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REQUIREMENTS FOR SUCCESS OF REFORESTATION PROJECTS IN A SEMIARID LOW-MOUNTAIN REGION OF THE JINSHA RIVER BASIN, SOUTHWESTERN CHINA

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ABSTRACT

Most reforestation projects have not been successful in the low-mountain region of the Jinsha River Basin, which has a harsh environment (high temperatures and lack of available water). Analysis of few successful reforestation cases in Yuanmou, Yunnan Province of China, a typical semiarid region of the Jinsha River Basin, reveals that a holistic approach is needed for successful reforestation in the region. Techniques of tree planting need to be taken into account to ensure normal growth during the early stages after transplanting from the nursery in such a dry and hot environment. More important are the follow-up management of trees and the implementation of management policies in reforestation areas, of which after-care and forest watching are important measures. Copyright © 2002 John Wiley & Sons, Ltd.

KEY WORDS: reforestation; semiarid; southwestern China; tree management; tree planting

INTRODUCTION

Yuanmou, Yunnan Province is a low-mountain region with a dry and hot climate, located in the Jinsha River (a tributary of the Yangtze River) Basin, southwestern China. Prior to 1958, the forest cover of the low-mountain region occupied 64 per cent of the land area. In 1958, the forest cover was removed for use as a fuel source for industrial purposes. Presently, forest cover is less than 1 per cent of the land area. This heavy reduction in forest cover has induced crucial soil erosion problems with erosion rates of 38–80 $t\,ha^{-1}\,yr^{-1}$ (Zhang *et al.*, 1995). The clearing of forest vegetation and severe erosion have increased the severity of droughts so that the main river, the Longchuan River a tributary of the Jinsha River in the upper reaches of the Yangtze River drainage basin, has gone dry during the months of April and May in recent years. Zhang (1992) describes this region as one of the most difficult for vegetation recovery in China. Since evaporation is several times greater than precipitation, forest establishment has proved difficult, thus savanna type vegetation has developed. Over the past few decades, before the beginning of the project in the study area, a lot of forest re-establishment projects have been conducted but with almost zero success (i.e. no surviving trees). Consequently, local people have believed that this region has become a ‘forbidden zone’ for reforestation (Shi *et al.*, 1994), largely due to lack of tree-planting techniques in harsh environmental conditions (high temperature and moisture stress).

Damage to soil and plants in arid and semiarid areas is not easily repaired (Zhang, 1992; Milton *et al.*, 1994). Chou (1987) reported that only shrubs and grasses could be grown in the arid and semiarid conditions. Albaladejo

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et al. (1998) has observed that the fragile ecosystems at the transition between semiarid and arid areas are not able to recover fully after a severe disruption such as vegetation removal. However, in the central part of Yuanmou, Yunnan Province there is a history of six to eight years of successful reforestation projects (72–77 per cent survival) on areas of approximately 100 ha. Du (1994), Li (1995), Li and Chen (1995) and Zhang and Chen (1997) have considered technical factors (moisture stress) as the primary constraints in re-establishment of forest vegetation, whereas, Hauck (1985), Hornetz (1993) and Stohl (1993) felt that the constraints were not technical but socio-economic in nature (overgrazing, cutting and litter collection).

Wood for fuel is a primary concern for people in Yuanmou, Yunnan Province because the existing forest is not capable of meeting the demand, and other fuel sources are too expensive. The local government has recognized the problem and shown a willingness to solve the problem. Thus, plans for reforestation were developed to provide forest plantations to conserve soil and water resources and to supply fuelwood for farmers. In view of the two perspectives above, the local government has established reforestation projects in close association with the local of forestry institute. It was determined that the success or failure of these projects could not be explained by either a single technical factor or a socio-economic one, but by a combination of both technical and socio-economic viability. This paper reports the conditions at two successful reforestation sites and describes the procedure leading to their success.

METHODOLOGY

The study was conducted at two villages (Xiaohengshan and Shaofangpo) in Yuanmou, Yunnan Province (25° 25′–26° 07′N and 101° 35′–102° 05′, see Figure 1). Yuanmou is located in the Jinsha River Basin, southwestern China covering an area of 2021 km^2. Forty per cent of the total area is a low-mountain region (900–1350 m a.s.l.) in the southern subtropical zone characterized by a hot and dry climate. Annual average temperature in the low-mountain region is 22°C with annual average rainfall of 611 mm. May and June are the warmest months with average temperatures of 26·6°C. A wet season occurs between May and October. Yearly evaporation exceeds 3900 mm, approximately five times greater than precipitation creating a serious water deficit for the whole year. Xiaohengshan is situated at 6 km northwest of Yuanmou and Shaofangpo 3 km southeast of Yuanmou. Fifty hectare of trees (*Eucalyptus camaldulensis* Dehnl) each were planted in Xiaohengshan (1991) and Shaofangpo (1993).

Our field observation and interviews with farmers were conducted in 1998. Trees were established successfully. Planted shrubs, *Dodonaea viscosa* (L.) jacg and *Phyllanthus emblica*, performed well. Grasses were scarce at the Xiaohengshan site, while at the Shaofangpo site the ground surface was almost covered with grasses *Heteropogon contortus* of 40–60 cm in height. Five sample plots of 100 m^2 along the toposequence were established to measure tree height and diameter at breast height (DBH). The history of local forest changes with time and tree planting (including method, time, survival rate, etc.) were obtained through the interviews with local farmers and the use of the county annals. Three farmers who were over 60 years of age were interviewed to assess the accuracy of the information given.

RESULTS AND DISCUSSION

Technical Aspects of Reforestation Success

Seedling nursery

From the experience of the past few decades, we have found that sapling age affects survival of trees at the early stage after transplantation. Our results showed that for *Eucalyptus camaldulensis* Dehnl, a sapling 90–100 days of age had a greater survival rate than saplings of 110–120 days. Seedlings older than this required a longer transplant recovery period because more lateral roots had been damaged in the transplanting process. A nursery with the trees in pots with plastic film plays an important role in the survival of the trees. Seedlings in nursery pots had an average survival rate of 77 per cent; whereas bare rooted seedlings only had a 53 per cent survival rate under the conditions introduced in the present paper (Table I). When potted seedlings are transplanted, seedlings are kept in a relative stable soil environment and their roots are not as easily damaged, thus creating a higher survival rate.

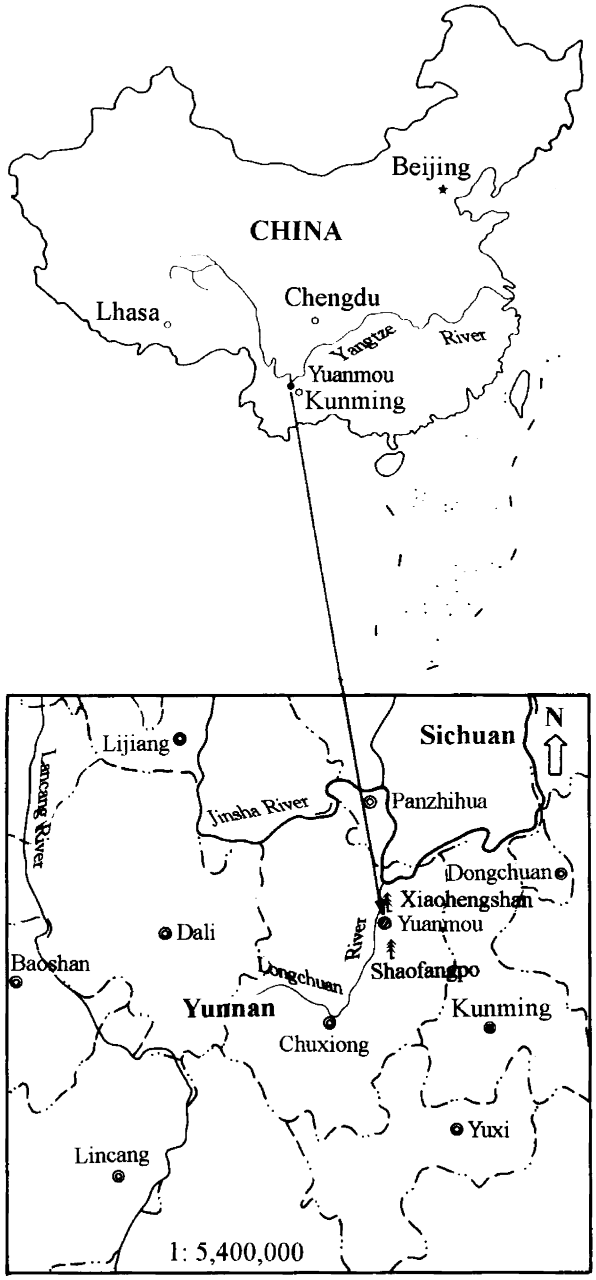

Figure 1. A map showing the study area.

Land preparation

Past failure of plantations has shown that land preparation is another important factor in the seedling survival rate. Dagar *et al.* (2001) observed that different land preparation methods for difficult soils led to different tree growth. Simply digging a small hole and planting the seedlings has been unsatisfactory in obtaining a desirable seedling survival in this region. Uncultivated lands on steep slopes with a compacted soil surface are subject to water runoff and low water infiltration. Consequently, where there is low rainfall, the seedlings cannot obtain enough water to meet their growth requirements. Maintenance of sufficient soil moisture is necessary for young seedlings (Lu,

Table I. Survival rates of transplanted seedlings with bare root and nursery pot techniques

Treatment	Number of transplanted seedlings	Number of survival tree (after 8 years)	Survival rate (%)	Difference significance of survival rates
Bare root	1300	689	53	$p < 0{\cdot}01$
Nursery pot*	1300	1001	77	

*The size of the nursery pot is 8 cm deep and 8 cm in diameter.

1994) and soil moisture is vital to the success of revegetation programmes (Banerjee, 1990), because soil moisture plays an important role in promoting root growth of plant seedlings (Xu and Ye, 1979; Li and Chen, 1995).

Based on previous experience, technicians and local farmers have developed a method of land preparation and applied it on the two sites, in 1991 at Xiaohengshan and in 1993 at Shaofangpo. The procedure developed is that parallel to the contour, ditches 0·6 × 0·5–0·6 m (width × depth) are excavated with a 3–4 m spacing between ditches. The most suitable period for land preparation is October to December, immediately following the wet season, when the soil contains appropriate moisture and is most easy to excavate. Before the beginning of the wet season in May, the excavated soil was placed back into ditches to a depth of 5 cm below the ground surface. Surplus soil was placed on the lower edge of the ditch so as to check or diminish runoff. Using this technique of land preparation, water can be effectively adsorbed by the soil and stored for seedling use.

Association with shrubs and grasses

The microclimatic conditions near a bare soil surface can be hostile and unfavourable to seedling establishment in this climate, and it is imperative that the microclimatic conditions near the ground surface be improved during seedling establishment. This can be done by providing surface ground cover. At the same time as tree seedling planting, shrubs are planted to reduce water runoff and soil erosion, while increasing soil water storage. A combination of trees, shrubs and grasses were therefore established at the successful reforestation projects. Trees were transplanted in 3–4 m rows with a tree spacing of 1–2 m. Shrubs were directly planted in rows between the rows of trees with 0·3–0·5 m spacing. A natural grass cover was allowed to establish over the rest of the area.

Socio-economic aspects of reforestation success

The success of rehabilitating former ecosystem structure and functioning depends not only on elucidating the pre-disturbance structure and function of the selected 'ecosystem of reference', but also on understanding and working with the socio-economic, technical, cultural and historical factors that caused the degradation in the first place (Aronson *et al.*, 1993). There has been relatively little social science input into the study and practice of ecological restoration (Walters, 1997). Experience revealed that social and economic factors, including people's knowledge about trees and tree planting, their patterns of land use and ownership and their social organization, interacted with ecological variables to affect differently the outcomes of restoration work. As mentioned previously, there has been little success of reforestation in the dry and hot valley of the Jinsha River in the past few decades. However, planners may be aware that reforestation must be done to protect the ecological environment, and they need to implement appropriate policies and measures despite a lack of technical knowledge.

In Yuanmou, the population is 190 000, of which over 80 000 are labourers. These labourers have remained in the rural areas and have not been attracted into big cities for jobs because this region is far from any big cities. Although most of the local farmers are not aware of the significance of soil and water conservation and rehabilitation of the ecological environment, they know that they have a need for fuelwood. Given this situation, the local government energetically mobilized farmers to participate in reforestation activities and proposed the following measure as an incentive. 'A person will be entitled to prune the trees that have been planted by himself, and the more he plants, the more trees can he prune.' In this way the fuel problem would be abated, thus farmers' enthusiasms were aroused. On the other hand, considering the poverty of farmers in this region, the government paid all expenditure for seedlings. In other words, these reforestation projects included a combination of government's financial resources and farmers' labours.

In addition to the financial resources provided by the local government, a strict implementation of management policies was established. Young forests are vulnerable to human intervention in a fragile ecological environment. Yates *et al.* (2000) investigated the impacts of livestock grazing on native plant species cover in remnant *Eucalyptus salmonophloia* F. Muell woodlands. Their results suggest that livestock grazing is associated with a decline in native perennial cover and disrupts the resource's regulatory processes that maintain the natural biological array in *E. salmonophloia* woodlands. The protection by exclosure of overgrazed steppe was useful as the accumulation of soil organic matter and the improvement of water balance were observed (Hongo *et al.*, 1995; Zhang *et al.*, 2000). Therefore, it was necessary that grazing grass cutting and root debris collection in young forests be banned. Only after the trees grew for a few years were the farmers allowed to prune tree branches. This action has provided farmers with daily fuel and simultaneously played a favourable role in tree growth in successful tree establishment. Livestock grazing, as a role, is banned in reforested areas. However, considering limited space for livestock grazing in the Xiaohengshan region, grazing under forests was permitted, but only for light animals such as goats and sheep.

In order to maintain the good growth of trees, the degree of pruning needs to be controlled at reasonable level. Some of the farmers may prune trees too early or too heavily because of their demand for fuel. In addition, some trees may be illegally harvested. In order to solve these problems, the local government has arranged for a forest guardian at each site and paid him for his work. The forest guardians came from local farmers who were willing to do that job. Compensation for such a job is generally low because of low living standard of local people. Apart from the prevention of thieving of trees, the responsibilities of the guardians include monitoring forest fires, diseases and insect pests, and the like. Forest watching action is planned to last 8–10 years for young forests, depending on specific situation change. More reforestation projects are expected to be successful in the future based on current experiences for forest re-establishment.

Forest protection policies have been formulated which include incentives for forest protectors and punishment for violators. So far, violations have been rare, and fires, diseases and insect pests have not occurred in the case of the study area. The practice demonstrated that forest watching, combined with these policies, is quite an efficient method to control the threats (grazing, illegal tree harvesting, fire, diseases and insect pests, etc.) to the survival and growth of seedlings. We speculate that this approach can be extended to large areas where a considerable low-cost labour force is available.

Tree densities were 2600 and 4120 plants ha^{-1}, respectively, at the Xiaohengshan and Shaofangpo sites. Strong competition between trees has been observed. On the basis of sample measurements, there is a great difference of tree height and DBH among the forests resulting from competition (Table II). In such a case, the thinning of trees should be considered for proper forest maintenance. Unfortunately, this action has been not conducted because the local government policy has been to allow only branch pruning. The original tree spacing of 1–2 m is too close for development of the trees. This problem is easy to solve as long as the policies concerned are rationally adjusted because labour is not a problem and the farmers would welcome the opportunity to harvest more fuelwood.

Serious human disturbance in young forests such as grazing, grass cutting and root debris collection, tree thieving, etc. is attributed to increase in the population and poverty. Consequently, key socio-economic factors of reforestation success are making good use of abundant labour resources, and providing initial funds for reforestation projects under the leadership of local government.

Table II. Growth variation of tree individuals

Location	Tree height					Diameter at breast height				
	Max (m)	Min (m)	Mean (m)	SD	CV (%)	Max (cm)	Min (cm)	Mean (cm)	SD	CV (%)
Xiaohengshan	11·5	1·2	6·3	2·25	36	13·0	0·7	5·1	2·46	48
Shaofangpo	10·0	2·5	6·4	1·95	30	13·5	0·5	4·9	2·35	48

CONCLUSIONS

Most reforestation projects in the past few decades have failed in the low-mountain region of the dry and hot valley of the Jinsha River, southwestern China. However, in this harsh environment, there have been some successful reforestation projects during recent years. Those projects' success is not an occasional event, but an inevitable result produced by the employment of a holistic approach in reforestation. Techniques of tree planting need to be taken into account to ensure establishment during the early stage after transplantation. More important are political willingness, social structure and economic possibilities in the areas where the reforestation projects were implemented. The projects have identified that leadership of local government, the use of technical knowledge, and the participation of local people, are important factors in the success of reforestation projects in the low-mountain region of the dry and hot valley of the Jinsha River.

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