*	2.	*Casuarina equisetifolia*
*	3.	*Dodonea viscosa*
*	4.	*Melia azedarach*
	5.	*Toona sureni*
	6.	*Quercus variabilis*
	7.	*Quercus pannosa*
*	8.	*Eucalyptus camaldulensis*
	9.	*Eucalyptus badjensis*
	10.	*Eucalyptus bunii*
	11.	*Eucalyptus amplifolia*
	12.	*Eucalyptus uiminalis*
	13.	*Eucalyptus citriodora*
	14.	*Eucalyptus umbellata*
	15.	*Eucalyptus exerta*
*	16.	*Jatroppa curcas*
	17.	*Aleurites fordii*
	18.	*Aleurites moluccana*
	19.	*Ricinus communis*
*	20.	*Bombax malabaricum*
	21.	*Choerospondia axillaris*
*	22.	*Trema angustifolia*
*	23.	*Ficus lacor*
*	24.	*Cupressus duclouxiana*
*	25.	*Platycladus orientalis*
	26.	*Ziziphus jujuba*
	27.	*Schima wallichii*
	28.	*Grevillea robusta*
*	29.	*Cajanus cajan*
*	30.	*Robinia pseudoacacia*
*	31.	*Leucaena leucocephala*
*	32.	*Acacia confusa*
*	33.	*Acacia auriculaeformis*
*	34.	*Albizia julibrissin*
*	35.	*Cassia siamea*
*	36.	*Tephrosia candida*
	37.	*Zenia insignis*
	38.	*Tamarindus indica*
	39.	*Prunus dehisens*
	40.	*Pinus kesiya*

N.B. "*" stands for the species still preserved.