Plantation Establishment on Degraded Forest Lands in Tropical China

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Abstract

Tropical China covers a land area of about 48 million ha. In olden times it was extensively covered with dense natural forests. However, the dual pressures from commercial exploitation and rapid expansion of the population led to the reduction of the total area of natural forests to less than 2 million ha at present from 3.85 million ha in the end of the 1940 s resulting in the degradation of the forest lands. It is roughly estimated that at least more than half of the forest lands are degraded. During the past four decades, great efforts were made to rehabilitate the degraded lands through mass afforestation/reforestation programs. Meanwhile, many research projects designed to study plantation establishment technology were carried out, including: transformation of coastal sandy wastelands, improvement of degraded and inferior forest stands, establishment of fast-growing and high-yielding short rotation plantations on flat and hilly lowlands, reforestation of degraded mountainous rainforest lands and afforestation of eroded barren lands. Based on a preliminary survey of the literature, this paper describes the technical approaches and research achievements of these projects. The future prospects and research needs for the rehabilitation of degraded forest lands in Tropical China are also outlined.

Introduction

Tropical China generally consists of two climatic zones in the northern tropics and the southern subtropics, mainly distributed in the southern part of the Guangxi, Guangdong, Fujian and Taiwan Provinces, the southern and southwestern of parts of Yunnan Province, the southeastern part of Tibet Autonomous Region, and Hainan Island (Province). The land area covers about 48 million hectares (ha), or 5% of the country's total land area (Kuang, 1985; Li, 1990). In olden times these areas were extensively covered with dense natural forests due to the abundance of solar energy, rainfall and heat resources. By the end of the 1940s, the area of natural forests still occupied about 8% (3.85 million ha) of the total land area (Kuang, 1985). At present, however, the remaining natural forests (including primary and secondary forests) cover less than 2 million ha (Jiang and Lu, 1991). A large portion of forest land has been logged, burnt and converted to other land uses for producing crops or for urbanization and industrialization. Particularly, the forests in Hainan and Yunnan Provinces have largely been destroyed. Rapid and excessive exploitation of forested lands has led to a remarkable deterioration of the ecological environment including land degradation.

Since the establishment of the People's Republic, the Chinese Government has been making utmost efforts to rehabilitate the degraded lands through the implementation of mass afforestation/reforestation and water and soil conservation programs. While a large amount of funds, labour and materials was in-

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vested for these programs, priorities were also given to research on plantation silvicultural technologies in degraded forest lands.

Based on a preliminary survey of the literature, this paper first deals with various aspects relating to the destruction and degradation of forest lands in tropical China and, through selected examples, describes plantation trials on degraded forest lands except for those carried out in Taiwan Province and Tibet Autonomous Region due to the lack of information. Finally, future prospects and research needs for the rehabilitation of degraded forest lands are also outlined.

Deforestation and land degradation

1 Deforestation

In a comprehensive review of the development and conservation of Chinese tropical forests, Kuang (1985) provided historical evidence to indicate that deforestation in tropical China is not a recent phenomenon, but has been taking place for at least the past four decades. Between 1952 and 1982, Hainan Island and the Xishuangbanna region of Yunnan Province lost 89.5% and 44.2% of their natural forests, respectively (Kuang, 1985). These rates of clearance of 1.66% and 2.97% per year were approximately three and five times higher than the present "alarming rate" of clearance (0.6% per year) for the closed-canopy forests in tropical Asia (World Resources Institute (WRI), 1989).

It is commonly reported in the literature that the conversion of forests to agricultural uses, commercial log harvesting, unrestricted felling for fuelwood and other uses and shifting cultivation are the major causes of deforestation in tropical China (Li, 1980; Kuang, 1985; Guo, 1985; Li, 1990). Other contributing causes include the low level of past investment in forestry, failure of forestry establishment to include rural development and lack of integration with planning in agriculture, water and soil conservation, energy and other sectors.

2 Degradation of forest lands

Based on the definition used by WRI (1989), degradation is defined as the reduction of the biological productivity expected of a given tract of land. Accordingly, any land in which bio-diversity declines or biological productivity decreased can be considered to be degraded land.

Land degradation is a serious problem in tropical China. It was reported that 66.2% of the total farm lands in South China were degraded (Chen and Zhang, 1990). In the forestry sector, although it is widely recognized that forest lands are being seriously degraded now, no systematic assessment or survey on forest land degradation has been carried out so far and no data have been provided to determine exactly how much of the forest land is degraded. Nevertheless, according to the above definition and considering the present use of forest land (Table 1), the degraded forest lands in tropical China can be classified into four types as follows:

1) Non-forested land: Land used for forestry purposes but without woody vegetative cover at present. The barren lands, cutting blanks, fire-damaged areas and coastal sandy wastes are included in this type which accounts for 35.6% of the total land area used for forestry.
2) Shrub land: Land bearing a vegetative cover dominated by shrubs due to the degradation of the tree cover. This type accounts for 9.9% of the total land area used for forestry.
3) Open forests: Mixed forests/grasslands with tree crowns covering 10–30% of the ground area. This type also includes the degraded logged forests to which selective cutting is applied. This type accounts for 9.4% of the land area used for forestry.
4) Second growth forests: They usually consist of closed forests with a low grade of productivity. They include secondary forests and dilapidated and inferior plantation stands. The area of this type is undermined since the concept of second growth forests seems to be somewhat subjective.

Based on the above classification and figures from Table 1, it can be seen that about 55% of the land used for forestry is degraded. This figure does not even include the second growth forests.

Table 1 Land use category of forest land in the five tropical provinces in China (thousand ha)

Land use category	Province					Total
	Yunnan	Guangxi	Guandong	Hainan	Fujian	
Forested land	9327.4	5227.2	4864.1	866.4	5003.4	25288.5
Nursery land	0	4.8	0	2.4	0	7.2
Unestablishedk plantation land	115.2	254.4	729.2	24.0	296.2	1419.0
Shrub land	4414.2	724.8	393.3	84.0	243.5	5859.8
Open forest land	2734.9	882.7	993.6	43.2	934.2	5588.6
Non-forested land	8420.6	6331.2	3166.0	696.0	2501.7	21115.5
Grand total						59278.6

Source: The Ministry of Forestry (1990).

Plantation establishment on degraded forest land

The following is a review of some projects related to plantation trials on different types of degraded forest lands in tropical China. This review will be restricted to the description of the technical approaches involved and results obtained.

1 Transformation of coastal sandy wastelands

The coastal zones of tropical China, which are characterized by a high density of population, low per capita arable land area and frequent occurrence of typhoons, cover an area of 4.46 million ha, of which 240,000ha are sandy wastelands (Liang *et al*., 1990). The transformation and utilization of these wastelands are, therefore, important for the improvement of the ecological environment and the economic development of the zones.

For the transformation and utilization of these sandy wastelands, the first studies, initiated in the early 1950s, aimed at establishing coastal protective forests (CPF). At first, Eucalyptus species were selected as the main planting species. However later it was found that pure eucalypt forests have a poor capacity of resisting strong wind. Eucalyptus trees were then replaced by casuarina trees (mainly *Casuarina eqiuisetifolia*) that showed a great adaptability to the conditions of the coastal zones. After years of practices, it was shown that the use of pure casuarina forests did not prevent wind damage and did not contribute significantly to the improvement of soil, as most of the forests had been aged and degraded.

Since the late 1970s, many research projects have been conducted by various research groups in different locations with emphasis placed on the selection of more appropriate tree species and planting models, and it is to the latter that much attention has been directed in recent years. Up to 1984, a total area of 281,200ha of CPF had been established and a large number of plant species had been selected as shown in Table 2 (The Ministry of Forestry, 1987). According to Liang et al. (1991), up to date, it is estimated at

Table 2 List of plant species used in the establishment of CPF systems in tropical China

Tree species:

Casuarina equisetifolia, Pinus teada, P. massoniana, P. elliottii, P. caribaea, Schima superba, Acacia confusa, A. mearnsii, Acacia auriculiformis, A. mangium, Taxodium distichum, Castanopsis hystri, Eucalypts, Bamboos, Mangroves.

Fruit species:

Phyllanthus emblica, Psidium guayava, etc.

Source: The Ministry of Forestry (1987).

that 70,000–90,000ha of the wastelands have already been exploited for agricultural use.

In the selection of planting models, good results have also been obtained. Fig. 1 presents one of the various planting models that have been successfully developed according to the specific conditions in different locations (Du, 1983).

2 Afforestation of eroded barren land

In 1959, a project designed to 1) rehabilitate tropical forest vegetation and 2) develop a model for the improvement and utilization of tropical and subtropical mountainous and hilly wastelands was initiated at Xiaoliang (110°54′18″E and 21°27′49″N), Dianbai county of Guangdong Province (Yu, 1985). The project area which was once covered with tropical monsoon forests was destroyed entirely by human activities and started to become a "desert" in the 1950. At that time the soil was being lost at a rate of 100,000m³/km² per year.

The recommended two approaches to implement the project are:

1) Rehabilitate the pioneer arborous communities by combining vegetative measures with engineering measures.
2) Establish mixed forests with multiple strata and species by introducing some broadleaved tree species, particularly nitrogen-fixing trees, into the pioneer communities.

Within a few years after the onset of the project, more than 2,200 checkdams were built and 400ha of pioneer communities of *Eucalyptus exserta*, *Acacia confusa* and *Pinus massoniana* were established. By 1973, about 10 plant species were found in the communities. From 1974 to 1980, 41 plant species such as *Cassia siamea*, *Acacia auriculiformis*, *Leucaena leucocephala*, *Albizzia procera*, *A. odoratissima*, *Calamus bonianus*, *Alpinia oxyphylla*, etc. were introduced into the communities. An investigation made in 1982

Soil type	Wind-drift sandy soil	Intermediate sandy soil	Tide-drift sandy soil
pH value	6.6	6.8	7.0
Total N (ppm)	3.762	5.661	2.172
Available P (ppm)	0.720	1.473	8.711
Available K (ppm)	19.800	30.100	66.800
Sultable tree species	*Acacia auriculiformis* *Eucalypts, Pines*	*Casuarina equisetifolia* *Acacia auriculiformis*	*Casuarina equisetifolia*

Fig. 1 Schematic representation of a planting model of CPF established in the coastal area of Zhanjiang city, Guangdong Province (Source: Du, 1983)

Table 3 Comparison of ecological effects of different vegetation types

Ecological effect	Vegetation type		
	Barren land	Pure eucalyot forest	Mixed broadleaved forests
Annual temperature fluctuation (°C)	14.3	14.0	13.0
Relative humidity (%)	83.2	85.5	87.3
Content of soil organic matter (%)	0.60	0.75	1.13
Soil pH (H_2O)	4.5	4.9	5.7
Annual loss of soil (kg/ha)	19897.5	5677.5	3.0
Moisture content of soil (0–10cm)	9.8	11.9	13.2
Depth of ground water (m)	3–5	9–11	1–4

Source: Yu (1985).

showed that an improved forest ecosystem was basically formed and the number of higher plant species reached 119, a much higher figure than the 51 speices originally introduced. Over 400 insect species and over 100 species of birds and other animals were found in the newly formed ecosystem. The investigation also showed that the ecological environment had been improved during the development of the biotic communities (Table 3).

3 Reforestation of degraded mountainous rainforest land

Research on reforestation of degraded mountainous rainforest lands started in the late 1950s. During the period 1958-1963, some reforestation attempts were undertaken in several logged blanks in the Jianfengling forest area, Ledong county of Hainan Island with some valuable timber tree species native to the area such as *Homalium hainanense*, *Manglietia hainanensis*, *Dalbergia odorifera*, *Podocarpus imbricatus*, *Madhuca hainanensis*, *Hopea hainanensis* and *Cephalotaxus mannii*. However, the results from the trials are by no means satisfactory. The main reasons for the failure were due to the lack of knowledge relating to the biological and ecological characteristics of the species planted (Jiang and Lu, 1991).

In addition, more experiments were carried out by Wang (1990). In 1977, an experiment designed to select suitable tree species for reforestation of degraded mountainous rainforest lands in Yunnan Province was initiated. The experimental site was located on a logged slope (10-20 degrees) at Puwen Forest Farm (Latitude 101° 06′ E, Longitude 22° 25′ N, Altitude 840-860m asl), northern part of the Xishuangbanna region. The remaining vegetative cover on the site was burnt and planting holes measuring 40 × 40 × 40 cm were dug. Seedlings of 26 species (Table 4) raised in a nursey for 6-12 months were transplanted in

Table 4 Growth performance of 26 tree species in a reforestation trial at Puwen Forest Farm, Yunnan Province

species	Mean annual increment		
	Height (m)	DBH (cm)	Standing Volume (m^3/ha)
Anthocephalus chinensis	2.06	2.14	34.056
Altingia excelsa	1.56	1.68	22.643
Paramichelia baillonii	1.44	1.27	22.334
Choerospondias axillaris	1.74	1.30	21.238
Aphanamixis grandifolia	1.52	1.49	19.314
Pinus khasya	1.23	1.35	18.989
Mytilaria laosensis	1.30	1.25	18.267
Gmelina arborea	1.60	1.30	18.174
Terminalia myriocarpa	1.28	1.21	13.994
Tectona grandis	1.06	1.30	13.874
Campyotheca acuminata	1.56	1.32	11.817
Alangium kuezii	1.38	1.34	10.598
Acacia mangium	1.66	1.44	10.347
Melia azedarach	1.31	1.10	9.845
Cinnamomum porrectum	1.23	0.92	9.806
Pometia tomentosa	1.31	1.05	9.366
Quercus altissima	1.36	1.45	8.627
Schima wallichi	1.20	1.53	7.629
Bischofia javanica	1.03	1.14	7.587
Duabanga grandifolia	0.99	0.88	6.567
Manglietia forrestii	0.73	1.12	5.775
Chukrasia tabularis	0.69	0.72	2.852
Parashorea chinensis	0.53	0.66	2.223
Acrocar fraxinifolius	0.63	0.79	2.439
Toona ciliata	0.39	0.60	2.082
Dipterocarpus turbinatus	0.44	0.63	0.600

Source : Wang (1990).

plots 1,332m² each at a spacing of 2 × 3m in the rainy season of 1977. These species were arranged in a non-replicated block design, due to the limited amount of seedlings. Within two years after planting, intercropping with dry land rice was practiced in all the plots. Weeding was performed two times in the third and fourth years after planting.

Results from a measurement at 12 years after planting given in Table 4 show that among the 26 species tested, 19 species performed well with mean annual increments of 1.0-2.1cm for DBH, 1.0-2.1m for height and 7-34m³/ha for standing volume. These species were recommended for use for further planting. The other 7 species, however, were eliminated.

4 Improvement of dilapidated and inferior forest stands

Dilapidated and inferior forests are widely distributed in tropical China. In Guangdong Province, for example, an examination of the status of afforestation undertaken by the provincial government showed that 2 million ha of open and dilapidated forests urgently need some form of improvement and another 3.333 million ha of pure pine forests need treatment with introduction of broadleaved tree species, especially nitrogen-fixing trees. Of the total area of the two types of forests, 85% is covered with masson pine (*Pinus massoniana*) and Chinese fir (*Cunninghamia lanceolata*) stands (The People's Government of Guangdong Province, 1990). In Guangxi Province, it is reported that more than half of the forest lands is covered with dilapidated and inferior masson pine stands (Liao, 1990). Indeed, how to effectively improve the dilapidated and inferior masson pine and Chinese fir forest stands has been a major problem of forest management in tropical China since the early 1950s. During the past four decades, a large number of studies were carried out and many successful results were obtained.

To improve these forests, according to Jiang (1990), the silvicultural measures commonly practiced are as follows: loosening of soil, additional fertilizer application, interplanting with green manure crops, enrichment planting and replacement. Experimental results showed that the former three measures can only be practiced at the thicket stage of the forests and on a small scale. Although replacement was the simplest measure, it increased the cost of reestablishment and maintenance of new plantings. The recommended measure was enrichment planting.

In enrichment planting, two problems that must be solved are the choice of species and planting pattern. For the choice of species, a large number of trials were conducted under various site conditions. Up to now many suitable species have been selected (Table 5). The results also showed that level-strip planting was the optimum planting pattern for large scale stand improvement. It was recommended that the strip should be cleared to a width of 2 times the mean height of the existing stands or to a width in which 4-5 rows of newly introduced species could be planted. Single-hole planting, line planting, small block planting were not suitable methods for large scale stand improvement, but they were the most appropriate

Table 5 List of species suitable for enrichment planting in different types of forests (based on site class)

Site class	Type of forest	Name of species
I and II	chinese fir	*Castanopsis hystrix, C. eyeri, C. fordii, Cinnamomum camphora, C. iners, Michelia macclurei, Manglietia glauca, Michelia macclurei, Mytilaria laosensis, Aquilaria sinensis, Ormosia henryi, Erythrophleum fordii and Albizzia procera.*
III	Chinese fir	*Ziziphus jujuba, Liquidambar formosana and Schima superba.*
III	Masson pine	*Erytrophleum fordii, Catanopsis hytrix, C. fordii, Cinnamomum camphora, Michelia macclurei, Manglietia fordiana, Aquilaria sinensis, Ormosia henryi.*
IV and V	Masson pine	*Quercus acutissima, Castanopsis fissa, Liquidambar formosana, Schima superba, Dallbergia hupeana, Acacia confusa, A. auriculiformis, A. cuninghamia, A. mangium, Leuceana leucocephala, Casuarina equisetifolia and Eucalyptus spp.*

Source: Jiang (1990).

ones to improve the stands in the forest areas for recreation or in forest parks.

5 Establishment of short rotation plantations in infertile platform and hilly lowlands

Systematic research on short rotation plantation (SRP) management in tropical China started in 1982 when the Research Institute of Tropical Forestry initiated a project entitled: "selection and cultivation of fine and fast-growing fuelwood species in tropical China". During the past decade, five experimental bases were established (two in Qionghai county, one in Tunchang county and one in Sanya city, Hainan Province and, one in Huaxian county, Guangdong Province). The soils of the selected bases were all infertile, with the following chemical properties: organic matter content: 0.19-1.25%, total N content 0.025 -0.400%, available P content 0.47-1.74ppm, available K content 0.23-9.00ppm and pH value of 4.8-6.0. Since the development of the project has been well described by Zheng *et al*. (1991) no further details will be provided here. A short discussion on the technical approaches that could be considered when establishing a forest plantation on infertile platform and hilly lowlands will be presented.

Choice of species

For the establishment of SRP on infertile lands, a species must have most of, if not all, the following characteristics: good adaptability, easy propagation, good water and nutrient economy, high productivity, good resprouting ability after cutting and high resistance against injury caused by biotic and abiotic agents. Based on this concept, between 1982 and 1987, elimination trials with 90 exotic/native species of the genera *Eucalyptus*, *Acacia*, *Allcasuarina*, *Casuarina*, *Cassia*, *Calliantra*, *Leuceana*, *Pinus* and *Zenia* were conducted. The results showed that *Eucalyptus urophylla*, *E. maculata*, *E. grandis*, *E. pellita*, *E. ABL No. 12*, *E. camaldulensis*, *E. tereticornis*, *E. citriodora*, *Acacia mangium*, *A. auriculiformis* and *A. cunninghamia* performed well with mean annual increments of 2-3cm for DBH, 2-4m for height and 10-30 ton/ha for aboveground biomass production (oven-dry weight) 4-5 years after planting and exhibited most of the desirable characteristics listed previously. These species were recommended to be used for further large scale SRP management. Species which were promising for further planting included: *E. torelliana*, *E. gummifera*, *E. cloeziana*, *E. prosa*, *Acacia concurrens*, *A. melanoxylom*, *A. leptocarpa* and *A. crassicarpa*.

Cultivation techniques

Trials related to site preparation, fertilization, planting spacing and mixed planting using selected species showed that certain techniques must be applied for the establishment of SRP on infertile lands, as follows: 1) complete site preparation for platform or gentle sloping land and level belt-like site preparation for hilly lowland, 2) basal fertilizer application (100g P + 20-30g N per tree) at the time of planting, 3) planting with appropriate dense spacing of 1 × 1m, 4) tending and additional fertilizer application (100g P + 30-50g N per tree) and mixed species planting wherever possible.

4 Future prospects and research needs

In tropical China, the interest in plantations is increasing rapidly. According to the Ministry of Forestry (1990), the total area of plantations had reached 8.9779 million ha as of 1989. Plantation establishment has received high priority from the government of China and it is becoming increasingly popular among all the people. There are evidences to show that the rehabilitation of degraded forest lands will make considerable progress in the near future. The Central Government has formulated it as a basic national policy to afforest the country which will ensure the rapid development of plantation forestry. Besides, some ambitious afforestation programs are being undertaken. For example in Guangdong, the provincial government launched an afforestation program in November 1985 aiming at "afforesting the wastelands in five years and making the province green in ten years". After four years (1986-1989) of implementation, with a total investment of 1.3 billion RMB yuan and an accumulative labour input of 0.3 billion man-days, 95% of 3.333 million ha of wastelands suitable for plantations in the whole province were replanted. This program is being continued now with emphasis placed on tending the new plantings and improving the dilapidated and inferior forest stands.

It is obvious from the above descriptions that although plantation establishment is practiced over extensive areas and shows various advantages, there is an almost total lack of information on the system-

atic assessment of details relating to forest land degradation. Therefore the first essential step in the rehabilitation of the degraded forest lands will obviously be to develop a system of assessment of degraded forest lands. This should include working standard, appraisal criteria, classification of degradation, as well as the identification of research fields requiring priority. Moreover, the following studies should be undertaken:

- Technology for reforestation of degraded mountainous rainforest lands and for regeneration of aged coastal protective forests;
- Social, economic and ecological effects of plantation establishment;
- Integration of forestry with other land uses, and people participation in land rehabilitation.

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