ITTO

The Study and Demonstration of the Management of Secondary Forests in Tropical Regions for the Purpose of Enhancing Economic and Ecological Benefits

PD 294/04 Rev.4 (F)

Final Technical Report

(Phase 1)

August 2008

Guangdong Academy of Forestry
Guangzhou P.R.China

广东省林业科学研究院 1958 Guangdong Academy of Forestry




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The Study and Demonstration of the Management of Secondary Forests in Tropical Regions for the Purpose of Enhancing Economic and Ecological Benefits

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Table of Contents

List of Acronyms and Abbreviation

GAF	Guangdong Academy of Forest
SDMSF	The study and demonstration of the management of secondary forests
DD	Demonstration District
EF	Ecological Forests
SF	Secondary Forests
TSF	Tropical Secondary Forests

Abstract

With the support of the International Tropical Organization (ITTO), and the funding assistance by Japanese government, also government of Australia, China conducted "the study and demonstration of the management of secondary forests (SF) in tropical regions for the purpose of enhancing economic and ecological benefits" (PD 294/04 Rev.4). In this Project, two demonstration districts (DD) had been established in Xinhui of Guangdong and Tongshi of Hainan respectively. In Xinhui DD, the spots include, a) a natural restoration of forest ecosystem; b) an rehabilitation and restoration of degraded TSF with 68 native hardwoods and 13 exotic species (67 ha); c) non-timber product species in the degraded TSF with 2 rattan species, 7 medicinal plant species, 2 bamboo species, 5 high yield resin pine families and 10 fruit tree species had been introduced. In Tongzha DD special for rattan, a 67 ha with 2 rattan species was introduced under the degraded TSF. It was considered: 1) The TSF were destructed and the land converted to commercial plantation continuously mainly was the residents highly relied on the forest product for the livelihood requirement in the mountain areas; 2) Most of SF were with simple species composition, growth slowly, weak ecological functions and low economic value, average stem volume was less than 70 M^3/ha, and only 15.8 % of original species was reserved and most of regional species were disappeared or degenerated; 3) Degraded SF developed slowly in nature condition, there are great potential of management; 4) Non-timber product species introducing could create economic benefit in a relative short stage, which was a very important strategy consider for stakeholder to meet the livelihood requirement without felling tree in the degraded SF management in rural area; 5) Quality seedling was a key factor in successful reintroducing into ST, the nursery stock more than 50 cm height could grow well; and 6) In the plantation, right place right species was a principle. Difference stand environment needed difference species to fit, such as in open area best for the species of light requirement, and under forest should be overcast born species.

1 Introduction

Background

The total tropical forest area in China is about 6.07 million ha, only about 34,000 ha and 600,000 ha typical natural forests (including primary forests) distributed in Hainan and southern part of Yunnan respectively, the rest is SF. SF mainly distributes in 124 counties or cities and part of 50 counties or cities in Guangdong, Hainan, Guangxi, Yunnan provinces, and some parts of Fujian and Tibet. China is one of the largest TSF distributed countries in the world. In rural areas, however, due to heavy population and low income, farmers almost completely relied on wood for living, about 6% of TSF was harvested annually and the land converted to another use, which led to the gradual reduction of natural tropical forests and tree species, forest pest and disease and frequent drought and flood disasters increased,.

It was documented in the Pre-project PPD 30/01 Rev.1 (F) that the decade-long neglect of Chinese TSF, which was due to the perceived low economic and ecological value. The project is aimed at accelerating sustainable forest management by better management of the secondary tropical forests in China. Its specific objectives was to establish demonstration forests in two selected provinces for the study and demonstration of management of TSF including planted trees and non-timber forest products

The successful completion of pre-project had increased our understanding of SF in tropical regions as well as its management status, and also provided the technical foundation and practical experiences for the designing of formal project. Base on these, PD 294/04 Rev.4 (F) had been approved in 40th ITTO Council Session June 2006 and founded.

In the previous, two Projects had been carried out through ITTO financed in this area. One was "Demonstration of sustainable management of tropical nature forest in Hainan island of China" (PD 14/92 Rev. 2(F), 1992-2001). In which, some fixed sample observation plot had established, including: 1) SF developed in early cutting; 2) nature forest development; 3) selection forest with tending; 4) comprehensive selection cutting; 5) strength in cutting; 6) ecological benefit in difference selection cutting forest, etc. Another was "DD of standard formulating and application of sustainable management of tropical nature forest in China" (PD 12/00 Rev.3 (F), 2001-2003). The DD in regional level were been established in Hainan and Simao, Xishuangbanna of Yunnan. Forest management district was been built in Bawangling, Diaoloshan of Hainan, and Shimao, Menglian of Yuannan.

Chinese government and local government organization had financed some project, such as management of Ecological Forests (EF). They mainly focused on rebuilding degrade forest in conservation district. But the species reintroduced into the degraded forest (DF) were still very simple and low of survive rate.

This project was aimed at accelerating sustainable forest management by better management of the TSF in China. Its specific objectives were: a) to establish demonstration forests in two selected provinces for the study and demonstration of management of TSF including planted trees and non-timber forest products and b) to train forestry staff and villagers in TSF rehabilitation techniques and to publish and disseminate the project results.(Phase 2)

2. Main text

2.1 Applied methodology

The Project objective is to accelerate SFM by better managed TSF in China.

The key problem that TSF had been disrupted for a long time was due to population explosion and poor economic condition in the rural areas. To tackle this problem, it was been considered in the project design to introduce super species with good ecological and economic benefits into degraded forest to create ecological and economic benefits to realize the protection and improvement of TSF. Applied methodologies in the project implementation including:

- **The selection of DD and background information collection**

DD of the Project has been selected in the SF of collective ownership, usually said community-based. Which mainly considered: 1) it could let more residents had an opportunity to participate in and share the benefits come from Project implementation; 2) help them to learn experience from the activities; and 3) replicate management technique in the future.

Xinhui DD

Background information collection of DD was most important step in the Project design, data collection included:

(i) Survives of social and economical development of demonstration region

Mainly on the data collection such as population, per capital income and basic life needing, source of revenue, resource of land area and forest land, social welfare situation etc., conducted by way of visiting or consulting government's statistical data

(ii) Observation of the fixed sample plots

Including the situations of vegetation, flora and fauna in the DDs, used the method of fixed sample observation.

a) Sampling method

The located survey plots were set up using the adjacent quadrat sampling method (see Annexes 1, Figs. 1-3). It was designed the experiment of 3 repeats (i.e., 3 study sites), representing 3 types of the SF communities that produced 5yr, 10yr and 20yr

Investigation team

after the pine (or fir) trees were felled. Each repeat comprised 2-3 plots: one was the interplant (or introduction) plot (10,000/3 m^2) used for interplanting about 80 species of non-timber economic plants, while the other one or two are the control plot (2000/3 m^2) without no interplant (i.e., maintaining the original vegetation). Around each such plot, 5 m-or-more-wide isolation belt was set up. For convenience of the survey, these plots each were divided into smaller quadrats of the size 10 m × 11.11 m, within which each individual of all vascular plants was recorded.

b) Survey methods

Growth investigation of the introduced species: Check the annual growth every autumn for each of the newly-interplanted species, including their height, breast and crown diameter, and growth status.

Plant community survey: Within each quadrat (10 m × 11.11 m) of each plot, recorded each individual's species name, DBH, height, crown diameter, etc. For several herbs of great density, such as *Dicranopteris dichotoma*, we used one or more 1 m × 1 m sampling frames to estimate their abundance (i.e., the number of individuals) in a quadrat. It was also checked the canopy density in tree layer and the ground cover degree in herb layer. The investigation on all the community plots, including interplant plots and corresponding CK plots, should be done in every autumn.

- **Selection of the introduced species**

It would be selected that regional native species were disappeared or degenerated in SF , and with better economic and ecological benefits, also could developed in the SF. The non-timber product species were mainly considered marketing of the product. Those were seleced through understanding and consulting with the local people and the historic records.

- **Super mother tree collection**

After the sureness of the introduced species, super mother trees were selected in the tropical regions of Guangdong, Guangxi and Hainan for the seedling breeding. Five-dominant-trees comparison method was be used in the super mother tree selection.

Super Tree Selection

- **Quality seedling breeding**

Quality seedlings breeding were conducted in the two nurseries in Guangzhou and Xinhui respectively. It was requested that seed of each species must be mixed up from seed at less five super trees in order to keep hereditary variety. The height of seedling must exceed 50 cm can be planted.

- **Introducing technique**

Plantation should be followed the principles: a) right place right species. That was the selection would rely on the place where the species can grow in normal; b) no vegetation was allowed to destroy unless the herbaceous near the cave used for planting; 3) choose rainy season in March to May for plantation, after the rain; 4) specification of planting cave was controlled in 40cm by 40cm by 40cm in length by width by depth; 5) each tree would put into 500 grams of after planting.

- **Tending**

After plantation, the introduced plants would be fertilized 500 grams of compounded fertilizer, and the non-timber product species, especially the medical plant needed to be take care more.

2.2 Presentation of the data

(i) Overview of the demonstration area

The demonstration districts were selected in the communities of Gudou in Xjnhui and Changhao in Tongshi respectively.

Gudou DD, located in Gudou Mountain, sitting beside Taishan city and Xinhui, longitude 112°52′30″E, and latitude 22°05′00″N, the vegetation was a regional monsoon evergreen broad-leaved forest, which was most typical SF in China. According to the meteorological data of Xinhui city, 2082.65 hrs/yr of sunshine, 45.5% of sunshine, yearly temperature 21.8°C, 13.4°C in January, and 28.3°C in July, yearly precipitation 1789.2mm and relative humidity 77%, in average. The months from April to September were rainy, while the others belong to the dry seasons in the region before. The total area of the community was 4196 ha. Among them, 3031 ha of SF, occupying 72.2% of the forest land; 967 ha of plantation forests, occupying 23.0%, 145 ha of farmland. There were 316 residents with total income 1,125.592 thousands Chinese Yuan (about 164.952 US＄), an annual per capital income was 522 US＄ in the community in 2007. Among the revenue, about 90.7 thousands US＄ came from felling tree, 24.7 thousands US＄ from the government subsidy of EF protection, 14.8 thousands US＄ ground leased, 9.9 thousands US＄ in agriculture, 8.2 thousands US＄ from services, and 16.5 thousands US＄ from others.

About 80 hectares of SF were felled and converted into commercial forest plantation such as Eucalyptus before 2006.

Tongshi DD for interplanting rattan under the forest was with an area of 67 ha. The forest stands were mainly composed of natural secondary broad-leaf species. The densities of stands were among 0.4 to 0.5, and the stands were poor in qualities. The vegetation were mainly including perennial herb and little bush, such as *Melastoma candidum,Melastoma sanguineum* ,etc.. Main arbor species were *Cyathea spinulosa,Quercus fabri,Liquidambar formosana Hance,Erythrophleum fordii,Syzygium cuminii(L.) Skeels.* The storage capacity of each hectare was less than 4 m^3; the growing amount under 0.2 m^3 each year. Where the SF stands were the most of representatively in Hainan.

(i) Vegetation

In the following data (table 1), the regional vegetation based on the records [1], and TSF vegetation came from the investigation of the Project in Xinhui DD. (detail see Annex 2).

Table 1 Comparison of Vascular Plants of TSF with Original Forest

Vegetation			Original Forests (a)	TSF Stands (b)	Percent of a/b
vascular plants		species	1161	184	15.8
		genera	607	138	22.7
		families	180	82	45.6
Among above:					
fern		species	81	16	19.8
		genera	50	10	20.0
		families	28	10	35.7
gymnosperm		species	20	4	20.0
		genera	13	3	23.0
		families	4	3	75.0
angiosperm	dicotyledon	species	858	147	17.1
		genera	423	108	25.5
		families	122	57	46.7
	monocotyledon	species	202	21	10.4
		genera	121	17	14.0
		families	22	12	54.5

Three sample plots of different succeed stage of the SF had been surveyed represented 5, 10 and 20 yrs. nature succeeding after the forest destroyed in the DD. In 5-year-old SF stand, the height in length of the community was 7-11 m, average 8.2 m, the layer structure was not very clear, and the tree layer was relatively lower and sparse, while the shrub layer was dense, and the herb layer was the densest among three layers; In the 10-year-old SF stand, very closed 5 yrs. stand, with 7-10 m in height, average 8.5 m, but obvious layer structure, and the tree layer (height ≥ 1.5 m) was relatively high and dense, the herb layer (height < 0.5 m) was flourishing, while the shrub layer (0.5 m ≤ height < 1.5 m) was the densest with high density; After 15 yrs. development, the growth amount also not much difference with the community 7.5-13 m height, average 10.3 m, but there were obvious layer structure, the herb and shrub layers were dense with great coverage at the ridge and peak of the site, while the tree layer was very high and dense, the shrub layer was relatively dense, and the herb layer was very thin elsewhere.

(i) Selection of the introduced species

103 species were selected as the species reintroduced into the degrade forests of Xinhui DDs Among them, 68 native species, 13 species from outside of China, 22 of species were non-timber product species, such as rattan, medicinal plant and fruit tree etc. (see Annex 3). In property of the species, there were 69 species of sunlight requirement, accounting for 67% （among them, about 25% can endure overcast in juvenile）, 15 species of overcast requirement, accounting for15%, and neuter, accounting for 18%.

(ii) Super mother tree selection and seedling breeding

There were 1434 super mother trees with 68 native species and 13 non-timber product species were selected from 50 counties, and the seeds were collected. Over 290000 quality seedlings were bred in two nurseries in Guangzhou and Xinhui.

(iii) Investigation of the reintroduced species

Survival rate and growth capacity of the reintroduced species was conducted in the fit sample plots in Xinhui DD at end of July 2008. The survival rate and annual high growth in average were 65.6% and 123.8 cm respectively. In the survival rate, there were 12.3% of species over 90%, 33.3% of species over 80%, and only 13.6% less than 50%. In the annual high growth, there were 69% of the species more than 100cm, the highest was 21icm (detail see Annex 4). The survival percent and annual growth in length of the plant with difference heights of seedling and closed canopies show table 2 and table 3 respectively.

Table 2 Survival Percent and Growth of the Plant with Difference Heights of Seedling

Height of Seedling (cm)	Average Survival Percent	Annual Growth in length（cm)
<50	36.364	38.3
50-100	68.788	89.1
>100	89.412	129.1

Table3 Survival Percent and Growth of the Plant with Difference Canopy of SF

Closed Canopy	Average Survival Percent	Annual Growth in length（cm)
0.34	83.2	118.7
0.48	68.1	99.4
0.65	48.4	100.2

Aleurites moluccana

Dracontomelon duperreanum

Grevillea robusta

(ii) Non-timber Produce species

There were some non-timber species have already begun outputs, such as *Litsea cubeba* had fruited, can harvest 5 to 10 kg each tree, worth about 2 to 4 US$. *Spatholobus suberectus, Euonymus fortunei* and some other species also had outcome of non-timber product.

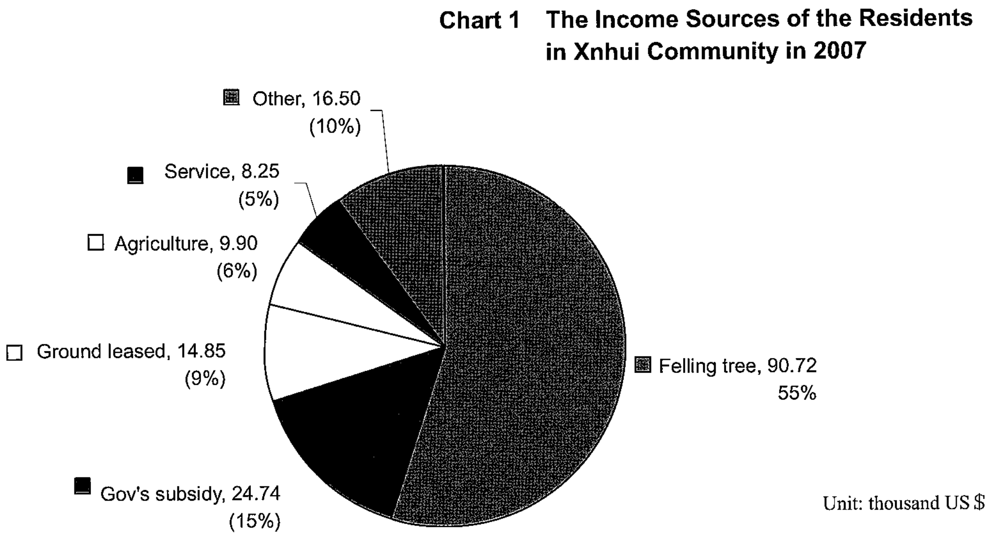
Litsea cubeba

Calamus tetradactylus

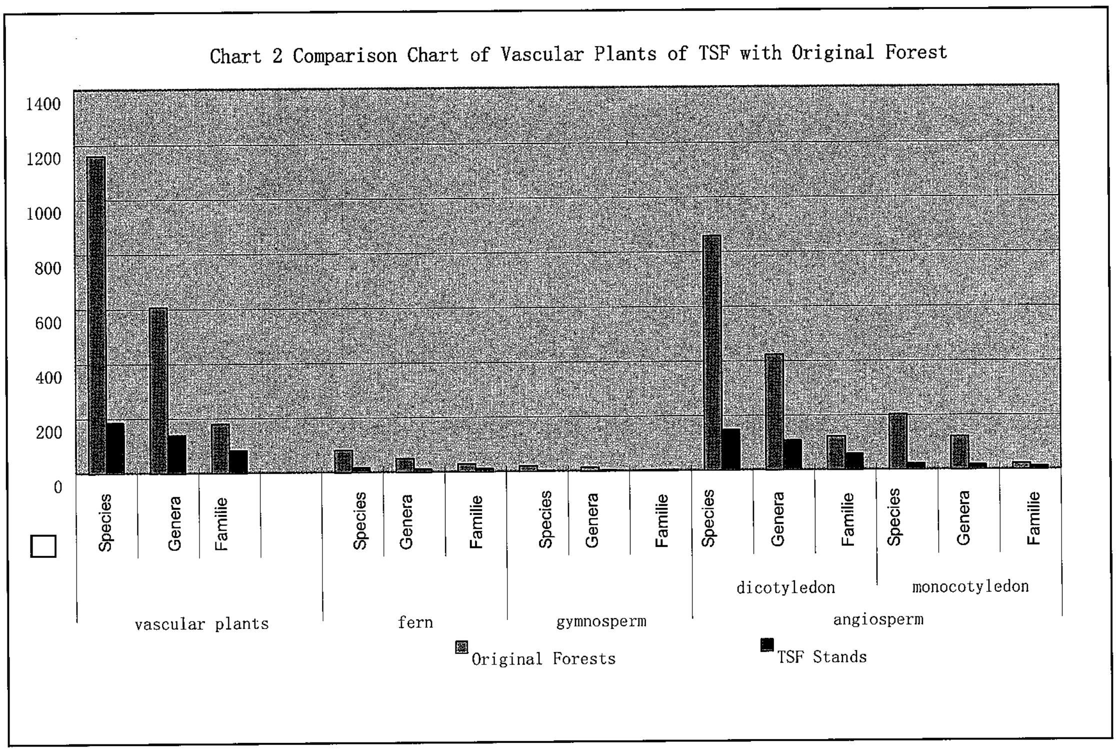
Spatholobus suberectus

2.3 Analysis of the data and results

(i) An analysis of the revenues, Among them, about 55% came from felling tree, 15% from the government's subsidy of EF protection, 9% ground leased, 6% in agriculture, 5% from service, and 10% from others, an annual income per capital was 522 US $ in the community of the demonstration region in 2007 (Chart 1). About 2% of the forest land was converted into commercial forest plantation annually. The TSF was still in interference and the land converted to commercial plantation continuously mainly was the residents highly relied on the forest product for the livelihood requirement in the mountain areas.



(ii) According to the data, there were only 184 species maintained in the SF, accounting for 15.8 % of original species after it was seriously interfered, most of the original species were disappeared or degenerated. See Chart 2



(iii) Compared the differences of 5 yrs and 20 yrs SF stand, growth amount was only 2.1 m in distance after 15 yrs development. But there were obvious in layer structure, the herb and shrub were dense with great coverage, tree layer was high in density, while the herb layer was relatively thin elsewhere. Degraded SF developed slowly in nature condition.

(iv) As we can see in table 2, there were obviously differences on survival percent and growth in length compare with different seedling height while planting. The survival percent and annual growth in length could reach 89.4% and 129.1m respectively when the seedling height was more than 100cm in length while planting. It couldn't grow well when seedling height less than 50 cm, only 36.4% could survive. It was believed that they were not strong enough to grow under the stand when the nursery stock was in small stage.

(v) In the table 3, the survival percent was obviously difference with difference closed canopies of forest without selection of species while planting. There was 83.2% survival percent in 0.34 of canopy but only 48.4% survive in 0.48 of canopy. It was much higher in open area than the place of density of crop.

2.4 Conclusions

(i) The reduced and degraded of TSF constantly as a result of the livelihood requirement of the residents highly relied on timber product in the mountain areas;

(ii) Most of SF were with simple species composition, growth slowly, weak ecological functions and low economic value in China;

(iii) There are great economic and ecological potential after management to TSF;

(iv) Degraded SF developed slowly in nature condition and difficulty to develop without management.

(v) Seedling those use for reintroduce into the degraded forest must be strong enough, and nursery stock must be more than 50 cm of height in length for planting prepare;

(vi) Non-timber product species can create economic benefit in a relative short stage, which is a very important strategy consider for stakeholder to meet the livelihood requirement without felling tree in the degraded SF management in rural area;

(vii) Right place right species is a principle in reintroduce planting of degraded forests.

2.5 Recommendations

(i) To accelerate SFM by better mnaged TSF in China is important to meet the requirements of ecological and economic as a large country in population and undeveloped;

(ii) Community-based management is an efficient development path to accelerate SFM, it can let more residents have an opportunity to participate in, and share the benefits;

(iii) Percentage of non-timber species don't to exceed 30%, otherwise too many man-made activity in the management will influence the normal ecosystem;

(iv) Native species is most important in species selection of degraded forest reintroducing for environment safety and succession normally in the future;

(v) The government should speed up to popularize the achievements of SF management in the national and local government's forest programs.

Responsible for the Project

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Chief-Engineer of GAF
August 10, 2008

References

(1) Zhang Jinquan, Xu Songjun and Huang Shaoming etc., *Master Plan of the Provincial Nature Protection District of Gudou Mountain of Guangdong*, Guangzhou, South China Normal University, 2002.

(2) Cai Yanling, Zeng Linghai and Wang Hongfeng, *The Investigation Report Case on the Region of Gudou Guangdong of Tropical Forest Resources with Social Economic Situation in Tropical Secondary Forest of China*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 4, 2008.

(3) Lian Huiming, Zlinghai and He Boxiang etc., *Study on the Species Selection of the Reintroducing into Degraded Tropical Secondary Forest*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 4, 2008.

(4) Wang Hongfeng, Zeng Linghai and He Boxiang etc., *Current Management Status and Techniques of Secondary Forests in Tropical Regions of China*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 3, 2008.

(5) He Boxiang, Xie Li and Zeng Linghai ect., *Reference Analysis on Study of The Management in Tropical Secondary Forests*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 3, 2008.

(6) Wang Hongfeng, He Boxiang and Zeng Linghai etc., *Study on the Distribution, Type and Area of the Tropical Secondary Forests in China*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 2, 2008.

(7) He Boxiang, Zeng Linghai and Wang Hongfeng etc., *Study on the Productivity Potential, Management Models of the Tropical Secondary Forests in China*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 2, 2008.

(8) He Boxiang, Zeng Linghai and Xue Li etc., *The Study on the Tropical Forests and the Management of Secondary Forests*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 1, 2008.

(9) Yin Zuoyin, Lina Huiming and Zeng Linghai etc., *Report on the Biodiversity Background of Xinhui DD of Guangdong*, Guangzhou, 2008.

Annex 1: The Adjacent Quadrat Sampling Method

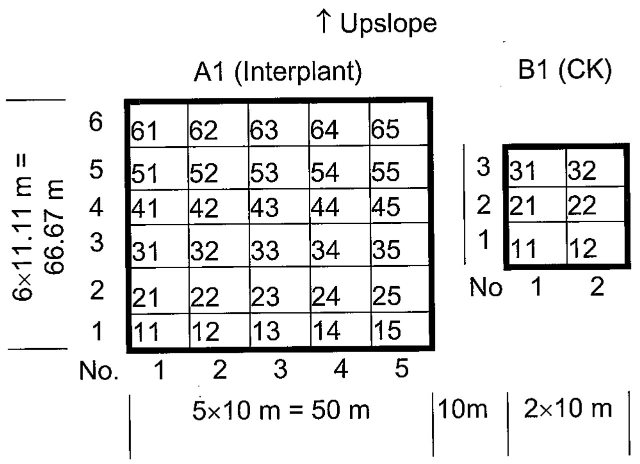

Fig. 1 Plot map (A1+B1) of Site 1 at Qingshikeng worked area in Xinhui ,Guangdong (Community type: 10 yr SF in the mountainside pine deforested area. Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

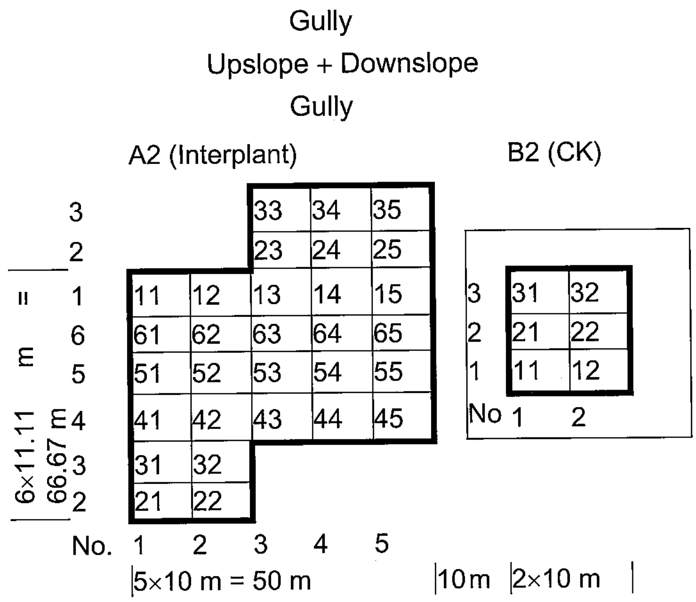

Fig. 2 Plot map (A2+B2) of Site 2 at Qingshikeng worked area in Xinhui ,Guangdong. (Community type: 5 yr SF in the gully fir deforested area. Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

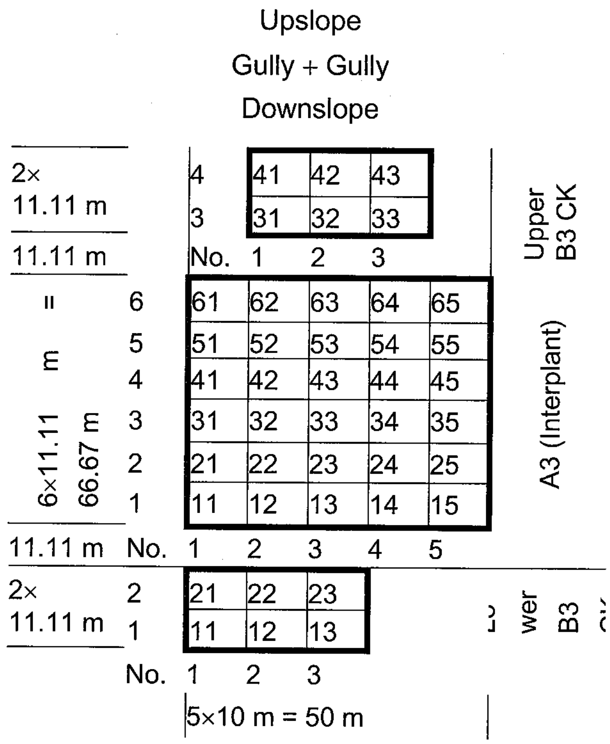

Fig. 3 Plot map (A3+2×B3) of Site 3 at Qingshikeng work area in in Xinhui ,Guangdong. (Community type: 20 yr SF in the mountaintop pine deforested area. Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

Annex 2 Vascular Plant Inventory of TSF in the DD of Qingshikeng, Xinhui

PTERIDOPHYTA 蕨类植物门

P.3. Lycopodiaceae 石松科

Palhinhaean A. Franco et Vasc. 灯笼草属

P.cemua(Linn.) Franco et Vasc.[Lycopodium cernum Linn.]灯笼草石松、铺地蜈蚣

P.4. Selaginellaceae 卷柏科

Selaginella Beauv. 卷柏属

S.doederleinii Hieron 深绿卷柏、多穗卷柏

S.uncinata (Desv.) Spring 翠云草

P.15. Gleicheniaceae 里白科

Dicranopteris Bernh. 芒萁属

D.dichotoma (Thunb.) Bernh. 芒萁

P.17. Lygodiaceae 海金沙科

Lygodium Sw. 海金沙属

L.japonicum(Thunb.)Sw.[L.microstachyum Desv.] 海金沙

L.scandens (Linn.) Sw. [L.microphylhum(Cav.)R.Br.] 小叶海金沙

P.19. Dicksoniaceae 蚌壳蕨科

Cibotium Kaulf 蚌壳蕨属、金毛狗属

C.barometz(1inn.)J.Sm. 金毛狗 (国家二级重点保护植物)

P.23. Lindsaeaceae 鳞始蕨科

Lindsaea Dry. 鳞始蕨属

L.heterophylla Dryand [Schizoloma heterophylum J.Sm.] 异叶双唇蕨

L.orbiculata(Lam.)Mett.ex Kulm. 团叶鳞始蕨

P.27. Pteridaceae 凤尾蕨科

Pteris Linn. 凤尾蕨属

P.ensiformis Burm. 剑叶凤尾蕨

P.longipinna Hayata 长叶凤尾蕨

P.multifida Poir ex Lam. 井栏边草

P.semipinnata Linn. 半边旗

P.31. Adiantaceae 铁线蕨科

Adiantum Linn. 铁线蕨属

A.flabellulatum Linn. 扇叶铁线蕨

P.42 Blechnaceae 乌毛蕨科

Blechnum linn. 乌毛蕨属

B.orientale linn. 乌毛蕨

P.46. Aspidiaceae 三叉蕨科

Hemigramma Christ. 沙皮蕨属

H.decurrens (Hook.) Copel. 沙皮蕨

SPERMATOPHYTA 种子植物门

Gymnospermae 裸子植物亚门

G.4. Pinaceae 松科

Pinus Linn. 松属

P.massoniana Lamb. 马尾松

G.5. Taxodiaceae 杉科

Cunninghamia R.Br 杉木属

*C.lanceolata (Lamm.) Hook. 杉木

G.11. Gnetaceae 买麻藤科

Gnctum Linn. 买麻藤属

G.montanum Markgr. 买麻藤

G.parvifolium(Warb.)C.Y.Cheng 小叶买麻藤

Angiospermae 被子植物亚门

Dicotyledoneae 双子叶植物纲

1. Magnoliaceae 木兰科

Magnolia Linn. 木兰属

M.championii Benth. 香港木兰

2A. Illieiaceae 八角科

Illicium Linn. 八角属

I.dunnianum Tutcher 红花八角

3. Schisandraceae 五味子科

Kadsura Kaempf ex Juss.南五味子属

K.coccinea(Lem.)A.C.Smith 黑老虎、臭饭团

8. Annonaeeae 番荔枝科

Artabotrys R. Br. ex Ker 鹰爪花属

A.hongkongensis Hance 香港鹰爪

Desmos Lour. 假鹰爪属

D.chinensis Lour.［D.cochinchinensis Lour.］ 假鹰爪、酒饼叶

Fissistigma Griff. 瓜馥木属

F.g1aucescens (Hance) Merr. 白叶瓜馥木

F.uonicum (Dunn.) Merr. 香港瓜馥木

Uvaria Linn. 紫玉盘属

U.microcarpa Champ.ex Benth. 紫玉盘

11. Lauraceae 樟科

Cassytha Linn. 无根藤属

C.filiformis Linn. 无根藤

C.innamomum Trew 樟属

C.camphora(Linn.)Presl 樟树、香樟 (国家二级重点保护植物)

Clyptocarya R.Br. 厚壳桂属

C.chinensis(Hance)Hemsl. 厚壳桂

C.concinna Hance[C.lenticellata Lec.] 黄果厚壳桂、生虫树

Lindera Thunb. 山胡椒属

L.chunii Merr. 鼎湖钓樟、陈氏钓樟

L.communis Hemsl. 香叶树

Litsea Lam. 木姜子属

L.cubeba (Lour.) Pers. 山苍子

L.romndifolia Hemsl. 圆叶豺皮樟

L.rotundifolia Hemsl.var.oblongifolia (Nees) Allen 豺皮樟

Machilus Nees 润楠属

M.breviflora(Benth.)Hemsl. 短序润楠

M.chinensis(Champ.ex Benth.)Hemsl. 华润楠

M.velutina Champ.ex Benth. 绒毛润楠、绒楠

2l. Lardizabalaceae 木通科

Stauntonla DC. 野木瓜属

S.maculata Merr. 斑叶野木瓜

23. Menispermaceae 防己科

Cocculus DC. 木防己属

C.orbiculatus (Linn.) DC. [C.trilobus(Thunb.)DC.] 木防己

Diploclisa Miers 秤钩风属

D.affmis(Oliv.)Diels ［D.chinensis Merr］秤钩风

Stephania Lour. 千金藤属

S.Longa Lour. 粪箕笃

30. Chloranthaceae 金粟兰科

Sarcandra Gardn. 草珊瑚属

S.glabra (Thunb.) Nakai 草珊瑚、九节茶

42. Polygalaceae 远志科

PolygalaLinn. 远志属

P.glomerataLour. ［P.chinensib Linn.P.densifiora Bl.］ 华南远志、金不换

8l. Thymelaeaceae 瑞香科

Wikstroemia Endll. 荛花属

W.indica(Linn.)C.A.Mey. 了哥王

W.nutans Champ. 细轴荛花

85. Dilleniaceae 五桠果科、第伦桃科

Tetracera Linn. 锡叶藤属

Tetracera asiatica (Lour.) Hoogl. 锡叶藤

88. Pittosporaceae 海桐花科

Pittosporum Banks.ex Soland. 海桐花属

P.glabratum Lindl. 光叶海桐

93. Flacourtiaceae 大风子科

Scolopia schreber 刺冬属

S.saeva Hance 广东刺冬、白皮刺冬

94. Samydaceae 天料木科

Homalium Jacq. 天料木属

H.cochinchinense (Lour) Druce 天料木

108. Theaceae 山茶科

Camellia Linn. 山茶属

C.oleifera Abel［C.drupifera Lour.］油茶

EuryaThunb.柃属

E. brevistyla Kobuski 短柱柃

E.chinensis R.Brown 米碎花、岗茶

E.glandulosa Merr.var. cuneiformis H. T. Chang 楔基腺柃

E.groffii Merr.(E.acuminata var.graffii Kobuski) 岗柃

E.nitida Korth. 细齿柃

Gordonia Ellis 大头茶属

G.axillaris (Roxb.) Dietrich 大头茶

Schima Reinw 木荷属

S.superba Gardn.et Champ.［S.confertifora Merr］ 木荷

108A.Pentaphylaceae 五列木科

Pentaphylax Gardn.et Champ. 五列木属

P.euryoides Gardn.et Champ. 五列木

113.Saurauiaceae 水东哥科

Saurauia Willd 水东哥属

S.tristyla DC. 水东哥

118.Myrtaceae 桃金娘科

Baeckea Linn. 岗松属

B.frutescens Linn. 岗松

Cleistocalyx Bl. 水翁属

C.operculatus (Roxb.) Merr.et Perry 水翁

Rhodomyrtus (DC.) Reichenb 桃金娘属

R.tomentosa (Ait.) Hassk. 桃金娘、岗稔

Syzygium Gaertn 蒲桃属

S.buxifolium Hook.et Arn. 赤楠蒲桃

S.championii (Benth.) Merr.et Perry 子凌蒲桃

120.Melastomaceae 野牡丹科

Melastoma Linn. 野牡丹属

M.candidum D.Don 野牡丹

M.dodecandrum Lour 地稔

M.sanguineum Sims 毛稔

Memecylon Linn. 谷木属

M.ligustrifolium Champ. 谷木

122.Rhizophoraceae 红树科

Carallia Roxb. 竹节树属

C.brachiata (Lour.) Merr. 竹节树

123.Hypericaceae 金丝桃科

Cratoxylum Bl. 黄牛木属

C.cochinchinense (Lour.) Bl. [Hypercum cochinchinense Lour.] 黄牛木

126.Guttiferae 藤黄科、山竹子科

Garcinia Linn. 藤黄属、山竹子属

G.multifiora Champ.ex Benth. 多花山竹子

G.oblongifolia Champ.ex Benth.　岭南山竹子

128A.Elaeocarpaceae　杜英科

Etaeocarpus Linn.　杜英属

E.japonicus Sieb.et Zucc.　日本杜英

Sloanea Linn.　猴欢喜属

S.sinensis (Hance) Hemsl.　猴欢喜

130.Sterculiaceae　梧桐科

Bytmeria Loefl.　刺果藤属

B.aspera Colebr.　刺果藤

Helicteres Linn.　山芝麻属

H.angustifolia Linn.　山芝麻

Sterculia Linn.　苹婆属

S.1anceolata Cav.　假苹婆

135A.Ixonanthaceae　粘木科

Ixonanthes Jack.　粘木属

I.chinensis Champ.　粘木(国家三级保护植物)

136.Euphorbiaceae　大戟科

Alchornea Sw.　山麻杆属

A.trewioides(Benth.)Muell. – Arg.　红背山麻杆

Antidesma Linn.　五月茶属

A.japonlcum Sieb.et Zucc.　日本五月茶、酸味子

Aporusa Bl.　银柴属

A.dioca(Roxb.)Muell. – Arg.［A.chinensis (Champ.) Merr.］　银柴

Brevnia J.R.et G.Forst　黑面神属

B.fruticosa(Linn.)Hook.f.　黑面神

Croron Linn　巴豆属

C.1achnocarpus Benth.　毛果巴豆

Glochidion J.R.et G.Forst.　算盘子属

G.eriocarpum Champ.et Benth.　毛果算盘子

Phyllanthus Linn.　叶下珠属

P.cochinchinensis (Lour.) Spreng.　越南叶下珠

Sapium P.Br.　乌桕属

S.discolor (Champ.ex Benth.) Muell. – Arg.　山乌桕

S.sebiferum (Linn.) Roxb.　乌桕

139.Escalloniaceae　鼠刺科

Itea Linn.　鼠刺属

I.chinensis Hook.et Arn.　鼠刺

143.Rosaceae 蔷薇科

Rhaphio1epis Lindl.　石斑木属、车轮梅属

R.indica Lind.　车轮梅、春花

Rubus Linn.　悬钩子属

R.alceaefolius Poir.[R.fmbriferus Focke]　粗叶悬钩子

R.1eucanthus Hance　白花悬钩子

146.Mimosaceae　含羞草科

Pithecellobium Mart. 牛蹄豆属、猴耳环属

P.lucidum Benth. 亮叶猴耳环

148.Papilionaceae 蝶形花科

Dalbergia Linn.f 黄檀属

D.bancei Benth. 藤黄檀

Ormosia G.Jacks. 红豆属

O.emarginata (Hook.et Art.) Benth. 凹叶红豆

O.glaberrimaY.C.Wu [O.kwangturtgensis L.Chen] 光叶红豆

O.semincastrata Hance 软荚红豆

159.Myricaceae 杨梅科

Myrica Linn. 杨梅属

M.rubra (Lour.) Sieb.et Zucc. 杨梅

165.Ulmaceae 榆科

Celits Linn. 朴属

C.tetrandra Roxb.subsp.sinensis(Pers.)Y.C.Tang.[C.sinensis Pers.] 朴树

Gironniera Gaud. 白颜树属

G.subaequalis Planch. 白颜树

Trema Lour. 山黄麻属

T. angustifolia (Planch.) Blume 狭叶山黄麻

T.cannabina Lour. 光叶山黄麻

T.orientalis (Linn.)Bl. 山黄麻

167.Moraceae 桑科

Broussonetia L'Herit ex Vent. 构属

B.papyrifera(Linn.)L'Herit ex Vent 构树

Ficus Linn. 榕属

F.hirtaVahl. 粗叶榕、裂叶粗毛榕

F.variolosa Lindl. ex Benth. 变叶榕

171.Aquifoliaceae 冬青科

Ilex Linn. 冬青属

I.asprella (Hook.et Arn.) Champ.ex Benth. 梅叶冬青、秤星树

I.memecylifolia Champ.ex Benth. 谷木冬青

I.pubescens Hook.et Arn. 毛冬青 Ilex pubescens Hook. et Arn.

I.triflora Bl. [I.theicarpa Harid. – Mazz.1 三花冬青

I.viridis Champ.ex Benth. [I.triflora Bl.var.viridis Loes] 亮叶冬青

173.Celastraceae 卫矛科

Euonymus Linn. 卫矛属

E.1axiflorus Champ. 蔬花卫矛

182.Olacaceae 铁青树科

Schoepfia Schreb. 青皮木属

S.chinensis Gardn.et Champ. 华南青皮

S.jasminodora Sieb.et Zucc. 青皮木

186.Santalaceae 檀香科

Dendrotrophe Miq. 寄生藤属

D.frutescens (Champ.ex Benth.) Danser [Henslowia Frutescens Champ.ex Benth.] 寄生藤

190.Rhamnaceae 鼠李科

Berchemia Neck.ex DC. 勾儿茶属

B.floribunda(Wall.)Brongn. [B.giraldiana Schneid.B.racemosa Sieb.et Zucc.] 多花勾儿茶

194.Rutaceae 芸香科

Acronychia J.R.et G.Forst. 山油柑属

A.pedunculara(Linn.)Miq. 山油柑、降真香

Evodia J.R.et G. Forst. 吴茱萸属

E.1epta (Spreng.) Merr. 三叉苦、三杈苦

Fortumella Swingle 金橘属

F. hindsii (Champ. ex Benth.) Swingle 山橘

Zanthoxylum Linn. 花椒属

Z.avicennae (Lam.) DC. 簕欓花椒

Z.dissitum Hemsl. 单面针、蚬壳花椒

Z.nitidum (Roxb.) DC. [Z.nitidum (Roxb.) DC. var. neglectum How.] 两面针

205.Anacardiaceae 漆树科

Rhus Linn. 盐肤木属

R.chinensis Mill. var. roxburghii(DC.)Rehd. 滨盐肤木

Toxicodendron Mill. 漆树属

T.succedaneum(Linn.)O.Kuntze 野漆树

206.Connaraceae 牛栓藤科

Rourea Aubl. 红叶藤属

R.microphylla (Hook.et Arn.) P1anch. 小叶红叶藤

R.minor (Gaertn.) Leenh. 红叶藤

212.Araliaceae 五加科

Dendropanax Decne et Planch 树参属

D.proteus(Champ.ex Benth.) Benth. 变叶树参

Scheffiera J.R.et G.Forst. 鹅掌柴属

S.octophylla(Lour.)Harms 鹅掌柴、鸭脚木

215.Eficaceae 杜鹃花科

Enkianthus Lour. 吊钟花属

E.qumqueflorus Lour. 吊钟花

216.Vacciniaceae 越桔科

Vaccinium Lirm. 乌饭树属

V.hancockiae Merr. 广东乌饭树

221.Ebenaceae 柿树科

Diospyros Linn. 柿树属

D.morrisiana Hance 罗浮柿

D.vaccmioides Lindl. 乌饭叶柿、小果柿

222A.Sarcospermaceae 肉实树科

Sarcosperma Hook.f. 肉实树属

S.1aurinum (Benth.) Kook.f. 水石梓

223.Myrsinaceae 紫金牛科

Ardlisa Swartz 紫金牛属

A.hanceana Mez. 大罗伞、紫金牛

A.punctata Lindl.　山血丹、斑叶朱砂根

A.qulnquegona Bl.　罗伞树

Embelia Burm.f.　酸藤子属

E.1aeta(Linn.)Mez　酸藤子

E.ribes Burm.f.　白花酸藤子

Rapanea Aubl.　密花树属

R.neriifolia (Sieb.et Zucc.) Mez　密花树

224.Styracaceae 安息香科

Alniphyllum Matsum.赤杨叶属

A.fortunei(Hemsl.)Makino　赤杨叶、拟赤杨

225.Sympiocaceae 山矾科

Symplocos Jacq.　山矾属

S.1ancifolia Sieb.et Zucc.　光叶山矾

S.1ancilimba Merr.　披针叶山矾、剑叶山矾

S. stellaris Brand　老鼠矢

230.Apocynaceae　夹竹桃科

Alyxia Banks ex R.Br.　链珠藤属

A.sinensis Champ.ex Benth.　链珠藤

Strophanthus DC.　羊角拗属

S.divaricatus (Lour.) Hook. et Arn.　羊角拗

232.Rubiaeeae 茜草科

Adina Salisb.　水团花属

A.pilulifera(Lam.)Franch.ex Drake　水团花

Coptosapelta Koch.　流苏子属

C.diffusa (Champ.ex Benth.) Steenis [Thysanospermum diffusum Champ.]　流苏子

Dunnia Tutch.　绣球茜属

D.sinensis Tutch.　绣球茜(国家：二级重点保护植物)

Gardenia Ellis.　栀子属

G.jasminoides Ellis.　栀子

Hedyotis Linn.　耳草属

H.auricularia Linn　耳草

H.bracteosa Hance　大苞耳草

H.lancea Thunb.　剑叶耳草

Ixora Linn.　龙船花属

I.chinensis Lam　龙船花、山丹

Lasianthus JaCk.　粗叶木属

L.Chmensis Benth.　粗叶木

Mormda Linn.　巴戟天属

M.officinalis How　巴戟天 (国家三级保护植物)

M.umbellate Linn.　羊角藤、鸡眼藤

Mussaenda Linn.　玉叶金花属

M.pubescens Ait.f.　玉叶金花

Psychotria Linn.　九节属

P. rubra (Lour.) Poir.　九节

P.serpens Linn. 蔓九节、白果仔

Randia Linn. 山黄皮属

R.canthloides Champ. 香楠、光叶山黄皮

Tarenna Gaertn. 乌口树属

T.mollissima(Hook.et Arn.)Robins 密毛乌口树

Tricalysia A.Rich.ex DC. 狗骨柴属

T.dubia(Lindl.)Ohw1 狗骨柴

233.Caprifoliaceae 忍冬科

Lonicera Linn. 忍冬属

L.confusa(Sweet)DC. 华南忍冬、山银花

Viburnum Linn. 荚蒾属

V.sempervirens K.Koch 常绿荚蒾、坚荚蒾

239.Gentianaceae 龙胆科

Canscura Lam. 穿心草属

C.melastomacea Hand. – Mazz. 罗星草

251.Convolvulaceae 旋花科

Erycibe Roxb. 丁公藤属

E.obtusifolia Benth. 丁公藤

263.Verbenaceae 马鞭草科

Clerodendrum Linn. 大青属、臭牡丹属

C.fortunatum Linn. 白花鬼灯笼、鬼灯笼

Monocotyledoneae 单子叶植物纲

290.Zingiberaceae 姜科

Alpinia Roxb. 山姜属

A.densibracteata T.L.Wu et Senjen 密苞山姜

293.Liliaceae 百合科

Dianella Lam. 山菅兰属

D.ensifolia (Linn.) DC. [Dracaena egisifolia Linn.] 山菅兰

Ophiopogon Ker – Gawl. 沿阶草属

O.bodinieri Le'v1. 沿阶草

297.Smilacaceae 菝葜科

Smilax Linn. 菝葜属

S.china Linn. 菝葜

S.glabra Roxb. 土茯苓、光叶菝葜

S.hypoglauca Benth. 粉背菝葜

S.riparia A.DC. 牛尾菜

311.Dioseoreaeeae 薯预科

Dioscorea Linn. 薯预属

D.cirrhosa Lour. 薯莨

314.Palmae 棕榈科

Calamus Linn. 省藤属

C.rhabdocladus Burret 华南省藤、杖枝省藤

315.Pandanaceae 露兜树科

Pandanus Linn. 露兜树属

P.austrosinensis T.L.Wu　露兜草

318.Hypoxidaeeae 仙茅科

Curculigo Gaertn.　仙茅属

C.orchioides Gaertn.　仙茅

326.Orchidaceae 兰科

Ania Lindl.　安兰属

A.hongkongensis(Roife.)Tang et Wang　香港安兰

331. Cyperaceae 莎草科

Gahnia J.R.et G.Forst.　黑莎草属

G.tristis Nees　黑莎草

Hypolytrum Perr.　割鸡芒属

H.nemoRUm(Vahl.).Spreng　割鸡芒

Lepidosperma Labill.　鳞籽莎属

L.chinensis Nees　鳞籽莎

332. Gramineae　禾本科

332A. Bambunoideae　竹亚科

Indocalamus Nakai.　箬竹属

I.vulgatus Lin et X.B.Ye　古兜箬竹

332B. Agrostidoideae 禾亚科

Ischaemum Linn.　鸭嘴草属

I.aristatum Linn.　芒穗鸭嘴草

I.indicum Merr.　[I.ciliare Retz.]　细毛鸭嘴草、纤毛鸭嘴草

Lophatherum Brongn.　淡竹叶属

L.gracile Brongn.　淡竹叶

Miscanthus Anderss.　芒属

M.sinensis Anderss　芒

Thysanolaena Nees　棕叶芦属

S.maxima (Roxb.) O. Kuntze　棕叶芦

Annex 3 List of the Species Selected for Introducing in Degraded SF

序号 No.	树种 Name of Species		科/属 Family/Genus	特性 Properties
A. Native Species 乡土树种				
1	肖蒲桃	*Acmena acuminatissima*	*Myrtaceae*	light and wet requirement
2	顶果木	*Acrocarpus fraxinifolius*	*Caesalpiniaceae*	light requirement
3	降真香	*Acronychia pedunculata*	*Rutaceae*	light requirement, can grow in dry and barren
4	海红豆	*Adenanthera paeonina*	*Mimosaceae*	overcast requirement in juvenile, but light requirement in late
5	石栗	*Aleurites moluccana*	*Euphorbiaceae*	light and wet requirement
6	大花五桠果	*Alstonia scholaris*	*Dilleniaceae*	overcast requirement
7	五月茶	*Antidesma bunius*	*Euphorbiaceae*	light requirement
8	大叶山楝	*Aphanamixis grandifolia*	*Meliaceae*	light and wet requirement, can grow in dry and barren
9	树菠椤	*Artocarpus heterophyllus* Lam.	*Moraceae*	light requirement, but can endure overcast in juvenile
10	红桂木	*Artocarpus nitidus*	*Moraceae*	light and wet requirement, like fertile soil.
11	羊蹄甲	*Bauhinia purpurea*	*Caesalpiniaceae*	light requirement
12	秋枫	*Bischofia javanica*	*Euphorbiaceae*	light and wet requirement
13	红花腊肠树	*Cassia fistula*	Caesalpiniaceae	light and wet requirement
14	雄黄豆	*Cassia javanica*	*Caesalpiniaceae*	light requirement
15	黄槐	*Cassia surattensis*	*Caesalpiniaceae*	neutral and partial light requirement, can endure overcast in juvenile.
16	藜蒴	*Castanopsis fissa*	*Fagaceae*	light requirement, but can endure overcast in juvenile
17	红锥	*Castanopsis hystrisc*	*Fagaceae*	shady to be able to bear
18	海芒果	*Cerbera manghas*	*Apocynaceae*	shady to be able to bear
19	麻楝	*Chukrasia tabularis*	*Meliaceae*	light requirement, but can endure overcast in juvenile
20	阴香	*Cinnamomum burmanii*	*Lauraceae*	light and wet requirement
21	樟树	*Cinnamomum camphora*	*Lauraceae*	light requirement, but can endure overcast in juvenile
22	蝴蝶果	*Cleidiocarpon cavaleriei*	*Euphorbiaceae*	light requirement
23	鱼木	*Crateva formosensis*	*Capparaceae*	light and wet requirement
24	降香黄檀	*Daibergia odorifera*	*Papilionaceae*	light requirement
25	猫尾木	*Dolichandrone caudafelina*	*Bignoniaceae*	tend to light requirement
26	人面子	*Dracontomelon duperreanum*	*Anacardiaceae*	light and wet requirement
27	尖叶杜英	*Elaeocarpus apiculatus*	*Elaeocarpaceae*	light requirement, but can endure overcast in juvenile
28	中华杜英	*Elaeocarpus Chinesis*	*Elaeocarpaceae*	light requirement, but can endure overcast in juvenile
29	杜英	*Elaeocarpus decipiens* Hemsl.	*Elaeocarpaceae*	light requirement, but can endure overcast in juvenile
30	水石榕	*Elaeocarpus hainanensis* Oliver	*Elaeocarpaceae*	light requirement, but can endure overcast in juvenile
31	山杜英	*Elaeocarpus sylvestris*	*Elaeocarpaceae*	light requirement, but can endure overcast in juvenile
32	格木	*Erythrophleum fordii*	*Caesalpiniaceae*	light requirement
33	菩提榕	*Ficus religiosa*	*Moraceae*	light and wet requirement
34	岭南山竹子	*Garcinia oblongifolia*	*Guttiferae*	light requirement, but can endure overcast in juvenile
35	银桦	*Grevillea robusta*	*Proteaceae*	light requirement

36	银叶板根	*Heritiera littoralis*	*Sterculiaceae*	light requirement
37	幌伞枫	Heteropanax fragrans (Roxb.) Seem.	*Araliaceae*	light requirement, but can endure overcast in juvenile
38	坡垒	*Hopea hainanensis*	*Dipterocarpaceae*	Overcast requirement in juvenile, but light requirement in late
39	塞楝	*Khaya senegalensis*	*Meliaceae*	light requirement
40	红花荷	*Khodoleia championii* Hook	*Hamamelidaceae*	light requirement
41	吊瓜	*Kigelia africana*	*Bignoniaceae*	light and wet requirement
42	复羽叶栾树	*Koelreuteria bipinnata* Franch	*Sapindaceae*	light and wet requirement
43	大叶紫薇	*Lagerstroemia speciosa*	*Lythraceae*	light requirement, but can endure overcast in juvenile
44	枫香	*Liquidambar formosana*	*Hamamelidaceae*	light requirement
45	山玉兰	*Magnolia delavayi* Franch.	*Magnoliaceae*	light requirement
46	白玉兰	*Magnolia heptapeta*	*Magnoliaceae*	light requirement, but can endure partial overcast .
47	扁桃	*Mangifera persiciformis*	*Anacardiaceae*	overcast requirement in juvenile, but light requirement in late
48	灰木莲	*Mangleitia glauca*	*Magnoliaceae*	partial light requirement, can endure overcast in juvenile.
49	黄兰	*Michelia champaca* Linn.	*Magnoliaceae*	light and wet requirement
50	乐昌含笑	*Michelia chapensis* Dandy	*Magnoliaceae*	light and wet requirement
51	火力楠	*Michelia macclurei*	*Magnoliaceae*	overcast requirement in juvenile, but light requirement in late
52	深山含笑	*Michelia maudiae*	*Magnoliaceae*	overcast requirement in juvenile, but light requirement in late
53	峨嵋含笑	*Michelia wilsomii*	*Magnoliaceae*	Overcast requirement in juvenile, but light requirement in late
54	米老排	*Mytilaria laosensis*	*Hamamelidaceae*	Overcast requirement in juvenile, but light requirement in late
55	海南红豆	*Ormosia pinnata*	*Papilionaceae*	light requirement, but can endure overcast in juvenile
56	乐东拟单性木兰	*Parakmeria lotungensis*	*Magnoliaceae*	light and wet requirement
57	亮叶猴耳环	*Pithecellobium lucidum* Benth.	*Mimosaceae*	partial light requirement, can endure overcast in juvenile.
58	竹柏	*Podocarpus nagi*	*Podocarpaceae*	overcast requirement
59	翻白叶	*Pterospermum heterophyllum*	*Sterculiaceae*	light requirement
60	海南菜豆树	*Radermachera hainanensis*	*Bignoniaceae*	light requirement
61	无忧树	*Saraca chinensis*	*Caesalpiniaceae*	light requirement
62	荷木	*Schima superba*	*Theaceae*	light requirement, but can endure overcast in juvenile
63	五味子	*Schisandra chinensis*	*Schisandraceae*	light requirement
64	海南蒲桃	*Syzygium hainanense*	*Myrtaceae*	light requirement
65	厚皮香	*Ternstroemia gymnanthera*	*Theaceae*	light requirement, but can endure overcast in juvenile
66	大叶榄仁	*Terminalia catappa*	*Combretaceae*	light requirement
67	莫氏榄仁	*Terminalia muelleri*	*Combretaceae*	light requirement
68	观光木	*Tsoongiodendron odorum* Chun	*Magnoliaceae*	Overcast requirement in juvenile, but light requirement in late
B. Exotic Species 外引树种				
1	盆架子	*Alstonia rostrata*	*Apocynaceae*	Native in Australia, light and wet requirement

2	玉蕊	*Barringtonia racemosa*	*Lecythidaceae*	Native in African, light requirement
3	大果决明	*Cassia fruticosa*	*Caesalpiniaceae*	Native in American, light requirement
4	具翼龙脑香	*Dipterocarpus alatus*	*Dipterocarpaceae*	Native in south-east Asia, light requirement
5	福木	*Garcinia subelliptica*	*Guttiferae*	Native in Australia, light and wet requirement
6	香坡垒	*Hopoa odorata*	*Dipterocarpaceae*	Native in south-east Asia, light requirement, neutral and partial overcast.
7	虎拉	*Hura polyandra*	*Euphorbiaceae*	Native in American, light requirement
8	蓝花楹	*Jacaranda mimosifolia*	*Bignoniaceae*	Native Latin American, light and wet requirement
9	钝叶娑椤双	*Shorea obtusa*	*Dipterocarpaceae*	Native in south-east Asia, light requirement, neutral and partial overcast.
10	泰国娑椤双	*Shorea siamensis*	*Dipterocarpaceae*	Native in south-east Asia, light requirement.
11	火焰木	*Spathodea campanulata*	*Bignoniaceae*	Native in African an American, light requirement.
12	风玲木	*Tabebuia chrysantha*	*Bignoniaceae*	Native Latin American, light and wet requirement
13	小叶榄仁	*Terminalia mantly*	*Combretaceae*	Native in American, light and wet requirement
C. Non-timber Product Species 非木质产品物种				
1	黄甜竹	*Acidosasa edulis*	*Gramineae*	For edible shoot
2	砂仁	*Amomum villosum*	*Zingiberaceae*	Fruit for medical use
3	树菠椤	*Artocarpus heterophyllus* Lam.	*Moraceae*	For fruit
4	阳桃	*Averrhoa carambola* L.	*Oxalidaceae*	For fruit
5	构树	*Broussonetia papyrifera*	*Moraceae*	For medical use
6	白藤	*Calamus tetradactylus*	*Palmae*	For sprouting stem
7	油茶	*Camellia olelfera* Abel	*Theaceae*	For edible oil
8	板栗	*Castanea mollissima*	*Fagaceae*	For fruit
9	方竹	*Chimonobambusa quadrangularis*	*Gramineae*	For edible shoot
10	黄皮	*Clausena lansium* (Lour.) Skeels	*Rutaceae*	For fruit
11	黄藤	*Daemonorops margaritae*	*Palmae*	For sprouting stem
12	枇杷	*Eriobotrya japonica*	*Rosaceae*	For fruit and medical use
13	扶方藤	*Euonymus fortunei*	*Celastraceae*	sprouting stem for medical
14	黄栀子	*Gardenia jasminoides*	*Rubiaeeae*	For medical
15	苹果梨	*Grafting variety*	*Rosaceae*	For fruit
16	山苍子	*Litsea cubeba* (Lour.) Pers	*Lauraceae*	Fruit for medical use
17	山银花	*Lonicara confusa*	*Caprifoliaceae*	Flower for medical use
18	芒果	*Mangifera indica*	*Anacardiaceae*	For fruit
19	高脂松	*Pinus massoniana* Lamb.	*Pinaceae*	For resin
20	番石榴	*Psidium guajava* Linn.	*Myrtaceae*	For fruit
21	鸡血藤	*Spatholobus suberectus*	*Leguminosae*	sprouting stem for medical
22	青枣	*Zizyphus mauritians* Lan	*Rhamnaceae*	For fruit

Annex 4 Statistics of Growth Reintroduced Species in Xinhui DD

NO.	Species	Survival Rate (%)	Average Height (cm)	Average Ground Diameter (cm)	Annual High Growth (cm)	Annual Ground Diameter (cm)	Highest Of Height (cm)	Highest Of Diameter (cm)
75	*Grevillea robusta*	46.7	246.0	3.7	210.9	3.1	350.0	5.6
37	*Michelia macclurei*	33.3	240.7	4.7	206.3	4.0	320.0	8.2
45	*Parakmeria lotungensis*	73.3	235.3	3.7	201.7	3.2	340.0	6.8
51	*Mytilaria laosensis*	100.0	227.0	2.6	194.6	2.3	280.0	3.7
11	*Shorea obtusa*	80.0	223.3	1.8	191.4	1.6	270.0	2.2
6	*Aphanamixis grandifolia*	66.7	216.0	2.7	185.1	2.3	310.0	4.3
34	*Michelia champaca* Linn.	86.7	215.3	4.6	184.6	3.9	280.0	8.0
38	*Spathodea campanulata*	93.3	210.0	2.5	180.0	2.2	300.0	3.6
23	*Ormosia pinnata*	33.3	209.3	3.1	179.4	2.7	310.0	4.4
25	*Schima superba*	46.7	209.3	3.0	179.4	2.5	300.0	5.2
52	*Terminalia muelleri*	80.0	207.3	2.6	177.7	2.3	270.0	4.0
80	*Elaeocarpus Chinesis*	86.7	204.7	2.9	175.4	2.5	340.0	5.0
55	*Ficus religiosa*	80.0	203.0	3.5	174.0	3.0	300.0	5.4
63	*Artocarpus heterophyllus*	73.3	198.7	3.4	170.3	2.9	300.0	5.9
41	*Acronychia pedunculata*	80.0	197.3	3.2	169.1	2.7	280.0	5.0
60	*Magnolia delavayi*	80.0	197.3	3.2	169.1	2.7	280.0	5.0
69	*Hopoa odorata*	93.3	194.7	2.3	166.9	2.0	270.0	3.2
39	*Elaeocarpus apiculatus*	46.7	193.3	2.6	165.7	2.2	260.0	4.8
35	Heteropanax fragrans Seem.	60.0	186.0	3.1	159.4	2.7	270.0	5.1
27	*Khodoleia championii*	73.3	186.0	1.9	159.4	1.6	240.0	3.8
50	*Dolichandrone caudafelina*	66.7	184.0	2.6	157.7	2.2	320.0	5.0
21	*Cerbera manghas*	80.0	182.0	2.1	156.0	1.8	310.0	3.4
53	*Alstonia rostrata*	60.0	173.3	4.0	148.6	3.4	280.0	6.5
28	*Cassia fistula*	46.7	170.3	1.7	146.0	1.5	210.0	4.4
19	*Tsoongiodendron odorum*	80.0	169.3	2.2	145.1	1.9	310.0	5.2
48	*Garcinia oblongifolia*	93.3	169.3	2.1	145.1	1.8	220.0	3.0
29	*Castanopsis hystrisc*	60.0	160.8	2.1	137.9	1.8	280.0	3.8
70	*Terminalia mantly*	73.3	158.0	2.0	135.4	1.7	280.0	3.9
3	*Cassia fruticosa*	53.3	153.3	2.5	131.4	2.1	230.0	3.7
7	*Lagerstroemia speciosa*	53.3	153.3	2.5	131.4	2.1	230.0	3.7
15	*Liquidambar formosana*	53.3	149.3	2.7	128.0	2.3	250.0	4.1
42	*Dipterocarpus alatus*	53.3	149.3	2.7	128.0	2.3	250.0	4.1
22	*Radermachera hainanensis*	46.7	148.7	3.1	127.4	2.7	210.0	6.0
79	*Cinnamomum camphora*	53.3	146.0	2.1	125.1	1.8	210.0	4.3
74	*Cinnamomum burmanii*	93.3	143.7	2.1	123.1	1.8	220.0	4.5
77	*Crateva formosensis*	66.7	143.6	2.0	123.1	1.7	200.0	4.1
49	*Chukrasia tabularis*	56.7	143.3	1.9	122.9	1.6	200.0	3.5
2	*Mangifera persiciformis*	100.0	141.7	1.7	121.4	1.5	220.0	2.3
32	*Hura polyandra*	100.0	140.0	1.6	120.0	1.4	140.0	1.6

58	*Khaya senegalensis*	66.7	139.3	2.1	119.4	1.8	190.0	3.5
57	*Dracontomelon duperreanum*	53.3	137.7	3.1	118.0	2.7	200.0	6.2
71	*Acmena acuminatissima*	73.3	137.3	1.6	117.7	1.4	260.0	3.0
68	*Antidesma bunius*	86.7	137.3	2.1	117.7	1.8	240.0	3.4
4	*Alstonia scholaris*	73.3	137.3	1.6	117.7	1.4	230.0	2.7
30	*Ternstroemia gymnanthera*	60.0	137.3	2.1	117.7	1.8	200.0	3.8
12	*Michelia wilsomii*	80.0	136.0	1.2	116.6	1.1	180.0	1.7
64	*Elaeocarpus hainanensis*	46.7	134.7	1.5	115.4	1.3	240.0	3.1
8	*Kigelia africana*	40.0	134.7	1.8	115.4	1.5	200.0	3.0
44	*Michelia chapensis*	60.0	133.5	1.7	114.4	1.5	210.0	3.2
66	*Saraca chinensis*	60.0	133.5	1.7	114.4	1.5	210.0	3.2
5	*Terminalia catappa*	66.7	133.3	2.2	114.3	1.9	170.0	2.4
62	*Aleurites moluccana*	93.3	127.3	1.6	109.1	1.4	200.0	3.0
36	*Mangleitia glauca*	60.0	125.0	1.1	107.1	0.9	180.0	1.8
46	*Castanopsis fissa*	46.7	125.0	1.4	107.1	1.2	150.0	1.9
67	*Schisandra chinensis*	80.0	122.0	1.5	104.6	1.3	280.0	2.4
59	*Elaeocarpus sylvestris*	53.3	120.3	2.3	103.1	2.0	220.0	4.8
33	*Cassia surattensis*	100.0	115.7	1.6	99.2	1.3	200.0	2.0
26	*Artocarpus nitidus*	93.3	114.7	1.5	98.3	1.3	160.0	2.3
72	*Cassia javanica*	50.0	112.2	1.4	96.2	1.2	170.0	2.0
1	*Magnolia heptapeta*	80.0	111.0	1.4	95.1	1.2	200.0	2.6
13	*Pterospermum heterophyllum*	66.7	109.1	1.6	93.5	1.3	230.0	2.9
78	*Barringtonia racemosa*	60.0	107.7	2.0	92.3	1.7	150.0	3.5
61	*Michelia maudiae*	66.7	107.3	1.9	92.0	1.6	200.0	4.2
10	*Elaeocarpus decipiens Hemsl.*	53.3	107.3	2.0	92.0	1.7	160.0	3.2
56	*Bischofia javanica*	33.3	107.0	1.3	91.7	1.1	280.0	3.5
65	*Shorea siamensis*	73.3	104.7	2.0	89.7	1.7	160.0	3.4
54	*Hopea hainanensis*	20.0	102.5	1.2	87.9	1.1	150.0	2.2
43	*Jacaranda mimosifolia*	86.7	97.7	1.5	83.7	1.3	170.0	3.0
14	*Tabebuia chrysantha*	80.0	97.3	1.3	83.4	1.1	150.0	2.3
24	*Syzygium hainanense*	6.7	97.1	1.6	83.3	1.3	140.0	2.5
20	*Adenanthera paeonina*	46.7	97.0	1.3	83.1	1.1	150.0	1.7
17	*Koelreuteria bipinnata*	33.3	86.7	1.3	74.3	1.1	120.0	1.6
40	*Daibergia odorifera*	60.0	84.4	1.0	72.4	0.8	125.0	1.6
81	*Podocarpus nagi*	80.0	82.7	1.4	70.9	1.2	120.0	2.0
31	*Cleidiocarpon cavaleriei*	73.3	75.0	2.3	64.3	1.9	110.0	3.6
76	*Heritiera littoralis*	60.0	72.0	1.2	61.7	1.0	160.0	2.5
9	*Acrocarpus fraxinifolius*	60.0	72.0	1.1	61.7	0.9	140.0	1.8
73	*Bauhinia purpurea*	20.0	63.3	1.1	54.3	0.9	80.0	1.3
47	*Pithecellobium lucidum*	66.7	59.7	1.0	51.1	0.9	80.0	2.5
16	*Garcinia subelliptica*	80.0	43.2	0.9	37.0	0.8	70.0	2.6
18	*Erythrophleum fordii*	60.0	40.4	0.8	34.6	0.7	60.0	1.1

Annex 5 Publications/Technical Reports

(1) Cai Yanling, Zeng Linghai and Wang Hongfeng, *The Investigation Report Case on the Region of Gudou Guangdong of Tropical Forest Resources with Social Economic Situation in Tropical Secondary Forest of China*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 4, 2008.

(2) Lian Huiming, Zebg Linghai and He Boxiang etc., *Study on the Species Selection of the Reintroducing into Degraded Tropical Secondary Forest*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 4, 2008.

(3) Wang Hongfeng, Zeng Linghai and He Boxiang etc., *Current Management Status and Techniques of Secondary Forests in Tropical Regions of China*, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 3, 2008.

(4) He Boxiang, Xue Li and Zeng Linghai ect., *Reference Analysis on Study of The Management in Tropical Secondary Forests*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 3, 2008.

(5) Wang Hongfeng, He Boxiang and Zeng Linghai etc., *Study on the Distribution, Type and Area of the Tropical Secondary Forests in China*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 2, 2008.

(6) He Boxiang, Zeng Linghai and Wang Hongfeng etc., *Study on the Productivity Potential, Management Models of the Tropical Secondary Forests in China*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 2, 2008.

(7) He Boxiang, Zeng Linghai and Xue Li etc., *The Study on the Tropical Forests and the Management of Secondary Forests*, Guangdong Forestry Science and Technology, Guangdong Forestry Science and Technology, Guangzhou, Guangdong Society of Forestry, No. 1, 2008.

(8) Xue Li, Zeng Linghai and Wang Hongfeng etc., *Advances in Ecological Studies of Tropical Secondary Forests*, Tropics, Japan, The Japan Society of Tropical Ecology, No. 2, 2007.

(9) Yin Zuoyin, Hairen and Peng Shaolin etc., *Using Generalized Poisson Describe to Describe the Abundance Patterns in Forest Community*, Guangzhou, 2008.

(10) Yin Zuoyin, Lian Huiming and Zeng Linghai etc., *Report on the Biodiversity Background of Xinhui Demonstration District of Guangdong*, Guangzhou, 2008.

中国热带次生林区森林资源及社会经济状况
——广东古兜山林区调查报告

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Forest Resources and Social Economic Situation of Tropical Secondary Forest Region of China -- The Investigation Report of the Gudou Mountain Forest Region of Guangdong

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Abstract In order to improve the tropical secondary forest(TSF) management, with the support of the International Tropical Timber Organization(ITTO), the investigation of forest resources and social economic situation was carried out in a typical TSF forest region--Gudou Mountain areas of Guangdong, which was one of the subject of "The Study and Demonstration of the Management of Secondary Forests in Tropical Regions for The Purpose of Enhancing Economic and Ecological Benefits", (PD 294/04 Rev.4 (F)). The result from which we considered that: Chinese tropical forest areas, with the exception of protected areas, almost existed as low-yield and low quality secondary forests, and activities of forest management had seldom developed, so it lacked of economic and ecological benefits. The residents' incomes were mainly from the Government's compensation for ecological forest, deforestation, rent of commodity forest land, and farming etc. Their life was still poverty and the annual per capita income was only 3,780 yuan (about 556 U.S. dollars). The generally desire of the forest farmer was developing fast-growing and high-yield commodity forest such as Eucalyptus to obtain higher management benefits. So China was still facing great pressure in the protection of TSF.

Key words tropical secondary forest, forest sources, forest management.

摘要　为更好地开展热带次生林经营，在国际热带木材组织“旨在提高经济和生态效益的热带地区次生林经营研究与示范”项目（ITTO PPD 294/04）的资助下，对较为典型的中国热带次生林——广东古斗兜山林区开展了森林资源与社会经济状况的相关调查，其结果认为：由于中国热带林区，除保护区外，热带森林几乎都以低产低质的次生林存在，这类林分质量普遍较差，很少开展经营活动，因此缺乏经济和生态效益。林区居民主要依靠政府的生态公益林补偿、砍伐林木、出租林地供商品林经营以及农耕等获得收入，生活仍然处于比较贫困的状态，人均年收入仅3780元（约合556美元）。林农普遍的愿望是将次生林地改种以桉树为代表的速生丰产商品林经营，以获得较高的经营效益，次生林的保护仍然面临巨大的压力。

关键词　热带次生林; 森林资源; 森林经营

热带次生林林分质量差，生物多样性日趋贫乏，生态功能脆弱而且生产力低，长期以来都被人们忽视并不断遭受破坏，林地挪作它用。因此，开展热带次生林经营已引起国际社会的重视。在国际热带木材组织（ITTO）的资助下，对较为典型的中国热带次生林——广东古斗兜山林区开展了森林资源与社会经济状况的相关调查，其目的是通过了解热带次生林地区森林资源与当地社会状况，有针对性地提出符合次生林区居民生活需求和社会发展需要的热带次生林经营方案，为中国和其它热带地区提供参考，探索一条热带次生林可持续经营的道路。

1　区域概况

调查对象为古兜山系的古兜山林场和古斗林场，经营总面积14760.9hm^2，林地面积约占86%，区内建有广东省古兜山省级自然保护区，面积11567.5 hm^2。该林区位于北回归线以南，东经112°53'30"～113°03'25"，北纬22°05'00"～22°21'15"，在广东省中南部江门市辖下的台山市与新会区之间。林场是以林业为主要经营对象的生产单位，在具有中国特色的管理体制下，对占42%的国有林经营管理来说有较大意义。

该区属南亚热带海洋性气候，其特点是光照充足，热量丰富，降水充沛，空气湿润，有干湿季之分。据台山市台城镇和新会区会城镇气象资料，年均日照时数2082.65小时，日照百分率45.5%；年平均气温约21°C～22°C，1月平均气温10°C～13°C，极端最低气温-2°C，7月平均气温32°C～28°C，极端最高气温39.9°C；

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年降水量2250mm～1790mm，日最大降水量达254mm；4～9月为雨季，10～3月为旱季；多年平均相对温度77%。雨热同季，有利生物繁衍更迭。

2 森林资源与社会经济状况

2.1 森林资源

据1996年二类森林资源调查，森林覆盖率在80%以上。区域内林地面积约12990 hm^2，其中约有天然次生常绿阔叶林面积9482 hm^2，占73%；常绿针叶林面积2601 hm^2，占20%；常绿针阔叶混交林面积43hm^2，占0.3%。但是，和其它地区近似，在经历1958年及1973年的森林大破坏后，已导致大面积的季风常绿阔叶林遭受干扰和破坏，天然次生林几乎都以低质低产的状况存在。天然次生常绿阔叶林的活立木蓄积量不足13.6m^3/ hm^2，常绿针叶树7 m^3/ hm^2，常绿针阔叶树34 m^3/ hm^2。

2006年采用相邻格子样方法，在古斗林场的青石坑工区选定、设置了三个群落样地，均为人工针叶林砍伐后经封育形成的不同年龄次生林。其中1号样地位于中下坡，且靠近沟谷，封育10年；2号样地位于中坡，封育5年；3号样地位于上坡，邻近山脊，封育20年。对这三个不同演替阶段次生林样地进行每株调查，其物种构成和生长情况见表1、表2。

其结果可以看出如下两大特点：

1）林下植物和灌木层密度大，上层乔木数量少。封育5年的2号样地中乔木植株占16.64%，灌木占36.66%，蕨类、藤及草本占46.71%；封育10年，1号样地的乔木比例比2号样地略有增长，达到了24.88％，灌木提高到45.50％，林下植物减少到29.62%；而在立地条件一般的3号样地，虽然封育20年，乔木植株比例仅为0.53％，灌木2.16％，97.31％

表1 三种不同次生林样地乔、灌、草物种构成情况

样地号	封育时间(年)	乔木		灌木		蕨类、藤及草本		合计	
		物种数	总株数	物种数	总株数	物种数	总株数	物种数	总株数
2号	5	32	1631	53	3594	71	4579	156	9804
1号	10	62	3893	98	7118	112	4634	272	15645
3号	20	14	68	26	279	21	12559	61	12906

注：每个固定样地面积 50 m×66.67 m，对样地内植株进行每木调查，下同。

表2 三种不同次生林样地株高5m以上的乔木树种生长情况

样地号	封育时间(年)	物种数	总株数	平均树高(m)	平均胸径(cm)	树高最大值(m)	胸径最大值(cm)	木材蓄积(m3/ha)
2号	5	13	92	5.76	4.58	10.70	12.50	1.49
1号	10	25	229	5.66	5.49	18.00	16.00	5.13
3号	20	5	7	5.66	2.46	8.50	6.50	0.03

的植株为蕨类等林下植物，且物种数量较少。

2） 林地能形成主林层的植株少，生长慢，蓄积量低。三个样地乔木树种中达到5m以上形成主林层的植株比例很低，分别为5.64%、5.88%和10.29%；林分蓄积量分别为1.49 m^3/ hm^2、5.13 m^3/ hm^2和0.03 m^3/ hm^2。

在物种方面，由于原生物种丰富，在经历近三十年的封山育林后，仍然保存有较多的物种。据调查[1]，古兜山自然保护区拥有维管植物1161种，分隶607属、180科，分别占广东省维管植物7055种、1645属、280科的16.46%、36.90%和64.29%。其中蕨类植物81种，分隶50属、28科；裸子植物20种，分隶13属、8科；被子植物1060种，分隶544属、144 科(双子叶植物858种，分隶423属、122科；单子叶植物202种，分隶121属、22科)。依据《中国珍稀濒危保护植物名录》，保护区共有珍稀濒危保护植物14 种，占广东省珍稀濒危保护植物总种数的17.72%。

样地调查结果也显示，1号样地植物物种数量达到了272种，其中不乏经济价值高、开发潜力大的物种，如防癌抗癌类的药用植物深绿卷柏，可提炼樟油的油脂植物豺皮樟等。样地内主要植物资源的类型和数量见表3。

据分析统计[2]，古兜山自然保护区约有药用植物300多种，观赏植物130多种，材用植物42种，芳香植

物48种，纤维植物47种，油脂植物54种，因此，积极开发林下植物资源，应用科学的林下套种技术，大力发展非木质产品产业，是逐步提高次生林经济和生态效益的一个有效途径。

2.2 社会经济状况

2.2.1 社区人口 古兜山区及周边共有6个镇、1个农场和2个林场，有农户约7.5万户，总人口为27.5万人。其中，国营古兜山林场隶属台山市，林场职工39人，与台山市的水步、四九、冲蒌、斗山、都制等5镇及金星农场为邻，有农户约6万余户，总人口23万余人；国营古斗山林场隶属新会区，林场职工22人，与新会区的崖门镇相连，约有农户1.1万户，总人口4万余人。

表3　1号样地植物资源的主要类型及数量

类 型	种 名	总株数	类 型	种 名	总株数
药用植物	鼠刺(*Itea chinensis*)	503	观赏植物	大头茶(*Gordonia axillaris*)	669
	蔓九节(*Psychotria serpens*)	244		绣球茜(*Dunnia sinensis*)	73
	三叉苦(*Evodia lepta*)	101		吊钟花(*Enkianthus quinqueflorus*)	30
	深绿卷柏(*Selaginella doederleinii*)	27		五列木(*Pentaphylax euryoides*)	13
	毛果算盘子(*Glochidion eriocarpum*)	7		野牡丹(*Melastoma candidum*)	2
	白花悬钩子(*Rubus leucanthus*)	3	纤维植物	小叶买麻藤(*Gnetum parvifolium*)	161
	夜花藤(*Hypserpa nitida*)	1		黑莎草(*Gahnia tristis*)	101
	乌饭树(*Vaccinium bracteatum*)	4		木防已(*Cocculus orbiculatus*)	85
油脂植物	豺皮樟(*Litsea rotundifolia*)	724		了哥王(*Wikstroemia indica*)	5
	小叶买麻藤(*Gnetum parvifolium*)	161		白藤(*Clamus tetradactylus*)	4
	山乌桕 (*Sapium discolor*)	44	鞣料植物	桃金娘(*Rhodomyrtus tomentosa*)	731
	酸味子 (*Antidesmajaponicum*)	12		藤黄檀(Dalbergia hancei)	17
	野漆树(*Toxicodendron succedaneum*)	10		山油柑(*Acronychia pedunculata*)	12
	油茶(*Camellia oleifera*)	2		猴耳环(Pithecellobium clypearia)	1
芳香植物	栀子(*Gardenia jasminoides*)	361	材用植物	光叶山矾(Symplocos lancifolia)	242
	岗松(*Baeckea frutescens*)	99		杉木 (*Cunninghamia lanceolata*)	61
	香港鹰爪(*Artabotrys hongkongensis*)	22		密花树 (*Rapanea neriifolia*)	4
淀粉植物	菝葜(*Smilax china*)	97	果类植物	桃金娘(*Rhodomyrtus tomentosa*)	731
	土茯苓(*S. glabra*)	11		多花山竹子(*Garcinia multiflora*)	8

2.2.2 交通和通讯条件 古兜山区交通条件相对比较便利。外接广东西部沿海高速公路和新台高速公路，距江门市60km左右，台山市10km。内部交通以林区道路为主，有林区公路和林道通往各主要林区，但多因缺乏养路经费而难以通行。无线通讯可覆盖全区。

2.2.3 区域经济状况 林业是该地区区域经济的主要来源，收入主要包括：1）生态公益林补偿；2）木材砍伐；3）出租产业和农耕地； 4）绿化苗木；5）其它收入。因此，区域经济对林业开发利用的依赖程度较高。据古斗林场2003－2007年的资料统计：全场年均总收入为189 万元。其中省地政府生态公益林补偿面积3000ha，年补偿资金36万元，占19.05%；年木材砍伐2667 m^3，收入75万元，占39.68%；出租产业和农耕地收入35万元，占18.52 %；绿化苗木收入6万元，占3.17%；淡水养殖年收入15万元，占7.94%；水果种植年收入16万元，占8.47%；其它收入6万元，占3.17%；林区居民年人均收入3780元，而相邻的新会区崖门镇近五年来的农民人均收入水平约5250元，两者相差28 %。

3 分析与讨论

3.1 林区居民生活仍处于较低的水平，木材生产仍然是解决经济问题最有效的途径。

从林区的经济水平和居民收入看，其经济状况仅仅在维持生计的水平。政府对生态公益林的补贴，除护林开支外已很有限。而其它非林经营性收入，公共开支占了很大部分。因此，砍伐非生态公益林林地的林木，最大限度种植短轮伐期速生丰产林取得木材收益，是当前林区经营者解决经济问题，实现脱贫致富的重要手段和最大愿望。

3.2 林业经营方式仍然是“砍”和“种”两种传统的方法，缺乏次生林经营的现代理念和实用的经营技术。

在经营方式上，“砍”和“种”仍然是林区两种主要经营方式。一方面是经济原因，当地居民有限的收入一般只能维持生计，次生林普遍低质低产的状况让人们缺乏获取经营效益的信心。另一方面是经营理念和技术方法上的问题，缺乏成熟技术的组装和示范样板，林农缺乏次生林经营的现代理念的技术支持。“砍”使天然林面积越来越小，物种不断散失；“种”使人工林面积越来越大，物种单一。此外，人工商品林种植的频繁耕作和病虫害治理等人为活动，很大程度上带来了水土流失和环境污染等问题。

3.3 次生林经营是林业经营中最具潜力的战略工程，林农是最主要的经营者，政府的角色是服务和支持。

占林地面积73%的次生林，由于林分退化，生长慢，使这一巨大的林地资源既缺乏经济，其生态效益也不高。这类林地常年积累枯枝落叶而有机质含量高，蕴藏着巨大的生产潜力。通过引入非木质产品物种和珍贵树种，既能在短期内不断取得林果、树脂、森林食品、中药材等非木质产品的收入，还能在未来通过合理采伐珍贵树种获取高值的回报。

但是，充分实现森林经营的生态和经济效益，需要依靠林农自身的力量和经营热情，避免长期依赖政府财政植树造林和林分改造的单一思维。针对这一问题，已有专家提出了按照“激励相容”原理来启动热带次生林的可持续经营[3]。政府对林业支持的重点应放在服务方面，包括制定稳定有效的政策、技术支持等，以扶持的方式给予林业财政补贴，切实有效的推动次生林的合理开发和利用。

4 结论

通过对古兜山林区森林资源和社区经济的调查，可以得出下列一般性结论：

4.1 热带地区水热资源丰富，次生林面积大，物种丰富，有很大的经营潜力。

4.2 现有次生林物质生产力低，林分质量差，木材产出少，主要采用“封山育林”的经营措施，缺乏经济和生态效益。

4.3 在调查林区，林农的经济仍然比较贫困，居民的生活水平尚在维持生计的状态，这在一定程度上也代表了中国大部分热带林区的居民生活状态。

4.4 林业的经营方式仍然停留在“砍”与“种”的传统阶段，迫切需要推广、应用生态和经济效益相结合的次生林现代经营理念和实用的经营配套技术，以缓解次生林保护面临的巨大压力，实现可持续发展。

参 考 文 献

[1] 张金泉．建立古兜山省级自然保护区的可行性研究[J]．生态科学，2000，19(4)：73－83．
[2] 刘浩，阮作庆，徐颂军等．广东古兜山自然保护区资源植物的现状及其保护[J]．华南师范大学学报（自然科学版），2006，(4)：106－112．
[3] 侯元兆．按照“激励相容”原理启动热带次生林和退化林地的可持续经营[J]．世界林业研究，2004，17(6)：25－29．

热带次生林经营引入物种选择研究

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Study on the Species Selection Introduced to the Management of Tropical Secondary Forests

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Abstract Supported by International Tropical Timber Organization (ITTO), the project entitled“The Study and Demonstration of the Management of Secondary Forests in Tropical Regions for the Purpose of Enhancing Economic and Ecological Benefits” was implemented in Xinhui Guangdong and Tongzha Hainan by Guangdong Academy of Forestry . The project aimed at sustainable forest management by introducing elite species into the tropical secondary forests which has been disturbed seriously, so as to enrich the species of the forests and increase economic benefit for the residents in forest community from the non-timber forest products. Protection and promotion of TSF would be realized. In the Xinhui demonstration district for management of tropical secondary forest, 91 species had been introduced, among them, 68 species amounting for 75%, are native species; 13 exotic species amounting for 14%; 10 NTFP species amounting for 11%. In addition, the species selection principle, method and management effect were summarized.

Key words Secondary forest Tropical Species selection Introduction

摘要 在国际热带木材组织（ITTO）的资助下，广东省林业科学研究院在广东新会和海南通什开展了“旨在提高生态和经济效益的热带地区次生林经营研究与示范”。其目的是通过在干扰破坏较严重的次生林中引入具有较好生态和经济效益的优良物种，使林分物种增加，林区居民能从经营中取得非木质产品的经济收益，达到保护和促进次生林的生长发育的目的，实现森林可持续经营的目标。本文广东新会热带次生林经营研究与示范区活动中，通过91个引入物种的试验研究，其中区域缺失和退化的乡土树种68中，占75%；外来树种13种，占14%；非木质产品物种10种，占11%。总结了低质低效次生林经营中物种选择的原则、方法和经营效果。

关键词 次生林 热带 树种选择 物种引入

热带次生林，特别是受到重度干扰后形成的次生林，所占比例很大，尤其在发展中国家。在经济比较落后的地区，由于林区居民生存对经济需求，次生林不但得不到合理的经营，而是继续不断遭到破坏，物种越来越单一，林地退化。即使在经济比较发达的地区，林分虽然受到保护，但仍然缺乏必要的经营活动，生态和经济效益很难提高。这种低质次生林要靠自然生长进入群落状态，恐怕需要一个相当长的时期，也许是百年以后的事。中国广东在上世纪50年代有一个次生林人工促进经营的试验，结果是在50年左右的时间里林分就进入了演替的较高级阶段，比未经经营的林分缩短了一半以上的时间。次生林的经营，不但可以加速生态环境的改善，又可产生经济效益，对广大的农村非常重要，是一个重大课题，应当尽早

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推进。正如 Eva Muller 博士对次生林问题的认识，“在很多热带国家，决策者和林业界在很多情况下都忽视了次生林问题，缺乏对热带次生林资源的数量的认识，对其现实及潜在经济价值的认识，以及其适用的经营选择等方面的信息。这种知识的贫乏，又导致了次生林在林业政策中的边缘化，极少的财政投入，并妨碍着研究、培训和推广计划的发展”。次生林经营成败的一个关键是引入物种的选择。只有选择合适的物种，才能使其发挥最好经营效益。只有生态和经济效益的兼顾，才能使经营者有经营积极性。

1 材料与方法

1.1 经营区概况

经营区位于新会古斗林场，东经 112° 53′30，北纬 22° 15′ 00″ 。属于罗浮山系余脉，南亚热带海洋性气候。地带性植破为季风常绿阔叶林。群落特征是:优势种不显著,上层乔木以壳斗科和梅科中的一些喜暖的种类为主,还有桃金 娘科、楝科、桑科的一些种类,中、下层则有较多的热带成分,如茜草科、紫金牛科、棕榈 科、杜英科、苏木科和蝶形花科等:群落外貌终年常绿,但与热带雨林不同之处是仍有比较显著的季相变化,附生植物也较丰富。该区的植被除具有明显的水平地带性—季风常绿阔叶林地带性特征外,在不同海拔高度的植被类型也不相同,具有较明显的垂直分布规律。由低至高为沟谷雨林(海拔 400m 以下)→低山丘陵季风常绿阔叶林(海拔 650m以下)→中山山地季风常绿阔叶林(海拔 650～850m→山顶山脊常绿阔叶灌草丛（海拔 650、800 或 900m以上[1]。

试验示范区植物群落类型为马尾松林砍伐迹地封育 20 年所形成的次生林。通过设立 3 个样方调查，一个面积为 10 000 m^2的引种样方和两个面积为 2000 m^2的对照样方，以相邻位置设置，两个对照样方分别位于上坡和下坡。群落高度 7.5~13 m，平均 10.3 m。群落分层很明显，除在山脊和山顶草本层或灌木层覆盖度较大外，其它地方的乔木层分布位置较高、密度较大，灌木层较茂盛，而草本层则变得很稀疏。

1.2 物种选择

1.2.1 物种选择原则

热带次生林之所以不断遭受干扰和破坏，林区居民不愿去经营，重要的原因有两个方面：一是农村缺乏经济来源，砍伐林木成为农民获取经济，解决当前生存问题的重要手段；二是林业经营周期长，缺乏经济实用、能在较短的时间内取得经济效益的经营技术、方法和种苗。本项目设计的思想基础是生态与经济效益的结合，把提高经济效益作为实现次生林保护、促进和发展的一个十分重要的前提条件来考虑。因为，农民只有解决了生计问题才能和你谈论诸如森林保护和生态等，这是一个十分现实的问题。只有生态效益与经济效益的结合，才能使次生林得到保护、促进和发展，才能步入可持续发展的道路。为此，本项目的战略遵循了这一原则，即在次生林经营中首先通过非木质产品物种的引入让林区居

民在短期内取得必要的经济来源，从而有条件开展对次生林保护和改良，提高其生态和经济效益，实现可持续经营的目的。

因此，物种选择的原则，在战略上遵循了国际热带木材组织《ITTO 热带次生林重建恢复培育经营指南》及与之相关的原则与建议行动。

生态和经济效益结合的原则---- 在生态优先的条件下，选择当地具有优势和地方特色，又能适合次生林林分环境生长的非木质产品物种，如花、果、林下植物等森林食品、药材，以及油、脂等日用工业原材料，使林农能通过经营不断获取经济收益的物种。

乡土树种为主导的原则---- 坚持以地带性乡土树种为主，确保生态安全和健康森林生态系统的形成。

适地适树原则---- 不同地区，不同干扰程度，不同阶段的次生林，其林分环境千差万别，引入物种的选择必须充分符合其生境需求，做到阴阳相合。

生物多样性原则---- 模拟当地物种群落的组成，引入尽可能多的物种，以提高生物多样性。此外，也可以适当引入外来优良物种，优化森林环境和提高经营效益。

1.2.2 树种和种源选择

根据物种引入原则和引入区的植被状况，本研究选择了缺失或退化的地带性乡土乔木树种、外来阔叶乔木树种和非木质产品物种三大类型的物种。其中乡土树种 68 种，占 75%；外来树种 13 种，占 14%；非木质产品物种 10 种，占 11%。在树种的环境适应性方面，耐阴树种占 7.4%，阳性树种占 76.5%，中性树种占 16.2%。引入物种见下表 1：

表 1　广东新会热带次生林经营引入树种名录

序号 No.	树　　种 Name of Species		科/属 Family/Genus	特性 Characteristics
A.　乡土树种 Native Species				
1	肖蒲桃	*Acmena acuminatissima*	*Myrtaceae*	喜湿但不耐荫，需要有足够的光照
2	顶果木	*Acrocarpus fraxinifolius*	*Caesalpiniaceae*	阳性
3	降真香	*Acronychia pedunculata*	*Rutaceae*	喜光，耐干旱瘠薄
4	海红豆	*Adenanthera paeonina*	*Mimosaceae*	幼苗较耐荫，壮龄后则喜阳光
5	石栗	*Aleurites moluccana*	*Euphorbiaceae*	喜光，喜高温多湿气候
6	大花五桠果	*Alstonia scholaris*	*Dilleniaceae*	耐荫树种
7	大叶山楝	*Aphanamixis grandifolia*	*Meliaceae*	喜阳，喜湿，但不耐积水，耐旱耐脊薄
8	树菠椤	*Artocarpus heterophyllus Lam.*	*Moraceae*	最喜光树种，幼苗和幼树稍耐荫
9	红桂木	*Artocarpus nitidus*	*Moraceae*	喜光、喜温湿及肥沃疏松的土壤
10	羊蹄甲	*Bauhinia purpurea*	*Caesalpiniaceae*	为阳性植物
11	秋枫	*Bischofia javanica*	*Euphorbiaceae*	为喜光树种

（续上表）

序号 No.	树　种 Name of Species		科/属 Family/Genus	特性 Characteristics
12	构树	*Broussonetia papyrifera*	*Moraceae*	喜光，幼树稍耐阴
13	雄黄豆	*Cassia javanica*	*Caesalpiniaceae*	属热带阳性树种
14	黄槐	*Cassia surattensis*	*Caesalpiniaceae*	中性偏阳，幼树能耐阴，成年树喜充分阳光
15	黧蒴	*Castanopsis fissa*	*Fagaceae*	喜光，但幼龄耐荫
16	红锥	*Castanopsis hystrisc*	*Fagaceae*	红椎具有较耐荫、萌生力强和速生的特
17	海芒果	*Cerbera manghas*	*Apocynaceae*	耐荫
18	麻楝	*Chukrasia tabularis*	*Meliaceae*	为喜光树种，幼年耐荫
19	阴香	*Cinnamomum burmanii*	*Lauraceae*	喜光，喜温暖湿润气候
20	樟树	*Cinnamomum camphora*	*Lauraceae*	幼年较耐荫，2～3 年后需光量增加，壮年需强光
21	蝴蝶果	*Cleidiocarpon cavaleriei*	*Euphorbiaceae*	喜光树种
22	鱼木	*Crateva formosensis*	*Capparaceae*	喜充分光照，喜温暖湿润气候
23	降香黄檀	*Daibergia odorifera*	*Papilionaceae*	为喜光树种
24	猫尾木	*Dolichandrone caudafelina*	*Bignoniaceae*	为偏喜光树种
25	人面子	*Dracontomelon duperreanum*	*Anacardiaceae*	喜光，喜温热湿润气候
26	尖叶杜英	*Elaeocarpus apiculatus*	*Elaeocarpaceae*	喜光，幼龄稍耐阴
27	中华杜英	*Elaeocarpus Chinesis*	*Elaeocarpaceae*	性喜阳光，也较耐阴
28	杜英	*Elaeocarpus decipiens Hemsl.*	*Elaeocarpaceae*	性喜阳光，也较耐阴
29	水石榕	*Elaeocarpus hainanensis Oliver*	*Elaeocarpaceae*	喜温暖湿润，稍耐阴
30	山杜英	*Elaeocarpus sylvestris*	*Elaeocarpaceae*	稍耐荫
31	格木	*Erythrophleum fordii*	*Caesalpiniaceae*	为喜光树种
32	菩提榕	*Ficus religiosa*	*Moraceae*	喜光，喜温暖湿润气候
33	岭南山竹子	*Garcinia oblongifolia*	*Guttiferae*	喜光，幼龄稍耐荫
34	银桦	*Grevillea robusta*	*Proteaceae*	喜光树种
35	银叶板根	*Heritiera littoralis*	*Sterculiaceae*	喜光
36	幌伞枫	Heteropanax fragrans (Roxb.) Seem.	*Araliaceae*	喜光 喜高温多湿气候，亦耐荫
37	坡垒	*Hopea hainanensis*	*Dipterocarpaceae*	幼苗期耐荫，随苗龄增长而需光程度逐渐增加
38	塞楝	*Khaya senegalensis*	*Meliaceae*	喜光树种
39	红花荷	*Khodoleia championii Hook*	*Hamamelidaceae*	为喜光树种
40	吊瓜	*Kigelia africana*	*Bignoniaceae*	喜光，喜温暖湿润气候
41	复羽叶栾树	*Koelreuteria bipinnata Franch*	*Sapindaceae*	喜光，喜温暖至高温湿润气候
42	大叶紫薇	*Lagerstroemia speciosa*	*Lythraceae*	喜光，能耐半阴，喜高温高热气候
43	枫香	*Liquidambar formosana*	*Hamamelidaceae*	喜光
44	山玉兰	*Magnolia delavayi Franch.*	*Magnoliaceae*	喜光

（续上表）

序号 No.	树种 Name of Species		科/属 Family/Genus	特性 Characteristics
45	白玉兰	*Magnolia heptapeta*	*Magnoliaceae*	阳性树，稍耐阴
46	芒果	*Mangifera indica*	*Anacardiaceae*	喜光树种
47	扁桃	*Mangifera persiciformis*	*Anacardiaceae*	幼年生长缓慢，稍耐庇荫，不喜强光直射，成年树喜光
48	灰木莲	*Mangleitia glauca*	*Magnoliaceae*	幼龄期稍耐荫，中龄后偏阳
49	黄兰	*Michelia champaca* Linn.	*Magnoliaceae*	喜光，喜温暖至高温湿润气候
50	乐昌含笑	*Michelia chapensis* Dandy	*Magnoliaceae*	喜光，喜温暖湿润气候
51	火力楠	*Michelia macclurei*	*Magnoliaceae*	幼年稍耐荫，成林后喜光，属中性偏阳树种
52	深山含笑	*Michelia maudiae*	*Magnoliaceae*	幼树稍耐阴，随林龄增大而更需光
53	峨嵋含笑	*Michelia wilsomii*	*Magnoliaceae*	喜光，稍耐阴，抗寒性较强，喜酸，稍耐微碱
54	米老排	*Mytilaria laosensis*	*Hamamelidaceae*	较喜光，幼苗耐荫
55	海南红豆	*Ormosia pinnata*	*Papilionaceae*	喜光树种，小苗、幼树耐荫，壮龄以后则喜阳光
56	乐东拟单性木兰	*Parakmeria lotungensis*	*Magnoliaceae*	较喜光树种
57	亮叶猴耳环	*Pithecellobium lucidum Benth.*	*Mimosaceae*	中性偏阳树种
58	竹柏	*Podocarpus nagi*	*Podocarpaceae*	耐荫树种
59	翻白叶	*Pterospermum heterophyllum*	*Sterculiaceae*	生性喜光，不耐荫
60	海南菜豆树	*Radermachera hainanensis*	*Bignoniaceae*	喜光树种
61	无忧树	*Saraca chinensis*	*Caesalpiniaceae*	属偏阳性树种，喜充足阳光
62	荷木	*Schima superba*	*Theaceae*	幼年时能耐荫，大树则喜光
63	五味子	*Schisandra chinensis*	*Schisandraceae*	喜光的植物
64	海南蒲桃	*Syzygium hainanense*	*Myrtaceae*	喜光
65	大叶榄仁	*Terminalia catappa*	*Combretaceae*	热带海滩树种，喜光，深根性，耐旱，抗风力强
66	莫氏榄仁	*Terminalia muelleri*	*Combretaceae*	喜光充分,排水良好,耐风,耐盐
67	观光木	*Tsoongiodendron odorum Chun*	*Magnoliaceae*	幼树忌强光，成年树喜光，稍耐荫
68	青梅	*Vatica mangachapoi Blanco*	*Dipterocarpaceae*	深根性喜光树种
B. 外引树种 Exotic Species				
1	盆架子	*Alstonia rostrata*	*Apocynaceae*	原产澳大利亚等地 喜阳、喜温暖、湿润气候
2	玉蕊	*Barringtonia racemosa*	*Lecythidaceae*	非洲等地，喜光
3	大果决明	*Cassia fruticosa*	*Caesalpiniaceae*	美洲等热带地区，喜光
4	具翼龙脑香	*Dipterocarpus alatus*	*Dipterocarpaceae*	东南亚，阳性树种
5	福木	*Garcinia subelliptica*	*Guttiferae*	原产澳大利亚等地 喜阳、喜温暖、湿润气候

（续上表）

序号 No.	树种 Name of Species		科/属 Family/Genus	特性 Characteristics
6	香坡垒	*Hopoa odorata*	*Dipterocarpaceae*	泰国、越南等地　　，中性偏荫
7	虎拉	*Hura polyandra*	*Euphorbiaceae*	美洲等热带地区，阳性树种
8	蓝花楹	*Jacaranda mimosifolia*	*Bignoniaceae*	拉丁美洲等地，喜温暖湿润、阳光充足的环境，阴性树种
9	钝叶娑椤双	*Shorea obtusa*	*Dipterocarpaceae*	泰国、越南，喜光
10	泰国娑椤双	*Shorea siamensis*	*Dipterocarpaceae*	泰国、越南，喜光
11	火焰木	*Spathodea campanulata*	*Bignoniaceae*	原产非洲和美洲，喜光、耐旱
12	风玲木	*Tabebuia chrysantha*	*Bignoniaceae*	原拉丁美洲阳性植物，需强光，
13	小叶榄仁	*Terminalia mantly*	*Combretaceae*	马达加斯加，喜光，喜高温干湿气候
C. 非木质产品物种 Non-timber Product Species				
1	高脂松	*Pinus massoniana* Lamb.	*Pinaceae*	采割松脂
2	油茶	*Camellia olelfera* Abel	*Theaceae*	果提取食用茶油
3	枇杷	*Eriobotrya japonica*	*Rosaceae*	水果或叶作药用
4	阳桃	*Averrhoa carambola L.*	*Oxalidaceae*	水果
5	番石榴	*Psidium guajava Linn.*	*Myrtaceae*	水果
6	芒果	*Mangifera indica Linn.*	*Anacardiaceae*	水果
7	树菠椤	*Artocarpus heterophyllus Lam.*	*Moraceae*	水果
8	黄皮	*Clausena lansium (Lour.) Skeels*	*Rutaceae*	水果
9	青枣	*Zizyphus mauritians Lan*	*Rhamnaceae*	水果
10	板栗	*Castanea mollissima*	*Fagaceae*	水果
11	苹果梨	嫁接杂种	——	水果
12	黄甜竹	*Acidosasa edulis*	*Gramineae*	采收食用笋
13	方竹	*Chimonobambusa quadrangularis*	*Gramineae*	采收食用笋
14	白藤	*Calamus tetradactylus*	*Palmae*	采收藤条
15	黄藤	*Daemonorops margaritae*	*Palmae*	采收藤条
16	砂仁	*Amomum villosum*	*Zingiberaceae*	果作药用
17	山银花	*Lonicara confusa*	*Caprifoliaceae*	药用
18	扶方藤	*Euonymus fortunei*	*Celastraceae*	药用
19	鸡血藤	*Spatholobus suberectus*	*Leguminosae*	药用
20	山苍子	*Litsea cubeba*	*Lauraceae*	药用

注：油茶是 2008 年春补植，山苍子为由次生林内抚育管理经营物种

在种源选择方面，要求引入物种为经选择的优质资源（种源或单株的繁殖材料）。乡土树种种质资源丰富，主要在天然林中选择。同时，受选树种在林分组成上占所占比例越大

越好，以有利于同种间生长和形态差异上的比较。非木质产品物种主要考虑要有地方优势和特色，有较高的经济价值，且经选育或改良的品种，以满足市场对品质的需求，易以储藏和加工利用。外引物种要有较大发展前景、生态和经济价值高，并经区试确认是当地适合的品系。同时，能与当地的物种形成共生的关系，没有检疫受限的病虫害。

2 结果与分析

2.1 乡土树种与外引树种保存率与生长分析

试验示范表明，遵循本上述次生林经营引入物种的选择原则和方法，大部分引入物种能在次生林环境中正常生长，树种的保存率与生长情况见表 2.

表 2 广东新会热带次生林经营引入树种生长情况统计表

树种	保存率（%）	平均树高（cm）	平均地径（cm）	年均高生长（cm）	年均粗生长（cm）	树高最大值（cm）	地径最大值（cm）
格木	60.0	40.4	0.8	34.6	0.7	60.0	1.1
福木	80.0	43.2	0.9	37.0	0.8	70.0	2.6
岭南山竹子	66.7	59.7	1.0	51.1	0.9	80.0	2.5
羊蹄甲	20.0	63.3	1.1	54.3	0.9	80.0	1.3
顶果木	60.0	72.0	1.1	61.7	0.9	140.0	1.8
银叶板根	60.0	72.0	1.2	61.7	1.0	160.0	2.5
虎拉	73.3	75.0	2.3	64.3	1.9	110.0	3.6
竹柏	80.0	82.7	1.4	70.9	1.2	120.0	2.0
降真香	60.0	84.4	1.0	72.4	0.8	125.0	1.6
复羽叶栾树	33.3	86.7	1.3	74.3	1.1	120.0	1.6
观光木	46.7	97.0	1.3	83.1	1.1	150.0	1.7
海南红豆	6.7	97.1	1.6	83.3	1.3	140.0	2.5
枫香	80.0	97.3	1.3	83.4	1.1	150.0	2.3
乐昌含笑	86.7	97.7	1.5	83.7	1.3	170.0	3.0
坡垒	20.0	102.5	1.2	87.9	1.1	150.0	2.2
水石榕	73.3	104.7	2.0	89.7	1.7	160.0	3.4
青梅	33.3	107.0	1.3	91.7	1.1	280.0	3.5
杜英	53.3	107.3	2.0	92.0	1.7	160.0	3.2
山玉兰	66.7	107.3	1.9	92.0	1.6	200.0	4.2
玉蕊	60.0	107.7	2.0	92.3	1.7	150.0	3.5
风铃木	66.7	109.1	1.6	93.5	1.3	230.0	2.9
白玉兰	80.0	111.0	1.4	95.1	1.2	200.0	2.6
雄黄豆	50.0	112.2	1.4	96.2	1.2	170.0	2.0
荷木	93.3	114.7	1.5	98.3	1.3	160.0	2.3
黄兰	100.0	115.7	1.6	99.2	1.3	200.0	2.0
塞楝	53.3	120.3	2.3	103.1	2.0	220.0	4.8
无忧树	80.0	122.0	1.5	104.6	1.3	280.0	2.4
火力楠	60.0	125.0	1.1	107.1	0.9	180.0	1.8

（续上表）

树种	保存率（%）	平均树高（cm）	平均地径（cm）	年均高生长（cm）	年均粗生长（cm）	树高最大值（cm）	地径最大值（cm）
亮叶猴耳环	46.7	125.0	1.4	107.1	1.2	150.0	1.9
深山含笑	93.3	127.3	1.6	109.1	1.4	200.0	3.0
大叶榄仁	66.7	133.3	2.2	114.3	1.9	170.0	2.4
乐东拟单性木兰	60.0	133.5	1.7	114.4	1.5	210.0	3.2
泰国娑椤双	60.0	133.5	1.7	114.4	1.5	210.0	3.2
吊瓜	40.0	134.7	1.8	115.4	1.5	200.0	3.0
树菠椤	46.7	134.7	1.5	115.4	1.3	240.0	3.1
峨嵋含笑	80.0	136.0	1.2	116.6	1.1	180.0	1.7
大花五桠果	73.3	137.3	1.6	117.7	1.4	230.0	2.7
蝴蝶果	60.0	137.3	2.1	117.7	1.8	200.0	3.8
五味子	86.7	137.3	2.1	117.7	1.8	240.0	3.4
肖蒲桃	73.3	137.3	1.6	117.7	1.4	260.0	3.0
秋枫	53.3	137.7	3.1	118.0	2.7	200.0	6.2
人面子	66.7	139.3	2.1	119.4	1.8	190.0	3.5
黄槐	100.0	140.0	1.6	120.0	1.4	140.0	1.6
扁桃	100.0	141.7	1.7	121.4	1.5	220.0	2.3
芒果	56.7	143.3	1.9	122.9	1.6	200.0	3.5
鱼木	66.7	143.6	2.0	123.1	1.7	200.0	4.1
阴香	93.3	143.7	2.1	123.1	1.8	220.0	4.5
樟树	53.3	146.0	2.1	125.1	1.8	210.0	4.3
海芒果	46.7	148.7	3.1	127.4	2.7	210.0	6.0
凤凰木	53.3	149.3	2.7	128.0	2.3	250.0	4.1
蓝花楹	53.3	149.3	2.7	128.0	2.3	250.0	4.1
大叶紫薇	53.3	153.3	2.5	131.4	2.1	230.0	3.7
大果决明	53.3	153.3	2.5	131.4	2.1	230.0	3.7
小叶榄仁	73.3	158.0	2.0	135.4	1.7	280.0	3.9
红锥	60.0	160.8	2.1	137.9	1.8	280.0	3.8
构树	80.0	169.3	2.2	145.1	1.9	310.0	5.2
麻楝	93.3	169.3	2.1	145.1	1.8	220.0	3.0
红花荷	46.7	170.3	1.7	146.0	1.5	210.0	4.4
盆架子	60.0	173.3	4.0	148.6	3.4	280.0	6.5
海红豆	80.0	182.0	2.1	156.0	1.8	310.0	3.4
猫尾木	66.7	184.0	2.6	157.7	2.2	320.0	5.0
红桂木	73.3	186.0	1.9	159.4	1.6	240.0	3.8
灰木莲	60.0	186.0	3.1	159.4	2.7	270.0	5.1
降香黄檀	46.7	193.3	2.6	165.7	2.2	260.0	4.8
香坡垒	93.3	194.7	2.3	166.9	2.0	270.0	3.2
山杜英	80.0	197.3	3.2	169.1	2.7	280.0	5.0
具翼龙脑香	80.0	197.3	3.2	169.1	2.7	280.0	5.0
石栗	73.3	198.7	3.4	170.3	2.9	300.0	5.9

（续上表）

树种	保存率（%）	平均树高（cm）	平均地径（cm）	年均高生长（cm）	年均粗生长（cm）	树高最大值（cm）	地径最大值（cm）
菩提容	80.0	203.0	3.5	174.0	3.0	300.0	5.4
中华杜英	86.7	204.7	2.9	175.4	2.5	340.0	5.0
莫氏榄仁	80.0	207.3	2.6	177.7	2.3	270.0	4.0
海南菜豆树	33.3	209.3	3.1	179.4	2.7	310.0	4.4
海南蒲桃	46.7	209.3	3.0	179.4	2.5	300.0	5.2
尖叶杜英	93.3	210.0	2.5	180.0	2.2	300.0	3.6
幌伞枫	86.7	215.3	4.6	184.6	3.9	280.0	8.0
大叶山楝	66.7	216.0	2.7	185.1	2.3	310.0	4.3
钝叶娑椤双	80.0	223.3	1.8	191.4	1.6	270.0	2.2
米老排	100.0	227.0	2.6	194.6	2.3	280.0	3.7
藜蒴	73.3	235.3	3.7	201.7	3.2	340.0	6.8
火焰木	33.3	240.7	4.7	206.3	4.0	320.0	8.2
银桦	46.7	246.0	3.7	210.9	3.1	350.0	5.6

由表2可知，81个树种中保存率在80%以上的有27个，其中扁桃、黄槐、黄兰与米老排保存率为100%，保存率在90%以上的有荷木、尖叶杜英、麻楝、深山含笑、阴香及香坡垒。只有11个树种保存率低于50%，说明大部分树种均适应于当地的环境与气候。

从生长量角度来看，平均高生长达到2.0m以上的树种有13个，最高的是银桦，达2.46m，其次是火焰木、藜蒴、米老排、钝叶娑罗双、幌伞枫、尖叶杜英、少南蒲桃、海南菜豆树、莫氏榄仁、中华杜英、菩提榕。平均高生长在1.5-2.0之间的树种有石栗、山杜英、具翼龙脑香、香坡垒、降香黄檀、红桂木、灰木莲、猫尾木、海红豆、盆架子等17个树种。生长较慢且平均高在0.5m以下的树种有3个，分别是岭南山竹子、福木和格木。从粗生长来看生长最好且平均地径达3.0cm以上的有树种14个，分别是火焰木、幌伞枫、盆架子、藜蒴、银桦、菩提榕、石粟、山杜英、具翼龙脑香、海芒果、秋枫、海南菜豆树、灰木莲和海南蒲桃，火焰木最粗达4.7cm。

2.2 非木质产品物种生长情况与经济效益预估

2.2.1 经济树种类

此类包括高脂马尾松、油茶、黄甜竹、方竹。高脂马尾松主要是用于割取松脂，目前保存率达100%，平均高生长达131.20cm，平均地径达2.03cm，最高树高达230.0cm，最粗地径达3.1cm，估计8-10年后可以开始采割松脂。油茶是2008年春补植，目前平均高达43.3cm，平均地径达0.43cm，预估3-5年后可以采摘油茶果。黄甜竹和方竹是笋用竹，竹笋供食用，两种竹已出新竹，周围出现2-5株新竹，预估2年后可以采笋。

2.2.2 果用植物类

果用植物种植了杨桃、番石榴、芒果、树菠椤、黄皮、青枣、板栗和苹果梨等8种植物。2008年7月调查显示板栗已有少量植株开始挂果，而芒果也有少量植株开花。其他生

长正常，暂未见开花结果。预估 3-5 年后有少量水量供应。

2.2.3 药用植物类

药用植物有砂仁、山银花、扶芳藤、鸡血藤、山苍子、黄栀子、枇杷 7 个物种。七个物种长势良好，生长旺盛。砂仁开始大量出现分蘖，多的达 24 个分蘖，但尚未结果；山苍子则有少量植株大量结果，据估平均每株可采 5-10kg 果实，如按单价 3 元/kg 计算，每株可采 15-30 元。鸡血藤开始出现缠树藤茎，据测量最长的已达 13m 以上。

2.2.4 藤用植物类

此类作物种植白藤与黄藤，2 种棕榈藤均生长正常，在长高的同时，少量出现新的分蘖。预估 6 年后可以采收藤条。

3 结论与讨论

a) 次生林经营中，适地适树是物种引入的关键。本示范根据林分的状况、郁闭程度，在不同区域选择适合物种生长特性的品种种植，成活率 %，树高当年生长量达到 m，是一个成功的范例。

b) 适度引入外来优良物种，能提高物种多样性、景观和经营价值。在引入的外来物种中，泰国和越南引入的龙脑香科树种香坡垒、印钝叶娑罗双，生长非常良好。不但丰富的当地物种，其景观和珍贵的材质都具有很大的优越性。

c) 非木质产品物种应强调持续的产出，适应性强和产品的市场潜力才能使林区居民有经营的积极性。林农，无论何种活动，经济是第一要素。因为，在大部分农村，满足生存仍然是面临的重要问题。只有持续、稳定的经济产出，才能使林农有自觉的经营行为。

d) 总结以往次生林缺乏经营的经营，缺乏示范和技术传播是十分主要的原因。政府和林业部门应当看到次生林经营的潜力和社会价值，重视次生林经营，重视总结、推动、建立示范和技术传播工作。

参考文献

(1) 张金泉、徐颂军、黄少敏，等. 广东古兜山省级自然保护区总体规划. 广州. 2002:8-9.

中国热带地区次生林经营现状和技术*

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Current Management Status and Techniques of Secondary Forests in Tropical Regions of China

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Abstract This paper summarized management policy, present management status and management technique of tropical secondary forests in China through analyzing the data regarding tropical secondary forest management in tropical secondary forests of China and field survey of key tropical secondary forest regions in Guangdong, Hainan, Guangxi and Yunnan or typical managements. Tropical secondary forest management of China was proposed initially after the People's Republic of China established soon in 1951, but the purpose was wood use with main management method of closing hillsides to facilitate afforestation from 50's to middle of 80's in 20 centuries. Up to late of 80's, large-scale management activity from timber production converting to ecological silviculture began in relative economical prosperous regions, such as Guangdong, and the construction scale of natural protect district enlarged. After serious flood and waterlogging took place in 1998, the central government enhanced ecological environment construction with forestry theme, tropical secondary forests began to get protection, and ecological construction was characterized by main management method of eco-public-benefit forest and natural protection project in this stage. Except for closing hillsides to facilitate afforestation, management technique was stressed on return cultivated land for forest, increasing species biodiversity and exploiting local trees of regions. However, tropical secondary forest management of China could not always break away from both extremes of timber make use or ecological protection, lacking sustainable management technique and practice for increasing ecological effect as well as economic effect satisfying demands of resident existence.

Key words secondary forests, management status, management techniques

摘要 文章分析了中国热带地区次生林经营相关资料,在对广东、海南、广西和云南重点热带次生林林区或典型经营区进行实地调查的基础上,分析和总结了中国热带次生林经营管理政策、经营现状和经营技术。中国的热带次生林经营在中华人民共和国成立后不久的1951年开始提出,但在20世纪50至80年代中期,主要以利用为目的,经营方式以封山育林为主。到了80年代后期,经济相对发达的地区如广东开始从木材生产为主向生态营林方向转化的大规模经营活动,自然保护区建设规模加大。1998年发生严重的洪涝之后,中央政府加强了以林业为主题的生态环境建设,热带次生林开始得到有效的保护,这一阶段的经营特点是生态建设,经营方式以政府主导的生态公益林、天然林保护等工程建设为主。经营技术除封山育林外,强调了退耕还林、提高物种的多样性和地带性乡土树种的开发利用。但是,中国的热带次生林经营始终未能走出木材利用或是生态防护的两个极端,缺乏既提高生态效益又提高经济效益、能满足生态和林区居民生存经济需求的可持续经营技术和实践。

关键词 次生林 经营现状 经营技术
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研究中国热带次生林经营现状和技术，目的是分析和总结次生林的经验，研究既能提高生态效益又能提高经济效益的可持续经营模式。中国的次生林经营，早期的重点是木材利用，而到了上世纪的80年代后期则偏重生态效益[1]。1993年ITTO PD 14/92资助开展了“中国海南岛热带森林分类经营永续利用示范项目”，取得了不少森林分类经营方面的研究成果[2]。但在次生林经营中，如何能在提高生态效益的同时提高经济效益，既实现对次生林的保护、促进和提高，又能取得林区居民生存需求的经济产出和物质需求，目前仍然缺乏研究和实践。本研究的目的，也就试图通过对中国次生林经营现状技术的分析和总结，研究能有效提高生态和经济效益的中国热带次生林经营模式，通过示范加以改良和推广，解决长期以来次生林资源不断衰退、农村经济落后的状况，满足社会各方面不断增加的需求。

1 中国热带次生林区的特点

中国的热带次生林区，除了气候、地貌上的独特性之外，还有如下几个特点[3,4]：

(1)大多存在于冲积平原、台地、低丘和沿海岛屿，人口比较密集的地区。热带次生林主要分布在广大的农村，经济普遍比较落后，破坏也最为严重，大部分缺乏生态和经济效益。农民一方面缺乏经营的经济基础，另一方面又缺乏经营技术经验。而在经济相对较发达的城市及其周边地区，由于近年来人们开始重视环境保护和利用，大部分划作城市森林加以环境保护或作为景观森林来经营；

(2)林木和林地权属比较复杂，集体和私人所有的次生林所占比例大。如广东省，集体所有的林地占林业用地总面积的92.8%，因而林权交叉复杂。而比较集中连片的国有林地，在上个世纪50～60年代就通过建立国营林场，大部分用作木材生产和开展人工林经营；

(3)水、热条件丰富。不但树木品种多，生长旺盛，而且水果、药用植物资源丰富。有道是，中国的热带地区，历来是一块神秘的地方；

(4)民族多，特别是海南和云南两省，除汉族外，居住着许多少数民族，有许多传统的生活习惯和生产经营方式。

2 次生林保护和经营的政策法规

中华人民共和国成立后不久，国家和地方政府开始制定关于次生林保护和经营的政策法规。中国的次生林保护和经营取得的成就，也主要依靠国家和地方政府政策法规的管制和政策扶持[5,6]，主要政策法规如下：1951年，国务院首次发布了《1951年农林生产的决定》，提出：“实行山林管理，严禁烧山和滥伐”，对于次生林的保护起了重要的指导作用；1952年，当时的林垦部鉴于我国森林资源少，赤地多，财力不足，颁布了对次生林和荒山进行封山育林的政策，开创了中国次生林经营的历史，并一直延用至今；1954年，林业部首次召开了全国次生林经营会议、提出了次生林经营方针，次年，林业部制订了“全面规划，因林制宜，抚育为主，抚育、改造和利用相结合”的次生林经营原则与方针；1962年，林业部作出《关于次生林改造若干问题的决定》；1963年，林业部在全国国营林场工作会议上决定，国营林场贯彻执行“以林为主，林副结合，综合经营，永续作业”的方针；1981年，国务院颁布了《关于保护森林发展林业若干问题的决定》；1984年，全国人大常委会颁布实施《中华人民共和国森林法》；1998年4月修正后，明确规定“林业建设实行以营林为基础，普遍护林，大力造林，采育结合，永续利用”的方针；1994年，颁布《中华人民共和国自然保护区条例》；1994年，国务院办公厅下发关于加强森林资源保护管理工作的通知；1996年，颁布《中华人民共和国野生植物保护条例》；1996年，国务院办公厅《关于治理开发农村“四荒”资源，进一步加强水土保持工作通知》；1998年，国务院关于保护森林资源，禁止毁林开垦和乱占林地的通知；1998年，开始全面实施天然林保护工程，其中海南省和云南省的热带林全部列入了保护工程范围；2003年，国务院下达关于加快林业发展的决定。

3 中国热带次生林的经营现状

在中国，除城市以外的大部分热带地区，长期以来由于经济不发达，乡村居民对次生林行为活动主要是采伐木材获取经济收入和砍伐各层植被用作能源，几乎没有保护和促进次生林生长发育的经营活动。生产经营单位的营林活动也主要是砍伐木材和在较平坦和肥沃的土地上种植人工林或经济林。对次生林的经营主要是依靠省级和中央由政府统一安排及资金扶持下组织实施，经营活动主要有以下几方面。

3.1 封山育林

"封山育林",就是利用自然力恢复植被的方法来培育森林,这是新中国成立后50多年来最主要的次生植被恢复方式之一。其方法简单,行之有效,经济可行。有长期封山育林、短期封山育林、轮番封山育林和半开放式封山育林。在面积大的边远地区林地多采用长期封山育林。如海南省中南部天然林区,从1984年开始进行封山育林,至今已收到良好效果,使该省天然林面积增加了42万hm^2。在次生林马尾松(*Pinus massoniana*)林封山之后,有"三年不见人"的说法,林地的林木已郁郁葱葱。粤东地区丘陵山地常采用轮番封山育林的办法,既照顾了当地居民采樵的需要,又保护了幼林的生长。在有传统经营非木质林产品的丘陵地区,则多采用半开放式的封山育林,规定只能在林下间种药材或采脂等,不能损害林木,居民可从中取得经济收入。关于实施封山育林,政府已有一套完整的规章制度进行管制。

3.2 建立自然保护区

自然保护区,是指对有代表性的自然生态系统、珍贵濒危野生动植物的天然集中分布区、有特殊意义的自然遗迹等保护对象所在的陆地、陆地水体或者海域,依法划出一定面积予以特殊保护和管理的区域。热带森林,由于动植物资源、生物多样性丰富和景观壮丽,通常被大面积划为自然保护区来管理[7]。

3.2.1 自然保护区的种类 热带林地区的自然保护区,多数是综合性的自然资源保护区。但也有专一性的野生动物或植物保护区。如海南尖峰岭自然保护区,既是森林生态系统保护区,又是热带林景观公园。广东省鼎湖山保护区,既是森林生态系统恢复、保持和发展示范区,也是名胜古迹旅游胜地。鼎湖山和西双版纳两个自然保护区已列入了"国际生物圈保护网"。海南东寨港红树林自然保护区也已列入"国际主要湿地保护名录"。较重要的保护区还有海南省陵水南湾猕猴自然保护区,白沙县邦溪海南坡鹿自然保护区,西沙群岛自然保护区等专一性自然保护区。

自然保护区有国家级、省级和地县级之分。一般说,国家级自然保护区的规模较大、重要性强、管理经费多且水平较高,省级次之,地县级较差。此外,广东省还建立有自然保护小区。

3.2.2 自然保护区的营建概况 中国政府重视自然保护区的建设,1956年就采纳了科学家"在全国天然林区建立禁伐区,以保存自然资源供科学研究的需要"的建议,在广东肇庆鼎湖山建设了中国第一个自然保护区,随后建设的也是时属广东的海南(1987年独立建省)乐东县尖峰岭建立自然保护区。1958年,云南省开始西双版纳自然保护区的建设。到上世纪80年代后期,开始建设大量的自然保护区。热带地区主要省保护区建设情况如下[8-11]:

广东:至2002年,广东省已建立各类自然保护区142处,面积达55万hm^2,面积比1985年增加近8倍,占全省国土面积3.1%。另外,还建设保护小区3.88万个,面积42万hm^2;森林公园38处,其中属国家级14处,省级24处,经营面积23.6万hm^2。自然保护区、保护小区和森林公园的合计面积为120.6万hm^2,占国土面积的6.78%;

海南:至1998年,建立自然保护区达到25处。包括:尖峰岭、吊罗山、坝王岭、黎母山和猴猕岭等五处森林公园,经营面积为15.67万hm^2,前二者为国家级公园,后三者为省级公园;

云南:1985年以前批准成立的自然保护区有10处,总面积为83.314万hm^2,其中热带林区的自然保护区占50%。至2000年,各类自然保护区已达121个,面积240万hm^2,占全省国土面积的6.1%。计划至2005年,增建自然保护区9个,面积80万hm^2。届时,自然保护区面积将占全省国土面积8%左右;

广西:现有自然保护区53处,面积173.0万hm^2,占全省国土面积的7.28%。

3.2.3 自然保护区的经营管理概况 建立自然保护区都要进行可行性报告论证,然后编制建设规划报上级主管部门批准后才能正式实施。国家级和省级重点自然保护区还有技术支撑单位,具体担负该区的科学研究工作,以提高自然保护的经营管理水平,充分发挥自然保护区的技术进步作用。保护区设有的管理机构,负责自然保护区的保护管理工作,国家和地方政府每年给予正常管理和维持费用的补助。

3.3 实施政府天然林保护工程

为保护天然林(主要是次生林),国家和地方政府通过林业工程建设的形式来实施保护和经营。1998年中央政府在全国开始实施的天然林保护工程,是中国有史以来最大的林业建设项目。到2001年,全国共投入建设资金200.7亿元,其中中央财政投入178.2亿元,地方配套22.5亿元。计划在未来十年,投入962亿元的巨额建设资金。同时,各省区地方政府也分别扩大了自己的林业保护和发展工程范围。天然林保护工程的核心是保护和发展天然林资源,以保护生态和改善人居环境。在建设上遵循"突出重点,先易后难,分步实施,注重实效"的原则;规划实施做到因地制宜,分类指导;经营过程中,坚持生态优先,生态、经济和社

会效益相结合；管理上依靠科学技术，实施目标责任制。

云南和海南两省的热带原始林和次生林基本纳入了此项保护计划。海南主要包括尖峰岭、吊罗山、坝王岭和黎母山 4 个国营森工企业和 7 个市县林场，经营面积 45.9 万 hm^2，其中天然林面积 31.9 万 hm^2，次生林约占 80% 以上，疏林灌木林面积 1.0 万 hm^2，未成林造林地 0.5 万 hm^2，有林地 7.0 万 hm^2，非林业用地 0.67 万 hm^2，其他 5.5 万 hm^2。云南省是全国推行天然林保护工程的重点省份，工程覆盖了 13 个地州市的 66 个县，17 个国有重点森工局的辖地，面积达 2 402.6 万 hm^2，占全省土地面积的 60.98%。西双版纳计划到 2010 年，还要增加森林面积 30 万 hm^2，森林覆盖率将由 1999 年的 64% 增加至 75%。

3.4　划作生态公益林来经营

《中华人民共和国森林法》定义生态公益林包括：防护林——以防护为目的的森林、林木和灌木丛，包括水源涵养林、水土保持林、防风固沙林、农田、牧场防护林；特种用途林——以国防、环境保护、科学实验等为主要目的的森林和林木，包括国防林、实验林、母树林、环境保护林、风景林、名胜古迹和革命纪念地的林木和自然保护区的森林。

生态公益林是中国实施森林分类经营的产物，与天然林保护工程涵盖的森林相比，生态公益林更具严格的科学含义和保护内容。而天然林保护工程，是针对中国当前森林过度采伐造成环境问题而停止天然林商品性采伐的一项紧急措施。

广东是中国提出并实施森林分类经营最早，生态公益建设规模最大，措施最得力的省份。1994 年，省政府作出全省建设 333.3 万 hm^2 生态公益林的决定。1998 年，正式颁布了《广东省生态公益林建设管理和效益补偿办法》。目前，每年安排的省财政补偿资金达到 4.08 亿元（120 元/ hm^2），地方配套资金约 1.2 亿元。广东的热带次生林，已大部分划作生态公益林来经营。

实际上，在上世纪 70 年代末各地都不同程度地实施生态公益林建设，只不过涵盖面较小，重点在自然灾害比较严重的地段。直到 90 年代末，生态公益林的建设才得到全面开展，并按国家、省和地市不同等级来划分和经营。

4　热带次生林经营技术

中国热带次生林的经营，除政府通过行政方式和以工程建设项目列入政府计划组织实施外，很少有社区经营活动[7-12]。林区生产单位和居民，通常只是利用较好的次生林地开展一些小规模的经济活动，如在次生林中种植药材、竹、棕榈藤、经济林果等。地区间的经济发展水平和传统习惯不同，其经营方式也有很大差别。由于社区经营缺乏总体规划和技术基础，没给次生林带来促进和提高的作用，反而更具破坏性，如经营过程中通过砍伐林木用于种植经济作物或在经营活动中伤及林木和植被等。

政府的经营活动是在总体规划原则下，通过编制经营方案来组织实施，目的性较强。其经营技术主要包括以下几点。

4.1　植被恢复

对稀疏的次生林地主要通过飞机播种和人工种植的方法引入新的植物，创造林木生长环境并加速其形成。一方面，使原有的地带性物种得到自然恢复。另一方面，可以通过人为的方法引入具有良好生态或经济价值的品种。

广东 1956 年 3 月首次在吴川取得飞机播种的成功后，直到上世纪 90 年代前飞机播种一直为植被恢复的主要手段。现在，海南、广西和云南利用飞播在促进林分更新和发育的植被恢复中也取得显著成绩。在药物处理种子以防止鸟、鼠害的技术成功后，飞机播种已经成为一个简易、有效和经济的植被恢复方法。

4.2　林分改造

受破坏比较严重的次生林，通常林分质量很差、树种单一。如广东、广西的次生林中，就约有 40% 以上是以马尾松为主的林分，其中又有半数以上是低等级林分，灾害性森林病虫害严重。广东马尾松毛虫为害面积每年约 4.5 万 hm^2；松突圆蚧自 1982 年发生以来，已扩散到 17 个市 58 个县级行政区，为害面积达 111 万 hm^2；松材线虫病 1988 年从深圳传入后，为害面积超过 2 万 hm^2。对这部分林分，普遍采用林分改造的办法，包括人工清除病害虫植株和引入乡土阔叶树种，以改善林分环境，提高生物多样性，防止病害虫的发生和蔓延，促进次生林的生长发育。城市的林分改造，主要以清除残次树木和引入观赏性强的景观树种为主，投入通常较大。

广东省林业局将生态公益林按树种、林种、郁闭度等分为三个等级。其中一类林占 16.7%，二类林

47.2%，其余为三类林。经营方法为：对二、三类林进行补植和改造，促进它们向一类林发展，使之成为树种多、林相结构好、环境功能等级高的林分。补植或改造时，规定只能作块状或条状作业，避免过度破坏原有植被。同时，要求采用生态效益好的乡土阔叶树种，促使被改造的林分形成针阔叶混交并向顶级群落转化。

4.3　间种经济林种

华南的大部分地区都有丰富的非木质产品收益的植物品种，如竹、耐荫的热带水果、药用植物等。间种毛竹(*Phyllostachys pubescens*)，每年春、冬可以收获竹笋两次，还可以通过间伐获取竹材，经营得当的林地每年每公顷收入可以超过10 000元，此外林地也能不断得到改良。

4.4　林下种植经济物种

在一些立地条件较好的地方种植经济作物，以取得经济收入。如中药材巴戟、砂仁、人参、棕榈藤等。据海南的调查反映，林下种植棕榈藤植物每年每公顷的收入超过12 000元。广东肇庆有林下间种南药，云南省有栽种茶叶以及在铁刀木林下栽种砂仁等传统。但是，林下种植药用植物的技术仍然很不规范，在大多数情况下，不但没有起到促进次生林生长发育的作用，反而破坏了林下植被，造成水土流失，甚至在经营过程中使林木遭到人为的破坏。

5　主要成就和经验

5.1　主要成就

5.1.1　*热带次生林大部分开始得到保护*　1992年联合国环境与发展大会以后，中国政府十分重视森林的可持续经营对社会经济可持续发展的基础地位作用，开展了一系列生态环境保护与建设的林业生态工程。这些林业生态工程的建设，直接推动了热带林地区次生林的建设。如云南省列入天保工程的总面积为2 402.6万 hm^2，占该省总土地面积的60.98%；海南省受天保工程保护的热带天然林和次生林面积45.9万 hm^2；广东1998年将137万 hm^2 的热带天然次生林全部作为生态公益林进行经营，热带天然林和次生林基本纳入工程范围。可以看出，中国热带次生林的保护已经纳入国家和社会宏观管理的轨道。

5.1.2　*热带次生林经营管理初显成效*　虽然中国的热带次生林经营管理开始实施的时间和速度不一样，但已经开始取得成效。在扩大次生林面积方面，海南省自1996年实施停止天然林采伐和封山育林后，次生林面积增加了4.2万 hm^2；云南西双版纳1998年实施天保工程，当年即停止了天然林采伐，封山育林2.92万 hm^2，人工促进天然更新1万 hm^2，退耕还林4.17万 hm^2，次生林面积大幅度增加。在提高次生林质量方面，近几年来，广东省在改造、提高生态林生态功能等级上做了许多工作，对低等级的生态林作林间间种套种，使用的主要树种是红锥(*Castanopsis hystrix*)、木荷(*Schima superba*)、火力楠(*Michelia macclurei*)、藜蒴栲(*Castanopsis fissa*)等约几十种乡土阔叶树种，期望被改造的针阔叶混交林能够向地带性常绿阔叶林方向转化。例如，余作岳等人曾在电白县马尾松、桉树等先锋树种林下栽植阔叶树，取得了很好的效果[13]。

5.1.3　*对热带次生林经营的重要性有了理性的认识*　中国次生林经营走过了漫长的道路，可以分为3个阶段：感性阶段、探索阶段、理性阶段。上个世纪50～60年代，可看作为感性阶段，在这个时期，仅从次生林面积对国家林业产生影响这个角度出发，提出了封山育林措施，是从感性认识去经营次生林；70～80年代中期为探索阶段，探索次生林发生与发展、经济价值和经营形成，开始认识到要经营利用好次生林，必须建立在了解次生林内在发育规律的基础上方能实现，开始迈向理性阶段；理性阶段，自80～90年代对次生林和南亚热带植物群落的演替规律作了系统的总结，为次生林的经营打下了良好的理论基础。所以，90年代中后期蓬勃发展的诸多生态建设工程，都是以地带性植物顶极群落和森林植物群落演替学说为基础，制订了各项经营措施。因此，在次生林经营中，根据对象的植被、立地和它们所处的演替阶段而采取的经营措施与技术是比较奏效的。

5.1.4　*经营目标逐步明确*　由于中国次生林面积占森林面积的比重很大，所以一直把它作为后备资源来培育，以增加森林蓄积量。基于这样的认识，次生林经营都是以获取木材为目的，而其保护生态环境、保护物种多样性等方面的功能则被置于很次要的位置。这种经营思想，自20世纪50年代一直延续到80年代。此后，国内外大环境的变化，特别是日趋严重的自然灾害引起了中国人的反思，次生林经营又转入了生态建设一端，忽视了经济功能作用。现在科学家们才开始认识到，在次生林经营上生态和经济效益的提高同等重要。

5.2　主要经验

5.2.1　*政府对保护、利用和发展次生林的作用非常重要*　上世纪80年代后期以来，中国的热带次生林保护

和发展取得的成就，主要就是在政府的生态公益林建设、天然林保护工程、退耕还林工程和封山育林等措施的作用下得到实现。

5.2.2 *必须寻找适合地区社会和经济特点的途径与方法* 作为一个经济仍不发达的国家，在经济和技术都还比较落后的情况下，通过采用比较经济的封山育林和工程保护的办法首先实现资源的保护，然后逐步开展有效的经营，是最好的途径和有效的方法。

5.2.3 *没有经济效益的经营是不可持续的经营* 在山区，由于工业化程度低，又缺少第三产业，居民对森林资源的依赖程度高。对次生林的保护和经营，如果缺乏经济效益，无论政府如何限制，也始终避免不了可能遭到的破坏。只有实现生态和经济效益的提高，才是可持续经营的道路。海南在实施天然林保护工程方面取得了二条经验：一是按资源属性分成国家和集体区别管理，前者侧重生态保护和保存物种多样性方面，划为重点保护区，实行专业队伍管护；后者与村民关系密切，实行森林管护责任区合同承包责任制管理。二是注重发挥林区的资源优势，包括发展热带名特优经济林果、养殖业和林副产品（如松香等），开辟热带森林旅游、充分利用水资源开发优质矿泉饮用水和水利发电，种植南药、热带花卉和棕榈藤等。以通过非木质产品的资源开发，增加林区居民的经济收入，实现可持续经营的目的。

中国是一个发展中国家，回顾中国热带次生林经营走过的历程可以看到，在经济仍不发达的地区，要由社区居民自发去对次生林实施有效的保护和经营，似乎是不大可能的事，因为他们既缺乏资金也缺乏技术，山区居民要做的事首先是解决温饱等生计问题。在发展中国家，热带次生林要得到有效的保护和经营，政府的作用和取得国际帮助非常重要。中国在热带次生林保护和经营方面，政府的作用就是一个成功的例子。

6 结论

6.1 与许多热带国家和地区比，中国热带次生林普遍质量低、生物多样性差、缺乏生态和经济效益。

6.2 中国人口多，大部分地区经济仍不发达，而热带次生林主要分布在山区，当地居民对次生林的依赖程度高。提高生态和经济效益的次生林经营，已经成为广大农村地区生态环境保护和改善农民生活和生存条件的迫切需要。

6.3 虽然上世纪 80 年代后期至今，中国在次生林保护和发展方面取得了不少经验和成就，但经营技术仍然比较落后，缺乏既有生态效益又有经济效益的经营技术、方法和实践。

6.4 由于大部分次生林区居民仍然在经济上比较困难和缺乏技术支持，自发对次生林进行保护和开展经营的很少。

参考文献

[1] 张俊红. 中国林业百科全书. 林业卷(上)[M]. 吉林：吉林电子出版社，2004.

[2] 侯元兆，于玲，王洪峰. 中国热带森林环境资源[M]. 北京：中国科技出版社，2002.

[3] 陈大珂，周晓峰，祝宁，等. 天然次生林——结构、功能、动态与经营[M]. 哈尔滨：东北林业大学出版社，1994.

[4] 李国猷. 北方次生林经营[M]. 北京：中国林业出版社，1992.

[5] 国家林业局. 中国 2000 年林业发展报告[R]. 北京：国家林业局，2000.

[6] 广东省林业局. 常用林业法律法规汇编[G]. 广州，2002.

[7] 周晓峰. 中国森林与生态环境[M]. 北京：中国林业出版社，1999.

[8] 广东森林编委会. 广东森林[M]. 广州：广东科技出版社，1990.

[9] 陈永富，杨秀森. 中国海南岛热带天然林可持续经营[M]. 北京：中国科学技术出版社，2001.

[10] 云南森林编委会. 云南森林[M]. 昆明：云南科技出版社，1986.

[11] 广西区野生动植物保护管理站. 广西植物资源[内部资料]. 广西，2004.

[12] 黄枢，沈国舫. 中国造林技术[M]. 北京：中国林业出版社，1993.

[13] 余作岳. 热带亚热带退化生态系统植被恢复生态学研究[M]. 广州：广东科技出版社，1996：38-90.

热带次生林经营研究文献分析*

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Reference Analysis on Study of the Management in Tropical Secondary Forests

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Abstract Tropical secondary forests own enormous potential and ecological function due to its vast area, and are an increasingly important component of the forest resources in the tropics. This paper reviews main research outcomes of secondary forests during their succession process. Soil-stored seeds significantly contribute to the development of secondary forests, increased levels of incident light temperature stimulate seed germination, whereas remnant vegetation and seed predator have strongly negative influence on the rate of initial colonization. Species and number of secondary forests generally increase with succession process. Early successional species are generally shade-intolerant while late successional species are shade-tolerant. Time frame that plant species richness in secondary forests approach old-growth values varies considerably depending on forest type, type and intensity of past land use, and environmental conditions. Artificial plantation can accelerate germination and growth of seed by improving the light, temperature and the degree of humidity of soil surface layer, so that they greatly accelerate processes of plant succession. Most herbivores feed in secondary forests because pioneer species in secondary forests do have little or no mechanical or chemical protection against herbivores and many early and late seral tree species in secondary forests produce edible fruits in large quantities. Environment and fire have some effects on secondary forest succession. In early succession, relatively more biomass is allocated to resource acquiring tissues (leaves and fine roots) and in later stages more is allocated towards structural materials (woody stems and coarse roots). The nutrient cycling of secondary forests is quick during approximately the first 15years of succession and it decreases as forests age. That the loss of soil organic matter and N due to deforestation and burning decreases soil fertility of secondary forests.

Key words tropical forests, secondary forests, management of secondary forests

摘要 热带次生林面积巨大且在热带森林资源中的作用越来越重要，因而拥有巨大的经营潜力和生态功能。次生林演替过程中的主要研究成果如下：土壤贮存的种子对次生林的再生非常重要，光投射的强度增加和温度提高将刺激种子萌芽，而残余植被群落强烈影响次生林种子的散布，食种子动物影响次生林的成林；次生林群落植物种类数量一般随演替的进程而增加；随着演替的进程，次生林内阳生树种趋于衰亡，耐荫树种不断增加；次生林的树种数量能接近原生林水平的时间过程更随着林分种类、过去土地的利用强度和利用种类，以及环境条件的不同而异；在一定环境中，人工林树种通过人工林树种改变光、温度和土壤表层的湿度，能够促进发芽和种子生长，改善林地和林下植被的状况，从而加速次生林演替。大多数食草动物喜欢在次生林中取食，因为次生林中先锋树种很少或没有机械和化学保护，且林内许多树种产生大量可食用的果实；环境和火对次生林演替有一定影响；在早期的演替过程中，更多的生物量分配到资源需求旺盛的组织（如叶和细根），在演替晚期阶段，更多的生物量则分配到结构组织中（如木质部和根端）。次生林在15至20年内能迅速积累生物量，然后积累逐渐减慢；次生林被砍伐或火烧后，森林土壤的结构被破坏，导致土壤有机质和氮减少。

* ITTO PD 294/04 Rev.4 (F)。旨在提高生态和经济效益的热带次生林经营系列研究报告之五。

关键词 热带森林 次生林 次生林经营
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在世界的热带地区，由于人口不断增加带来的毁林开荒和森林商业性采伐，热带森林被大量破坏后转变为次生林或退化为荒地。据ITTO的材料，热带次生林或退化荒地占热带森林面积的60%。由于热带次生林的可及性强、面积巨大，因而拥有巨大的经营潜力。热带次生林能改善环境，如防止污染、固定CO_2[1]，提供森林恢复模式[2]，提供生物多样性保护区，同时具有多种产出[3]。在热带地区，人们对次生林的利用远远超过对原始林的利用，采集薪材、放牧、游耕农业和收获非木质林产品等与林区和周边地区群众生活密切相关的生产活动，绝大多数都是在次生林里进行的[4,5]。随着工业化和城市化的进展，在下个世纪热带次生林的面积将有所增加[6]。因此，加强对次生林的研究，对于促进次生林经营和管理，发挥次生林的生态经济潜力，具有重要的意义。

为总结过去世界热带地区次生林的经营和研究工作经验，为今后次生林研究和生产经营工作提供技术支持，本综述共检索世界与热带次生林经营相关的文献605篇，其中包括森林生态学文献306篇，内容涵盖了植被特征的研究、热带次生林植被动态的研究、森林的更新、演替、结构功能动态、生殖生态学、苗木更新、个体生态学、恢复生态学、水分动态、元素循环尤其是碳循环，以及次生林的生态功能方面、保护生物学等方面；森林动物学及低等生物学文献67篇，主要包括了热带次生林动物的区系组成、生物多样性及其与植物的相互关系和热带次生林低等生物的研究；森林土壤学文献95篇，森林经营学文献81篇；森林栽培学文献56篇。目的是总结次生林演替中的变化，提出需要进一步研究的问题。

1 热带次生林经营研究历程

对热带次生林的研究，多从生态学角度，研究植物群落、演替过程和生态位方面的较多。从现有的文献看，国际上对热带次生林的研究起始于20世纪的50年代初。Greig-Smith[7] 1952年开始对西印度群岛特立尼达的三片次生林进行了以林分结构为主要对象的生态学调查，是目前已知最早开展的热带次生林研究工作。之后，Bartholomen等[8]报道了刚果湿润热带林刀耕火种后2~18年生的次生林生物量和养分含量；Ross[9]研究了尼日利亚干旱性热带林刀耕火种23年后5~17年生次生林的林分结构；宋君等[10]报导了中国广东南亚热带常绿阔叶林种类组成与分布、群落结构的研究；彭少麟等[11]研究了中国广东南亚热带常绿阔叶林约40~400年生的代表着不同演替阶段的主要树种群落动态；管东生[12]研究了中国香港和广东烧荒后季风常绿阔叶林生物量、初级生产力、凋落物和养分；Aide等[13]总结了波多黎哥热带低地雨林农耕、放牧、择伐后10~60年土地利用对次生林的影响；蔡锡安等[14]研究了中国广东南亚热带400年以上常绿阔叶林群落均匀度和多样性的12年定位观测结果等。近20多年来，热带次生林研究的范围越来越广，发表的文献也越来越多。

2 热带次生林的类型

综合各国的情况，热带次生林主要可以分为以下类型：

(1)过度开采的次生林(post-extraction secondary forests)。由于某次或某个时期在某地采伐使原有森林植被显著减少后再生的森林，即森林—砍伐—次生林。

(2)弃耕后恢复的森林(swidden fallow secondary forests)。在森林被砍伐后种植农作物，然后休耕以便恢复地力，再在栽培农作物的土地上形成的森林，即森林—砍伐—炼山—农作物—休耕—次生林(—砍伐—炼山—农作物)。

(3)次生林农庄(secondary forest gardens)。相当肥沃的休耕地上或在管理松散的小地产主的人工林中树木大量自发再生的森林，即森林—管理松散的小地产主人工林 + 天然次生林；或森林—砍伐—炼山—农作物—相当肥沃的休耕地。

(4)火灾引起的次生林(post-fire forest)。由于一次或连续的森林火灾使原有森林植被显著减少后再生的森林，即森林—火灾—次生林。

（5）人工恢复的次生林（rehabilitated secondary forests）。在退化林地上再生的森林，通常人为帮助恢复森林或通过防止剧烈干扰、维持立地的稳定性、水分管理和造林加速天然更新，即森林—退化林地—森林恢复或更新。

3 热带次生林的发育

次生林的演替是从种子传播和根桩萌孽开始的。种子的传播有利于次生林的发展，但是土壤贮存的种子对森林的再生显得更为重要。即使林地由于火烧使土壤贮存的种子减少[15]，对绝大多数树种而言，它对林木再生所起的作用要大于传播的种子[16]。光投射的强度增加和温度提高将刺激种子萌芽[17]。随着土地使用强度的增加，来自土壤种子库的次生林木的再生潜力不断降低。Aide 和 Cavelier 认为在哥伦比亚的退化草地上，来源于种子库的森林再生是不重要的[18]。土地使用强度也影响种子库的物种组成，这可以在土地弃置后形成一个预定的植物群落。通常砍伐原始森林后的物种丰富度小于砍伐自然演替的林分。土地利用的种类也将影响种子库的数量和质量。例如，农耕地或其他森林破坏地附近的种子库的种类组成包含大量的喜光灌木和草本，而次生林种子库的草本较少[19]。

残余植被群落通过对其种子的散布，强烈影响次生林的形成速度。在大规模的森林破坏地区，对种子分布的空间限制成为影响演替的障碍之一。Aide 和 Cavelier[18]精确测量了牧场上林木种子的散播距离从最近的林中空地算起不超过 20 m。Parrotta[20]研究发现苗木密度和最近的种源之间存在显著的负相关关系。

种子散播后，另外一个影响成林的因素就是种子被掠食。在刀耕火种的 Rio Negro 废弃地上被取食的种子要比邻近的林地要高。Nepstad 等报道在巴西的 Paragominas，由于蚂蚁和啮齿动物的取食，11 个试验树种种子中的 6 种在 20 天内被吃掉 80% 以上。他们研究发现，小粒种子容易扩散到达牧场，而大粒种子被取食的可能性则较小[21]。因此小粒种子的扩散状况要好，而大粒种子则容易成林。但是 Holl 和 Lulow 通过观察认为，林木种子大小与其保存率没有明显的相关关系[22]。这种差异可能由于种子在不同地点被取食情况的不一样，也可能是林地退化和植被覆盖类型的不同而造成的。

4 热带次生林的树种组成与林分结构

森林群落的演替以物种组成和群落结构的变化为表征。次生林群落植物种类数量一般随演替进程而增加。Kellman 发现在不到 30 年的时间内，次生林的树种数量就几乎与附近成熟林所拥有的数量相当[23]；次生林的树种丰富度较老龄林低，但两种林分的幼苗和幼树树种丰富度相当，且两类林分的幼树种类十分相似[24]。有的研究发现，次生林比热带雨林拥有更多的树种。例如，Laska 对哥斯达黎加 12～25 年生次生林和热带雨林的研究发现，12～25 年生次生林的植物种类比热带雨林大约多 50%，密度也大于后者。12～25 年生次生林的林冠比热带雨林的稀疏，使更多的光照到达灌木层，导致其灌木的种类多于后者[25]。有的研究发现，次生林在演替过程中，种类数量有一定波动。刀耕火种后引起的演替强烈地受邻近种子资源和土地利用强度的影响[26]。在被弃置的广大牧区，或是在退化严重的区域，演替规律很可能不一样，所期待的生态功能的恢复也将非常缓慢[27]。

5 热带次生林演替过程中的树种变化

随着演替的进程，次生林内阳生树种趋于衰亡，耐荫树种（顶极群落优势种）不断增加是一种普遍规律。在美国 Arkansas 东南部的海岸平原的次生林演替过程中，早期演替的树种是不耐荫的松树。随着演替进行，不耐荫的松树的重要性下降，而耐荫的硬木树种，特别是栎树增加，林冠变成多层，上层为不耐荫的松树，接下来为栎树和其他中等耐荫的树种，中层为没有潜力生长到林冠上层的耐荫树种。松树由于衰老而引起个体死亡或由于灾害引起群体死亡后，栎树和其他树种变成上层林冠的树种[28]。

在潮湿的热带低地，废弃地的森林演替最初 10 年的特征是草类、灌木类、阔叶牧草占优势，它们最终被那些生命周期短的喜光树种所取代。接下来，此区域又将被长寿的、更高大的喜光树种所控制。因为耐荫树种在荫蔽环境下更易萌芽、生长并成材，所以这些树种不能够在其自身的林冠蔽荫下更新，最终被耐荫树种所取代[24,29]。

在印度，当森林被转变成农地后，由于火灾、农作物收获期间野草的入侵和其他的破坏，导致树种的多样性减少。而在次生演替期间，树种的多样性逐渐增加[30]。在低海拔地区，群落结构随次生演替的进行变化

显著，开始为野草，接着是竹林，最终为混交阔叶林[31]。

次生林演替可能会经历数世纪之久后，其种类组成到最后接近于原始林，树体结构也随演替而变化。在演替早期，大部分阳性树种具有展开的树冠，从第10到第30年，林冠层逐渐被一些既喜光又能耐一定庇荫的树种占据；第30年后，稳定的林冠层开始疏开，为中性或耐荫树种逐渐占据林冠层提供方便[32]。

通常来讲，和原生林比较，年幼的次生林有更高的密度，更低的树干断面积以及更小的林冠层高度[13,29]。不同次生演替时期的树种特征有所不同。与次生演替晚期的树种相比，次生演替早期的树种：①具有窄树冠，主干的顶层枝条的生长速度快于其他枝条，顶端优势明显。这些特征保证次生演替早期的树种能够生长快和获取更多的光照；②次生演替早期的树种叶生产量大，新叶比老叶的比例高，这样有利于其捕获光能和加快光合作用；③次生演替早期的树种，根的结构与次生演替晚期的树种不同。次生演替早期养分在土壤表面快速积累，演替早期树种的根系集中于土壤表层，有利于获得土壤表层中的养分。次生演替晚期随着养分的消耗，养分在土壤各层的分布趋于均匀，演替晚期树种的根系较均匀地分布于土壤各层，有利于获得不同土壤层次中的养分[31]。

6 热带次生林的植物种类与土地利用强度

虽然林地废弃几十年后出现的次生林的树种数量能接近原生林的水平，但却需要一个相当长的过程，特别是对更新时间更长的优势树种来讲更是如此[33]。这个时间过程更会随着林分种类、过去土地的利用强度和利用种类，以及环境条件的不同而异。在经营强度轻微到中等的土地上，当种源在附近时，植物种类的丰富度在次生林演替的头些年迅速增加。废弃不超过几十年的土地，植物种类的丰富度可接近原生森林。然而，在强度经营的林地上，由于土地过于板结、繁殖受限以及森林火灾的存在，物种恢复情况比较缓慢[21]。在山区，优势冠层树种将比低海拔林地更快地恢复到原始森林的水平[34]。在土地废弃后，过去的土地利用强度不仅影响物种定居的可能性，也影响早期的群落组成。例如在哥斯达黎加，如果林分被砍伐以后立即闲置，有些生命周期短的先锋树种的丰富度呈明显下降趋势。树种群落组成开始被喜光的长寿树种所支配[35]。缺乏无机矿物的土壤，植物残体和凋落物存在使得短命的小粒种子的萌芽和生长很困难[36]。在波多黎各 的 Luquillo 山脉，Cecropia 在牧地废弃的头几十年内不能定居，尽管它是最适生的先锋树种[13]。土地的既往利用情况也将影响废弃土地上的植物组成。Zimmerman 比较有 60 年种植历史的咖啡地和牧草地上的植被时发现，2 种林地的乔木和灌木的多样性比较类似，而植物的组成却大不一样。即使 5 年前有一场强烈的飓风影响了这 2 块林地，但对物种组成影响更大的仍然是过去的土地利用情况[37]。Rivera 和 Aide 报道，废弃牧地上形成的次生林与废弃的咖啡林地上形成的次生林的植物种类多样性比较接近，但组成上有显著差异[38]。

7 热带人工林对次生林演替的影响

在一定环境中，人工林树种通过改善林地的和林下植被的状况，能够加速森林演替。人工林树种改变光、温度和土壤表层的湿度，能够促进发芽和种子生长，并抵御来自邻近森林的野生动物和其他传病媒介的危害[39]。Otsamo 的研究发现[40]，在印度尼西亚的 Riam Kiwa 地区，在草本植被（Imperata）占优势的土地上，苗木恢复比在无植被或灌木占优势的土地上显著慢。用适合的速生外来树种（*Acacia mangium*、*Gmelina arborea*、*Paraserianthes falcataria*）营造人工林，可以促进各种乡土树种的天然更新，这有利于生态系统的快速恢复及促进速生外来树种和天然更新的乡土树种形成混交林。人工林树种对于林下植被的苗木密度和树种的多样性有重要影响，其中马占相思（*Acacia mangium*）林分中的苗木种类有 29 种，密度达 3 042 株/hm^2，在 3 种人工林中最高。因此，营造速生和林冠早期郁闭的人工林是在 Imperata 草地上次生演替成功的最初手段，否则林分将参差不齐。Imperata 草的数量庞大时，次生演替缓慢。Lugo 研究了波多黎哥次生林的结构和动态，并与同龄的加勒比松（*Pinus caribaea*）人工林和桃花心木（*Swietenia macrophylla*）人工林对比。未经营的幼年人工林的林下树种多样性小于同龄次生林，但是人工林的林下树种多样性随林龄的增加而增加，50 年生的桃花心木人工林的林下树种多样性已接近同龄次生林[2]。Oberhauser 研究了 7，12，21，28 年生的松树（*Pinus kesiya*）人工林，发现维管种类很多。随着中层和低层植物林冠的发展，林下其他植物取代松树。在较老的松林中动物散播种子的树种不断增加。木本植物在松林中恢复得比在废弃的农田快。随着时间的推移，松林的树干断面积不断减少，而其他树种的树干断面积不断增加，说明松树人工林能够促进混交林的

形成[41]。

8 热带次生林与动物

原始森林转变为次生林对树栖哺乳动物有不利影响，因为原始森林为野生动物提供更多的隐蔽场所。但是次生林却能为野生动物提供更多的食物。因为次生林中的先锋树种很少或没有，同时，次生林早期和晚期演替系列中的许多树种产生大量可食用的果实，这就是大多数食草动物喜欢在次生林中取食的原因[42]。繁茂的次生林可以改善食草动物的生存环境。一些鸟类需要在原始森林繁育和做巢，迁移鸟类喜欢在受到破坏的森林中取食，在次生林中它们的数量会有增长[43]。对香港的次生林和 *Lophostemon confertus* 人工林中的鸟类进行比较发现，次生林比 *Lophostemon confertus* 人工林的树种多，因而林内鸟类密度和种类比后者多。研究显示，鸟类的物种多样性与栖息地的植被复杂性有相关关系[44]。

9 热带次生林的演替与环境

环境对次生林演替有一定影响。Leak 报道了次生林在美国 New Hampshire 的次生林演替特征[45]：①演替方向随地点而变化。在粘土上向山毛榉、糖槭和阔叶树种的方向演替；在沙土上向山毛榉为优势树种的方向演替；在土层薄和干旱土壤上向云杉和铁杉方向演替；②5 个生态种的作用是明显的。随着时间的推移，主要的顶极种显著增加，稳定的顶极种保持稳定和丰富，次要顶极种占据小面积的异常生境。持续演替种是不耐荫或中性种类，他们在反复的破坏中生存下来。短暂的演替种显著减少；③演替过程由一开始就存在的优势种的变化构成；④Barlett 地区的老的、未砍伐的阔叶和针叶林包含了至少 70% ~80% 的耐荫顶极种类。Corlett 认为，在新加坡的退化土地上的次生演替最初受土壤因素——可能是养分缺乏或定期缺水的控制，后来是受种子扩散的控制[46]。生长在沙壤上的次生林受到湿度不足的影响[47]，特别是有显著干旱季节的地区[48]。

Rivera 和 Aide 对波多黎哥岩溶地区次生林的研究表明，与废弃的咖啡林相比，废弃的牧场上的树种多样性高，原因可能是喜光和耐荫树种在森林的这个发展阶段共存。岩溶地区次生林的恢复比波多黎哥的其他次生林快，原因可能是其独特的地形。岩溶地区次生林位于山谷，在飓风和热带风暴期间可以避开强风。另外，山谷地形有利于土壤和有机质的积累，避开强烈的阳光和减少土壤侵蚀，因而促进了树木生长[38]。

地面上小生境的差异影响次生林演替过程中早期植物的构成[15]。Harcombe 对植物演替策略的研究表明，同一生长时期牧草在肥沃的土壤上占优势，而灌木和树木本在贫瘠土壤上较多[49]。次生林演替过程中不管是植物区系还是生命形式构成，均受土壤中可利用养分的影响。高生长率的树种可能不相称地占有丰富的资源，这导致它们在早期的演替过程中往往占据过强的支配位置，因为生长慢的树种对提高资源利用水平不敏感。由于一个林分的树种组成不仅受土壤的影响，同时它能对其他树种利用资源情况产生影响，进而影响了整个演替过程。土壤肥力的变化影响树种的结构和分布。Herrear 和 Finegan 报道了两种在林冠层占优势的树种的空间分布情况。Vochysia ferruginea 的个体集中生长在缓坡的酸性土壤上，而 Cordia alliodora 的个体更集中分布在地势平坦的中性土壤上[50]。

火灾对次生林的植物种类有一定影响。次生林比原始森林干燥快，因而容易发生火灾。在许多天然林窗内原有的苗木大部分被火毁灭，土壤裸露，因而火灾地形成的次生林往往物种多样性低，上层林冠种类贫乏。火灾后的次生林容易再次受到火灾伤害。现有土地契约的不安定性、缺乏森林恢复和森林防火的经费不足等，是影响火灾后次生林再生的重要因素[51]。

斯里兰卡（Sri Lanka）西南地区的 dipterocarp 混交林，在森林发展后期的优势树种依赖于象风、干旱、病害和昆虫这样的再生破坏，许多后期演替的林冠优势树种局限于雨林景观的特殊地形[52]。

10 热带次生林的生物量和生产力

次生林演替的典型特征是植物群落内生物量的转移。在早期的演替过程中，更多的生物量分配到资源需求旺盛的组织（如叶和细根），在演替晚期阶段，更多的生物量则分配到结构组织中（如木质部和根端）。直径小于 2 mm 的细根生物量的积累要比叶的少，但是其更新速度仍然很快。次生林比林龄相近的人工林拥有更多细根生物量[53]。经过 1 年至 10 年的演替后，次生林拥有同原始林相似甚至更多的细根生物

量[54]。次生林在其再生过程中能积累生物量，这样也就沉积了大气中的碳[55]。一般来说，次生林在15至20年内能迅速积累超过100 t/ha的生物量[56]。气候、土地既往利用情况等这类因素对次生林的生物量积累有影响，地上部分生物量显示出和时间有关的渐近模式。

有资料表明，热带次生林的生物量积累有以下突出的特点：①林分发育头15年左右是生物量积累的高峰期，一般可达100 t/hm²。15年生以后，生物量积累有较大差异。林龄达80年左右的次生林，其生物量几乎都不超过200 t/hm²。大多数次生林的叶片生物量积累在演替早期（约20年）达到最大，以后略有减少并基本保持不变，直到林分成熟[2,55]。

人工林的生物量和地上部分净生长量也大于同龄次生林，而根密度、生物量和根系深度小于同龄次生林[2]。一般而言，次生林有较高的生产力，这就是它们被称为重要的木材资源的原因。在早期成林过程中（例如小于20年）其叶的生产量远比木材的生产量大。木材生产量的快速增加要在叶和根充分发育之后出现。经过这段时期之后，次生林的木材生产能力要比原生林高出许多[56]。热带次生林的净初级生产力在演替早期（约30年生）一般较高，约2～11 t/(hm²·a)，普遍高于成熟林1～8 t(hm²·a)，但林龄>40 a时，生产力普遍下降1.0～4.5 t/(hm²·a)。Yoneda等发现低山雨林采伐后几年，次生林的初级生产力即达到峰值，以后趋于稳定，稳定后的初级生产力与原始林的初级生产力没有显著差异[57]。起源于农耕地的次生林的生长速度要快于荒废牧地上形成的次生林[11]。

11 热带次生林的养分循环

树木的生长量和养分循环是紧密联系的，因为植物组织在生长时需要吸收养分，而当这些组织死亡之后，又将一部分养分返回到土地。次生林大约在前15年的演替过程中能迅速积累生物量，使养分沉积并将养分输送到叶和根部[56]。如此迅速的养分积累与养分循环联系在一起，其速度要比人工林或其他土地要快[2]。到成林期，绝大多数的生物量已集聚到木质部，而养分的循环下降。在次生林的早期演替过程中，一般养分循环模式是养分在叶部和根部迅速地积累以及这些养分的快速循环。在演替后期，养分的循环明显变慢。土地利用历史、气候和土壤类型影响了养分循环的速率，同样的养分循环模式出现在许多次生林演替过程中。

印度的长期休耕地在次生演替发生15～20年期间，可以观察到物种的多样性和凋落物产量及净初级生产量之间有种显著的线性关系。在早期休耕阶段，土壤中的养分快速迁移到植被中。在淋溶和径流引起养分大量损失的情况下，植被吸收养分使土壤养分快速枯竭。在休耕10年后，植被凋落物归还使土壤的养分收入大于消耗，因而是土壤肥力恢复的重要途径[31]。McDonald等研究了Jamaica山区的次生林和原始森林养分循环[58]，发现次生林的径流和流失的土壤沉淀物中的养分损失速率低，树干断面积恢复到原始森林的81%，凋落物量大。通过对土壤的化学分析和对植物的生物测定判断，土壤肥力已经得到很好的恢复。在陡坡的中部，农耕停止后养分循环、土壤状况和肥力在次生演替20年后得到有效的恢复。Johnson研究了生长于东亚马逊流域（原为农田）沙壤上10，20和40年生次生林的地上部分的碳和养分的储量，并与原始森林对比。次生林的叶平均C、N、P、K、Ca、Mg含量与原始森林相比无显著差异[59]。原始森林干材的平均Mg含量低于次生林，而平均N含量高于次生林。由于次生林的叶生物量大于原始森林，其叶的养分储量大于后者。除了Mg的储量外，次生林的干材的其他养分储量小于原始森林。次生林土壤中可交换Ca的含量随林龄的增加而减少，可交换Mg的含量大于原始森林。Lugo报道[2]，松树人工林的林下植物组织，特别是凋落叶的养分含量大于同龄次生林，人工林的林下植物的生物量中贮存的养分量大于同龄次生林，而根系中贮存的养分量小于后者。次生林根系发达的特点有利于其从土壤中吸收养分。与人工林相比，次生林的养分循环速率快，凋落物的养分周转快，而人工林在叶凋落前比次生林有更多的养分回流。Montagnini等对巴西的25年生次生林和原始森林的土壤状况进行了研究，发现次生林的土壤pH、C、N、P、Ca、Mg含量比原始森林的土壤高。次生林的凋落物量和凋落物中的养分量也大于原始森林[60]。由于次生林中的优势树种的再生长，次生林的土壤状况得到了改善。

热带次生林的养分分配存在一定的规律性：土壤中的N和全P总量通常高于植被和凋落物的N和全P总量，而与土壤类型、厚度及林龄的差异无关，但土壤有效P少于植被和凋落物的有效P。随着演替年限的增加，微生物的数量、土壤呼吸作用强度、土壤酶的活性以及纤维素分解强度均呈增加趋势，说明演替改善了土壤的物理、化学和生物学状况，提高了土壤的活力[2]。

12 热带次生林的土壤

林地的土壤状况是影响先锋树种成林的重要因素。在伐林或被火烧之后,森林土壤的性质发生很大的变化。一个显著的影响就是土壤结构的破坏,这可以从土壤容重的增大和孔隙的减少得到证明。土地的转化过程中也发生了一系列化学变化,但这些过程的规律却很难归纳。土壤有机质减少对土壤是不利的,因为这种有机质能聚合土壤,增加土壤持水能力,为土壤分解者提供能量,并通过保持营养的有机形式和增强阳离子交换能力而影响了土壤肥力。氮在次生林演替中损失的可能性很大[61]。在皆伐过程中,氮由于生物量的转移、燃烧时的挥发、反硝化和淋溶而受到损失。然而砍伐森林后土壤 N 的含量有可能增加。例如,对哥斯达黎加的雨林进行砍伐和炼山后,NO_3和 NH_4含量增加到远比附近林地高的水平,并持续保持 6 个月之久。次生植被发展过程中土壤中的养分通过 3 种途径来保持养分平衡:①生物量中营养的贮藏;②生物量的转化和分解生物使土壤营养增加;③根系吸收淋溶的营养物质。许多研究表明,林地的土壤养分随林龄的增加而逐渐增多[62]。土壤恢复到以前功能的过程随森林类型的不同而异[63]。例如,从牧区发育而来的次生林的恢复过程要远远快于从农业用地发育而来的次生林。以前是农业用地的次生林地贮存的养分要比生长在其他用地上的次生林地要丰富[59]。尽管有这些差异,一旦植物开始定居,各种林地植物的反馈作用将加速土壤功能的恢复。

13 结论和建议

人口增长、工业迅速发展和大规模的基础设施建设引起大面积的森林破坏,包括集中采伐、开矿、林地转变成人工林和农业用地、修建水坝、道路和其他基础设施而引起的破坏。原始森林的面积随着采伐、火灾和转变为其他用途的土地而急剧减少。次生林的数量和相对面积倾向于增加。作为热带林重要组成部分的次生林,近年来已经受到国际社会的广泛关注。热带次生林正在成为一个新的研究热点。有关次生林的生态学、造林学和社会经济学知识已达到一定程度,森林恢复、更新和次生林管理的研究也正在增多。然而,热带次生林研究的重点在基础研究,特别是生态方面,而森林培育和管理的论文较少,而且关于生物和社会进程联系的研究很少。虽然存在一些热带次生林管理的例子,但没有统一的管理模式,而且已有经验也没有在政策中得到体现。然而热带次生林的管理不仅要考虑森林的生物特征,还要考虑它们的社会背景和经济特征。我们需要考虑新的和正在形成的生态计划,通过这些计划有效地把生态过程和社会过程相联系。为了实现现存自然资源的有效管理,我们还需要更加完整的方法用于次生林的研究。从基础和应用的角度看,砍伐后的森林恢复过程仍然是现在的研究重点[2,56,64]。研究者对生长中的树林结构特征(例如胸高断面积、生物量、树种丰富度以及树种组成等)进行过较多的研究,对其功能特征(养分循环、净生产力、林下植物的光环境)也进行过一定的研究。次生林演替的研究重点放在控制演替过程的物种或物种组合方面[65]。持续定位研究少;对微生物、动物或其他非生物因子随森林群落演替的变化研究较少;缺乏对诸如种间关系、物种生态位以及演替过程中植物生理生态学特性的变化等有关演替机理的基础研究,在次生林演替过程中的结构与功能特点几乎没有科学地结合。这些内容有待于在将来的热带次生林研究中取得进展。

参考文献

[1] Fearnside PM, Guimaraes WM. Carbon uptake by secondary forests in Brazilian Amazonia[J]. For Ecol Mgmt,1996,80:35-46.

[2] Lugo AE. Comparison of tropical tree plantation with secondary forests of similar age[J]. Ecol Monogr,1992,62: 1-41.

[3] Chazdon RL, Coe FC. Ethnobotany of woody species in second growth, and selectively logged forests of Northeastern Costa Rica [J]. Conserv Biol,1999,13:1312-1322.

[4] FAO. Forest resources assessment 1990-Survey of tropical forest cover and study of change processes[M]. FAO Forestry Paper 13. Rome. FAO,1996.

[5] Dotzauer H. The potential of secondary forest management from a development policy point of view: An overview[M]//Bittner A, Achtnich W, Atanasiu N, et al. Plant Research and Development 47/48, Tübginen: Institute for scientific Co-operation,1998:79-87.

[6] Thomlinson JR, Serrano MI, del M López T, et al. Land-use dynamics in a post-agriculture Puerto Rican landscape (1936-

1988)[J]. Biotropica, 1996, 28: 525-536.

[7] Creig-Smith P. Ecological observations on degraded and secondary forest in Trinidad, British West Indies. I. General features on the vegetation[J]. Journal of Ecology, 1952, 40: 283-315.

[8] Bartholomen WV, Meyer J, Laudelot H. Mineral nutrient immobilization under forest and grass fallow in the Yangambi (Belgian Congo) region[J]. Publications de L1nstitut National pour LEtude Agronomique du Congo Belge, Série Scientifique, 1953, 57: 27.

[9] Ross R. Ecological studies on the rain forest of Southern Nigeria. III. Secondary succession in the Shasha reserve[J]. Journal of Ecology, 1954, 42: 259-282.

[10] 宋君，王伯荪. 南亚热带常绿阔叶林优势种群的生物量与生物量增量[J]. 生态科学, 1996, 15(2): 1-5.

[11] 彭少麟，方炜. 南亚热带森林演替过程生物量和生产力动态特征[J]. 生态科学, 1995(2): 1-9.

[12] 管东生. 华南南亚热带不同演替阶段植被类型的初级生产力和养分[J]. 生态学杂志, 1996, 15(3): 11-14.

[13] Aide TM, Zimmerman JK, Rosario M, et al. Forest recovery in abandoned cattle pastures along an elevational gradient in Northeastern Puerto Rico[J]. Biotropica, 1996, 28: 537-548.

[14] 蔡锡安，彭少麟. 广州罗岗村边次生常绿阔叶林群落分析[J]. 应用与环境生物学报, 1998, 4(2): 107-114.

[15] Uhl C, Clark K, Clark H, et al. Early plant succession after cutting and burning in the upper Rio Negro region of the Amazon basin[J]. Journal of Ecology, 1981, 69: 631-649.

[16] Young KR, Ewel JJ, Brown BJ. Seed dynamics during forest succession in Costa Rica[J]. Vegetatio, 1987, 71: 157-173.

[17] Raich JW, Gong WK. Effects of canopy openings on tree seed germination in a Malaysian dipterocarp forest[J]. Journal of Tropical Ecology, 1990, 6: 203-217.

[18] Aide, TM, Cavelier J. Barriers to lowland tropical forest restoration in the Sierra Nevada de Santa Marta[J]. Colombia. Restoration Ecol, 1994, 2: 219-229.

[19] Dupuy JM, Chazdon RL. Long-term effects of forest regrowth and selective logging on the seed bank of tropical forests in NE Costa Rica[J]. Biotropica, 1998, 30: 223-237.

[20] Parrotta JA. Secondary forest regeneration on degraded tropical lands: The role of plantations as 'foster ecosystems[M]//Lieth H, Lohmann M (eds). Restoration of Tropical Ecosystems. Kluwer, Dordrecht, 1993: 63-73.

[21] Nepstad DC, Uhl C, Pereira CA, et al. A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia[J]. Oikos, 1996, 76: 25-39.

[22] Holl KD, Lulow ME. Effects of species, habitat, and distance from edge on post-dispersal seed predation in a tropical rain forest[J]. Biotropica, 1997, 29: 459-468.

[23] Kellman MC. Secondary plant succession in tropical montane Mindanao[M]. Australian National University Publication BG/2. Canberra: Australian National University, 1970.

[24] Guariguata MR, Chazdon RL, Denslow JS, et al. Structure and floristics od secondary and old-growth forest stands in lowland Costa Rico[J]. Plant Ecol, 1997, 132: 107-120.

[25] Laska MS. Structure of understory shrub assemblages in adjacent secondary and old growth tropical wet forests, Costa Rica[J]. Biotropica, 1997, 29: 29-37.

[26] Kochummen KM, Ng FSP. Natural plant succession after farming in Kepong[J]. The Malaysian Forester, 1977, 40: 61-78.

[27] Uhl C, Buschbacher R, Serrao EAS. Abandoned pastures in eastern Amazonia. I. Patterns of plant succession[J]. Journal of Ecology, 1988, 76: 663-681.

[28] Cain MD, Shelton MG. Secondary forest succession following reproduction cutting on the Upper Coastal Plain of southeastern Arkansas, USA[J]. For Ecol Mgmt, 2001, 146: 223-238.

[29] Denslow JS, Guzman S. Variation in stand structure, light, and seeding abundance across a tropical moist forest chronosequence, Panama[J]. J Veg Sci, 2000, 11: 201-212.

[30] Toky OP, Ramakrishnan PS. Secondary succession following slash-and-burn agriculture in north-eastern India. I. Biomass, litterfall and productivity[J]. Journal of Ecology, 1983, 71: 735-745.

[31] Ramakrishnan PS, Kushwaha SPS. Secondary forests of the Himalaya with emphasis on the north-eastern hill region of India [J]. Journal of Tropical Forest Science, 2001, 13: 727-747.

[32] Vester HFM, Cleef AM. Tree architecture and secondary tropical rain forest development: a case study in Araracuara, Colombian Amazonia[J]. Flora Jena, 1998, 193: 75-97.

[33] Finegan B. Pattern and process in neotropical secondary rain forest: the first 100 years of succession[J]. Trends Ecol Evol, 1996, 11: 119-124.

[34] Olander LP, Scatena FN, Silver, WL. Impacts of disturbance initiated by road construction in a subtropical cloud forest in the Luquillo Experimental Forest, Puerto Rico[J]. Forest Ecology and Management, 1998, 109: 33-49.

[35] Guariguata MR. Early response of selected tree species to liberation thinning in a young secondary forest in Northeastern Costa Rica[J]. For Ecol Mgmt, 1999, 124: 255-261.

[36] Putz FE. Treefall pits and mounds, buried seeds, and the importance of soil disturbance to pioneer trees on Barro Colorado Island[J]. Panama. Ecology, 1983, 64: 1069-1074.

[37] Zimmerman JK, Aide TM, Rosario M, et al. Effects of of land management and a recent hurricane on forest structure and composition in the Luquillo Experimental Forest, Puerto Rico[J]. Forest Ecology and Management, 1995, 77: 65-76.

[38] Rivera LW, Aide TM. Forest recovery in the karst region of Puerto Rico[J]. Forest Ecology and Management, 1998, 108: 63-75.

[39] Parrotta, JA, Turnbull, JW, Jones N. Catalyzing native forest regeneration on degraded tropical lands[J]. Forest Ecology and Management, 1997, 99: 1-7.

[40] Otsamo R. Early development of three planted indigenous tree species and natural understorey vegetation in artificial gaps in an Acacia mangium stand on an Imperata cylindrica grassland site in South Kalimantan, Indonesia[J]. New Forests, 2000, 19: 51-68.

[41] Oberhauser U. Secondary forest regeneration beneath pine (*Pinus kesiya*) plantations in the northern Thai highlands: a chronosequence study[J]. Forest Ecology and Management, 1997, 99: 171-183.

[42] Perera GAD. The secondary forest situation in Sri Lanka: a review[J]. Journal of Tropical Forest Science, 2001, 13: 768-785.

[43] Kartawinata K, Riswan S, Gintings AN, et al. An overview of post-extraction secondary forests in Indonesia[J]. Journal of Tropical Forest Science, 2001, 13: 621-638.

[44] Kwok HK, Corlett RT. The bird communities of a natural secondary forest and a *Lophostemon confertus* plantation in Hong Kong, South China[J]. For Ecol Mgmt, 2000, 130: 227-234.

[45] Leak WB. Secondary forest succession in New Hampshire, USA[J]. Forest Ecology and Management, 1991, 43: 69-86.

[46] Corlett RT. Plant succession on degraded land in Singapore[J]. J Trop Ecol, 1991, 4: 151-161.

[47] Johnson CM, Zarin DJ, Johnson AH. Post-disturbance aboveground biomass accumulation in global secondary forests: climate, soil texture, and forest type effects[J]. Ecology, 2000, 81: 1395-1401.

[48] Nepstad DC, de Carvalho CR, Davidson EA, et al. The role of deep roots in the hydrological and carbon cycles of Amazonian forests and pastures[J]. Nature, 1994, 372: 666-669.

[49] Harcombe PA. The influence of fertilization on some aspects of succession in a humid tropical forest[J]. Ecology, 1977, 58: 1375-1383.

[50] Herrera B, Finegan B. Substrate conditions, foliar nutrients and the distributions of two canopy tree species in a Costa Rican secondary rain forest[J]. Plant and Soil, 1997, 191: 259-267.

[51] Dennis R, Hoffmann A, Applegate G, et al. Large-scale fire: creator and destroyer of secondary forests in Western Indonesia [J]. J Trop For Sci, 2001, 13: 786-799.

[52] Ashton MS, Gunatilleke CVS, Singhakumara BMP, Gunatilleke. Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models[J]. For Ecol Mgmt, 2001, 154: 409-430.

[53] Cuevas E, Brown S, Lugo AE. Above-and belowground organic matter storage and production in a tropical pine plantation and a paired broadleaf secondary forest[J]. Plant and Soil, 1991, 135: 257-268.

[54] Cavelier J, Estevez J, Arjona B. Fine root biomass in three successional stages of an Andean cloud forest in Colombia[J]. Biotropica, 1996, 28: 728-736.

[55] Brown S, Lugo AE. Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon[J]. Interciencia, 1992, 17: 8-18.

[56] Brown S, Lugo AE. Tropical secondary forests[J]. J Trop Ecol, 1990, 6: 1-32.

[57] Yoneda T, Kohyama T, Hotta M. Successional changes of structure and productivity of tropical secondary forest stands after clear cutting in West Sumatra[J]. Indonesia Tropics, 1998, 8: 357-375.

[58] McDonald MA, Healey JR. Nutrient cycling in secondary forests in the Blue Mountains of Jamaica[J]. For Ecol Mgmt, 2000, 139: 257-278.

[59] Johnson CM, Vieira ICG, Zarin DJ, et al. Carbon and nutrient storage in primary and secondary forests in eastern Amazô nia [J]. For Ecol Mgmt, 2001, 147: 245-252.

[60] Montagnini F, Fanzeres A, Vinha SGD. The potentials of 20 indigenous tree species for soil rehabilitation in the Atlantic forest region of Bahia, Brazil[J]. Journal of Application Ecology, 1995, 32: 841-856.

[61] Vitousek PM, Matson PA, Van Cleve K. Nitrogen availability and nitrification during succession: primary, secondary, and old-field seres[J]. Plant and Soil, 1989, 115: 229-239.

[62] Silver WL, Scatena FN, Johnson AH, Siccama TG, Watt F. At what temporal scales does disturbance affect belowground nu-

trient pools[J]. Biotropica, 1996, 28: 441-457.

[63] Neill C, Melillo JM, Steudler PA, et al. Soil carbon and nitrogen stocks following forest clearing for pasture in the southwestern Brazilian Amazon[J]. Ecol Appl, 1997, 7: 1216-1225.

[64] Holl KD. Factors limiting tropical rain forest regeneration in abandoned pasture: seed rain, seed germination, microclimate, and soil[J]. Biotropica, 1999, 31: 229-242.

[65] Finegan B. The management potential of neotropical secondary lowland rain forest[J]. For Ecol Mgmt, 1992, 47: 295-321.

中国热带次生林分布、类型与面积研究*

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Studies on the Distribution, Types and Area of the Tropical Secondary Forests in China

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Abstract　This paper expounded the distribution, types and area of the tropical secondary forests in China through analyzing the management and statistics materials of China's tropical forests and field investigation results during the project implementation. The China's tropical forests mainly distributes in Guangdong, Hainan, Guangxi, Yunnan, Taiwan and some parts of Fujian and Tibet, including 124 counties or cities and part areas of 50 counties or cities. According to the authorized statistics, the tropical woodland area of China (except for Taiwan) is 11.256 6 millions hm^2, among which 10.744 9 millions hm^2 are woodland and the area of secondary forests is 5.44 millions, accounting for 48.33% of the area of China's tropical forests and 50.63% of the area of woodland in China. The actual areas of China's tropical woodland and secondary forests are 6% higher than these estimated, because the forest vegetation especially tropical forest vegetation was recovered quickly in recent years, since the Chinese government laid emphasis on forestry construction. The major types of China tropical forests are: tropical rain forest (including humid rain forest and mountain rain forest); tropical seasonal rain forest (including half-evergreen seasonal rain forest, deciduous seasonal rain forest, limestone seasonal rain forest); south sea coral island vegetation; coast mangrove. From the view of forest management, the China's tropical secondary forests can be divided four types: (1) secondary broadleaved forests, including secondary evergreen broadleaved rain forest, secondary seasonal rain forest and secondary monsoon evergreen broadleaved forest; (2) shrub-wood; (3) secondary coniferous forests; (4) secondary mangrove and coral vegetation.

Key words　tropical forests, secondary forests, forest area, forest types

摘要　热带林的保护问题已受到世界各国的高度重视,由于占世界热带林面积约三分之一的热带次生林,其经济和生态效益通常较差,处于相对被忽视的状态,因此也往往被进一步破坏。将次生林经营纳入可持续经营的轨道,是实现热带林可持续经营目标的重要战略。通过对中国热带森林研究、经营和统计资料的分析,结合本项目实施过程的实地调研取得的结果,文章对中国热带地区次生林分布、面积和类型作了阐述。热带森林主要分布在海南、广东、广西、云南、台湾,以及福建和西藏的部分地区,包括124个县市的全部和50个县市的部分地区。据可认可的资料统计,中国热带林地面积(不含台湾省)约1 125.66万hm^2。其中有林地面积1 074.49万hm^2,次生林面积544万hm^2。次生林占热带地区林地面积的48.33%,占有林地总面积的50.63%。中国热带林地和次生林的实际数字估计要比这一数值大6%以上,因为中国这几年高度重视林业建设,森林植被特别是热带森林植被恢复得很快,林地和次生林一直在不断增加。热带森林类型主要

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有：热带雨林（包括湿润雨林、山地雨林）；热带季雨林（包括半常绿季雨林、落叶季雨林、石灰岩季雨林）；南海珊瑚岛植被；海岸红树林等。从森林经理的角度，中国热带次生林的类型可分为：(1)次生阔叶林，包括次生常绿阔叶雨林、次生季雨林和次生季风常绿阔叶林；(2)次生灌木林；(3)次生针叶林；(4)次生红树林及次生珊瑚岛林等四大类型。

关键词 热带森林 次生林 森林面积 森林类型

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中国是世界上热带森林分布面积较大的国家，有林地面积（不含台湾）约1 074.49万hm^2，居世界各国的第18位[1-2]。除海南岛及云南省南部尚存少量原始森林之外，天然林均为次生林及残次林，而且大部分都是封山育林所形成的植被。ITTO PD 39/98 Rev.2(M)“中国热带森林资源价值核算及纳入国民经济核算体系的研究”项目曾对热带森林面积做过统计，但没有对次生林情况进行专门研究。长期以来，中国由于经济的不发达、人口高速增长，热带森林资源受到人为的破坏情况严重，资源不断退化、物种日益减少。占有林地面积50.63%的热带次生林，生产力低，生物多样性日趋贫乏，且往往反复遭受破坏或林地被改作它用。因此，有必要通过调研的方法对热带次生林分布、类型与面积等基本情况进行了解，并在此基础上开展旨在提高和生态效益的次生林经营研究。这对一个次生林面积大，人口多且密度大，经济又仍然比较落后的国家来说，不但是热带林保护和发展的重要步骤，而且是对众多林区居民生存需求至关重要的事情。

1 调研方法

按照PPD30/01(F)预项目工作计划，调研工作采用文献分析、实地调查等方法[3]。在此基础上形成了项目规定产出的基本观点。

文献资料收集：从2002年5月开始，通过互联网、北京的国家图书馆、中国林科院、广州的中山图书馆、广东省林业科学研究院、华南农业大学图书馆和中国科学院华南植物研究所等广泛收集有关热带次生林的资料。共收集国内外出版物27本，文献1 045篇，以及政府相关的文件和林业生产部门的情况报告等。

外业调查：于2002年6～10月多次组织专家组到广东、海南、广西和云南等进行实地调查，采用调查访问和重点典型观察相结合的方法。一是访问以上四省区省林业行政、研究、勘探设计等部门，以及典型的热带次生林地区；二是实地观测调查。调查的典型和重点地区包括：广东新会国营古兜林场干扰后的沟谷雨林，鹤山的封山育林，肇庆的石灰岩次生林，云浮的农耕退化地，以及连平、和平的集体林地等；海南通什和三亚等地的封山育林；广西百色和凭祥的“石漠化”山地植被恢复；云南西双版纳的“刀耕火种”山地植被恢复。林地调查的方法有实地观测和标准样地调查，内容主要包括：次生林类型，物种组成、演替阶段、经营和管理措施、生态和经济效能等。此外还结合专题分析工作，到一些地方进行了补充性调研。

座谈讨论：召开了多次规模不等、时间不一的专家座谈会，主要是有关中国热带次生林的类型、现状、经营技术和面临的问题等。

2 中国热带地区和热带森林

2.1 中国热带地区

中国的热带区域，自20世纪50年代就开始研究，包括气象、地理、土壤、植被和林业等不同学科的学者，提出不同的划分标准或划分界线。但植被分布（天然的和引种的）仍然是各学科遵循的主要划分原则，因为植被分布综合反映了气候、土壤、地形地势和地理位置状况。一般而言，热带亚热带界限并不是一条几何学上的曲线线段，因为气候带之间有若干宽度的过渡地带[1-2]。我们采纳中国几位权威植物学家（如侯学煜）和林学家（如吴中伦），以及权威著作如《中国植被》、《中国森林》、《中国林业区划》、《中华人民共和国植被图》等的观点，确认北界大致变动于北纬21°～24°之间（但在西藏东南部河谷的局部地段达到北纬28°～29°）；东部从东经123°附近，至西部东经86°地区（即西藏东南部的亚东、聂拉木附近）。范围包括：海南岛全岛和南海诸岛，台湾全岛，广东及广西北回归线以南地区，云南北回归线以南地区，福建南端及南部沿海，以及西藏东南部的雅鲁藏布江下游流域。共包括124个完整县市，及50个县市的部分地区，区域总面积为3 080.53万hm^2，约占全国总面积的3.2%左右（见图1，表1）。但是，北界线在广东的中东部因受寒潮的影

响而南移；在广西的南部，由于东南季风北上，其北界北移至北纬24°左右；在福建东南部，因受海洋的影响，热带北界北移至北纬26°左右，即纬度与台湾北端齐平的沿海地区；云南因受印度洋西南季风和孟加拉湾暖流影响，热带植被从滇东南至滇南北纬23°30′～23°，向滇西南逐渐北移到北纬25°；西藏的东南部，因西南季风所带来的印度洋暖湿气流受到喜马拉雅山的阻挡，形成了丰富的水、热环境，使热带植被分布的北界抵达北纬28°～29°，即察隅、墨脱、达旺以南和亚东、聂拉木一带[4-6,8]。应当说明，GIS和GPS技术的应用不算成功，主要是由于上述划界问题[9]。图1仅供参考。

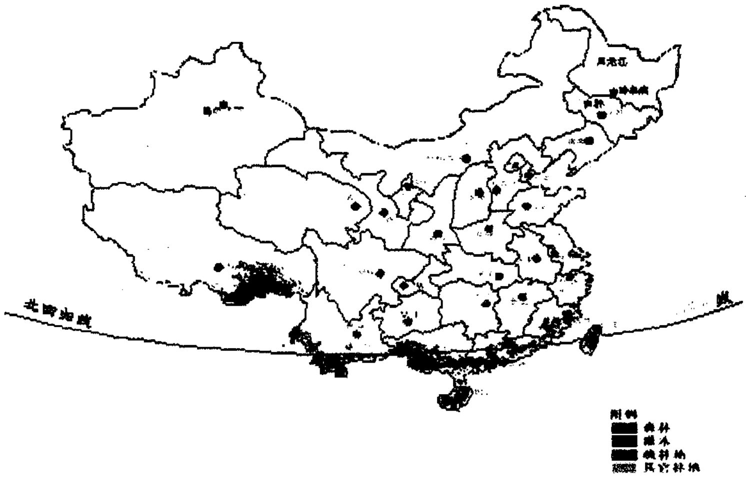

图1　中国热带林地分布

表1　中国热带区域的市区分布

省区	完整的县(市)	不完整的县(市)
广东	潮州市的湘桥、潮安、饶平(区、县、市，下同)；汕头市的潮阳、澄海、南澳；揭阳市的榕城、普宁、揭东、揭西、惠来；汕尾市的城区、陆丰、陆河、海丰；惠州市的惠城、大亚湾、惠阳、惠东、博罗、龙门；深圳市；东莞市、中山市、珠海市的香洲、斗门；广州市的白云、番禺、花都、从化、增城；佛山市的顺德、南海、高明、三水；肇庆市的鼎湖、高要、四会；江门市的蓬江、江海、台山、新会、开平、鹤山、恩平；阳江市的江城、海陵、阳春、阳西、阳东；茂名市的茂南、水东、信宜、高州、化州、电白；湛江市的东海、坡头、麻章、廉江、吴川、雷州、遂溪、徐闻；省属国营林业局(林场)；省农垦局、雷州林业局等16个市的80个单位。	
广西	那坡县、靖西县、德保县、天等县、隆安县、大新县、龙州县、宁明县、崇左县、扶绥县、凭祥市、南宁市区、南宁市郊区、邕宁县、武鸣县、北海市区、合浦县、防城港市区、港口区、防城区、上思县、东兴市、钦州市区、钦南区、钦北区、灵山县、浦北县、博白县、陆川县。	百色市、田阳、田东、平果、上林、宾阳、横县、玉州区、兴业、福绵区、北流市。
福建	长乐、福清、平潭、安南、晋江、惠安、泉州、漳州、长泰、南靖、平和、龙海、漳浦、云霄、东山、厦门、同安、诏安。	罗源、连江、福州、永泰、莆田、仙游、永春、安溪、华安、龙岩、永定。
海南	全岛及南海诸岛。	
滇南	德宏傣族景颇族自治州、龙陵县、镇康县、耿马傣族佤族自治县、沧源佤族自治县、西盟佤族自治县、澜沧拉祜族自治县、孟连傣族拉祜族佤族自治县、思茅市、江城哈尼族彝族自治县、西双版纳傣族自治州、绿春县、元阳县、金平苗族瑶族傣族自治县、河口瑶族自治县、屏边苗族自治县、马关县、麻栗坡县、富宁县、元江哈尼族彝族傣族自治县。	
西藏	察隅、墨脱、达旺以南的雅鲁藏布江下游流域及亚东、聂拉木一带。	
台湾	(全省)	

2.2 中国热带森林

2.2.1 中国热带森林面积 据上述热带地区的划分，结合其他数据来源判断，中国有热带林地面积1 125.66 万 hm^2，其中有林地 1 074.49 万 hm^2。在有林地面积中，天然林总面积为 607.38 万 hm^2，人工林面积467.11 万 hm^2，总蓄积约6.6 亿 m^3（表2）。

表2 中国主要热带林区森林资源分布情况 单位：万 hm^2

省（区）	林业用地面积	有林地面积			林木蓄积（万 m^3）
		总面积	天然林	人工林	
海南省	181.52	146.80	61.08	85.72	9028.5
云南热带林区	242.98	234.80	176.60	58.20	2144.6
广东热带林区	383.04	306.57	137.50	169.07	9000.0
广西热带林区	395.85	240.16	128.87	111.29	8455.7
福建热带林区	159.89	118.46	75.63	42.83	2461.5

此外，西藏热带林区主要分布在喜马拉雅山东部的南侧、雅鲁藏布江下游。分布海拔在 500 ~ 1 100 m，均处陡峭河谷底部或低山地段，年均温 20.0 ~ 25.5℃左右，东喜马拉雅山南侧峡谷地带年降雨量达 4 494 mm。主要为热带湿润雨林，少量为半常绿季雨林。具体面积估计不会超过 0.7 万 hm^2。台湾森林面积约为 210.24 万 hm^2，森林覆盖率 58.53%。主要为半常绿季雨林、落叶季雨林、山地雨林等。尚有南海诸岛的珊瑚礁和粤、桂、琼、闽、台湾省沿海海岸红树林，估计总面积在 5 万 hm^2 以内。在红树林面积中，海南面积为 0.5 万 hm^2，广西 0.96 万 hm^2，广东 1.47 万 hm^2。

因为无法在有限的时间里进行如此大规模的调查，所以本面积数据以经林业部资源司官方认可的 1999 年由侯元兆、庄作峰等人统计的为基础（中国第 5 次森林资源清查没有单独统计热带森林资源）。由于统计的时差关系，数据不一定很准确，但毕竟是经官方认可的最新数据。

事实上，目前中国热带森林实际面积要比上述的大。因为侯元兆、庄作峰等人统计的数据来源于第 4 次森林资源清查（1989 ~ 1993 年）（为一般性的资料调查后调整得出的结论：热带林地面积为 1 187.3 万 hm^2，有林地面积为 952.56 万 hm^2。据 2000 年中国政府出版的中国林业发展报告公布[14]，中国第 5 次森林资源清查（1994 ~ 1998 年）的森林面积比第 4 次平均提高了 18.7%。热带地区的森林面积在近年来提高得更快，如广东在 1985 ~2000 年的十五年时间里，有林地面积增加了 1.02 倍，这是近年中国重视林业建设取得的成果。

2.2.2 中国热带森林类型 中国的热带区域位于地球热带北缘，热带林类型比较丰富。主要有：热带雨林，包括湿润雨林和山地雨林；热带季雨林，包括常绿季雨林、半常绿季雨林、落叶季雨林和石灰岩季雨林；海岸红树林和南海珊瑚岛植被[5-6,11-13,15]。在各省（区）的具体分布如下。（1）海南中部和东部为热带雨林、常绿季雨林和山地雨林，北部为半常绿季雨林，西部为落叶季雨林和热带稀树草原。珊瑚岛植被主要为热带珊瑚岛常绿林，有乔木林，也有灌木林。植被类型比较独特，但植物区系相对简单。（2）云南南部的热带林区，因受孟加拉湾暖流影响，包括了湿润雨林、季雨林、半常绿季雨林、石灰岩季雨林和山地雨林等各种类型。（3）粤、桂、闽热带林区，主要包括广东、广西北回归线以南地区，及福建东南沿海至北纬 26°的地区。该地区是台风的主要登陆地区，天然林主要类型是半常绿季雨林、石灰岩季雨林等，植被特色要逊于海南和滇南，有时也被称为“季风常绿阔叶林”。（4）西藏的热带森林类型主要为热带湿润雨林，少量为半常绿季雨林。西藏热带林成孤立片状，分布在喜马拉雅山东部陡峭河谷底部，具体面积估计不会超过 0.7 万 hm^2。这些地区年均温 20.0 ~ 25.5℃左右，年降雨量甚至达 4 494 mm（东喜马拉雅山南侧峡谷地）。（5）台湾主要为半常绿季雨林、落叶季雨林和山地雨林等。（6）南海诸岛有珊瑚礁植被，粤、桂、琼、闽和台湾省沿海海岸有红树林。

3 中国热带次生林

3.1 次生林的定义

国内外对次生林有多种定义，这些定义都有共同的原则，就是自然发育于受干扰破坏后的原始森林植被或人工林，但也有其不同之处[1,7,10-11,14,16-17]（表3）。

表3 热带次生林的定义

项目	定义	相同点	区别
ITTO(2002)	在热带原始森林植被遭受破坏后形成的裸露土地上（剩余原始植被在10%以下）重生出来的林木植被。这种次生植被是以自然的方式，在游垦农业、永久农业、牧业或造林不成功的林地上，自然地进行着发育和演替。	次生林是原始林或人工林受干扰破坏后，包括自然灾害和人为的，自然地发育和演替形成林木植被。	源于原始林或人工林受干扰破坏的程度。
Sist et al(1999)	森林覆盖的90%被人为或自然因素破坏后重新恢复的木本植被。		
中国林业词典(1994)	原始林或人工林，经人为或自然因素的破坏之后，未经人为的合理经营，借助自然力量恢复起来的一种天然林。		

表3可见ITTO和Sist et al都认为，次生林源于90%以上的原始森林植被或人工林受破坏后形成的植被。而中国，没有提出受干扰破坏的程度。

总结国内外多数学者对次生林的定义，结合本项目对中国热带森林的调查研究。我们认为，衡量次生林应当依据其现有森林植被的林学特性和建群树种。如果其林学特性和建群树种脱离了原始林被或人工林特点，而成为一种新的状态，那么它就划分为次生林。因此认为：次生林是原始林和人工林在较大程度上经人为或自然因素破坏后，以天然更新和自然发育为主，在林学特征和种群结构上失去原有植被特点的森林类型。以及人工造林不成功的林地上通过自然的次生演替形成的森林类型。

这明确了：(1)在程度上以失去原有森林的特征为标准；(2)无论是来自轮垦地、农业弃耕地和其他类型的土地，其性质都是一样；(3)以天然更新和自然发育为主，不排除有某种程度上的人为经营活动存在。

3.2 中国热带次生林的形成

根据文献和现场调查分析，我们归纳出如下次生林形成过程（见图2）。

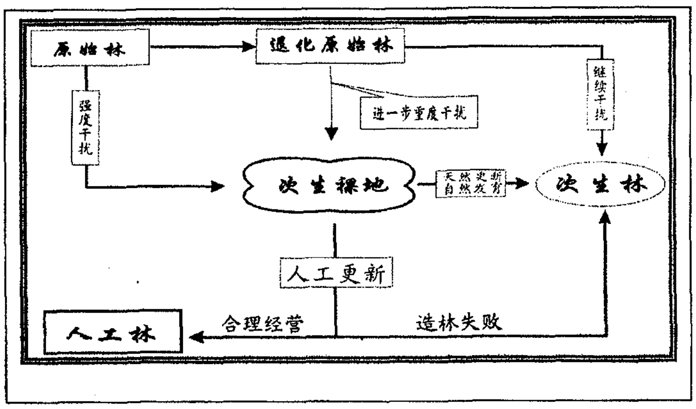

图2 次生林形成过程

图2显示，不同森林类型之间是一个动态变化的过程。原始林在各种因素干扰下，可形成退化的原始林、退化林地、次生林、人工林等。次生林通过良好的封育管理，经过充分长的时间，也完全有能力发育演替到顶极群落，形成接近原始林功能的森林。次生林也可在人为因素作用下，转变为人工林或裸露的土地。中国热带原始林的破坏和其他地带性森林一样，经历了漫长的历史阶段。目前，中国除少量热带原始林外，其他均为次生林和已退化林地[19,23]。

3.3 中国热带次生林和退化林地面积

在中国现有的607.38万 hm^2 热带天然林中，除了海南尚有不足3.4万 hm^2 和云南省南部约有60.00万 hm^2 比较典型的天然林（包括原始林），其余均为次生林。中国热带次生林的总面积约为544万 hm^2，占中国热带地区林业用地总面积的48.33%，占热带地区有林地总面积的50.63%。如2.2.1所述，中国热带次生林的面积实际要比这一数值大。

中国的已退化林地，过去没有精确的统计。因为各省可能将一部分这类土地列入林业用地的规划中，更多的这类土地可能没有被列入。以云南为例，据云南省林科院院长张欲农教授的文献，云南热带地区共有各类荒山荒地和疏林地总计332.2万 hm^2（其中疏林地75万 hm^2，灌丛草地200万 hm^2，占云南热带地区总面积的33.9%[12]。再加上近年各省退耕还林，总面积将更为广大。

3.4 中国热带次生林类型的划分原则

热带次生林作为一大类森林类型，与地带、植被以及开发利用的历史相关，同时表现出复杂多样性。如何把它系统归类，是一个复杂的问题。因研究和应用目的的不同，一般有以下几种划分方法[7,10,17-18]：(1) 按次生演替发生的时间，分为早期、中期和晚期次生林；(2) 按经营管理措施，分为抚育型、改造型、利用型和封育型次生林；(3) 按干扰程度，可分为轻度干扰、中度干扰和重度干扰次生林；(4) 按森林自然特征如树种、生态和林型等划分的次生林类型；(5) 按起源划分，如灾后形成的次生林、伐后形成的次生林（损毁的原始林）等；(6) 按地形地貌划分，如广西热带地区的喀斯特次生植被就是中国的一大类型。划分热带次生林的类型，根本目的是在分类的基础上来安排合理经营。对次生林的经营而言，以上任何一种分类方法都不足以满足经营的需要。

3.5 中国次生林主要类型

从方便经营出发，本预备项目以植被类型为主要标志进行划分。这里也暗含了演替阶段的划分原则，结合了中国的情况[18,20-22]。

3.5.1 *次生阔叶林* 这一类型次生林，通常形成于原生林受破坏程度相对较小，且经历了较长的自然更新和发育时间，表现出较强的群落地带性。其主要特点是林分发育已较完善，群落稳定，立木蓄积量较大，能部分采伐利用，生物多样性丰富，各种生态功能已较理想。从经营上来说，这类热带次生林已无需特意经营，问题是采伐利用要特别小心。根据干扰前地带性森林植被特点，可进一步细分为：

(1) 次生常绿阔叶雨林 海南岛的坝王岭、吊罗山、黎母山、五指山等地除原始林之外的天然林，都属此类型。

广东次生常绿阔叶雨林主要分布在阳江、茂名与廉江一线以南的平原、台地和低丘。优势树种有榕树（*Ficus retusa*）、楝树（*Melia azedarach*）、大药树（*Antiaris toxicaria*）、菜豆树（*Radermachera sinica*）、鸭脚木（*Schefflera octophylla*）、蒲桃（*Syzygium jambos*）等。

云南的热带常绿阔叶雨林，主要分布在西双版纳和思茅等地区，代表种是云南龙脑香（*Dipterocarpus tonkinensis*）、毛坡垒（*Hopea molissima*）和隐翼（*Crypteronia paniculata*）等；云南热带山地次生常绿阔叶雨林是雨林向亚热带森林过渡的一种湿润性森林，其林冠平整，散生突出林冠的大树较少，主要优势树种有盆架树（*Winchia calophylla*）、伪含笑（*Paramichelia baillonii*）、葱臭木（*Dysoxylum gobara*）、滇楠（*Phoebe namu*）、鸡毛松（*Podocarpus imbricatus*）、烟斗石栎（*Lithocarpus corneus*）、版纳青梅（*Vatica fleuryana*）、滇木花生（*Madhuca pasquieri*）、云南蕈树（*Altingia yunnanensis*）和刺栲（*Castanopsis hystrix*）等；在山地雨林中，有些肉托果（*Semecarpus reticulata*）、滇楠（*Phoebe nannu*）林受破坏后的迹地上通常被蒙自桦（*Betula alnoides*）、樱桃（*Cerasus pseudocerasus*）、羊蹄甲（*Bauhinia variegata*）等阳性树种，以及萌芽能力强的滇桂木莲（*Manglietia forrestii*）、山韶子（*Nephelium chryseum*）等主要树种占领。

(2) 次生季雨林　主要分布在海南和云南。

海南的次生季雨林早期先锋树种主要有土沉香(*Aquilaria sinensis*)、大沙叶(*Aporosa chiensis*)、红鳞蒲桃(*Syzygium hancei*)、山麻黄(*Trema orientalis*)、白背叶(*Pterospermum heterophyllum*)等,灌木主要有谷木(*Memecylom Ligustrifolium*)、密花树(*Rapanea neriifolia*)和桃金娘(*Rhodomyrtus tomentosa*)。

云南的次生季雨林主要有半常绿或落叶季雨林及石灰岩山地等三种类型,其植物区系主要有楝科(Meliaceae)、桑科(Moraceae)、木棉科(Bombacaceae)、梧桐科(Sterculiaceae)和豆科(Leguminosae)等的一些种类。组成不同森林群落的树种有高山榕(*Ficus altissima*)、毛麻楝(*Chukrasia tabularia*)、铁力木(*Mesua ferrea*)、铁刀木(*Cassia siamea*)、木棉(*Bombax malabaricum*)、华楹(*Albizia chinensis*)、千果榄仁(*Terminalia myriocarpa*)、劲直刺桐(*Erythrina stricta*)、马蹄果(*Protium serratum*)、刺栲、羊蹄甲、四数木(*Tetrameles nudiflora*)、白头树(*Garuga forrestii*)等,高山榕、毛麻楝形成的次生林会形成根系很发达的植株,铁刀木则萌芽能力很强,石灰岩山地由四数木、白头树阔叶季雨林破坏后形成的次生林常为羊蹄甲、一担柴(*Colona floribunda*)等树种为主,并伴生木紫珠(*Callicarpa arborea*)、朴叶扁担杆(*Grewia celtidifolia*)、黄牛木(*Cratoxylun cochinchinensis*)等乔木的落叶季雨林次生林。

(3) 次生季风常绿阔叶林　主要分布于广东、云南和广西。

广东的次生季风常绿阔叶林与海南低、中山次生雨林树种的科属有些接近。由于地形地势、雨量和气温的差异,一般可分为两类:一类是热带北界,即北回归线与北纬21°50′之间低山丘陵生长的次生季风常绿阔叶林;另一类为北纬21°50′以南的丘陵台地生长的次生季风常绿阔叶林。前者的次生植被主要代表树种有青钩栲(*Castanopsis kawakamii*)、长果厚壳桂(*Cryptocarya concinna*)、华南栲(*C. chinensis*)、刺栲、木荷(*Schima superba*)及蒲桃类(*Syzygium*);后者的次生植被主要乔木树种代表有榕树(*Ficus*)、五月茶(*Antidesma bunius*)、伪苹婆(*Sterculia lanceolata*)、亮叶围涎树(*Pithecellobium lucidum*)、黄桐(*Endospermum chinensis*)、刺栲、石斑木(*Photinia pruniforlia*)等。

云南次生季风常绿阔叶林,主要是由栲属(*Castanopsis*)、石栎属(*Lithocarpus*)、黄肉楠属(*Actinodaphne*)、桢楠属(*Machilus*)、木荷属(*Schima*)和茶梨属(*Anneslea*)等属的树种为优势种组成的季风常绿阔叶林破坏后形成的次生林。云南这类森林,多分布于热带区范围较北部和较高海拔处。包括:以刺栲、印度栲(*C. indica*)为优势种,蒺藜栲(*C. tribuloides*)、红木荷(*Schima wallichii*)为次优势种组成形成的次生林,由刺栲、蒺藜栲、湄公栲(*C. mekongensis*)、杯状栲(*C. calathiformis*)和山油柑(*Acronychia pedunculata*)和茶梨(*A. fragrans*)等乔灌萌芽林为主,如果再次破坏,会演化为思茅松林或灌丛,这类演替在滇西南容易见到;以小果栲(*C. fleuryi*)、截果石栎(*L. truncatus*)、罗浮栲(*C. fabrii*)、杯状栲为优势种组成的季风常绿阔叶林,形成的次生林由栎类和杯状栲等萌芽力强的树种为主,这类森林主要分布在滇中南和东部;以蒙自桦为主形成的次生林,由于其种子小、易飞散、萌发力强,天然更新良好,还具极强的萌生能力,能依靠其自身力量恢复,并常与杯状栲、南酸枣(*Choerospondias axillaris*)、檫木(*Sassafras tzumu*)、红木荷、山龙眼(*Helicia formosana*)等混生。

广西次生季风常绿阔叶林的主要优势树种有厚壳桂(*C. chinensis*)、黄果厚壳桂(*C. concinna*)、厚叶琼楠(*Beilschmiedia pergametaeca*)、猪脚楠(*Machilus thunbergii*)、米椎(*Castanopsis carlesii*)、刺栲、华南栲、罗浮栲(*C. fabri*)、红木荷、藜蒴栲(*C. fissa*)、南酸枣、鸭脚木、毛阿芳(*Alphonsea mollis*)、樟等组成主林层。主要分布在桂南北面的大瑶山和莲花山、镇龙山、大明山一带,以及南部的六万大山、十万大山、大古山和公母山等地。

3.5.2　*次生灌木林*　在干扰较为严重,以及恢复时间较短地区,形成以灌木林为主的植被,也称为次生灌木林。其主要群落及特点如下:

(1)云南东南、西南和南部,低海拔和沿河流峡谷的森林被过度破坏后形成的次生灌木林,树种组成主要有糙叶水锦树(*Wendlandia scabra*)、云南银柴(*Aporosa yunnanensis*)、降真香(*Acronychia pedunculata*)、谷木(*Menecylon ligustrifolium*)、光叶山柑子(*Glycosmis craibii* var. *glabra*)、黄牛木、中平树(*Macaranga denticulate*)、银叶巴豆(*Croton kongensis*)、椴叶山麻杆(*Alchornea tiliaefolia*)、大叶紫珠(*Callicarpa macrophylla*)、毛桐(*Mallotus barbatus*)、白背叶(*Mallotus apeltus*)、蒲桃(*Syzygium jambos*)等,河溪旁的灌木还有虾子花(*Woodfordia fruticosa*)、金合欢(*Acacia farnesiana*)等。

（2）广西热带地区分布面积较大的是石灰岩稀疏灌木林（喀斯特地貌植被），常见且组成树种有木奶果（*Baccaurea ramiflora*）、番荔枝（*A. squamosa*）、海南大风子（*H. hainanensis*）、火焰花（*Phlogacanthus curviflorus*）、菜豆树、山合欢（*Acacia kalkora*）、石山山竹子（*Garcinia bracteata*）、厚叶琼楠（*Beilschmiedia pergamentacea*）、硬叶樟（*C. calcarea*）、石山樟（*C. saxatile*）、伪苹婆等。

3.5.3 次生针叶林 这是中国最典型的一种次生林类型，特别是在广东、广西和福建地区，是原生植被完全破坏后由种子飞散容易、生长能力强的树种形成，典型的树种为马尾松。主要有以下几种类型：

（1）次生马尾松（*Pinus massoniana*）林 在广东、广西和福建所占面积最大，约占总面积的40%左右。特点是林相极不整齐，疏密、大小不一，林分质量和生长量低。林下的灌木草本，在近热带北界山地丘陵地带主要是桃金娘、柃木（*Eurya japonica*）、算盘子（*Glochidion puberum*）、岗松（*Baeckea frutescens*）、牡丹（*Paeonia suffruticosa*）、芒萁（*Dicranopteris dichotoma*）、野牡丹（*Melastoma cadidum*）及毛鸭咀草（*Ischaemum ciliare*）等；在平缓低丘至南部滨海是马尾松分布边缘，生长差，早衰，林下灌草还有蜈蚣草（*Eremochloa ciliaris*）及鹧鸪草（*Eriachne pallescens*）等。

（2）次生杉木（*Cunninghamia lanceolata*）林 主要分布在广东、广西和福建，多生长于水分和养分较充足的中下坡和沟谷地带，面积相对较小。

（3）次生针叶混交林 广东、广西和福建一般以马尾松为主，也有杉木和其他阔叶树种，同时伴生有桃金娘、柃木、算盘子、岗松、牡丹、芒萁、野牡丹及毛鸭咀草等林下灌木。

（4）其他次生针叶林 广西的防城港市东南部还有小面积的南亚松（*P. latteri*），它与红鳞蒲桃、九节（*Psychotria rubra*）、伪鹰爪（*Desmos chinensis*）、桃金娘、芒穗鸭咀草（*Ischaemum aristatum*）等组成次生群落。云南的针叶次生林主要是在季风常绿阔叶林被破坏后，被思茅松占据形成纯林，或与小果栲、红木荷、麻楝（*Chukrasia tabularis*）、喜树（*Comptotheca acuminata*）等组成混交林。

3.5.4 次生红树林及次生珊瑚岛林 中国热带地区天然红树林主要类型有秋茄（*Kandelia candel*）林、木榄（*B. gymnorhiza*）林、桐花树（*Aegiceras comzicutatum*）林、白骨壤（*Avicennta marina*）林，及由这些红树林种类组成的混生林。由于受到长期反复地破坏，80%的现存红树林都是低质量、低功能的次生林。

热带珊瑚岛常绿次生林主要由以麻疯桐（*Pisonia grandis*）、海岸桐（*Guettarda speciosa*）和草海桐（*Scaevola sericea*）为优势种，群落由裸露珊瑚沙地，经草本植物群落、灌木群落而演变成常绿林群落。林分高8～10 m，最高达14 m，林冠茂密。林下灌木有海巴戟（*Morinda citrifolia*），多数为萌生林。

4 结论

4.1 中国热带次生林面积大，占中国热带地区有林地总面积的50.63%。

4.2 由于中国热带地区地处热带北沿，因受北方寒流影响，在热带区内镶嵌有亚热带植物区系的成分，加上热带北界曲折复杂的地理成分变化和东西部的气候差异。因此，具有典型的过渡性、镶嵌性，这是世界其他地区所没有的。

4.3 原生林类型多，物种丰富，拥有中国物种总数的1/3到1/2，生态系统类型的25.8%。

4.4 由于次生林受到的持续干扰破坏时间长，大部分次生林树种结构单一，林分质量差、林分质量不高，普遍处于次生演替的初期阶段。每公顷平均蓄积量不足70 m^3，为世界平均水平的60%左右。特别是在广东和广西地区。

4.5 无论从生态、经济和社会角度看，中国的热带次生林主体上是处于一个敏感、脆弱的时期。

参考文献

[1] 陈大珂，周晓峰，祝宁，等. 天然次生林[M]. 哈尔滨：东北林业大学出版社，1994.
[2] 李国猷. 北方次生林经营[M]. 北京：中国林业出版社，1992.
[3] 曾令海，侯元兆，王洪峰，等. 国际热带木材组织（ITTO）"旨在提高经济和生态效益的热带地区次生林经营研究与示范"

预备项目建议书[R]. 广州,2001.
[4] 中国农业百科全书编辑委员会. 中国农业百科全书:林业卷下卷[M]. 北京:农业出版社,1989.
[5] 广东森林编委会. 广东森林[M]. 广州: 广东科技出版社,1990.
[6] 文焕然. 历史时期海南岛的森林[M]. 广州:中国科学院地理研究所,1982.
[7] 北京林业大学. 造林学[M]. 北京:中国林业出版社,1981.
[8] 张俊红. 中国林业百科全书:第一卷[M]. 吉林:吉林电子出版社,2004.
[9] 侯元兆. 中国热带森林环境资源[M]. 北京:中国科技出版社,2002.
[10] 陈大珂. 天然次生林[M]. 北京: 中国林业出版社,1994.
[11] 陈永富, 杨秀森. 中国海南岛热带天然林可持续经营[M]. 北京: 中国科学技术出版社,2001.
[12] 云南森林编委会. 云南森林[M]. 昆明:云南科技出版社,1999.
[13] 广西区野生动植物保护管理站. 广西植物资源[内部资料]. 2002.
[14] 周晓峰. 中国森林与生态环境[M]. 北京: 中国林业出版社,1999.
[15] 海南省人民政府. 天然林资源保护工程海南省实施方案[R]. 海南:海南林业厅,2001.
[16] 余作岳,彭少麟. 热带亚热带退化生态系统植被恢复生态学研究[M]. 广州: 广东科技出版社,1996:36-51.
[17] 黄枢, 沈国舫. 中国造林技术[M]. 北京: 中国林业出版社,1993.
[18] 周晓峰. 国森林与生态环境[M]. 北京: 中国林业出版社,1999.
[19] 周生贤. 中国可持续发展林业战略研究调研报告[M]. 北京: 中国林业出版社,2002.
[20] 侯元兆. 世界热带林业研究[M]. 北京:中国林业出版社,2001.
[21] 侯元兆. 热带林学——基础知识与现代理念[M]. 北京:中国林业出版社,2002.
[22] 温茂元. 海南热带人工林持续经营[M]. 海南:海南出版公司,2000.
[23] 黄世能. 海南尖峰岭热带山地雨林采伐迹地的次生群落动态[D]. 广州:中山大学,2000.

中国热带次生林生产潜力与经营模式研究*

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Study on the Productivity Potential, Management Models of the Tropical Secondary Forests in China

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Abstract After completing analyses for related data of present status and management of tropical secondary forests in China and field investigation of key regions, we think that tropical secondary forests display good ecological effects in conserving water, holding water and soil and maintaining soil fertility compared to artificial plantations, whereas their functions of absorbing CO_2, releasing O_2 and improving soil are strong and fixing soil and retaining water effects are weak. Because of poor management, timber production ability of secondary forests is low, their mean stem volume per unit area is only 78 m^3/hm^2, being 68% of mean stem volume of forests in the world. Secondary forests of china have relative great ecological and economic potentiality and development space if properly managed. Because Chinese economy, especially its rural economy, is still backward, and it's environmental protection and existence problems are outstanding. Therefore, only choosing the management mode considering both ecological effect and economic effect, can secondary forest protection and sustainable development realized. By 1-year investigation, according to Chinese secondary forest management tradition and present status, we summarized three popular modes, that is the management model of community forest, the management model of rehabilitation and reconstruction of natural forests and the management model of the intercropping of economic plants.

Key words tropical forests, secondary forests, forest management

摘要 在完成对中国热带地区次生林现状、经营情况的相关资料分析和重点地区的实地调查后认为:从目前次生林的生态效益来看,对比人工林,次生林在涵养水源、保持水土、维持地力等方面表现出较好的效益;与原始林比较,次生林在吸收 CO_2 和释放 O_2 和改良土壤的功能相对强,而固土效益和蓄水效益则较低。在经济效益方面,通过样地的调查分析,由于缺乏经营,次生林的木材生产能力相当低,单位面积平均蓄积量约仅78 m^3/hm^2,为世界平均森林蓄积水平的68%左右。通过经营,中国次生林有较大的生态和经济潜力开发空间。由于中国经济仍然比较落后,特别是在农村,环境保护和生存问题都很突出。因此,要保护和发展次生林,只有选择生态和经济效益同时兼顾的经营模式,才能实现其可持续性。通过一年的调研,根据中国的经营传统和结合现实状况,归纳出目前在中国可以普遍推广的三个主要经营模式,即:社区综合经营模式、天然林的恢复与重建模式和经济物种套种经营模式。

关键词 热带森林 次生林 森林经营
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由于经济、人口和生产力相对落后的原因，中国在某些方面至今还未能突破传统的发展模式，林业方面表现尤为突出。林业行业在森林经营方面，依然保留许多传统的观念，以及经营方法和手段，许多方面有待重新审视、调整、改善或更新。中国森林的问题主要是林分质量差，生态系统单调，生物多样性低，经济产出少，森林现有单位面积平均蓄积量仅有 78.06 m^3/hm^2，为世界平均水平的68.5%。在热带次生林方面，我国的热带次生林长期遭受反复地破坏，生态功能差，生物多样性指数低。由于热带次生林经济产出较低，其经营一直得不到重视，不少林分朝着逆向演替。到目前为止，中国热带次生林面积已占全国整个热带森林面积的 1/2 以上(加上已退化林地可能接近于 2/3)。同时，热带地区往往人口稠密、经济滞后，当地居民的生存和发展与热带森林息息相关[1]。因此，加强或改善热带次生林的经营已成为一个急迫而又重大的问题。然而，解决这个问题的关键，是要找到既能保障热带次生林走向正向演替，同时又能使当地居民获得经济收入的有效经营途径。而这却是需要认真解决的课题。针对这个问题，在 ITTO 的资助下，调研了这一世界性难题，其目的是提出热带次生林可持续经营的模式，并通过建立示范区尽快向社会推广。

1 中国热带次生林的现实生产力

中国热带地区的森林资源以次生林为主体。从 20 世纪 50 年代到 70 年代末期，解放后的中国需要经济恢复和发展生产，人口和经济发展面临着巨大压力，人口的快速增长使所需要的食品和生活必需品也成指数增加。从 1949 年到 1981 年 32 年的时间里，人口从 5 亿猛增到 10 亿，翻了一翻。木材、钢铁和水泥成为国民经济的“三大原材料”，木材生产计划作为硬性指标必需完成并鼓励超额完成。林业活动成为以木材利用为中心，首要任务是生产木材，这种历史导致出现了森林资源分布不均、质量和单位面积蓄积量低；林龄结构不合理，可利用资源不足；林地流失数量巨大；林木蓄积消耗量呈上升趋势，超额采伐问题严重等后果[2-3]。

热带林的迅速破坏，使原来生物多样性丰富、生态系统健康循环的森林成为物种简单、生态功能脆弱且缺乏经济效益的次生林，这主要都归咎于过去几十年来农业扩张和森林过度采伐的结果。

1.1 生态功能脆弱

直到 20 世纪 80 年代初期，中国热带次生林资源质量一直处于退化过程，森林生态功能已经变得极其脆弱，灾难性病虫害扩散速度快，水土流失严重。据广东省资料统计：自 1993 年以来，无林地仍连续 8 年增加，至 2000 年已达 56.7 万 hm^2，比 1999 年增加 2 966 hm^2；2000 年，林分单位面积平均蓄积量不足全国平均数的一半，年生长量比全国平均数少 1/3，水土流失面积仍有 1.4 万 km^2；到 2001 年，次生林中，一类林比率仅占 16.7%，而二类林占 47.2%，其余为失去生态和经济效益的残次林。

1.2 物质生产力

我们通过对广东新会古斗山森林采伐利用后 20～30 年自然演替形成的次生林进行样地调查，每样方面积为 100 m^2，其植物类型和生长情况见表 1。

表 1 广东新会古斗山 20～30 年天然演替次生林群落生产力现状

样地号	基本情况	乔木及藤本数			胸径 >3 cm 株数		树高 >5 m 的株数		乔木物种数(种)
		萌生(丛)	实生(株)	藤、竹(丛)	合计	最大胸径(cm)	合计	最高(m)	
1	封山育林 30 年	53	42	5	31	13	36	10.0	59
2	封山育林 30 年	14	48	5	26	21	25	14.0	64
3	封山育林 20 年	14	52	4	17	7	10	6.5	47
4	封山育林 20 年	1	47	6	18	19	17	11.0	49

由上表可以看出：(1) 自然演替 20～30 年后的次生林的生产力差异很大，林分内保留乔木数、萌芽和实生的林木株数、胸径和树高均有较大差异，这与干扰前林分状态、干扰强度、干扰次数密切相关；(2) 次生林木材生产能力较低。经 30 年演替的次生林中，胸径大于 3 cm 的株数仅占林分总株数的 31%，树高大于 5 m 的株数仅占林分总株数的 36%。林分中，林木最大树高 10～14 m，胸径 13～21 cm。如果利用此类次生林作生产木材用，木材的产值将不抵砍伐的人工费用。

对人工造林失败后形成的植被生产力调查结果是：人工营造的马尾松和湿地松，由于造林后缺乏管理，造林树种成活率低，天然更新物种在群落中的数量超过了人工造林树种，植被以天然更新为主。造林15年后，造林树种马尾松和湿地松保留仅10株/100 m^2，保存率为34%。马尾松平均高3.9 m，胸径4.5 cm；湿地松平均高6.3 m，胸径7.5 cm，高径生长极差，难以发挥应有的生态和经济效益。地被以乌毛蕨和芒萁为主，藤本少。天然更新的灌木和杂草在林分中占据了主要地位，萌芽植株占24%，其余为天然实生树木。萌芽和自然更新株的平均高为1 m，径粗只有1 cm。

以上两种类型的样地，在中国热带地区有一定代表性，很大程度上反映了次生林的生产力现状。

2　中国热带次生林的生产潜力

在热带地区，人们对次生林的利用远远超过对原始林的利用，这是一个没有商业意义而被国际社会长期忽略的事实。采集薪材、放牧、游垦农业和收获非木质产品等与林区和周边地区群众生活密切相关的生产活动，绝大多数都是在次生林里进行的[4-6]。

另一方面，有关次生林的木材生产潜力却一直未引起足够的重视，次生林在保护原始林（通过利用次生林而减少对原始林的依赖与压力）和恢复与重建业已失去的生物多样性方面的重要作用，更未得到正式评估[7]。

2.1　生态效益潜力分析

对次生林的生态效益，我们可以从两个方面来认识，一是次生林现有的生态功能等级及其通过改善经营后可以达到的水平；二是与人工林和原始林比较，次生林可以发挥的功能水平如何。

2.1.1　*现有生态功能提高的潜力*　广州日报有这样一篇报道：广东省经过4年的封山育林、定向培育、限制采伐、调整结构、综合开发，全省生态林体系的林种树种明显优化，生态功能逐年提高。涵养水源的功力相当于增添了1 000多个100万 m^3 库容的水库，加上保持水土、防风固沙、净化空气、调节气候、美化环境等作用，相当于同期投入的15倍，4年间共产出综合效益达300亿元，仅仅产生的氧气就达2 600多万t[8]（表2）。

表2　广东省生态林4年间产出的效益统计

项目	生态效益	经济效益	项目	生态效益	经济效益
固化 CO_2	>3500万t	>29亿元	涵养水源增益水	>30亿 m^3	≈9亿元
产生 O_2	>2600万t	>180亿元	森林景观旅游	>800万人次	>8亿元
森林蓄积增加值	>2700万 m^3	>67亿元	减少土壤及养分流失	>200 t	>600万元

中国热带次生林由于大部分处于经济不发达的地区，普遍缺乏经营和保护，生态功能和经济产生能力都处于极低的水平。如果有适度的投入并通过科学研究得到合理经营，必然能显现巨大潜力。

2.1.2　*与人工林和原始林比较*　据福建杉木研究中心测算，通过炼山营造人工林，第一年的迳流量和固体迳量量分别比不炼山的大11倍和88倍。全N、全P和K流失量分别比不炼山大2倍、17倍和11倍。即使在人工林旺盛时期，由于人工林树种单一、生物多样性差，抗逆能力远不能与一个经营好的次生林进行比较。次生林复杂的结构，构建了良好的生态系统，大大增强了林分的稳定性和生态平衡，加快了物种循环速度和途径，提高了林分自肥能力，改善了土壤理化性质，增强了涵养水源和抗灾害能力。

据海南岛尖峰岭热带森林生态定位站的观测材料，次生林的 CO_2 固定效益、释放 O_2 效益和森林凋落物改良土壤效益均比原始林强，而固土效益和森林蓄水效益则低于原始林。观测结果包括：(1) CO_2 固定效益：热带原始林可净固定 CO_2 量1.36 $t/hm^2 \cdot a$，天然更新次生林则可净固定 CO_2 量为7.213 $t/hm^2 \cdot a$；(2)年释放 O_2 效益：热带原始林年可释放 O_2 为9 745.190 4 $kg/hm^2 \cdot a$，天然更新次生林为13 891.046 4 $kg/hm^2 \cdot a$；(3)森林凋落物改良土壤效益：热带原始林的凋落物产量为9.117 $t/hm^2 \cdot a$，天然更新次生林

为9.323 t/hm^2 · a;(4)固土效益:有林地与无林地被雨水冲刷的泥土量之差可视为森林的固土效益,每公顷热带原始林平均可减少泥沙冲刷数量是7.5 t,而天然更新次生林则为4.5 t;(5)森林蓄水效益:有森林的林地类似一座天然的水库,可储蓄大量降水。热带原始林平均蓄水量为2 250 m^3/hm^2 · a;天然更新次生林平均为1 351 m^3/hm^2 · a。

2.2 次生林的物质生产潜力分析

过去导致次生林一直被忽视的主要原因是次生林的物质生产力,也就是经济产出水平较低。反之,也就是因为次生林没有得到经营,本身才蕴藏着巨大的增产空间和潜力。

2.2.1 *次生林中树种的木材生长潜力* 次生林中的乡土阔叶树种,传统上被人们认为生长较慢。如表1,演替了30年的次生林林分中,树高最高只有14 m,胸径21 cm。年平均胸径生长0.7 cm,树高不到0.5 m。但实际上,据2003年对深圳凤凰山次生林改善性经营后的生态风景林调查结果,改造后3年生的45种乡土阔叶树种,平均树高达3.75 m,胸径6.55 cm,显示出这些树种生长的巨大潜力(表3)。

比较上述经营和没有经营的林分生产力,经营林分的林木生长量是未经营林地的2.1~5.2倍。

表3 深圳凤凰山次生林改善性经营3年生树种生长调查结果

序号	树种	平均树高(m)	平均胸径(cm)	序号	树种	平均树高(m)	平均胸径(cm)
1	南洋楹	6.74	·11.10	24	盾桂木	3.20	7.01
2	石栗	6.60	14.25	25	水石榕	3.15	4.78
3	红胶木	6.43	4.90	26	绿楠	3.13	9.34
4	红锥	5.53	4.86	27	凤凰木	3.10	4.56
5	海南菜豆树	4.80	7.75	28	泰国大枫仔	3.00	4.70
6	海红豆	4.73	6.58	29	加卜	3.00	4.35
7	喜树	4.62	7.90	30	青皮	3.00	4.78
8	米老排	4.60	10.35	31	深山含笑	2.96	4.90
9	米老排	4.50	10.51	32	火力楠	2.95	2.79
10	铁刀木	4.46	8.12	33	法国枇杷	2.85	6.85
11	苦楝	4.45	7.48	34	苹婆	2.80	3.50
12	海南石梓	4.32	10.38	35	木棉	2.75	5.41
13	仪花	4.20	6.69	36	紫檀	2.70	5.73
14	水翁	4.18	8.85	37	人面子	2.57	6.05
15	火焰木	4.00	8.49	38	大头茶	2.55	1.43
16	秋枫	4.00	10.19	39	盆架子	2.50	6.37
17	尖叶杜英	3.98	6.69	40	甜槠	2.50	2.94
18	爪哇木棉	3.98	9.24	41	扁桃	2.48	3.44
19	木菠萝	3.88	7.25	42	樟树	2.40	4.14
20	黎蒴	3.58	9.87	43	格木	2.28	5.22
21	枫香	3.45	5.18	44	大叶紫薇	2.27	5.10
22	大叶胭脂	3.43	8.81	45	小叶竹柏	2.25	0.00
23	雨树	3.30	7.96		总体平均	3.75	6.55

注:种植时间:2000年4~5月,调查时间:2003年3月20日。

2.2.2 *演替过程中物种的经济潜力* 中国热带地区地带性群落中,有很多具有重大经济价值的物种可以开发,包括乔木、灌木和草本植物。如藤本植物,是热带地区地带性植被——热带雨林、季雨林、季风常绿阔叶林中的常见植物,具有经济价值高和水土保持能力强的特点,能在短期内取得经济效益;有些灌木和草本,是很高价值的中药材和健康食品原料。南药是中国传统的药材,种类多,经济价值高。天然林中采取的药材,都是上品原料。如天然的黄杞(*Engelhardtia roxburghiana*),其叶是一种良好的健康食品,已开发成饮料黄杞茶,有较好的市场前景。有许多专家呼吁,要利用次生林所形成的独特生态环境,充分发挥部分物种独特的生态位优势,进行中药材标准化规模种植。

从立体经营角度出发，如何充分利用林地空间，进行多层次的林药立体经营，是施行以短养长，长短结合，是实现综合开发的技术措施。

2.2.3 *林分总体生产潜力* 次生林经过自然演替，形成多树种复层混交，其林分结构能充分利用土壤和太阳能，具有比人工林更高的生产潜力。

影响森林生产力的主要因素是林中光能利用率与土壤中营养元素和水分供应状况。混交林营养元素循环快，土壤有效态营养元素供应优于纯林。天然次生林由于不同树种种类间、林下植物根系的相互作用，使根系在土壤中镶嵌分布，分布更均匀、分布范围加深，根系密度（根量）增加，从而改善了林中植物对土壤水分和养分的吸收，改善了土壤养分和水分供应状况。由于林分光能利用率决定于林分的植物组成和空间分布，人工纯林乔、灌、草层植物的种类和层次少，林冠长度小，所有林木对光能吸收特性一致，林冠郁闭度大，林下植被可利用的光能就较少，因此系统光能利用率低。而天然次生林林中植物物种多样性高，不同物种对光能吸收特性不一样，光能利用互补，且林分层次多，光能利用率高。

在中国热带地区，尽管因过度开发利用带来的资源质量严重衰退，使次生林的经营被忽视，但次生林仍然蕴藏着巨大的经营开发生产潜力。

3 主要经营模式及技术设计

ITTO认为森林可持续经营是为达到一个或多个明确的特定经营目标的经营过程，这种经营应考虑到在不过度减少其内在价值和未来生产力以及对自然环境和社会环境不产生过度的不利影响的前提下，期望的森林产品和服务连续不断生产。

次生林经营模式设计是一个复杂的问题，包括了生态学、经济学、森林经理、土壤学、环境科学和农学等多种学科，民族和社区的传统习惯、土地权属、以及生产方式等都是一个重要因素，一个成功的次生林经营模式必须来自于自然科学与社会科学的结合。

总结各国次生林经营的实践和经营，结合中国的国情和社会经济特点，综合选择归纳出三种适用于目前中国热带次生林的经营模式，即社区林业经营模式、经济植物套种经营模式和天然林的恢复与重建经营模式。

3.1 社区林业经营模式

任何社会发展和生产过程都与社区的活动有关。同样，在农村地区的热带次生林经营规划中，将农业、牧业等农业生产综合纳入社区的规划发展方案，让社区居民广泛参与，必将产生最佳的效果。1978年在印度尼西亚雅加达召开的第八届世界林业大会，曾就发展中国家林业发展战略问题进行了深入的讨论。强调指出，世界森林资源少，发展中国家森林危机，致使生态环境日益恶化。号召世界人民为保护森林、发展林业、改善环境做出贡献，并提出“森林为人民”的林业指导思想，即林业经营必须摆脱同乡村发展相脱离的传统林业经营模式，注重林业与农业结合，林业与农村社区服务，改变林业封闭经营，吸收社会力量和广大农民群众参与。社区林业在培育和保护森林资源、维护生态环境和消除贫困等方面正在发挥越来越大的积极作用，农村、农业和农民都在从中受益。

社区经营模式的宗旨是林业发展促进农业丰收、增加农民收入和改善人居环境，农村经济的发展促进森林的保护。因此，其核心是人口、资源与环境。特点是社区居民共同参与的可持续性经营方式。这种经营模式适用于大部分乡村地区，包括集体林地、国有林地和私有林地。

3.1.1 *设计原则* 设计原则主要包括：(1)次生林得到保护、发展，林分质量逐步改善；(2)通过次生林的经营，农民得到生活所需的经济来源；(3)改善耕作条件，促进农业丰收；(4)经营成本低，技术操作方便，易于推广。

3.1.2 *经营设计规划* 以社区（村、部落）为经营单位，包括从生态学和经济学的角度评价现有农业、林业、畜牧业的合理性，按照国家和地方有关法律和政策规定对现有土地利用方式进行评估，必要时做出合理调整。规划内容包括社区发展规划、林业、农业、畜牧业等。社区综合经营规划设计技术路线见图1，各组成的比例应视各经营区的实际界定。

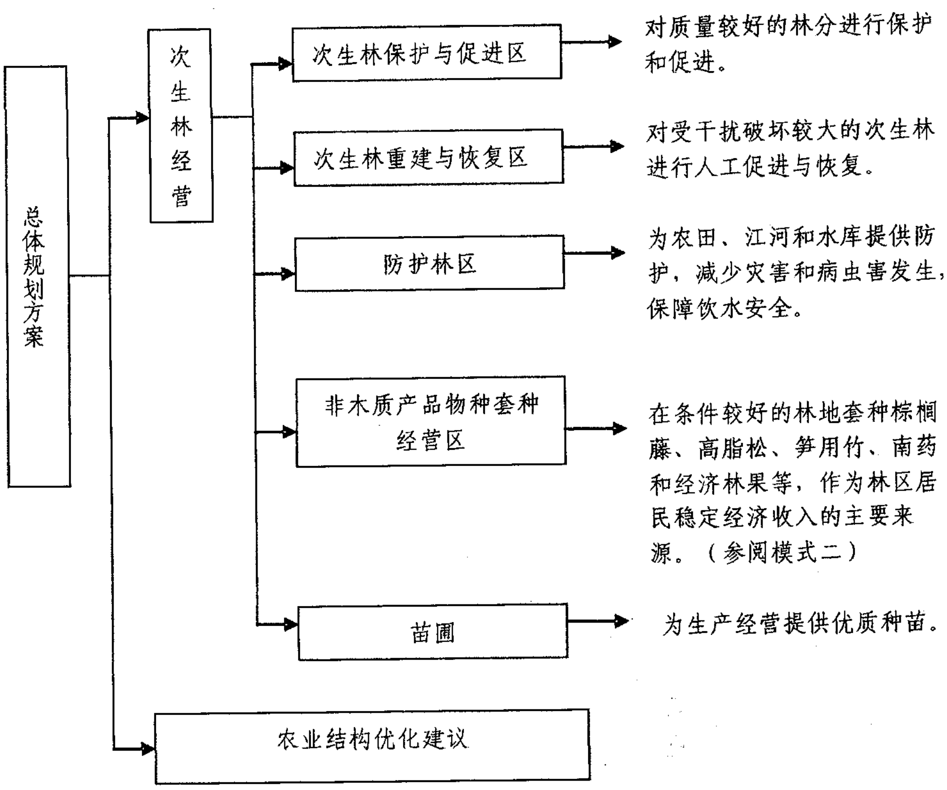

图 1　社区综合经营技术路线

3.2　经济植物套种经营模式

经济植物套种经营，主要是以提高次生林的生态效益和次生林地及其环境的利用创造经济利用为核心。经营对象应当是林地现有物种比较丰富，立地条件较好和次生林发育处于演替中期阶段的林地。这种经营模式，比较适用于个体农户，也可以作为社区综合经营的组成部分。

经济植物套种经营模式，是在次生林中，选择部分交通及立地条件较好的地段，通过引入适生的有较高经济价值的物种。利用林地经济生产活动过程促进次生林的生长发育，获得经济收益。

中国热带地区在次生林开展以经济收入为目的的生产活动已经有很长的时间，同时也取得了许多很好的经验，如海南的林下种植棕榈藤、特产药材，广东的林中间种笋用竹、地方特产药材如巴戟（*Morinda officinalis* How.）、砂仁（*Amomon villosum*），广西的石灰岩地区种植食用作物仙人掌（*Opuntia dillenii*）等。主要套种经营方式和技术要点包括：

3.2.1　经济藤本植物的种植　云南南部农民世代就有在林中或村旁种植棕榈藤的习惯。哈尼族、阿昌族和布朗族人长期以山上、屋旁和菜园种植 *C. nambariensis* var. *yingjiangensis*、*C. nambariensis* var. *alpinus* 和 *C. nambariensis* var. *xishuangbannaensis* 等为家庭经济收入的来源。

在海南，藤类种植也是许多地区的重要经济来源。早在 20 世纪 60 年代早期，海南岛就采用天然藤的分蘖条进行了栽培试验，70 年代开始大规模栽培。到 1980 年，海南岛和广东省大量栽培白藤（*Calamus tetradactylus*）和少量黄藤（*D. margaritae*）。在广东省还栽培有短叶省藤（*C. egregius*）和单叶省藤（*C. simplifolius*）等藤种。80 年代后期，许煌灿先生在国际竹藤组织的支持下，先后在海南、广东和广西等省（区）建立了藤种园和收集圃，引进国内外不同藤种进行研究[9]。据许煌灿的研究表明：选择宜藤林地，以林木为主要经营目标实施林藤间作，种植密度控制在 1 000 ~ 1 500 丛/hm^2。6 ~ 10 年可以收获，25 年期内白藤（*C. tetradacty-*

lus)、异株藤(*C. dioicus*)可采收 6 ~ 7 次,其他藤种 3 ~ 5 次。每公顷原藤产总产量可达 15 t,产值 5 ~ 6 万元[10]。

3.2.2 *药用和保健食品植物栽培* 中国热带地区的地带性群落中,有很多灌木与草本植物都是很有价值的中药和保健食品原材料。利用次生林独特的生态位,引入这些药用植物作为中层和下层植被进行合理培育,可在短期内取得经济效益。

在次生林中规模性种植药用和保健食品植物,在中国热带地区尚处于探索阶段,其经营技术尚待总结和研究,但这种经营模式已经引起林地经营者、政府及企业的重视。从立体经营角度出发,如何充分利用林地空间,进行多层次的林药立体经营,是实行以短养长,长短结合,综合开发山区经济的新技术措施。如云南植物研究所,成功取得了中草药立体栽培的经营技术经验。

栽培品种的选择应以传统栽培品种和具有区域产业化优势的品种为主,以保证产品的市场。外来品种要通过引种试验,并进行市场可行性研究。任何栽培品种的选择,都应以良种为基础,才能保证产品的市场竞争力。

3.2.3 *其他非木质产品物种经营* 高产脂松树、笋用竹等,都是次生林经营中能发挥生态和经济效益的优良品种。在广东地区,一棵高产脂马尾松出租给脂农(采割松脂获取收入的人),一年能给林主带来 4.8 元的租金收入。如果每公顷套种或改种 375 ~450 株高产脂马尾松,每年每公顷的租金收入就达 1 800 ~2 160 元,既提高了次生林的生态效益,又能使农民获取很高的经济收益。笋用竹分生能力强,竹笋营养价值高,适当的栽培管理即可获得较高的产量和经济收入。

3.3 天然林的恢复与重建经营模式

中国热带森林植被由于长期过度采伐、农业耕作和对次生林经营管理的忽视,形成了生物多样性低、生态功能差的各式各样的退化生态系统。由于退化生态系统面积大 ,其恢复和重建是一个庞大的工程。对这样一项短期内难于取得效益的基础性工作,依靠本来就比较贫困的林区自觉去重建几乎不能现实,政府和社会力量应当成为支持这种模式经营的主导。

要想将生态系统恢复到破坏前那样,几乎是不可能的。恢复生态系统的目的是在于保护该地区地带性生态系统的生物多样性,以及该生态系统的结构与动态特征。生物多样性在生态系统中地位最为重要,它既是生态系统的关键组成和结构表达形式,又是功能发挥的保障,也是生态系统存在和演化的动力。生物多样性的丧失和退化必然导致环境的退化,同时引起生态系统结构和功能的退化。

森林恢复和生态系统的重建涉及到的内容十分广泛,在种群水平上有个体和遗传变异对聚集、定居、生长和演替的影响、物种生活史、种间关系等;在群落水平上有群落演替过程、发生规律、脆弱性和稳定性问题等;在生态系统水平上有生产力、结构和功能、生态系统的物质生产过程和生态系统的服务功能等;在景观水平上有区域的空间异质性,区域格局和管理等。

3.3.1 *森林恢复和生态系统的重建应重点解决的关键技术* (1) 裸地的生态重建:原生裸地和次生裸地,如石质山地,水土流失及失去土壤覆盖的次生裸地等;(2) 森林采伐和火烧迹地恢复:采伐和干扰条件下的植被恢复,包括森林更新和人工造林技术等;(3) 弃耕地和退耕地的恢复:弃耕地,尤其是退耕还林地的恢复途径和恢复技术;(4) 沙地和矿山废弃地恢复:山地和矿山废弃地恢复或重建的可能性,应采取的措施和对策;(5) 退化次生林的改良等。

3.3.2 *技术设计的原则* (1) 乡土树种原则:即尽可能使用多的地带性乡土树种,特别是乡土阔叶树种;(2) 生物多样性原则:包括有灌木、草本等各种物种组成;(3) 良种原则:恢复和重建引入的物种应当使用经选择的良种;(4) 效益原则:在乡村,主要树种应选择具有水土保持功能强、经济价值高的珍贵乡土阔叶树种,同时种植非木质产品经营的经济物种如棕榈藤、高脂松、笋用竹、果树、药用植物等,以便使农民长期获得生活所需的经济收入;在城市主要树种则应选择抗污染能力强,景观良好的树种。飞机播种、封山育林、人工补植和林地健康管理是森林恢复和生态系统重建的重要手段。

3.3.3 *主要造林技术* 裸地的重建,主要通过模仿地带性植被进行树种选择和经济物种的配置。退化林地的改良,可以采用保育式方法补植,即抚育管理林地已有的健康植被,引入地带性优良乡土树种和适宜经营的经济物种。

4 结论

4.1 中国热带次生林由于受到破坏的时期较长，大部分林分质量低，生态功能脆弱，缺乏经济效益。

4.2 长期以来，由于缺乏技术性经营，因此中国的热带次生林存有较大的促进和开发空间，生产经营潜力大。

4.3 在发展中国家，大部分农民的生活仍然处于比较困难状态。次生林经营中，应当在提高生态效益的基础上强调经营的经济效益，才能解决好农村、农民的生存和发展问题，实现可持续发展的目标。没有经济效益的经营，最终是不可持续的经营。

4.4 目前在中国可以普遍推广的三个主要经营模式，即：社区综合经营模式、天然林的恢复与重建模式和经济物种套种经营模式。中国是一个以集体所有制为主的国家，社区综合经营模式的适用程度较高。

4.5 次生林在生态利用的基础上，木材和其他非木质产品的利用和开发也是重要的方面。特别是对生态效能进入衰退期的植株进行间伐利用，获取木材和其他产品的经济利益，才能满足人类生活的基本需求，也是社会发展的必然需要。

参考文献

[1] 陈大柯，周晓峰，祝宁，等. 天然次生林[M]. 哈尔滨：东北林业大学出版社，1994.

[2] 周晓峰. 中国森林与生态环境[M]. 北京：中国林业出版社，1999.

[3] 中国可持续发展林业战略研究项目组. 中国可持续发展林业战略研究总论[M]. 北京：中国林业出版社，2002.

[4] P. Kunstadter, E. C. Chapman, S Sabhasri. Farmers in the forest: economic development and marginal agriculture in northern Thailand[M]. Honolulu. The University Press of Hawaii, 1978.

[5] FAO. Forest resources assessment 1990-Survey of tropical forest cover and study of change processes[M]. FAO Forestry. Rome. FAO, 1996:13.

[6] Dianto Bachriadi, Mustofa Agung Sardjono. Local initiatives to return communties´control over forest lands in indononesia: conversion or occupation[C]. 11th Biennial Conference of International Association for the Study of Common Property, Bali-Indonesia, 2006.

[7] Dotzauer H. The potential of secondary forest management from a development policy point of view: An overview[C]//Bittner A, Achtnich W, Atanasiu N, et al. Plant Research and Development 47/48. Tübginen: Institute for scientific Co-operation, 1998:79-87.

[8] 广东省林业厅. 广东在全国率先建设生态公益林体系，营造生态公益林 340 万公顷——四年“种”出 300 亿元[N/OL]. 广州日报电子版，2003-03-10(A13)[2008-06-15]. http://www.dayoo.com/gb/content/2003-03/10/content_980081.htm.

[9] 许煌灿，尹光天，曾炳山. 棕榈藤的研究[M]. 广州：广东科学技术出版社，1994.

[10] 尹光天，许煌灿. 棕榈藤物种的收集和引种训化研究[J]. 林业科学研究，1993, 6(6):609-617.

在国际热带木材组织(ITTO)的资助下,广东省林业科学研究院与中国林业科学研究院共同组织开展了旨在提高生态和经济效益的热带次生林经营研究。本系列研究报告包括:"热带森林与次生林经营状况研究"、"热带次生林经营研究综述"、"中国热带次生林及其经营研究"以及"旨在提高生态和经济效益的热带次生林经营"等。本文是旨在提高生态和经济效益的热带次生林经营系列研究报告之一。

热带森林与次生林经营研究*

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The Study on the Tropical Forests and the Management of Secondary Forests

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Abstract Accounting for 31% of total tropical forest area in the world (FAO, 1996), has received considerable attention by international societies. The study were conducted by Guangdong Academy of Forestry and Chinese Academy of Forestry under the support of International Tropical Timber Organization (ITTO), it aims at improving the ecological and economic benefits by the management of the tropical secondary forests. This serial reports include: "The Studies on Tropical Forestry and the Management of Secondary Forests", "The Summarizing on the Studies of the Management of Secondary Forests in Tropical Region", "The Studies on Tropical Forests and the Management of Secondary Forests in China", and the reports base on the studies of the management of secondary forests aim at improving ecological and economic benefits. This paper discussed the distribution of forest resources in the tropics, their main types, main characteristics and present management status, and proposed twelve management modes, and these modes include establishing nature conservation region, eco-public-benefit forest management, extravisme, limiting logging and regeneration after logging, logging three and remaining seven method, tropical shelterwood system, sylviculture douce, whole cultivation method, specialized cultivation method, strip clearcutting method, developing tree species of lacking noted and nature regeneration, closing hillsides to facilitate afforestation. Moreover, forest classification management, namely implementing management by dividing secondary forests into commercial forest, public-benefit forest and multi-function forest according to main purpose of management, was suggested. The problems of tropical secondary forest were analyzed and some measures solving the problems were recommended.

Key words tropical forests, secondary forests, forest management

摘要 文章综述了世界热带地区的森林资源分布、基本类型、主要特征,以及世界次生林的经营现状和主要经营方式。这些经营方式包括建立自然保护区、生态公益林经营、"采掘主义"、限制采伐和伐后更新、"砍三留七"法、"扶持"式育林法、"抑制"式育林法、整体培育法、专门培育法、带状皆伐法、开发欠知名树

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种、自然更新和封山育林。同时提出了森林分类经营，即按照经营的主要目的将其划分为商品林、公益林和多功能林等基本类型的方法。此外，分析了热带次生林存在的问题，并提出解决这些问题的措施。

关键词　热带森林　次生林　森林经营

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热带森林是世界上生物多样性最为丰富的生态系统。随着原始森林的破坏和其他人类活动，森林破坏后形成的次生林在许多热带国家占有的森林覆盖率的比例较大，而且呈增加的趋势。全球热带国家和地区约有120个，广泛分布于欧洲以外的其他各大洲。热带地区陆地面积约占全球陆地面积的1/3以上，而热带森林面积则占全球森林面积的1/2以上。由于热带地区基本属于发展中国家，人口、经济与资源的压力，使大量热带森林受到破坏而成为次生林或退化林地。不断增长的人口和社会需求对次生林和退化林地的索取，使次生林一方面生态功能日趋弱化，另一方面土地生产力日趋下降。

占全球热带森林面积约31%(FAO1996)[1]的热带次生林的可持续经营已开始引起国际社会的关注。次生林是热带地区森林资源的一个越来越重要的组成部分，它们提供木材和林副产品，缓解了原始森林的压力。此外，它们还在保护环境和生物多样性方面起着重要作用。世界上一些国家的科学家早已关注对次生林和已退化林地的研究，如 Gómez-Pompa 等上世纪70年代初就提出"我们正处于一个次生森林植被的时代"(The Era of Secondary Forest Vegetation)[2]；Wadsworth 提出"将来热带林经营的成功与否可能完全取决于我们对次生林的生态学是否有足够的认识"[3]。与此同时各国也开展了许多生产实践，如东南亚地区采用一次回归经营(Morocyclic System)和多次回归经营(Polycyclic System)。然而，因为次生林管理的主要目的是木材的管理和利用，其有关次生林的生态效益、生物多样性保护和提高的研究以及生产实践仍是有限的。为了促进次生林的可持续管理，有必要了解次生林目前的管理状况和发展管理模式。本文综述了热带森林资源及其经营状况，旨在通过对次生林的合理经营提高其生态和经济效益，实现国际热带木材组织(ITTO)提出的"保持生物多样性、维持立地生产力、保障森林资源、构建健康的森林生态系统、旨在促进社会经济可持续发展"目标。

1　热带地区与森林资源

1.1　热带国家与人口

世界上有热带国家和地区约120个，生活在热带地区的人口约18.5亿。其中约有10亿在亚洲，非洲5亿，大洋洲0.5亿，北美洲1亿，南美洲2.35亿。在亚洲热带地区，特别是印度半岛、印度支那、菲律宾和印度尼西亚的爪哇岛人口最为稠密，每平方公里在200人以上；加勒比地区，南美洲的北部、西北沿海地区、东部沿海地区，人口密度也多在每平方公里200人以上，西非沿海地区也较稠密；非洲北回归线以南荒漠区、澳大利亚荒漠区、南美洲亚马逊流域的雨林区、阿拉伯半岛荒漠区，以及巴布亚新几内亚和亚洲的加里曼丹雨林区，人口密度多在每平方公里1人以下；其他热带地区的人口密度多在每平方公里10~200人[4]。

1.2　热带地区的森林资源分布

世界热带森林以赤道为轴心，呈带状分布，一般情况下向南、北各延伸至23°30′回归线。据联合国粮农组织(FAO)估计，全球森林面积约有34.54亿 hm^2，占陆地面积的25%。其中亚洲、非洲、拉丁美洲的热带森林面积约有19亿 hm^2，占热带陆地面积的40%，大洋洲热带林也占有重要地位。热带森林南北界限并不是和回归线完全吻合，有些地方未达到回归线，而另一些地方却可能超出了回归线，如纬度达到28°~29°的中国喜马拉雅山东南侧的河谷地带就有热带林的分布。世界热带森林分布见图1。

1.3　热带森林资源状况

世界热带森林丰富，为人类的生产和生活不断提供着物质财富和环境服务。但是，长期以来，热带森林只是被人们简单当作木材、原料的产地，林地也被作为农耕地的来源，从而造成了森林大面积的减少、物种大量消退。据FAO统计的全球87个热带林国家中，热带森林每年消失率为0.9%，其中拉丁美洲为0.9%、非洲0.8%、亚洲1.2%，亚洲的消失率最高[5](见图2)。

热带森林面临的主要压力在各个洲表现不同。在亚洲主要是人口增长、贫困、管理水平落后、森林大火；在非洲主要是人口增长、贫困、缺乏森林管理的政策、政治不稳定、城市扩张；在美洲主要是粮食匮乏、城市扩张、政府政策不连贯；在大洋洲主要是木材贸易。林区居民对森林的主要利用方式是薪材消耗，而森林衰退

的主要原因是木材过度采伐和游垦农业。表 1 列出了世界各主要洲的自然林、人工林、保护林经营状况。

表 1　热带森林管理现状　　单位:万公顷

		非洲	亚洲和大洋洲	拉丁美洲和加勒比海	总计
天然林	总面积 Total area	70,461.0	9,737.7	18,472.7	35,256.5
Nature	有管理计划的面积 With management plans	1,001.6	5,506.0	3,117.4	9,625.0
	达到管理要求的面积 Certified	148.0	491.4	415.0	1,054.4
	可持续经营管理面积 Sustainably managed	430.3	1,439.7	646.8	2,516.8
人工林	总面积 Total area	82.5	3,834.9	560.4	4,477.8
Planted	有管理计划的面积 With management plans	48.8	1,145.6	237.1	1,431.5
	达到管理要求的面积 Certified	0	18.4	158.9	177.3
保护林	总面积 Total area	3,927.1	7,097.9	35,124.9	46,149.9
Protection	有管理计划的面积 With management plans	121.6	824.7	837.4	1,783.7
	可持续经营管理面积 Sustainably managed	172.8	514.7	434.3	1,121.8
合计	总面积 Total area	11,055.7	20,670.5	54,158.0	85,884.2
All	可持续经营管理面积 Sustainably managed	603.1	1,954.4	1,081.1	3,638.6

注:摘自《ITTO 热带森林管理 2005》。[6]

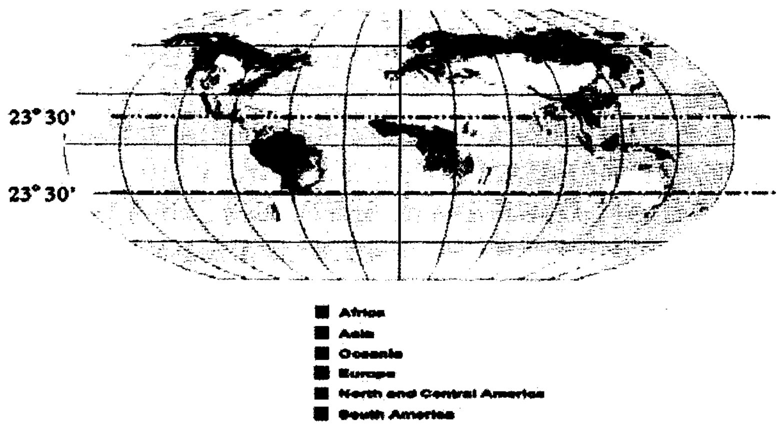

图 1　全球热带森林分布图(FAO,2001)

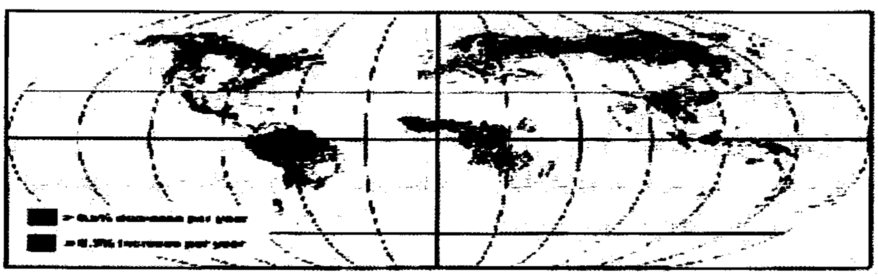

图 2　全球森林面积消退率图(1990～2000)(FAO,2001)

1.3.1　*南亚地区的森林资源状况*　南亚地区包括6个热带国家和地区，森林面积7 430.4 万 hm^2，森林覆盖率22.13%。1990～2000年间，平均每年森林面积减少5.9 万 hm^2。快速增长的人口、贫困和森林管理不力是森林资源面临的主要压力。该区域人口占到世界的22%，而森林资源仅占2%。薪材消耗是该区域居民利用森林的主要方式。

1.3.2　*西部非洲的森林资源状况*　西部非洲包括16个国家和地区，热带森林面积约85 079 000 hm^2，森林覆盖率约11%，从1990～2000年的统计数据看，森林每年减少1 351 hm^2。快速增长的人口、经济发展、贫困和缺乏有效的管理政策是森林资源面临的主要压力，毁林的主要原因是农业用地的转化、采伐、城市扩张以及采矿。在这个区域薪材的消耗是当地居民利用森林的主要方式，其数量占到能量利用的85%。尽管非木质产品对于当地居民来说是重要的，但是可以提供的数据非常少。

1.3.3　*加勒比地区森林资源状况*　加勒比地区包括22个国家和地区，主要是加勒比海的岛屿，森林面积571.1 万 hm^2，森林覆盖率25.0%，1990～2000年间，森林平均年增长为1.3 万 hm^2。该地区的森林生态系统复杂多样，物种丰富，旅游收入是森林得以维持的重要原因。在这里，森林保护问题不仅是社会、文化和政策环境引起的，直接原因是经济问题。

2　热带次生林状况

2.1　热带次生林的面积与分布

在二十世纪90年代，热带天然林年平均采伐面积估计为1 520 万 hm^2，其中1 420 hm^2 在采伐后林地被转而用于其他用途。当然，估计也有100 万 hm^2 的非林业用地（特别是农业用地），由于森林的自然扩散重新恢复成了森林植被。

2002年5月，ITTO第32次会议上发表了由5个国际机构合作提交的一份关于热带次生林的报告。这五个机构是：国际热带木材组织（ITTO）；联合国粮农组织（FAO）；国际林业研究中心（CIFOR）；世界自然保护联盟（IUCN）；国际林联（IUFRO）。报告中专家小组以2000年为时间基准，对77个热带国家的已退化林地和次生林的面积做了一个大约估计，结果是，已退化林地和次生林的总面积大约是8.50 亿 hm^2。这一面积占到了被统计的热带森林总面积的60%以上。

2.2　热带次生林的基本类型

次生林产生的主要因素是人为干扰（the anthropogenic disturbance）或自然灾害（natural disaster）。根据干扰的类别，可将次生林划分为下列五种类型[7-8]。

2.2.1　*过度采伐后自然恢复的森林*（post-extraction secondary forests）　即经过采伐，原有森林植被显著减少后重新形成的森林，也即森林→砍伐→次生林。如在马来西亚，以龙脑香为主的原生林在集约采伐后就转化为 *Melaleuca* spp. 和 *Trema* spp. 或其他树种为先锋树种的次生林；在哥斯达黎加，以 *Pentaclethra macroloba* 为主的森林在采伐后就会转化为物种相同但结构不同的林分；

2.2.2　*农业用地弃耕后恢复的森林*（swidden fallow secondary forests）　即森林→砍伐→农耕→休耕→次生林。如亚马孙流域热带雨林就转化为以 *Trema micrantha* 和 *Heliocarpis appendiculatus* 等树种为主的森林；

2.2.3　*火灾迹地次生林*（post-fire forests）　由于一次或连续的森林火灾把原有森林植被烧毁后再生的森林，即森林→火灾→次生林；

2.2.4　*人工恢复的次生林*（rehabilitated secondary forests）　即在退化林地上通过人工促进而新生成的森林植被，即森林→退化林地→森林恢复或更新；

2.2.5　*农业次生林*（secondary forest gardens）　在相当肥沃的休耕地上或在管理松散的小地主的人工林中大量自发再生的森林，即森林→砍伐→管理松散的人工林＋自然再生林、或森林→砍伐→农耕→休耕地→次生林。

2.3　热带次生林的主要特征

德国技术合作局（German Agency for Technical Co-operation，GTZ）对次生林的特征作了这样的阐述：次生林是一种森林演替植被（forest successional vegetation），它具有如下特征：①成因是人类引起的干扰；②在相当大面积的原始林植被完全（至少90%以上）破坏后形成；③因小气候的改变与更新条件的不同而具有与原生林不同的树种组成、林分结构与动态；④还没有恢复到原生植被的状态。GTZ的定义是基于拉丁美洲的经验形成的，其中的一些标准（definition criteria）在亚洲和非洲也得到了认可[9]，它使人们了解到次生林是一种处于演变过程（演替）中的森林植被，其演变的结果最终可能达到接近原生林的状态。但GTZ没有恰当

表达自然灾害形成次生林的观点。

从生态学讲，次生林是森林破坏后的演替产物，它可能处于不同的演替阶段，但基本处于新植被正向演替发展或原有植被逆向演替的时期。次生林通常生态和经济效益很低，因此常被人们忽视并极少受到关注。

从功能上来说，尽管次生林不能代替原始林，但是其经营潜力很大，应被看作是解决社区发展与天然林保护矛盾的缓冲区域。

从另一个角度讲，次生林却是人们最容易进行管理的生态系统，因为它处于当地居民容易到达的地区，也是当地居民采集日常生活用品的主要地点。

3 热带次生林经营现状及其经验

由于热带森林生物多样性丰富，对人类生存环境有重大影响，林学家和生态学家都十分重视热带森林研究。但在热带次生林的经营方面，却长期忽视。这可能是由于热带林地区的经济普遍欠发达，而热带林生态和经济低下所致。直到 1997 年第十一届世界林业大会提出“开展对热带次生林现状、生产潜力及可持续发展的经营措施的统一或专项行动”后，热带次生林经营方面的研究和生产实践才开始得到重视。

3.1 次生林的经营现状

由于热带地区次生林产生的历史背景不同，各国的体制、经济、文化、民族习惯和生产方式不同，热带次生林的经营方式、深度和广度也差异很大。尽管最近次生林经营问题已受到关注，一些国家已逐步开展了一些经营活动，在政策方面也开始予以重视，但规模仍然很小，效果仍然欠佳。

在全世界，次生林经营基本可以分成两大类。一类是以生态环境保护为目的的生态公益林经营，另一类是以木材生产为主要目的的商品林经营。商品林经营又基本可以分成两种类型：一种是一次性回归经营(morocyclic system，uniform system)，即把所有大树在一次作业中伐倒，并把非商品树木毒杀至死，依靠天然幼树成长为新林；另一种是多次回归经营(polycyclic system)，或称选伐经营(selective system)，即选伐成熟林木，保留青壮林木(half-grown adolescents)以为下次采伐做资源准备。一次性回归经营损伤大，采伐间隔期长(如龙脑香林的回归期一般需要 70 年)，但作业方便，林中空间大，有利于速生树种生长。多次回归经营因保持较多的树木不被触动，林中空间小，不利林下树木发育，但每隔 20～40 年，一般就可以再次进行采伐。

印度尼西亚、东南亚地区曾广泛采用一次性回归经营方式，如沙巴由于几乎都是龙脑香林，现在仍采用此种经营方式。目前亚洲热带林经营方式基本与非洲、拉丁美洲相似，主要采用多次回归经营方式。由于多次回归经营方式允许进行多次择伐，又适应市场对大径材的要求，深受企业界和政府资源管理部门的青睐。缅甸采用多次回归经营方式很成功，已有百余年历史，他们经营的柚木林采用这种经营方式后 20～40 年就可轮伐一次，仰光以北的 Pegu Yomas 森林现已处于第三、四次轮伐期中。印度尼西亚的多次回归经营方式经过这些年的发展，已演变成为择伐与栽培相结合的经营方式，简称为 TPTI 方式[10]。

从生态学观点和技术角度来看，实施一次性回归和多次回归经营的方式，对实现天然林的持续经营和保持木材永续利用是完全可行的。但最近国际自然保护联盟(IUCN)对印度尼西亚的一个研究报告指出，森林经营计划实施广泛持续是可行的，但执行中却往往失败。原因非常复杂，如政府对森林承租者缺乏长远的鼓励办法；林业部门也没有有效防止破坏的监控方法；木材生产公司为降低采运成本，运出原木时常常不惜损伤幼苗、幼树和保留的林木。研究报告同时认为，现在天然林难以持续，并非由于森林结构脆弱，而是由于政治、社会和经济的原因。

中国政府对热带次生林的保护可能是世界上最有力的国家，未来十年政府将投资 962 亿元用作天然林保护工程。到 2002 年，已完成投资 286.9 亿元。海南、云南的热带次生林已严令禁伐，政府采用财政补偿的办法来保护，同时制定了一系列的政策法规[11]。广东省的力度更大，1985 年开始对热带次生林全面实施促进式经营，约有 1/3 的热带次生林被划为地方生态公益林加以管理，政府用财政资金加以补偿，每公顷补偿费由 1999 年的 37.5 元增加到 2003 年的 120 元，同时出台了《广东省生态公益林建设管理和效益补偿条例》等地方法规。但是，中国的森林经营只注重了资源保护和生态效益的一面，而忽视了经济效益，能否做到永续经营仍需时间的检验。

3.2 国际热带次生林经营的主要方式

侯元兆对世界各国热带森林的经营方式方法进行了归纳，认为大约有 12 种[7]。在此基础上，本文进一步补充归纳如下。

3.2.1 建立自然保护区　政府以自然保护区的形式，保护具有特定意义的热带林生态系统和热带地区的特

殊生境、特有物种等。发展自然保护区不但有利于资源保护、科学研究，也有利于发展旅游经济。但是，对发展中国家来说，一个现实问题是缺乏保护区管理经费，往往徒有虚名。

3.2.2 生态公益林经营 对江河沿岸、沿海地带、水土流失地区、集水区的森林等生态效益突出的森林生态系统，划作生态公益林来管理。这部分森林主要经营目标是生态效益，由政府代表全民用户对林地所有者进行生态效益补偿。但也考虑非木质林产品的经营，以取得一定的经济收入。

3.2.3 "采掘主义"(extravisme) 是对热带林一种利用概念及方式，它是由 J. P. Lescure 及 A. de Castro 在亚马孙地区中部经过调查后提出的，意即对如木材、树脂、纤维、果实、毛皮、野生动物、矿物等自然产品的采收活动。其做法是基本不破坏森林生态系统，只收取森林中的部分天然产品。其条件是必需有大面积的林区才能实现。如果生态公益林的经营采用这种方法，将可能避免人们担忧的经济收入问题。非木质产品可以为生活在森林附近的人们提供生活来源，包括食品、药材、原材料，对森林的破坏程度比收获木质产品小。在热带地区对森林非木质产品的经营日益受到人们的重视。"采掘主义"，也是非木质产品经营方法。在热带林区，土著居民保持着在森林中获得药物、食品等非木质产品的传统。在巴西，babaçu palm kernels 的收集和加工占当地居民现金收入的39%和全部家庭收入的34%。需要注意的是对林下产品的过度利用会造成资源枯竭。在南部非洲，伴随着工业的快速发展和市场的开拓，对可供编制篮、筐的30种纤维材料和22种燃料的过度利用导致了这些资源的枯竭。计划利用可以做到资源的持续利用，如在尼泊尔计划利用高需求的林产品，保证了生物资源没有减少。

3.2.4 限制采伐，伐后更新 这是许多国家普遍的做法。政府通过控制采伐指标来控制森林采伐，采伐指标的确定是一个地区单位面积在保持一定的林分蓄积的前提下，生长量大于采伐量。同时，一些国家的政府还通过强制收取一定比例的木材销售资金用于更新造林(如中国)。这种做法能在一定程度上抑制过度采伐，但管理比较困难，量的计算和控制都非常粗放。近年来，一些发达国家提出热带木材永续生产标记法，有的国家则抵制热带木材进口，也是属于这类做法。

3.2.5 "砍三留七"法 即按单位面积蓄积量，砍三成留七成。中国海南曾使用过"砍三留七"和"砍五留五"的方法。这类方法类似一些国家进行过的采伐强度试验，如巴西 Tapajos 森林的试验表明，75 m^3/hm^2 采伐量是个极限。其原理是适当采伐木材，尽量减缓对森林生态系统带来的冲击。

3.2.6 "扶持"式育林法 即针对目的树种采取种种措施加以扶持、帮助，以促进其生长，法文称之为"Sylyiculture pour"。在热带林经营中，是一个比较普遍和很自然的做法。该法应用历史相对较早，也有不少成功的例子。如在加蓬，通过几代人的努力，已搞清楚了奥库梅的生态习性，在天然林经营中既能增加株数，又能加速其生长。

3.2.7 "抑制"式育林法 相对于"扶持"式育林法，即对不希望的树种和植株进行生长控制和破坏，为目的树种的生长创造条件，但对森林生态系统的建立不利。Schmitt 在圭亚那就 Gonfolo (*Qualea rosea*)进行的研究就清楚地表明，这一方法不能为某个特定树种提供理想的生长条件。

3.2.8 整体培育法 是对生态系统进行整体的干预，使其逐渐演变，并不破坏某个特定树种。

3.2.9 专门培育法 确定一些树种在各个发育阶段上的最适环境条件，并采取一些相应的措施促进其生长。总体上属于"扶持式育林法"，但目的树种更加专化。

3.2.10 带状皆伐法 这是在秘鲁东部 Palacagu 农村发展计划中设计的一种方法。即对森林进行带状皆伐，带宽100～300 m，带间保留宽150 m 的林木。皆伐面积占林分面积的46%，轮伐期为30～40年。其原理是利用保留带的生物多样性庇护与扩散效应，重新盘踞皆伐带。一方面利用砍伐木材，另一方面达到改善和促进林分状况的目的。

3.2.11 开发欠知名树种 对市场不了解，使用不多的非商业树种进行开发，以扩大资源利用率。其出发点是充分利用立木资源，避免伐一棵丢一片，从而减缓热带林的破坏进程，但持续经营这一核心问题并未解决。近年来，在法国和日本等都在系统研究，ITTO 也资助过一批这样的项目。

3.2.12 自然更新和封山育林 自然更新包括天然下种和萌芽更新，这种方法的特点是成本低和用工省，是最便宜的方法。在热带地区，尤其是东南亚地区的龙脑香林普遍采用。萌芽更新是有萌芽能力的树种，采伐时控制伐桩高度，采伐后的林地通过适当的措施，如林地的健康清理等，使主要树种通过萌芽来恢复，如越南中部高原的龙脑香林。封山育林就是在规划要自然恢复植被的地带，禁止人和牲畜进入，确保植被在不受干扰的条件下自然生成。有时也采取飞机播种或人工补植的促进措施加大幼树密度。在次生林破坏比较严重的地方，甚至在天然林的生态系统基本被破坏后，采用封山育林是一种简单而又行之有效的方法。在中

国，这种方法已经应用到了非常成熟的地步，是大面积恢复森林植被的重要措施。但封山育林如果缺乏积极的促进措施，森林演替进程就比较缓慢，再一个问题是，封山育林所启动的正向演替，过程较长，此间一般不会产生经济收益。应当说，封山育林只是森林恢复早期阶段适用的一种方法。

次生林的经营，不同生产方式、不同树种和环境等，差别很大。但通过用森林分类经营，即按照经营的主要目的将其划分为商品林、公益林和多功能林的几个基本类型的方法来实施，具有共同的特性。这样，就有可能实现最大的经营效果，是次生林经营的基本策略，适用于世界各国。如：在一些防护区域，将林地划为具有公益性质的森林种类，包括水土保持林、水源涵养林、防风固沙林、农田防护林、环境保护林、自然保护区、森林公园等森林种类来经营。位于大洋洲的新西兰有3/4的国有天然林被保护作国家公园和国土保安林，25%的私有天然林中4/5是不可及的、或处于保护状态，而占比例5%的人工林（150万 hm^2）可以生产99%的商业木材。在那些立地条件合适的地区，发展高度集约化的工业人工林，并且与加工业相结合，形成现代化的林业产业带，是巴西、印度尼西亚、马来西亚等很多国家的成功经验。这种发展往往与更加广泛的国家发展计划相结合，其意义已远远超出了林业的范畴。而另一方面，次生林的绝大部分，实际上是多功能利用的森林生态系统，它们既发挥生态效益，又发挥多种经济效益。农林牧人工生态系统几乎是所有国家都在努力发展的一种模式。这种多功能的林业，通常也就是人们所说的社区林业。社区林业的一个基本点是通过社区居民的参与，达到林业可持续经营的目的，其优势就是将林业经营与社会文化结合起来，注重人与林业的关系，把农民与森林、树木联系起来，最根本的问题是满足需求。社区林业目前在一些国家已经开展了广泛的实践。在尼泊尔，政府对于社区林业给予了高度重视，并且不断通过调整政策来促进森林资源的管理和保护。在印度，农民群众在历史上第一次可以参与国家森林管理，并从中获益，将村民的利益、集体的利益和国家的利益统一起来。社区林业在一些发达国家也逐渐受到重视，例如在澳大利亚所实施的农用林业政策。

3.3 国家和地区政策

1990年以来，除了哥伦比亚，几乎所有热带林国家都通过了正式的国家林业政策。然而，哥伦比亚已经采取了可信的措施改善其森林经营，包括对森林特许权协议以及规章制度框架进行批判性审查、总面积在200万 hm^2 以上的12个特许权协议被废除。特别是ITTO成员国，都在政策和法规的改革和制定方面取得了明显的进步，并颁布了许多新的林业法规支持这些政策。同时，各国根据自己的国情，制定了新的林业发展战略和总体规划。这样，就为本国的森林实现可持续发展创造了良好的条件。在非洲和拉丁美洲，政策和法规方面的完善已经促使了林业管理部门的改革和重组。中国是林业政策制定和完善方面力度较大的国家，已制定和修改国家林业政策法规达到80多项，对森林经营和林业发展起到了极为重要的作用。

4 热带次生林经营的意义与存在问题

4.1 热带次生林的重要性

国际热带木材组织（ITTO）前执行主任B. C. Y. Freezailah先生1991年指出，热带森林的持续利用是一个非常重要的课题，哪个国家解决了，哪个国家就将对人类作出历史性的贡献。热带次生林占热带森林面积的比重达到60%，在某种意义上说，只有经营好了次生林，才会实现热带森林的可持续经营。

4.1.1 *具有战略性的环境价值* 热带森林是地球之肺和全球生物多样性的宝库，热带次生林占据着世界热带森林的主体地位，因此，热带次生林具有战略性的环境价值。

4.1.2 *维系热带社区居民的生计* 据估计，热带地区生活着约18.5万亿人，其中3/4人口依赖薪炭材及其他传统能源作为生活能源。其中1亿人仅能得到最低限度的能源，10亿人是通过过度采伐森林获取他们所需。在发展中国家，为了满足最低水平的能源需求，年缺材至少4亿 m^3。

人口越集中和越贫困的地方，次生林往往破坏得越严重。想要改善这部分人的生活和环境条件，次生林的经营尤为重要，因为他们通常依赖森林而生存。次生林是满足当地的薪材、饲料、果实、可食用的植物、建材和药材等多种需求的基本资源，并有助于减少农作物经营失败和其他灾害而带来的风险。此外，对热带次生林进行合理的经营，才能够满足木材及林产品的市场需求，同时也是农业生产正常进行的重要保障。

4.2 热带次生林经营存在的问题

4.2.1 *热带次生林面积不断扩大* 据有关资料统计，世界每年约有750万 hm^2 热带雨林被毁掉，约占热带森林总面积的0.62%[12]，周围大面积的森林植被也会因此遭到反复烧垦、过度放牧、过度开发，带来环境恶化等一系列问题。

4.2.2 *次生林经济效益的下降* 拥有广袤热带次生林的社区和贫困人口，难以利用他们手中的资源，这已

经成为社区发展和林业可持续经营一个不可忽视的重要问题。在很多地区，特别是人口密集地区，次生林还容易被转变成高度集约经营的人工林，从而会进一步减少生物多样性。应当找出既能保护和促进次生林的发育，又能使地方居民不断获得近期收益的经营利用途径。

4.2.3 次生林的退化带来诸多环境恶化的问题 如喜马拉雅山脉森林破坏后的“反座效应”是无穷的灾难，洪水与旱灾在印度、巴基斯坦、孟加拉国的广大地区年年交替发生。根据目前森林消失和次生林衰退的速度估测，到2015年将有4% ~8%的热带雨林物种消失灭绝。高山地区的珍贵物种的消失率更高。

4.2.4 次生林经营具有更多的不确定因素 次生林多处于农业、牧业和林业活动用地的冲突地区，其保护和经营有很大的特殊性，更多地涉及到经济和社会等不确定因素。

4.2.5 缺乏针对次生林保护和发展的政策 世界过去似乎不约而同地忘记了热带次生林，各国经营普遍缺乏对热带次生林的重视，缺乏政府和社会资金的扶持。

4.2.6 缺乏科学合理的经营模式 既往的经营模式，大部分都是从培育商品木材目标出发予以设计的。这些模式，应当在充分考虑生态价值的前提下，重新加以评估，必要时要加以调整。

4.2.7 热带次生林的环境价值没有得到描述从而也没有向全世界昭示 需要开展这项工作。特别是应当在此基础上进一步研究热带次生林的环境效益内部化的问题，其中主要是要研究如何通过市场化途径实现热带次生林的某些价值。

5 结论与建议

5.1 次生林管理既不同于人工林的集约管理，也不同于原始森林的保护。必须在生态学规律的指导下，充分融合生态效益和经济效益的提高。在尽可能不妨碍次生林发挥其生态服务功能的前提下，提供尽可能多的森林产品。达到这一目标应该解决的问题核心就是把握次生林演替的方向，调节其演替的速度，根据当地的实际科学选择经营模式和方法，在保持或改善生态环境的基础上通过保持或提高木质产品和非木质产品的产量和质量来提高生产力和产品质量。如果得到恰当的管理、恢复或更新，次生林便会发挥重要的环境功能、产生重要的经济价值。

5.2 尽管有关次生林的生态学、造林学和社会经济学知识已有一定的积累，次生林管理的研究正在增多，但在次生林的管理、利用和保护方面做的还不够。次生林管理的问题包括次生林经济效益的减少；次生林退化引起的诸多环境问题；次生林管理被许多不确定因素所影响，例如与农业和牧业竞争土地；次生林保护和发展政策的缺乏，大多数管理模式是为木材生产而设计的；热带次生林的环境效益没有得到足够的宣传。为了解决以上问题，需要采取一些措施，这些措施包括：在对应用于次生林的各种管理策略进行成本分析的基础上通过加工增加木材和林副产品的价值；次生林管理要以健全的生态和造林学分析和知识为基础，以避免次生林的森林产品和服务的衰退；次生林应结合土地利用计划以避免与农业及牧业竞争土地；在国家水平上使次生林的保护和发展合法化；实行森林分类管理；提高公众关于次生林特点、重要性和管理的认识。

5.3 热带次生林的经营既要防止只注重生态的经营思想，又要防止只讲经济效益的经营思想。只有这样，才有可能真正实现可持续经营的目的。

参考文献

[1] FAO. Forest resources assessment 2000-Survey of tropical forest cover and study of change processes[M]. FAO Forestry. Rome: FAO, 1996: 13.

[2] Gómez - Pompa, A. and Vázquez - Yanes, C.. Studies on the secondary succession of tropical lowlands: the life cycle of secondary species[C]//W. H. van Dobben and R. J. Lowe-McConnell. Proceedings of the First International Congress of Ecology. Junk, The Hague. 1974: 336-342.

[3] Wadsworth FH. Production of usable wood from tropical forests[M]//Golley FB (Ed.) Tropical Rain Forest Ecosystems. Structure and Function. Ecosystems of the World 14A. Elsevier. New York, 1983: 279-288.

[4] 侯元兆. 热带林[M]. 北京：中国林业出版社，2002.

[5] FAO. Global Forest Resources Assessment 2000(Main report)[M]. Rome. FAO, 2001.

[6] ITTO. STATUS OF TROPICAL FOREST MANAGEMENT 2005[J]. ITTO Technical Sereis, 2006, 24: 48-53.

[7] 侯元兆. 世界热带林业研究[M]. 北京：中国林业出版社，2001.

[8] Ashton MS, Gunatilleke CVS, Singhakumara BMP, Gunatilleke. Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models[J]. For Ecol Mgmt,2001, 154: 409-430.
[9] Dotzauer H. The potential of secondary forest management from a development policy point of view: An overview. [M]//Bittner A, Achtnich W, Atanasiu N, Böger P, Caesar K, Hoeppe C & Guo L (Eds). Plant Research and Development 47/48. Tübginen: Institute for scientific Co-operation. 1998;79-87.
[10] Sist P., Sabogal C., Byron Y. Management of Secondary and Logged-Over Forests in I ndonesia[C]. Selected Proceedings of an International Workshop, 1997.
[11] 温茂元. 海南热带人工林经营[M]. 海南:海南出版社,2000.
[12] 侯元兆. 中国热带森林环境资源[M]. 北京:中国科技出版社,2002.

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—*Mini Review*—
Advances in ecological studies of tropical secondary forests

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ABSTRACT Tropical secondary forests own enormous potential and ecological function due to their vast area, and are an increasingly important component of the forest resources in the tropics. This paper reviews main research outcomes of secondary forests during their succession process. Soil-stored seeds significantly contribute to the development of secondary forests, increased levels of incident light temperature stimulate seed germination, whereas remnant vegetation and seed predator have strongly negative influence on the rate of initial colonization. Species and number of secondary forests generally increase with succession process. Early successional species are generally shade-intolerant while late successional species are shade-tolerant. The time frame that plant species richness in secondary forests approach old-growth forests varies considerably depending on forest type, type and intensity of past land use, and environmental conditions. Plantation can accelerate germination and growth of seeds by improving the light, temperature and the degree of humidity of soil surface layer, so that they greatly accelerate the processes of plant succession. Most herbivores feed in secondary forests because pioneer species in secondary forests do have little or no mechanical or chemical protection against herbivores and many early and late serial tree species in secondary forests produce edible fruits in large quantities. Environment and fire have some effects on secondary forest succession. In early succession, relatively more biomass is allocated to resource acquiring tissues (leaves and fine roots) and in later stages more is allocated towards structural materials (woody stems and coarse roots). The nutrient cycling of secondary forests is quick during approximately the first 15 years of succession and it decreases as forests age. The losses of soil organic matter and N due to deforestation and burning decreases soil fertility of secondary forests.

Key words: composition, construction, nutrient cycling, succession, tropical secondary forests

INTRODUCTION

In the world's tropical region, many tropical forests were changed into secondary forests or degraded to wasteland, because of ruining wood for crop and timber derived increasing population. According to the ITTO data, tropical secondary forest or degraded wasteland accounts for 60% of tropical forest areas (ITTO, 2002). Tropical secondary forest owns enormous potential because of its strong plasticity and vast area. Meanwhile, the tropical secondary forest can improve environment, prevent pollution, fix CO_2 (Fearnside and Guimaraes, 1996), provide the forest instauration modes (Lugo, 1992), provide the sanctuary for biological diversity and has various outputs at the same time (Chazdon and Coe, 1999). In the tropics, people's exploitation to the tropical secondary forests is more than primary forests. The great majority of collecting fuel wood, pasturing, vacillant agriculture, collecting non-wood forest products, and production exercises which are closely-related with the life of local people living in forest regions and nearby the regions are conducted in secondary forests (FAO, 1996; Dotzauer, 1998). They are also important with environmental services, such as protecting soils from erosion processes, fixing and storing carbon, conserving biodiversity in fragmented landscapes (most of them are presented in summary fashion in Table 1).With the progress of city and industrialization, the area of tropical secondary forests will increase this century (Thomlinson

Table 1. Characteristics of secondary forests (compiled from ITTO, 2002).

Location	Accessible area
Intensity of disturbance	Severe intensity, caused by the clearing of at least 90% of the original forest cover
Common causes of disturbance	Clear-cutting, burning and abandonment of area Catastrophic large-scale natural disturbances: fire, flooding, storms, landslides.
Regeneration	Seed dispersion and germination from tree stump and root stake
Vegetation development process	A sequence of successional changes takes place after the perturbation. In this process several phases or stages with specific floristic, structural and dynamic characteristics can be distinguished. Plant species composition changes in dominance gradually from early to late successional species
Species composition	Relatively uniform species composition
Tree growth	Rapid
Biomass accumulation	Rapid at early stages of succession and slow at later stages of succession
Productivity	Varies with site conditions, time since settlement, the number of crop-fallow cycles at a particular site, the type and intensity of land use during the cropping stage, and the prevalence of disturbances
Nutrient cycling	Rapid at early stages of succession and slow at later stages of succession
Soil fertility	Low
Total biodiversity	Low to medium sometimes high
Environmental services	Good. If properly restored and managed, they protect soils from erosion processes; regulate the water regime, favouring the hydrological cycle and reducing water loss thru run-off on hillsides; fix and store carbon, and help conserve genetic resources.
Resource property	Variety of supply of timber and non-wood forest products
Future availability of land	Increasing
Future source of timber production	Increasing

et al. 1996). Therefore, enhancing research of secondary forests has important meaning for promoting their management and economic value.

There were many researches on plant community, succession process and niche of tropical secondary forests from an ecological viewpoint. The study of tropical secondary forests began from the 1950's. The earliest study of secondary forests is Greig-Smith's ecological investigation on stand structure of three secondary forests in Reggae Islands Trinidad in 1952. Afterward, Bartholomew et al. (1953) reported biomass and nutrient contents of 2 to 18 year secondary forests developed from humid tropical forests after being slash-and fire in the Congo; Ross (1954) studied stand structure of 5 to17 year secondary forests developed from dry tropical forests being slashed-and-burned 23 years ago in Nigeria; The study range of secondary forests became more and more wide and many papers were published in the last 20 years. For example, Guang (1996) studied biomass, primary production, litterfall and nutrient of monsoon evergreen broadleaved forests growing buried wasteland in Hong Kong and Guangdong, China; Zimmerman et al. (1996) summarized the influence of land use on secondary forests developed from tropical lowland rain forests being farmed, herded or selective felled in Puerto Rico.

The objective of this review is to summarize main research outcomes in structure and function of secondary forests.

DEFINITION AND TYPES OF SECONDARY FORESTS

Secondary forests were defined as "Forest regenerating largely through natural processes after significant human disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major change in forest structure and/or canopy species composition (Chokkalingam et al., 2001). There are five main types of secondary forests (Table 2).

The above types of secondary forests can be basically divided into secondary forests which come from rest area——swidden fallow secondary forests and secondary forest gardens and secondary forests which come from non-rest area——post-extraction secondary

Table 2. Types of secondary forestry (from Chokkalingam et al., 2001 and ITTO, 2002).

Types	Definition	Examples
Post-extraction secondary forests	Forests regenerating after significant reduction in the original forest vegetation through tree extraction at a single point in time or over an extended period, namely forest —harvest—— regeneration.	Dipterocarp-dominated forests transformed into forests dominated by short-lived *Trema orientalis* and *Macaranga* spp., *Alphitonia* sp., and *Mallotus* spp. following intensive logging in the Philippines
Swidden fallow secondary forests	Forests regenerating in woody fallows of swidden agriculture for the purpose of restoring the land, for cultivation again, namely forest—clear ——burn—crop—fallow—clear.	Lower montane rain forests transformed into forests dominated by *Schima wallichii*, *Eurya acuminata*, *Castanopsis armata*, etc. in shifting cultivation fallows of northern Thailand
Secondary forest gardens	Considerably enriched swidden fallows, or less intensively managed smallholder plantations where substantial spontaneous regeneration is tolerated, maintained, or even encouraged, namely forest—clear——burn—crop—considerably enriched fallow.	Dipterocarp-dominated forests converted to jungle rubber systems after swidden cultivation in Kalimantan
Post-fire secondary forests	Forests regenerating after significant reduction in the original forest vegetation due to a human-induced fire or succession of fires, namely forest—fire—regeneration.	white spruce (*Picea glauca*) stands transformed into aspen (*Populus tremuloides*) and paper birth (*Betula papyrifera*) following fire in boreal forests of Alaska
Rehabilitated secondary forests	Forests regenerating on degraded land, often aided by rehabilitation efforts, or the facilitation of natural regeneration through measures such as protection from chronic disturbance, site stabilization, water management and planting, namely forest—degraded land—rehabilitation + natural regeneration.	Native plant species recruitment in North Queensland following rehabilitation efforts on degraded forest lands. Most common species regenerating were *Omalanthus novo-guineensis* and *Cryptocarya triplinervis*

forests, post-fire secondary forests and rehabilitated secondary forests. The environmental benefits of fallow include restoration of soil stability and fertility and the enhancement of useful biodiversity. Post-extraction secondary forests cause forest ecosystem slow decline through selective logging. On the conditions of intensive forest exploitation for post-extraction secondary forests and post-fire secondary forests, ecosystems rapidly decline, resulting in large tracts of degraded secondary forests. In rehabilitated secondary forests, seed sources are often absent and the ground vegetation dense and highly competitive, and silvicultural interventions can facilitate the survival and growth of existing seedlings and accelerate forest rehabilitation.

SEEDS OF TROPICAL SECONDARY FORESTS

Development of secondary forests starts from seed dispersion and from root stake. Seed dispersion contributes to the development of secondary forests, but soil-stored seeds to forest regrowth is more important (Garwood, 1989), which contributes much more than that of recently dispersed seeds for most species (Young, 1987). The potential of secondary forests to regenerate from soil-stored seeds diminishes with increasing intensity of land use. Aide and Caveliev (1994) suggested that in severely degraded grasslands in the Sierra Nevada de Santa Marta, Colombia, the effect of forest regeneration from a seed bank is less important than the intensity of land use. Usually, the species richness and abundance of vegetation that developed from the clearing of old-growth forest tends to be poorer than those arising from cleared sites previously supporting successional vegetation (Young, 1987). The dominant type of land use in the surroundings influences floristic composition and density. For example, secondary forests close to agricultural or otherwise deforested land contain large amounts of light-demanding shrub and herbaceous species, whereas the soil seed banks of secondary forests have a smaller proportion of herbage (Dupuy and Chazdon, 1998). Increased levels of incident light temperature stimulate seed germination (Raich and Gong, 1990). Birds and other animals contribute to forest regeneration as seed dispersers (Oberhauser, 1997).

Remnant vegetation can strongly influence seed dispersal. In extensively deforested area, spatial distance may be a critical barrier to succession. Aide and Cavelier (1994) found no dispersed seeds in pastures at only 20 m away from the nearest forested patch. Parrotta (1993) has observed a significant negative correlation between seedling density distance and nearest possible seed source. After seeds are dispersed, seed predation is another important obstacle to tree establishment. Seed removal was higher in abandoned slash-and-burn farms than in adjacent forest in the upper Rio Negro, Venezuela (Uhl, 1987). In Paragominas, Brazil, more than 80% seed removal within 20 days for six out of 11 tree species examined, and the probability of small seeded species arrival into pastures was higher than those of larger seeded species, but the probability of seed predation was lower for the latter (Nepstad et al. 1996). Xiao et al. (2004) found that the big nuts were better survived with longer cache lifetime, longer dispersal distances and higher proportion of emerged seedlings than small nuts. In contrast, Holl and Lulow (1997) observed no obvious correlation between seed size and seed removal rates in an abandoned pasture of Costa Rica.

THE COMPOSITION AND CONSTRUCTION OF TROPICAL SECONDARY FORESTS

Forest succession is characterized by changes of species composition and community structure. Plant species and number of secondary forests generally increase with succession process. Kellman (1970) discovered the plant species number of secondary forests was almost the same as that of nearby mature forests. Some researches found younger secondary forests have more tree species than old ones. For example, Laska (1997) pointed out in analyzing 12-year and 25-year secondary forests in Costa Rica, the younger forest growth is richer and has more plants per plot than a 25-year old forest. In general, old growth forest tree assemblages are more diverse than secondary growth tree assemblages in the tropics. Younger secondary growth forest has a more open canopy structure than older growth forests, allowing higher levels of light at shrub layer which may result in shrub assemblages of higher diversity than adjacent old growth forest. Although the basal area, tree height and biomass of the old secondary forest approached that of the primary forest, mortality, recruitment, turnover and tree growth rates were greater in the old secondary forest. The seed bank of the old secondary forest contained more than double the number of seeds of the primary forest seed bank and many more seeds were of shrub species (Brearley et al. 2004).

Early successional species are generally shade-intolerant while climax or late successional species are shade-tolerant, being found under their own canopy or that of early successional species. Cain and Shelton (2001) found that early successsional tree species were shade-intolerant pine during secondary succession in Arkansas, USA. With succession progressive, the shade-intolerant pines declined and the more shade tolerant hardwoods increased, the canopy gradually becomes multi-layered with the intolerant pines occupying the upper-most layer followed by the oaks and other intermediate-tolerant canopy species, and then the most shade-tolerant members of the community develop to midcanopy, and finally they attain dominant canopy positions due to pine individual mortality from senescence or collective mortality form catastrophic disturbance. In the lowland moist and wet Neotropics, the first decade of forest succession after site abandonment is dominated by grasses, shrubs, and forbs, which are eventually shaded out by short-lived, light-demanding "pioneer" tree species. After this period, the canopy is dominated by long-lived, taller-statured, and light demanding tree species, and sometimes much larger-sized and even longer-lived species. Eventually, the canopies of these secondary stands may be replaced by other shade tolerant species characteristic of old-growth forest (Guariguata *et al.*, 1997, Denslow and Guzman, 2000).

In India, when a forest is converted to farmland, perturbations due to fire, the introduction of crop species, weeding and other disturbances during crop harvest all result in a large reduction in the number of species. During secondary succession, the number of species increases gradually (Toky and Ramakrishnan, 1983). The change in community structure was very marked at the low altitude, from the initial weedy herbs, to a bamboo forest and, finally, to a mixed broad-leaved forest (Ramakrishnan and Kushwaha, 2001).

Species composition of secondary forests is closed to that of primary forests after secondary succession for few centuries. For example, Saldarriga et al. (1988) observed a small seedling with species characteristic of a primary forest become the dominant species for no longer than 60 years. With succession process, forest basal areas tended to increase and total individual density decreased, individual with DBH>10 cm increased (Lugo, 1992).

Young stands characterize higher tree densities, lower basal areas, and shorter canopy heights compared to old growth forest (Aide et al., 1996; Denslow and

Guzman, 2000). Tree species characteristics change with succession stages. Compared with late successional tree species, early successional tree species attain a narrow crown form with rapid extension growth from the main axis, a faster rate of branch production of different orders, which ensure them faster growth, capitalizing upon the high light availability in a transient environment; the early successional species have a higher rate of leaf production, faster turnover rate, and consequently a larger proportion of younger leaves to older ones. Root architecture and the consequent ability to exploit different profiles of the soil for early successional species is different to that of late successional species. With the rapid accumulation of nutrients in the surface layers of the soil after the clear cutting of a forest, the early successional species tend to distributes their roots in more surface soil, so as to absorb nutrients, whereas roots of the late successional trees have more uniform distribution down the profile (Ramakrishnan and Kushwaha, 2001).

PLANT SPECIES OF TROPICAL SECONDARY FORESTS AND LAND USE INTENSITY

Though plant species richness in secondary forests can approach old-growth values within a few decades after site abandonment, returning to a species composition similar to old-growth forest will be a much longer process (Finegan, 1996). Abandonment time and land use history are of overwhelming importance in determining the species composition of recovering forests (Chinea et al. 2003). This time frame will vary considerably depending on the intensity of past land use. Under light-to-moderate land use intensity, and when seed sources are nearby, plant species richness rapidly increases, which reaches similar values comparable to old-growth forest after a few decades. However, as intensity of past land use increases, recovery of species richness become slow due to soil compaction, propagule dispersal limitation, and fire occurrence (Nepstad et al. 1996). In montane forests, recovery of canopy composition with respect to old-growth forest may be reached much more rapidly than at low elevations (Olander et al. 1998). Past land use intensity also affects the composition of early colonizers. In wet Costa Rica, e.g., when land abandonment immediately follows forest cutting there tends to be a notable reduction in abundance of typical short-lived species. The absence of exposed mineral soil, and the presence of residual vegetation and litter may make it difficult for very small-seeded, short-lived pioneers to germinate and establish (e.g. Putz, 1983). In Puerto Rico, *Cecropia* could not colonize abandoned pastures the first decades post-abandonment (Aide et al. 1996), in spite of being the most common tree invader after landslides. The type of past land use may also affect species composition following abandonment. Zimmerman (1995) found that in 60-year-old abandoned coffee vs. abandoned pasture sites, tree and shrub species diversity was similar but floristic composition was greatly different. Rivera and Aide (1998) reported that similar species richness were found in secondary forests on abandoned pasture sites and on abandoned coffee sites, but their species composition was different. Degradation affects both the productivity and the species richness of secondary vegetation that may subsequently develop on the land. On abandoned subsistence farms in the Venezuelan Amazonand pastures in northeastern Brazil, the mean number of tree species in 0.01 ha plots was three to six times greater on cleared and burned but immediately abandoned land than on land grazed or cultivated in varying degree (Uhl, 1987; Uhl et al. 1988).

EFFECT OF ARTIFICIAL STANDS ON TROPICAL SECONDARY FORESTS

Plantation can accelerate germination and growth of seed by improving the light, temperature and the degree of humidity of soil surface layer (Parrotta et al. 1997). Plantation monocultures established on degraded tropical sites can greatly accelerate processes of plant succession and rates of biomass and nutrient accretion in vegetation and soils. In comparison with adjacent control areas, 4.5-year-old *Albizia lebbek* plantation stands showed a 11-fold increase in aboveground plant biomass, a 7-fold increase in root and forest floor biomass, and marked differences in aboveground and belowground structure (Parrotta et al. 1997). Otsamo (2000) found that In Riam Kiwa region, Indonesia, planting artificial plantations with suitable foreign species, such as *Gmelina arborea, Paraserianthes falcatariamay* accelerated natural regeneration of local tree species. Plantation species had a considerable influence over understorey seedling/sapling density and species richness, which was highest in the *A. mangium* stands with an average of 3,042 seedlings of 29 species per hectare. Therefore, only successful plantations with good growth and early canopy closure can act as initial steps in the secondary succession of *Imperata* grasslands. Otherwise the stands will remain uneven, the amount of *Imperata* grass will be very high and secondary succession will be as slow as it is in grassland areas.

Lugo (1992) compared the structure and dynamic of secondary forests with those of paired *Pinus caribaea* and *Swietenia macrophylla* plantations of similar age. Although the small-unmanaged plantations had a lower number of species in the understory than paired secondary forests, the understory of the older plantations developed high species richness, including many of native tree species. After 17 years, native tree species invaded the overstory of plantations. After 50 years the species richness in the understory of a *S. macrophylla* plantation approached that of its paired secondary forest.

Oberhauser (1997) studied four *Pinus kesiya* plantations, aged 7, 12, 21 and 28 years, growing on abandoned agricultural areas. Results of the study revealed a high number of vascular species in the plots. Increasingly complex forest structure could be observed as mid-and low-level canopies had developed and other species replaced pines in the overstorey. Increasing numbers of animal dispersed tree species became established in the older plantations. Recovery of woody vegetation was faster in plantations than in areas not afforested with *P. kesixa*. It appears that *P. kesiva* plantations can enhance establishment of mixed forests.

TROPICAL SECONDARY FORESTS AND ANIMALS

Conversion of primary forests to secondary forests has a negative impact on the populations of arboreal mammals, because it alters their habitat and decreases food supply (Kartawinata et al. 2001). Some secondary forests near high forests may help in maintaining high wildlife diversity because high forests provide most of the required habitats for wildlife, but secondary forests contain more foods for animals. Pioneer species that are common in secondary forests do have little or no mechanical or chemical protection against herbivores and this may be one reason that most herbivores feed in secondary forests. Also, many early and late seral tree species in secondary forests produce edible fruits in large quantities. These are reasons why most herbivores like to find foods in secondary forests (Perera, 2001). The situation for browsing animals may be improved by the luxuriant secondary forest regeneration. Some species of birds require a large area of relatively undisturbed forest to maintain breeding populations or mature trees for nesting, whereas colonizing birds prefer to feed in disturbed forest and their numbers increase in secondary forests (Kartawinata et al. 2001). Natural secondary forests were a better habitat for forest birds than the plantation. Compared to the plantation, there were most tree species in secondary forests, and both bird density and the number of breeding species were much high. Many studies have shown that plantations are unsuitable habitats for some animal species, because of a lack of food and complexity of stand structure and species composition (*e.g.* Gjerde and Sætersdal, 1997; Di'az et al. 1998; Garcia et al. 1998). Some researchers found that bird species diversity is correlated with the vegetation complexity in a habitat (Kwok and Corlett, 2000).

TROPICAL SECONDARY FOREST SUCCESSION AND ENVIRONMENT

Environment has important effect on secondary forest succession. Leak (1991) reported that successional attributes of secondary forests in New Hampshire, USA: Successional direction varies by site. Fine till soils tend toward beech, sugar maple, and associated hardwoods; sandy tills toward a predominance of beech; shallow or dry sites toward hemlock and spruce. In Amazônia, moisture limitations are likely factor to constrain secondary forest growth (Johnson et al. 2000), particularly where there is a pronounced dry-season (Nepstad et al. 1994).

Rivera and Aide (1998) found in studying the karst region of Puerto Rico that species diversity of trees greater than 1 cm DBH was high in abandoned pastures in comparison with abandoned coffee plantations. The higher diversity in the abandoned pasture sites may be due to the presence of both light demanding and shade tolerant species that co-occur at this stage of forest development. The unique topography of the karst region may be most important factor contributing to the rapid recovery of secondary forest. Karst topography includes long narrow valleys surrounded by hill with steep slopes. This topography protects the valleys from strong winds during hurricanes and tropical storms. In addition, the accumulation of soil and organic matter in the valley bottoms creates better conditions for plant growth. The long narrow valleys will be more protected from direct sun light and less soil erosion.

Aboveground microhabitat differences influence early plant composition during secondary succession (Uhl et al. 1981), and small-scale variation in soil nutrients has the potential to affect the distribution, composition, and growth of colonizing species. Harcombe (1977) found in examining successional trajectories that herbs dominated fertilized plots, while shrubs and trees dominated unfertilized plots during the same time period. Floristic and life-form composition during secondary forest succession are influenced by the availability of soil resources. Species with high growth rates may be disproportionately favored under ample resource levels which leads to their over dominance during early succession because slow-growing species tend to be less responsive to enhanced resource levels (Chapin et al. 1986). Soil resources do not only influence species composition of a site, it also can affect the availability of these resources to other species and thus further affect successional trajectories. Local variation in soil fertility can affect not only structure, but also the distribution of tree species. Herrera and Finegan (1997) reported that spatial distributions of *Vochysia ferruginea* concentrated on steeper slopes with acid soils, while *Cordia alliodopra* were more abundant on gentler topography with more basic soils. Moreover, these within-stand differences in canopy dominants were found to significantly influence understory floristic composition and species richness.

Altitude has certain effect on species composition. At lower altitudes, the dominant species in old-growth stands with a strong sprouting capacity also dominated secondary stands, and species composition of secondary and old-growth stands was similar, whereas at higher altitudes, the dominant species in old-growth stands had little sprouting capacity and were poorly represented in diverse secondary stands, and secondary stands had greater species diversity than old-growth stands (Aiba et al. 2001).

Logging and canopy gap have important effect on the regeneration of second forests. 8 years after selective logging, density and species richness in secondary stands were found lowered as compared to pre-harvest levels, but no major changes in family level taxonomic composition were observed (Cannon et al. 1998). Light levels under canopy and in gaps are highly heterogeneous. Large gaps have a hot, dry microclimate that increases mortality; excess shade will reduce growth (ITTO, 1989). Clearance of undergrowth to at least 10 m around planted patches would result in greater growth rates in planted seedlings and accelerate the regeneration of forest (Bebber et al. 2002).

Hurricanes contribute to regional landscape-scale variation in both stand structure and species composition. Hurricanes cause moderate to severe defoliation and can directly damage and kill trees through uprooting, breakage and loss of minor and major branches, and stem breakage (Walker, 1991). Hurricane winds directly affected large individuals by uprooting and bole snapping, and indirectly affected understory individuals by falling canopy trees and debris (*e.g.* Basnet et al. 1992; Fu et al. 1996). The death of individual stems reduced competition and increased light and nutrient availability, resulting in increasing growth of surviving stems into larger size classes (Pascarella et al. 2004).

Echeverria and Lara (2004) found in studying environmental influence in secondary forests in southern Chile that higher diameter-growth rates were associated with intermediate annual rainfall, a short dry period, and sandy soil. Lower rates were associated with an intermediate frost-free period, a low summer humidity index, a long dry period and silty soil.

BIOMASS AND PRODUCTIVITY OF TROPICAL SECONDARY FORESTS

Above-ground biomass, forest stand volume, and basal area increase slowly at the initial stages, then they rapidly increase in advanced stages. In contrast, average stand diameter and height increase relatively fast in initial stages, and then increase slowly in advanced stages (Lu et al. 2003).

Typically, secondary forest succession is characterized by shifts in the biomass allocation of the plant community. In early succession, relatively more biomass is allocated to resource acquiring tissues (leaves and fine roots) and in later stages more is allocated towards structural materials (woody stems and coarse roots). Fine root (<2mm diameter) biomass accumulates at a slower rate than leaf biomass, but its recovery can still be quite rapid. Secondary forests can also have similar or higher fine root biomass than old-growth forest after 1 to 10 year post-abandonment (Cavelier et al. 1996). Secondary forests are generally sinks of biomass as they re-vegetate, and thus they are also sinks of atmospheric carbon (Lugo and Brown, 1992). In general, secondary forests rapidly accumulate up to 100t/ha of biomass for about 15-20 years after abandonment (Brown and Lugo, 1990). Aboveground biomass usually shows an asymptotic pattern with time, although factors such as climate and past land use tend to affect the rate of accumulation.

Tropical secondary forests develop maximum biomass of 100 ton/ha in their first 15 years. After 15 years, forests diverge in the amount of biomass accumulation. Few of the forests accumulated more than 200 t/ha by age 80 years. Most tropical secondary forests reach leaf biomass peak by age 20 years and then remain steady or decrease slightly, their root biomass increases slowly with age, whereas their wood biomass increases rapidly during the first 15 to 20 years, followed by a steady but slower rate until maturity (Brown and Lugo 1990; Lugo 1992). Ticktin and Nantel (2004) compared the population dynamics of the understory under old-growth and secondary rainforests in Southeast Mexico. The results show that growth rates of secondary forest populations are higher than those of old-growth populations under both ramet-harvest and no-harvest conditions. Secondary forests that originated after shifting cultivation grow faster than secondary forests developing in abandoned pastures (Fearnside and Guimaraes, 1996).

NUTRIENT CYCLING IN TROPICAL SECONDARY FORESTS

Plants absorb nutrients for tissues grow and return some of the nutrients by litterfall to the soil. The vegetation of secondary forests quickly accumulates nutrients into leaves and roots during approximately the first 15 years of succession (Brown and Lugo, 1990). Such rapid nutrient accumulation is accompanied by nutrient return to soil (Lugo, 1992). With forest growth, however, most of the biomass is allocated to woody tissue and the rate of nutrient return decreases (Brown and Lugo, 1990).

A remarkably liner relation existed between species diversity and litter production and net primary productivity during the first to 20 years of succession in swidden fallow secondary forests in India. With the rapid transfer of nutrients from the soil to the vegetation during the early phase of fallow, rapid depletion of nutrients occurs in soil even though losses by leaching and runoff are greatly reduced. It is only after about 10 years of fallow that transfer of nutrients back to the soil through litterfall becomes important and soil fertility recovers (Ramakrishnan and Kushwaha, 2001)

McDonald and Healey (2000) found in studying primary and secondary forests in Jamaica that rates of nutrient loss in runoff and eroded sediment in secondary forest were low. Basal area had recovered to 81% of primary forest levels and rates of litterfall were high. Soil fertility had recovered well in the secondary forests. In the middle of steep slopes, following the cessation of agriculture, tight nutrient cycling and soil condition and fertility are effectively restored during ca. 20 years of secondary succession.

Johnson et al. (2001) compared nutrient concentrations and stocks in aboveground vegetation and soils between secondary forests (10-, 20-, and 40-year-old stands subject to repeated cycles of slash-and-burn agriculture) and a primary forest fragment in the Bragantina region of Brazil. There were no significant differences in median foliar tissue concentrations of N, P, K, Ca or Mg between the secondary forests and the primary forest. In woody tissue, the primary forest had a lower median Mg concentration than all secondary forest plots and a higher median N concentration than the 40-year-old secondary forest. Foliar nutrient stocks were higher in the secondary forests than in the primary forest due to higher foliar biomass estimates for those plots. Aboveground woody nutrient stocks were the greatest in the primary forest with the exception of Mg. Soil concentrations of exchangeable Ca decreased with increasing stand age; soil concentrations of exchangeable Mg were higher in all secondary plot soils than in the primary plot soil. Labile P stocks were greater in the primary forest soil than in all secondary forest soils.

Lugo (1992) reported that understory plant tissue, particularly leaf litter, had higher nutrient concentration in pine plantations than in paired secondary forests. Secondary forests recycled nutrients much faster than the plantations, which tended to store the nutrients. Litter of the secondary forests had a faster nutrient turnover than plantation litter.

Montagnini et al. (1995) studied the soil conditions of a 25-year secondary forest and a primary forest in Brazil. Their results show that soil pH, C, H, P, Ca and Mg were higher under secondary forest than under primary forest. Litter accumulation on the forest-floor was greater in secondary than in primary forest. Soil condition in the secondary forest may have improved as a result of the impacts of the dominant plant species in the regrowth.

Nutrients in litterfall released by litter decomposition. Variation in land management practices changes most of the factors that influence decomposition. Clearing and burning the vegetation for agricultural practices increases air and soil temperature and decreases soil moisture, which may lead to less litter input and a tendency toward slower decomposition of leaf litter than in the plots with canopy cover (Mesquita et al. 1998). Decomposition was related to forest development phase as well as leaf chemical composition. The earlier successional phase showed higher decomposition rates than later stages of succession, which was correlated with higher P concentration. Enhanced nutrient content favors more rapid decomposition in young forests, and enhanced microbial environments favor more rapid decomposition in older forests (Xuluc-Tolosa, 2003).

SOIL OF TROPICAL SECONDARY FORESTS

Soil properties can affect the growth and species composition of colonists on deforested land. After deforestation or burning, soil structure becomes badly because of increase in bulk density and decrease in soil porosity. The loss of soil organic matter decreases the water-holding capacity of soils and soil fertility. During land clearing, N is lost mainly through biomass removal, volatilization during burning, denitrification, and leaching. The clearance of the secondary forest lead to large changes in most measured soil properties. Over 5 years amounts of organic matter declined by 298.00 kg ha^{-1} a^{-1}, total N by 7.95 kg ha^{-1} a^{-1}, exchangeable K by 0.45 kg ha^{-1} a^{-1}, exchangeable Ca by 7.11 kg ha^{-1} a^{-1} and exchangeable Mg by 0.57 kg ha^{-1} a^{-1}; over the same period bulk density increased by 0.4 Mg m^{-3}. Of the soil properties more subject to year-to-year fluctuations, after 5 years the concentration of available P was 36% (0.004 g kg^{-1}) less in cleared plots than in forest (McDonald et al. 2002). The recovery of soil to its previous functions varies with forest type (Neill et al. 1997). For instance, secondary forests that were formerly pastures have a faster recovery of soil carbon than former agricultural fields (Silver et al. 1996). Former agricultural fields subjected to fertilization may have greater amounts of nutrients than secondary forests that regrow after other land uses (Brown and Lugo, 1990). Despite these variations, once plants begin to colonize a site through the processes described before, a variety of soil-plant feedback processes facilitate the recovery of soil functions.

RESEARCH EXPECTATION

Population increases, quick development in industry and construction of large-scale foundation facilities cause large-scale forest land perturbations including intensive logging, mining, conversion of forest lands to large-scale plantations and agriculture, as well as construction of dams, roads and other infrastructure. The number and area of secondary forests tend to increase. Tropical secondary forests as an important form of tropical forests have received the international social extensive concern in recent years. Tropical secondary forests become an important research content.

Regeneration from seed has been studied by some researchers, whereas study on re-sprouting from tree stumps and root-stocks is little, which is an important mechanism of regeneration for remaining primary forest species in highly fragmented landscapes. Much of emphasis in secondary succession has focused on dominating species or group of species during every stages of succession (Finegan, 1992). Differences in growth rates among species at different stages play an important role in succession. In order to accelerate succession, research of promoting tree growth by silvicultural treatments such as liberation thinning, refinement, and cleanings should be reinforced in the future study. Understanding how forests recover after logging is still a current research topic (Brown and Lugo, 1990; Lugo, 1992; Holl, 1999), the impact of logging on animal species and the impact of forest fragmentation on plant and animal species should not be neglected. The sample is insufficient to provide statistical descriptions linking rates of succession to logging and fire. Little is known about the effects of soil types, litter decomposition, prior land use on biomass accumulation. Fixed position study, the study on changes of microorganism, animal or other abiotic factors with forest succession is little. A multidisciplinary study including vegetation structures, key groups of plant, animal and microorganism species, plant functional types and abiotic factors, such as soil nutrient will establish useful linkages between these factors. Basic researches about successional mechanism, such as interspecific relationship, species niches and plant physiological and ecological characteristics during successional process are lacking. There has been little scientific integration of the structural and functional characteristics and processes that occur during secondary succession. These contents remain to make progress in future study of tropical secondary forests.

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REFERENCES

Aiba, S., Hill, D.A. & Agetsuma, N. 2001. Comparison between old-growth stands and secondary stands regenerating after clear-felling in warm-temperate forests of Yakushima, southern Japan. *Forest Ecology and Management*, **140**: 163–175.

Aide, T.M. & Cavelier, J. 1994. Barriers to lowland tropical forest restoration in the Sierra Nevada de Santa Marta, Colombia. *Restoration Ecology*, **2**: 219–229.

Aide, T.M., Zimmerman, J.K., Rosario, M. & Marcano, H. 1996. Forest recovery in abandoned cattle pastures along an elevational gradient in Northeastern

Puerto Rico. *Biotropica*, **28**: 537–548.

Bartholomen, W.V., Meyer, J. & Laudelot, H. 1953. Mineral nutrient immobilization under forest and grass fallow in the Yangambi (Belgian Congo) region. *Publications de L'Institut National pour L'Etude Agronomique du Congo Belge, Série Scientifique* No: 57, 27pp.

Basnet, K., Likens, G.E., Scatena, F.N. & Lugo, A.E. 1992. Hurricane Hugo: damage to a tropical rain forest in Puerto Rico. *Journal of Tropical Ecology*, **8**: 47–55.

Bebber, D., Brown, N., Speight, M., Moura-Costa, P. & Wai, Y.S. 2002. Spatial structure of light and dipterocarp seedling growth in a tropical secondary forest. *Forest Ecology and Management*, **157**: 65–75.

Brearley, F.Q., Prajadinata, S., Kidd, P.S., Proctor, J. & Suriantat. 2004. Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *Forest Ecology and Management*, **195**: 385–397.

Brown, S. & Lugo, A.E. 1990. Tropical secondary forests. *Journal of Tropical Ecology*, **6**: 1–32.

Cain, M.D. & Shelton, M.G. 2001. Secondary forest succession following reproduction cutting on the Upper Coastal Plain of southeastern Arkansas, USA. *Forest Ecology and Management*, **146**: 223–238.

Cannon, C.H, Peart, D.R. & Leighton, M. 1998. Tree species diversity in commercially logged Bornean rainforest. *Science*, **281**: 1366–1368.

Cavelier, J., Estevez, J. & Arjona, B. 1996. Fine root biomass in three successional stages of an Andean cloud forest in Colombia. *Biotropica*, **28**: 728–736.

Chapin, F.S., Vitousek, P.M. & Van Cleeve, K. 1986. The nature of nutrient limitation in plant communities. *American Naturalist*, **127**: 48–58.

Chazdon, R.L. & Coe, F.G. 1999. Ethnobotany of woody species in second growth, and selectively logged forests of Northeastern Costa Rica. *Conservation Biology*, **13**: 1312–1322.

Chinea, J.D. & Helmer, E.H. 2003. Diversity and composition of tropical secondary forests recovering from large-scale clearing: results from the 1990 inventory in Puerto Rico. *Forest Ecology and Management*, **180**: 227–240.

Chokkalingam, U., Smith, J. & de Jong, W. 2001. A conceptual framework for the assessment of tropical secondary forests dynamics and sustainable development potential in Asia. *Journal of Tropical Forest Science*, **13**: 577–600.

Dennis, R., Hoffmann, A., Applegate, G., von Gemmingen, G. & Kartawinata, K. 2001. Large-scale fire: creator and destroyer of secondary forests in Western Indonesia. *Journal of Tropical Forest Science*, **13**: 786–799.

Denslow, J.S. & Guzman, S. 2000. Variation in stand structure, light, and seeding abundance across a tropical moist forest chronosequence, Panama. *Journal of Vegetation Science*, **11**: 201–212.

Díaz, M., Carbonell, R., Santos, T. & Tellería, J.L. 1998. Breeding bird communities in pine plantations of the Spanish plateaux: biogeography, landscape and vegetation effects. *Journal of Applied Ecology*, **35**: 562–574.

Dotzauer, H. 1998. The potential of secondary forest management from a development policy point of view: An overview. In: *Plant Research and Development* 47/48 (eds. Bittner, A., Achtnich, W., Atanasiu, N., Böger, P., Caesar, K., Hoeppe, C. & Guo, L), pp. 79–87. Tübginen: Institute for scientific Co-operation.

Dupuy, J.M. & Chazdon, R.L. 1998. Long-term effects of forest regrowth and selective logging on the seed bank of tropical forests in NE Costa Rica. *Biotropica*, **30**: 223–237.

Echeverría, C. & Lara, A. 2004. Growth patterns of secondary *Nothofagus obliqua-N. alpina* forests in southern Chile. *Forest Ecology and Management*, **195**: 29–43.

FAO. Forest resources assessment 1990. 1996. Survey of tropical forest cover and study of change processes. *FAO Forestry Paper* 13. Rome.

Fearnside, P.M. & Guimaraes, W.M. 1996. Carbon uptake by secondary forests in Brazilian Amazonia. *Forest Ecology and Management*, **80**: 35–46.

Finegan, B. 1992. The management potential of neotropical secondary lowland rain forest. *Forest Ecology and Management*, **47**: 295–321.

Finegan, B. 1996. Pattern and process in neotropical secondary rain forest: the first 100 years of succession. *Trends in Ecology Evolution*, **11**: 119–124.

Fu, S., Pedraza, C.R. & Lugo, A.E. 1996. A twelve-year comparison of stand changes in a Mahogany plantation and a paired natural forest of similar age. *Biotropica*, **28**: 515–524.

Garcia, S., Finch, D.M. & León, G.C. 1998. Patterns of forest use and endemism in resident bird communities of north-central Michoacán, Mexico. *Forest Ecology and Management*, **110**: 151–171.

Garwood, N.C. 1989. Tropical soil seed banks: a review. In: *Ecology of Soil Seed Banks*, (eds. Leck, M.A., Parker, V.T. & Simpson, R.L.), pp. 149-209. Academic Press, San Diego.

Gjerde, I. & Sætersdal, M. 1997. Effects on avian diversity of introducing spruce *Picea* spp. plantations in the native pine *Pinus sylvestris* forests of western Norway. *Biological Conservation*, **79**: 241-250.

Greig-Smith, P. 1952. Ecological observations on degraded and secondary forest in Trinidad, British West Indies. I. General features on the vegetation. *Journal of Ecology*, **40**: 283-315.

Guan, D-S. 1996. Primary productivity and nutrients in the plant communities of succession in southern subtropical zone of South China. *Chinese Journal of Ecology*, **15**: 11-14.

Guariguata, M.R., Chazdon, R.L., Denslow, J.S., Dupuy, J.M. & Anderson, L. 1997. Structure and floristics od secondary and old-growth forest stands in lowland Costa Rico. *Plant Ecology*, **132**: 107-120.

Harcombe, P.A. 1977. The influence of fertilization on some aspects of succession in a humid tropical forest. *Ecology*, **58**: 1375-1383.

Herrera, B. & Finegan, B. 1997. Substrate conditions, foliar nutrients and the distributions of two canopy tree species in a Costa Rican secondary rain forest. *Plant and Soil*, **191**: 259-267.

Holl, K.D. 1999. Factors limiting tropical rain forest regeneration in abandoned pasture: seed rain, seed germination, microclimate, and soil. *Biotropica*, **31**: 229-242.

Holl, K.D. & Lulow, M.E. 1997. Effects of species, habitat, and distance from edge on post-dispersal seed predation in a tropical rain forest. *Biotropica*, **29**: 459-468.

ITTO. 1989. Pre-Project Study Report: Enrichment Planting. International Timber Trade Organization.

ITTO. 2002. Guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. *Thirty-second Session Bali*, Indonesia.

Johnson, C.M., Vieira, I.C.G., Zarin, D.J., Frizano, J. & Johnson, A.H. 2001. Carbon and nutrient storage in primary and secondary forests in eastern Amazonia. *Forest Ecology and Management*, **147**: 245-252.

Johnson, C.M., Zarin, D.J. & Johnson, A.H. 2000. Post-disturbance aboveground biomass accumulation in global secondary forests: climate, soil texture, and forest type effects. *Ecology*, **81**: 1395-1401.

Kartawinata, K., Riswan, S., Gintings, A.N. & Puspitojati, T. 2001. An overview of post-extraction secondary forests in Indonesia. *Journal of Tropical Forest* Science, **13**: 621-638.

Kellman, M.C. 1970. Secondary plant succession in tropical montane Mindanao. *Australian National University Publication* BG/2. Canberra: Australian National University.

Kwok, H.K. & Corlett, R.T. 2000. The bird communities of a natural secondary forest and a Lophostemon confertus plantation in Hong Kong, South China. *Forest Ecology and Management*, **130**: 227-234.

Laska, M.S. 1997. Structure of understory shrub assemblages in adjacent secondary and old growth tropical wet forests, Costa Rica. *Biotropica*, **29**: 29-37.

Leak, W.B. 1991. Secondary forest succession in New Hampshire, USA. *Forest Ecology and Management*, **43**: 69-86.

Lu, D-S, Mausel, P., Brondizio, E. & Moran, E. 2003. Classification of successional forest stages in the Brazilian Amazon basin. *Forest Ecology and Management*, **181**: 301-312.

Lugo, A.E. 1992. Comparison of tropical tree plantation with secondary forests of similar age. *Ecological Monograph*, **62**: 1-41.

Lugo, A.E. & Brown, S. 1992. Tropical forests as sinks of atmospheric carbon. *Forest Ecology and Management*, **54**: 239-255.

McDonald, M.A. & Healey, J.R. 2000. Nutrient cycling in secondary forests in the Blue Mountains of Jamaica. *Forest Ecology and Management*, **139**: 257-278.

McDonald, M.A., Healey, J.R. & Stevens, P.A. 2002. The effects of secondary forest clearance and subsequent land-use on erosion losses and soil properties in the Blue Mountains of Jamaica. *Agriculture, Ecosystems and Environment*, 92: 1-19.

Mesquita, De C.G.R., Workman, S.W. & Neely, C.L. 1998. Slow litter decomposition in a *Cecropia*-dominated secondary forest of central Amazonia. *Soil Biology & Biochemistry*, **30**: 167-175.

Montagnini, F., Fanzeres, A. & Vinha, S.G.D. 1995. The potentials of 20 indigenous tree species for soil rehabilitation in the Atlantic forest region of Bahia, Brazil. *Journal of Application Ecology*, **32**: 841-856.

Neill, C., Melillo, J.M., Steudler, P.A., Cerri, C.C., de Moraes, J.F.L, Piccolo, M.C. & Brito, M. 1997. Soil carbon and nitrogen stocks following forest clearing for pasture in the southwestern Brazilian Amazon. *Ecological Application*, **70**: 1216-1225.

Nepstad, D.C., de Carvalho, C.R., Davidson, E.A., Jipp, P.H., Lafabvre, P.A., Negreiros, G.H., da Silva, E.D., Stone, T.A., Trumbore, S.E. & Vieira, S. 1994. The role of deep roots in the hydrological and carbon cycles of Amazonian forests and pastures. *Nature*, **372**: 666–669.

Nepstad, D.C., Uhl, C., Pereira, C.A. & da Silva, J.M.C. 1996. A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia. *Oikos*, **76**: 25–39.

Oberhauser, U. 1997. Secondary forest regeneration beneath pine (*Pinus kesiya*) plantations in the northern Thai highlands: a chronosequence study. *Forest Ecology and Management*, **99**: 171–183.

Olander, L.P., Scatena, F.N. & Silver, W.L. 1998. Impacts of disturbance initiated by road construction in a subtropical cloud forest in the Luquillo Experimental Forest, Puerto Rico. *Forest Ecology and Management*, **109**: 33–49.

Otsamo, R. 2000. Secondary forest regeneration under fast-growing forest plantations on degraded Imperata cylindrica grasslands. *New Forests*, **19**: 69–93.

Parrotta, J.A. 1993. Secondary forest regeneration on degraded tropical lands: The role of plantations as ' foster ecosystems' In: *Restoration of Tropical Ecosystems*, (eds. Lieth, H. & Lohmann, M.), pp. 63–73. Kluwer, Dordrecht.

Parrotta, J.A., Turnbull, J.W. & Jones, N. 1997. Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management*, **99**: 1–7.

Pascarella, J.B., Aide, T.M. & Zimmerman, J.K. 2004. Short-term response of secondary forests to hurricane disturbance in Puerto Rico, USA. *Forest Ecology and Management*, **199**: 379–393.

Perera, G.A.D. 2001. The secondary forest situation in Sri Lanka: a review. *Journal of Tropical Forest Science*, **13**: 768–785.

Putz, F.E. 1983. Treefall pits and mounds, buried seeds, and the importance of soil disturbance to pioneer trees on Barro Colorado Island, Panama. *Ecology*, **64**: 1069–1074.

Raich, J.W. & Gong, W.K. 1990. Effects of canopy openings on tree seed germination in a Malaysian dipterocarp forest. *Journal of Tropical Ecology*, **6**: 203–217.

Ramakrishnan, P.S. & Kushwaha, S.P.S. 2001. Secondary forests of the Himalaya with emphasis on the north-eastern hill region of India. *Journal of Tropical Forest Science*, **13**: 727–747.

Rivera, L.W. & Aide, T.M. 1998. Forest recovery in the karst region of Puerto Rico. *Forest Ecology and Management*, **108**: 63–75.

Ross, R. 1954. Ecological studies on the rain forest of Southern Nigeria. III. Secondary succession in the Shasha reserve. *Journal of Ecology*, **42**: 259–282.

Saldarriaga, J.D., West, D.C., Tharp, M.L. & Uhl, C. 1988. Long-term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. *Journal of Ecology*, **76**: 938–958.

Silver, W.L., Scatena, F.N., Johnson, A.H., Siccama, T.G. & Watt, F. 1996. At what temporal scales does disturbance affect belowground nutrient pools? *Biotropica*, **28**: 441–457.

Thomlinson, J.R., Serrano, M.I., del M López, T., Aide, T.M. & Zimmerman, J.K. 1996. Land-use dynamics in a post-agriculture Puerto Rican landscape (1936–1988). *Biotropica*, **28**: 525–536.

Ticktin, T. & Nantel, P. 2004. Dynamics of harvested populations of the tropical understory herb *Aechmea magdalenae* in old-growth versus secondary forests. *Biological Conservation*, **120**: 461–470.

Toky, O.P. & Ramakrishnan, P.S. 1983. Secondary succession following slash-and-burn agriculture in north-eastern India. I. Biomass, litterfall and productivity. *Journal of Ecology*, **71**: 735–745.

Uhl, C. 1987. Factors controlling succession following slash-and burn agriculture in Amazonia. *Journal of Ecology*, **75**: 377–407.

Uhl, C., Clark, K., Clark, H. & Murphy, P. 1981. Early plant succession after cutting and burning in the upper Rio Negro region of the Amazon basin. *Journal of Ecology*, **69**: 631–649.

Uhl, C., Buschbacher, R. & Serrao, E.A.S. 1988. Abandoned pastures in eastern Amazonia. I. Patterns of plant succession. *Journal of Ecology*, **76**: 663–681.

Walker, L.R. 1991. Tree damage and recovery from Hurricane Hugo in the Luquillo Experimental Forest. Puerto Rico. *Biotropica*, **23**: 379–385.

Xiao, Z-S., Zhang, Z-B., Wang, Y-S. 2004. Dispersal and germination of big and small nuts of *Quercus serrata* in a subtropical broad-leaved evergreen forest. *Forest Ecology and Management*, **195**: 141–150.

Xuluc-Tolosa, F.J., Vestera, H.F.M., Ramı´rez-Marcial, N., Castellanos-Albores, J. & Lawrence, D. 2003. Leaf litter decomposition of tree species in three successional phases of tropical dry secondary forest in Campeche, Mexico. *Forest Ecology and Management*, **174**: 401–402.

Young, K.R., Ewel, J.J. & Brown, B.J. 1987. Seed dynamics during forest succession in Costa Rica.

Vegetatio, **71**: 157–173.

Zimmerman, J.K, Aide, T.M., Rosario, M., Serrano, M. & Herrera, L. 1995. Effects of land management and a recent hurricane on forest structure and composition in the Luquillo Experimental Forest, Puerto Rico. *Forest Ecology and Management*, **77**: 65–76.

Zimmerman, J.K. et al. 1996. Past land use as an important determinant of species composition in secondary forests of Puerto Rico. Paper presented at the Symposium "Ecological processes in low land tropical secondary forests", held at IITF, Puerto Rico.

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Using Generalized Poisson Distribution to Describe the Species Abundance Patterns in a Forest Community

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Abstract

In many biological communities, the species abundance (SA) has an obvious inverse J-shaped pattern. Here we examined whether a discrete zero-truncated generalized Poisson (GP) distribution could describe this pattern, and whether its parameters were related to species diversity using data from a lower subtropical mixed forest in Dinghushan Biosphere Reserve, South China. The observed SA patterns of all three layers (tree, shrub, to herb layer) were inverse J-shaped and followed the zero-truncated GP with two parameters (λ, α), with significantly decreasing λ and slightly increasing α. The SA patterns for all three layers of the forest showed similar inverse J-shaped distribution curves, similar median (= 2–3) and α values, and identical mode (= 1), possibly due to the homogeneity of macroenvironment at the forest stand in the lower subtropical monsoon climate zone. There were also some different properties, e.g., the significant decrease of mean, variance, and λ from the tree, shrub, to herb layer, possibly caused by the heterogeneity of local habitat in the forest layers of different height. The two parameters, α and λ, led the SA curves to be inverse J-shaped rather than single hump-shaped but α would better reflect the diversity than λ. Comparisons between the GP and Poisson lognormal (PLN) distributions showed that the former fitted to the SA data better than the latter. GP particularly fits the SA datasets with over-dispersion and may have broader applications than PLN.

Key words: Dinghushan Biosphere Reserve, forest community, inverse J-shape, species abundance (SA), generalized Poisson (GP) distribution

Introduction

The species abundance (SA) pattern or distribution (i.e., SAD) is one of the most fundamental aspects of community structure once referred to as the "minimal community structure" (Sugihara 1980). For example, the distribution of commonness and rarity among species, firstly described by Preston (1948, 1962), has often been regarded as one of the best-documented patterns in natural communities (Molles 1999). In many cases, the SA pattern in a community (or strictly speaking, a multi-species collection) is obviously inverse J-shaped, i.e. there are a few common species and many rare species (particularly, single-individual species or singletons), but in total, the former usually have more individuals than the latter (Pielou 1985).

To model the SA pattern, ecologists have developed various statistical and niche models, including the log-series distribution (Fisher *et al.* 1943) and its generalized form (Kempton 1975), lognormal distribution (Preston 1948), Poisson-lognormal distribution (Grundy 1951), negative binomial distribution (Brian 1953) and its generalized form (Engen 1974), and broken stick model (MacArthur 1957). Each of these models has some unique characteristics which may fit the SA data in different types of biological communities (Peng *et al.* 2003). Among all these models, Preston's lognormal distribution has been most widely used to fit a variety of SA data from surprisingly diverse plant and animal communities or collections (e.g. Whittaker 1965; Gauch & Chase 1974; May 1975; Slocomb *et al.* 1977; Krebs 1978; Coleman 1981; Ugland & Gray 1982; Miller & Wiegert 1989; Brown *et al.* 1995; Basset *et al.* 1998; Hill & Hamer 1998; Engen 2001; Fesl 2002; McGill 2003; Yin 2005; Yin *et al.* 2005b, 2005c).

The lognormal is a continuous distribution in statistics. However, the abundance of a species is often expressed as the number of individuals of the species (r), which is apparently a discrete variable. Preston (1948) regarded species abundance in relative terms and grouped r on a $\log_2$ scale called the "octave". Preston (1948) expressed the SAD as a frequency distribution and proposed to fit the lognormal distribution. He treated the observed distribution as a truncated, grouped lognormal distribution (Preston 1948; see also Bliss 1965; Yin and Liao 1999). However, such statistical treatment ignored the effect of the sampling variability and adopted more-or-less arbitrary abundance grouping (Yin *et al.* 2005c). Furthermore, this method does not provide a satisfactory approximation to the probabilities, P_r, when r is near to zero, as shown in Grundy (1951) and reiterated by Cassie (1962) and Kempton and Taylor (1974). In any case, it should be more reasonable to use some discrete probability distributions to model count dataset (not grouped) where the abundance is a discrete variable. Ecologists have used a mathematically more accurate compound distribution, the Poisson lognormal (PLN; Grundy 1951; Cassie 1962; Pielou 1969, 1985; Bulmer 1974; Kempton and Taylor 1974; Etienne and Olff 2004). But the PLN distribution is based on the assumption that the number of members per species in the collection is a Poisson variate (Grundy 1951; Pielou 1969; Bulmer 1974). This assumption is often not realistic because in nature, individuals of most species are seldom randomly or regularly but commonly contagiously distributed through space (Taylor *et al.* 1978; Greig-Smith 1983; Brown *et al.* 1995; He *et al.* 1997; Condit *et al.* 2000; Yin *et al.* 2005a).

In these cases, we proposed a discrete probability distribution, the generalized Poisson (GP) distribution, without the above Poisson supposition. The GP with two parameters, introduced by Consul and Jain (1973) and studied extensively by Consul (1989), is defined on the non-negative integers. It is a natural extension of the standard Poisson distribution with one parameter and has some unique properties (Tuenter 2000; also see Methods). It extends the Poisson by its ability to describe settings where the occurrence probability of a single event does not remain constant as in a Poisson process, but is influenced by previous occurrences (Tuenter 2000). Consul (1989) found that the GP can accurately describe the spatial distribution of insects, where initial occupation of a spot by an individual of a species has an impact on the attractiveness of the spot to other members of the species, and the number of units of different commodities purchased by consumers, where current sales have an influence on the subsequent ones through repeat purchases (see also Tuenter 2000). Similarly, in the case of the hypothesis that the abundance of a species should affect the others, we used the GP to describe an inverse J-shaped SAD in a forest community. Since no species will have zero (or smaller than one) individuals in the sample, the distribution described here is zero-truncated. Up to date, the GP distribution has not been reported to model the SAD in community ecology (see review by Peng *et al.* 2003; also see Yin *et al.* 2005b, 2005c).

Methods

Community sampling

In accordance with the Smithsonian/MAB biodiversity program (Dallmeier 1992), a 1-ha permanent forest community plot (100 m × 100 m) was established in 1999 at an elevation of 250 m in Dinghushan Biosphere Reserve (112°30′39″–112°33′41″ E, 23°09′21″–23°11′30″ N), Guangdong Province, South China (Zhang *et al.* 2002). The site belongs to lower subtropical evergreen needle- and broad-leaved mixed forest, with several dominant tree species such as *Castanopsis chinensis* Hance, *Schima superba* Gardn. et Champ., and *Pinus massoniana* Lamb.. We censused all the tree species with a diameter at breast height (DBH) ≥ 1 cm in the tree layer of the community at 25 400-m^2 quadrats at each of which we also chose a 25-m^2 quadrat to census the shrubs and seedlings of trees (DBH < 1cm, height ≥ 50 cm) in the shrub layer, and meanwhile we chose a 1-m^2 quadrat at each of 25 25-m^2 quadrats to census the herbs and seedlings of trees and shrubs (height < 50 cm) in the herb layer.

Distribution model

Following Famoye (1993; see also Tuenter 2000), the function P_r is defined on the non-negative integers by

$$P_r = \left(\frac{\lambda}{1+\alpha\lambda}\right)^r \frac{(1+\alpha r)^{r-1}}{r!} \exp\left(-\frac{\lambda(1+\alpha r)}{1+\alpha\lambda}\right), \qquad (1)$$

where $r = 0, 1, 2, \ldots, \lambda > 0, \alpha \geq 0$. This defines a discrete probability distribution, known as the generalized Poisson (GP) distribution where the mean M and variance V of r are given by

$M = \lambda$ (2)
$V = \lambda(1 + \alpha\lambda)^2$. (3)
The GP distribution is a natural extension of the standard Poisson distribution. If $\alpha = 0$, the probability function in Equation (1) reduces to the standard Poisson distribution with equidispersion, i.e. $V = M$. If $\alpha > 0$, then $V > M$ and the GP distribution represents count data with over-dispersion (Wang and Famoye 1997).

This study attempted to model the SA count data in a community with over-dispersion, i.e. $V > M$, by using a GP distribution. Assume that the SA pattern in a community with total number of species (S^*) follows a complete GP distribution, i.e., the numbers of species S_0, S_1, S_2, ... with the numbers of individuals per species $r = 0, 1, 2, \ldots$, respectively, where $S_r = S^* P_r$, are species numbers expected from P_r.

However, the true value of S^* is usually unknown because the expected number of individuals of some species are smaller than 1 and such species are basically overlooked in an observation (Pielou 1985). If the observed total number of species is S, then $S^* - S = S_0$ is the number of species without any individuals (i.e., not collected in a sample). Since $S_0 = S^* P_0$ and $S^* - S = S_0$, we can obtain the estimate of S^*, given by

$S^* = S / (1 - P_0)$ (4)

where

$P_0 = \exp[-\lambda / (1 + \alpha\lambda)]$ (5)

is the probability with no individuals, which can be obtained by substituting $r = 0$ in Equation (1).

To fit the observed SA data in which there is no species with no individuals, we proposed a zero-truncated probability distribution described as

$P_r' = P_r / (1 - P_0) \quad (r = 1, 2, \ldots)$, (6)

where P_r is the probability function of a complete distribution defined by Equation (1). P_r' in Equation (6) is thus a probability function with the mean M' and variance V' given by

$$M' = \frac{\lambda}{1 - \exp[-\lambda/(1+\alpha\lambda)]} \tag{7}$$

$$V' = \frac{\lambda}{1 - \exp[-\lambda/(1+\alpha\lambda)]}\left((1+\alpha\lambda)^2 - \frac{\lambda \exp[-\lambda/(1+\alpha\lambda)]}{1 - \exp[-\lambda/(1+\alpha\lambda)]}\right) \tag{8}$$

Data analysis

From the count data of each species in the community, we first denoted the SA pattern as follows: S_1 species represented by one individual, S_2 species by two individuals, ..., S_r species by r individuals, ..., and then plotted S_r on r to obtain the SA frequency distribution histogram. We used the number of individual per species, r, as a concrete random variable following some probability distribution such as a zero-truncated GP distribution used in this study.

The distribution parameters from a sample was estimated using the maximum likelihood technique and value-trying method (Yin *et al.* 2005c), i.e. finding precise estimates of the parameters such that the log likelihood function reaches a maximum, written as

$$\ln L(\lambda,\alpha) = \sum_{r=1} S_r \ln P_r^{'} = \max \,, \qquad (9)$$

where S_r, equivalent to the observed frequency of r individuals, is the observed number of species with r individuals; $S_1 + S_2 + \ldots + S_r + \ldots = S$, equivalent to the sample size, is the observed total number of species.

We tested the goodness of fit of the expected distribution to the observed discrete count data or SA data. Because of the nature of the dataset, we applied the goodness-of-fit chi-square (χ^2) test (Glover & Mitchell 2001). Finally, we compared the GP with PLN in fitting the SADs through the Akaike information criterion (AIC; Akaike 1973; also see Wang and Famoye 1997) and the consistent AIC (CAIC; e.g., Gurmu and Trivedi 1996; Melkersson and Rooth 2000), which are defined as

$$\text{AIC} = -\ln L + K;\ \text{CAIC} = -2\ln L + K(\ln S + 1), \qquad (10)$$

where $\ln L$ is the value of the log likelihood function, K the number of estimated parameters, and S the sample size (i.e., the observed total number of species in our study). The smaller the AIC or CAIC, the better the model.

Results

Our investigation at the 1-ha permanent forest community plot in Dinghushan Biosphere Reserve showed that: (1) the tree layer had 3890 individuals belonged to 69 species including several dominant trees such as *C. chinensis*, *S. superba*, and *P. massoniana* in 25 400-m^2 quadrats; (2) the shrub layer had 428 individuals of 39 species including a few dominant shrubs such as *Litsea rotundifolia Var. oblongifolia* (Nees) Allen, *Psychotria rubra* (Lour.) Poir., and *Rhodomyrtus tomentosa* (Ait.) Hassk. in 25 25-m^2 quadrats; and (3) the herb layer had 151 individuals of 32 species including some dominant herbs such as *Lophatherum gracile* Brongn. in 25 1-m^2 quadrats.

The Shannon-Wiener diversity indexes (D_{sw}'s) of the tree, shrub and herb layers of the forest were 3.923, 4.010 and 4.207, respectively, and the measures of equitability or evenness based on these indexes (E_{sw}'s) were correspondingly 0.642, 0.759 and 0.841. The observed mean (m), variance (v) and v/m ratio of r significantly decreased from the tree, shrub to herb layer, and again all the ratios were much greater than one. On the other hand, the medians (= 2–3) and modes (= 1) of r for three layers were almost equal (Table 1).

While plotting the number of species S_r with r individual(s) against r, we obtained the inverse J-shaped frequency distributions of the observed SAs in three layers. Since the observed variance of the random variable r was much larger than the mean for each layer (Table 1) and there was an over-dispersion in the SA data, we applied the zero-truncated GP distribution to describe this pattern. We examined these observed SA patterns in the three layers of the community and found consistent zero-truncated GP distributions in the three layers (chi-square test, $P(\chi^2) > 0.05$; Table 1).

As to the distribution parameters, the λ values significantly decreased while the α values were close to one another although slightly increased from the tree, shrub, to herb layer in the community (Table 2). In the expected zero-truncated distributions, the curve's steepness followed the tendency: tree layer < shrub layer < herb layer, or the curve's slope rate (< 0) at any point of r had a converse tendency (Fig. 1). Moreover, P_0 (i.e. the probability of species with no individuals), calculated by Equation (5), showed the same tendency of magnitude as α-parameter, D_{sw} and E_{sw} but the converse pattern with λ-parameter for the three layers (Table 2). In particular, of two parameters of fitted GP distribution, the parameter α showed a more similar pattern to the diversity index than the parameter λ (Tables 1 and 2): like the D_{sw} or E_{sw}, the α showed much less increase from tree layer to shrub layer to herb layer, or, the values of α for three layers were much close to each other; while the λ decreased dramatically, or, the three λ values were very different. We also found that, for each layer, the α value was nearly two times the evenness E_{sw}, further suggesting that the parameter α may describe the species diversity.

Comparisons between the observed and expected statistics (or parameters) for each layer (Tables 1 and 2), showed that the expected mean from the zero-truncated GP distribution was equal to the observed (i.e., $M' = m$), indicating that the GP model fitted well to the SA data; but the expected variance was much larger than the observed (i.e., $V' > v$), maybe due to the large variation of abundances among the species in the observation where there were no species existing at many r's.

By comparing the GP and PLN distributions in the goodness of fit to the observed SADs, we found that the former agreed with the data better than the latter in each of the three layers. This is because for each layer in the forest community, either AIC or CAIC value of the fitted GP was smaller than the corresponding value of the fitted PLN (Table 3). But there were different appearances among three layers for the AIC or CAIC value: the GP was dramatically less than the PLN for the tree layer, while the former was slightly less than the latter for the other two layers.

Discussion and conclusion

The SA pattern in either tree, shrub, or herb layer in the evergreen needle- and broad-leaved mixed forest community in Dinghushan Biosphere Reserve, Guangdong of South China, showed a GP distribution that can describe the over-dispersion shown in the count data. Our data show that the abundance of a species, especially of a dominant species, can greatly affect the abundances of others in diverse and complex communities like the mixed forest in our case. In long-term succession of a forest, the occurrence of a species may influence the invasion or establishment of subsequent species, thus generating the GP distribution. We further found that the GP is always better than the PLN in terms of the goodness of fit to the same SA data in the three layers in the forest, suggesting the GP's possibly wider applicability to the description of SADs with the over-dispersion in other communities.

For all the three layers of the community, the SA frequency distribution curves were inverse J-shaped, the respective medians and modes were almost equal, and the α-parameter values of the fitted zero-truncated GP distributions were close to one another. These similarities in the SA patterns among the three layers might be due to the homogeneity of macroenvironment at the same forest stand in the lower subtropical monsoon climate zone (Yin *et al.* 2005c). On the other hand, the SA patterns between the three layers had some different properties, including the remarkablely decreasing means, variances, variance/mean ratios, and λ-parameter values of the zero-truncated GP distribution from the tree, shrub, to herb layer. This might be because of the heterogeneity of microenvironment (i.e., local community habitat with the different distribution height among species) (Yin *et al.* 2005c).

The zero-truncated GP distribution's two parameters determine its scale and shape. The numerical computation in the software Mathematica 4 shows that only if $0 \leq \alpha \leq 0.291$ and $2.01 \leq \lambda \leq \infty$, the distribution graph may become unimodal (i.e., hump-shaped), otherwise inverse J-shaped. In this study, we have $\alpha > 0.291$ for all the layers of the community, therefore, the distribution curves are all inverse J-shaped. Furthermore, when $\alpha \geq 1.1$ and $\lambda \geq 1.2$, the larger α or the smaller λ, the smaller the curve's slope rate (< 0) at any point of r, suggesting the greater steepness of the inverse J-shaped curve. This may be why the distribution curve for the herb layer is sleeper than the one for the shrub layer that in turn is sleeper than the one for the tree layer (Fig. 1). A steeper SA distribution curve implies more rare species (particularly singletons) and fewer common species in a community, and consequently suggests a lower steepness of rank-abundance curve (Yin *et al.* 2005c), resulting in a larger Shannon-Wiener diversity index (D_{sw}) even if the species richness is still the same, i.e. a greater evenness based on this index (E_{sw}) (Molles 1999). This is the case: for the steepness of SA distribution curve, herb layer > shrub layer > tree layer (Fig. 1), while similarly for the evenness E_{sw} (Table 1).

In sum, the zero-truncated GP distribution may well quantify the SA pattern in a community with over-dispersion (i.e. variance/mean ratio > 1) and be related to species diversity. As mentioned above, the larger α (or the smaller λ), the higher the species diversity. As shown in Equation (5) and Table 2 as an example, P_0 increases with decreasing λ and increasing α, suggesting that the higher the probability of species not collected in a sample, the higher the species diversity. Further, the patterns of SA relationships seem often more informative than several species diversity indices (Novotny 1993). Consequently, a zero-truncated GP distribution describing the SA pattern, especially the P_0 value calculated by the distribution parameters and independent of sample size (i.e. the observed total number of species, S, or related sampling area), could be a better measure of species diversity than some species diversity indices such as Shannon-Wiener index because the latter is often influenced by sample size. Finally, of the two GP parameters, α may be more appropriate to reflect the species diversity than λ because (1) α mostly reflected the variation and over-dispersion of the SAD (the more the variation, the higher the diversity; see Yin *et al.* 2005c), while λ represented the mean of the SAD, and (2) α showed more similar trend to the diversity index (D_{sw} and E_{sw}) than λ for each case.

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References

Akaike, H. (1973) Information theory and an extension of the likelihood ratio principle. In: Petrov, B.N. and Csaki, F. (eds) *Proceedings of the second international symposium of information theory.* Akademiai Kiado, Budapest.

Basset, Y., Novotny, V., Miller. S. & Springate, N.D. (1998) Assessing the impact of forest disturbance on tropical invertebrates: some comments. *Journal of Applied Ecology*, **35**(3), 461-466.

Bliss, C.I. (1965) An analysis of some insect trap records. In: Patil GP, ed. *Classical and Contagious Discrete Distributions*. Statistical Publishing Society, Calcutta. pp. 385-397.

Brian, M. (1953) Species frequencies in random samples from animal populations. *Journal of Animal Ecology*, **22**, 57-64.

Brown, J.H., Mehlman, D.W. & Stevens, G.C. (1995) Spatial variation in abundance. *Ecology*, **76**(7), 2028-2043.

Bulmer, M.G. (1974) On fitting the Poisson lognormal distribution to species abundance data. *Biometrics*, **30**, 101-110.

Cassie, R.M. (1962) Frequency distribution models in the ecology of plankton and other organisms. *J Anim Ecol*, **31**, 65-92.

Coleman, B.D. (1981) On random placement and species-area relations. *Mathematical Biosciences*, **54**(3-4), 191-215.

Condit R., Ashton P.S., Baker P., Bunyavejchewin S., Gunatilleke S., Gunatilleke N., Hubbell S.P., Foster R.B., Itoh A., LaFrankie J.V., Lee H.S., Losos E., Manokaran N., Sukumar R. and Yamakura T. (2000) Spatial patterns in the distribution of tropical tree species. *Science*, 288, 1414-1418.

Consul, P.C. (1989) Generalized Poisson distribution: properties and applications, Volume 99 of *Statistics: Textbooks and Monographs*, Marcel Dekker Inc., New York.

Yin, Z. Y. (2005) Modeling on Species Abundance and Distribution Patterns in Plant Communities. Ph.D. thesis, South China Botanical Garden and Graduate School of the Chinese Academy of Sciences, China.

Yin, Z. Y., Guo Q, Ren H, Peng S L. (2005a) Seasonal changes in spatial patterns of two annual plants in the Chihuahuan Desert, USA. *Plant Ecology*, **178**(2): 189-199.

Yin, Z.Y. & Liao, W.B. (1999) Studies on lognormal distribution patterns of species abundance of south subtropical forest community, China. *Guihaia*, **19**(3), 221-224.

Yin, Z.Y., Peng, S.L., Ren, H., Guo, Q. & Chen, Z.H. (2005b) LogCauchy, log-sech and lognormal distributions of species abundances in forest communities. *Ecological Modelling*, **184**(2-4), 329-340.

Yin, Z.Y., Ren, H., Zhang, Q.M., Peng, S.L., Guo, Q. & Zhou, G.Y. (2005c) Species abundance in a forest community in South China: a case of Poisson lognormal distribution. *Journal of Integrative Plant Biology*, **47**(7), 801-810.

Technical Report of ITTO Project PD 294/04 Rev.4 (F)

------Report on the Biodiversity Background of Gudou Forest Farm of Guangdong Province, South China

(By Zuo-Yun Yin)

1. Front cover

1.1. First page

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1.2. Title page

- 项目科研技术人员—项目协调员和主要项目成员的名称
- 单位的全称、地址、电话、传真和 e-mail 地址

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2. Contents

3. Abstract

In order to evaluate the effect of interplanting the economic plants on the forest community, we must know about the background of the local biodiversity. In this study, we set up the study sites at Gudou Forest Farm of Guangdong Province, South China. We first collected the data of the local natural environment, especially including the vegetation, flora and fauna. We then designed the experiment of three repeats to examine the influence of introducing economic species (mostly exotic ones) on the biodiversity and species abundance distributions at the study areas, through space (i.e., comparisons of the biodiversity between the interplant plots and CK plots in the same site) and time (changes of the biodiversity in the same interplant plots after introduction). By the end of the year 2006, we completed the background survey of the plant communities in the study site. Preliminary studies showed that: (1) the community height and species diversity increase with age of the secondary forest; and (2) the community layer structure changes with time: the herb layer becomes from dense to sparse, the shrub layer from sparse, dense, to sparse, while the tree layer increases in canopy density stage by stage. In the spring of 2007, 80 species of economic plants were interplanted in the undergrowth gap. These plants causes little influence on the local biodiversity at present, but we need long-run and located research to examine whether they survive and thus influence the local biodiversity or not.

4. Introduction

China has much large areas of tropical forest, ranking 18th in area of forest land in the world. The tropical forests in China mostly distribute in the south to the Tropic of Cancer, such as Hainan, Taiwan, islands in South Sea, Guangdong, Guangxi and Yunnan (Zeng et al., 2003). In the last decades, because of the intense economic activities of humankind, the centuries-old original tropical forests exist little with scattered distribution. The other natural forests are mainly the secondary forests that developed through closing the land for reforestation in deforested or burned area, accounting for 50.6% of the area of China's tropical woodland. These secondary forests have lower productivity, biodiversity, and ecological benefit, and they cannot meet the living demands of local people. Therefore, it is a project of great importance how to properly manage the tropical secondary forests to enhance their economic benefit, as well as ecological benefit. The existing studies on the tropical secondary forests, mostly from view of traditional ecology, include population and community structure, function and dynamics (Hu & Li, 1992; Zhang & Wang, 1995; Peng, 1996; Yin & Liao, 1999; Peng et al., 2003; Yin et al., 2005a, 2005b; Yin et al., 2006; Guo et al., 2006); or from view of rising restoration ecology, they focused on the vegetation regeneration in the southern degraded forest land (Yu & Peng, 1996; Ren & Peng, 2001； Peng, 2003). However, Most of these studies gave no attention to the woodland's economic benefit, or did not appropriately take account of both ecological and economic benefits at the same time (Zeng et al., 2003). So far, there are few studies on the influence of interplanting economic species on the local ecology (especially biodiversity) in China.

On basis of collection of existing research data, this study established the study sites at Gudou Forest Farm of Guangdong Province, Jiangmen, Guangdong Province of South China, where the tropical secondary forests distribute. The local biodiversity was surveyed by methods of the general and located investigation. We also designed the three repeats of the comparing experiments to evaluate the influence of introducing economic species on the local biodiversity. Main study objectives include: (1) the annual growth and its change of newly introduced species in the tropical secondary forest management; (2) comparisons of community diversity, species abundance pattern, biomass, and their dynamics among the different management methods; and (3) comparisons of community microclimate, physical and chemical characters of soil, and their dynamics among the different management methods.

5. Text

5.1. Natural environment

The state-owned Gudou Forest Farm with the management area of 4320 ha, is located in Xinhui District, Jiangmen City, Guangdong Province of South China. Its southwestern part with 2918.0 ha in area was merged into the Gudoushan Nature Reserve of Guangdong Province with the geographical location of 112°53′30″–13°03′25″E, 22°05′00″–22°21′15″N and total area of 12990.4 ha. The study sites in this project were set up at the Qingshikeng work area in the Gudou Forest Farm of Guangdong Province, within the experimental zone of the Reserve.

The Gudoushan Reserve is the stretch of Luofushan mountain with the granite physiognomy of the middle mountain, low mountain and foothill. It stands to the southwest of the Pearl Delta plain and belongs to the valley of Tanjian River according to its surface hydrology. The Reserve has the low subtropical marine climate with the sufficient sunlight, abundant rain and heat, and humid air (but with dry and wet seasons in a year). According to the meteorologic data of Huicheng Town, Xinhui, the average sunshine hour is 2082.65 hrs/yr, sunshine percentage 45.5%. The yearly average air temperature 21.8°C, the average air temperature 13.4°C in January, and the average air temperature 28.3°C in July. The yearly average precipitation 1789.2mm, the average relative humidity 77%. The months from April to September are rainy, while the others belong to the dry seasons. In the Reserve, the parent rocks mostly belongs to the granite, and the zonal soil is the latosolic red soil.

5.2. Vegetation, flora and fauna

On the basis of the community characteristics, such as species composition, physiognomy, layer and habitat, the vegetation in the Gudoushan Reserve is classified into the following types: (1) low mountain, hill and ravine rain forest, such as *Cleistocalyx operculatus* + *Sterculia lanceolata* community; (2) monsoon evergreen broad-leaved forest, including *Castanopsis carlesii* + *Cryptocarya chinensis*, *Syzygium championii* + *Machilus chinensis*, and *Altingia chinensis* + *Rhodoleia championi* communities distributed in low mountain and hilly land, and *Lithocarpus hancei* community distributed in middle mountain; (3) evergreen needle- and broad-leaved mixed forest, such as *Pinus massoniana* + *Schima superba* community; (4) evergreen needle-leaved forest, *Podocarpus nagi* + *Schefflera octophylla* community; (5) low mountain and hill bamboo forest, including *Arundinaria* and *Indocalamus* forests; (6) evergreen broad-leaved shrub and herb land, e.g., *Baeckea frutescens* + *Rhodomyrtus tomentosa* and *Itea chinensis* communities in hilly land, and *Enkianthus qumqueflorus* + *Rhododendron simsii* community; and (7) hilly grassland, distributed with *Pinus massoniana* – *Dicranopteris linearis* var. *dichotoma*, and *Pinus massoniana* – *Eriachne pallescens* communities with sparse trees in hilly land (Zhang et al., 2004). The artificial vegetation includes: (1) evergreen broad-leaved economic forest, such as *Acacia mangium*, *Eucalyptus* forests and tea garden; and (2) evergreen needle-leaved economic forest, e.g., *Cunninghamia lanceolata*, *Pinus massoniana*, *Pinus caribaea*, and *Pinus elliottii* forests. According to the second-class forest resource survey in 1996, the evergreen broad-leaved forest is 7976.6 ha in area, accounting for 74.35% of the total area of the woodland (10324.3 ha) in the Reserve; and the evergreen needle-leaved forest, evergreen needle- and broad-leaved mixed forest, and economic forest account for 25.20%, 0.42%, and 0.03% of the total area of the woodland respectively (Zhang et al., 2004).

The zonal vegetation in the Gudoushan Reserve is the monsoon evergreen broad-leaved forest with some features as follows. The forest community is very rich in plant species composition, but the dominant species is not very clear. Its upper layer mainly includes some thermophilous tree species such as Fagaceae and Lauraceae, as well as Myrtaceae, Theaceae, Hamamelidaceae, Meliaceae and Moraceae. In the middle and low layers, there are many tropical species such as Rubiaceae, Myrsinaceae, Palmae, Elaeocarpaceae, Caesalpiniaceae and Papilionaceae. The community's physiognomy is evergreen and different from the one of the rain forest that still has remarkable seasonal changes. The layer structure is complicated generally with 4 – 5 layers; i.e., besides the shrub and herb layers, the tree layer may be divided into 2 – 3 layers. In the community exist both herby lianas and woody lianas, as well as rich epiphytes (Zhang et al., 2004). While the natural vegetation in the Reserve has apparent horizontal zonality (i.e., the zonal monsoon evergreen broad-leaved forest), it also has apparent vertical zonality in the mountain, i.e., from low to high altitude, the community type is in the following order: (1) rain forest in valley (elevation lower than 400 m); (2) monsoon evergreen broad-leaved forest in low mountain and hilly land (elevation lower than 650 m); (3) monsoon evergreen broad-leaved forest in middle mountain (elevation 650 – 850 m); and (4) evergreen broad-leaved shrub and herb land in mountain top and ridge (above 650 m, 800 m, or 900 m).

The Gudoushan Reserve lies to the south of the Tropic of Cancer with the latitude 1° to the south more than the Dinghushan Biosphere Reserve, and its span from the south to the north is 16′15″ that is much greater than the latter. So the natural environment here is more complicated and changeful, and can thus provide more diverse living and reproducing conditions for various species with different habitat demands. According to the preliminary survey, the Gudoushan Reserve has1161 species of vascular plants that are subordinate to 607 genera and 180 families, respectively accounting for 16.46%, 36.90%, and 64.29% of the total of vascular plants (i.e., 7055 species, 1645 genera, and 280 families) in Guangdong Province. Among these, the fern (Pteridophyta) is 81 species, 50 genera, and 28 families; the gymnosperm (Gymnospermae) 20 species, 13 genera, and 4 families; and the angiosperm (Angiospermae) 1060 species, 544 genera, and 144 families with the dicotyledon (Dicotyledoneae) 858 species, 423 genera, 122 families and the monocotyledon (Monocotyledoneae) 202 species, 121 genera, 22 families (Ye, 1989; Yan and Wei, 2001; Zhang et al, 2004). The wild animal in the Reserve is 196 species subordinate to 74 families, 30 orders, and 5 classes, among which the mammal class (Mammalia) is 25 species, 14 families, 6 orders; the bird (Aves) 86 species,31 families, 13 orders; Reptilia 41 species, 11 families, 3 orders; Amphlbia 21 species, 6 families, 2orders; and the fish (Pisces) 23 species, 12 families, 6 orders (Chang, 1999; Li, 2002).

5.3. Survey on the plant community plots

5.3.1. Methods

5.3.1.1 Plot setting

The located survey plots were set up using the adjacent quadrat sampling method (Figs. 1 – 3). We designed the experiment of 3 repeats (i.e., 3 study sites), representing 3 types of the secondary forest communities that produced 5yr, 10yr and 20yr after the pine (or fir) trees were felled. Each repeat comprised 2 – 3 plots: one is the interplant (or introduction) plot (5 *mu*, i.e., 10 000/3 m^2) used for interplanting about 80 species of non-timber economic plants, while the other one or two are the control plot (1 *mu*, i.e., 2000/3 m^2) without no interplant (i.e., maintaining the original vegetation). Around each such plot, 5 m-or-more-wide isolation belt was set up. For convenience of the survey, these plots each were divided into smaller quadrats of the size 10 m × 11.11 m, within which each individual of all vascular plants was recorded. The plot selection and setting were completed in October to November of the year 2006.

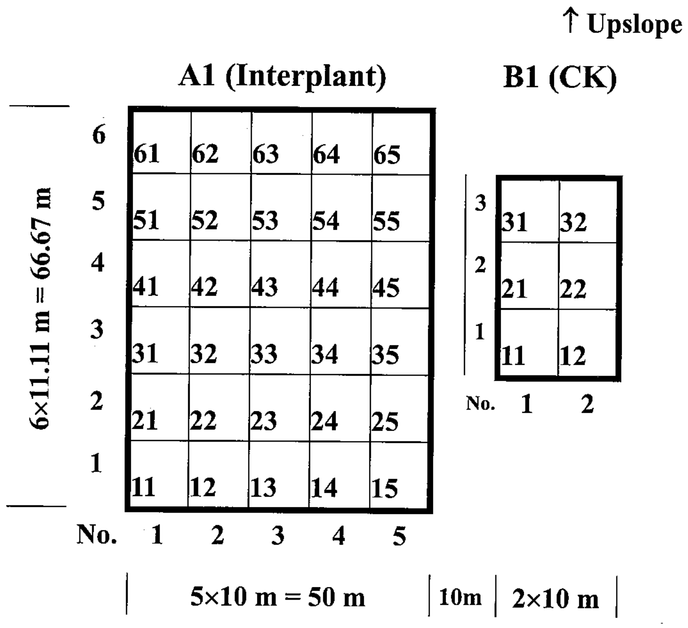


Fig. 1 Plot map (A1+B1) of Site 1 at Qingshikeng work area in Gudou Forest Farm of Guangdong Province, Xinhui, Jiangmen, Guangdong Province.
(Community type: 10 yr secondary forest in the mountainside pine deforested area.
Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

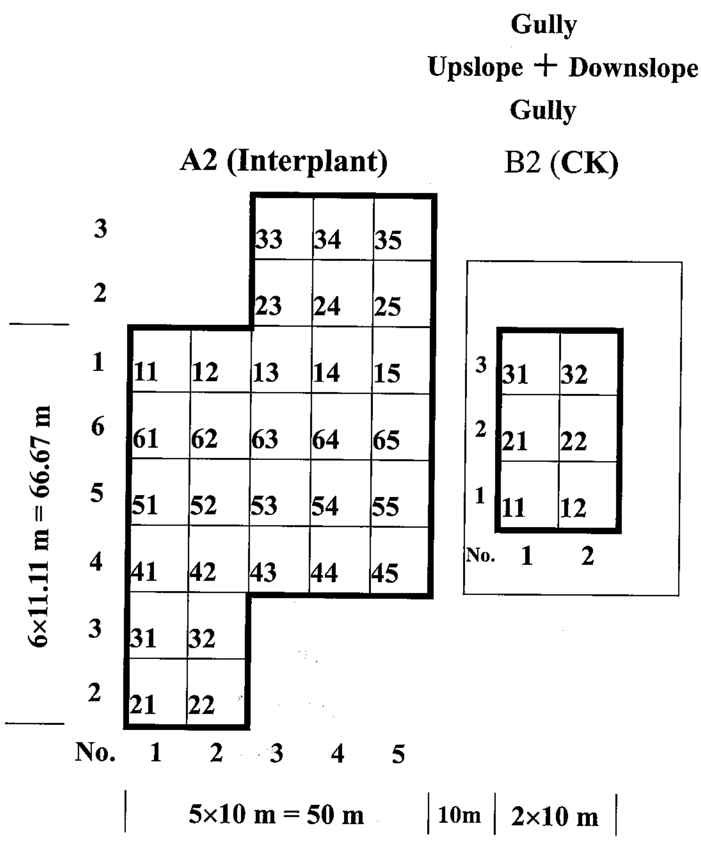


Fig. 2 Plot map (A2+B2) of Site 2 at Qingshikeng work area in Gudou Forest Farm of Guangdong Province, Xinhui, Jiangmen, Guangdong Province.
(Community type: 5 yr secondary forest in the gully fir deforested area.
Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

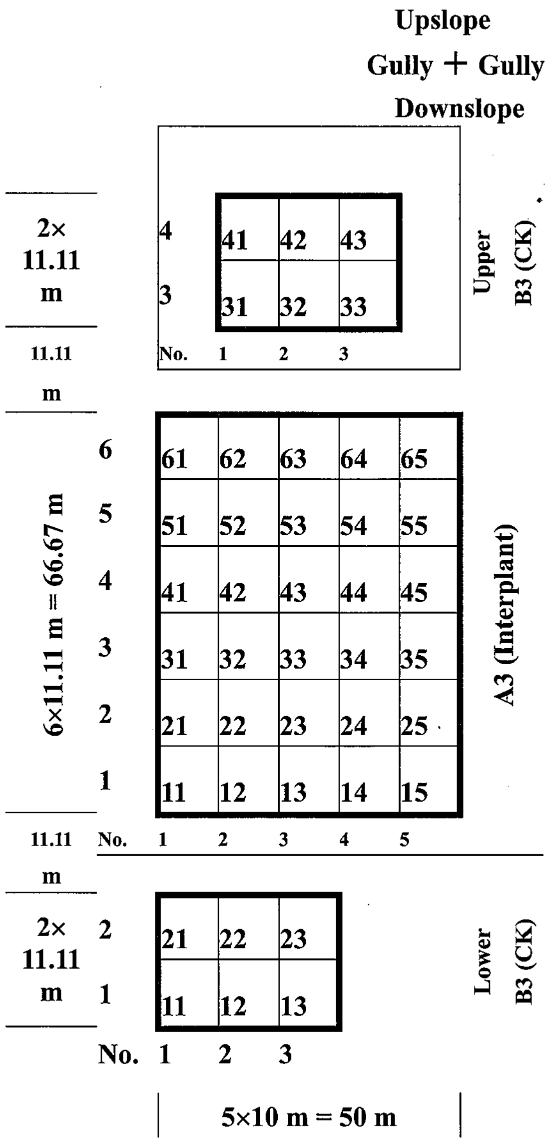


Fig. 3 Plot map (A3+2×B3) of Site 3 at Qingshikeng work area in Gudou Forest Farm of Guangdong Province, Xinhui, Jiangmen, Guangdong Province.
(Community type: 20 yr secondary forest in the mountaintop pine deforested area. Interplant --- Interplant (or introduction) plot; CK---control plot with no interplant)

5.3.1.2 Survey methods

(1) Growth investigation on the introduced species

Check the annual growth every autumn for each of the newly-interplanted species, including their height, breast and crown diameter, and growth status (see Table 1).

Table 1 Growth examination table of the interplanted economic plants in plots of Gudou Forest Farm of Guangdong Province

Plot:______________ Quadrat:_________ Elevation:____ Slope:____ Aspect of slope: ____

Community type:____________ Date:____________ Weather: ___ Investigator: ___________

No. (Plot – Quadrat – Individual)	Species	Height (m) (height from the ground to the natural top of each plant)	$D_{1.3}$ (cm) (DBH, i.e., diameter at 1.3 m height away from the ground)	Crown diameter (m)	Status
A1–1–1					
A1–1–2					
≈					

For No. A1–1–2, 'A1' is the plot number, '1' the subplot (i.e., quadrat) number, and '2' the individual number.

(2) Plant community survey

The methods of observing the plant community were as follows (see Table 2). Within each quadrat (10 m × 11.11 m) of each plot, we recorded each individual's species name, DBH, height, crown diameter, etc. For several herbs of great density, such as *Dicranopteris dichotoma*, we used one or more 1 m × 1 m sampling frames to estimate their abundance (i.e., the number of individuals) in a quadrat. We also checked the canopy density in tree layer and the ground cover degree in herb layer. The investigation on all the community plots, including interplant plots and corresponding CK plots, should be done in every autumn, and the first background survey was finished in November to December of the year 2006.

Table 2 Background examination table of the plant communities in plots of Gudou Forest Farm of Guangdong Province

Plot:______________ Quadrat:_________ Elevation:____ Slope:____ Aspect of slope: ____

Community type:____________ Date:____________ Weather: ___ Investigator: ___________

No.	Species	$D_{1.3}$ (cm)	Height (m)	Crown diameter (m)	x (m)	y (m)	Notes
B1–1–1							
B1–1–2							
≈							

For No. B1–1–2, 'B1' is the plot number, '1' the subplot (i.e., quadrat) number, and '2' the individual number.

5.3.2. Results

Three community sites (each with 2 – 3 plots) all were located at the Qingshikeng work area that belongs to the experiment zone of the Gudoushan Nature Reserve of Guangdong Province. These three stands represented three types of the secondary forests of different age, the three types that generated through closing the land for the reforestation of 5, 10 and 20 years (marked with Site 2, 1, and 3 respectively) after pine / fir deforestation.

5.3.2.1. Site 1 at Gudou Forest Farm

Site 1 was at the west-by-south slope, where the community type was the 10-year-old secondary forest after pine (*Pinus massoniana*) deforestation. This study site included a 10 000/3 m^2 (i.e., 5 *mu*) interplant plot (No. A1) and a 2000/3 m^2 (i.e., 1 *mu*) control plot (B1), set up in right-and-left neighbour (Fig. 1). The community was 7.5 – 10 m high, average 8.5 m with obvious layer structure. The tree layer (height ≥ 1.5 m) was high and dense, the herb layer (height < 0.5 m) was flourishing, while the shrub layer (0.5 m ≤ height < 1.5 m) was the densest with high density. In the **tree layer,** there were following trees: *Pinus massoniana* Lamb., *Gordonia axillaris* (Roxb.) Dietrich, *Itea chinensis* Hook. et Arn, *Abarema lucida* (Benth.) Kosterm., *Cunninghamia lanceolata* (Lamb.) Hook., *Ormosia semicastrata* Hance, *Sinosideroxylon wightianum* (Hook. et Arn.) Aubr., *Homalium cochinchinense* (Lour.) Drucc, *Acronychia pedunculata* (L.) Miq., *Diospyros morrisiana* Hance, *Engelhardtia roxburghiana* Wall., etc.

The **shrub layer** at Site 1 was distributed with many shrubs and small trees, such as *Rhodomyrtus tomentosa* (Ait.) Hassk., *Ficus variolosa* Lindl. ex Benth., *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Phyllanthus cochinchinensis* Spreng., *Melastoma sanguineum* Sims, *Raphiolepis indica* (L.) Lindl., *Baeckea frutescens* L., *Gardenia jasminoides* Ellis, *Clerodendron fortunatum* L., *Glochidion eriocarpum* Champ.ex Benth., *Litsea cubeba* (Lour.) Pers., *Ilex memecylifolia* Champ. ex Benth., *Breynia fruticosa* (L.) Hook. f., *Zanthoxylum avicennae* (Lam.) DC., *Croton lachnocarpus* Benth., *Indocalamus vulgatus* Lin et X.B.Ye, *Ilex triflora* Bl., *Ilex pubescens* Hook. et Arn., *Evodia lepta* (Spreng.) Merr., *Euonymus laxiflora* Champ., *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Dunnia sinensis* Tutch., *Syzygium buxifolium* Hook. et Arn., *Tricalysia dubia* (Lindl.) Ohwi, *Pittosporum glabratum* Lindl., *Antidesma japonicum* Sieb. et Zucc., *Securinega virosa* (Roxb.ex Willd.) Baill., and *Diospyros vaccmioides* Lindl. Besides, there were many trees' seedlings in the shrub layer, including *Gordonia axillaris* (Roxb.) Dietrich, *Abarema lucida* (Benth.) Kosterm., *Symplocos lancifolia* Sieb. et Zucc., *Acronychia pedunculata* (L.) Miq., *Itea chinensis* Hook. et Arn, *Ardisia hanceana* Mez, and *Ormosia emarginata* (Hook.et Art.) Benth..

In the **herb layer** at Site 1, the plant species were very rich, including the herbs, such as *Lepidosperma chinensis* Nees, *Dicranopteris dichotoma* (Thunb.) Bernh., *Miscanthus sinensis* Anderss., *Blechnum orientale* L., *Dianella ensifolia* (L.) DC., *Lophatherum gracile* Brongn., *Hedyotis lancea* Thunb., *Pteris ensiformis* Burm., *Adiantum caudatum* L., *Adiantum capillus-veneris* L., *Hypolytrum nemorum* (Vahl) Spreng., *Gahnia tristis* Nees, *Alpinia chinensis* (Retz.) Rosc., *Ischaemum indicum* (Houtt.) Merr., *Ardisia punctata* Lindl., *Hedyotis bracteosa* Hance, *Melastoma dodecandrum* Lour., *Pandanus austrosinensis* T. L. Wu, *Lindsaea orbiculata* (Lam.) Mett., *Sarcandra glabra* (Thunb.) Nakai, *Schizoloma heterophyllum* (Dry.) J. Sm., and *Liriope spicata* Lour.; and the seedlings of those trees and shrubs, such as *Rhodomyrtus tomentosa* (Ait.) Hassk., *Raphiolepis indica* (L.) Lindl., *Gordonia axillaris* (Roxb.) Dietrich, *Gardenia jasminoides* Ellis, *Acronychia pedunculata* (L.) Miq., *Zanthoxylum avicennae* (Lam.) DC., *Abarema lucida* (Benth.) Kosterm., *Diospyros morrisiana* Hance, *Croton lachnocarpus* Benth., *Ilex pubescens* Hook. et Arn., *Melastoma sanguineum* Sims, *Ilex triflora* Bl., *Litsea cubeba* (Lour.) Pers., *Sapium discolor* Muell.-Arg., *Garcinia multiflora* Champ. ex Benth., *Tarenna mollissima* (Hook. et Arn.) Rob., *Phyllanthus cochinchinensis* Spreng., *Ficus variolosa* Lindl. ex Benth., *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Syzygium buxifolium* Hook. et Arn., *Ardisia hanceana* Mez, *Eurya brevistyla* Kobuski, *Tricalysia dubia* (Lindl.) Ohwi, *Ilex memecylifolia* Champ. ex Benth., *Ormosia glaberrima* Wu, *Symplocos lancifolia* Sieb. et Zucc., *Securinega virosa* (Roxb.ex Willd.) Baill., *Machilus velutina* Champ. ex Benth., *Ormosia semicastrata* Hance, *Indocalamus vulgatus* Lin et X.B.Ye, *Evodia lepta* (Spreng.) Merr., *Sinosideroxylon wightianum* (Hook. et Arn.) Aubr., *Rhaphiolepis lanceolata* Hu, *Diospyros vaccmioides* Lindl., *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Euonymus laxiflora* Champ., *Itea chinensis* Hook. et Arn, *Vaccinium hancockiae* Merr., *Ficus hirta* Vahl, *Dunnia sinensis* Tutch., and *Schefflera octophylla* (Lour.) Harms.

The **interstratum plants** distributed in the different layers of the community with the following lianas: *Psychotria serpens* L., *Smilax china* L., *Smilax hypoglauca* Benth., *Smilax lanceaefolia* Roxb. var. opaca A. DC., *Smilax riparia* A. DC., *Gnetum parvifolium* (Warb.) C. Y. Cheng, *Embelia laeta* (L.) Mez, *Embelia ribes* Burm. f., *Mussaenda pubescens* Ait. f., *Dalbergia hancei* Benth., *Strophanthus divaricatus* (Lour.) Hook. et Arn., *Cassytha filiformis* L., *Dendrotrophe frutescens* (Champ. ex Benth.) Danser, *Lygodium japonicum* (Thunb.) Sw., *Calamus rhabdocladus* Burret, *Morinda umbellata* L., *Rubus leucanthus* Hance, *Rubus alceaefolius* Poir., *Stauntonla maculata* Merr., *Jasminum lanceolarium* Roxb., *Cocculus orbiculatus* (L.) DC., *Alyxia sinensis* Champ. ex Benth., and *Rourea microphylla* (Hook.et Arn.) Planch..

5.3.2.2. Site 2 at Gudou Forest Farm

Site 2 was located at the north slope, where the community type is the 5-year-old secondary forest formed by closing hillsides after fir (*Cunninghamia lanceolata*) deforestation. At Site 2, there were a 10 000/3 m^2 interplant plot (No. A2) and a 2000/3 m^2 control plot (No. B2) , set up in up-and-down neighbour (Fig. 2). The height of the community was 7 – 11 m, average 8.2 m. The layer structure was not very clear. The tree layer was relatively lower and sparse, while the shrub layer was dense, and the herb layer is the densest among three layers. In the **tree layer**, tree species included: Cunninghamia lanceolata (Lamb.) Hook., *Acronychia pedunculata* (L.) Miq., *Litsea cubeba* (Lour.) Pers., *Schefflera octophylla* (Lour.) Harms, *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Baeckea frutescens* L., *Sapium discolor* Muell.-Arg., *Garcinia multiflora* Champ. ex Benth., *Sterculia lanceolata* Cav., *Toxicodendron succedaneum* (Linn.) O. Kuntze, *Ilex triflora* Bl., *Abarema lucida* (Benth.) Kosterm., and *Diospyros morrisiana* Hance.

The **shrub layer** at Site 2, there were shrubs and small trees including *Rhodomyrtus tomentosa* (Ait.) Hassk., *Melastoma sanguineum* Sims, *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Phyllanthus cochinchinensis* Spreng., *Ficus variolosa* Lindl. ex Benth., *Raphiolepis indica* (L.) Lindl., *Baeckea frutescens* L., *Gardenia jasminoides* Ellis, *Clerodendron fortunatum* L., *Glochidion eriocarpum* Champ.ex Benth., *Litsea cubeba* (Lour.) Pers., *Breynia fruticosa* (L.) Hook. f., *Zanthoxylum avicennae* (Lam.) DC., *Ilex triflora* Bl., *Ilex pubescens* Hook. et Arn., *Evodia lepta* (Spreng.) Merr., *Euonymus laxiflora* Champ., *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Tricalysia dubia* (Lindl.) Ohwi, *Securinega virosa* (Roxb.ex Willd.) Baill., *Psychotria rubra* (Lour.) Poir., *Wikstroemia indica* (L.) C. A. Mey., *Ixora chinensis* Lam., *Eurya chinensis* R. Br., *Melastoma candidum* D. Don, *Ficus hirta* Vahl, *Tarenna mollissima* (Hook. et Arn.) Rob., *Rhaphiolepis lanceolata* Hu, *Fortunella hindsii* (Champ. ex Benth.) Swingle, *Baeckea frutescens* L., *Cratoxylon coclunclunense* (Lour.) Bl., *Vaccinium hancockiae* Merr., and tree seedlings such as *Eurya brevistyla* Kobuski, *Abarema lucida* (Benth.) Kosterm., *Symplocos lancifolia* Sieb. et Zucc., *Acronychia pedunculata* (L.) Miq., *Ardisia hanceana* Mez, *Garcinia multiflora* Champ. ex Benth., *Diospyros morrisiana* Hance, *Pinus massoniana* Lamb., *Cunninghamia lanceolata* (Lamb.) Hook., *Sterculia lanceolata* Cav., *Machilus velutina* Champ. ex Benth., *Ilex asprella* (Hook. et Arn.) Champ. ex Benth., and *Aporosa dioica* Muell.-Arg..

The plants in the herb layer at Site 2 included the herbs such as *Lepidosperma chinensis* Nees, *Dicranopteris dichotoma* (Thunb.) Bernh., *Miscanthus sinensis* Anderss., *Blechnum orientale* L., *Dianella ensifolia* (L.) DC., *Lophatherum gracile* Brongn., *Hedyotis lancea* Thunb., *Pteris ensiformis* Burm., *Adiantum caudatum* L., *Adiantum capillus-veneris* L., *Hypolytrum nemorum* (Vahl) Spreng., *Gahnia tristis* Nees, *Alpinia chinensis* (Retz.) Rosc., *Ischaemum indicum* (Houtt.) Merr., *Ardisia punctata* Lindl., *Melastoma dodecandrum* Lour., *Pandanus austrosinensis* T. L. Wu, *Liriope spicata* Lour., *Sarcandra glabra* (Thunb.) Nakai, *Schizoloma heterophyllum* (Dry.) J. Sm., *Lycopodium cernuum* L., *Selaginella doederleinii* Hieron., *Cyperus exaltatus* Retz., *Cibotium barometz* (L.) J. Sm., *Thysanolaena maxima* (Roxb.) Kuntze, *Pteris semipinnata* L., and the seedlings of trees and shrubs such as *Rhodomyrtus tomentosa* (Ait.) Hassk., *Raphiolepis indica* (L.) Lindl., *Gardenia jasminoides* Ellis, *Acronychia pedunculata* (L.) Miq., *Zanthoxylum avicennae* (Lam.) DC., *Abarema lucida* (Benth.) Kosterm., *Ilex pubescens* Hook. et Arn., *Melastoma* *sanguineum* Sims, *Ilex triflora* Bl., *Litsea cubeba* (Lour.) Pers., *Sapium discolor* Muell.-Arg., *Garcinia multiflora* Champ. ex Benth., *Tarenna mollissima* (Hook. et Arn.) Rob., *Phyllanthus cochinchinensis* Spreng., *Ficus variolosa* Lindl. ex Benth., *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Ardisia hanceana* Mez, *Tricalysia dubia* (Lindl.) Ohwi, *Symplocos lancifolia* Sieb. et Zucc., *Securinega virosa* (Roxb.ex Willd.) Baill., *Machilus velutina* Champ. ex Benth., *Evodia lepta* (Spreng.) Merr., *Rhaphiolepis 1anceolata* Hu, *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Euonymus laxiflora* Champ., *Vaccinium hancockiae* Merr., *Ficus hirta* Vahl, *Schefflera octophylla* (Lour.) Harms, *Psychotria rubra* (Lour.) Poir., *Wikstroemia indica* (L.) C. A. Mey., *Ixora chinensis* Lam., *Glochidion eriocarpum* Champ.ex Benth., *Melastoma candidum* D. Don, *Clerodendron fortunatum* L., *Breynia fruticosa* (L.) Hook. f., *Cratoxylon coclunclunense* (Lour.) Bl., *Sterculia lanceolata* Cav., *Baeckea frutescens* L., *Cunninghamia lanceolata* (Lamb.) Hook., *Fortunella hindsii* (Champ. ex Benth.) Swingle, *Ilex asprella* (Hook. et Arn.) Champ. ex Benth., and *Aporosa dioica* Muell.-Arg..

The **interstratum plants** at Site 2 were the lianas such as *Psychotria serpens* L., *Smilax china* L., *Smilax hypoglauca* Benth., *Smilax lanceaefolia* Roxb. var. *opaca* A. DC., *Gnetum parvifolium* (Warb.) C. Y. Cheng, *Embelia laeta* (L.) Mez, Mussaenda pubescens Ait. f., *Dalbergia hancei* Benth., *Strophanthus divaricatus* (Lour.) Hook. et Arn., *Cassytha filiformis* L., *Dendrotrophe frutescens* (Champ. ex Benth.) Danser, *Calamus rhabdocladus* Burret, *Morinda umbellata* L., *Rubus alceaefolius* Poir., *Stauntonla maculata* Merr., *Alyxia sinensis* Champ. ex Benth., *Rourea microphylla* (Hook.et Arn.) P1anch., *Desmos chinensis* Lour., *Celastrus orbiculatus* Thunb., *Tetracera asiatica* (Lour.) Hoogl., *Lygodium scandens* (L.) Sw., *Parthenocissus heterophylla* (Bl.) Merr., *Stephania longa* Lour., and *Byettneria aspera* Colebr..

5.3.2.3. Site 3 at Gudou Forest Farm

Site 3 lay at the south-by-west slope, where the community type is the 15-year-old secondary forest after pine (*Pinus massoniana*) deforestation. This study site includes a 10 000/3 m^2 interplant plot (No. A3) and two 2000/3 m^2 control plot (Upper B3 and Lower B3), set up in up- and down-slope neighbour (Fig. 3). The community height is 7.5 – 13 m, average 10.3 m with obvious layer structure. The herb and shrub layers are dense with great coverage at the ridge and peak of the site, while the tree layer is very high and dense, the shrub layer is relatively dense, and the herb layer is very thin elsewhere. In the **tree layer**, there were tree species as follows: *Ormosia semicastrata* Hance, *Abarema lucida* (Benth.) Kosterm., *Itea chinensis* Hook. et Arn, *Sinosideroxylon wightianum* (Hook. et Arn.) Aubr., *Acronychia pedunculata* (L.) Miq., *Pinus massoniana* Lamb., *Symplocos lancifolia* Sieb. et Zucc., *Eurya brevistyla* Kobuski, *Ormosia glaberrima* Wu, *Engelhardtia roxburghiana* Wall., *Tricalysia dubia* (Lindl.) Ohwi, *Schefflera octophylla* (Lour.) Harms, and *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen.

In the shrub layer of Site 3, there were shrubs and small trees such as Baeckea frutescens L., *Rhodomyrtus tomentosa* (Ait.) Hassk., *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Phyllanthus cochinchinensis* Spreng., *Melastoma sanguineum* Sims, *Raphiolepis indica* (L.) Lindl., *Ficus variolosa* Lindl. ex Benth., *Gardenia jasminoides* Ellis, *Clerodendron fortunatum* L., *Glochidion eriocarpum* Champ.ex Benth., *Litsea cubeba* (Lour.) Pers., *Ilex memecylifolia* Champ. ex Benth., *Breynia fruticosa* (L.) Hook. f., *Zanthoxylum avicennae* (Lam.) DC., *Croton lachnocarpus* Benth., *Indocalamus vulgatus* Lin et X.B.Ye, *Ilex triflora* Bl., *Ilex pubescens* Hook. et Arn., *Evodia lepta* (Spreng.) Merr., *Euonymus laxiflora* Champ., *Eurya glandulosa* Merr. var. *cuneiformis* H. T. Chang, *Syzygium buxifolium* Hook. et Arn., *Tricalysia dubia* (Lindl.) Ohwi, *Antidesma japonicum* Sieb. et Zucc., *Securinega virosa* (Roxb.ex Willd.) Baill., *Diospyros vaccmioides* Lindl., *Cratoxylon coclunclunense* (Lour.) Bl., *Psychotria rubra* (Lour.) Poir., *Eurya chinensis* R. Br., *Sapium discolor* Muell.-Arg., *Rhaphiolepis lanceolata* Hu, *Tarenna mollissima* (Hook. et Arn.) Rob., *Vaccinium hancockiae* Merr., *Wikstroemia nutans* Champ., *Carallia brachiata* (Lour.) Merr., *Lasianthus chinensis* Benth., *Wikstroemia indica* (L.) C. A. Mey., and *Ficus hirta* Vahl. The shrub layer also had the seedlings of many trees, including *Gordonia axillaris* (Roxb.) Dietrich, *Abarema lucida* (Benth.) Kosterm., *Symplocos lancifolia* Sieb. et Zucc., *Acronychia pedunculata* (L.) Miq., *Itea chinensis* Hook. et Arn, *Ardisia hanceana* Mez, *Ormosia emarginata* (Hook.et Art.) Benth., *Ormosia semicastrata* Hance, *Eurya brevistyla* Kobuski, *Garcinia multiflora* Champ. ex Benth., *Symplocos decora* Hance, *Rapanea neriifolia* (S. et Z.) Mez, *Machilus velutina* Champ. ex Benth., *Schefflera octophylla* (Lour.) Harms, *Diospyros morrisiana* Hance, *Toxicodendron succedaneum* (Linn.) O. Kuntze, *Etaeocarpus japonicus* Sieb.et Zucc., and *Sinosideroxylon wightianum* (Hook. et Arn.) Aubr..

The herb layer at Site 3 was distributed with 1) the herbal plants: *Lepidosperma chinensis* Nees, *Dicranopteris dichotoma* (Thunb.) Bernh., *Miscanthus sinensis* Anderss., *Blechnum orientale* L., *Dianella ensifolia* (L.) DC., *Lophatherum gracile* Brongn., *Hedyotis lancea* Thunb., *Pteris ensiformis* Burm., *Adiantum caudatum* L., *Adiantum capillus-veneris* L., *Hypolytrum nemorum* (Vahl) Spreng., *Gahnia tristis* Nees, *Ischaemum indicum* (Houtt.) Merr., *Ardisia punctata* Lindl., *Hedyotis bracteosa* Hance, *Melastoma dodecandrum* Lour., *Pandanus austrosinensis* T. L. Wu, *Lindsaea orbiculata* (Lam.) Mett., *Liriope spicata* Lour., *Sarcandra glabra* (Thunb.) Nakai, *Schizoloma heterophyllum* (Dry.) J. Sm., *Alpinia densibracteata* T.L.Wu et Senjen, *Thysanolaena maxima* (Roxb.) Kuntze, *Lycopodium cernuum* L., and *Selaginella doederleinii* Hieron.; and 2) the seedlings of shrubs and trees: *Rhodomyrtus tomentosa* (Ait.) Hassk., *Raphiolepis indica* (L.) Lindl., *Gordonia axillaris* (Roxb.) Dietrich, *Gardenia jasminoides* Ellis, *Acronychia pedunculata* (L.) Miq., *Zanthoxylum avicennae* (Lam.) DC., *Abarema lucida* (Benth.) Kosterm., *Diospyros morrisiana* Hance, *Melastoma sanguineum* Sims, *Croton lachnocarpus* Benth., *Ilex pubescens* Hook. et Arn., *Ilex triflora* Bl., *Litsea cubeba* (Lour.) Pers., *Sapium discolor* Muell.-Arg., *Garcinia multiflora* Champ. ex Benth., *Tarenna mollissima* (Hook. et Arn.) Rob., *Phyllanthus cochinchinensis* Spreng., *Ficus variolosa* Lindl. ex Benth., *Litsea rotundifolia* Hemsl. var. *oblongifolia* (Nees) Allen, *Syzygium buxifolium* Hook. et Arn., *Ardisia hanceana* Mez, *Eurya brevistyla* Kobuski, *Tricalysia dubia* (Lindl.) Ohwi, *Ilex memecylifolia* Champ. ex Benth., *Ormosia glaberrima* Wu, *Symplocos lancifolia* Sieb. et Zucc., *Securinega virosa* (Roxb.ex Willd.) Baill., *Machilus velutina* Champ. ex Benth., *Ormosia semicastrata* Hance, *Indocalamus vulgatus* Lin et X.B.Ye, *Evodia lepta* (Spreng.) Merr., *Sinosideroxylon wightianum* (Hook. et Arn.) Aubr., *Rhaphiolepis lanceolata* Hu, *Diospyros vaccmioides* Lindl., *Eurya glandulosa* Merr.var. *cuneiformis* H. T. Chang, *Euonymus laxiflora* Champ., *Itea chinensis* Hook. et Arn, *Ficus hirta* Vahl, *Schefflera octophylla* (Lour.) Harms, *Baeckea frutescens* L., *Clerodendron fortunatum* L., *Rapanea neriifolia* (S. et Z.) Mez, *Antidesma japonicum* Sieb. et Zucc., *Carallia brachiata* (Lour.) Merr., *Gironniera subaequalis* Planch., *Viburnum sempervirens* K. Koch, *Wikstroemia indica* (L.) C. A. Mey., *Etaeocarpus japonicus* Sieb.et Zucc., *Rapanea neriifolia* (S. et Z.) Mez, *Breynia fruticosa* (L.) Hook. f., *Psychotria rubra* (Lour.) Poir., *Pittosporum glabratum* Lindl., *Melastoma candidum* D. Don, and *Uvaria microcarpa* Champ. et Benth..

The **interstratum plants** at Site 3 included the following lianas: *Psychotria serpens* L., Smilax china L., *Smilax hypoglauca* Benth., *Smilax riparia* A. DC., *Gnetum parvifolium* (Warb.) C. Y. Cheng, *Embelia laeta* (L.) Mez, *Mussaenda pubescens* Ait. f., *Dalbergia hancei* Benth., *Strophanthus divaricatus* (Lour.) Hook. et Arn., *Cassytha filiformis* L., *Dendrotrophe frutescens* (Champ. ex Benth.) Danser, *Calamus rhabdocladus* Burret, *Rubus alceaefolius* Poir., *Cocculus orbiculatus* (L.) DC., *Rourea microphylla* (Hook.et Arn.) Planch., *Morinda officinalis* How, *Dioscorea cirrhosa* Lour., *Kadsura longipedunculata* Finet et Gagnep., *Smilax glabra* Roxb., *Tetracera asiatica* (Lour.) Hoogl., *Berchemia floribunda* (Wall.) Brongn., and *Byettneria aspera* Colebr..

5.4. Discussion and suggestion

To evaluate the effect of interplanting the economic plants (mostly exotic species) on a forest community, it should first be known about the background of the community biodiversity. Three study sites at the Gudou Forest Farm of Guangdong Province, South China, were established in the winter of the year 2006. We collected the previous data of the local natural environment, including the vegetation, flora and fauna. We then designed the experiment with three repeats (i.e., 3 community sites) to examine the influence of introduced economic species on the biodiversity and species abundance distributions in the local community, through space (i.e., comparisons of the biodiversity between the interplant plots and CK plots in the same site) and time (i.e., changes of the biodiversity in the same interplant plots after the introduction of the economic plants).

In designing three repeats of experiment on comparisons between the interplant plots and control plots, we specially chose three pine- and fir-deforested sites that have been closed for reforestation for 5, 10, and 15 years respectively. The three sites represented the secondary forest communities of different ages restored from the starting point of the needle-leaved forests. Based on the studies on these communities, we try to explore the successional laws of the local forest communities, especially including the dynamics of the biodiversity and species abundance distributions, in the natural conditions or the artificial disturbance (e.g., interplanting non-native species). The background survey on the plant communities in 2006 showed that with age of the secondary forest community, 1) the height and diversity increased; and 2) the layer structure changed dramatically: the herb layer became gradually from dense to thin, the shrub layer from sparse to dense, finally sparse with the trees invading and growing, while the tree layer increased in crown density year by year.

We began to the interplanting activities at the Gudou Forest Farm in the Spring of 2007. About 80 economic species were interplanted in the gap of forest. Therefore, actually only a few herbal individuals were cut and their abundance decreased a bit, the layer structure of the whole forest community was not destroyed, and the species richness did not change. It needs more located observations for years whether these economic plants can survive on the backgroud of the local plant community, and moreover influence on the native species diversity.

6. Appendix:

Vascular plant inventory in the three plots at Qingshikeng work area in Gudou Forest Farm of Guangdong Province, South China

PTERIDOPHYTA 蕨类植物门

P.3. Lycopodiaceae 石松科

Palhinhaean A. Franco et Vasc. 灯笼草属

P.cemua(Linn.) Franco et Vasc.[Lycopodium cernum Linn.]灯笼草石松、铺地蜈蚣

P.4. Selaginellaceae 卷柏科

Selaginella Beauv. 卷柏属

S.doederleinii Hieron 深绿卷柏、多穗卷柏

S.uncinata (Desv.) Spring 翠云草

P.15. Gleicheniaceae 里白科

Dicranopteris Bernh. 芒萁属

D.dichotoma (Thunb.) Bernh. 芒萁

P.17. Lygodiaceae 海金沙科

Lygodium Sw. 海金沙属

L.japonicum(Thunb.)Sw.[L.microstachyum Desv.] 海金沙

L.scandens (Linn.) Sw. [L.microphylhum(Cav.)R.Br.] 小叶海金沙

P.19. Dicksoniaceae 蚌壳蕨科

Cibotium Kaulf 蚌壳蕨属、金毛狗属

C.barometz(1inn.)J.Sm. 金毛狗 (国家二级重点保护植物)

P.23. Lindsaeaceae 鳞始蕨科

Lindsaea Dry. 鳞始蕨属

L.heterophylla Dryand [Schizoloma heterophylum J.Sm.] 异叶双唇蕨

L.orbiculata(Lam.)Mett.ex Kulm. 团叶鳞始蕨

P.27. Pteridaceae 凤尾蕨科

Pteris Linn. 凤尾蕨属

P.ensiformis Burm. 剑叶凤尾蕨

P.Iongipinna Hayata 长叶凤尾蕨

P.multifida Poir ex Lam. 井栏边草

P.semipinnata Linn. 半边旗

P.31. Adiantaceae 铁线蕨科

Adiantum Linn. 铁线蕨属

A.flabellulatum Linn. 扇叶铁线蕨

P.42 Blechnaceae 乌毛蕨科

Blechnum linn. 乌毛蕨属

B.orientale linn. 乌毛蕨

P.46. Aspidiaceae 三叉蕨科

Hemigramma Christ. 沙皮蕨属

H.decurrens (Hook.) Copel. 沙皮蕨

SPERMATOPHYTA 种子植物门

Gymnospermae 裸子植物亚门

G.4. Pinaceae 松科

Pinus Linn. 松属

P.massoniana Lamb. 马尾松

G.5. Taxodiaceae 杉科

Cunninghamia R.Br 杉木属

*C.lanceolata (Lamm.) Hook. 杉木

G.11. Gnetaceae 买麻藤科

Gnctum Linn. 买麻藤属

G.montanum Markgr. 买麻藤

G.parvifolium(Warb.)C.Y.Cheng 小叶买麻藤

Angiospermae 被子植物亚门

Dicotyledoneae 双子叶植物纲

1. Magnoliaceae 木兰科

Magnolia Linn. 木兰属

M.championii Benth. 香港木兰

2A. Illieiaceae 八角科

Illicium Linn. 八角属

I.dunnianum Tutcher 红花八角

3. Schisandraceae 五味子科

Kadsura Kaempf ex Juss.南五味子属

K.coccinea(Lem.)A.C.Smith 黑老虎、臭饭团

8. Annonaeeae 番荔枝科

Artabotrys R. Br. ex Ker 鹰爪花属

A.hongkongensis Hance 香港鹰爪

Desmos Lour. 假鹰爪属

D.chinensis Lour.［D.cochinchinensis Lour.］ 假鹰爪、酒饼叶

Fissistigma Griff. 瓜馥木属

F.glaucescens (Hance) Merr. 白叶瓜馥木

F.uonicum (Dunn.) Merr. 香港瓜馥木

Uvaria Linn. 紫玉盘属

U.microcarpa Champ.ex Benth. 紫玉盘

11. Lauraceae 樟科

Cassytha Linn. 无根藤属

C.filiformis Linn. 无根藤

C.innamomum Trew 樟属

C.camphora(Linn.)Presl 樟树、香樟 (国家二级重点保护植物)

Clyptocarya R.Br. 厚壳桂属

C.chinensis(Hance)Hemsl. 厚壳桂

C.concinna Hance[C.lenticellata Lec.] 黄果厚壳桂、生虫树

Lindera Thunb. 山胡椒属

L.chunii Merr. 鼎湖钓樟、陈氏钓樟

L.communis Hemsl.　香叶树

Litsea Lam.　木姜子属

L.cubeba (Lour.) Pers.　山苍子

L.romndifolia Hemsl.　圆叶豺皮樟

L.rotundifolia Hemsl.var.oblongifolia (Nees) Allen 豺皮樟

Machilus Nees 润楠属

M.breviflora(Benth.)Hemsl.　短序润楠

M.chinensis(Champ.ex Benth.)Hemsl.　华润楠

M.velutina Champ.ex Benth. 绒毛润楠、绒楠

21. Lardizabalaceae 木通科

Stauntonla DC.　野木瓜属

S.maculata Merr.　斑叶野木瓜

23. Menispermaceae　防己科

Cocculus DC.　木防己属

C.orbiculatus (Linn.) DC. [C.trilobus(Thunb.)DC.]　木防己

Diploclisa Miers 秤钩风属

D.affmis(Oliv.)Diels［D.chinensis Merr］秤钩风

Stephania Lour.　千金藤属

S.Longa Lour.　粪箕笃

30. Chloranthaceae　金粟兰科

Sarcandra Gardn.　草珊瑚属

S.glabra (Thunb.) Nakai　草珊瑚、九节茶

42. Polygalaceae 远志科

PolygalaLinn.　远志属

P.glomerataLour.［P.chinensib Linn.P.densifiora Bl.］　华南远志、金不换

81. Thymelaeaceae　瑞香科

Wikstroemia Endll.　荛花属

W.indica(Linn.)C.A.Mey.　了哥王

W.nutans Champ.　细轴荛花

85. Dilleniaceae　五桠果科、第伦桃科

Tetracera Linn.　锡叶藤属

Tetracera asiatica (Lour.) Hoogl.　锡叶藤

88. Pittosporaceae 海桐花科

Pittosporum Banks.ex Soland.　海桐花属

P.glabratum Lindl.　光叶海桐

93. Flacourtiaceae　大风子科

Scolopia schreber　刺冬属

S.saeva Hance　广东刺冬、白皮刺冬

94. Samydaceae　天料木科

Homalium Jacq.　天料木属

H.cochinchinense (Lour) Druce　天料木

108. Theaceae　山茶科

Camellia Linn.　山茶属

C.oleifera Abel［C.drupifera Lour.］油茶

EuryaThunb.柃属

E. brevistyla Kobuski 短柱柃

E.chinensis R.Brown 米碎花、岗茶

E.glandulosa Merr.var. cuneiformis H. T. Chang 楔基腺柃

E.groffii Merr.(E.acuminata var.graffii Kobuski) 岗柃

E.nitida Korth. 细齿柃

Gordonia Ellis 大头茶属

G.axillaris (Roxb.) Dietrich 大头茶

Schima Reinw 木荷属

S.superba Gardn.et Champ. ［S.confertifora Merr］ 木荷

108A.Pentaphylaceae 五列木科

Pentaphylax Gardn.et Champ. 五列木属

P.euryoides Gardn.et Champ. 五列木

113.Saurauiaceae 水东哥科

Saurauia Willd 水东哥属

S.tristyla DC. 水东哥

118.Myrtaceae 桃金娘科

Baeckea Linn. 岗松属

B.frutescens Linn. 岗松

Cleistocalyx Bl. 水翁属

C.operculatus (Roxb.) Merr.et Perry 水翁

Rhodomyrtus (DC.) Reichenb 桃金娘属

R.tomentosa (Ait.) Hassk. 桃金娘、岗稔

Syzygium Gaertn 蒲桃属

S.buxifolium Hook.et Arn. 赤楠蒲桃

S.championii (Benth.) Merr.et Perry 子凌蒲桃

120.Melastomaceae 野牡丹科

Melastoma Linn. 野牡丹属

M.candidum D.Don 野牡丹

M.dodecandrum Lour 地稔

M.sanguineum Sims 毛稔

Memecylon Linn. 谷木属

M.ligustrifolium Champ. 谷木

122.Rhizophoraceae 红树科

Carallia Roxb. 竹节树属

C.brachiata (Lour.) Merr. 竹节树

123.Hypericaceae 金丝桃科

Cratoxylum Bl. 黄牛木属

C.cochinchinense (Lour.) Bl. [Hypercum cochinchinense Lour.] 黄牛木

126.Guttiferae 藤黄科、山竹子科

Garcinia Linn. 藤黄属、山竹子属

G.multifiora Champ.ex Benth. 多花山竹子

G.oblongifolia Champ.ex Benth. 岭南山竹子

128A.Elaeocarpaceae 杜英科

Etaeocarpus Linn. 杜英属

E.japonicus Sieb.et Zucc. 日本杜英

Sloanea Linn. 猴欢喜属

S.sinensis (Hance) Hemsl. 猴欢喜

130.Sterculiaceae 梧桐科

Bytmeria Loefl. 刺果藤属

B.aspera Colebr. 刺果藤

Helicteres Linn. 山芝麻属

H.angustifolia Linn. 山芝麻

Sterculia Linn. 苹婆属

S.lanceolata Cav. 假苹婆

135A.Ixonanthaceae 粘木科

Ixonanthes Jack. 粘木属

I.chinensis Champ. 粘木(国家三级保护植物)

136.Euphorbiaceae 大戟科

Alchornea Sw. 山麻杆属

A.trewioides(Benth.)Muell. – Arg. 红背山麻杆

Antidesma Linn. 五月茶属

A.japonlcum Sieb.et Zucc. 日本五月茶、酸味子

Aporusa Bl. 银柴属

A.dioca(Roxb.)Muell. – Arg. [A.chinensis (Champ.) Merr.] 银柴

Brevnia J.R.et G.Forst 黑面神属

B.fruticosa(Linn.)Hook.f. 黑面神

Croron Linn 巴豆属

C.lachnocarpus Benth. 毛果巴豆

Glochidion J.R.et G.Forst. 算盘子属

G.eriocarpum Champ.et Benth. 毛果算盘子

Phyllanthus Linn. 叶下珠属

P.cochinchinensis (Lour.) Spreng. 越南叶下珠

Sapium P.Br. 乌桕属

S.discolor (Champ.ex Benth.) Muell. – Arg. 山乌桕

S.sebiferum (Linn.) Roxb. 乌桕

139.Escalloniaceae 鼠刺科

Itea Linn. 鼠刺属

I.chinensis Hook.et Arn. 鼠刺

143.Rosaceae 蔷薇科

Rhaphiolepis Lindl. 石斑木属、车轮梅属

R.indica Lind. 车轮梅、春花

Rubus Linn. 悬钩子属

R.alceaefolius Poir.[R.fmbriferus Focke] 粗叶悬钩子

R.leucanthus Hance 白花悬钩子

146.Mimosaceae 含羞草科

Pithecellobium Mart. 牛蹄豆属、猴耳环属

P.lucidum Benth. 亮叶猴耳环

148.Papilionaceae 蝶形花科

Dalbergia Linn.f 黄檀属

D.bancei Benth. 藤黄檀

Ormosia G.Jacks. 红豆属

O.emarginata (Hook.et Art.) Benth. 凹叶红豆

O.glaberrimaY.C.Wu [O.kwangturtgensis L.Chen] 光叶红豆

O.semincastrata Hance 软荚红豆

159.Myricaceae 杨梅科

Myrica Linn. 杨梅属

M.rubra (Lour.) Sieb.et Zucc. 杨梅

165.Ulmaceae 榆科

Celits Linn. 朴属

C.tetrandra Roxb.subsp.sinensis(Pers.)Y.C.Tang.[C.sinensis Pers.] 朴树

Gironniera Gaud. 白颜树属

G.subaequalis Planch. 白颜树

Trema Lour. 山黄麻属

T. angustifolia (Planch.) Blume 狭叶山黄麻

T.cannabina Lour. 光叶山黄麻

T.orientalis (Linn.)Bl. 山黄麻

167.Moraceae 桑科

Broussonetia L'Herit ex Vent. 构属

B.papyrifera(Linn.)L'Herit ex Vent 构树

Ficus Linn. 榕属

F.hirtaVahl. 粗叶榕、裂叶粗毛榕

F.variolosa Lindl. ex Benth. 变叶榕

171.Aquifoliaceae 冬青科

Ilex Linn. 冬青属

I.asprella (Hook.et Arn.) Champ.ex Benth. 梅叶冬青、秤星树

I.memecylifolia Champ.ex Benth. 谷木冬青

I.pubescens Hook.et Arn. 毛冬青 Ilex pubescens Hook. et Arn.

I.triflora Bl. [I.theicarpa Harid. – Mazz.1 三花冬青

I.viridis Champ.ex Benth. [I.triflora BI.var.viridis Loes] 亮叶冬青

173.Celastraceae 卫矛科

Euonymus Linn. 卫矛属

E.1axiflorus Champ. 疏花卫矛

182.Olacaceae 铁青树科

Schoepfia Schreb. 青皮木属

S.chinensis Gardn.et Champ. 华南青皮

S.jasminodora Sieb.et Zucc. 青皮木

186.Santalaceae 檀香科

Dendrotrophe Miq. 寄生藤属

D.frutescens (Champ.ex Benth.) Danser [Henslowia Frutescens Champ.ex Benth.] 寄生藤

190.Rhamnaceae 鼠李科

Berchemia Neck.ex DC. 勾儿茶属

B.floribunda(Wall.)Brongn. [B.giraldiana Schneid.B.racemosa Sieb.et Zucc.]　多花勾儿茶

194.Rutaceae　芸香科

Acronychia J.R.et G.Forst.　山油柑属

A.pedunculara(Linn.)Miq.　山油柑、降真香

Evodia J.R.et G. Forst.　吴茱萸属

E.1epta (Spreng.) Merr.　三叉苦、三杈苦

Fortumella Swingle　金橘属

F. hindsii (Champ. ex Benth.) Swingle　山橘

Zanthoxylum Linn.　花椒属

Z.avicennae (Lam.) DC.　簕欓花椒

Z.dissitum Hemsl.　单面针、蚬壳花椒

Z.nitidum (Roxb.) DC. [Z.nitidum (Roxb.) DC. var. neglectum How.]　两面针

205.Anacardiaceae　漆树科

Rhus Linn.　盐肤木属

R.chinensis Mill. var. roxburghii(DC.)Rehd.　滨盐肤木

Toxicodendron Mill.　漆树属

T.succedaneum(Linn.)O.Kuntze　野漆树

206.Connaraceae　牛栓藤科

Rourea Aubl.　红叶藤属

R.microphylla (Hook.et Arn.) P1anch.　小叶红叶藤

R.minor (Gaertn.) Leenh.　红叶藤

212.Araliaceae 五加科

Dendropanax Decne et Planch　树参属

D.proteus(Champ.ex Benth.) Benth.　变叶树参

Scheffiera J.R.et G.Forst.　鹅掌柴属

S.octophylla(Lour.)Harms　鹅掌柴、鸭脚木

215.Eficaceae　杜鹃花科

Enkianthus Lour.　吊钟花属

E.qumqueflorus Lour.　吊钟花

216.Vacciniaceae 越桔科

Vaccinium Lirm.　乌饭树属

V.hancockiae Merr.　广东乌饭树

221.Ebenaceae　柿树科

Diospyros Linn.　柿树属

D.morrisiana Hance　罗浮柿

D.vaccmioides Lindl.　乌饭叶柿、小果柿

222A.Sarcospermaceae　肉实树科

Sarcosperma Hook.f.　肉实树属

S.1aurinum (Benth.) Kook.f.　水石梓

223.Myrsinaceae 紫金牛科

Ardlisa Swartz　紫金牛属

A.hanceana Mez.　大罗伞、紫金牛

A.punctata Lindl.　山血丹、斑叶朱砂根

A.qulnquegona Bl.　罗伞树

Embelia Burm.f. 酸藤子属

E.1aeta(Linn.)Mez 酸藤子

E.ribes Burm.f. 白花酸藤子

Rapanea Aubl. 密花树属

R.neriifolia (Sieb.et Zucc.) Mez 密花树

224.Styracaceae 安息香科

Alniphyllum Matsum.赤杨叶属

A.fortunei(Hemsl.)Makino 赤杨叶、拟赤杨

225.Sympiocaceae 山矾科

Symplocos Jacq. 山矾属

S.1ancifolia Sieb.et Zucc. 光叶山矾

S.1ancilimba Merr. 披针叶山矾、剑叶山矾

S. stellaris Brand 老鼠矢

230.Apocynaceae 夹竹桃科

Alyxia Banks ex R.Br. 链珠藤属

A.sinensis Champ.ex Benth. 链珠藤

Strophanthus DC. 羊角拗属

S.divaricatus (Lour.) Hook. et Arn. 羊角拗

232.Rubiaeeae 茜草科

Adina Salisb. 水团花属

A.pilulifera(Lam.)Franch.ex Drake 水团花

Coptosapelta Koch. 流苏子属

C.diffusa (Champ.ex Benth.) Steenis [Thysanospermum diffusum Champ.] 流苏子

Dunnia Tutch. 绣球茜属

D.sinensis Tutch. 绣球茜(国家：二级重点保护植物)

Gardenia Ellis. 栀子属

G.jasminoides Ellis. 栀子

Hedyotis Linn. 耳草属

H.auricularia Linn 耳草

H.bracteosa Hance 大苞耳草

H.lancea Thunb. 剑叶耳草

Ixora Linn. 龙船花属

I.chinensis Lam 龙船花、山丹

Lasianthus JaCk. 粗叶木属

L.Chmensis Benth. 粗叶木

Mormda Linn. 巴戟天属

M.officinalis How 巴戟天 (国家三级保护植物)

M.umbellate Linn. 羊角藤、鸡眼藤

Mussaenda Linn. 玉叶金花属

M.pubescens Ait.f. 玉叶金花

Psychotria Linn. 九节属

P. rubra (Lour.) Poir. 九节

P.serpens Linn. 蔓九节、白果仔

Randia Linn. 山黄皮属

R.canthloides Champ.　香楠、光叶山黄皮

Tarenna Gaertn.　乌口树属

T.mollissima(Hook.et Arn.)Robins　密毛乌口树

Tricalysia A.Rich.ex DC.　狗骨柴属

T.dubia(Lindl.)Ohw1　狗骨柴

233.Caprifoliaceae　忍冬科

Lonicera Linn.　忍冬属

L.confusa(Sweet)DC.　华南忍冬、山银花

Viburnum Linn.　荚蒾属

V.sempervirens K.Koch　常绿荚蒾、坚荚蒾

239.Gentianaceae　龙胆科

Canscura Lam.　穿心草属

C.melastomacea Hand. – Mazz.　罗星草

251.Convolvulaceae 旋花科

Erycibe Roxb.　丁公藤属

E.obtusifolia Benth.　丁公藤

263.Verbenaceae　马鞭草科

Clerodendrum Linn.　大青属、臭牡丹属

C.fortunatum Linn.　白花鬼灯笼、鬼灯笼

Monocotyledoneae 单子叶植物纲

290.Zingiberaceae　姜科

Alpinia Roxb.　山姜属

A.densibracteata T.L.Wu et Senjen　密苞山姜

293.Liliaceae　百合科

Dianella Lam.　山菅兰属

D.ensifolia (Linn.) DC. [Dracaena egisifolia Linn.]　山菅兰

Ophiopogon Ker – Gawl.　沿阶草属

O.bodinieri Le'v1.　沿阶草

297.Smilacaceae 菝葜科

Smilax Linn.　菝葜属

S.china Linn.　菝葜

S.glabra Roxb.　土茯苓、光叶菝葜

S.hypoglauca Benth.　粉背菝葜

S.riparia A.DC.　牛尾菜

311.Dioseoreaeeae 薯预科

Dioscorea Linn.　薯预属

D.cirrhosa Lour.　薯莨

314.Palmae 棕榈科

Calamus Linn.　省藤属

C.rhabdocladus Burret　华南省藤、杖枝省藤

315.Pandanaceae　露兜树科

Pandanus Linn. 露兜树属

P.austrosinensis T.L.Wu　露兜草

318.Hypoxidaeeae 仙茅科

Curculigo Gaertn. 仙茅属

C.orchioides Gaertn. 仙茅

326.Orchidaceae 兰科

Ania Lindl. 安兰属

A.hongkongensis(Roife.)Tang et Wang 香港安兰

331.Cyperaceae 莎草科

Gahnia J.R.et G.Forst. 黑莎草属

G.tristis Nees 黑莎草

Hypolytrum Perr. 割鸡芒属

H.nemoRUm(Vahl.).Spreng 割鸡芒

Lepidosperma Labill. 鳞籽莎属

L.chinensis Nees 鳞籽莎

332.Gramineae 禾本科

332A.Bambunoideae 竹亚科

Indocalamus Nakai. 箬竹属

I.vulgatus Lin et X.B.Ye 古兜箬竹

332B.Agrostidoideae 禾亚科

Ischaemum Linn. 鸭嘴草属

I.aristatum Linn. 芒穗鸭嘴草

I.indicum Merr. ［I.ciliare Retz.］ 细毛鸭嘴草、纤毛鸭嘴草

Lophatherum Brongn. 淡竹叶属

L.gracile Brongn. 淡竹叶

Miscanthus Anderss. 芒属

M.sinensis Anderss 芒

Thysanolaena Nees 棕叶芦属

S.maxima (Roxb.) O. Kuntze 棕叶芦

7. 参考文献

常弘. 建立古兜山省级自然保护区野生动物资源调查报告. 中山大学, 1999.

黎振昌. 广东古兜山省级自然保护区鱼类及两栖爬行动物名录. 2002.

Hu Y J, and Li Y X. The Tropical Rain Forest of Hainan Island. Guangzhou: Guangdong Higher Education Press, 1992. (in Chinese)

Peng S L. Study and Application of Restoration Ecology in Tropical and Subtropical China. Beijing: Science Press, 2003. (in Chinese)

Peng S L. Community Dynamics in Lower Subtropical Forest. Beijing: Science Press, 1996. pp. 84-99. (in Chinese)

Peng S L, Yin Z Y, Ren H, and Guo Q F. Advances in research on the species-abundance relationship models in multi-species collection. *Acta Ecologica Sinica*, 2003, 23(8): 1590-1605. (in Chinese with an English abstract)

Ren H and Peng S L. Introduction to Restoration Ecology. Beijing: Science Press, 2001. (in Chinese)

严岳鸿, 韦强. 新会古斗山蕨类植物名录(1). 华南植物研究所, 2001.

叶向斌. 广东古兜山省级自然保护区植物区系的探讨. 仲恺农业技术学院学报, 1989, 2(1).

Yin Z Y, Ren H, Zeng L H, and Guo Q F. Fitting Three-Parameter Growth Models: A Study Case of Two Dominant Tree Populations in Monsoon Evergreen Broad-leaved Forest, China. *Journal of Biomathematics*, 2006, 21(3): 428-434. (in Chinese with an English abstract)

Yin Z Y and Liao W B. Studies on lognormal distribution patterns of species abundance of south subtropical forest community, China. *Guihaia*, 1999, 19(3), 221-224. (in Chinese with an English abstract)

余作岳, 彭少麟. 热带亚热带退化生态系统植被恢复生态学研究. 广州: 广东科技出版社, 1996.

Zeng L H, Hou Y Z, Wang H F, et al. Final Technical Reports on the ITTO Pre-project *The Study and Demonstration of the Management of Secondary Forests in Tropical Region for the Purpose of Enhancing Economic and Ecological Benefits*. Guangdong Acadaemy of Forestry, Chinese Academy of Forestry, 2003.

张金泉, 徐松军, 项颂信, 等. 广东古兜山自然保护区总体规划. 北京: 中国林业出版社, 2004.

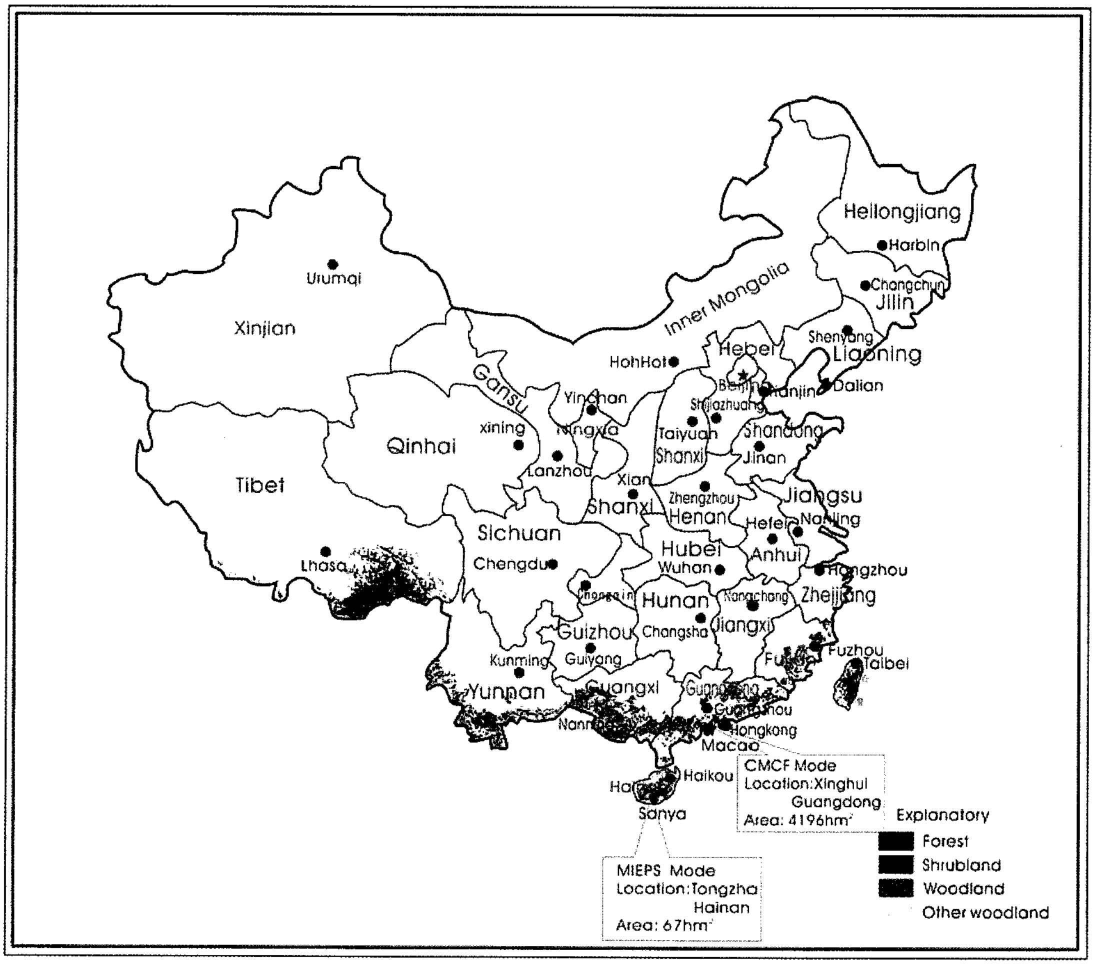
Guo Q F, Ren H, and Yin Z Y. Biodiversity's ecosystem functioning: a unity of both quantity and quality. *Journal of Plant Ecology*, 2006, 30(6): 1064-1066.

Yin Z Y, Peng S L, Ren H, Guo Q F, Chen Z H. LogCauchy, log-sech and lognormal distributions of species abundances in forest communities. *Ecological Modelling*, 2005a, 184(2-4): 329-340.

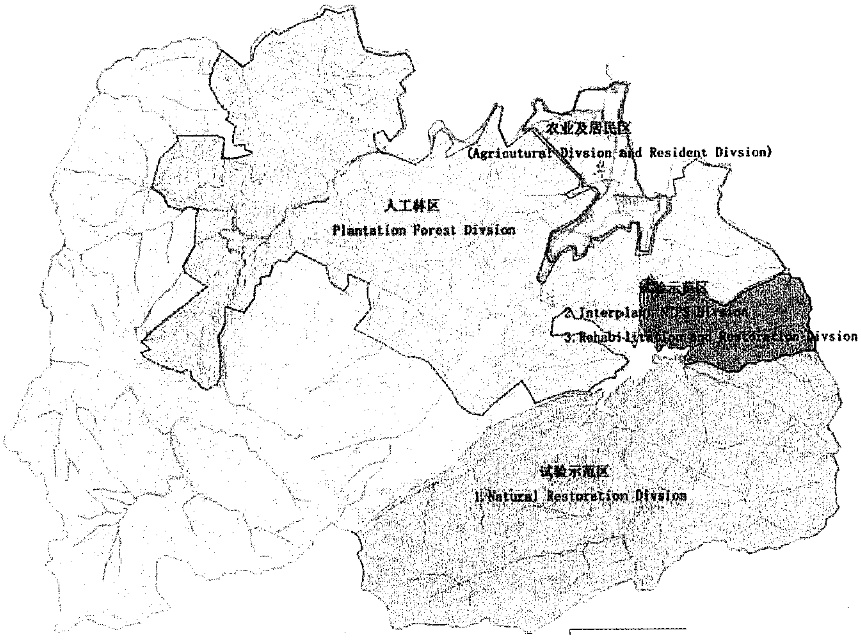
Yin Z Y, Ren H, Zhang Q M, Peng S L, Guo Q F, Zhou G Y. Species abundance in a forest community in South China: a case of Poisson lognormal distribution. *Journal of Integrative Plant Biology*, 2005b, 47(7): 801-810.

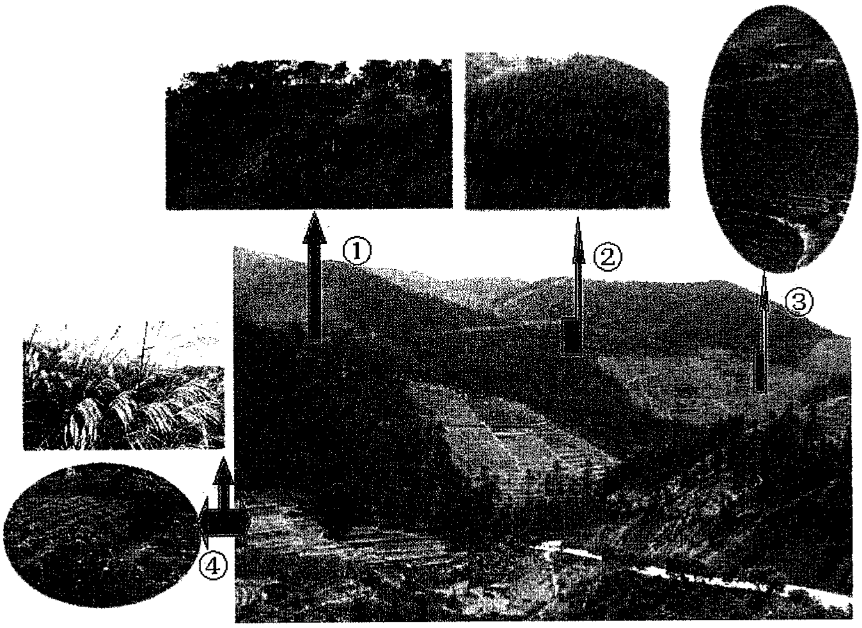
Annex 6 Photos of the Project Relative

Demonstration Districts Location Map

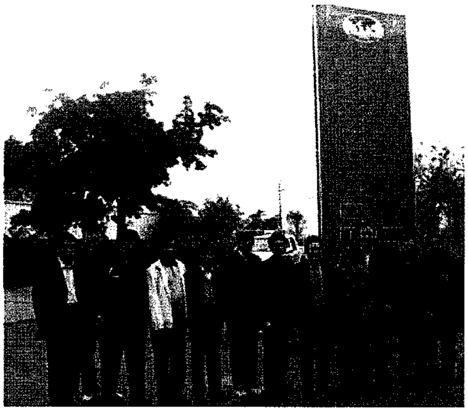


Overall Planning Drawing of Xinhui DD





1. Low productivity conifer forest
2. Eucalyptus plantation after felling the conifer forest
3. Orchard after felling conifer forest
4. Ruderal land and agricultural land



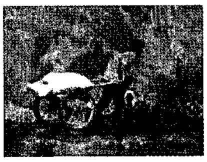
Xinhui Demonstration District, Guangdong

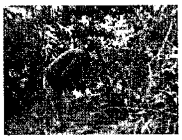
Tongshi Demonstration District, Hainan

Super Tree Selection

Nersury Stock

Splot of Rehabilitation and restoration of degraded ecosystem





Reintroducing Plantation

The Species Reintroduced

Ormosia pinnata

Syzyqium hainanense

Castanopsis hystrisc

Daibergia odorifera

Bamboo

Lisea cubeba

Ratten

Spatholobus suberectus

FINAL TECHNICAL REPORT