ITTO PD 14/92 Rev.2 (F)

Demonstration of Classified Management and Sustainable Utilization of Tropical Forest in Hainan Island, China

Demonstration and Theory of Forest Sustainable Development

(Project completion technical report)

The project team would like to extend its sincere thanks to former executive director
Dr. Freezalah for his help and support.

Demonstration of sustainable management of tropical forest
ITTO Project in Hainan, China

Key project members:

Hong Jusheng, Chief Scientist, Project Director
Han Jianzhun, Director General, Deputy Project Director
Huang Jincheng, Division Director, Director of Project Office and Head of the subproject 3
Hou Yuanzhao, Research Professor, Deputy Director of Project Office and head of the subproject 5
Wen Maoyuan, Associate Research Professor, Head of the subproject 1
Chen Yongfu, Research Professor, Head of the subproject 2
Li Yide, Research Professor, Head of the subproject 4
Zhou Xumei, Division Director, Head of the subproject 6.

Project region: Hainan Island, China

Duration: September 1993-December 2001
Supported directly by Japan Government and Switzerland Government
Implementation agency:

Hainan Provincial Forestry Bureau
Haikou, China
Tel: 00 86 898 6534 2784
Fax: 00 86 898 6534 1139

Chinese Academy of Forestry
Beijing, 100091, China
Tel: 00 86 10 6288 9731
Fax: 00 86 10 6288 4836

Contents

1. Summary

The project was intended to explore ways of realizing sustainable management of tropical forest by taking Hainan Island as an example. The project consists of 6 subprojects as listed below:

Subproject 1: Demonstration area for tropical plantation
Subproject 2: Demonstration area for sustainable management of tropical natural forest
Subproject 3: Demonstration area for artificial agriculture-forestry-pasture ecological system
Subproject 4: Demonstration area for tropical primary forest protection
Subproject 5: Investigation on information
Subproject 6: Human resource development, extension and demonstration

The project was completed in 3 phases, lasting for 8 years in total. The total project duration was actually 10 years by adding the pre-project period and the project summarization period. 6 subprojects in 3 phases have produced 68 outcomes by carrying out 300 activities. The total investment was 40 million RMB including 3.28 million US$ from ITTO. In addition, the fund for the pre-project was 0.025 million US$ from WWF. The key project members were 40 fulltime experts and project leaders. The project also involved about 200 external experts and 1500 workers.

During the 10 years of project implementation, The project made significant progress of 2 important fundamental sciences, 3 conceptual innovations, 27 technical achievements, 16 formal academic publications (9.03 million words and 21,200 copies), 60 research reports submitted and 62 formally published papers (11 papers was in English). The project significantly developed the ideas of classified forest management in China and "substitution" of ITTO. Based on these ideas, a set of "**integrated development models**" of sustainable tropical forestry management has been further proposed, providing a successful demonstration for sustainable forest management, a major contemporary issue. The economic benefit from the demonstration itself was up to **0.19 billion RMB**. The indirect economic benefit of plantation technology was up to **5.423 billion RMB**. Part of the directly measured ecological benefit was up to **4.390 billion RMB/year**. The more direct economic and ecological benefits were **10.003 billion RMB/year**.

The main tasks finished by subproject 1 were application of modern breeding concepts and technologies at international level to establish a central demonstration nursery and 2000 ha demonstration plantation of tropical forest, including many researches that produced quite a few achievements. The main tasks finished by subproject 2 were systematically summarizing the domestic and overseas research achievements and production experiences of sustainable tropical forest utilization, based on which a set of scientific sustainable tropical natural forest utilization models and technical systems have been developed, 30 less known forest species have been studied and an information management system for tropical natural forest has been developed by carrying out researches on the established 2000 ha demonstration plantation. The major work by subproject 3 was exploring approaches of developing and balancing agriculture, forestry and pasture in order to stabilize ecological environment and social development in surrounding areas of tropical forest, a 500 ha highly efficient artificial agriculture-forestry-pasture ecosystem has

been established. The main work of subproject 4 was capacity building for a nature reserve of tropical primary forest, studies of the structure, functions, biodiversity and its conservation of tropical primary rainforest ecosystem, and experiments on developing non-timber industries as substitute of the harvesting economy to raise awareness of functions, benefits and biodiversity of tropical primary forest ecosystem and to create a set of effective protection models. The main tasks of subproject 5 were mainly to lay a foundation for developing China's tropical forestry information and to conduct systematic studies on achievements and experiences in tropical forestry development in other countries, providing effective information services for the project, meanwhile, the project also laid a modern information basis for sustainable tropical forestry development in China. The main tasks of subproject 6 were the organization of training for project leaders and core experts. Meanwhile, some forestry officers and technicians from Hainan Province and other tropical provinces were also trained by the project. New technologies and new concepts of each demonstration project have been publicized, strongly promoting forestry development in the province.

The main contents and conclusions of the report are given below:

(1) The main themes and existing worldwide conditions for the themes were briefed in the Introduction of the report. Aspects of innovation of the project were described together with descriptions of project objectives and approaches.

The core of the report is the third part, in which 2 basic theoretical progresses on tropical mountainous rainforest ecosystem, 3 conceptual innovations for sustainable utilization of tropical natural forest, establishment of tropical plantation and balanced development of agriculture, forestry and pasture in circumjacent area of the major forest region, and other 8 demonstration achievements have been analyzed. Based on the above analyses, it was concluded that the project was successful and exceeded its original objectives. The project not only contributed at an appropriate time an excellent demonstration system of sustainable tropical forest management to the natural forest protection program launched in 2000 and the World Bank project started in 2001, but also greatly developed the original idea of classified forest management by proposing a conception model named as "**Integrated Development Model**", which went beyond technology and forestry, to problems from a larger and more in-depth socio-economic context. We called the theory of integrated development model as "Forest Sustainable Development Theory". In view of sustainable development theory, "sustainable forest management" is the basis for "sustainable forestry development". Without sustainable forest management nothing could be discussed about sustainable forestry development. This was a general conclusion (referred to appendix 1). Ten years of exploration by the project has indisputably told us that in order to realize sustainable forest management we must create the sustainability of forest from a wider range of fields of sustainable forestry development, that is to say that the conditions for being sustainable rely not only in forest management but also in forestry development. We have found in theory that the two theoretical concepts, sustainable forest management and sustainable forestry development, of which the former was subjected to the later, could indeed affect each other. Hence, the critical of the criteria and indicators of sustainable forest management proposed by ITTO at **national level** and **FMU (forest management unit) level** is the regional level. Only could the regional level be the key for realizing sustainable forest management at both national and FMU levels. Because an individual forest management unit could not create sufficient condition for forest sustainability.

The condition could at least be met at regional level. We define the sustainable forest management at regional level as "Forest Sustainable Development Theory". It was a valuable theoretical sublimation from the original directive idea of classified management to the scientific conclusion of integrated development model. In addition, the project has produced significant benefits and huge impacts in many aspects. It has won very high honor in forestry population in China and other countries. For example, Prof. Duncan Poore, who is a forestry professor of Britain and chief constitutor of the ITTO sustainable tropical forest management criteria and indicators, noted in an article, "**In all these later developments, the People's Republic of China has played an important part -- intellectually, in developing the component ideas of sustainable forest management and, here in Hainan, in setting up a practical model of which, from what I have read, the country should justly be proud. I hope to be able to hear more about it and see it for myself in the next few days.**" Of course, there were some regrets in the project; for example, it did not contain enough studies on forestry institutions, policies and environmental economics of tropical forest.

(2) The reference and appendices have been given in the fourth and fifth part respectively.

2. Introduction

2.1 Project theme and domestic and overseas conditions

Considering the importance of tropical forest and the heavy pressure it faces with, it is a key contemporary scientific issue that how to reach the sustainable state of tropical forest while promoting local economic development and people's income. In short the issue is: **How could sustainable tropical forest management be realized?**

In 1990, International Tropical Timber Organization (ITTO) identified the objectives 2000 of sustainable tropical forest management and formulated a system of regular reporting. But the international society did not indicate how to achieve to the objectives. No experiences were available in how to solve quite a few problems encountered in realizing sustainable tropical forest management. However, the objectives 2000 have undoubtedly forced the ITTO member countries to take practical actions. The Hainan project in China was proposed with such a background. We strongly believe that we could make our innovative contribution to solving the scientific problem.

Of course, ITTO also presented an idea to develop plantations as substitute of natural forest (see ITTO policy development series No. 4). But how to substitute, how much should be substituted, where should be substituted and how the economy develops in natural forest after substitution; how the circumjacent areas cooperate; how to preserve and manage commonweal tropical forest; how to deal with the relationships among the above mentioned three aspects; all these questions have not jet been answered. Although a lot of studies and experiments for a single measurement have been carried out in other countries, there was no integrated experimental project aimed at solving the above-mentioned problems and conducting classified management of tropical forest for sustainable development.

ITTO has formulated recently criteria and indicators of sustainable tropical forest management

and guidebook for using these criteria and indicators. The literature showed that realization of sustainable forest management was the basis for realization of sustainable forestry development; and without sustainable forest management if will be impossible to achieve sustainable forestry development. There were two C&I systems for sustainable forest management, i.e. one is at national level and the other is at management unit level.

Some Chinese experts thought that the essence of sustainable tropical forest management was to find a way to avoid conflict between economic and ecological objective so that forest could meet the increasing structural demand and expanding gross demand by human society. China proposed in as early as 1980s the theory of "Forestry function differentiation" (the concept of classified forest management) that was expected to be suitable for tropical forestry. Hopefully the above-mentioned scientific theme could be solved although necessary experiments were needed.

Firstly the so-called theory of "forestry function differentiation" (see appendix 2) was briefly described below. Traditional forestry is a kind of social production based on alterable production combinations, under which the output of two or more products could not be simultaneously maximized at all according to the rule that one grows and the other declines. This is just the common Chinese saying "fish and the bear palm is not obtainable concurrently". However, according to the idea of "forestry function differentiation", this internal constraint of forestry productivity could be avoided in the following way. Firstly, a small proportion of forestry land is selected for growing plantations for industrial timber production using modern technologies such as clonal forestry, so that the demands for wood raw material can be met. Secondary, areas need to be protected or ecologically fragile are identified and should be used for commonweal forest development. Finally, the rest forests or forestry land are managed as multi-function forest. The first two parts of forestry land have single management objective, but the last part has multiple management objectives and is actually the traditional forestry. This differentiation of forest management pattern requires corresponding adjustment in forestry development mechanism, forestry administration mechanism and forestry policies and laws. Actually such a management pattern accords with the theory of new classical economics concerning specialization division and could bring with very high efficiency. Thereby, according to the theory of "forestry function differentiation" it is possible to provide the society with private goods (i.e. visible forest products) and public goods (i.e. environmental products of forest) to meet the demands for expanding by modern forestry with lower cost and more rapid speed.

The main objectives of the project was to design and establish a demonstration system of sustainable tropical forest management according to the above-mentioned theory to solve a series of relevant problems, improve the theory, develop relevant ITTO guidelines and promote sustainable tropical forest management in China.

2.2 Objectives and methodology

2.2.1 Objectives

Being based in Hainan Island, China, the project will establish a demonstration system, widely using research results in China and other countries and its own innovations. The demonstration system will not only practically protect tropical forest but also sustainablly and increasingly

produce tropical timber. The demonstrated system will then be further extended to other places to promote sustainable management of tropical and even subtropical forests in China. In the established demonstration system bio-diversity of tropical forest could be credibly preserved; The big tropical forest ecosystem could be continually expanded with dynamic stabilization and sustainable production of medium to large timber; Market would continuously be provided with quality industrial tropical timber at lower cost; The objectives of protection and development of tropical forest would not conflict but supplement with each other. We intend to carry out a series of activities to explore the designed sustainable management model and create a set of practical experiences through the cases in order to achieve the above-mentioned objectives.

A series of fundamental studies or demonstration work to assemble the existed advanced technologies still need to be carried out.

2.2.2 Methodology

Firstly, the theoretical basis for sustainable tropical forest management was identified. That is the theory of "forestry function differentiation" (i.e. theory of Classified Forest Management), which was developed by Chinese scientists through the process from theory to practice and then from practice to theory in the 1980s. The State Forestry Administration (formerly the Ministry of Forestry) attaches great importance to this theory, and decided that development of forest resources in China will follow the "classified management".

Secondary, specific investigations were carried out in the target demonstration area, and detailed work program was designed for application of the theory of "classified management", which was just like organizing a pre-project. The pre-project started in 1990 and lasted 2 years. Since then the challenges to forestry development and the socio-economic causes for these challenges have been made much clearer.

Thirdly, the overall preparative plan for classified management of tropical forest resources in Hainan was designed, including identification of previously existed components that can be assembled with the existing components of future demonstration system, and identification of demonstration components that should be prioritized for development, in order to assemble a demonstration system.

Fourthly, all the identified key components for demonstration were put together to form an ITTO project, which was scheduled into 3 phases and would be completed in 6 years. The project was intended to keep watching international standards in technology aspects and to conduct a full review in the mid term of the project, meanwhile make adjustments to the original project design in order to absorb domestic and overseas advanced technologies and keep its advantages.

In general, the project was a complicated system of "integrated study + integrated experiments + integrated demonstrating + integrated extension". Integrated study included not only fundamental studies on tropical forest ecosystem, but also applied researches on domestic and overseas-existing technologies, socio-economic investigation and development of information and human resources.

2.3 Project innovation

Innovation in project design was reflected in 5 aspects:

Firstly, what the project developed through experiments was the theory of "Classified Forest Management" of China, which was considered as a theory moving towards sustainable management. If a theory were proved to be effective for sustainable forest management and its effects could be demonstrated by a case, such effects would be more important than obtaining many single techniques. As far as we knew, there was no project designed in such a way so far.

Secondary, what the project sought for was to achieve sustainable tropical forest management by taking systematic measures. At the designing stage it was considered that even if one or two measures were implemented successfully, it might not be effective for realizing sustainable tropical forest management, because some other factors may totally counteract the exertion of these measures, which often occurs.

Thirdly, due to limitation of funding, human resource and time, the project adopted the approach of making good omissions and supplying deficiencies, that was to fully make use of existing national and regional development conditions, filling up important gaps (usually representing development trend), and establish a demonstration system, thus making the project plan not only practicable but also demonstrative.

Fourthly, considering the long project duration, the project reserved certain time for mid term review and adjustment to the project plan according to new situation, therefore further ensuring to achieve of the project goals.

Fifthly, fully considering the specific realistic situation in China's tropical regions, two supportive subprojects, i.e. subproject 5 (Information infrastructure construction) and subproject 6 (Human resource development and research extension), were proposed. Without these two subprojects neither the demonstration achievements could be extended, nor could the success of the demonstration project itself be guaranteed, even if the project plan was extremely outstanding.

Sixthly, an important innovation of this project management was that before project implementation a set of project management system, including financial system, personnel system, dossier system and project activity monitoring system, was formulated. Taking the financial system as an example, it required that the project director withheld 10% of each subproject's annual financial budget as security reserve, which would be allocated with the exact amount if the annual tasks were finished as planned and otherwise be retained as a punishment (in fact no punishment occurred); and it also required that another 10% would be withheld as project contingency for unpredictable events and connection to different project phases. Such a financial system would not disobey ITTO's financial principles and would ensure successful implementation of the whole project plan. The project management system set up beforehand has been agreed by Mr. Freezalah, ITTO's ex-Executing Director, and was to be summarized upon project completion. This innovation would be introduced as an achievement in the core part of the report.

3 Main text

3.1 The scientific theme: how to realize sustainable management of tropical forests?

In 1990, ITTO released its policy series No 1, "Guidelines of sustainable management of tropical natural forest", and formally raised the subject sustainable management of tropical forest. In the same year, ITTO also determined the objective that "up to 2000, all tropical timber products sold in markets should come from sustainablly managed forest".

In 1991, ITTO made a new explanation for this objective. This explanation actually set up a very desirable goal for ITTO. According to the new explanation each country should: (1) classify forests by different purposes based on the principle of balanced utilization and protection; (2) how to sustainablly manage every piece of natural forest should be determined by its purpose. So an idea through classified management to achieve the goal of sustainable tropical forest management was actually shaped, although this idea was not very clear yet.

In the project proposal prepared in 1992, we raised the issue in the following way: For tropical forest, the conflict between protection and utilization had not been solved yet, the remaining tropical natural forest could not be cut any more in view of ecological and environmental benefits. But from the viewpoint of economic needs of production and consumption, more timber needs to be produced. Protection and utilization of tropical forest could not just depend on traditional measures, so it was necessary to try new management models. Application of new concepts and advanced technologies could solve the conflict between protection and utilization of tropical forest. It is possible to increase by several times the production of tropical timber with various sizes while the tropical forest ecosystem and its biodiversity were effectively preserved, creating a scientific model for sustainable tropical forest management in the world. Based on studies on the theory of classified forest management in China, we proposed an ITTO demonstration project to test and develop the theory.

3.2 Theoretical base

We did choose such a theory as the guiding theory of experiment design in Hainan Island and took the optimization and development of this theory as one of the project objectives. Below will describe basic claims of theory and the detailed description and discussion were given in specific papers (see appendix 2 and 3).

Theory of Classified Forest Management:

Human needs for forestry has gone through primary needs, and simple needs, and now has entered the stage of "modern needs". The modern needs are characterized with rapid expansion in whole and increasing differentiation in structure. It can be approximately divided into 2 types, economic and environmental needs. The economic needs include the needs for large, medium and small sized timber and many other types of forest products, and the environmental needs include 3 types of needs, the needs of natural environment, economic environment (for protecting industrial and

agricultural production), and human environment (necessary for maintaining human life). Now the problem is that the total needs by the society is continuously expanding, no matter economic or environmental needs. For example, the world's average paper consumption per capita respectively 100, 50 and 10 years ago were very much different. And the population involved in paper consumption is expanding as well. The global population is now 6 billion and will probably increase to 8 billion or more in future. Furthermore, in the past the demand for both timber and hunting could be sufficiently met by the same piece of forestland, indicating that "one forest for multiple uses" was practical. But today it may not be sufficient even if all trees in the world were cut; and in order protect environment all trees must be retained. Traditional forestry, in a modern environment of modern needs, has to meet both types of needs, which appeared to be difficult.

Modern demand essentially requires that forestry itself achieve sustainable development and participate in sustainable social and economic development (Appendix 1). Specifically, it requires future forestry hold simultaneous considerations of 5 interest pairs, interests of present vs. future generations, economic vs. environmental benefits, material vs. spiritual interests, local vs. overall interests, national and international interests.

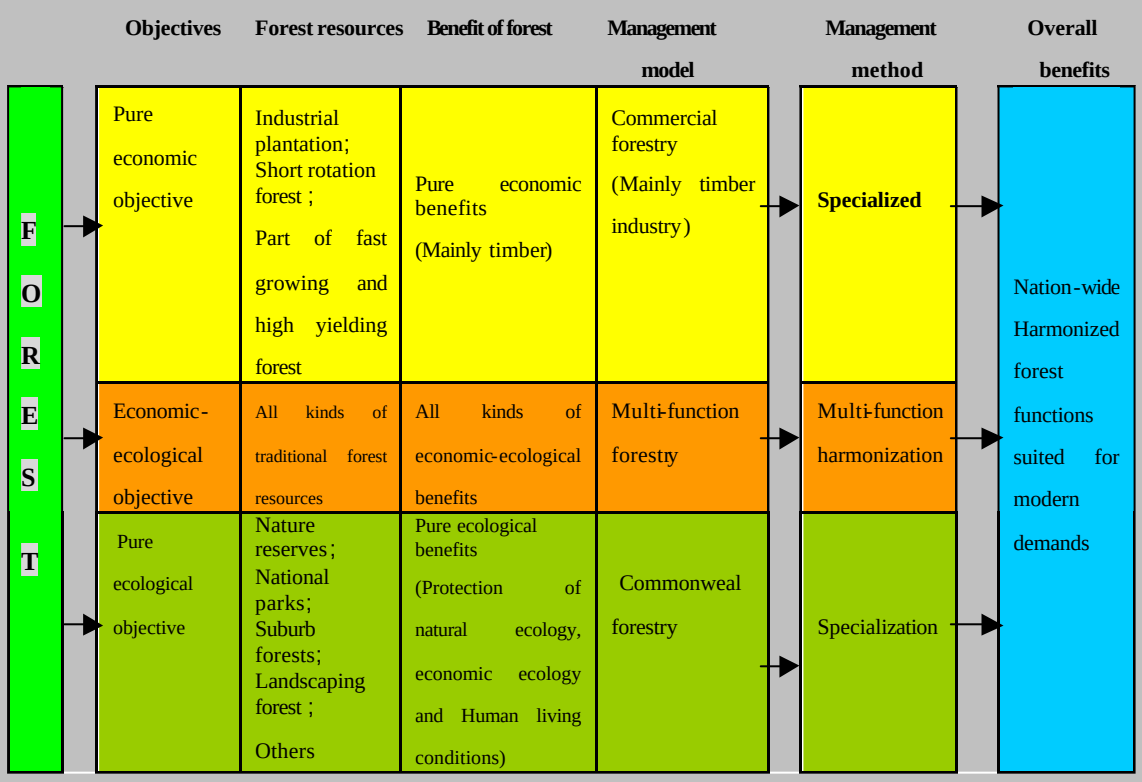
The relations between interests of each of the above 5 pairs are actually all, which is an issue of quantity and quality and the transition from quantity to quality, i.e. to what extent of quantitative change the two contrary and unitary side can coexist, and to what extent the relation will be naturally broken and new things emerge.

There were many quantitative forecasts on timber demand, many of which have warned that the existing forest could only provide timber for some years. Concerning tropical forest it is not difficult to imagine that the world's existing 1.7 billion ha tropical forests would be completely harvested within 100 years at the current rate of deforestation (17 million ha/year).

The systematical studies by Hou Yuanzhao demonstrated that traditional forestry could not meet the present-day demands due to its imperfect internal economic mechanism and functional restraints and that the real demands has already exceeded the critical point maintaining the contrary and unitary balance mentioned above.

For this reason Chinese scholars proposed the idea that through classified management of forest resources to ensure sustainable development, and demonstrated in theoretical, practical and technical aspects. The basic principle of the classified management was shown in figure 1.

Figure 1, Conceptual model of future forestry development



According to this idea, the demand for forest resources would no longer be subdued to protect the existing forests, and it was advised to aim at the demands and introduce the idea of specialization to adopt the strategy that "locally dividing one into two and wholly combining two into one", part of the forest is managed for pure economic purposes, and another part of the forest for pure ecological purpose. At the same time, most forests would be kept for traditional multi-function management. So the development of forest resources actually become in three kinds of models: commercial, commonweal and multi-function forests. Such a development trend is an internal process under market economic system. Market mechanism itself will lead to allocation of various resources moving towards the above model of resource deployment. But in a country transiting from planed economy to market economy, at least at the initial period external forces were needed to arrange the deployment.

Commercial forest should include all kinds of forest that can be used to produce forest products (known as private goods in economics). It particularly highlights timber-cultivating industry (Ligniculture), producing timber material in a way of farming. In general, with about 10 % of its existing forestry lands being used for commercial forest, the original timber production in a country can be substitute or greatly exceed. There are many successful examples in the world of commercialized management of commercial forest.

Commonweal forest, basically aimed at ecological protection of all kinds of natural, economic and human living environment, including nature reserves, special water preservation forests, water and soil conservation forests, desertification preventing and combating forests, suburb recreational

forest and special landscaping forests. Commonweal forest is managed for public benefits or long-term national benefits, therefore should be financed by national public fund or financially compensated for production of the public goods by institutions/individuals of commonweal forest management through some appropriate measures.

Multi-functional forest, managed for simultaneous ecological and economic benefits. It holds the function of timber production, but in order to avoid damaging environmental benefit, harvesting of trees is strictly controlled (weak disturbance to the environment). Multi-functional forest should be managed in long rotation, mainly by natural forces and for medium and large trees. Indeed it is the natural forest managed in traditional way (or plantation managed for naturalization). Multi-functional forest is still the main body of national forest resources. Its management body should be provided with necessary support and favorable taxation policy because they provide the society with a public good, the environment.

For the management of commercial forest, as long as technologies keep progressing, the production of timber material can be indefinitely increased in a limited area of land, just like crop production. Therefore, it is not impossible that timber eventually gets over produced leading to reduction of production base and expansion of natural forest ecosystem. Commercial forest usually grows quickly with short rotation, difficult to produce medium and large timber with high quality, which must be supplemented by the multi-functional forest in the market.

In general, in this development model, commercial forest and multi-functional forest were used to meet the economic demands and commercial forest plays the main role. Commonweal forest and multi-functional forest were used to meet environmental demands and commonweal forest plays the main role. The respective areas of commercial forest and commonweal forest are not too large and multi-functional forest is still the main body in terms of area.

Traditional forest management indeed wastes lots of potential economic and environmental benefits due to its compromise to different demands. As a result, although many countries have large area of forest, they are unable not meet various demands. Classified forest management avoids constraints among the internal functions and alleviates conflict among management objectives. For the above listed special types of forests, as long as technologies can reach, their potential effects will be unlimited. So a new model was proposed, paying attention to both economic and ecological benefits at the same time. It is an open, dynamic and new system that continually meets human's ecological and economic demands, i.e. forestry under sustainable development.

Until recent years, it has been a common sense of the international society that classified management is the core of resource allocation for sustainable forest management.

3.3 The plan of Hainan project

Investigations suggested that classified forest management in Hainan be divided into 4 aspects consisting of 7 specific projects (see to appendix 3):
The first aspect is commercial forest development. Large area of **commercial plantations** will be

developed in coastal hills and tableland, and plantation management will be significantly improved, so as to produce more timber (including timbers for industrial uses, rural uses and fuel wood uses) and more economic benefits. At the same time, large area of **tropical economic forests** will also be developed, making full use of the favorable light, heat, and water and soil conditions. Such commercial forest development can be financed and managed according to market system.

Secondary the existing **mountain primary rainforest** in the central mountain hinterland will be entirely protected, prohibiting logging and conducting biodiversity studies and conservation of endangered species. In addition, **mountain closure** will be enforced for large areas of barren mountains to restore vegetation. This type of forest is for conserving the water resources, the lifeline for all people in the Island, and for conserving the biodiversity, the common treasure of China and the world. This type of forest is commonweal forest and its management and investment should be the responsibility of the Central and local governments.

Thirdly **the existing natural forests (tropical secondary forest)** in all forest areas and 1500 km long coastal shelterbelt plantation forests should be managed as multi-functional forest. Such forests should be managed with long rotation mainly for production of large timber and impacts on forest ecosystem should be reduced as much as possible. The institutions responsible for management should develop multiple products to ensure financial input. The state government should provide appropriate support or reduce taxes.

Fourthly **artificial agriculture-forestry-pasture ecosystem** will be developed in low mountains, where conflicts among forestry, agriculture and pasture are most evident. Intensive management I each sectors will be implemented according to the specific local conditions, in order to stabilize, restored and expand the fractured forest ecosystem, improve local people's income, reduce the extension of farming and pasturing activities to hinterland of forest areas.

Considering the successful experiences in commercial forest, mountain enclosure for forest restoration and coastal shelterbelt forest, the ITTO project only approved the other 4 aspects as 4 demonstration subprojects, and other two supportive subprojects, "information investigation" and "training and research".

The overall objectives of the project were: (1) Establishment of 2000 ha demonstration base of high quality and high yield plantation in Hainan Island and managed according international standards; (2) Establishment of a 2000 ha demonstration area for sustainable utilization of natural forest, summarization of harvesting experiences of tropical forest in China in the past 40 years, absorption of international experiences and development of a model of sustainable management of tropical natural forest in China; (3) Establishment of a demonstration model of artificial ecosystem of agriculture-forestry-pasture in low mountain terrains with an area of 500 ha, development of methods to effectively solve conflicts among agriculture, forestry and pasture; (4) Establishment of a 2000 ha demonstration nature reserve of tropical mountain primary rainforest, development of a self-supporting economic system, a monitoring system of primary forest protection, a biodiversity investigation and conservation system and fundamental studies on tropical forest

ecology.

The project intends to explore approaches of classified management of tropical forest and to deepen theoretical knowledge of classified management.

3.4 Scientific progress 1: New knowledge on types, structure and functions of ecosystem of tropical mountainous rainforest

Tropical forest ecosystem, especially tropical rainforest, is the most complicated terrestrial ecosystem. Unevenness, variability, complexity and special diversity are important characteristics of tropical rainforest. So far the types, structure and functions of the ecosystem, especially its operating mechanism and biodiversity formation mechanism, have not been fully understood. Ecosystem of tropical rainforest has not jet been perfectly duplicated by human. The international symposium on tropical rainforest held in France governed Guyana in 1990 has given it an impersonal appraisal.

The project lasted nearly 10 years and achieved new important progress on tropical forest ecology, which will be briefly described below:

3.4.1 New understanding of tropical forest ecosystem structure

The complex inter-population relationship in tropical forest has been revealed. The significant characteristics were:

1) **Narrow niche of populations:** most populations of tropical forest have narrow niche, and only few populations have broad niche (such as naturally regenerated pioneer population).

2) **Resource highly fragmented by population:** The ambiguity of inter-population relationships of tropical forest was that no matter for primary or regenerated forest the niche proportional similarity and niche overlap between populations were very small, and the extent of fragmentation of resources is very high, indicating a highly harmonized multi-population forest ecosystem.

3) **Population mutualism and competitiveness:** There are some populations with large nice breadth in tropical forest, but the proportional similarity and overlap among these populations may not necessarily high. In another situation, the niche breadth of two populations is not large but the proportional similarity and overlap are high, the reason is that these populations often appear together due to their utilizing competition. Populations at the same level have higher niche overlap, and whether it is caused by utilizing competition or by disturbing competition will depend on specific circumstances. Both relations between niche overlap and utilizing competition and between niche overlap and disturbing competition exist in tropical forest.

The research results of population relations have significant theoretical and practical values for establishment of mixed forest of native species in tropical areas, establishment of agroforestry system, improvement of secondary tropical forest and sustainable management of

tropical forest. For example, when considering species composition, we may consider the niche breadth of each population, the niche proportional similarity and niche overlap between populations, and whether there is utilizing competition relation between populations. If the ecological relation between populations is competitive, it at least requires that a certain dimension of resources is not overlapped and avoid disturbing competition as much as possible so as to allow the established artificial population to be in a highly harmonized system.

3.4.2 New understanding of tropical forest ecosystem functions

1) Through construction of carbon sequestration curve model of tropical forest population, it was proved that only when the tropical forest resources were rationally used, tropical forest become the atmosphere carbon sequestration can then be secured, meanwhile, parameters of rational use were obtained.

The models indicated that when tropical forest evolved into maturing period, the net growth of population tends to stop, and the material cycling is at a state of dynamic balance, the emission and sequestration of carbon are equivalent. During this period, the net carbon sequestration of the primary forest tends to be approximately 0 t/hm^2/year. During years with more typhoons and storms the net carbon sequestration is a negative value, otherwise it will be a positive value if impacts of typhoons and storms are small, but even the largest net carbon sequestration will not exceed 1.0 t/hm^2/year. This is the fluctuation process of carbon dynamics of forest ecosystem. Since the naturally regenerated forest is at a period of rapid growth, the carbon sequestration is much larger than the emission, and the population net carbon sequestration can reach more than 7.0 t/hm^2/year.

So proper utilization should be made after forest become mature. The problem is to what extent the utilization degree should be in order to make sure that bio-diversity would not be damaged, ecological function would be maintained and the maximum atmospheric CO2 could be sequestrated.

Through the carbon sequestration curve and analysis of other data (such as population structure, forest window dynamics and water and soil conservation functions), it was found that when the extent of tropical forest utilization is 20-30%, not only the biodiversity conservation and ecological environment protection (the limits are not broken yet) can be secured, but also the function of capture of atmosphere CO2 of forest can be better elaborated (This is also proved by the second sub project “integrated selective harvesting for sustainable tropical forest management”)..

2) The project has revealed that preservation of water resources and conservation of soil were the two most important ecological functions of tropical forest in Hainan Island by quantitative comparative studies on tropical primary forest, naturally regenerated forest and artificial young forest.

- **The function of conserving flood for drought:** The average annual runoff of natural forest accounts for 46.7% of the rainfall, of which 26% runoff is used for "conserving flood for drought". When a single rainfall is below 200 mm, the hydrological response will be about 10%. The variation in a year is that alleviation flood during the rainy season (August to October) and release drought during the dry season (February to April). Under the conditions of typhoon and storm, the alleviation of flood by primary forest can reach 328 mm, 1.5-2.1 times of the young plantations. When rainfall reaches 600 mm, the effect reaches the highest. Under different storms, different forest types have different effect of flood alleviation. Generally, taking young plantation as control, tropical primary forest can reduce 40-69% of the flood peaks, and the naturally generated forest can reduce 18-56% of the flood peaks.

- **The function of soil conservation:** The mud and sand loss in non-forested land is 3.3 times of young plantation and 575.8 times of primary forest. Compared with young plantation, tropical natural forest could decrease the annual net soil nutrient loss up to 237kg/ha.

Therefore, tropical forest has significant functions of soil conservation and soil fertility maintenance. This conclusion has special directive value for management of multi-functional forest ecosystem. Firstly, weak intervention should be used; secondary artificial measures should be taken to promote natural regeneration. In addition, except for special situation complete land cultivation should be avoided in establishing tropical plantation. Otherwise the function of environmental protection of forest ecosystem would be totally lost.

3.4.3 New understanding of the ecological theories of tropical forest

Ecological study on tropical forest peaked in 1950s, about one century later than that on temperate forest. The theoretical basis of tropical forest ecology was mostly introduced from theories of temperate forest ecology, which in most cases could not clearly explain the tropical forest problems. This project proposed some new models and concepts, mainly including:

1) New formula of edge effect: Studies has been made on species composition, spatial structure, species diversity pattern, population growth and decline, dynamic connection and population spread of the main populations in tropical forest population during regeneration and succession. Especially the edge effects of main population of regenerated forest after harvesting and primary forest population without harvesting have been studied. The complex mechanism of population spread of tropical forest has been preliminarily found. A new edge effect model suitable for tropical forest population was developed as below:

$$Y = a + e_0[1-(D/D_{\max})]$$

The equation indicates that the edge effect e_0 of the distance D of a point to an edge decreases with the increase of distance D, the value of Y will be a when the distance reaches to its maximum D_{max}, Y= a, i.e. a constant not affected by the edge effect, reflecting the random distribution of most tropical forest populations. The time dependency of the edge effect reflects that with the increase

of time of population regenerative succession the edge effect of the population decreases and ultimately reaches value *a*.

Edge effect properly explains the mechanism of population spread of tropical forest, providing theoretical basis for sustainable tropical forest management and artificial promotion of natural regeneration in future, which is of important theoretical significance and practical values.

2) New concept "unusual forest residues": Regions under tropical monsoon often attacked by tropical thunderstorms and typhoons (known as hurricane in tropical America). Considering that typhoon not only severely affect biodiversity and population structure of tropical forest ecosystem, but also severely affect material cycling of the ecosystem, dramatically increase the amount of residues, the project therefore suggested the new concept "unusual residues" and determined that in Hainan's tropical rainforest the unusual residues accounted for 43%-47% of the total amount of the total amount of residues in a year, significantly affecting the bio cycling model of forest ecosystem. Meanwhile, the project also proved that well structured and healthy ecosystems are less affected by unusual residues than simply structured ecosystem.

Effects of "unusual residues" should be fully considered during construction and managing tropical plantation ecosystem, because it involves the pattern of biological cycling, the nutrient supply, restoration and health of the system must take relevant measures to prevent ecosystem degradation.

3) Provide scientific explanation for the "morning rain" mechanism of tropical rainforest: why does the tropical rainforest produce water drips during early morning? What is the scientific explanation? Trough studies on forest microclimate, air dynamics, variation patterns of environment and energy, and with the use of a uniform and one-dimensional equation $E_t = -(rek(\overline{u}_2 - \overline{u}_1)(\overline{e}_2 - \overline{e}_1) or (\overline{c}_2 - \overline{c}_1)/(P_a[\ln(z_2/z_1)]^2)$ for approximation and equilibration, we studied the canopy response in order to gradually obtain canopy environment benefits and to display the difference and regular pattern of microclimate of tropical mountain rainforest between dry and rainy seasons; the tropical rainforest water vapor pressure gradient change indicates the mechanism of morning rain formation of rainforest, i.e. the vapor pressure in rainy season is characterized as that during 5:00 to 7:30 in the morning and the height of the forest from 9 to 21 m it is a low pressure eddy (τ<19 mb) and vapor could coagulate to form morning rain; during 14:00-19:00 and at height below 12 m it will be a high pressure eddy (τ>26.6 mb) and at height from 21-29 m it will be a high pressure eddy (τ>25.6 mb) and water will evaporate into the air. This conclusion gives an scientific explanation on the definition of tropical rainforest, meanwhile it also explains that forest creates condition for increasing rainfall, protection of forest could increase regional rainfall hence improve local conditions for water cycling.

4) Regular pattern of long-term climate variation in forest region: With use of power spectrum, the year to year variation of climate in tropical forest region was analyzed, results indicated that the evaporation rate of rainfall in rainy season varies in a cycle of 6.7 to 10 years, the variation is particularly evident with a 10 year cycle. In addition to an evident variation cycle of 6 months for

both the monthly water vapor pressure and monthly low clouds, there are respectively a 36-18 month and a 13-8.7 month evident variation cycle. Moreover, the maximal entropy of monthly water vapor pressure displayed a variation cycle of 4.4 months. The power spectrum of monthly wind speed displayed variation cycles of 60 months and 2.3 months. Ground surface relative humidity had higher correlation between June and July, and had evident resonance in the range of the curve at the fourth wave and the cycle of 8.5 years, the relative delayed displacement was 0.48 years. Through studies of these variation, the seasonal and yearly variation of rainfall, ground evaporation, water vapor pressure and other climate factors can be understood, hence to predict annual rainfall and deficit of water, providing significant climate information for the growth, development, physiological and ecological characteristics, biological adaptability, biological succession, biodiversity of tropical trees.

3.5 Scientific progress 2: New understanding of biodiversity of tropical forest and its conservation

3.5.1 New progress in studies on species diversity

The situation of various biological species in Jianfengling region has been made clear, and its position in biodiversity in Hainan, in China and in the world has been also determined. The total number of species of plants, animals and microorganisms is over 5700, accounting for 4-20% of the total number of species in the whole country. There are 37 families, 74 genera and 133 species of wild ferns, accounting for 36.7% of the total number of ferns in Hainan; 5 families, 8 genera and 12 species of Gymnosperm plants, accounting for 76.5% of the total; 179 families, 898 genera and 2075 species of Angiosperm plants, accounting for 75.0% of the total; 48 families, 141 genera and 215 species of birds, accounting for 62.5%; 23 families, 48 genera and 68 species of Beasts, accounting for 83%; 7 families, 12 genera and 38 species of Amphibians, accounting for 76%; 12 families, 37 genera and 50 species of Reptiles, accounting for 48.1%; 33 families, 83 genera and 312 species of large fungi, accounting for 47.9% of the total number in Hainan; 2222 insect species have been identified for their Latin names, belonging to 145 families and 13339 genera, of which the number of butterflies reached 449 species, belonging to 10 families and 201 genera.

The tropical forest population in Jianfengling has a very high value of species diversity index. Investigation indicated that the species diversity index of tropical primary forest was 5.78~6.28, which was similar to that of the tropical rainforest population in Brazilian Amazon (6.21), and was higher than that of the tropical rainforest population in Burma (5.4). The species diversity index of 40-year-old naturally regenerated mountain rainforest was also 4.52~4.77, which was equivalent to that of southern subtropical monsoon evergreen broad-leaved old forest. The population evenness was over 81% and higher than that of southern subtropical evergreen broad-leaved forest.

The tropical characteristics of the biota in Jianfengling were summarized. Taking the flora as an example, it has several obvious characteristics:

- The composition of families, genera and species is abundant, but the number of species within genera is relatively small and differentiation weak, fully reflecting diverse composition and ancientness of origins;

- Geographic components are diverse, specific components are relatively rich, is important component of the flora in Hainan or even in the whole Southeastern Asia;
- Tropical component dominates significantly, only in mountain areas (altitude of more than 900 m) the tropical-subtropical transitional feature gradually appears, and the number of species is small.

This fully indicates the complexity of species composition and the non-evident dominant species of tropical forest population, illustrating that protection of tropical forest is the protection of the abundant biodiversity resources.

3.5.2 New development of theories and practices of conservation biology of tropical forest

Duo to the varying and diverse environment, tropical forest usually has small populations, complex inter-species relations and abundant biodiversity, becoming the hot spot of conservation biological studies in the world.

Hainan is an independent island geographic unit, and after many years of exploitation and utilization, tropical forest has been highly fragmented, leading to big difficulties in protection of biological resources and the ecology. The demonstration studies in Jianfengling has made progress in following aspects:

1) **Determination of the abundance of rare and endangered plants:** Jianfengling region has 56 rare and endangered plant species under state protection with priority, accounts for 2.52% of the total number of all wild high plants (about 2220) in Jianfengling region, among which 11 species are extincted plants (8 species can be found in literature and 3 species were sampled for specimen), accounting for 0.5% of the total number of wild plant speceis; 8 species are endangered plants, 10 species are vulnerable plants and 12 species are rare plants. If the endangered, vulerable and rare plants were pooled together as "highly endangered" species, the number of such species would account for 1.35% of the total number wild plant species in Jianfengling region. Additionally, 15 species currently have certain number of populations of which ecological distributions were also characterized.

   These data and conclusion provided essential information for protection of rare and endangered species in Jianfengling and for the design of nature reserve.

2) **Determination of the ecological footprint of the nature reserve:** According to the theory of conservation biology, the core area of nature reserve should be satisfactory for intra-population gene flow of all species, particularly the rare and endangered species, so as to protect the species and their genetic diversity. In Jianfengling, to meet this requirement, how large the baseline area is needed?

   This project determined the ecological footprint of the nature reserve of plant species according to "species-area curve" (Arrehenius bi-logarithm curve model) $S=cA^m$, where m is a very useful indicator, gradually changing with the area A, but when A changes to a certain extent, m turns to have very small change or almost no change. This can be understood as:

when the area continues to increase, the number of species ***S*** increases very slowly or no more increase, at this situation the area of the nature reserve is the ecological footprint.

Research indicated that for wild plants protection in Jianfengling the ***m*=0.27**, basically close to the island wide indicator **(*m*=0.24)**, ecological footprint should be between 45000~50000 ha., basically meeting several requirements in conservation biology: minimum viable population (MVP), surviving time of higher level plants of the food chains, genetic diversity of species, impacts of diseases and insects, and edge effects etc.

3) **New experience in ex situ conservation of rare and endangered species:** Ex situ conservation of plants is an important component of ex situ biodiversity, whether ex situ conservation of a species can succeed, on one hand we need to know whether the species can survive and reproduce offspring, on the other hand, we need to know how large the MVP can secure its genetic diversity.

The formula for calculating MVP is: ***Pn*=*Lf* × *Ee* × *Am***. For ex situ conservation species, the conservation number of each species (***Pn***) should be calculated on parameters such as conservation number required for survival ***(Lf)***, Ecological and genetic types of trees (***Em***) and mating system (***Am***). Comparison with other relevant results indicates that monoecious plants require that the MVP for arbor trees should be at least 12 trees, more than 48 trees for shrubs and more than 120 individuals for Grasses. The MVP for dioecious and non-melting reproduction species can be relatively smaller.

Jianfengling tropical arboretum has successfully conserved 42 state priority protected rare and precious plant species (of which 35 species are native species to Hainan). 90% of the species have good growth performance, and only a few (about 10%) alpine species have poor growth at the arboretum with low altitude. The success of ex situ conservation are mainly reflected: 1) basic survival and good growth: in terms of average DBH and height growth, the average DBH growth is usually 0.4~1.2 cm/year, total average can reach 0.8 cm/year, the height growth is usually between 0.4~0.8 m/year with a total average of 0.5 cm/year. The DBH growth of species with good growth can exceed 0.7 m/year, about 0.4~0.5 cm/year for species with medium growth, and DBH growth of 4 species with medium growth was lower than 0.2 cm/year. These species are mainly distributed in mountains with high altitude and have strict requirements for habitat, such as *Cephalotaxus hainanensis* and *Podocarpus imbricatus*; 2) all species are basically flowering, and reproducing offspring.

However, there was very little understanding of the basics of the genetic models and reproductive system or even no study has been conducted. As a result, it is impossible to clearly understand its MPV for each ex situ conserved species, leading to that the number of conserved rare and precious species and state-level priority protected species in the tropical arboretum is still not satisfactory, therefore impossible to effectively protect its abundant genetic biodiversity resources. These are the research activities urgently need to be started after this project.

3.6 Conceptual innovation 1: Modern concept of tropical natural forest management proposed

3.6.1 Revision of traditional concept

Up to date, no matter in China or abroad, all models of tropical natural forest cultivation and all types of experiments, even people's ideas (see appendix 3), have only one objective, development of timber. However, Is this the model of management and utilization of tropical forest?

At present and in future, human beings hope, through protecting forests, particularly tropical forests, to obtain some kind of guarantee of fortune and prospect and a safer Earth home, i.e. sustainable economic and social development. This is determined by the importance of tropical forests and requires us to modify the above traditional forest management conception and technology. We are clearly aware that the demonstration projects are unavoidably facing with this problem.

Due to this awareness, we have given up the traditional conception of tropical forest management, and proposed a modern management concept, that is:

> ***Modern management of tropical forest should be the management of the entire tropical forest ecosystem for multiple forest products and various environmental benefits, particularly for conservation and rational utilization of biodiversity, which the management itself will be sustainable. We do not support continual extending management measures for suppressing the growth of non-timber species and promoting growth of timber species for producing and cultivating more timber. To destroy other surrounding species only for the growth of a precious tropical timber species is out of time and the loss is greater than the gain.***

According to this conception, we should rethink the traditional tropical forest management practices and research achievements at a new high standpoint, to design and explore modern tropical forest management model. Based on systematic integration of existing concepts appeared in China and abroad in recent years, we proposed a modern tropical forest management model, i.e. **"Technological/economic/social system for sustainable tropical forest management"**.

3.6.2 Technological/economic/social system for sustainable tropical forest management

The technological/economic/social system for sustainable tropical forest management based on new conceptions is generally called "forest sustainable development" theory. Because the concept of "management" itself has changed, not restricted to technology, and even to forestry, it is a set of measures combining social and economic background. The followings are 12 measures:

1. Implementation of weak disturbance logging

The so-called weak disturbance logging means the impacts on forest ecosystem caused by selective logging are kept as small as possible. The weak disturbance logging includes several

aspects. The first is to reduce tree-cutting for road construction as much as possible; the second is to reduce the logging intensity as much as possible; the third is to carefully design and control the falling direction of cut trees; the fourth is to try best to adopt ways of log collection causing no damage to forest structure; the fifth is to properly extend the logging cycle.

2. Development of less-known tree species

In most tropical forests, there are only few individuals of the well-known commercial tree species per ha. Destroying one ha of tropical natural forest could only produce a few commercial tree species, and the ecological and productive costs are too high. To explore and utilize these less known tree species is an important way to save tropical forest resources. (For this reason, the project has studied 30 less known tree species in Hainan's tropical natural forest.)

3. Biodiversity conservation

Biodiversity conservation has received special attention in the modern management concept of tropical forest. It is not only a measure of the modern tropical forest management but also a goal toward sustainable tropical forest management.

4. Development and implementation of criteria and indicators of sustainable tropical forest management

ITTO has developed criteria and indicators of sustainable tropical natural forest management and implementation manual, and has devoted itself to certificating mechanism for carrying out and examining the criteria and indicators. The ITTO documents had very important value as reference. (The project has also formulated criteria for Hainan according to Hainan's situation.)

5. Implementation of eco-certification

Eco-certification (also called forest certification) aimed at making sure that sustainable forest management is an important safeguard for sustainable tropical forest based on above-mentioned criteria and indicators, which requires a comparatively neutral certification agency or an audit system.

6. Development of non-timber products and non-timber industries

Except for the commercial and less-known tree species there are still lots of plants in the tropical forest ecosystem that can be used for food, clothes, housing, travel, and industrial raw material for human beings.

7. Paying close attention to management of tropical secondary forest

In tropical region, the area of secondary forest and degraded forestland is usually larger than the area of present natural forest. If secondary forest and degraded forestland were ignored in sustainable tropical forest management, it would be impossible to guarantee the existence of the big tropical forest ecosystem. The management of tropical secondary forest and degraded forestland is a more complex problem, on which few studies were done in the past, and it is now an important issue.

8. Establishment of balanced development agriculture, forestry and pasture

The object is to stabilize social and economic environment in the peripheral areas of the forest region, to develop the local economy, to help the local people to become rich and to improve the fragmented forest ecosystem. The main measure is to induct intensive management of agriculture and pasture. (see section 3.8)

9. Development of secondly industry for forest logging

Reducing forest logging caused decrease of income, by which it was an inevitable problem that how the existing community in the forest area could be maintained, especially how the staff and local residents can shift their occupations and obtain reemployment. The most effective solution for such problems is to make use of other local resource advantage to develop secondly industries, including forest tourism, small hydro power station, fruit tree cultivation, cropping and livestock raising, special local products, tea cultivation, bee raising, various processing industry, chemical industries of rosin and active carbon, and bamboo and rattan cultivation and processing, etc.

10. Development of modern forestry industrial zone

It is the main way of establishing backbone industry in tropical region to develop modern industrial plantation and timber processing industry system that integrates cultivation and processing. This is usually to select an area large enough, flat and suitable for mechanical operation, where industrial plantations are purposely developed, and paper mill and other timber processing enterprises were established, which constitute a modern forestry industry zone.

11. Participation by local communities and residents

Local communities exist in or around forest areas. Active participation by local community should be more favorable for sustainable forest management. Community participation should be included even at the stage of developing management plan so their benefits can be taken into account. In project implementation, local community and residents can and absolutely should undertake some tasks. It is an important idea that local community and residents participate in sustainable tropical forest management.

12. Accounting of ecological value of tropical forest and internalization of the external benefit

Of the total value of tropical forest, timber was only a small part, and most of its value was reflected as ecological value. But how this value can be understood and expressed, whether and how the external benefit can be internalized, even be partly included and reflected in the national economic accounting system, are still being studied. Anyway it is a necessary part of the modern forest (including tropical forest) management concept to account the forest environment values and to develop relevant internalization policies.

The "technological/economic/social system of the modern tropical forest management" approximately includes these 12 aspects and it does not exclude new measures that could be proposed.

3.7 Concept innovation 2: modern concept of tropical plantation management

In Hainan, the history of plantation development has been more than 30 years and the total area is now 1.13 million ha. But natural forests are still under pressure for timber production, and forestry economy is still weak. In fact, many countries including China have encountered such a situation. In reverse, New Zealand, Brazil and Chili have used very small part of their national land to establish strong national forestry economy, which effectively substituted natural forestry economy. It was enough to show that the development strategy of plantation should be taken into account to create plantation management concept.

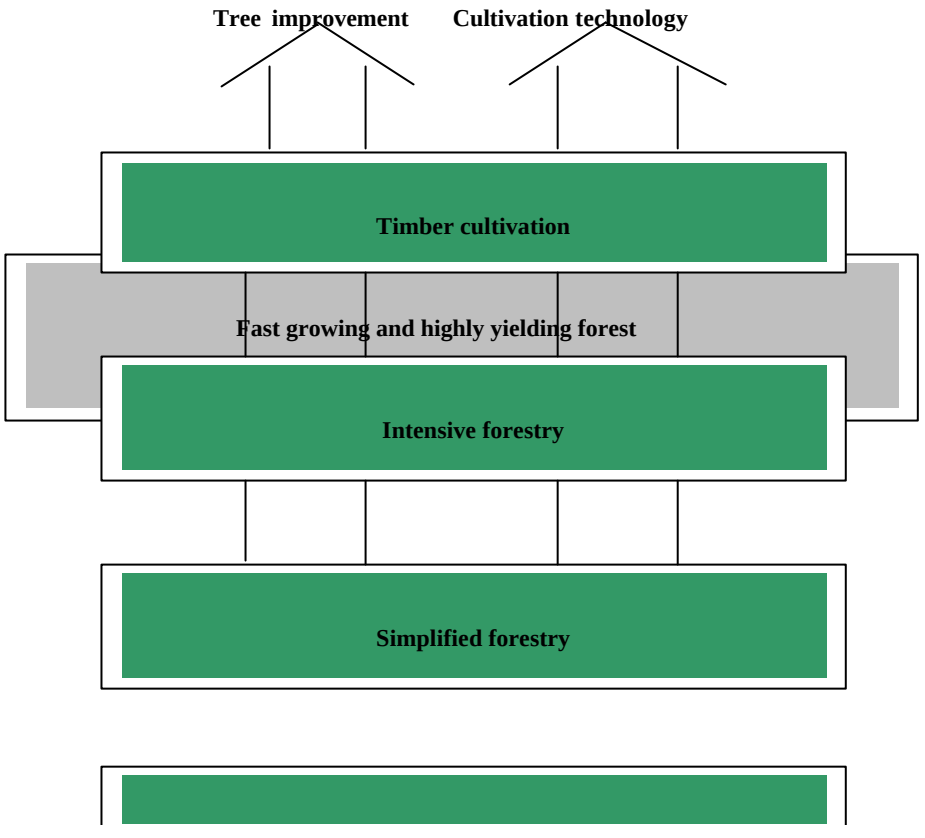
The project goes beyond the traditional concept of plantation and fast growing and highly yielding forest, and proposes to develop timber cultivation industry (Ligniculture) and industrial plantations by combining with processing industries. The proposed modern management concept of tropical plantation includes the following 4 levels:

a. Modern development concept

The core of modern development concept of plantation is to develop timber cultivation industry and modern forestry industry zone.

Timber cultivation industry is a specialized production system for developing wood raw material, which relies on modern forestry technologies and intensive investment. Because timber cultivation is only conducted to meet a specific demand (oriented cultivation), timber cultivation is usually closely connected with agencies of utilizing and processing its products, and even becomes a "green workshop" for producing raw material, and then it is called as "industrial plantation". Such an area then becomes a modern forestry industry zone.

Figure 2, The status of timber cultivation industry



The basis for intensification of timber cultivation is the same as for agriculture, i.e. on one hand, superior species should be used, and on the other hand, advanced cultivating and harvesting techniques should be adopted. The essence of timber cultivation industry is to change from logging economy to modern agricultural economy. This is a transformation of forestry production pattern and a revolution of forestry concept as well. The main ways of timber cultivation include cultivation of large trees originated from seeds and clones, and cultivation of fast growing and short rotation plantation of small trees. The timber cultivation is at a level above the highest level of technical advancement of tree genetics and improvement and tree cultivation, it is the most advanced industrial tree cultivation. The figure 2 has shown the status of timber cultivation industry in forestry. We suggest that such a development concept be followed for plantation forest in tropical region.

Timber cultivation can significantly shorten harvesting rotation; lower the costs of production facilities and their maintenance to a minimum level; products have highly uniform quality; production efficiency is extremely high; organization of production is rationalized; costs for logging and transportation is very low. These characteristics provide possibilities for combination with processing industries. The timber cultivation industry that has entered modern economic field has better competence than agriculture, and even not worse than some industrial sectors. It would become backbone industry of the forestry economy.

Theoretically the timber cultivation industry will become a main force of national economy. Especially, tropical region is very suitable for development of timber cultivation due to its good conditions of light, heat, water and soil.

b. Modern breeding concept

The combination of sexual and asexual breeding is the modern breeding concept. Based on the traditional breeding such as selection of superior provenance and families as well as artificial hybridization, clonal selection is conducted and the selected clones are used to develop superior clonal cultivars, this is the only way to greatly improve economic benefit of plantations.

c. Modern concept of propagation and plant-stock raising

"Tissue culture + cutting propagation" is the modern concept of propagation and raising plant-stocks. Vegetative propagation does not lose genetic quality of the cultivars and facilitates the use of advantages of early growth of trees so as to keep the stand highly uniform. Tissue culture and cutting propagation are the two main ways of vegetative propagation. Cost of tissue culture of trees is very high and many tree species are not easy by cutting propagation (no rooting or aging problem). It is suggested that tissue culture be used as main means for keeping planting

materials juvenile and cutting propagation be used for industrial propagation of the materials being kept juvenile by tissue culture.

Juvenilization is an important technology of vegetative propagation. The planting material fully juvenilized will release its advantages in growth, avoiding production of never-grow-up trees and effectively improving rooting rate of cutting propagation.

Balancing root system of plant stocks is an important modern nursery concept. A tangled root system will cause the tree to grow slowly and reduce resistance. The main reason for variation within clones is the imbalanced root system. Nursery techniques must be centered on the goal of developing well-rooted and balanced root system. Balancing root system of plant stocks becomes a core issue of studies on nursery theories and technologies in foreign countries.

d. Modern afforestation concept

This concept particularly highlights appropriate wide spacing of plantation and proper retaining of natural vegetation in the afforestation area according to the realistic situation in China.

3.8 Concept innovation 3: balanced development of agriculture, forestry and pasture

Protection and sustainable management of tropical natural forest is not just a pure technical problem, meanwhile it is also an important social and economic problem. The social economic problem is mainly reflected in the 2 aspects: The first is an internal problem of the forest region, the pressure on forest caused by operation of enterprises and living of residents in the forest region; the second is an external problem, mainly reflected as the pressure on forest by the development of agriculture and pasture in the surrounding areas of the forest regions. Concerning the first problem, discussions will be presented later in the report. Here is focused on the conception of balanced agriculture-forestry-pasture development in the surrounding areas of the forest regions.

There are active agriculture and animal husbandry activities in region of tropical secondary forest and degraded forest. It is these activities that destroyed the original forest ecosystem, turning it into damaged forest or severely degraded non-forest land, and continually threatening forest in the core area. This is unbalanced development of agriculture-forestry-pasture.

The suggested balanced agriculture-forestry-pasture development is to establish intensive agriculture and pasture in the surrounding areas of the forest region, to reduce areas of land needed for agriculture and pasture, to alleviate the pressure on forest by development of agriculture and pasture and to create more space for expansion of forest. Thereby stabilize the forest ecosystem in the surrounding areas of natural forests, protect local ecological environment of agriculture and pasture, and guarantee natural forest not to further shrink. In this way, landscape of mixed farming land, pastureland and blocks of forests emerged in the surrounding areas of the large forest regions (Figure 3 and 4). It is suggested that land use conflict among agriculture, pasture and forestry in the surrounding areas of the natural forest regions be the main conflict of

social and economic development, and that balanced development of agriculture, forestry and pasture be the best solution. Later the central government took a strategic measure to protect natural forest through land conversion from farming to forest, which is approximately the same idea in principle. The concept of balanced development of agriculture, forestry and pasture does not suggest conversion of farming land first, but through intensive management of agriculture and pasture to leave extra land for tree planting, hence protect core area of forest region. The main measure for balanced agriculture-forestry-pasture development is intensive management of agriculture and pasture.

Intensive agriculture and pasture management will save land for conversion to forest. Although this will reach the same goal, as will do the traditional land conversion through different routines, it more conforms to the logic of development. This is the idea of the project, under which one demonstration area has been established by the project.

Figure 3, Figure 4, Artificial agriculture, forestry and pasture ecosystem of in low mountains and hills.

3.9 Achievement 1: Establishment of tropical plantation

In Danzhou state-owned forest farm of Danzhou Municipality and Chengmai state-owned forest farm of Chengmai county the project has established a demonstrating nursery with annual productivity of 3 million plant stocks and a demonstration plantation of 2000 ha according to international standard through applied studies and assembling of overseas and domestic technologies. Although the project has not been finally completed yet, nursery techniques in the whole Island have been renewed due to the demonstration effects. And modern plantations are established throughout the island according to the demonstration plantation model.

In general, the timber growth of demonstration plantation is as high as 5 times of that of traditional plantation. Rotation was shortened from 12 years to 6 years. That is to say present 1 hectare is equivalent to original 10 hectare.

The 6 specific achievements are given below:

1) A series of superior eucalypt clones have been developed, production of eucalypt plantation reaches international level.

A set of new afforestation materials has been developed, including 207 superior families, 52 superior clones and 84 superior hybrid combinations by sexual crossings. For example, the one-year-old Urograndis has an average height of 7.64 m and an average DBH of 6.00 cm;

average height of Uroterreticornis is 7.36 m and average DBH of 6.00 cm; Urophylla no. 98-6 has a height of 7.48 m and average DBH of 6.80 cm. A wilt disease experiment showed a zero affection rate. This batch of clones has been propagated by tissue culture and has been used in afforestation, displaying fast growth, disease resistant and wind firm. The achievement of "selection and breeding of superior clone Reyan B of Eucalyptus Congo no. 12" obtained the third class Scientific and Technological Progress Award by Hainan Province in 1998.

Figure 5, Superior families of Eucalyptus urophylla developed by the project(16.5 m in height and 15.5 cm in DBH at age of 3 years of age)

Figure 6, Several eucalypt hybrid trees reached 27.3 cm in DBH at 3 year old, to be identified and clones will be developed by vegetative propagation

The production of traditional Eucalyptus plantation in Hainan is generally 5-7m^3/ha/year. The plantation established with use of the above-mentioned achievement by the project reached an annual growth of 22.5m^3/ha/year in the first Phase, 27.0 m^3/ha/year in the second phase and up to 37.5 m^3/ha/year in the third phase, 5 times higher than the growth of regular plantation. Small area of the plantations reached 45-60 m^3/ha/year, the advanced international level. New hybrid crossing experiments have shown further encouraging results: some the hybrid individuals have reached 27.3 cm in DBH at 3 year old, clones of these hybrids will be further developed by vegetative propagation.

2) Developed a series of more advanced nursery propagation technologies mainly for eucalypt species. The technologies cover aspects of mother tree cultivation, collection of scions, cutting propagation, media composition, container types etc. Rooting percentage of eucalypt trees can reach more than 85% with the highest of 98.2%. The cutting propagation can be conducted throughout the four seasons. "Cutting propagation of eucalypt trees with branches" was rewarded the third class Hainan provincial science and technology progress award in 1999. This result has been applied in afforestation programs in Danzhou city, Dongfang city,

Changjiang County, Chengmai County, Qiongshan City in Hainan province and relevant nurseries in Guangdong province, APP Group, Sinoforest Group.

3) Successfully conducted spacing trials for eucalypt industrial plantation, providing scientific basis for using appropriate planting density in the development of modern industrial plantations in Hainan.

4) Successfully conducted site management trials, such as whole cultivation site preparation, fertilization, intermediate soil loosening and fertilization, water and soil conservation (integrated measures) and sustainable high yield trials at a later time. Of these trials, the "Fertilization based on nutrition diagnostics for Eucalyptus" was rewarded the third class science and technology progress award by the Ministry of Agriculture in 1999. Continual post-establishment management trial solved the problem of reduction of growth after 4 years for Eucalyptus in Hainan.

5) Developed afforestation models for the western region of Hainan Island (where is the major region for plantation development in Hainan).

6) Conducted nursery and afforestation experiments on *Acacia*, *Podocarpus nagi*, *Chukrasia tabularis*, *Ormosia henryi* and other species.

3.10 Achievement 2: Sustainable management of tropical natural forest

The "demonstration area of sustainable management of tropical natural forest" was set up in Bawangling forest region, with a total area of 2,000 ha. The objective is to analyze the existing experience and knowledge in both China and abroad and to set up a series of experiments and conduct analyses of the data obtained from these experiments, based on which to conduct basic researches in fields of harvesting, growth, resource management, management model, sustainable management criteria and indicators, development of less known species etc, hence to seek for solutions of the core problem, sustainable management of tropical natural forests.

Six research achievements have been obtained, including some innovations in the ideology of management (See appendix 5)

1) Conducted an analysis and summarization of the effectiveness of various harvesting methods that were used in the past in Hainan Island. The concept of "**naturalness of tropical forest**" was invented and applied in practical operation.

The so-called "forest naturalness" refers to the similarity of the present state to the primary state of forest. Ecologist Jiang Youxu first introduced the "naturalness" in forest ecosystem studies. This project for the first time introduced the concept of naturalness in forest management and defined it as "forest naturalness". "Forest naturalness" has significant implications on sustainable management of tropical natural forests:

- Firstly, tropical natural forest is characterized as mixture of species, different ages, multiple canopy layers, and unclear dominant species, a concept is needed to reflect these characteristics;

- The concept of forest management itself has changed, not only needs to consider how to take measures to promote growth, but also needs to consider the impacts of human activities on the growth and environment, and biodiversity conservation. In this case, simple stand parameters become inadequate to be the criteria for measuring modern forest management, and the "forest naturalness" can meet the contemporary needs. According to the concept of forest naturalness, the project conducted a resource inventory and planning on the 2,000 ha tropical natural forest in Bawangling forest region in Hainan, and developed a forest management plan, reflecting good effects.

2) Proposed a method of sustainable harvesting of tropical forest, "**integrated selective harvesting**" based on economy, ecology and biodiversity conservation. Its purpose is to maximize economic benefit, maintain forest ecological balance, protect and develop forest biodiversity in order to achieve the goal of sustainable management of tropical natural forest. "Integrated selective harvesting contains the following conceptions:

   - *Maintaining first and harvesting second;*
   - *Maintain the food chain of forest ecosystem;*
   - *Harvesting with short cycle, weak disturbance and maximal integrated benefit.*

According to this method, harvesting can be conducted with no damage to ecological environment, no reduction of biodiversity and favorable for regeneration, and even with some profit after deduction of costs. This method pays attention simultaneously to ecological, economic and social benefits, and is a scientific harvesting method for sustainable management.

3) Proposed sustainable management models for different types of tropical natural forests, including mountain closure, integrated selective harvesting and tending selective harvesting. Established a theoretical system of management and organization of tropical forest compartments.

4) Established a modern management system of tropical forest resources, including subsystems of resources information management, dynamic monitoring of resources by remote sensing, and information and network services.

5) Completed studies of 30 less known species, including distribution, number, biological and taxonomic characteristics of each species, as well as their wood properties and potential uses. This research achievement has already been published.

6) Developed a criteria and indicators framework of sustainable management of Hainan's natural forests.

In order to extend the achievement in sustainable natural forest management obtained in Bawangling forest region to the whole island, more inventories on natural forests in Jainfengling, Diaoluoshan, Wuzhishan and Limushan were conducted. Referring to ITTO's criteria and indicators of sustainable management of tropical natural forest and other relevant studies in both China and abroad, The "framework of criteria and indicators of sustainable management of tropical natural forests in Hianan" was developed, presenting 7 criteria and 79 indicators suitable for Hainan at regional and management unit levels, providing scientific basis and standards for

implementing sustainable management of tropical natural forest in Hainan province.

3.11 Achievement 3: Artificial tropical "agriculture-forestry-pasture ecosystem"

The total area of surrounding low mountains of tropical natural forests in Hainan is about 1.12 million ha accounting for one third of the total land area of the province, and the population is about 1.5 million accounting for one fourth of the total provincial population, mainly the minorities of Li and Miao etc. People in these areas are relatively poor and the living standard is very low, heavily relying on forest. Agriculture and pasture are very simply managed, not only compete for land with each other, but also squeeze and occupy land from forestry land. This vigorous force of expansion directly threatens the already broken forest ecosystem. More seriously, this tends to encircle and gradually encroach the central part of the forests. In spite of this, the income local residents will not increase due to area expansion. Contrastingly, due to increasing environment deterioration, the agriculture and pasture productivities are increasingly declining. This is a typical mechanism of non-sustainable development.

According to the conception of balanced development of agriculture, forestry and pasture, the project design and established a 503 ha demonstration area of "agriculture-forestry-pasture artificial ecosystem" in Yasing township of Danzhou municipality. In the demonstration area, models of high efficient agriculture and intensive pasture were established, a number of locally adapted production models such as garden economy etc were also developed in the area, and forest vegetation was repaired, in such an area not big reversed the economic and environment non-sustainability and developed a sustainable mechanism for development, basically established an example for solving the conflict of land occupation in the intersections among agriculture, forestry and pasture in surrounding areas of natural forests, developing economy and enriching people. This achievement is not of a significant scale, but it at least has provided a very valuable new concept and new idea.

3.12 Achievement 4: Protection of tropical primary forest

A demonstration area of complete nature reserve of tropical primary forest was established in Jianfengling forest region. The objectives are to strengthen the capacity building (patrol, communication, transport, fire prevention) of the nature reserve of primary forest; to study biodiversity and its conservation of tropical primary forest; to study ecosystem of tropical primary forest and to explore the economic alternatives of forest harvesting and other important issues. Through nearly 10 years of research, the demonstration area has achieved the following 5 outputs:

1) Based on a systematic economic and social investigation and GIS technology, an "overall plan of Jianfengling tropical forest nature reserve" was developed, and GIS and multimedia technologies were applied in management. The core area of the nature reserve was 145.74 ha, buffer zone and experiment area was 222.29 ha, ecological management area was 268.81 ha and the integrated agriculture-forestry-pasture development area was 1377.16 ha. The GIS management system developed by the project includes topographic maps, land use maps in surrounding areas, forest volume distribution maps, arboretum plan and layout, Tianchi tourism road map and thematic maps. The system has functions of image overlapping and multi-level search. Meanwhile, the system is also an important tool for management decision

making.

2) By building up nature reserve boundary tablets and posts, establishing and improving patrol system (patrol vehicle), communication system (imported a Japanese Kenwood wireless interphone system), rapid response system and publish security system etc, the protection capacity of the nature reserve was effectively strengthened, particularly, a high standard watch tower was built in a forest region in Hainan, for the first time applying an automatic monitoring system (equipped with a 10 times zoom lens and electronic signal amplification and transfer devices which can watch 80% of the nature reserve). Hereafter, Hainan provincial forest fire prevention agency followed by extending to the whole province. The capacity of traditional protection of Jianfengling tropical forest was significantly improved by taking the chance of this project.

3) Using advanced method, based on previous studies, research on structure and functions of Jianfengling tropical forest ecosystem reached a new high level. Main studies were conducted on classification, structure and open spot of mountain rainforest; functions and benefits such as soil, hydrology, meteorology, thermodynamics, energy, water cycle, carbon balance etc. of tropical forest. Many new findings were obtained in these aspects.

4) Conducted systematic investigation on biodiversity. Six forest types were identified to compose Jianfengling forest ecosystem. Biodiversity in Jianfengling forest and its status were identified (see section 3.5.1 of this report). Significant progress was made in investigation and conservation of endangered species (*in situ* and *ex situ* conservation). Forest ecology was extended in some aspects (see section 3.5.2 of this report). Ex situ conservation of 9 endangered plant species were established in Jianfengling tropical arboretum, an area of shade liking plants (collected 130 species) and an area of palm plants (collected 57 species) were newly established.

5) Explored and preliminarily established self sufficient economic model as the alternative of economic activities of nature reserve and surrounding areas, including building small hydropower, ecotourism project, cropping and animal husbandry, and integrated processing project. 4 demonstration models were established: agroforestry system, cropping system, animal husbandry system, and integrated management system, providing experiences and ideas for sustainable development of nature reserves of tropical forests.

3.13 Achievement 5: Development of China tropical forestry information system

An integrated achievement was obtained in information research, i.e. "**Infrastructure construction and development of China tropical forestry information**", including 6 achievements such as tropical forestry information resources, means of tropical forestry information services, basic research on tropical forestry information, training material for tropical forestry and dissemination and service of tropical forestry information.

There were two main objectives of this subprojects: one is to provide direct services for all subprojects, mainly reflected as before and after the commencement of the project, to provide information on international tropical forestry research progress, achievements, problems, hot topics and technologies in order to facilitate the development of technical plans as reference, or as

the basis for overseas study tours and trainings; and reflected during the mid-term of project implementation as to facilitate the assessment and adjustment the demonstration plans in order to keep the advancement of the demonstrations. The second objective is to lay a foundation for information. In recent 10- years, nearly 40 persons who worked have worked in this aspect, and obtained significant effectiveness.

1) Firstly at the launching stage of the entire project the subproject 5 submitted a progress report on international tropical forestry, organized training courses by inviting domestic and overseas experts to give lectures, and organized discussions among key project staff, which provided guarantee for other subprojects to design scientific and reasonable technical plans. In addition, a systematical mid-term project assessment was made and at the same time technical suggestions were provided for the demonstrating areas for developing further construction plans.

2) Establishment of the huge tropical forestry literature resources was completed. It mainly included that domestic and overseas tropical forestry literature sine 1980 was systematically and fully collected, manual searching cards were made, 4 books of searching tools were printed, searching databases and full text databases were established and 16,000 literature originals were stored in Hainan for use. More than 20 persons have worked for nearly 8 years.

3) Means of tropical forestry information service was established. It mainly consists of manual, computer and Internet searches. At the same time reading rooms and library were established and improved. Now users can visit the websites at ***http://www.lknet.ac.cn*** or ***http://www.caf.ac.cn*** to search for various types of tropical forestry information.

4) Studies on fundamental information of domestic and overseas tropical forestry were carried out, which includes information resources of domestic and overseas tropical forestry, basic models and technologies of tropical forest management in the world, basic scientific and technological conditions for tropical forestry in the world, tropical forestry market condition and fundamental condition of tropical forestry development. Major activities include organization of 1 international workshop, several overseas study tours and a number of international meeting.

5) Systematic news reporting and dissemination on tropical forestry and the project information were carried out. The major activities include publishing 24 issues of journal "Tropical Forestry Information", publishing 12 issues project information in English, making 6 videos (12 versions in total including both Chinese and English) and several sets of slides and lots of propaganda in other journals and public medias, such as newspaper, radio broadcasting and TV. The related information has been disseminated to more than 100 countries, especially in the biannual ITTO meetings at which the new "Newsletter" is disseminated and very good responses feedback from readers.

6) 3 monographs were published: "Proceeding of International Symposium on Sustainable Management of Tropical Forests" (English version), "Studies on World Tropical Forestry" and "Tropical Forestry-Fundamental Knowledge and Modern Concepts".

3.14 Achievement 6: development of human resource in tropical forestry and

achievement extension

There is no specialized forestry school in Hainan, so professional training could not be carried out, resulting in serious lack of forestry technicians. It was the ITTO project in Hainan that filled up this gap. The project has strengthened the capacity building for human resource development for forestry in Hainan Province, and qualifications of forestry professionals have been improved throughout the province by a series of training activities. The following 3 specific achievements have been made.

1) A tropical forestry training center has been established with a total area of 360 m^2, consisting of classrooms, meeting rooms, offices and dormitories for trainees and teachers and equipped with a full set of regular electronic facilities and connection to Internet, it can be used for a training program with 80 trainees at the same time.

2) In recent 10 years, human resource development has been conducted in an irregular way, the project has driven the technology to improve and the technology has driven the personnel development. In total, the project has trained 2382 person/times for local forestry officers and technicians from Hainan and other provinces, 20 person/times of foreign foresters, 1000 person/times for workers and forest farmers have been trained, and 62 person/times overseas study tours have been carried out. So the forestry technical human resource increased from 1150 persons before the implementation of the project to 2500 persons. Of them senior personnel increased from 9 persons to 30 persons and middle ranking personnel increased from 54 to 260. 13 persons specialized in foreign language have been educated and 5 doctoral students and 7 postgraduate students for master degree have been educated. 15 project officers have been promoted to high positions and 3 persons have won the title of excellent expert at state or provincial level. The training activities were conducted in long, medium and short term at high, middle and basic levels in a way of combining on-site training and off-job training.

3) A set of training materials has been formed, such as "Tropical forestry---fundamental knowledge and modern concepts", "Techniques for cultivation of major tropical economic tree species in China", "Tropical forestry nursery and silviculture techniques", "Techniques for Eucalyptus cutting propagation", "Techniques for management of agriculture-forestry-animal husbandry artificial ecosystem", "Database technology application of tropical forestry" and "Training material for tropical forestry nature explication".

3.15 Achievement seven: 16 monographs and 62 academic papers

The project has formally published in total 16 monographs with 21200 copies and 9.03 million words and 62 academic papers.

3.15.1 16 monographs formally published:

1) "Hainan Sustainable Tropical Plantation Management" by Nanhai Print Company
2) "Cultivation of Robust Eucalyptus Seedling" by Nanhai Print Company
3) "Lesser-known Tree Species of Tropical Forest in Hainan Island" by China Scientific and Technological Press

4) “Sustainable Tropical Natural Forest Management of China Hainan Island” by China Scientific and Technological Press
5) “Tropical Artificial Ecosystem of Agriculture, Forestry and Animal Husbandry” by Nanhai Print Company
6) “Biologic Species Book in Jianfengling, Hainan Island” by China Forestry Press
7) “Researches on Tropical Forest Ecosystems in Jianfengling of China” by China Forestry Press
8) “Natural Preserve of Jianfengling, Hainan Island, China (Map Collection) by China Forestry Press
9) “Techniques for Cultivation of the Main Tropical Economic Trees of China” by China Forestry Press
10) “Studies on Tropical Forest and its Bio-diversity Protection in Hainan Island of China” by China Forestry Press
11) “Proceeding of International Symposium on Sustainable Management of Tropical Forests” by China Forestry Press
12) “Tropical Forestry-Fundamental Knowledge and Modern Concepts” by China Forestry Press
13) “Studies on World Tropical Forestry” by China Forestry Press
14) “Astonished Tree Sight in Hainan” by China Forestry Press
15) “Marvelous Trees in Hainan” by China Forestry Press
16) “Forest Insect of Hainan” by Science Press

3.15.2 62 formally published papers

1) “Studies on cutting propagation from sprouts of Eucalyptus”, Wen Maoyuan, Tropical Forestry, 1997, 4; Eucalyptus Science and Technologies, 1999, 2.
2) “Preliminary Studies on Optimal Models for Eucalyptus Plantation in West of Hainan Island”, Wen Maoyuan, Tropical Forestry, 2001, 3.
3) “Experiments on screening of seedling raising container and cutting basic substance of Eucalyptus”, Xu Jianmin, Tropical Forestry, 2000,2.
4) “Experiments of fertilizing frequency for Eucalyptus”, Wen Maoyuan, Tropical Forestry, 2000, 3
5) “Selection and breeding of Reyan B clone of Eucalyptus 12 ABL”, Wen Maoyuan, Eucalyptus Science and Technologies, 1998, 1. Tropical Forestry, 1998, 2.
6) “Techniques for cutting propagation of Eucalyptus”, Wen Maoyuan, Tropical Forestry, 1997, 2.
7) “Selection criteria for superior tree of Eucalyptus”, Wen Maoyuan, Tropical Forestry, 2001, 1.
8) “Studies on experiments of screening Eucalyptus clones”, Wen Maoyuan, Tropical Forestry, 2002, 1.
9) “GIS management system for tropical forest reserves and national forest parks in Jianfengling”, Li Yide
10) “Ecohydrological effects of tropical mountain rainforest ecosystem in Jianfengling”, Chen

Bufeng, Lin Mingxian, LiYide et al,. 2000; Acta Ecologica Sinica, 20(3).

11) "Effect of Tropical Mountain Rainforest Ecosystem on Water Quality of Precipitation", Chen Bufeng, Lin Mingxian, Wu Zhongmin et al,. Forest Research, 1999, 12(4).

12) "The Background Value and Ecological Effect of Water Quality of Tropical Forest Catchments in Jianfengling", Chen Bufeng, Lin Mingxian, Zeng Qingbo et al,. Forest Research, 1998, 11(3).

13) "Sustainable ecosystem management of tropical forest in Jianfengling, Hainan", Guo Ning, Jiang Zhongliang, Li Yide et al,. Tropical Forestry, 2002, 30(2).

14) "Linking Dynamic among tree species of the secondary tropical mountain rainforest in Jianfengling, Hainan", Huang Shineng, Li Yide, Luo Shishou et al,. 2000; Acta Phytoecologica Sinica, 24 (5).

15) "Composition and geographic distribution of flora of seed plants in Jianfengling, Hainan", Huang Shineng, Zhang Hongda, Wang Bosun et al,. 2000; Guibaia, 20(2).

16) "Tropical forest resource and its protective function for eco-environment", Li Yide, Tropical Forestry, 2002, 30(1).

17) "Eco-engineering technologies and its application for economic development in mountainous area", Li Yide and Dai Ruikun, Tropical Forestry, 2002, 30(2).

18) "Rare and endangered plants and their abundant degree in Jianfengling, Hainan",Li Yide, Lin Yumei, Guo Ning and Xie Mingdong, Tropical Forestry, 2002, 30(3).

19) "The tropical natural forest of China and its influence on atmospheric CO2",LiYide, Wu Zhongmin and Zhou Tiefeng, Ecological Science, 1999; Ecologic Science, 15(2).

20) "Estimation of the Amount of Carbon Pool in Natural Tropical Forest of China",Li Yide, Zeng Qingbo, Wu Zhongmin at el, Forest Research, 1998, 11(2).

21) "Research on Benefits of Three Agroforestry Systems in Jianfengling,Hainan Island", Li Yide, Zeng Qingbo, Wu Zhongmin at el, Forest Research, 1999, 12(2).

22) "Tropical natural forest resources of China and sustainable management countermeasure", Li Yide and Zhou Tiefeng, 1999; Forest Ecology Forum(I), Edited by Forest Ecology Branch of Chinese Forestry Association, China Agricultural Scientific and Technological Press.

23) "Litter and soil respiration in a tropical mountain rainforest in Jianfengling, Hainan Island", Luo Shishou, Chen Bufeng, Li Yide at el, 2001; Acta Ecologica Sinica, 21(12).

24) "Planting Rubber tree promoting protection of tropical natural forest in Jianfengling", LuoShishou, Zhou Tiefeng, 1999; Forest Ecology Forum(I), Edited by Forest Ecology Branch of Chinese Forestry Association, China Agricultural Scientific and Technological Press.

25) "Types and benefits of agriforestry management model in the surrounding areas of tropical forest reserves", Zeng Qingbo and Zhou Tiefeng, 1999; Forest Ecology Forum(I), Edited by Forest Ecology Branch of Chinese Forestry Association, China Agricultural Scientific and Technological Press.

26) "Water balance and geo-chemical cycling of main nutrients in the tropical mountain rainforest", Zhou Guangyi, Chen Bufeng, Zeng Qingbo et al, 1996; Acta Ecologica Sinica, 16(1).

27) “Growth process of Manglietia Hainanensis in Jianfengling”, Zhou Guangyi, Lin Mingxian, Chen Bufeng et al, Scientia Silvae Sinica, 1999, 35(3).

28) “Enlightenment of successful contracting by specialized afforestation household, Forestry and Society, 2000, 5.

29) “Preliminary Report on Introduction of A Hybrid Bamboo Species (Bambusa pervariabilis × Dendrocala mopsis grandis)”, Tropical Forestry, 2001, 4.

30) “Preliminary Report on Growth of Young Forest of Teak”, Guangdong Forestry Science and Technology, 2002, 2.

31) “Studies on multiple management model and its benefit in tropical and south sub-tropical region”, Modern Agriforestry, 1998, Vol 6, No3.

32) “Optimal model for enriching countryside ---Chicken raising under forest”, Tropical Forestry;

33) “A good method for poverty alleviation, vigorous development of cropping industry in minority concentrated regions”, Tropical Forestry.

34) “A research report on development of modern forestry industrial zone in south of China”, Scientia Silvae Sinica, Vol.35; No1.

35) “Comparison of overseas and domestic plantation used for timber and a tentative plan for developing modern forestry industrial zone in hill region of southeastern of China”, Workshop of National Plantation used for timber towards 21st Century (July 1999).

36) “Differentiated Forest Management---An important way towards sustainable development of tropical forestry” Hou Jusheng and Hou Yuanzhao, Scientia Silvae Sinica, 1999, 1.

37) “Differentiated Management of Forest Resource is Prioritized Selection for Sustainable Forestry Development”, Workshop Proceeding of Forestry Scientific and Technological Development and Business Exchanging between the Inland and the Island, A Series of Books for Taiwanese Forestry, No. 80, 1997.

38) “Establishing modern forestry industrial zone was strategic choice of China forestry development”, Forestry Economy, 1999, No. 6

39) “Demonstrating value of ITTO’s Hainan tropical forest project for natural forest protection of China”, Scientia Silvae Sinica, 1999, Vol.35; No3.

40) “A Study on Site Quality Evaluation of Natural Tropical Mountainous Rainforest in Hainan Island” Chen Yongfu, Yang Xiusen et al,. Forest Research, 2000, 13(2)

41) “A study on sustainable management unit, criteria, indicators and cutting practices in tropical natural forest in Hainan Island” Chen Yongfu, Hua Wangkun, Yang Xiusen et al,. Forest Research, 1998,11(5)

42) “Sustainable tropical natural forest management in Malaysia”, Chen Yongfu, Wang Songling et al., World Forestry Research, 2000, 12

43) “Stand volume assumption and stand damages analysis of integrated selected cutting in tropical rainforest” Chen Yongfu, Yang Xiusen et al., Forestry Science and Technology Newsletter, 1997(11).

44) “Classified management is ultimate way of realizing sustainable forestry development” Chen Yongfu, Cao Zaixin et al,. in “theory of classified forest management”, 1998

45) " Discussion on issues related to sustainable forestry development" Chen Yongfu, Hua Wangkun et al,. Forestry Resource Management, 1997

46) "A Study on the measures of tree growing competition for tropical rainforest in Hainan Island" She Guanghui, Chen Yongfu et al,. Journal of Nanjing Forestry University 1998

47) "A Study on regular pattern of tropical rainforest structure with Improved Weibull Function" Zhou Chunguo, Chen Yongfu et al,. Journal of Nanjing Forestry University 1998

48) "Discussion on logging ways of tropical rainforest in Bawangling", Zhou Yadong, Yang Yanchen et al,. Forestry Resource Management, 1997

49) "Experiment on forest fostering after diameter-sized selected logging of tropical mountainous rainforest in Hainan Island" Yang Yanchen, Li Dajiang et al,. Forestry Resource Management, 1997

50) "Analysis of stand structure after integrated selected logging in tropical rainforest", Chen Yongfu, Yang Xiusen et al., Forestry Science and Technology Newsletter, 1996(9)

51) "Soil carbon storage in initial stage of harvesting management of tropical mountainous rainforest in Bawangling Hainan Island", Luo Shishou, Yang Xiusen et al,. Forest Research, 2000, 13(2)

52) "Studies on regular pattern of tropical rainforest structure in Bawangling Hainan Island" Fang Zixing, Hua Wangkun et al,. Forestry Resource Management, 1995

53) "Hydrochemical Cycling and Effect of Tropical Mountain Rainforest Ecosystem at Jianfengling", Chen Bufeng, Zhou Guangyi, Zeng Qingbo et al,. 1998, In: Proceeding of International Symposium on Sustainable Management of Tropical Forests. China Forestry Publishing House

54) "The effect of shifting cultivation and its alternate techniques on Jianfengling Natural Reserve", heng Yufu, Zeng Qingbo, Chen Bufeng, 1998(Abstract), In: Proceeding of International Symposium on Sustainable Management of Tropical Forests. China Forestry Publishing House

55) "Establishment of the monitoring system for tropical forest biodiversity in Jianfengling Nature Reserve", Li Yide, 1996, Tropical Forestry Newsletter, ITTO/ISTI, No.2.

56) "Research report of tropical forest ecosystem", Li Yide, Chen Bufeng, Zeng qingbo, 2000, Tropical Forestry Newsletter , ITTO/ISTI Newsletter, 2000(1).

57) 57 "GIS management system of Jianfengling Natural Reserve and National Forest Park", Li Yide, Zeng Qingbo, 1998, In: Proceeding of International Symposium on Sustainable Management of Tropical forests (Ed: Hong Jusheng), China Forestry Publishing House.

58) "Studies on biodiversity of tropical forest vegetation and plant at Jianfengling, Hainan Island", Li Yide, Zeng Qingbo, 1998, In: Proceeding of International Symposium on Sustainable Management of Tropical forests (Ed: Hong Jusheng), China Forestry Publishing House.

59) "A preliminary research on the carbon storage and CO2 release of the tropical forest soils in Jianfengling, Hainan Island, China", Wu Zhongmin, Zeng Qingbo Li Yide et al., 1998, In: Proceeding of International Symposium on Sustainable Management of Tropical Forests. China Forestry Publishing House

60) “Stategies for the effective management in the Jianfengling National Forest Park”, Wu Zhongmin, Zhou Guangyi, 1998(Abstract), In: Proceeding of International Symposium on Sustainable Management of Tropical Forests. China Forestry Publishing House

61) “APPROACH OF ITTO TROPICAL FOREST PROJECT IN HAINAN PROVINCE OF CHINA”, Forest Operations of Tomorrow, HOU Yuanzhao, 1999, 10 FAO/CEE/IUFRO, Beaurdeau France

62) “Sustainable management on compartment level of tropical natural forests in Hainan Island”, CHEN Yongfu, YANG Xiusen et al, Proceeding of international symposium on sustainable management Of tropical forests, 1998

3.16 Achievement 8: Efficiency and mechanism---management experience of implementing large international project

The ITTO former Executive Director, Mr. Freezalah requested that the project management experience be reported as an achievement for extension after the project is completed. He knew the outstanding effects at every step of the project implementation and the causes behind these effects. The main experiences are: correct project identification, careful and precise design, combination of research and production, rigorous organization and well developed institutions.

3.16.1 Correct project identification

Project identification needs not only to consider world’s hot topics and the needs of international organizations but also need to consider domestic demands. And the project needs to be of high value for theoretical studies and can promote disciplinary development. After two years of pre-study, a project “ITTO project in Hainan on classified management and sustainable utilization of tropical forest” was propose, the title, objectives and specific contents of the proposed project conform to the above 3 principles for project identification. The project obtained supports from the Ministry of Foreign Trade and Economic Cooperation, the State Forestry Administration, the Hainan Provincial government and the Chinese Academy of Forestry, and from all ITTO member countries. It was confirmed as one of the ITTO’s extra large projects. The results of project implementation proved that the project was of important values for the currently implementing natural forest protection program in China, sustainable tropical and sub-tropical natural forest management in China, sustainable forestry development of Hainan, development of tropical forestry disciplines in China. And the project has also provided a scientific solution for solving the sustainable problem of tropical forest concerned by ITTO. The project ITTO PD 14/92 Rev. 2(F) and effects the project produced were especially mentioned in the ITTO progress report on sustainable management of tropical forest objective 2000.

3.16.2 Careful design

After the project is determined, careful and scientific design of the project according to project objectives and contents become critical for the success, especially for such a large and complex project that will take many years. When the project was approved the entire project was divided into 3 phases and a phased implementing plan was drafted according to suggestions made by the ITTC meeting. Then a work plan and an implementation plan were made for each of the three

phases. Within the project each subproject was also required to have its phased work plan and implementation plan, which were reviewed by experts and then revised and approved by the project director. In this way, the specification of outputs of each subprojects, scientific implementation plan and credibility of the expected outputs can be ensured.

3.16.3 Combination of research and production

The project was not only a theoretical project but also a practice one. Large amount of project implementation work will be carried out at different sites. This feature requires that the project must rely on the administration of local government and local forestry bureau and participation by key technical staff, not only guarantee successful implementation, but also ensure extension of research results, and meanwhile favorable for training local personnel via the project. The project director was taken by Chinese Academy of Forestry, who was mainly responsible for science and technology and international contacts; the deputy director of the project was taken by the leader of Hainan Forestry Bureau, who was mainly responsible for organization, implementation and administration of project programs. 6 subprojects were participated by same number of persons of both sides. The directors of 3 subprojects were taken by Hainan province and the corresponding deputy directors were taken by Chinese Academy of Forestry, and the directors and deputy directors of other 3 subprojects were from the two institutions in a reversed way. The project fund was allocated according to actual need of each subproject. Both sides cooperated very well during the 10 years of project implementation. It was an important factor that made the project successful.

3.16.4 Rigorous organization

A steering committee was set up for the project, consisting of representatives from the State Forestry Administration, the Ministry of Foreign Trade and Economic Cooperation, Hainan Provincial government, Hainan Provincial Forestry Bureau, the Chinese Academy of Forestry, ITTO Secretariat and the ITTO host government, the committee convenes once or twice every year to examine project progress, approve project activities and solve severe problems encountered in project implementation.

Project director and deputy director were completely responsible for project implementation and were appointed by the State Forestry Administration. A Project Office was set up under the project director to assist the project director for project management.

The project was divided into 6 subprojects, each of which was led by a leader and a deputy leader. A core expert group, consisting of about 5 experts, was set up for each subproject. Each subproject could also set up several sub-subproject groups according to actual needs. Except for standing experts, other experts were temporarily appointed or committed in order to reduce cost.

3.16.5 Complete institutions

Project institutions include 5 aspects such as finance system, personnel system, implementation monitoring system, archive system and project asset management system. There is another “manual for project staff”.

1) **Finance system** formulates that, when each project fund arrives at the project office, two 10% will be deducted from the budget of each subproject, one 10% will be used as reserved security fund, and will be delivered at end of the year when the subproject is qualified by examination. Since the biannual project working meeting and an annual project steering committee meeting are the monitoring system to control the implementation of project plan, therefore this is not a nominal, but firm finance safeguarding measure. Another 10% will be used as adjusting reserve which will be used at end of every two years mainly for supplement of deficit during project implementation, damages of unpredictable disasters and possible budget deficit of the total project or any subproject; it will also be used to support experiment activities that cannot be stopped during the period between two phases of ITTO project. All these finance institutions are within the range of ITTO finance institutions. For example, the ITTO finance institutions formulate that actual expenses of each project activity should not exceed 10% of the budget, if need to exceed, it should be reported to ITTC for approval. If this happens, it would be difficult to make adjustment, and certainly will affect project activities. Practice proved that this finance system plays a significant role in balancing project budget, safeguarding daily project implementation activities. All project staff regard the finance system as an innovation in project finance management.
2) **Personnel system** formulates that, any person hired by the project, including high level project managers, is entitled for equal opportunities for various training and other favorable offers provided by the project, but any staff who intends to leave the position must report 3 months in advance and complete all duties for the worked period. The project is entitled to dismiss any staff not carefully conducting duties. In practices, retired and promoted persons were all treated in this way, bringing no trouble to the project. In general, although the project duration is long, the 40 key project members are relatively stable, safeguarding the project implementation.
3) **Monitoring system**, the first main measure is to hold regular biannual project working meetings, and regular examinations by the project director and deputy project director as well as the project office. Before and after each meeting, participants, particularly the project director and deputy director need to conduct on-site studies and instructions. The project director submits progress report twice a year and completion report at the end of each phase. Detailed on site investigations need to be conducted before writing a report each time. The second main measure is that the two main management authorities of the project, Ministry of Forestry and Ministry of Foreign Trade also need to inspect the project before and after each meeting of the project steering committee. In most cases, there are always one or two Director Generals who can chair the meetings. The ITTO project in Hainan has always been the target of concern by the two ministries. During 10 years of project implementation, the responsible Director Generals of the two ministries have been changed for more than 10 times, but they are familiar with all the project members. The third, donor country and ITTO Secretariat paid close attention to this project. For each Steering Committee meeting, the ITTO Secretariat, Japanese Ministry of Foreign Affairs and Swiss International Cooperation Center have sent representatives to participate in the meeting. ITTO executive director, Mr. Freezalah made 3 visits to China for these meetings. Every time when they came to China, they usually made on site inspections or requested presentation of real objects to prove the written report. During

the recent 10 years, 13 steering committee meetings and 18 project working meetings have been held, and 34 reports, 4 video records have been submitted to ITTO, 20 inspections by the two ministries and 21 inspections by ITTO have been received.

4) **Archive system.** Project archive is divided into project document (project application in both Chinese and English, project implementation plan in Chinese and English, formal legal documents such as international and domestic contracts); working reports of the total project and subprojects; financial report and auditing report; Project office documents, copy of domestic and international communications; project publications and audio and video media etc. Two sets of various archives were kept (each in Beijing and Haikou). During the recent 10 years, all above mentioned archives have been completely stored, about 50 boxes and 500 types of archives in total. The total number of words was about 20 million words (including publications). All outputs and achievements of the project were recorded in both words and multimedia.

The total cost of the ITTO project in Hainan was about 40 million RMB, displaying an extremely high use efficiency and effectiveness. Mr. Freezalah once said that if all ITTO projects were like the Hainan project he would have nothing worry about.

3.17 Overall effects

Base on the above sections from 3.1 to 3.16, this section will analyze the overall effects of the project through analyses of demonstration value, scientific value, economic value, ecological value, social benefit, and internal and external impacts of the project.

3.17.1 Demonstration value

1) The project proved that "classified management" is a scientific way and core strategy of achieving sustainable management of tropical forest.

At the very beginning, this report put forward the question of "how to realize sustainable management of tropical forest" and presented current status on this issue in China and abroad. The report also described the theoretical basis and methodology adopted by the project to explore answers for the question.

Through nearly 10 years of efforts by more than 40 project scientists and with a cost of 40 million RMB, we conclude that the project objectives have been completely achieved. This is to say that the project, through its very effective demonstration system, proved with evidences a scientific way of achieving sustainable management of tropical forest. The project displayed with strong evidence the power of the theory of classified management.

Classified management of forest resources is the best strategy and arm that can be used to react with the continually expanding and increasingly subdivided requirements to forestry by modern economy and society. Only in this way, the deadlock of traditional forest management model with economic and ecological goals can be unlocked, and unlimited space for releasing economic and environmental potentials of forest can be provided (see details in appendices 2 and 3).

Through its exploration, the project developed ITTO recognition on developing plantations as substitute of natural forest, which answers the questions put forward in the last paragraph of section 2.1 of this report, making this idea very clear, specific and with strong workability. This provides an example and reference for various countries and regions to implement this idea and to solve problems emerged during the implementation.

We should not say that such a demonstration project has ended the world's difficult problem of sustainable management of tropical forest. However, it can be confirmed anyway that the project announced with evidence and theories to the world that "classified management" is a successful way and scientific strategy of sustainable management of tropical forest.

2) The project further developed an integrated development model, reaching a new high of theories

Based on proving above mentioned classified management theory and development of ITTO "substitute" idea, the project further developed an "integrated development model" to achieve sustainable management of tropical forest.

The 68 objective outputs and 27 scientific achievements laid a firm foundation and set up a model for sustainable management of Hainan's tropical forests. However, through 10 years of practices and explorations, the project far reached the project objectives initially set, providing a model at a higher level for sustainable management of tropical forest: a development model beyond technology and forestry, and from a wider context and deeper root to solve problems. We call it "**integrated development model**", which to some extent expanded the theory of sustainable forest management (we call this the theory of "**sustainable tropical forest management**"). From the initial idea of classified management to the integrated scientific conclusion at the completion of the project, it is a very valuable theoretical sublimation. We think that the theory has practically solved the problem raised by ITTO that sustainable tropical forest management must have sustainability at both national and management unit levels, i.e. the regional sustainability. Only when the regional sustainability was achieved, the sustainability at management unit and national levels can be achieved. Prior to this, not literature in China and abroad has mentioned it.

We clearly recognize that single idea or method cannot solve any problem of sustainable management of tropical forest. We pay much attention to the roles of technology, but we also clearly aware that technology productivity is restrained by production relations. In solving the problem of sustainable forest management, there will be no way out if our sights were limited only on technology.

"Classified management" is a technical method, but also an economic and sociological method.

ITTO China demonstration project in Hainan developed an integrated development model closely connected with economic and social background. The value of this demonstration project is not only the success of certain techniques and success of certain projects, but also success of a completely new idea!

3.17.2 Scientific value

As mentioned above (section 3.4-3.8), this project produced new knowledge in a few fields related to tropical forest ecology and developed several important modern concepts in tropical silviculture and tropical forest management.

1) In forest ecology:

- Further revealed complicated population relations of tropical forest, further revealed narrow niche of population, high fragmentation of resources by population, and reciprocal benefit and competition.
- Further revealed some functions of tropical forest ecosystem: through construction of accumulative carbon curve of tropical forest populations, proved that only when the tropical forest resources are rationally used, the tropical forest can become the capture of atmosphere carbon, meanwhile found parameters for rational use (when intensity of use is 20-30%, the ecological benefit reaches the best); through comparison of quantified ecological functions of tropical primary forest, natural regeneration and young plantation revealed that water reservation and soil conservation are two most important functions of Hainan's tropical forest, and also described these two functions.
- Further enriched tropical forest ecological theory, proposed the new formula of "edge effect" and the new concept of "abnormal residue"; revealed the "morning rain" mechanism of tropical forest and pattern of long-term climate change in forest regions.

2) In biodiversity research:

- Made clear about the background of various biological species in Jianfengling region and identified its position in biodiversity in the world, China and Hainan; summarized the tropical characteristics of the biota in Jianfengling.

3) In conservation biology of tropical forest:

- Assessed the richness of rare and endangered plants in Jianfengling; identified the basic area of nature reserve; obtained some new experiences in ex situ conservation of rare and endangered plants.

4) In tropical forest silviculture:

- Proposed the concept of "modern management of tropical natural forest" (see section 3.6.1), constructed a "technical/economic/social measurement system of sustainable management of tropical forest (sustainable development of tropical forest) including the following 13 strategic measures: promoting weak disturbance harvesting; developing and implementing criteria and indicators for sustainable management of tropical forest; implementing ecological certification; exploring less known species; exploring non timber products and developing non timber industries; paying attention to management of tropical secondary forest; protecting biodiversity; developing a mechanism of balanced development of agriculture, forestry and pasture; developing alternative industries for forest harvesting industry; paying attention to modern forestry industrial zones; participation by local communities and

residents; accounting of ecological values of tropical forest and push forward the internalizing process of external benefit.

- First introduced the concept of "naturalness" in forest management, and defined as "forest naturalness". The concept of "forest naturalness" has significant implications to implement sustainable management of tropical forest.
- First created the sustainable forest harvesting technique, "integrated selective harvesting" based on economy, ecology and biodiversity conservation. This harvesting method also included some new conceptions, such as the concept of conserve first and harvesting second; the concept of maintaining sustainability of food chain of forest ecosystem; the concept of short cycle, weak disturbance and maximized integrated benefit; the concept of sustainable forest management at compartment level; the concept of artificial regeneration of large open area and log collection paths in forest; the conception of post-harvesting tending of elimination harvesting and liberating harvesting.

5) In artificial planting and management:

- Proposed concept of modern management of tropical plantations, including the following 4 strata: the concept of modern development of timber industries which is the core of the management concept; the concept of modern breeding of combining sexual and non sexual breeding; the concept of modern propagation and nursery production by "tissue culture and cutting propagation" including rejuvenation treatment and rooting-balanced container-raised plant stock raising; he modern concept of tree-planting with appropriate wide spacing and proper conservation of natural vegetation in afforestation area which was particularly stressed.

3.17.3 Economic value

3.17.3.1 A value of 190 million RMB of assets directly formed by the project

Demonstration nursery:	Total value of 1.77 million RMB;
Demonstration plantation:	Total value of 70 million RMB;
Demonstration agro-forestry-pasture:	Total increased value of about 5 million RMB (5 million of fruit orchard, 1 million of forest, 0.5 million of pasture, 0.2 million of Bamboo stand, 0.3 million of others, totaled at 7 million RMB)
Bawangling demonstration area	Added total value of 50 million RMB
Jianfengling demonstration area	Added total value of 50 million RMB
Formal publications	Total value of 1.427million RMB
Established literature center	Total value of 2 million RMB
Established training center	Total value of 1.5 million RMB
Intellectual property rights (new varieties, new technologies etc.) formed by the project	Total value of 5 million RMB
Other fixed capital (vehicles, equipments, exhibition room and products, watch tower and accessories, constructed roads etc.)	Total value of 5 million RMB

Total	**190 million RMB**

3.17.3.2 Total annual production value of 542.304 million RMB of economic benefit by demonstration plantations

There was about 1.13 million ha plantation in Hainan Island with average annual volume growth of 12 m^3/ha/year and rotation age usually of 12 years. If annual harvesting area were 94,000 ha, with an output rate of 80% of industrial fiber timber, the total timber production would be about 10.8288 million m^3/year. With a price of 200 RMB/ m^3 for the industrial fiber timber, the total production value will be 2,156.76 million RMB.

The growth of Eucalypt demonstration plantation established by the demonstration project has reached 22.5-37.5 m^3/ha/year and current rotation is 6 years. With an average growth of 30 m^3/year, the volume growth per ha is now 2.5 times of the traditional plantation and rotation was shortened to half. This indicates that within 1 ha of forestland and 12 years as the traditional plantation, it would produce timber 5 times as the traditional plantation, or alternatively the 1 ha of current demonstration plantation equals to 5 times of traditional plantation. If 180,830 ha (rotation of 6 years) of the 1.13 million ha of plantation in Hainan are harvested annually, the total timber production would be 2711.52 m^3/year, and **the annual production value would be 5,423.04 million RMB** (Table 1).

Table 1, Comparison of economic benefits of demonstration and traditional plantations (For Eucalyptus)

	Volume growth	Rotation/annual harvesting area	Total annual growth	Total annual timber production	Total annual production value
Traditional	**12** m^3/ha/yr	**12** yr/94,000 ha	**1353.6** m^3/ha/yr	**1082.88** m^3/ha/yr	2,156.27 million RMB
Demonstration	**30** m^3/ha/yr	**6** yr **/** 188,300 ha	**3389.4** m^3/ha/yr	**2711.52** m^3/ha/yr	5,423.04 million RMB
Ratio	**1: 2.5**	**1: 0.5**	**1: 2.5**	**1: 2.5**	**1: 2.5**

Conditions:

1) Total area of traditional plantations was 1.13 million ha;

2) Out put rate of industrial fiber timber was 80%;

3) Unit price of industrial eucalypt timber was 200 RMB//m^3.

Currently, Hainan's eucalypt plantation is rapidly achieving this goal. What have already been realized are: all planting material in the whole province have been renewed, the varieties produced by the project are widely needed. Nursery technologies have been improved throughout the province, many modern industrial plantations are emerging one after the other.

The above mentioned potential values that have already been realized include: Currently 53,000 ha of modern industrial plantations already established, adding a value of 190 million RMB compared to traditional plantation.

3.17.3.3 Descriptions of sustainable management of natural forest, protection of primary forest and demonstration of agro-forestry-pasture system

- **Jianfengling area:** The annual income of forest harvesting of Jianfengling forestry bureau in the past was 14.66 million RMB, average income per capita was 4,433 RMB. After the shift of production model, the non-harvesting income reached 14 million RMB, and the average annual income per capita was 5,193 RMB. The income of demonstration households had a higher income: for example, some households generated income from inter-cropping medicinal plants with Gmelina plantations with an annual production value of 10,000-30,000 RMB. The Li's demonstration household of generated a total income of 24,000 RMB by planting Kuding Tea; The Fan's demonstration household generated a total income of 20,000 RMB from garden economic activities; Many households in Jianfengling forest region are planting *Prunus salicina*, generating income of 1,000-3,000 RMB per year for each household; The annual income of some demonstration households supported by the project have reached several tens of thousand RMB, far more than the income from traditional forest

harvesting.

- **Bawangling area:** Since logging ban of natural forest, the established new industries has substituted 70% of the previous income from harvesting, which has been supported by the project in many aspects. Bawangling forestry bureau generated an income of 10 million RMB from forest tourism in 2001, and 20 million RMB from small hydropower, 20 million RMB from processing of small timber, all these together has been far beyond the previous income of 30 million RMB from traditional timber harvesting. Average annual income per household from growing areca was 20,000-30,000 RMB for the staff families.
- **Artificial "Agro-forestry-pasture" ecosystem area:** Total area of the demonstration was 503 ha. During project period the total input in production was 0.986 million RMB, total income was 1.8829 million RMB, total value of in-production was 1.1893 million RMB. The total production value of in-production and finished products was 3.0722million RMB, with an input/output ratio of 1:3.1. The project introduced new sugar cane varieties and improved cropping technologies, resulting a production of 2-3 times of the traditional production; the net income of sugar cane cropping households was 7,216 RMB per year, while the traditional households can only balance their input and output, producing no net income. During the past several years, the project team successfully grew 29 ha introduced tropical pasture grass. By rough estimation the carrying capacity of the demonstration pasture was increased by 10 times compared to natural pasture or traditional free grazing, the nutritional value of the introduced grass reached the best level. Additionally, the use of new and improved animal species would make it completely possible to lead to an intensive and modernized pasture in Hainan. This would be definitely in favor of solving the conflict among agriculture, forestry and pasture and improving the productivity in the low mountain areas.

  An example of sugar cane management: the annual production of traditional sugar cane managed by local minority people was usually 30-40 ton/ha/year (occasionally 50 ton/ha), unit price was 135-145 RMB/ton, leading to a input/output ration of 1:1. The net income was only 1 RMB/ha/year. In contrast the sugar cane production of the demonstration households was 92 ton/ha/year, unit price was 165 RMB/ton and net income was 211.2 RMB/ha/year. The average production value of the 10 ha pure sugar cane of variety Xintai 86368 for demonstration was 157,000 RMB/ha/year, and the net profit was 5,000 RMB/ha/year.

  An example of bamboo management: The production value was 15,000 RMB/ha/year for Yulan bamboo and 12,100-18,500 RMB/ha/year.

  Pasture: The total income of sheep and cow sales of the 29 ha pasture during the demonstration period was 158,500 RMB, the value of the breeding animal was 40,300 RMB and the value of the pasture was 400,000 RMB. The input/output ratio was 1:2.41.

3.17.4 (Partial) ecological value of 4,390 million RMB/year

The ecological benefit itself has a value and will ultimately reflected in economic benefit. In terms of direct ecological value, it was estimated for Bawangling area that if intensive harvesting were avoided and forest were scientifically managed the 36,000 ha natural rainforest would conserve 3.744 million tons of water, and 27.396 million tons of soil and 1.818 million tons of nutritional

organic matter. According to estimation for the Jianfengling area where the area rainforest was about 16,300 ha, the value of adjusting water for only 3 typhoons in 1996 was accounted for 6.97 million RMB, the benefit of soil fixation was 969,180 RMB and the benefit of conserving fertility was 9.3385 million RMB.

Influenced by the ITTO project, harvesting in the entire natural forests in Hainan has been stopped since 1994. Based on this to calculate the partial ecological values of the existing 246,300 ha of primary forests and 380,000 ha of secondary natural forests (626,300 ha in total) are:

- Fixation of CO_2: 0.901 billion RMB/year;
- Emission of O_2: 1.002 billion RMB/year;
- Residues as fertilizer: 0.283 billion RMB/year;
- Soil fixation: 0.036 billion RMB/year;
- Fertility conservation: 0.184 billion RMB/year;
- Water conservation: 0.592 billion RMB/year;
- Water adjustment: 1.084 billion RMB/year;
- Improvement of tourism condition (such as adjustment of temperature and humidity, increase of negative ions and essences): 0.308 billion RMB/year.

The total value of these items comes to 4.39 billion RMB/year, and the future benefit produced from biodiversity conservation will be inestimable.

The theory and method of accounting of forest ecological values are still quite immature so far, meanwhile due to limited number of study sites of ecological functions and diverse tropical forest types, it is very common to conduct assessment with parameters locally obtained for the entire forests, leading to large errors in the estimation. But anyway, the huge ecological values of tropical forest can be seen from this.

3.17.5 Internal and external impacts of social benefit

1) Impacts on forestry development in Hainan

- Brought along the formulation and development of modern plantation and economic forest industries in the whole province, created new ideas and a new phase of forestry development in the province. The integrated sustainable tropical forest management model developed by the project was taken as the strategic conception for the 10^{th} 5-year development plan of forestry in Hainan. For example, the Singaporean Asian Pulp and Paper (APP) is implementing a 0.23 million ha afforestation plan in Hainan, and already established a 67 ha central nursery several years ago. The reason why APP selects Hainan as the production base is largely depended on the success of the demonstration project. Currently, APP is rapidly expanding its industrial plantation eucalypts in a way of cleaving bamboo stem. The technologies and varieties that APP is using were mainly provided by the project. The American company Fumos also planted 50,000 ha industrial plantation of eucalypts in Baisha county of Hianan. Some other industries are also establishing plantations in Hainan. For

another example, the forest farmers in Danzhou, Chengmai and Lingao where the demonstration plantations are located have been trained for many times in aspects of vegetative propagation and afforestation technologies, they are now much more technically advanced in nursery stock production and afforestation than farmers in other counties/municipalities. For one more example, led by the provincial forestry bureau, the province launched a project of growing one million Mu of coconut trees and an economic forest development project growing red peony, hairy jujube, tropical pomegranate and common averrhoa etc. In the middle part of the province, growing bamboo and rattan and developing pastures are encouraged.

- Promoted economic development in project area and its surrounding areas: The integrated agro-forestry-pasture development demonstration established an economic development model for about one third of low mountain and hilly areas in Hainan.
- The technologies of sustainable management of tropical natural forest developed by the project, including compartment management, integrated harvesting, integrated silviculture operation in various natural forests, and dynamical management of forest resources, provided important reference for sustainable management of Hainan's natural forests.
- With the organization by staff who were trained by the project, a new situation of thriving international cooperation in forestry emerged in Hainan, which refers to on one hand the frequent international contacts and exchanges of Hainan forestry, and on the other hand the approved new international projects. Of these projects, are two new ITTO projects (a total of 0.7 million US$ as aid) and one German aid project (6 million German Marks).
- Significantly improved qualifications of staffs in forestry sector throughout the province, and optimized the structure of forestry professionals in Hainan. Since the implementation of the project, the overseas study tours and visiting researches by Hainan forestry sector not only brought back new technologies, new varieties, but more importantly the new ideas and new sights. Accompanying with this process, the key project members in Hainan have become the forestry elites in Hainan, and they are operating Hainan's forestry development from a new visual angle. For example, the million Mu of coconut project, the flower base development program and so forth are mostly coming out from these persons. The new phase of international forestry cooperation in Hainan is also the successful pursuit of these persons who have new visual angles and new ideas, and is also the social benefit of the project worth of affirmation.

2) Impacts on forestry development in China and abroad

- The ITTO project in Hainan was taken as the model by World Bank "Sustainable forestry development project"

During late March 1993, a World Bank delegation of more than 10 experts and government representatives of some countries led by Mr. Juexgen Blasec visited China on a project identification mission for "China sustainable forestry development project". The delegation heard twice reports by the Hainan ITTO project. Later a small group of experts made a special visit to Hainan to study the demonstration area in Bawangling of sustainable management of tropical natural forest and the demonstration area in Jianfengling of nature reserve of tropical primary forest.

The expert group expressed that the ITTO project in Hainan started to demonstrate natural forest protection 5 years before the country, the experiences and conceptions produced by the project would be applied in the new World Bank aid project in China. The phase 4 of the loan-project decided to provide support to China's natural forest protection program in 4 aspects: the first was to support plantation development to solve the problem of shortage of timber supply due to the stopped and reduced logging of natural forests; the second was to support the use technologies of sustainable management of natural forests; the third was to support the protection of natural forests in key sites of significant importance of ecological protection and biodiversity conservation; the forth was to support the transition of harvesting industries after the logging ban of natural forest, and life security of the laid off staffs and harvesting dependant people in the forest region. These conceptions area just the same as the integrated development model created by the project.

- Just as the what the World Bank expert said, ITTO project in Hainan did provided models and accumulated experiences for the natural forest protection program late implemented in China. The significance of the ITTO project as reference for China's natural forest protection and sustainable forest management in mainly reflected in following aspects:

Firstly, the project successfully demonstrated that the high quality and efficient timber plantation could alleviate the pressure on natural forest for timber production. It can be seen from the above analyses that in Hainan the intensively managed plantation could produce several times of timber as produced by the traditional plantations, making it possible to bring along a group of timber processing industries, from afforestation to processing it would create many employment opportunities and produce higher economic benefit. Whereas the plantations could also have ecological benefits of conserving water and soil, fixing nitrogen and emission of oxygen.

Secondary, through establishing artificial agriculture-forestry-pasture productive ecosystem in the surrounding areas of the major forest region, to develop the economy in the surrounding areas, to lead the people in the surrounding areas to live and work in peace and contentment and to generate incomes through working, and to improve the economic and social environment in the surrounding areas of the major forest region. This conception is of great practical significance. If social stability was achieved in the natural forest region and its surrounding areas, the economy were developed and the people were enriched, naturally the people would not encroach the forests any more.

Thirdly, since the ban or limit of natural forest logging, the financial income of previous forest harvesting enterprises and local government were likely significantly affected, how to develop alternative industries or establish economic self-sufficient system is an acute practical problem. This is also the reality of developing countries. In developing countries, the administrative agencies in forest region have to find their own ways of fund raising, not only to support the economic needs but also to invest in forest protection, because the state appropriation is always of limit. ITTO project in Hainan fully envisaged this problem and conducted experiments and demonstrations. Currently, the development of alternative industries in Hainan forest regions has overcome the difficulties. This should be regarded as the third important experience of the ITTO

project in Hainan.

Fourthly, scientific management of natural forest itself. Not only to cultivate and harvest medium to large precious timber but also to maintain biodiversity of the forest ecosystem and functions of sustainable development is a problem that must be solved. Because it is not an everlasting strategy keep natural forest not harvested forever, if natural forest could be harvested without damage to its productivity and ecological functions, why not to do it? The project took this as the main goal for breakthrough and carried out integrated systematic researches, including investigation and analyses of historical and world's experiences, based on these investigation and analyses a set of scientific solutions were preliminarily formulated.

Fifthly, effective protection of public forest is also a practical problem. The project has demonstrated mainly in aspects of establishment of patrolling system (fire prevention, transportation, communication, patrolling team…), development of self-sufficient economy (cropping, tourism…) and conservation of endangered species and significant effects have been achieved. However, due to the limit of finance, the problem of road construction, electricity supply and communication etc. has not been effectively solved (these belongs to population development work). Even though, the experiences generated by the project are of reference value for administration and management of public forests.

Sixthly, the information and personnel training of the project is of great significance anyway as a reference for the natural forest protection program. The information subproject once systematically investigated overseas tropical forestry information, systematically and completely reviewed literature of tropical forestry and prepared subject reports on several hot topics and difficult problems, playing a safeguarding role in controlling the main project direction, targeting advanced quality levels and timely absorbing advanced experiences. Whereas the training subproject conducted wide range of training at different levels with different contents in different forms for the project members and persons from the society. In terms of the whole Hainan province, the training has fully improved the qualification of foresters, and extended the technologies produced by the project. In addition, the project also incubated a lot of middle level cadres with international knowledge, apprehensiveness and capability of speaking foreign languages.

Seventhly, also the most important, the experiences in natural forest protection created by this demonstration project are the development of productivity to alleviate pressure on natural forest through specialized dividing of labor; the independent management of classified forest resources; and going beyond the pure technology and beyond the pure forestry sector to take dialectic measures in social, economic and technical aspects. This type of protection is not only from a systematic starting point but also has clear focuses. The theoretical basis of the protection is through division of labor to achieve the integration and its philosophic background is to control by dividing and eventually reach the unification. This is a new theoretical context.

This demonstration project, 5-6 years before the implementation of the national natural forest protection program, took tropical natural forest as an example to carry out systematic studies on

natural forest protection and established demonstration. Hainan province firmly and completely stopped harvesting of natural forest as early as in 1994. With a forward looking vision and creative work 5-6 years in advance and at the most urgent needs by the country, the ITTO project in Hainan contributed a demonstration system of natural forest protection.

- ✧ "Criteria and indicators framework of sustainable management of tropical natural forest in Hainan" developed by the project was taken as an important component of the "criteria and indicators of sustainable management of China's tropical forest" and is being applied in practice.
- ✧ The infrastructure construction and development of information on China's tropical forestry filled up the gap in this aspect in China. The project established a number of databases of China's tropical forestry. Currently, users can conveniently make searches on the Internet for all tropical forestry literature (Title, part of the full-text Chinese literature and foreign literature) of Chinese literature sources since 1980.
- ✧ The successful implementation of the project gradually attracted attention in China and abroad. About 270 persons from ministries of the central government and some provinces and autonomous regions visited the project, including several leaders of the Ministry of Forestry (currently the State Forestry Administration). Several media such as CCTV, Hianan TV and the globally distributed multi- lingual "Beijing Weekly" have visited and reported the project.
- ✧ The project itself produced wide and enthusiastic responses from foreign countries. More than 130 persons from 12 countries such as the US, France, Germany, Japan, Switzerland, Malaysia and Indonesia etc. have visited the project in Hainan.
- ✧ It is worth of noting influences of this project in member countries of the International Tropical Timber Council (ITTC) and relevant international organizations. ITTO project in Hainan is one the few extremely large ITTO projects. Therefore, the international position of the project is self-evident. At the biannual ITTC meetings, the project always received attention. At the 16 meetings in total, representatives of various countries always hear the voice of this project, or get the nicely designed and printed project newsletter in English, or watch a short English video movie, or hear the project progress report. In the impression of the representatives of various countries, it is a project with novel conceptions, in-depth consideration, large-scale of engineering and significant effects. In ITTO report on sustainable tropical forest management: goals and progress in 2000, the project and its impacts were particularly mentioned.

After brief description of China's efforts, the ITTO report "Sustainable management of tropical forest: goals and progress in 2000" particularly pointed out that, the ITTO supported project "Demonstration of classified management and sustainable use of tropical forest in Hainan, China" rapidly improved the traditional forest silvicultural methods to a new level, and the production of demonstration plantation was also greatly increased. The report recited Mr. Poore's words: ***"In all these later developments, the People's Republic has played an important part--intellectually, in developing the component ideas of sustainable forest management and, here in Hainan, in setting up a practical model of which, from what I have read, the country should justly be proud.***

I hope to be able to hear more about it and see it for myself in the next few days".

3.18 Analysis and summarization

3.18.1 Achievement of the project goals

All project goals have been completely achieved. The project further created a integrated model of "sustainable development of tropical forest".

Protection and development, is always a prominent conflict in sustainable tropical forest management, and also the key problem for which tropical forest managers and scientists of different countries seek solution. The project took the way of achieving the goals of sustainable tropical forest management as the main tasks, by applying the classified management theory, and by establishing and developing certain area of tropical industrial plantation (commercial forest), to meet the demands for timber by local economic development and to alleviate the pressure on tropical natural forest; for the tropical natural forest itself, forests with fragile ecosystem and rich biodiversity are categorized as the ecological public forest. By establishing nature reserve, the protection and research can be strengthened. Meanwhile, try to explore alternative industries in the forest region, in order to solve the problem of supporting enterprises and residents after ban or reduction of logging of natural forest and supporting economic development in the mountain areas, try to enforce the transition from timber dependent economy to multiple income generating economy, completely solve the problem of sustainable tropical forestry development; in the low mountain and hilly areas around the surrounding intersections of agriculture, forestry and pasture of the natural forests, the balanced agro-forestry-pasture development conception should be followed through establishing artificial "agriculture-forestry-pasture" ecosystem, to improve the intensity of agriculture and pasture management, develop the economy, improve peoples' life, in order to alleviate the encroachment and pressure on natural forest by people in the surrounding areas, so as to supplement each other between natural forest protection and development. Practices proved that the 4 demonstration areas established according to the above conceptions are surprisingly effective.

3.18.2 Shortcomings and development potential of the project

1) Since the project was not intended to solve all the problems, therefore, some important issues of sustainable forest management are still not involved. For example, there was lack of studies on forestry management systems and forest environment economic systems.

2) The project has development potential in many aspects:

- The superior hybrid individuals produced during later period of the project can reach 27.3 cm in diameter and 18 m in height at age of 3 years, it would be possible to increase the volume growth of the demonstration plantation to more than 45-60 m^3/ha/year and the rotation would be shortened to 3 years or even high growth if continual breeding was conducted. In terms of resistance breeding, there is much work need to do, particularly for wind firmness and resistance to infertile soils. The afforestation technology of native broadleaved tree species also needs to be explored.

These species often need a forest environment.

- Up to date, all studies on sustainable use of natural forest have been from the starting point of timber production. However, it is now necessary to use the sustainable management theory to look at this old issue again. Studies should conducted on new issues of forest ecosystem management, utilization of entire forest, production and utilization of non timber products, protection and utilization of the service function of forest and the ecological values of forest. There are many issues need to be studied concerning *ex situ* conservation of rare and endangered plants.
- Secondary natural forest, particularly management of poor quality secondary forest predominated by medium and small shrubs formed after mountain closure is an important issue. This kind of poor quality secondary forest may produce timber 200 years later if they rely on natural growth. Meanwhile, the area of this secondary forest is especially large (about 5.6 million ha in China, accounting for 50% of the total area of China's tropical forests; about 0.85 billion ha in the world accounting for more than 60%of the total area of world's tropical forests). The project did not pay attention to this issue in the past. Now scientists suggest grow palm rattan or medicinal plants in the poor quality secondary forests, not only to improve the environment but also to produce economic benefit, meanwhile to promote growth of natural vegetation. This is worth of experimenting.
- Development of alternative industries for forest harvesting, such as the form of organization, the way of activities, financial support, method of grasping market and capacity building, as well as how to develop a new mainstay industry, is still an important problem, the project itself is unable to solve.
- The way of production is usually less advanced in large areas of degraded forest zones, where all agriculture, forestry and pasture exist, around the major forest region, the farmers are poorer and still the potential threat to the natural forests. These areas account for one third of the total area of Hainan Island and host a population of about 1.5 million. Economic and social studies and even studies on participation by women in these areas should be a core activity. The project was unable to conduct more activities in these aspects.
- The website of China tropical forestry should be continually developed.

3) Conclusion regarding implementation

- Sufficient investigations on current status and problems should be conducted first in order to correctly put forward problems need to be solved. Based on this, project design can be conducted and propose possible ways of solving the problems, hence to develop the action plan. This is a successful experience.
- Collaboration between high level research institution and project province/region (administrative agency of tropical forestry), elaborate advantages of each party and learn strong points from each other to offset own weakness, likely helpful for achieving project objectives. This is another successful experience.
- Project implementation and participation by the beneficiaries avoid intermediary for extension after completion of the project, extremely favorable for adoption of project

conceptions and techniques.

- Development of a set of project institutions acceptable by each party of the project implementation, including financial incentive mechanism, personnel management system, archive management system, achievement management system and project progress monitoring system, and strict implementation is another safeguard for success.
- Although careful arrangement can be made beforehand, many changes may still occur, leading to errors caused by many reasons. Therefore, adjustment of plan according to reality and permission for the implementation staff to take any possible opportunities to flexibly develop the project are necessary.