INTERNATIONAL TROPICAL TIMBER ORGANIZATION

ITTO

Type of Report:	**FINAL TECHNICAL REPORT**
Title:	Training on Demonstration, Application and Extension of *ITTO Manual on Restoring Forest Landscapes* in Tropics of China
Serial Number:	PD 423/06 Rev.2 (F)
Executing Agency:	Institute of Forest Resource Information Techniques, Chinese Academy of Forestry
Host Government:	The People's Republic of China
The place it was issued:	Beijing, China
The date it was issued:	October 8, 2010

Project technical and scientific staff:

Names of Project Coordinator:

Huang Qinglin, Project director

Names of main staff:

Huang Qinglin, Zhang Xiaohong, Huang Jincheng, Liang Youhao,

Yang Keren, He Chulin, Tian Aiying, Ding Changchun,

Xie Mingdong, Zhang Chao, Huang Jianwen, Chen Bowang

The institution's full name: Research Institute of Forest Resource Information Techniques, Chinese Academy of Forestry (CAF)

Address: Box 33, Chinese Academy of Forestry (CAF)

Wan shou shan, Beijing 100091,

P. R. China

Tel: +86-10-62888889

Fax: +86-10-62888889

E-mail: huangql@caf.ac.cn

Table of Contents

Abstract

Forest landscape restoration (FLR) is a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes. It provides a complementary framework to sustainable forest management and the ecosystem approach in landscapes where forest loss has caused a decline in the quality of ecosystem services. It doesn't aim to re-establish pristine forest, even if this were possible; rather, it aims to strengthen the resilience of landscapes and thereby keep future management options open. It also aims to support communities as they strive to increase and sustain the benefits they derive from the management of their land. As a vehicle for delivering on internationally agreed commitments on forests, biodiversity, climate change and desertification, FLR has got broad attention internationally. Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this technical report constructed the systematic approach to FLR from the view of regional-level and community-level based on overview of study on FLR theory and techniques. Key techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies, and application of Participatory Rural Appraisal (PRA) method were put forward to provide the basis for restoration and sustainable management of degraded and secondary forests.

The systematic approach to FLR was constructed through field application of FLR in study area. Analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating are the contents and following steps to implement FLR. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in the contents. The "double filter", public participation and adaptive management are the principles that must be followed in the whole process. These methods, principles and steps above constitute the systematic approach to FLR.

Three RS data (in 1991, 1999 and 2008) are the source of baseline information in landscape pattern analysis of Lingshui Li Autonomous County. Based on RS information extraction, participatory subcompartment division and inventory is the method to obtain the basic community-level data. In view of forest restoration and rehabilitation, system of forest landscape element types was set up, mainly including degraded primary forest, secondary forest, degraded forest land and plantation. In order to provide the basis for identification of priority sites and making FLR plan, landscape pattern and dynamics of study area were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The dominant forces responsible for changes on forest landscape were identified using transition probability matrix and the participatory approach. The results show that forestry policies and key programs are the dominant factors which cause the increase of forest quantity and quality during the period of 1991 to 2008 in Lingshui Li Autonomous County. Reducing rural poverty through development, livelihood development, village greening and farm-shelter, sand excavation, pond culture and tourism development are important factors in the changes on forest landscape in different areas of the county. Forest landscape dynamics during 1990 to 2009 in Dagan FLR demonstration area is the joint results caused by several driving forces,

such as the basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices.

Based on the analysis of characteristics of degraded and secondary forests, the site-level restoration strategies were developed. Degraded primary forest has integrity community structure. Most of valuable trees in the sub-storey I in arbor storey have been used while there are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings. The basic restoration strategy for degraded primary forest can be perused protection and artificial measures promoting natural regeneration. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey. Protection and enrichment planting are the management strategies for secondary forest. Protective "decompression" is the main strategy for collective-owned secondary forest while enrichment planting combined with protection is the suitable strategy for individual-owned secondary forest. Species for enrichment planting should be valuable native trees, such as *Dalbergia odorifera*, *Hopea exalata*. The rehabilitation strategy for degraded forest land focuses primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Planting live green fence is one of the effective measures for protection of degraded and secondary forests.

The results of study on the application of PRA at the community level showed that the most important information related to FLR in Dagan FLR demonstration area could be got by PRA method and PRA was the effective approach to help community residents and other stakeholders to participate in FLR activities. PRA provided a proactive and effective approach for implementation of FLR and could embody the public participation of FLR theory.

Key words: Forest Landscape Restoration (FLR), degrades and secondary forest, double-filter, public participation, landscape pattern, driving forces

1 Introduction

As the main body of terrestrial ecosystems, forests not only provide material products and environmental services for human beings survival and development, but also play an irreplaceable role in the maintenance of biodiversity, improvement of ecological environment, maintaining the global carbon balance and supporting human lives. However, over-harvesting and land use changes that result in the disappearance of large areas of forest landscape, also result in the forest degradation or fragmentation in the past century. Globally, an estimated 40 - 50 percent of the original forest cover has disappeared, and of that which remains in the tropics, less than half is still found in large, contiguous tracts. Most of the rest exists only in the form of fragmented, modified or degraded woodlands and other areas too degraded to be even classified as forest (IUCN, 2005). At least 830 million ha of tropical forest are confined to fragmented blocks, of which perhaps 500million ha are either degraded primary or secondary tropical forest and can be considered part of modified forest landscapes (ITTO and IUCN, 2005). Secondary forest resulted from degraded primary forest that were unable to regenerate and beyond the normal effects of natural processes. These forest areas have lost most of the forest attributes (structure, function, productivity, composition) (ITTO, 2002). Forest degradation and fragmentation are also seriously affected the life of forest-dependent people, especially the poor who obtain building materials, fuel, food and other necessities from the forest, because they have only limited agricultural land, and mainly rely on forests as social security , social and economic problems would emerge if there is no forest. In 2001, the World Conservation Union (IUCN), the World Wide Fund for Nature (WWF), the International Tropical Timber Organization (ITTO) and other non-governmental organizations coined the term “forest landscape restoration” (Veltheim T, 2005), which was defined as “a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes”, to face the challenge of restoration forest products and services in degraded or modified forest landscapes. In order to implement the idea of forest landscape restoration to action, IUCN, WWF and the Forestry Commission of Great Britain launched the Global Partnership on Forest Landscape Restoration (The Global Partnership on FLR) in March 2003 in Rome, providing a shared worldwide experiences and mutual learning tool.

At present, China is on her way of building a moderately prosperous society in an all-round way and in the new development stage of accelerating the socialist modernization. The harmony between economic development and population, resources, environment, as well as sustainable development strategy of People in Harmony with Nature have entrusted an important position on forestry. Forestry is not only an important basic industry of national economy, but also one of public welfare utilities concerning ecological environment development. It shoulders the dual mission of optimizing the environment and promoting development, playing an irreplaceable role in achieving sustainable social and economic development. Forest resources are the basis for sustainable forestry development and in order to achieve sustainable forest development, it is necessary to manage forest sustainably.

Strictly speaking, except few primary forests in the southwest of China (southeastern Tibet), the northeast and the Tianshan Mountains, forest in other areas of China can be classified as degraded forest. Forest degradation would cause the decline of forest functionality, and are the root causes for other environmental degradation (Liu G H et al, 2000). If we want to successfully address some of the major challenges facing management and conservation of natural resources, including contributing to poverty reduction, biodiversity conservation and enhancing resilience to climate change, then just rely on large areas of continuous forests

cover stretching uninterrupted forests is not enough. On the other hand, natural forests in China is mainly distributed in the northeast and southwest state forests region, the southern collective forests region, as well as Tibet and the northwest forests area, are the livelihood and culture basis for forest-dependent communities (mainly minority residents) in remote mountainous areas that have poor infrastructure development. With strict protection of natural forest resources, the contradiction between forest protection (ecological construction) and local economic development (community life) has been increasingly prominent. Therefore, it is necessary to seek approaches to restore degraded and secondary forests and improve the welfare of community residents to promote the sustainable management of natural forests and the sustainable economic and social development.

FLR provides a complementary framework to sustainable forest management and the ecosystem approach in landscapes where forest loss has caused a decline in the quality of ecosystem services. As a vehicle for delivering internationally agreed commitments on forests, biodiversity, climate change and desertification, forest landscape restoration has drawn widely international concern.

Under the impetus of IUCN, WWF, ITTO and other international organizations, many countries and regions are actively engaged in the implementation and research of forest landscape restoration.

However, we still lack a complete and systematic study on the concept and approach of FLR, the international practical experience and lessons of FLR, as well as the systematic approach to FLR. Therefore, it is easy to copy the practice from other countries, or refuse to accept FLR for being unable to indentify the differences between FLR and forest restoration, ecosystem restoration or community forestry.

In fact, China has accumulated substantial experiences in forest rehabilitation, such as the Natural Forest Protection Program (NFPP), the Conversion of Cropland to Forest Program (CCFP) and other major forestry programs (Li W H, 2004). Studies have been conducted on participatory forestry, forest resources monitoring and evaluation, silviculture, analysis of forest landscape pattern, and ecological restoration etc., which are the theoretical basis of FLR or methods involved in FLR. China has joined the Global Partnership on Forest Landscape Restoration in 2008, taking FLR to the level of national decision-making. Therefore, it is a new task for us to study FLR from the perspectives of both theory and practice.

2 Previous works

2.1 Study of FLR implementation

The implementation of FLR at national level was started from the “Ngitili (woodland important to local livelihoods)” restoration in Shinyanga, northern Tanzania since 1985. By the year 2000, over 350,000 ha of Ngitili have been restored in the 833 villages of the region in a period of 15 years, human well-being has been significantly improved from aspects of per capita income and forest products output, etc (Barrow et al, 2002). As an example of forest landscape restoration, Shinyanga may not be a textbook case. It certainly predates the term FLR and has its origins in soil conservation rather than landscape restoration. However, it quickly evolved away from traditional forestry practice to the wider restoration of forest goods and services – and it illustrates perfectly the central aim of FLR to restore landscape integrity while also enhancing human well-being (Monela et al, 2005). At the same time, Kenya, Uganda, Vietnam, Laos, Cambodia, Thailand also began the reconstruction of degraded forest landscapes (Gilmour D A et al, 2000).

Under the impetus of IUCN, WWF, ITTO, FAO and other international organizations, many countries and regions are actively engaged in the implementation of forest landscape restoration, and many successful cases of FLR have been emerged (IUCN, 2005a; Thomas P T, 2005). Working examples from 5 ecoregions supported by WWF are: protection and restoration of the floodplain forests of the Bulgarian Danube Islands, restoring panda landscapes in China, protecting and restoring habitat along the Kinabatangan River in Malaysia, increasing the extent and quality of Brazil’s fragmented Atlantic Forest, protecting and restoring the dry tropical forests in New Caledonia (Ecott T, 2002). Degraded hillsides in the Middle Hills of Nepal have been restored by natural regeneration under monoculture plantation (Lamb D, 2003). Ecological integrity and human well-being at a landscape scale have been enhanced in Indonesia. Meanwhile, central and western Finland, the Nordic region, central Russia, Scotland have launched FLR programs (Veltheim T, 2005; IUCN, 2006).

Practice of FLR has been developed rapidly since the Petropolis Workshop on Implementation of FLR held in April, 2005 in Petrópolis, Brazil. Some successful examples of using FLR approach to restore important forest products and ecological services of degraded or deforested landscapes and thereby improve human well-beings in the field were listed in “the Petrópolis Challenge”, including FLR works in Tanzania, United Kingdom, Brazil, China, India, Mali and so on. “Arborvitae”, the IUCN/WWF Forest Conservation Newsletter, provided some cases worldwide, including Ngitili restoration in Tanzania, restoring a mangrove wetland in India, restoring ancient woodlands in England, restoring Cork Oak Landscapes in Portugal support by WWF, etc. (IUCN and WWF, 2005). Meanwhile, “Restoring Forest Landscapes: an introduction to the art and science of forest landscape restoration” published jointly by ITTO and IUCN in 2005 based on the “ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests ”which were published by ITTO in collaboration with FAO, Intercooperation, IUCN and WWF International in 2002, has been compiled as a series of “essential reading” chapters on the key principles and techniques of FLR and will serve as a bridge between the policy-level guidance provided by the ITTO guidelines and the context-specific field guides. The main aim of Restoring Forest Landscapes is to help forest-restoration practitioners to understand FLR, appreciate its benefits and start to implement it (ITTO, 2005).

Some successful lessons for implementing FLR can be identified from the analysis of some examples in different areas: developing practical and comprehensive objectives, involving of local people in the decision–making process and subsequent implementation, placing local communities in the centre of attention, i. e. considered as the main actors, being promoted and supported by government, recognizing restoration not the substitute for the prevention of forest degradation and not full recovery of all functions of forest values, making the right choices between natural regeneration and human restoration, taking a landscape-level perspective into account in site-level management.

Experience has shown that successful forest landscape restoration starts from the ground up, with the people who live in the landscape and stakeholders directly affected by the management of the landscape. There is no blueprint for successful forest landscape restoration, since each situation will develop from local circumstances. Restoring forest landscapes is a tricky business. There are three common impediments to its implementation: determining the interests or preferences of the various stakeholders, identification of priority sites, incentives and compensation. The most important factor is to improve public participation (from on-the-ground practitioners to international organizations and policy processes concerned with forests), especially the participation of local inhabitants.

2.2 Global Partnership on FLR

The joint strategy of WWF and IUCN entitled “Forests for Life” was one of the starting points of the initiative on FLR. This initiative set off and consolidated a global partnership of international organizations and governmental agencies. Before giving a conclusive definition of ”Forest Landscape Restoration”, the promoters of the Global Partnership focused on two complementary aspects: field experience and policy dialogue, including an important component of ”partnership building”. Moving from dialogue to action called for a dynamic approach to implementation that built a culture of success after the term of FLR was coined. This should involve linking inter-governmental initiatives with concrete actions at the local and regional level – explicitly linking policy with practice - and bringing key actors together to share constructive insights and identify opportunities. In response to this challenge, the Global Partnership on FLR was established and was formally launched in Rome in March 2003. Its continuing aim is to catalyze and reinforce a network of diverse examples of forest landscape restoration that deliver benefits to local communities and nature and contributes to the fulfillment of international commitments on forests (Dudley M, 2005).

Partners include the governments of United Kingdom, Kenya, Finland, the United States, Japan, El Salvador, Italy, Switzerland and South Africa, the Forestry Research Institute of Ghana, the Centre for International Forestry Research (CIFOR), IUCN, WWF, the UN Food and Agriculture Organization (FAO), the International Tropical Timber Organization (ITTO), the Program on Forests (PROFOR), the UNEP–World Conservation Monitoring Centre (UNEP-WCMC), the Secretariat of the UN Forum on Forests (UNFF), the World Agroforestry Centre (ICRAF), the Secretariat of the Convention on Biological Diversity (CBD), the Alliance of Religions and Conservation (ARC), and CARE International. China has become one of the members of partners in 2008. Positive steps on forest landscape restoration are also being taken in many countries beyond the work of the partnership (IUCN and WWF, 2005).

More than 100 participants from 42 countries attended the “Workshop on Forest Landscape Restoration Implementation” held in Petrópolis, Brazil on April 4-8, 2005. The participants described FLR and highlighted its contribution to the Millennium Development Goals (MDGs) and to national development

processes. The partnership encouraged new members to come on board and called for the restoration of forest landscapes to benefit people and nature and contribute to reversing the trends of forest loss and degradation. Workshops have been held in a wide range of countries including Brazil, China, Colombia, Pakistan, Thailand, Ghana, Vietnam, and in sub-regions or regions such as Mt. Elgon in Kenya/Uganda, the Mediterranean, Central and Northern Europe, West, East, Central and North Africa, South East Asia, Meso and South America (Veltheim T et al, 2005; IUCN, 2005; Barrow et al, 2002; Ecott T, 2002).

2.3 FLR in China

With the increasing attention to FLR internationally, China has also started the study on FLR. A workshop on Forest Landscape Restoration in China was held in Sichuan Province in 2004, which was the first seminar on FLR in China. On behalf of the State Forestry Administration, Jiang Zehui attended the international workshop on Forest Landscape Restoration in Brazil in April 2005 and made a presentation titled “Ecological landscape restoration of degraded land and degraded forest in China (Jiang Z H, 2005) ”. China joined the Global Partnership on Forest Landscape Restoration in March 2008. At present, the project which aimed at restoring panda habitat landscape in Minshan, Sichuan funded by the WWF has been successfully commpleted. ITTO project “Training on Demonstration, Application and Extension of ITTO Manual on Restoring Forest Landscapes in Tropics of China” and IUCN project “Forest Landscape Restoration and Community Livelihoods Improvement” are being implemented smoothly.

Forest landscape restoration has also received attention from scholars in China, such as the Jia Lesi wrote a brief introduction to the book “Forest Restoration in Landscapes: Beyond Planting Trees” published by WWF in” Restoring forest landscapes” (Jia L S, 2006). Lou Xinpan summed up the importance of implementation of forest landscape restoration (Zhang X H et al, 2007). Although studies on theory and methods of FLR in China are still at the stage of translation and introduction, a large number of studies on landscape ecology, restoration ecology, participatory forestry, monitoring and evaluation, etc. have been conducted in China (Zang R G, 1998; Peng, Z H, 1999; Guo J p et al, 2000; BAO W K, 2001; Ren H et al, 2002; Guo J p and Zhang Y X, 2002; Guo X M et al, 2002; He Z S, 2003; Li X Z et al, 2004), which providing a solid theoretical foundation and technical methods for FLR in China. On the face of decline of forest landscape ecological function and human well-beings caused by forest degradation, fragmentation and modification, it needs to integrate existing landscape ecology, forest restoration, community forestry and other research results through learning lessons and advanced techniques on FLR from other countries to guide the work of forest landscape restoration in China.

3 Brief introduction of study area

3.1 Brief introduction of Lingshui Li Autonomous County

Lingshui Li Autonomous County lies in the southeast of Hainan Island. The county located at 18° 22' - 18° 47' N and 109° 45' - 110° 08' E, connecting Sanya city in the south, adjoining with Qiongzhong county in the north, and its east border is Wanning county, west border is Baoting county. It is 196 km from the center of the county to the capital (Haikou City) of Hainan Province (see Figure 3.1). The total cover land area of the county is 1,128 km^2 and water area is 79 km^2.

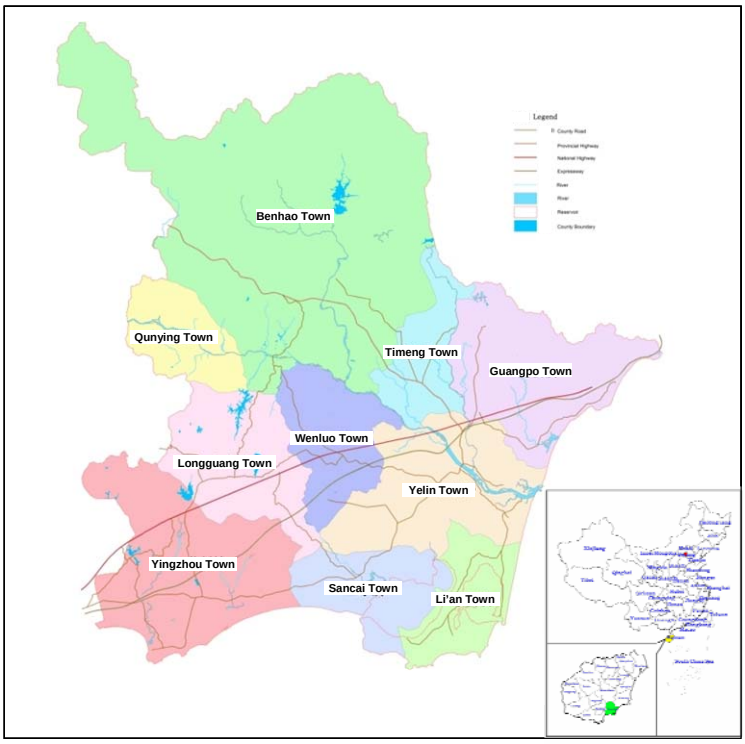


Figure 3.1 *Location and Administrative Division of Lingshui Li Autonomous County*

The climate of the county is classified as “tropical monsoon”, where the annual average temperature is 24 ℃ and the annual rainfall is about 1,500 - 2,500 mm. The rain season and dry season are quite distinct. The rain season is from May to October while dry season lasts from November to next April. It is high in the northwest and low in the southeast of the terrain. The west is the mountain area, the middle part is the hilly area, and the southeast is the plain area. The peak is Diaoluoshan Mountain with an elevation of 1,499.8 m. The soil of the county can be divided into 4 types, 14 subtypes, 28 soil genus. The Granite yellow soil is mainly distributed in mountains above the elevation of 750 m. The Granite laterite is mainly distributed in mountains with the elevation of 450 - 750 m. The soil type in the hills and tableland below 450 m is granite red soil.

Due to climate differentiation, the natural vegetation of Lingshui Li Autonomous County presents vertical distribution. Forest land and unused land are two land types of natural vegetation distribution, covers an area of 59,738 ha, accounting for 53.4% of the total land area.

Natural vegetation types of the county are alpine coppice, mixed broadleaf-conifer forest, mixed evergreen-deciduous forest, secondary forest and planted forest. Alpine coppice is mainly distributed in Diaoluo mountain area above the elevation of 1,000 m. The growth of trees are limited and the height of trees is 5 - 8 m because of barren land and strong wind. Representative plants are *Polyspora axillaris, Castanopsis cuspidata*, etc.The mixed broadleaf-conifer forest is distributed in mountainside with altitude 600 – 1,000 m. Representative trees are *Dacrydium pierrei Hickel*, *Hopea hainanensis*, *Homalium hainanense*, *Alseodaphne hainanensis*, etc. The mixed evergreen-deciduous forest is located in Niuling hills and suffered heavy human damage. The forest land which altitude is below 300 m has converted into shrub land and secondary forest. The representative trees are *Vatica mangachapoi*, *Amoora dasyclada*, *Castanea henryi*. Secondary forest is mainly distributed in western mountains with elevation of 400 - 600 m, including Daganling and Liaociling. Primary forest has been deforested and replaced by shrub and grassland. Planted forest is located in the southeast coastal beaches and barren sand hillsides. The native vegetation is thorn shrubs and cactus. The main tree species are *Casuarina equisetifolia, Eucalyptus emserta, Melia azedarach, Acacia confusa, Homalium hainanense, Cinnamomum Parthenoxylon, Dalbergia odorifera* and *Tectona grandis* after afforestation.

The county consists of 17 towns, with 114 administrative villages, 611 natural villages. The site has three state-owned institutions: Nanping farm under the province, Lingmen farm and Diaoluoshan forestry bureau. There are 16 minorities in the whole county, such as Li, Miao, Zhuang etc. In 2009 the total population is 364,000 and the Han accounted for 44.8% while other minority accounted for 55.2%. The main dialects are Chinese (Hainanese), Li and Miao language. Hainanese is the primary language. In 2009, the GDP of the county was 3.81 billion RMB, of which the output value of the first, second and tertiary industries were 1.91 billion RMB, 0.75 billion RMB, 1.15 billion RMB respectively. The ratio of industries was 50.2:19.6:30.2.

3.2 Brief introduction of Dagan FLR demonstration area

Dagan FLR demonstration area is located in the Qunying town, that in the northwest of Lingshui county. It is the area which main produce grains and economic crops in the central hills. The geographic coordinate is 18 ° 34'35 "N, 109 ° 51'05" E, the size of the area is 399.48 ha, in which the size of cultivated land is 41.14 ha (paddy field area is 26.82 ha), including three villages: Dagan, Fenyou and Fenjie village (see Figure 3.2).

Landforms of the areas are mostly low mountains, hills, with the landform pattern of higher South to lower North, high in the East and West, and low in the middle with elevation of 30 - 340 m. Species diversity of the region is rich. The major soil type is brown-yellow soil. The site is suited for the growth of varied tropical cash crops because of sufficient rainfall, good light and temperature conditions and suitable climate. Moreover, the loam of strongly weathered granite is deep and contains much sand, also suitable for the growth of forests, parks and other woody plants. In the west of demonstration area there is a stream penetrating north-south section and running through Lingshui River, which provides irrigation water for agriculture and forestry.

Demonstration area has serious soil erosion and frequent meteorological disasters such as drought, typhoons. However, reduction of vegetation and land conversion due to desertification and human disturbance, such as slash and burn, management and investment, make the soil erosion even severe in

rainy season. In addition, pond-deposit caused by soil erosion coupled with uneven seasonal rainfall also makes frequent drought in the area. For example, the original fields for autumn rice can not be used to grow spring rice due to lack of water. Rice can be grown in June and July even in rainy season. Typhoons also occur sometimes.

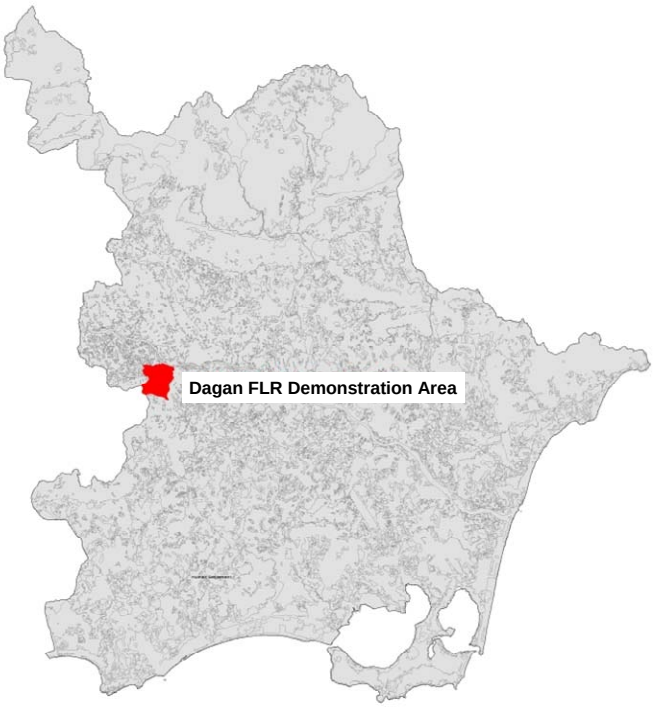


Figure 3.2 *Location of Dagan FLR Demonstration Area*

Demonstration area is a typical minority nationality habitant, belonging to the Li minority area, economic development in the area lagged behind the county average. The total number of families in demonstration area is 134 in 2009 with a total population of 586 (Li nationality). The annual per capita net income is about 110 US$. As to the total amount of land resources in the region, land resources is rich, but cultivated land is small, the average area of paddy fields is 0.20 ha, which concentrated in the basin surrounded by hills and the original autumn fields can only plant as single-season field due to water shortages, a few is available for two seasons.

Economic income comes from forest and garden products. The main crops are rice, potato and maize, industrial crops are cassava, winter vegetables and fruits, and economic products are rubber, betel nut, papaya, mango and other tropical fruits, while the *eucalyptus* forest is also widely planted. Livestock and poultry are mainly local pigs, chickens, ducks and geese. Slash and burn is still a style of farming. The energy for domestic uses such as cooking, pig husbandry and bathing is also mainly from the trees in mountains.

In addition, transport in the demonstration area is impassable and the only one rural road to the county is in poor condition, which is unfavorable for the transportation of agricultural products, technology and information and. It will be surveyed and built under current policy-oriented of stimulating domestic demand.

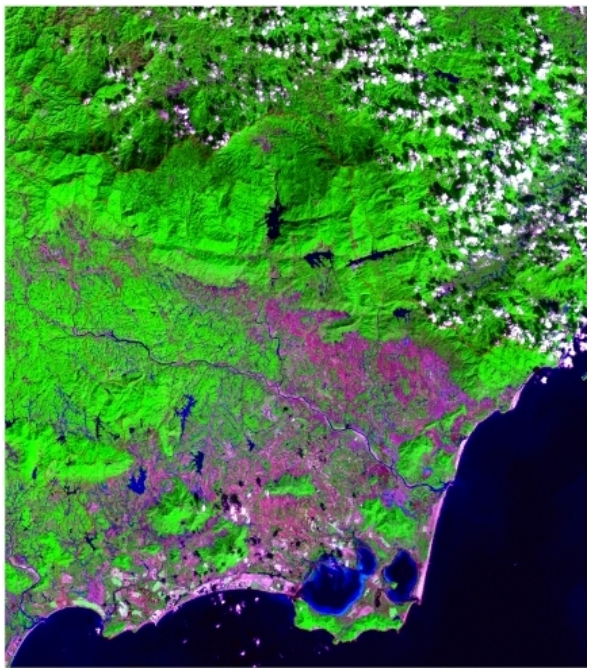
4 Data collection and applied methodology

4.1 Data collection

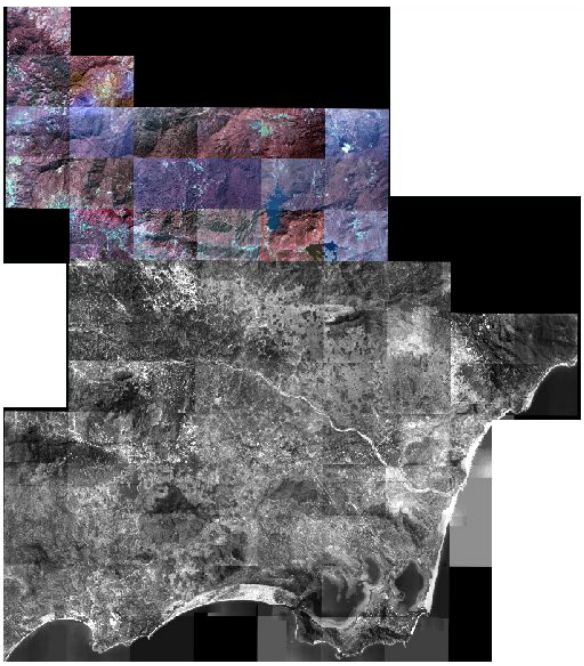
Several remote sensing images of project area were collected (see Figure 4.1), including 3 images which completely covered the county: the LANDSAT-TM images of Lingshui County on October 30, 1991, the LANDSAT-ETM images on December 31, 1999 and the SPOT2 images on May 15, 2008 (PAN and MULTI-BAND). High resolution images collected are aero photo in 1999 with resolution of 1m and SPOT5 image in 2006 with resolution of 5m. Furthermore, land-use map of Lingshui County in 1997, revision of land use planning map of Lingshui County from 1996 to 2010 and land use planning map of Lingshui County from 2006 to 2020 were collected.

Two remote sensing images that covering Dagan demonstration area were collected, which are aero photo of Dagan FLR demonstration area in 1999 and Worldview image of Dagan FLR demonstration area in December 9, 2008 (see ANNEX 9). The “11th Five-Year Plan" of Qunying Town and reports on basic conditions of the villages were also collected.

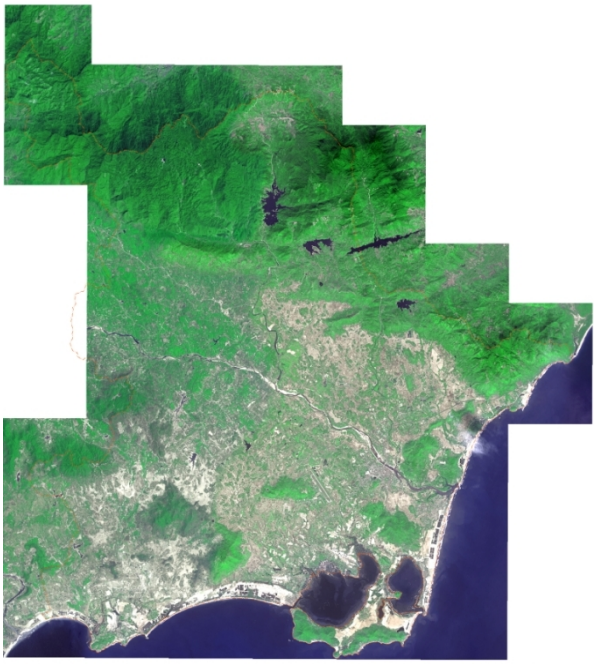
LANDSAT-TM image in 1991



LANDSAT-ETM image in 1999



aero photo in 1999



SPOT5 image in 2006

ALOS image in 2007

SPOT2 image in 2008

Figure 4.1 *RS images of Lingshui Li Autonomous County*

4.2 Applied methodology

4.2.1 Remote sensing data processing

Selected clear ground points from 1:10,000 topographic maps as coordinates for image correction and then fused the images. Information extraction was carried out using methods of automatic classification in combination with visual interpretation. Different periods of landscape mosaic maps were obtained after post

classification processing such as accuracy assessment and cluster analysis of small patches. Information extraction process was shown in Figure 4.2.

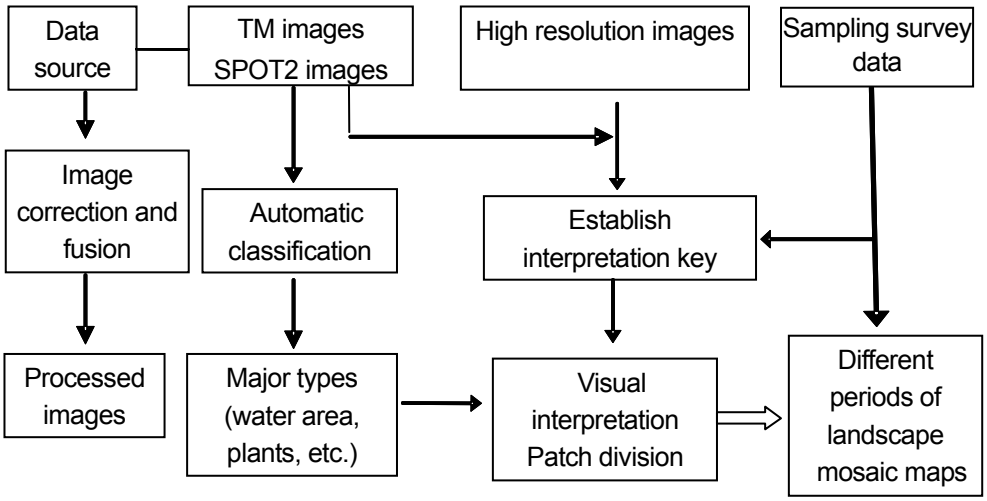


Figure 4.2 *The flow chart of remote sensing information extraction*

4.2.2 Landscape index method

Based on characteristics of the study area and research purposes, select representative landscape indices including the Class Area (CA), Area Percentage (PLAND), Patch Number (NP), Patch Density (PD), Mean Patch Size (MPS), Edge Density (ED), Mean Patch Shape Index (MSI), Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D). Use the tool “Patch analysis” which is an extension of ArcView GIS 3.3 (Chen W B et al, 2002; Bu R C et al, 2005; He P et al, 2009) to analyze the forest landscape patterns.

4.2.3 Landscape dynamics prediction model

There are many simulation models designed to study landscape dynamics, including Markov model, Logistic regression model and compartment theory, which are used to simulate the landscape dynamics under different disturbances. Markov model has been given more attention in prediction of forest landscape dynamics for its reasonable structure, strong practicability and high prediction accuracy. Based on this, Markov model was used in this report to analyze landscape dynamics from the point of FLR.

Landscape element types are the states in the Markov process during Landscape dynamics prediction. The ratio of area to the original area of landscape element types is called the transition probability. Supported by GIS tools, different periods of landscape mosaic maps were overlaid to get unchanged area of each types and the area converted to other types. Transition probability matrix was constructed using the ratio of area to the original area of landscape element types. Landscape dynamics was predicted using formulas 4.1 and 4.2.

$$S_{t+1} = P_{ij} \cdot S_t \quad (4.1)$$

S_t, S_{t+1} are the states in stages t and (t + 1) respectively. P_{ij} is transition probability matrix, which can be shown by formulas 4.2.

$$P_{ij} = \begin{bmatrix} P_{11} \cdots P_{1n} \\ \vdots \\ P_{n1} \cdots P_{nn} \end{bmatrix} \quad (4.2)$$

N is the number of landscape element types. P_{ij} is the probability of landscape element type (j) converted from landscape element type (i). Meanwhile, P_{ij} must be met two following conditions:

（1）$0 \le P_{ij} \le 1$;

（2）$\sum_{j=1}^{n} P_{ij} = 1 (i, \ j = 1,2,\cdots, \ n)$

4.2.4 Field inventory

In combination with participatory inventory. subcompartment division and subcompartment inventory were conducted in Dagan FLR demonstration area in Lingshui Li Autonomous County during the periods of November to December, 2008 and March to May, 2009 according to the “Technical regulations of forest management inventory” issued by the State Forestry Administration in 2003 and “Operation rules for Forest Resource Inventory in Hainan Province” issued by Hainan Provincial Forestry Bureau in 2008.

4.2.5 Method of characterization of degraded and secondary forest

4.2.5.1 Coenology method and forest measuration method

Community characteristics inventory was conducted using sample plot method to (Wang B S, 1996). Four communities of degraded primary forest and four communities of secondary forest in demonstration area were inventoried in March 2009. A strip plot with area of 720 m^2 composed of 20 quadrats (6 m ×6 m) for each community was set up. Trees with DBH ≥ 5 cm in communities of degraded primary forest were measured and trees with H ≥ 1.3m in communities of secondary forest. Two typical sample circles were selected to investigate plants in shrub layer and herb layer. Important to value was calculated according to the concept proposed by J T Curtis and R P McIntosh. Forest measuration characteristics were inventoried combining community characteristics inventory (Meng X Y, 1996).

4.2.5.2 Species diversity

Species Richness, Species Diversity Index, Species Evenness and Ecological Dominance Index were chosen to measure species diversity. Species Richness (R) is the number of species that is the species richness communities (S). Use Shannon-Wiener index (SW) to express the Species Diversity Index,

Shannon-Wiener evenness to express the Species Evenness (E), Simpson dominance index for Ecological Dominance (ED) (Wang B S et al, 1996). The formulas are as follows:

$$SW = \sum_{i=1}^{S} P_i \cdot \log_2 P_i = 3.3219(\lg N - \sum_{i=1}^{s} n_i \cdot \lg n_i / N) \quad (4.3)$$

$$E = SW/\log_2 S \quad (4.4)$$

$$ED = \sum_{i=1}^{s} n_i (n_i - 1)/(N(N-1)) \quad (4.5)$$

SW is Shannon-Wiener index, S is the number of species, n_i is the number of species i, N is the total number of individuals of the community (plot), P_i is the percentage of the number of species i in the total number of species, E is Species Evenness，ED is Simpson Ecological Dominance.

4.2.6 PRA (Participatory Rural Appraisal)

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used in the report.

5 Systematic approach to FLR

FLR takes a landscape-level view. It means that site-level restoration decisions needs to accommodate landscape-level objectives and take into account likely landscape-level impacts (WWF, 2004). The “Landscape” can be understood as one geographic area towards the horizon with conflicts, need to balance land-use trade-offs. Spatial entity covered by the region is changeable. From the theoretical point of view, the global, nation, sub-nation (state or province), city (district), county, town, village, and other administrative areas at all levels, as well as watersheds (natural areas) can be regarded as a Landscape. From the practical point of view, FLR mainly involves landscapes at two levels, one is the operational level and the other is the control level.

Landscape at operational level emphasizes the operability of forest landscape restoration measures and decision-making process of "bottom up". Village is the most appropriate scale and the community level is the most appropriate formulation. Although the community can refer to the “Earth Community”, the community is usually understood as "a fixed geographical area where the members exercise social functions, create social norms matters based on living environment, which is the same level as village(s)”. Landscape at control level emphasizes the role of macro-control of FLR and the decision-making process of "top down". The region of “regional economic and social sustainable development” is the most appropriate scale and the region level is the most appropriate formulation. The county is the full grass-roots administrative unit and the county economy is the foundation of national economy. The county is the most basic spatial scale for regional economic and social sustainable development. Therefore, the FLR includes FLR initiatives both at region level and community level. The "community" refers to the village(s) while the "region" means the county or the unit above county.

Taking FLR planning process of Lingshui Li Autonomous County and planning and implementation process of FLR in Dagan demonstration area as a case, this report constructed the systematic approach to FLR according to Chinese conditions in terms of the stakeholder analysis, building FLR support, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating.

5.1 Framwork of FLR approach

Analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating are the contents and following steps to implement FLR. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in FLR. The "double filter", public participation and adaptive management are the principles that must be followed in the whole process. These methods, principles and steps constitute the systematic approach to FLR (see Figure 5.1).

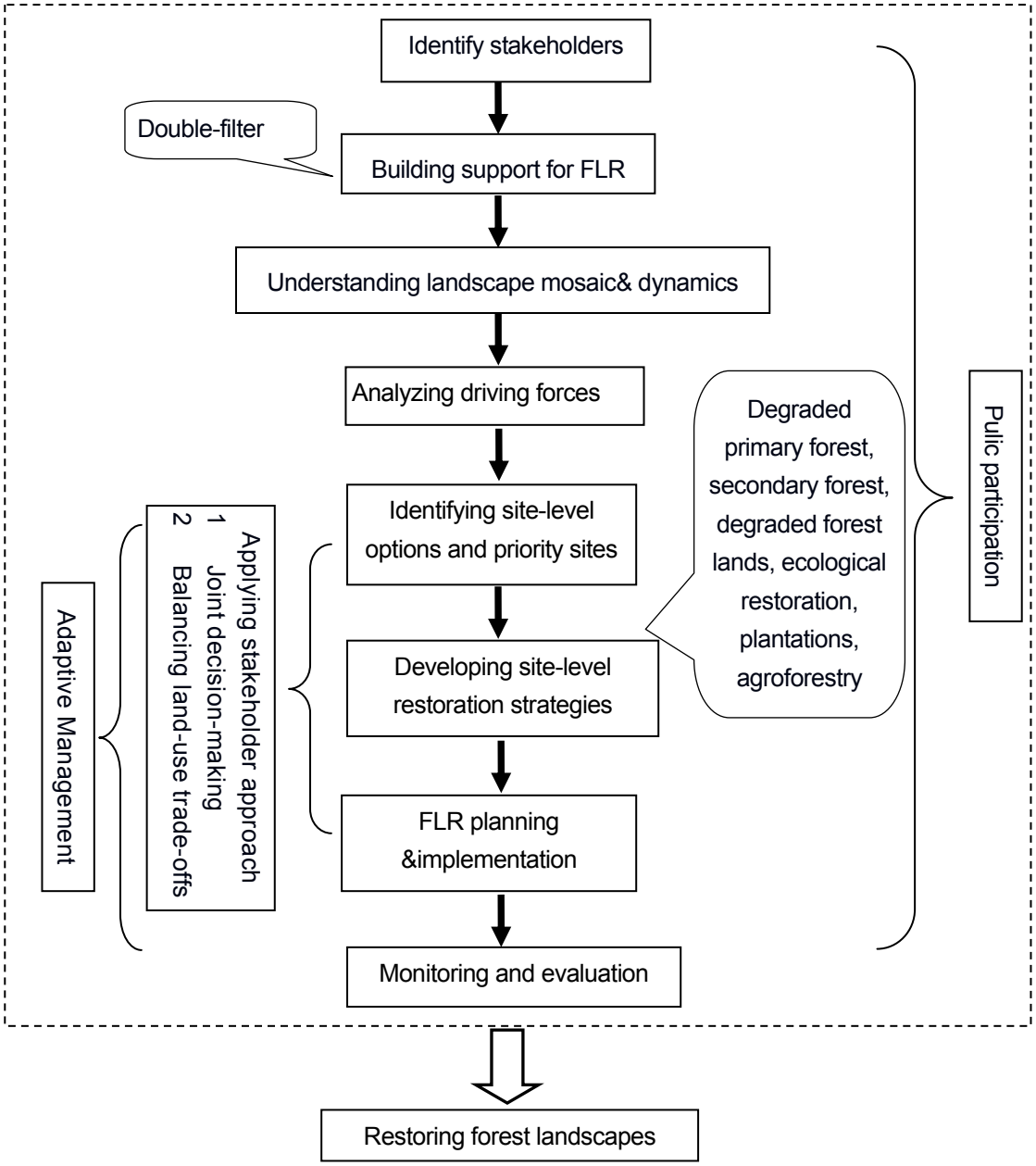


Figure 5.1 *Framework chart of FLR approach*

5.2 Stakeholder analysis

It is the first step to identify the key stakeholders in FLR implementation. A stakeholder is defined as an individual, a group of people or an organization that can directly or indirectly affect the FLR initiative in Lingshui Li Autonomous County or can be directly or indirectly affected by the FLR. Using common approaches, such as identification by the stakeholders themselves, by other stakeholders, by knowledgeable individuals or groups, by field-based staff of the FLR initiative and identification based on demography, stakeholder groups of FLR initiative in Lingshui Li Autonomous County were identified. They are Lingshui Forestry Bureau, Lingshui Agriculture Bureau, Lingshui Land, Environment and Resource Bureau, Lingshui Tourism Bureau, Lingshui Water Bureau, Lingshui Marine and Fishery Bureau, Lingshui Ethnic and Religious Affairs Bureau, Lingshui Development and Reform Bureau, Lingshui Poverty

Alleviation and Development Office, and three state-owned institutions: Nanping Farm under the province, Lingmen Farm and Diaoluoshan Forestry Bureau.

Table 5.1 *Stakeholder analysis of Dagan demonstration area on FLR*

Stakeholders	Characteristics	Needs, interests	Potentials	Degree of participation
Primary stakeholders				
Local villagers, indigenous groups	Owners, derive income from forests, active group	Under poverty, lack of economic incentives and alternative economic source	Desire to receive Assistance, local knowledge, belief in institutions	Directly involved in FLR implementation, Primary project Beneficiary
Forest communities	Owners, depend on degraded and secondary production forest, active group	Base for community Development threatened, lack of economic incentives	Desire to receive assistance; local knowledge, belief in institutions	Directly involved in FLR implementation, Primary project Beneficiary
Local forestry agency	Responsible for sustainable forest management	Insufficient capacity for reducing deforestation and degradation	Experienced in forest inventory and working with villagers	Directly involved in FLR implementation
Local government agencies	Responsible for making and implementing community development plans	Lack of information on FLR	Authority and influence in community, can implement FLR	Directly involved in FLR implementation
Secondary stakeholders				
Civil-society organizations	Actively involved in implementing and provide advice to rural development activities	Lack skills for advice on village development micro-planning	Experienced in working with villages	Can assist the project to implement relevant activities
Private sector	Owners of high-yield production plantation	Lack of information on FLR, needs to seek investment opportunities	Experienced in logging, investment capacity	Can assist the implementation FLR relevant activities
Tertiary stakeholders				
Education and research institutions	Have education and research missions	Lack means to finance collaboration	Competence in research, studies and surveys	Might collaborate in implementing relevant activities
Donors and finance institutions	Finance local development activities	Lack means to finance collaboration	Experience in implementing FLR	Might collaborate in FLR initiative

Local villagers, indigenous groups, forest communities, local forestry agency, project staff, government agencies at different levels, civil society organizations, education and research institutions, and donors are stakeholders in Dagan FLR denonstration area (see Table 5.1).

As forest-dependent people, local villagers, indigenous groups and forest communities in project area are concerned about and benefit from the FLR initiative. FLR will help them to reduce poverty, improve livelihoods through increased forest products and services. Local forestry agency that is responsible for management and protection of degraded and secondary forest are directly employed to conduct the fieldwork of the project. They will get experience on how to reduce deforestation and forest degradation. Government agencies are lack of information for policy decisions concerning FLR planning and reducing deforestation and forest degradation. The FLR initiative will help them to improve institutional implementation capacity for restoration and rehabilitation of secondary forests and degraded forest areas, avoid unplanned deforestation and all types of forest degradation, as well as improve the capacity for adaptation of tropical forests to negative effects brought about by climate change and human-induced impacts. Civil society organizations involved in implementing rural development activities will benefit from the improved capacity to participate in policy development and strengthen capability to support forest communities in improving their livelihoods and ecosystem services. For the private sectors who plan to convert degraded and secondary forest to high-yield production plantation will get information on newly developed policies for degraded and secondary forest and improve the capacity of implementing sustainable forest management (SFM). Donors and the international community will get valuable lessons and new knowledge on how to develop and implement financing mechanisms such as PES schemes and how existing support strategies can be enhanced to deliver the targeted global, national and local objectives.

5.3 Building support for FLR

Successful FLR requires supportive local and national policy frameworks and a strong constituency of local-level support for the restoration activities. Building support for FLR is to build the support of stakeholders for FLR initiatives. During the planning, the support of stakeholders for Lingshui Li Autonomous County can be built by a series of activities: data collection, stakeholder analysis, holding training courses on FLR to representatives of stakeholder groups, participatory interviews and setting up the steering team of FLR. Holding training courses on FLR is the most important means of building support among these activities. The content of training courses related to socio-economic losses caused by forest degradation, the concept and characteristics of FLR, and successful experiences of global FLR initiatives, etc. “ITTO/IUCN Manual on Forest Landscape Restoration” and “ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Forests” are the main training materials.

In addition, consultations and communications with stakeholders were conducted through radio, television, and posters to raise public awareness and understanding of the contribution of FLR to poverty reduction, local economic growth, environmental security, and biodiversity conservation (Elliott S, 2000; Marghescu T, 2001; Kerr J, 2002).

5.4 Understanding the landscape mosaic

A landscape mosaic is made up of different components, pieced together to form an overall landscape-level "patchwork". The actual composition of the mosaic and the pattern in which the components are distributed will be unique to each landscape. Different landscape elements have different contribution to the objectives of FLR (Castillo-Campos et al., 2008). Landscape mosaic analysis involves data collection, forest landscape classification and landscape pattern analysis, and other contents and methods (see Chapter 6).

5.4.1 Landscape elements classification

According to relevant definitions of different forest and non-forest conditions, combining with the resolution of collected RS images and the classification of national land uses, landscape elements classification system of Lingshui County was established in the view of FLR. There are totally 13 landscape element types: primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* plantation, trees around villages, other plantation, other forest land, residential quarters land, garden plots, agricultural land and other land.

5.4.2 Data collection and processing

Data of Forest Management Inventory can be used directly. However, there are no such kind of data meeting the requirements for time or funds. Under this circumstance, remote sensing data are the best source for region-level FLR.

Forest Management Inventory of Lingshui Li Autonomous County was only carried out in 1994 and mapping data has been lost. So the landscape pattern analysis was based on RS data in this study. Community-level data has been obtained by participatory subcompartment division and inventory based on RS image information extraction to indentify the edge of each patch which has different ownerships, different landscape types or different management histories, Information of each patch has been collected by direct observation, such as topography, slope position, slope, use status, community structure, vegetation cover, growing condition of forest stand, by asking, such as the origin, use, ownership, management, investment, conversion or development time of landscape patches in different period, and by inventory, such as the number of trees, height of trees, diameter at breast height and so on. Meanwhile, the conversion or development history, the underlying drivers, land use in future were all collected. Maps of landscape mosaic in different periods were presented under the support of GIS tools.

Different types of landscape elements should be the basis for classifying the patch boundaries for analysis of landscape pattern while different ownerships and landscape element types should be the basis for classifying the patch boundaries for identifying site-level restoration strategies.

5.4.3 Analyzing landscape pattern

Landscape analysis needs some methods to describe the spatial pattern quantitatively, compare different landscapes, distinguish the landscape with special significance, and identify interrelation among landscape patterns, function and process (Guo L et al, 2009). Quantitative research methods of landscape pattern include landscape pattern indices for landscape element characteristics analysis, landscape pattern

analysis model for overall analysis, and landscape simulation model for simulating landscape dynamics.

Landscape pattern analysis both at region level and at community level can use landscape indices to describe landscape mosaic. Select Class Area (CA), Area Percentage (PLAND), Patch Number (NP), Patch Density (PD), Average Patch Area (MPS), Edge Density (ED) and Mean Patch Shape Index (MSI) to describe the characteristics of the landscape elements while the area, total number of patches, Patch Density (PD), Mean Patch Area (MPS), Edge Density (ED), Mean Patch Shape Index (MSI), Landscape Diversity Index (SDI), the Evenness Index (SEI) and the Dominance Index (D) for description of the general landscape characteristics.

In addition, contribution of key areas of the landscape to an FLR initiative should be also evaluated (see Table 5.2). For example, the plantation can serve as a buffer zone around restored and protected areas, playing ecological and social functions.

Table 5.2 *Contribution of key areas of the landscape to an FLR initiative*

Key areas of the landscape		**Contribution to an FLR initiative**
Forest areas	Intact natural forest (large areas)	These contain much of the conservation and development values of the initial forest landscape and are often the key building blocks for FLR initiatives. They generally need to be connected with restored and rehabilitated areas of the landscape to strengthen their contribution to FLR objectives
	Intact natural forest (small areas)	These provide important conservation and development values on-site that can be enhanced by expansion and connection to other key forest patches and areas to be restored and rehabilitated
	Plantations	These contain some conservation and development attributes that can be enhanced by management. They can also serve as useful buffers around degraded forests and protected areas
	Degraded forest or shrublands (large areas)	These can be key targets for restoration and rehabilitation and for connecting to other parts of the forest landscape
	Degraded forest or shrublands (small areas)	These can provide some conservation and development values that can be enhanced by restoration and rehabilitation and by connecting these areas to other key parts of the forest landscape
Non-forest areas	Farmland	Management of this land can be modified to contribute to FLR objectives
	Trees on farms	These can contribute to conservation and development outcomes, particularly if connected with intact forest patches
	Riverine (riparian) strips	These are important habitat types and building blocks for connectivity in the landscape. They may require restoration or rehabilitation to protect both on-site and downstream soil and water values
	Degraded area	These provide an opportunity for rehabilitation for on-site conservation and development benefits and for improved connectivity between natural forest patches
	Eroded areas, landslips	These require special treatment to protect both on-site and downstream values

5.5 Analyzing forest dynamics and driving forces

Forest Landscape Restoration aims to restore the overall structure and functionality of forest landscapes, what we want to manage and restore is the product of dynamic forces acting as direct or indirect causes for changes. Landscape dynamics presents the changes in spatial structure in different scales. It is essential to understand the landscape dynamics and address the forces responsible for landscape change before implement the FLR initiative.

5.5.1 Analyzing and predicting of forest dynamics

The overall landscape structure and dynamics were shown by analysis of landscape indices and RS images. Class Area (CA), Area Percentage (PLAND), Patch Number (NP) were selected to describe the changes in the structure of the landscape elements, Patch Density (PD) and Edge Density (ED) for changes on heterogeneity of landscape element types, and the area, total number of patches, Patch Density (PD), Edge Density (ED), Landscape Diversity Index (SDI), the Evenness Index (SEI) and the Dominance Index (D) for changes on overall landscape characteristics. Landscape dynamics at community level can be analysis from changes on both landscape element types (that is the composition of different landscape element types such as forest lands, agricultural lands or residential quarters) and individual landscape element (such as the conversion to agricultural lands from forest land). Markov Model can be used to predict landscape dynamics both at region level and at community level. Supported by GIS tools, different periods of landscape mosaic maps were overlaid to get unchanged area of each types and the area converted to other types. Transition probability matrix was constructed using the ratio of area to the original area of landscape element types.

5.5.2 Analyzing driving forces of landscape dynamics

The dominant forces responsible for changes on forest landscape both at region level and at community level can be identified using transition probability matrix and the participatory approach. The source of changes on each landscape element types can be identified by analyzing the transition probability matrix, for example, the decrease of area of degraded primary forest would be caused by the conversion from this type to secondary forest, but the driving forces for this conversion can not be obtained by transition probability matrix.

Therefore, the dominant forces responsible for changes on forest landscape both at region level and at community level should be identified by participatory methods, such as semi-structured interviews, matrix, brainstorming, etc. to communicate and discuss with stakeholders based on analysis of transition probability matrix, combing interview with inhabitants in different areas, field investigation and look up relevant documents, as well as make use of existing data on resources, environment and socio-economic, especially policies and regulations on forest use and environmental protection.

5.6 Identifying priority sites

One of the key features of FLR is that site-level decisions need to be made within a landscape context and indentifying priority sites needs to take both landscape-level and site-level perspective into account. We

must first determine the residual, undisturbed forests, particularly those forests of high conservation value forests as a starting point, and then gradually carrying out the specific site-level interventions at the landscape level (Hobbs and Norton, 1996). The variety of ecological conditions and diversity of stakeholder views mean that it may not be possible to restore forest at all sites in a landscape. However, by strategically targeting areas for various kinds of reforestation, these interventions will collectively improve the key ecological processes (e.g. hydrological functions, nutrient cycling etc), restore biodiversity and thereby improve livelihoods across the landscape.

There are many applicable principles for identifying priority restoration sites, as follows: (1) According to provisions of Article XIV of "The People's Republic of China Soil and Water Conservation Law" and Article XXⅡ of "The People's Republic of China Forest Law Enforcement Regulations," hills slope above 25°which have been cultivated for agricultural land should be gradually converted to grass and forest. (2) Remaining areas of undistrubed or well-managed natural forest (most are primary forest) should be protected; plantations established around residual forests are a good way of protecting these from further disturbances. (3) Degraded primary forest and secondary forest are prohibited to be converted to plantations, non-timber forests or agricultural lands, which can be restored through protection, natural regeneration and valuable native trees enrichment planting. (4) Forest linkages or corridors can be created between remaining natural forest areas. It is the best if these are structurally complex and species-rich, but even monoculture plantations can be useful, especially if natural regeneration produces an understory beneath the tree canopy. (5) Buffer areas along road and river banks within landscapes can be fostered by creating forest linkages or corridors. (6) According to provisions of Article Ⅲ of " Provides on Construction and Protection of Coastal Shelterbelt in Hainan Province", coastal shelterbelt should be under restoration and protection. (7) According to provisions of Article XⅥ of "The People's Republic of China Soil and Water Conservation Law", protection forests such as water conservation forest, soil and water conservation forest, wind-breaking and sand-fixing forest should only be allowed harvested in forms of tending and regeneration. (8) Habitats for special species, areas liable to rockfall, landslide and debris flow, as well as other sites of ecologically important features should be protected or restored.

Based on these principles, priority sites of FLR initiative in Lingshui Li Autonomous County were indentified (see Annex 4) after discussion and consultation with different stakeholders, including degraded primary forests, secondary forests, degraded forest land, agricultural land with slope above 25°, forest corridors connecting secondary forest island (plaque), shelter belt (green corridor) along the roadsides and river banks, water conservation forest around the reservoir and farmland shelterbelts. Priorities sites of FLR in Dagan FLR demonstration area include degraded primary forests, secondary forests, degraded forest land, agricultural land with slope above 25°, plantation connecting degraded primary forest and secondary forest (forest corridors along ridges), forest along the roadsides and river banks (see Annex 8). Forest landscape restoration planning is to arrange restoration interventions for priority sites from the perspectives of time and space perspective and to implement the planning relying on stakeholders.

5.7 Developing site-level restoration strategies

The purpose of FLR is not to return forest landscapes to their original "pristine" state, even if that were possible. Rather, it should be thought of as a forward-looking approach that can help strengthen the resilience of forest landscapes and keep future options open. It is important to understand that any individual application of this approach will be a flexible package of site-based techniques – from pure

ecological restoration through blocks of plantations to planted on-farm trees – whose combined contribution will deliver significant landscape level benefits. The site-level techniques can include: the rehabilitation and active management of degraded primary forest, the active management of secondary forest growth, the restoration of primary forest-related functions in degraded forest lands, the promotion of natural regeneration in degraded lands and marginal agricultural sites, ecological restoration, plantations and planted forests and agroforestry and other configurations of on-farm trees. The specific activities of any FLR initiative could include one or more site-level techniques. Indeed, a fundamental characteristic of FLR is the use of combined technical approaches to solve problems, rather than relying on one particular type of intervention.

5.7.1 Analysis of characteristics of degraded and secondary forests

Analysis of characteristics of degraded primary forests in the view of forest management would contribute to develop site level restoration measures in the light of local conditions. Characteristics of degraded primary forests in Dagan FLR demonstration area were analyzed. The community was composed of arbor storey, shrub storey and grass storey. The arbor storey has high species diversity and the Shannon-Wiener index (SW) is 3.61 - 4.46. Dominant species in the inventoried communities are (1) *Garcinia oblongifolia* and *Hopea exalata*, (2) *Engelhardtia roxburghiana* and *Garcinia oblongifolia*, (3) *Amesidodendron chinense* and *Garcinia oblongifolia*, and (4)*Sarcosperma laurinum, Dalbergia hainanensis and Polyalthia laui* respectively. The stand average DBH, height, growing stock and density are 10.2 - 14.3 cm, 8.50 - 13.39 m, 142.51 - 199.44 m^3/ha and 2,321 – 3,545 N/ha respectively. The DHB distribution of each degraded primary forests showed the inverse J shape. Most of valuable trees in the sub-storey I in arbor storey have been harvested while there are still many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*，*Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in each forest stand have rich species and valuable tree saplings and seedlings. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey.

5.7.2 Site-level restoration strategies

Protection and natural recovery of degraded primary forest

Degraded primary forests still retains the main characteristics of the original forest, such as species composition, soil structure and stand structure, and has capacity of natural regeneration, and has important function of ecological protection, so a basic management principle of forest restoration is to “decompress”, that is degraded primary forests can be restored as managed primary forest, even converted to primary forest by protecting the site from further disturbance or stress factors such as deforestation, over harvest of timber and non-timber forest products, slash and burn, etc. and allowing natural colonization and succession processes to occur. This strategy is sometimes called “passive restoration”. Another measure to promote the protection of degraded primary forest is to plant live fence. Planting *Acacia mangium, Eucalyptus* and other fast-growing species as live fence in the boundary among planted forest, degraded forest land and agricultural land can protect the degraded primary forest from further human disturbance.

Protection and enrichment planting of secondary forest

Secondary forest from clear-cutting of degraded primary forest still has valuable native tree species in arbor storey, rich species and valuable tree saplings and seedlings in shrub storey and grass storey. So this type of secondary forest should be taken the same forest restoration measures as that of degraded primary forest, protective “decompression ", that is to achieve natural recovery under the use of existing saplings, seedlings by establishing live fence and avoiding human disturbances as much as possible.

Secondary forest regenerated through a natural process after more than 10 years’ abandonment of alternative land uses still has commercial timber species, but lack of valuable native species. Protection and enrichment planting are the management strategies for this type of secondary forest, using existing tree seedlings and saplings for protective restoration, together with planting of valuable native species to restore forest communities with commercially valuable trees, such as *Dalbergia odorifera*, *Aquilaria sinensis*, etc., so as to improve ecological integrity and community benefits. The biggest conflict for this type of secondary forest is between protection and development of planted economic forest. Local villagers are the decision makers in solving this conflict, which means the secondary forest is facing human interventions of converting to other uses all the time. Therefore, forest owners should be consulted about specific restoration activities such as tree species selection. It is a principle to select acceptable native species to balance economic benefit and ecological services, that is to meet the “double filter” condition of FLR.

Rehabilitation of degraded forest land

The rehabilitation for degraded forest land has been focused primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Most of degraded forest lands are characterized as low soil fertility and poor soil structure, soil erosion and subjected to frequently human disturbance. In such situations, restoration activities are better focused on the recovery and maintenance of primary processes. Firstly, pioneer trees were selected as nurse crop, important silvicultural characteristics of species suitable for nurse crop include fast-growing, tolerant to drought and diseases, if necessary, exotic species can be selected. Then valuable native species are planted understory. The sites will be logged in a few years to increase the lighting needed by native species. In this way, both rehabilitation of degraded forest ecosystem and income of local villagers will be improved. Because the degraded forest land is waste land after development for other uses and the use right belongs to the villagers who developed first, the species selection and decision-making for restoration activities should give full consideration to the value orientation of the villagers and implemented by local villagers.

Restoration forest functions on agricultural land (Agroforestry)

Farmland shelterbelt forest can be developed in centrally distributed agricultural land, so that on-farm trees can play an important part in improving the microclimate of farmland, sand-fixing, resisting natural disasters, and improving ecosystem connectivity, etc. as well as providing forest products to local communities. As to agricultural land in special ecological position, including in river banks, roadsides, around the reservoirs, in hill slopes above 25°, they were indentified as priority sites for restoration and would be converted to forest lands gradually through agroforestry. Because Agroforestry aims to balance the developments of agriculture, forestry and animal husbandry, rare and valuable native tree species were selected for planting and interplant crops and understory cash crops were grown in the first few years of planting to increase economic benefits.

5.8 Monitoring and evaluation

FLR initiatives face major technical, economic, social, cultural and institutional challenges. Monitoring and Evaluation (M&E) provides information of changes. M&E needs to be prepared during the initial planning phase of the restoration and based on a good understanding of the context of the FLR intervention. M&E is the basis and foundation of adaptive management in FLR. The core of M&E is to establish a set of indictors to evaluate the context and implementation of FLR to find the problems existing in current restoration activities and identify future options. A set of FLR M&E indictors was established following three principles: scientific principles, objective principle and realistic principle, including process indictors and outcome indicators, totally 77 indicators (see Table 5.3). It should be noted that the indicator system is not fixed and could be identified based on specific circumstances of FLR implementation sites, and it can be adjusted and supplemented.

Table 5.3 *Indicator system of Monitoring & Evaluation for FLR*

	Factors	Indicators
Process indicators	*1 Stakeholder participation*	1.1 identification of the right stakeholders and target groups 1.2 competence and level of authority of participating stakeholders 1.3 stakeholders' roles in the FLR process 1.4 disadvantaged groups, such as the poor, with attention to gender equity 1.5 early stakeholder participation in FLR planning 1.6 participation in implementation and monitoring 1.7 leadership groups/individuals for community development
	2 Stakeholder consultations	2.1 quality of information shared and how widely it is shared 2.2 partnerships among stakeholders 2.3 coordination of stakeholders 2.4 institutionalization of consultations to discuss issues and solve problems
	3 Service delivery	3.1stakeholder satisfaction 3.2 services obtained by stakeholders 3.3 level of access of stakeholders to the advisory and support services 3.4 compliance with the workplans and schedules 3.5 extent to which FLR objectives were achieved
	4 Community needs´ assessment and dissemination of results	4.1 information and communication tools produced 4.2 sensitivity to needs of weak/disadvantaged groups 4.3 community satisfaction 4.4 level of community participatory of the FLR intervention 4.5 spreading path and extent of assessment results
	5 Stakeholder capacity-building	5.1 demonstration actions undertaken 5.2 implementation of activities associated with project objectives 5.3 mechanisms for conflict analysis and resolution 5.4 strength of local self-governing organizations 5.5 organizational capacity of women
	6 Implementation	6.1 coordination of key stakeholders 6.2 incentives for restoration actions 6.3 flexibility to adapt as lessons are learned
Outcome indicators	*7 Strengthened capacity of responsible agency(ies) to support FLR activity*	7.1 fiscal capacity of responsible agency(ies) 7.2 capacity of full-time multidisciplinary staff 7.3 volume of certified production 7.4 level of institutional capacity to sustain the results
	8 Integrated resource management	8.1 approved management plans(forest production, protected areas, etc) 8.2 production diversification (timber and non-timber forest products, environmental services) 8.3 existence of land-use plans

	Factors	Indicators
Outcome indicators	*9 Landscape patterns and forest products*	9.1 area and area proportion of forest landscape element types 9.2 levels of fragmentation of forest landscape element types 9.3 landscape diversity 9.4 conditions of degraded and secondary forest 9.5 types and yield of forest products 9.6 sustainable harvest of non-timber forest production 9.7 levels of resource use 9.8 diversity of resource users 9.9 existence of degraded forests restoration plans
	10 Recovery of ecosystem integrity	10.1 forest coverage 10.2 species diversity 10.3 structure of forests 10.4 areas under natural regeneration 10.5 planted areas 10.6 protection measures for wildlife 10.7 improvement of wildlife habitat 10.8 functions played by the restored forests 10.9 existence of corridors to link forest ecosystems 10.10 use of local knowledge for FLR 10.11 water yield in the watersheds 10.12 level of soil erosion 10.13 frequency of forest fires 10.14 carbon sequestration 10.15 pressure of human activities (domestic animal, crop production, etc)
	11 Diversified sources of community income	11.1 availability of forest resources 11.2 access to forest resources 11.3 provision of wood/fuelwood to communities 11.4 provision of fodder from plantations 11.5 number of jobs created 11.6 jobs which went to targeted groups (women, tribal/ethnic groups, youth, etc) 11.7 changes in income
	12 Financial income	12.1 costs versus benefits 12.2 contribution to local finance 12.3 economic income of locally processed productions
	13 Participatory M&E	13.1 monitoring tools 13.2 sources of information on ecological and socioeconomic dimensions 13.3 method of data collection 13.4 implementin agencies of M&E 13.5 levels of public participatory 13.6 contribution to reporting 13.7 lessons learned

6 Analyzing landscape pattern at region level

6.1 Landscape elements classification

Any individual application of FLR will be a flexible package of site-based techniques, whose combined contribution will deliver significant landscape-level benefits. Site-based techniques within the context of an FLR program mainly refer to site-level strategies and their associated silvicultural techniques for restoring degraded primary forest, managing secondary forest, rehabilitating degraded forest land or restoring forest functions on agricultural land.

According to relevant definitions of different forest and non-forest conditions, combining the resolution of collected RS images and the classification of national land uses, landscape elements classification system of Lingshui County was established in the view of FLR. There are totally 13 landscape element types: primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* plantation, trees around villages, other plantation, other forest land, residential quarters land, garden plots, agricultural land and other land, as outlined in Table 6.1.

Table 6.1 *Landscape element system of Lingshui Li Autonomous County*

No.	Class	Description
1	Primary Forest	Forest which has never been subject to human disturbance, or has been so little affected by hunting, gathering and tree-cutting that its natural structure, functions and dynamics have not undergone any changes that exceed the elastic capacity of the ecosystem.
2	Degraded Primary Forest	Primary forest in which the initial cover has been adversely affected by the unsustainable harvesting of wood and/or non-wood forest products so that its structure, processes, functions and dynamics are altered beyond the short-term resilience of the ecosystem; that is, the capacity of these forests to fully recover from exploitation in the near to medium term has been compromised.
3	Secondary Forest	Woody vegetation regrowing on land that was largely cleared of its original forest cover (ie carried less than 10% of the original forest cover). Secondary forests commonly develop naturally on land abandoned after shifting cultivation, settled agriculture, pasture, or failed tree plantations.
4	Degraded Forest Land	Former forest land severely damaged by the excessive harvesting of wood and/or non-wood forest products, poor management, repeated fire, grazing or other disturbances or land-uses that damage soil and vegetation to a degree that inhibits or severely delays the re-establishment of forest after abandonment.
5	Rubber Plantation	Land with rubber trees.
6	Trees around Villages	Lands which are planted trees around the villages.
7	*Casuarina equisetifolia* Plantation	*Casuarina equisetifolia* is the main tree species of coast protection forest.
8	Other Plantation	Referring to eucalyptus planted forest.
9	Other Forest Land	Forest land not classified as above types.
10	Residential Quarters land	House sites used for daily life (including the independent courtyard).
11	Garden Plots	Mainly refers to the litchi, mango, betel nuts and other non-timber forest.
12	Agricultural Land	Cropland, including paddy field and non-paddy cropland.
13	Other Land	Land not classified as to other type, such as rivers, reservoirs, lake and sandy lands.

6.2 Forest Landscape Pattern

The total area of forest landscape in Lingshui Li Autonomous County was 108,611 ha in 2008. There were 6303 patches and the average patch area (MPS) was 17.23 ha. The patch shape index (MSI) was 86.82. Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D) were 1.86, 0.70 and 0.80 respectively (see Table 6.2).

Table 6.2 *Overall Features of Forest landscape Patterns in Lingshui Li Autonomous County（in 2008）*

Index	Area （ha）	NP （n）	PD （n/100 ha）	MPS （ha）	ED （m/ha）	MSI	SDI	SEI	D
Value	108,611	6,303	5.80	17.23	131.67	86.82	1.86	0.7	0.80

Features of forest landscape elements in 2008 were shown in Table 6.3. The area of Agricultural Land was 26,651 ha with 829 patches, which was the largest landscape element type, accounting for 24.5% of the area of landscape. Agricultural Land was mainly distributed in plain areas and bottomland of hills. Followed by Secondary Forest, its area was 24,764 ha with 344 patches, accounting for 22.80% of total area, mainly in the northern middle hills region and the whole hilly area. The area of Garden Plots was 8,693 ha, 8.00% of total area. This landscape element type had wide distribution including northern middle hills region, the hilly region, central plain area and coastland. The area proportion of Rubber Plantation and Trees around Villages were 7.66% and 6.78% respectively, ranking sixth and seventh. Rubber Plantation was mainly in the western hills and upper reaches of Lingshui River while trees around villages were distributed around the residence. There were 1,574 patches of *Casuarina equisetifolia* Plantation and Other Plantation. *Casuarina equisetifolia* Plantation was mainly distributed in coastal areas for coast protection forest with the area of 452 ha. The area of Degraded Primary Forest was 6,837 ha, accounting for 6.29% of the total area of the landscape. Degraded Primary Forest was mainly in the northern mountains (Diaoluo mountain forest area) with low disturbance where were far away from human settlements. The area of Other Land covering rivers, reservoirs, lake and sandy lands was 6,478 ha, occupying 5.96% of the landscape. Primary Forest was continuously distributed in northern Diaoluo mountain forest area with high altitude and its area was 5,153 ha, accounting for 4.74% of the landscape. Residential Quarters Land was mainly in eastern and southern coastal areas, accounting for 3.80% of the landscape. The area of Degraded Forest Land was 2,358 ha with 766 patches, covering 2.17% of the landscape. Most degraded forest lands were wasteland after development of natural forest and scattered around in the secondary forest. In addition, the area of Other Forest Land not included in above forest types was 176 ha, accounting for 0.16% of the total area of the landscape.

Table 6.3 *Features of Forest landscape elements in Lingshui Li Autonomous County（in 2008）*

Landscape type	CA（ha）	PLAND%	NP（n）	PD（n/100 ha）	MPS（ha）	ED（m/ ha）	MSI
PF	5,153	4.74	11	0.21	468.43	38.39	2.31
DPF	6,837	6.29	110	1.61	62.15	57.52	2.00
SF	24,764	22.80	344	1.39	71.99	68.23	35.14
DFL	2,358	2.17	766	32.48	3.08	341.38	1.82
RP	8,324	7.66	58	0.70	143.51	104.87	19.42
TaV	7,365	6.78	505	6.86	14.58	265.76	839.83
*Ce*P	452	0.42	44	9.73	10.27	213.37	2.02
OP	7,235	6.66	1530	21.15	4.73	250.81	2.26
OFL	176	0.16	13	7.40	13.51	161.56	1.91
RQL	4,126	3.80	1202	29.13	3.43	293.26	2.33
GP	8,693	8.00	301	3.46	28.88	144.09	10.95
AL	26,651	24.54	829	3.11	32.15	110.58	3.60
OL	6,478	5.96	590	9.11	10.98	158.43	83.24

Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

Forest landscape pattern shows regular zonal distribution with different hydrothermal condition. Lingshui Li Autonomous County is high in the northwest and low in the southeast from a macro point of view. The county can be classified into four geomorphological regions: northern mountainous region, western hills area, central plain terrain and southeast coastal terrace. This geomorphological pattern and the resulting hydrothermal condition formed the unique forest landscape pattern of Lingshui Li Autonomous County (see Annex 4). Primary forest, secondary forest and degraded forest land were the main landscape element types in northern mountainous region. Western hills area was dominated by rubber plantation and secondary forest. Agricultural land and garden plots were the main landscape element types in central plain terrain while agricultural land and residential quarters land were dominated in southeast coastal terrace. Forest landscape of Lingshui Li Autonomous County presented high Landscape diversity index (SDI) and landscape dominance index (D). There were big differences among the area and the number of different landscape element patches. The area of both agricultural land and secondary forest was 51,415 ha; accounting for 47.34% of the landscape, thereby these two types could be regarded as the dominant landscape element types of the Lingshui County. Primary forest, degraded primary forest or rubber plantation in the landscape occupied a smaller proportion, but they all presented large patch size and centralized distribution. Moreover, degraded forest land had low patch connectivity and high fragmentation because of repeated human disturbance and the division of agricultural land and rubber plantation. Lingshui Li Autonomous County as a whole was a heterogeneous forest landscape in which forest lands as the matrix were intertwined by agricultural land and other land which had smaller patches, residential quarters land and garden plots were scattered among the matrix.

6.3 Forest landscape dynamics

6.3.1 Change on general features of landscape

General features of Forest landscape in Lingshui Li Autonomous County in different periods (1991, 1999 and 2008) were analyzed (see Table 6.4). The results showed that the number of landscape patches increased by 5,340 and patch density increased to 6.72/100 ha from 1.81/100 ha during 1991-1999 while the number of landscape patches reduced by 898, patch density decreased correspondingly from 1999 to 2008. Meanwhile, both landscape diversity index (SDI) and landscape evenness index (SEI) has increased, but landscape dominance index (D) has decreased during the period of 1991-2008. The area proportions of forest land accounting for the landscape in different periods (1991, 1999 and 2008) were 61.02%, 53.65% and 50.91% respectively, which showed that forest land has decreased gradually from 1991-2008 caused by the land use conversion from forest land to garden plots and residential quarters land.

Table 6.4 *Changes on general features of Lingshui Li Autonomous County Forest landscape*

Period (year)	Area （ha）	NP（n）	PD （n/100ha）	ED（m/ha）	SDI	SEI	D	Forest Land	
								Area （ha）	%
1991	108,611	1,961	1.81	74.13	1.16	0.45	1.42	66,279	61.02
1999	108,611	7,301	6.72	131.99	1.55	0.59	1.08	58,268	53.65
2008	108,611	6,303	5.80	131.67	1.86	0.70	0.80	55,298	50.91

Changes of landscape indices showed that the number of landscape patches has increased significantly and each patch has become regular caused by the interdivision among different landscape element types of Lingshui Li Autonomous County from 1991 to 2008, which resulted in the landscape fragmentation become more and more evident (see Annex 1-3).

6.3.2 Change on landscape element types

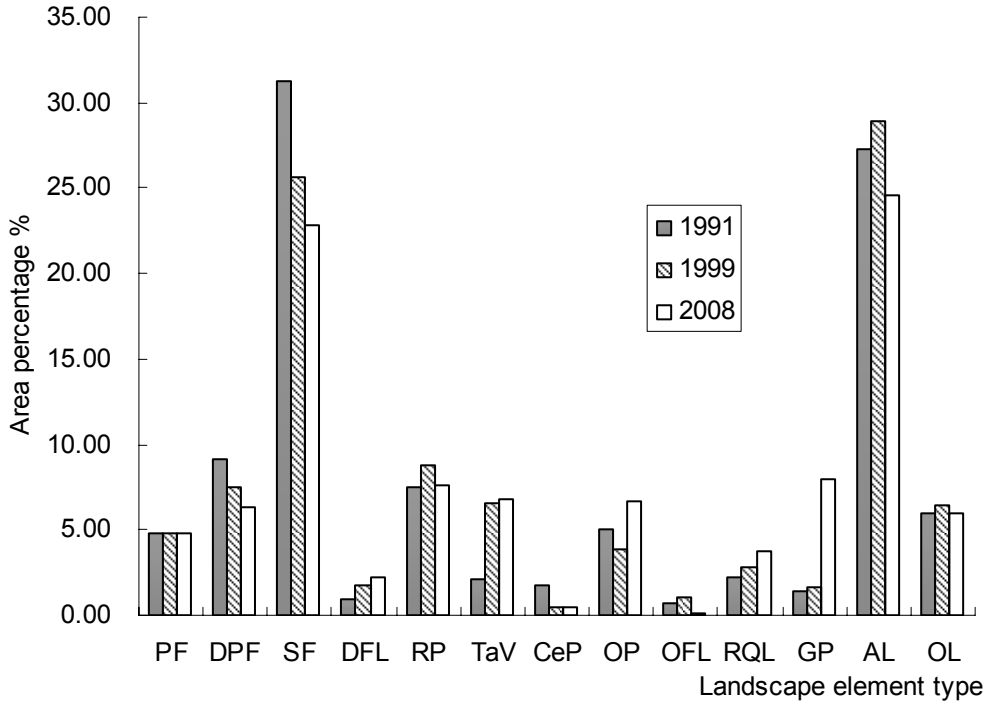
Area of each landscape element type except primary forest has changed from 1991 to 2008 in Lingshui Li Autonomous County. The total landscape area of Lingshui Li Autonomous County was 108,611 ha. The area of each landscape element type has changed except primary forest with the increase of areas of garden plots, trees around villages, residential quarters land, other plantation and the decrease of areas of secondary forest, degraded primary forest, agricultural land, *casuarina equisetifolia* plantation (see Table 6.5 and Figure 6.1). Summarily, the proportion of natural forest (including primary forest, degraded primary forest and secondary forest) was going down constantly (45.15% in 1991, 37.81% in 1999 and 33.83 % in 2008) and that of plantation forest (garden plots, rubber plantation, trees around villages, *casuarina equisetifolia* plantation and other plantation) was on the contrary (17.84% in 1991, 21.25% in 1999 and 29.52% in 2008).

Table 6.5 *Changes on areas of different landscape element types of Lingshui Li Autonomous County*

Landscape type	CA（ha）			PLAND%			changes of area %		
	1991	1999	2008	1991	1999	2008	1991-1999	1999-2008	1991-2008
PF	5,153	5,153	5,153	4.74	4.74	4.74	0.00	0.00	0.00
DPF	9,882	8,124	6,837	9.10	7.48	6.29	-17.79	-15.84	-30.82
SF	34,004	27,790	24,764	31.31	25.59	22.80	-18.28	-10.89	-27.17
DFL	954	1,859	2,358	0.88	1.71	2.17	94.95	26.87	147.34
RP	8,200	9,473	8,324	7.55	8.72	7.66	15.52	-12.13	1.51
TaV	2,283	7,125	7,365	2.10	6.56	6.78	212.14	3.37	222.65
*Ce*P	1,846	463	452	1.70	0.43	0.42	-74.91	-2.39	-75.51
OP	5,505	4,211	7,235	5.07	3.88	6.66	-23.50	71.80	31.43
OFL	735	1,196	176	0.68	1.10	0.16	62.65	-85.31	-76.11
RQL	2,442	3,057	4,126	2.25	2.81	3.80	25.20	34.98	69.00
GP	1,553	1,798	8,693	1.43	1.66	8.00	15.74	383.60	459.74
AL	29,614	31,365	26,651	27.27	28.88	24.54	5.91	-15.03	-10.01
OL	6,441	6,999	6,478	5.93	6.44	5.96	8.66	-7.45	0.57
Total	10,611	108,611	108,611	100.00	100.00	100.00	-	-	-

Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

According to the area change of single landscape element type, primary forest area has been kept stable. Secondary forest was the landscape element type with biggest changes on area, which changed from 34,004 ha in 1991 to 24,764 ha in 2008 and its proportion has decreased by 2.81%. Followed by the degraded primary forest, the area has decreased by 3,045 ha and the proportion has reduced by 2.81%. Garden Plots was the landscape element type with the largest area increase, from 1,553 ha to 8,693 ha and area percentage has increased by 6.57%. Followed by trees around villages, the area has increased by 5,083 ha.



Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

Figure 6.1 *Area proportions of different landscape element types of Lingshui Li Autonomous County*

From the changes on area of landscape types in different periods, Garden Plots is the type with the biggest area changes, the area has constantly increased from 1991 to 2008 and the area in 2008 was 4.6 times of that in 1991, but the increase mainly occurred during the period of 1999-2008. The area of Trees around Villages in 2008 was 2.23 times as much as that in 1991 and this change mainly happened in 1999 to 2008. The amplitude of variation of degraded forest land was 174.34%, which were 94.45% in 1991 to 1999 and 26.87% in 1999 to 2008 respectively. The area of Residential Quarters Land has also constantly increased, but amplitude of variation in 1999 to 2008 was bigger than that in 1991 to 1999. The area of Secondary Forest, Degraded Primary Forest and *Casuarina equisetifolia* Plantation has constantly decreased from 1991 to 2008 and mainly happened in the period of 1991 to 1999. Among those forest landscape types, the area of secondary forest and *Casuarina equisetifolia* Plantation changed significantly in two periods with decreasing area in 1991 to 1999 obviously more than that in 1999 to 2008. The fact that the area of secondary forest and degraded forest has reduced shown that the area of natural forest had a decreasing trend from 1991 to 2008. Changes on areas of Rubber Plantation and Other Lands increased first and then followed by decrease, but both types have increased due to the increased area in the previous period larger than the decreased area in the latter period.

By comparing Patch Density (PD) and Edge Density (ED) of various landscape feature types of Lingshui Li Autonomous County in 1991, 1999 and 2008 respectively, the heterogeneity change of landscape elements was analyzed (see Table 6.6).

In 1991，Residential Quarters Land had the biggest PD（21.34 /100 ha）and ED（200.27m/ ha）with high fragmentation for the scatter composition pattern. The patch density index of Rubber Plantation was the smallest, 0.20/100 ha, which showed that the cultivation area of Rubber Plantation was smaller in 1991 and concentrated in state-owned or collective-owned farms. The PD of Garden Plots, Degraded Forest Land, Trees Around villages were 8.63 /100 ha, 8.39 /100 ha and 6.40 /100 ha respectively. These types showed higher degree of fragmentation for mosaic distribution among the types of other landscape elements caused by frequent human disturbances. Both Primary Forest and Secondary Forest had smaller PD and ED with more regular shape of patches because they had been protected and had concentrated distributions.

Table 6.6 *Changes on PD and ED of different landscape element types of Lingshui Li Autonomous County*

Landscape type	PD（n/100 ha）			ED（m/ ha）		
	1991	1999	2008	1991	1999	2008
PF	0.21	0.21	0.21	38.39	38.39	38.39
DPF	0.30	1.01	1.61	36.64	49.58	57.52
SF	0.30	0.75	1.39	38.91	52.67	68.23
DFL	8.39	33.84	32.48	141.70	285.40	341.38
RP	0.20	1.11	0.70	54.46	109.55	104.87
TaV	6.40	24.48	6.86	180.80	327.09	265.76
*Ce*P	3.47	13.17	9.73	127.66	227.69	213.37
OP	2.14	35.64	21.15	119.61	293.79	250.81
OFL	2.86	2.84	7.40	150.68	165.34	161.56
RQL	21.34	29.90	29.13	200.27	270.10	293.26
GP	8.63	7.34	3.46	168.04	191.55	144.09
AL	1.90	3.86	3.11	82.31	133.72	110.58
OL	2.42	9.54	9.11	152.43	209.36	158.43

Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

The rank of patch density index of different landscape element types in 1999 was similar to that in 1991. Patch density (PD) of other types had increased except Primary Forest and Garden Plots. The sequence of patch density index of different landscape element types in 1999 was similar to that in 1991. Patch density (PD) of other types had increased except Primary Forest and Garden Plots. The PD of Other Plantation had increased from 2.14/100 ha to 35.64/100 ha while that of Degraded Forest Land had increased from 8.39/100 ha to 33.84/100 ha.during the period of 1991-1999, showing that impact of human activities on Other Plantation and Degraded Forest Land had enhanced which resulted in further fragmentation of the two types. Trees around Villages was the type with the biggest edge density in 1999 and its patch density also varied obviously. Patch density indices of Degraded Primary Forest and secondary forest had

increased as well as the area had deceased. This showed that impact on the two types by human activities had become bigger, the patch shape tended to be more complex and thereby they become more fragmented.

The patch density indices of Degraded Primary Forest, Secondary Forest had constantly increased from 1991 to 2008, which showed that the two types had become more and more fragmented. Except Primary Forest, the patch density of other types had increased first and then decreased during this period with different amplitude of changes, reflecting that the impacts on study area of human disturbances had first increased and then reduced. According to the changes on edge density of different landscape element types, primary forest had been kept stable in edge density, patch shapes of Degraded Primary Forest, Secondary Forest, Degraded Forest Land, Rubber Plantation and Residential Quarters Land became more and more irregular, and other types had become more squared during 1999 to 2008.

6.3.3 Prediction of forest landscape dynamics

Understanding the forest landscape dynamics is a major factor for successful implementation of FLR initiative since it is a process that will take at least 10 years, often much longer, facing major technical, economic, social, cultural and institutional challenges. Using Markov models, transition probability matrix among different landscape element types from 1999 to 2008 (see Table 6.7) was constructed to predict and analyze the forest landscape dynamics of Lingshui Li Autonomous County.

The results (see Table 6.7 and Figure 6.2) showed that forest and other natural landscape would reduce gradually while semi-natural landscapes such as agricultural land and human-induced landscape like residential quarters land would increase. This would result in degradation of landscape pattern towards poor ecological environment if Lingshui Li Autonomous County maintains the development trend of 1999-2008 in the next decades. The area proportions of agricultural land and residential quarters land would increase to 32.65%, 7.06% respectively while that of primary forest and secondary forest would reduce to 1.33% and 7.49% respectively by 2089. Obvious changes would occur in these four types. Other types including Trees around Villages, *Casuarina equisetifolia* Plantation, Other Plantation, Garden Plots and Other Forest Land would increase slowly. Rubber Plantation and Other Land would decrease and then climb up but in small fluctuation. Overall, this landscape dynamics would not be consistent with socio-economic development of the county, especially the sharp reduction of degraded primary forest, secondary forest and other natural forest together with the unlimited expansion of agricultural land, residential quarters land. Therefore, appropriate intervention should be undertaken on current landscape pattern to improve the positive direction of land use.

Table 6.7 *Landscape class transition area of Lingshui Li Autonomous County form 1999 to 2008*

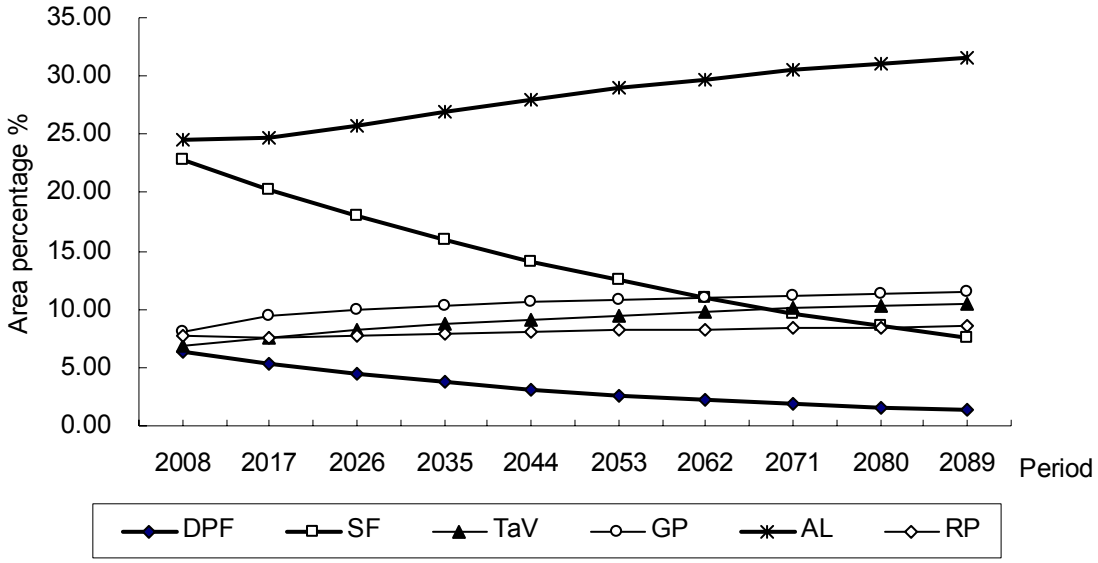
1999	2008													
	PF	**DPF**	**SF**	**DFL**	**RP**	**TaV**	**CeP**	**OP**	**OFL**	**RQL**	**GP**	**AL**	**OL**	**1999**
PF	4.74	-	-	-	-	-	-	-	-	-	-	-	-	4.74
DPF	-	6.29	0.85	0.09	-	-	-	-	-	-	0.21	-	0.03	7.48
SF	-	-	21.95	0.93	0.31	0.18	-	0.90	-	0.04	0.66	0.50	0.11	25.59
DFL	-	-	-	0.16	0.23	0.03	0.01	0.97	-	0.01	0.17	0.08	0.04	1.71
RP	-	-	-	0.42	5.50	0.21	-	0.65	0.04	0.07	1.11	0.61	0.11	8.72
TaV	-	-	-	0.02	0.04	2.60	0.02	0.45	0.01	0.72	0.71	1.75	0.23	6.56
CeP	-	-	-	-	-	0.01	0.05	-	-	0.02	-	0.23	0.12	0.43
OP	-	-	-	0.12	0.32	0.48	0.06	0.92	0.04	0.14	0.62	0.89	0.29	3.88
OFL	-	-	-	-	0.07	0.05	-	0.08	0.02	0.03	0.28	0.56	0.01	1.10
RQL	-	-	-	0.03	0.07	0.54	0.01	0.09	-	1.75	0.09	0.20	0.04	2.81
GP	-	-	-	0.00	0.14	0.15	-	0.10	-	0.03	0.50	0.72	0.02	1.66
AL	-	-	-	0.32	0.81	2.32	0.08	1.91	0.05	0.86	3.22	17.83	1.47	28.88
OL	-	-	-	0.07	0.17	0.20	0.20	0.59	0.01	0.12	0.43	1.16	3.49	6.44
2008	4.74	6.29	22.80	2.17	7.66	6.78	0.42	6.66	0.16	3.80	8.00	24.54	5.96	100.00

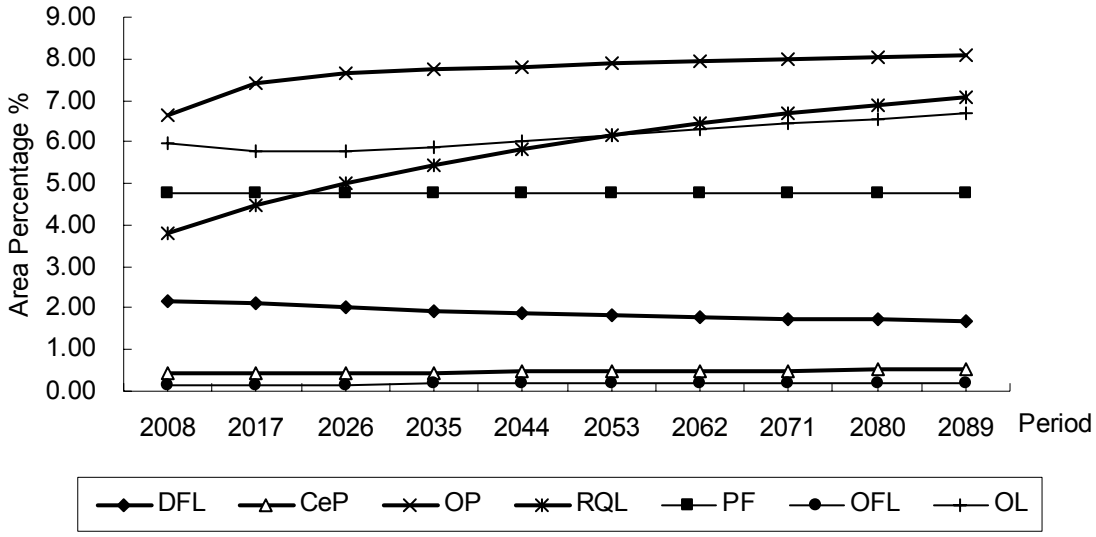
Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

Table 6.8 *Status and forecast of the occupation rate by each stage of landscape class types in Lingshui Li Autonomous County*

Landscape type	Occupation rate（%）									
	2008	**2017**	**2026**	**2035**	**2044**	**2053**	**2062**	**2071**	**2080**	**2089**
PF	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74
DPF	6.29	5.30	4.46	3.75	3.16	2.66	2.24	1.88	1.58	1.33
SF	22.80	20.28	18.00	15.95	14.11	12.46	10.99	9.68	8.52	7.49
DFL	2.17	2.09	2.01	1.95	1.89	1.84	1.79	1.75	1.71	1.68
RP	7.66	7.60	7.73	7.88	8.02	8.15	8.28	8.38	8.48	8.57
TaV	6.78	7.55	8.20	8.72	9.13	9.49	9.79	10.05	10.28	10.48
*Ce*P	0.42	0.43	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52
OP	6.66	7.43	7.63	7.73	7.81	7.88	7.94	8.00	8.05	8.09
OFL	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
RQL	3.80	4.46	5.01	5.46	5.85	6.17	6.44	6.68	6.88	7.06
GP	8.00	9.46	10.03	10.37	10.63	10.86	11.06	11.23	11.39	11.52
AL	24.54	24.72	25.82	26.97	28.02	28.94	29.75	30.47	31.10	31.65
OL	5.96	5.76	5.76	5.86	6.00	6.15	6.30	6.44	6.56	6.68

Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.





Note: PF- Primary Forest, DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, RP- Rubber Plantation, TaV- Trees around Villages, CeP- *Casuarina equisetifolia* Plantation, OP- Other Plantation, OFL- Other Forestry Land, RQL- Residential quarters land, GP- Garden plots, AL- Agricultural Land, OL- Other Land.

Figure 6.2 *Status and forecast of the occupation rate by each stage of landscape class types in Lingshui Li Autonomous County*

7 Analyzing landscape pattern at community level

7.1 Landscape elements classification

According to result of landscape elements classification in the view of FLR in chapter 6, combining the land use of Dagan FLR demonstration area, forest landscape in Dagan FLR demonstration area was classified as 8 types: Degraded Primary Forest, Secondary Forest, Degraded Forest Land, Plantation, Non-paddy Cropland, Paddy Field, Human Settlement, Reservoir or Pond.

Maps of forest landscape mosaic of Dagan FLR demonstration area in different periods were obtained by participatory inventory, subcompartment division and inventory using GIS tools based on RS image interpretation. The results of survey, division and maps were consulted and communicated again and again through PRA tools such as the community workshop and semi-structured interviews so as to obtain maps of forest landscape mosaic in 1990, 1999 and 2009 (see Annex 5 - 7). Different types of landscape elements should be the basis for classifying the patch boundaries for analysis of landscape pattern while different ownerships and landscape element types should be the basis for classifying the patch boundaries for identifying site-level restoration strategies.

7.2 Forest Landscape Pattern

The demonstration area, with a total area of 399.48 ha in 2009, lies in Qunying Town which is located in the northwest of Lingshui Li Autonomous County. There were 159 patches and the average patch area (MPS) was 2,051 ha. Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D) were 1.35, 0.65 and 0.73 respectively (see Table 7.1).

Table 7.1 *Overall Features of Forest landscape Patterns in Dagan FLR demonstration area（in 2009）*

Index	Area （ha）	NP （n）	PD （n/100 ha）	MPS （ha）	ED （m/ha）	MSI	SDI	SEI	D
Value	399.48	159	39.80	2.51	329.12	1.63	1.35	0.65	0.73

The demonstration area was a heterogeneous forest landscape in which Plantation was the matrix and other types was scattered among the matrix. Plantation was located in the north and centre of the demonstration area and Secondary forest and Degraded Primary Forest were most distributed in the southern hills at higher elevation, with less human activities. Degraded Forest Land and Non-paddy Cropland mosaicked among Plantation, Secondary forest and Degraded Primary Forest. There are 5 ponds or reservoirs in the area. Paddy Field was distributed along the river or around the reservoir and Human Settlement was distributed in the basin. The landscape had serious fragmentation, especially for Degraded Primary Forest, Secondary Forest and Degraded Forest Land. The map of landscape mosaic showed that Plantation dominated the overall pattern and distributed along the river or around the reservoir with important ecological interest, but Degraded Primary Forest with high biodiversity only distributed in the peak of southern or eastern hills not access to the forest and thereby the landscape has low heterogeneity.

Features of forest landscape elements in 2009 were shown in Table 7.2. The area of Plantation was 240.30 ha with 14 patches, which was the largest landscape element type, accounting for 60.15% of the total area of landscape. Followed by Secondary Forest, its area was 47.55 ha with 43 patches, accounting for 11.90% of total area. The area of Degraded Primary Forest was 42.06 ha, 10.53% of total area. The area proportion of Paddy Field and Degraded Forest Land were 6.71% and 4.53% ranking forth and fifth. The areas of Non-paddy Field, Human Settlement and Reservoir or Pond were 15.32 ha, 8.32 ha and 1.00 ha respectively. The number of patches of Non-paddy Field was more than that of Human Settlement or Reservoir or Pond.

From the distribution point of view, Plantation in the demonstration area nearly filled the entire space, especially in central and northern regions. Secondary Forest were concentrated in the southwest and mostly scattered among plantations, resulting in the typical mosaic pattern plantation-secondary forest. Degraded Primary Forest were mainly distributed in hill peaks in south or southeast which have not developed for some limiting factors, such as poor transport, far away from water sources, poor soil, etc. Degraded Forest Land was mainly from deserted land after development and distributed in the south of the demonstration area and in mosaic among Degraded Primary Forest.

Table 7.2 *Features of Forest landscape elements in Dagan FLR demonstration area in 2009*

Landscape type	CA（ha）	PLAND%	NP（n）	PD（n/100ha）	MPS（ha）	ED（m/ha）	MSI
DPF	42.06	10.53	6	14.27	7.01	320.19	2.21
SF	47.55	11.90	43	90.43	1.11	519.63	1.68
DFL	18.11	4.53	37	204.31	0.49	684.69	1.44
P	240.30	60.15	14	5.83	17.16	222.24	1.94
NpC	15.32	3.83	30	195.82	0.51	671.17	1.45
PF	26.82	6.71	21	78.30	1.28	511.79	1.82
HS	8.32	2.08	3	36.06	2.77	317.70	1.63
RoP	1.00	0.25	5	500.00	0.20	843.99	1.27

Note: DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, P- Plantation, NpC- Non-paddy Cropland, PF- Paddy Field, HS- Human Settlement, RoP- Reservoir or Pond.

Related to the distribution of Degraded Forest Land and Non-paddy Field, these two types had the highest degree of fragmentation with small average patch area and big ED because both types were got the most frequent human activities, of which the PD and MPS of Degraded Forest Land were 204.31/100 ha and 0.49 ha. The fragmentation of Secondary Forest was much more severe for its division by Degraded Forest Land and Non-paddy Field. Its MPS was 1.11 ha with irregular boundary. The PD of Degraded Primary Forest was 14.27 /100 ha, which showed that it had less human interventions. The PD and ED of Plantation were the smallest and its MPS was 17.16 ha, showing plantation had the lowest fragmentation because of the continuous large area of betel nut and rubber tree planting instead of less human disturbances.

7.3 Forest landscape dynamics

7.3.1 Change on general features of landscape

The demonstration area showed different trends in the period of 1991 - 1999 and 1999 - 2008 (see Table 7.3). Non-paddy Field and Degraded Primary Forest were the matrix of the demonstration area in 1990. The number of patches had increased from 124 to 162 and patch density, edge density, mean patch shape index had also increased significantly while the MPS had decreased from 3.22 ha in 1990 to 2.47 ha in 1999, showing that the landscape fragmentation had become more severely, the boundaries of each patch had become more irregular in this period. With the increase of Plantation and the reduction of Degraded Primary Forest and Secondary Forest, Plantation, Non-paddy Field and Degraded Primary Forest have become the main types in the landscape in 1999 and landscape dominance decreased. This result can also be got from changes on SDI, SEI and D. SDI has increased from 1.45 in 1990 to 1.54 while SEI from 0.70 to 0.74. During the period of 1999 to 2009, the number of patches in demonstration area has reduced from 162 to 159 while MPS has increased from 2.47 ha to 2.51 ha, which indicated that landscape fragmentation and landscape heterogeneity decreased. The decrease of MSI also showed that the shape of patches has become regular. The SDI and SEI were 1.35 and 0.65 respectively in 2009. With the sharply increase of Plantation during 1999 to 2009, Non-paddy Field only distributed among plantations and would not be the main type any more. Plantation was the main type in demonstration area while degraded primary forest only distributed in hills not easy to access for local people.

Table 7.3 *Changes on general features of Dagan FLR demonstration area*

Period (year)	Area （ha）	NP （n）	PD （n/100ha）	ED （m/ha）	MSI	SDI	SEI	D
1990	399.48	124	31.04	309.73	1.74	1.45	0.70	0.63
1999	399.48	162	40.55	388.47	1.85	1.54	0.74	0.54
2009	399.48	159	39.80	329.12	1.63	1.35	0.65	0.73

7.3.2 Change on landscape element types

Changes on landscape pattern of Dagan demonstration area are mainly reflected in the decrease of Non-paddy Field, Degraded Primary Forest and the increase of Plantation. The loss of Degraded Primary Forest and the expansion of Plantation has taken place during 1990 to 1999 while the loss of Non-paddy Field and the expansion of Plantation has taken place during 1999 to 2009 (see Table 7.4 and Figure 7.1). The type with greatest change is Plantation which has increased 208.88 ha from 1990 to 2009 and this kind of change has mainly taken place in the period of 1999 - 2009, indicating the intervention of human activities on the landscape has enhanced.

Table 7.4 *Changes on areas of different landscape element types in Dagan FLR demonstration area*

Landscape type	CA（ha）			PLAND%			changes of area %		
	1990	1999	2009	1990	1999	2009	1990-1999	1999-2009	1990-2009
DPF	97.64	68.42	42.06	24.44	17.13	10.53	-7.31	-6.6	-13.91
SF	34.42	29.83	47.55	8.62	7.47	11.90	-1.15	4.43	3.28
DFL	5.68	4.67	18.11	1.42	1.17	4.53	-0.25	3.36	3.11
P	31.42	87.57	240.3	7.87	21.92	60.15	14.05	38.23	52.28
NpC	194.17	172.84	15.32	48.61	43.27	3.83	-5.34	-39.44	-44.78
PF	26.82	26.82	26.82	6.71	6.71	6.71	0	0	0
HS	8.32	8.32	8.32	2.08	2.08	2.08	0	0	0
RoP	1.00	1.00	1.00	0.25	0.25	0.25	0	0	0
Total	399.48	399.48	399.48	100.00	100.00	100.00	-	-	-

Note: DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, P- Plantation, NpC- Non-paddy Cropland, PF- Paddy Field, HS- Human Settlement, RoP- Reservoir or Pond.

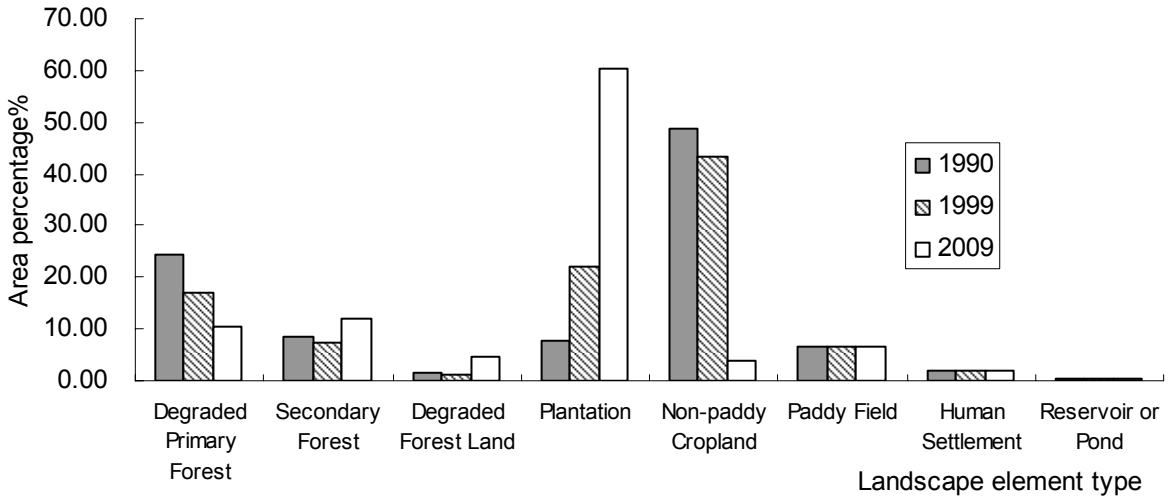


Figure 7.1 *Changes on areas of different landscape element types in Dagan FLR demonstration area*

Degraded Primary Forest has decreased from 97.64 ha in 1990 to 42.06 ha in 2009 and the percentage has dropped by 13.91%. Different from Plantation, its changes during the two periods were similiar, 29.23 ha and 26.36 ha respectively. Non-paddy Field has decreased from 208.88 ha from 194.17 ha in 1990 to 15.32 ha in 2009 and this kind of change has mainly taken place in the period of 1999-2009. The economic income were the main basis for land use conversion from the reduction of Degraded Primary Forest and Non-paddy Field while the expansion of Plantation. Changes on Secondary Forest and Degraded Primary Forest were similar, but Paddy Field, Human Settlement and Reservoir or Pond have kept steady for topography, climate and other natural factors.

Changes on NP (Number of patches) in Dagan demonstration area during 1990 - 2009 were mainly shown in its increase of Degraded Forest Land and Secondary and its decrease of Plantation. The increase of NP from 1991 to 1999 was mainly shown in Non-paddy Field and Plantation. The increase of NP of Degraded Forest Land and Secondary Forest and the drop of Plantation and Non-paddy Field were taken place during the period of 1999 - 2009 (see Table 7.5 and Figure 7.2).

Table 7.5 *Changes on NP of different landscape element types in Dagan FLR demonstration area*

Landscape type	Number of Patches			Percentage of NP (%)			Changes of NP (N)		
	1990	1999	2009	1990	1999	2009	1990-1999	1999-2009	1990-2009
DPF	9	8	6	7.26	4.94	3.77	-1	-2	-3
SF	29	28	43	23.39	17.28	27.04	-1	15	14
DFL	8	10	37	6.45	6.17	23.27	2	27	29
P	24	36	14	19.35	22.22	8.81	12	-22	-10
NpC	25	51	30	20.16	31.48	18.87	26	-21	5
PF	21	21	21	16.94	12.96	13.21	0	0	0
HS	3	3	3	2.42	1.85	1.89	0	0	0
RoP	5	5	5	4.03	3.09	3.14	0	0	0
Total	124	162	159	100.00	100.00	100.00	38	-3	35

Note: DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, P- Plantation, NpC- Non-paddy Cropland, PF- Paddy Field, HS- Human Settlement, RoP- Reservoir or Pond.

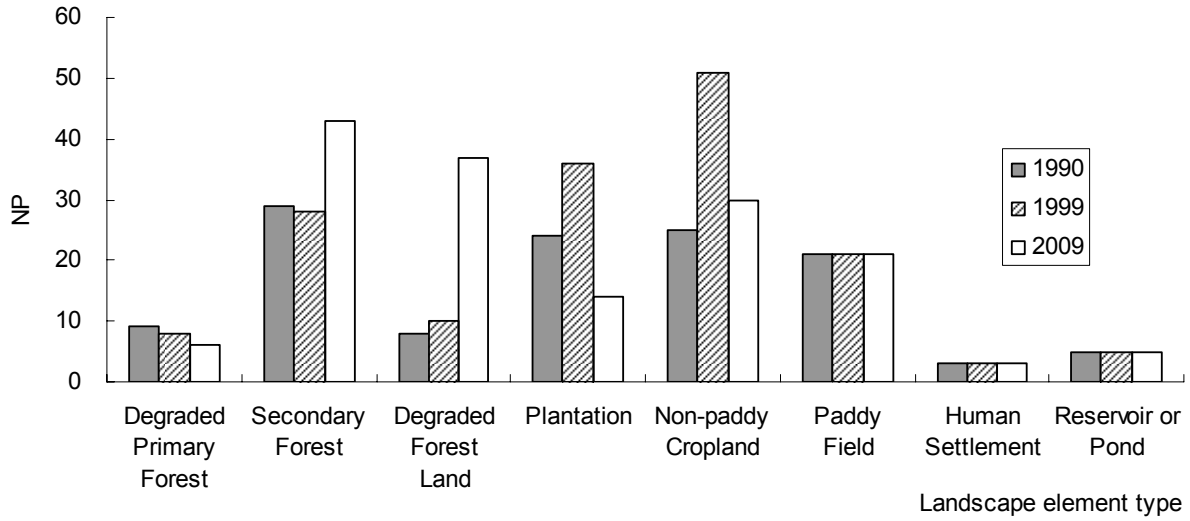


Figure 7.2 *Changes on NP of different landscape element types in Dagan FLR demonstration area*

Changes on the heterogeneity of landscape element types were indicated by analysis of patch density (PD) and edge density (ED) (see Table 7.6). Changes on both patch density and edge density of different types showed the same trend during the period of 1990 - 2009. The PD and ED of Degrade Primary Forest and

Non-paddy Field have increased during this period especially that of Non-paddy Field, which suggested that human disturbances to Degrade Primary Forest and Non-paddy Field have become more frequently, patch boundary has become more irregular and degree of fragmentation has increased. Different from the concentrated distribution, patches of Non-paddy Field were scattered by the division of adjacent patches, such as plantations and secondary forest. The PD and ED of Plantation showed a downward trend and the MPS has increased, showing that the patch boundary has become more regular and degree of fragmentation has decreased because distribution of Plantation has become more and more concentrated for the human disturbances and the constraints of management. The PD and ED of Secondary Forest and Degraded Forest Land were first increased and then decreased and that in 2009 was slightly higher than 1990. The year 1999 was a turning point for local people using these two types. Secondary Forest and Degraded Forest Land was converted to cassava and other Non-paddy Field and rubber plantations during the previous period while Non-paddy Field was first deserted and then converted to Secondary Forest and Degraded Forest Land by natural succession during the latter period. Secondary Forest and Degraded Forest Land showed different changes on fragmentation because of disturbance of development - use – desert. Fragmentation of degraded primary forest and secondary forest has led to the loss and fragmentation of habitats and thereby reduced the biodiversity in demonstration area directly.

Table 7.6 *Changes on PD and ED of different landscape element types in Dagan FLR demonstration area*

Landscape type	PD（n/100 ha）			ED（m/ ha）		
	1990	1999	2009	1990	1999	2009
DPF	9.22	11.69	14.27	207.68	278.76	320.19
SF	84.25	93.87	90.43	494.63	519.56	517.63
DFL	140.85	214.13	204.31	646.44	764.70	684.69
P	76.38	41.11	5.83	485.65	440.44	222.24
NpC	12.88	29.51	195.82	258.97	355.65	671.17
PF	78.30	78.30	78.30	511.79	511.79	511.79
HS	36.06	36.06	36.06	254.85	254.85	317.70
RoP	500.00	500.00	500.00	668.93	668.93	843.99

Note: DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, P- Plantation, NpC- Non-paddy Cropland, PF- Paddy Field, HS- Human Settlement, RoP- Reservoir or Pond.

7.4 Prediction of forest landscape dynamics

Using Markov models, transition probability matrix among different landscape element types from 1999 to 2009 was constructed to predict and analyze the forest landscape dynamics of Dagan demonstration area (see Table 7.7 and Figure 7.3). The results showed that degraded primary forest would reduce gradually from 42.06 ha in 2009 to 3.64 ha in 2089, the occupation rate (area ratio) would reduce by 9.62% while secondary forest degraded forest land and plantation would increase slightly that would result in landscape heterogeneity decrease and the landscape would reach a relatively steady state by the year 2089. Occupation rates of degraded primary forest, secondary forest, degraded forest land, plantation and non-paddy field would be 0.91%, 16.75%, 5.15%, 65.98%, and 2.84% respectively at steady state. Overall

structure of landscape would not change fundamentally, and plantation would be the matrix and other types would mosaic, but quality and production potential of the landscape would be significantly reduced. Degrade primary forest would be developed into plantation by human disturbances driven by economic interest and traditional slash and burn farming. Degraded primary forest are mainly distributed in hill peaks with higher elevation, playing an extremely important ecological function, is the main body for ecological environment construction. The loss of degraded primary forest would bring some environment problems, such as biodiversity loss, soil erosion and thereby cause social and economic problems such as deterioration in the quality of forest products, energy shortages, and income decrease, etc. Overall, this landscape dynamics would not be consistent with socio-economic development of the demonstration area, especially the sharp reduce of degraded primary forest. Therefore, appropriate intervention should be undertaken on current landscape pattern to improve the positive direction of land use.

Table 7.7 *Status and forecast of landscape in Dagan FLR demonstration area*

Period	Occupation rate							
	DPF	**SF**	**DFL**	**P**	**NpC**	**PF**	**HS**	**RoP**
2009	10.53	11.90	4.53	60.15	3.84	6.71	2.08	0.25
2019	6.47	14.77	4.94	62.22	2.57	6.71	2.08	0.25
2029	3.98	16.07	5.07	63.18	2.66	6.71	2.08	0.25
2039	2.45	16.59	5.13	64.05	2.75	6.71	2.08	0.25
2049	1.50	16.70	5.15	64.77	2.79	6.71	2.08	0.25
2059	1.30	16.74	5.15	65.32	2.82	6.71	2.08	0.25
2069	1.10	16.75	5.15	65.71	2.83	6.71	2.08	0.25
2079	0.92	16.75	5.15	65.91	2.84	6.71	2.08	0.25
2089	0.91	16.75	5.15	65.98	2.84	6.71	2.08	0.25

Note: DPF- Degraded Primary Forest, SF- Secondary Forest, DFL- Degraded Forest Land, P- Plantation, NpC- Non-paddy Cropland, PF- Paddy Field, HS- Human Settlement, RoP- Reservoir or Pond.

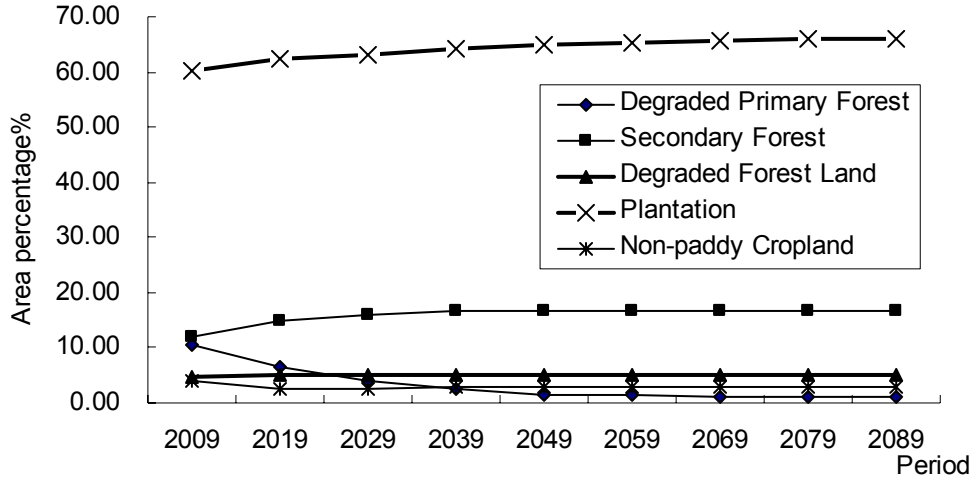


Figure 7.3 *Status and forecast of landscape in Dagan FLR demonstration area*

8 Analyzing driving forces of landscape dynamics

There are a large number of studies on forest landscape changes and its driving forces in China in recent years (Lu L et al, 2001; Zhang Y M et al, 2004; Li J G et al, 2004; Liu J Y, et al, 2009). Analysis of area changes, transition probability matrix and changes of landscape indices were main methods for studies of landscape changes (Ma R H et al, 2001; Liu J Y, et al, 2002; Song D M, 2003; Chen W B, 2004; Liu M, 2005). Qualitative analysis (Chen W B, 2004; Xu X L et al, 2004b), principal component analysis, multivariate statistical analysis and other quantitative analysis methods (Cao Y, 2004; Liu X H, 2005), Logistic regression model (Liu M et al, 2007; Xie H L, 2008) were usually used in analysis of driving forces of landscape change. Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this chapter used transition probability matrix and participatory survey method to study the driving forces of forest landscape dynamics both at region level and at community level.

8.1 Driving forces of landscape dynamics at regional level

Based on analysis of transition probability matrix, driving forces responsible for the forest landscape dynamics of Lingshui Li Autonomous County during the period of 1991 to 2008 were analyzed using PRA method such as semi-structured interview, matrix ranking and brainstorming, as well as discussions and interviews with representatives of different stakeholder groups and field survey.

Forestry policies and key programs were the dominant factors to improve the quantity and quality of forest. “Forest Protection Management Regulations of Hainan Province” was developed on July 30, 1993. The government of Hainan Province decided to implement the logging ban on natural tropical forest and made a Policy to Coordinate Economy Development with Environment in 1994, and the Consultative Committee for Environment Protection of Hainan Province was set up. “The Natural Forest Protection Program (NFPP)” has been implemented since 1998. The People’s Congress of Hainan Province made a decision on Construction Ecology Province on February 1999 and then the Standing Committee of the Provincial People's Congress approved the overall plan for ecological province construction in July. “The Conversion of Cropland to Forest Program (PCCF)” was initiated in 2002. Besides, the key forest programs also included “Wildlife Conservation and Nature Reserves Development Program”, “Non-commercial Forest Protection and Construction Program (NFPCP)”, “Coastal Shelterbelt Protection and Construction Program (CSPCP)”, “Forest Industrial Base Development Program in Key Regions with a Focus on Fast-growing and High-yielding Timber Plantations (FIBDP)”. The implementation of these key forestry programs not only controlled the decline of tropical forest, protected and restored the tropical natural forest effectively, particularly the northern Diaoluoshan National Forest area, but also helped the increase of tropical plantation and the quality of natural forest stands in the tropics. The results from forest management inventory in 1994 and forest management sampling inventory in 2005 showed that the stock volume had increased by 18.2% from 175.5 m^3/ ha to 207.5 m^3/ ha.

Reducing rural poverty through development were important factors in the changes on forest landscape in western hills area and northern middle hills region.

As the biggest project in western hills and northern middle hills region of Lingshui Li Autonomous County, Reducing rural poverty through development has become the major force driving the landscape dynamics.

To complete the goals and tasks advanced by the "China Rural Poverty Alleviation and Development Outline (2001 - 2010)", according to the poverty alleviation pilot requirements in “cadre training plan in poverty-stricken areas in 2006”, Lingshui Li Autonomous County developed the planting base construction taking industrialization-oriented poverty relief as breakthrough. 15 rubber planting bases and 10 betelnut bases have been developed in Qunying Town and Benhao Town, totally constructed 1,333 ha rubber plantations and 533 ha betelnut plantations under government support. In 2008, 800,000 RMB was invested in Benhao Town and Longguang Town to plant 280 000 betelnut seedlings with an area of 167 ha. Meanwhile, 500,000 RMB was invested in Benhao Town, Longguang Town and Qunying Town to plant 120, 000 rubber tree seedlings. In order to meet farmer needs, 500,000 RMB was invested to support the poor to manage rubber plantation of 200 ha, betel nut of 133 ha, and mango of 200 ha.

Although the poverty relief way that make full use of resources in poverty-stricken areas increased the economic development in rural area, such as 46 poverty-stricken villages and civilized ecological villages have been supported, the development of planting bases relied on land-use conversion, resulting in the conversion of degraded primary forests, secondary forest, degraded forest land, agricultural land in the planting area to plantation and garden plots.

Livelihood development was an important factor in the changes on forest landscape in the whole hills area and middle hills region.

As one of the national poverty-stricken counties, Lingshui Li Autonomous County is a backward economic county and people live in poverty. Agricultural land in the whole hilly area and middle hills region are limited so that development of economic crops has become the major choice for subsistence. Furthermore, "slash and burn" (shifting cultivation agriculture), traditional farming of Li Nationality, was the major driving force for landscape change and resulted in the diminishing of degraded primary forest and secondary forest.

Village greening and farm-shelter were important factors in the changes of forest landscape in central plain terrain.

Trees around villages increased gradually for new rural construction and ecological civilization construction. The need of windbreak and farmland protection was the important factor in the formation of fame-shelter undesignedly in central plain terrain. With the continuous construction, trees around villages and farm-shelter have become the important ecological security barrier in central plain terrain.

Sand excavation, pond culture and tourism development are important driving forces for changes on forest landscape in coastal area.

There were large area of coastal shelterbelt forest and the *Casuarina equisetifolia* forest performed very well in Lingshui Li Autonomous County in the early 1990s. But coastal shelterbelt forest had suffered from severe damage and the area had decreased sharply because of titanium mining during 1991-1994. And then the forest has been restored due to the campaign of ” wiping out the barren hills” in the province. However, the coastal shelterbelt forests were damaged severely once again due to conversion to shrimp-farming ponds or watermelon fields for economic interests since 2004, because high income can be generated from shrimp-farming and watermelon industry. The 3rd Hainan Province Standing Committee of People's Congress has approved the “Regulations on Coastal Shelterbelt Forest Protection and

Construction in Hainan Province" on November 29, 2007. At present, coastal shelterbelt forest restoration has been referred to one of the "three Lingshui" targets, particularly the target of ecological county. According to the notice "[2007] 9" to strengthen the protection of coastal shelterbelt forest, any group or individual should not occupy forest land within 200 m wide from high tide line, key projects at or above province level which have to expropriate and occupy the forest land must keep at least 100 m wide shelterbelt forest and deal with the land use change in accordance with law. Restoration of the coastal shelterbelt forest is conducted through the "returning pond fishery back to forest" and other projects. Planting watermelon understory is also controlled strictly without affecting normal growth of the forest. Tourism development will affect the development of coastal shelterbelt forest to some extent in recent years.

8.2 Driving forces of landscape dynamics at community level

Similar to analysis of dominant forces responsible for forest landscape changes at region level, the driving forces of forest landscape in Dagan demonstration area was analyzed by communication and discussion with villagers using PRA tools such as village meeting, semi-structured interviews, resources mapping, matrix ranking and problem causal analysis based on analysis of transition probability matrix in different periods.

Basic living allowances

Basic living allowances and expansion of agricultural land were the dominant factors to drive the changes on forest landscape in Dagan FLR demonstration area. Cultivated land in demonstration area is only 0.04 ha. Most of the residents in Dagan FLR deomonsration area were short of food and clothing in the early of 1990s. Even today there are still a few villagers having the problem of food shortages for 2 months a year. In order to solve the problem of food and clothing shortages, local residents developed the degraded primary forest and secondary forest into cassava fields in 1990s, especially during the period of 1990 - 1999. However, energy needs of life necessities have run throughout the study period, so firewood has played an important part in the change of forest landscape because electricity, coal, gas and other alternative energy sources were seldom used.

Policies of poverty alleviation

The main form of policies of poverty alleviation was to provide seedlings for non-timber forest plantation, which caused the conversion from agriculture land such as cassava to lychee, mango and other non-timber forest and rubber, betel nut plantation. Villagers have great enthusiasm on these policies so that they planted rubber tree and betel nut trees along roads and streams and other areas which were agricultural lands before. In order to increase efforts of poverty alleviation for the poor minority areas, Lingshui Li Autonomous County implemented the policies of poverty alleviation in the form of providing seedlings and trainings during the period of 1990 - 1999. This contributed to the conversion to plantation from degraded and secondary forest. Policies of poverty alleviation turned to develop rubber, nuts and other industries based on existing technology and management experience after 1999, resulting in great increase of rubber, betel nut and other plantation during 1999 - 2009. With increasing efforts in poverty reduction, improvement of living standards and increased economic benefits of rubber and betel nut trees, most secondary forest developed from deserted cassava fields have been converted to plantations. Meanwhile, some existing

secondary forests are still in the risk of deforestation driven by economic interests. This is the key trade-off needs to be considered in the FLR at community level, which is the conflict between plantation expansion and secondary forest protection.

Prices of forest products

Prices of forest products as driving force for forest landscape change in the demonstration area mainly happened in the period of 1999 - 2009. Prices of rubber, betel nut and *Eucalyptus* trees have increased steadily in recent 5 years. Villagers are able to get sufficient basic subsistence for their lives and do not rely on expanding the cassava or corn fields to make lives. So agricultural fields developed before were converted to plantations and rubber trees, betel nut trees and *Eucalyptus* have become the favorite species. Another effect was that degraded primary forest, secondary forest or degraded forest land were converted into plantations directly in this period and non-paddy field was not the transition between degraded and secondary forest and plantation, which indicated the strong desire of residents to expand the planted forest.

Traditional practices

Traditional practices were important factors in the changes on forest landscape in demonstration area. As Li minority village, every family in demonstration area should set aside a certain area of land for unmarried men. Therefore, families having boys would reclaim as much land as possible, resulting in the conversion from degraded primary forest to agricultural fields or plantation. Farmers have mentioned that children would ask parents for enough land to survive their future families when they grow up. Another traditional practice is that the user right of a land would belong to the developer as long as the land was developed. Field survey has found that couch grass, stones or shrubs were used to mark the boundaries of developed but not planted land.

9 Analysis of characteristics of degraded and secondary forests and restoration strategies

The specific activities of FLR initiative should be implemented at site level whether for regional level FLR or community-level FLR. Compared to other restoration approaches, FLR puts emphasis on the restoration and management of degraded and secondary forests (ITTO and IUCN, 2005). Categories of degraded and secondary forest were defined in "ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forest" published in 2002, including degraded primary forest, secondary forest and degraded forest land. Degraded and secondary forests tend to be located in more accessible areas close to human settlements and are used more than primary forests. Thus they are an increasingly important component of the forest resource in the tropics, providing special economic functions for the poor people living in rural areas (Banerjee A, 1995; Gilmour D A, 2000; Mcshea W J, 2009).

China has done some important studies on biodiversity, community structure and dynamics of degraded primary forest (Li Y D, 1997; An S q et al, 1999; Zang R G et al, 2002; Ding Y, 2007; Yang Y C, et al, 2008; Xu H, et al, 2009), as well as types, characteristics and management status of secondary forest (Huang S N et al, 2000; Hou Y Z, 2003; He B X et al, 2008; Hou Y Z et al, 2008; Wang H F, 2008), but few studies focused on community and measuration characteristics of tropical degraded and secondary forest in view of forest management. Characteristics of degraded and secondary forest in Dagan FLR demonstration area in Lingshui Li Autonomous County were analyzed from forest management perspective based on fully understanding of the definitions of different forest categories and site-level restoration strategies were identified, so as to provide foundation for protection, restoration, sustainable management and use of degraded and secondary forest.

9.1 Characteristics of degraded primary forest

9.1.1 Dominant species

Importance value of plants in arbor storey of degraded primary forest in Dagan demonstration area was shown in Table 9.1. There were totally 42 tree species in the arbor storey of community of *Garcinia oblongifolia- Hopea exalata*. The importance value of *Garcinia oblongifolia* was 41.05%, which was the biggest. Followed by *Hopea exalata*, its important value was 34.98%. The importance values of *Engelhardtia roxburghiana*, *Ixonanthes chinensis*, *Diospyros potingensis*, *Acronychia oligophlebia*, *Canarium album*, *Symplocos lancifolia* and *Ficus henryi* ranked 3-9 respectively while those of other 33 species were less than 10%. There were totally 26 tree species in arbor storey of community *Engelhardtia roxburghiana -Garcinia oblongifolia*. The importance value of *Engelhardtia roxburghiana* was 70.94%, which was the biggest. Followed by *Garcinia oblongifolia* and *Ixonanthes chinensis*, the importance values were 55.21% and 35.50% respectively. The importance values of *Symplocos lancifolia*, *Lithocarpus pseudovestitus*, *Sarcosperma laurinum*, *Ficus microcarpa*, *Dalbergia hainanensis*, *Diospyros potingensis* and *Dalbergia odorifera* ranked 4 - 10 respectively. There were totally 35 tree species in arbor storey of community *Amesidodendron chinense -Garcinia oblongifolia*. The importance value of *Amesidodendron chinense* was 48.16%, which was the biggest one. Followed by *Garcinia oblongifolia*, the importance values was 42.14%. The importance values of *Engelhardtia roxburghiana*, *Lithocarpus pseudovestitus*,

Gonocaryum lobbianum, *Polyspora balansae* and *Symplocos lancifolia* ranked 3 - 7 respectively. There were totally 21 tree species in arbor storey of community *Sarcosperma laurinum*, *Dalbergia hainanensis*-*Polyalthia laui*. The importance value of *Sarcosperma laurinum* was 33.21%, which was the biggest one. Followed by *Dalbergia hainanensis*, *Polyalthia laui*, *Elaeocarpus sylvestris* and *Diospyros susarticulata*, ranking 2 - 5 respectively.

Tree species in arbor storey of 4 communities are mainly from families as Euphorbiaceae, Moraceae, Theaceae, Lauraceae, Fagaceae, Ebenaceae, Papilionaceae and Dipterocarpaceae. There were some valuable native species in Hainan Province, such as *Dalbergia odorifera* (endangered species with special type of wood), *Vatica mangachapoi* (vulnerable species with first class wood), *Litchi chinensis* (vulnerable species with special type of wood), *Hopea exalata* and *Ixonanthes chinensis* (vulnerable species), *Amesidodendron chinense* (with first class wood), etc.

Table 9.1 *Importance value of tree species in different degraded primary forests*

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community 1: *Garcinia Oblongifolia - Hopea exalata*	1	*Garcinia oblongifolia*	15.61	11.50	13.94	41.05
	2	*Hopea exalata*	16.18	12.39	6.41	34.98
	3	*Engelhardtia roxburghiana*	5.78	6.19	9.79	21.77
	4	*Ixonanthes chinensis*	5.78	4.42	6.96	17.17
	5	*Diospyros potingensis*	6.94	5.31	3.84	16.09
	6	*Acronychia oligophlebia*	6.36	6.19	2.06	14.61
	7	*Canarium album*	4.62	5.31	3.66	13.59
	8	*Symplocos lancifolia*	2.89	4.42	3.35	10.67
	9	*Ficus henryi*	1.16	0.88	8.47	10.51
	10	*Schima crenata*	2.31	2.65	3.64	8.61
	11	*Piptanthus laburnifolius*	0.58	0.88	6.73	8.20
	12	*Eriobotrya deflexa*	2.89	2.65	2.26	7.80
	13	*Lithocarpus fenzelianus*	1.73	2.65	2.88	7.27
	14	*Castanopsis fissa*	1.73	1.77	3.62	7.12
	15	*Amesidodendron chinense*	2.31	2.65	2.05	7.02
	16	*Ficus microcarpa*	1.73	2.65	1.26	5.65
	17	*Sapium discolor*	1.73	0.88	2.83	5.45
	18	*Gonocaryum lobbianum*	1.73	2.65	0.94	5.33
	19	*Lithocarpus pseudovestitus*	1.16	1.77	2.06	4.98
	20	*Vatica mangachapoi*	1.16	1.77	0.83	3.76
	21	*Suregada glomerulata*	0.58	0.88	2.19	3.65
	22	*Pithecellobium clypearia*	1.16	1.77	0.70	3.63
	23	*Cinnamomum parthenoxylon*	1.16	0.88	0.91	2.95
	24	*Decaspermum albociliatum*	0.58	0.88	1.46	2.92
	25	*Ficus nervosa*	0.58	0.88	1.31	2.78
	26	*Dolichandrone cauda-felina*	0.58	0.88	1.08	2.54
	27	*Phoebe hungmaoensis*	1.16	0.88	0.48	2.52
	28	*Artocarpus tonkinensis*	0.58	0.88	0.74	2.21
	29	*Photinia benthamiana*	0.58	0.88	0.48	1.94
	30	*Euodia lepta*	0.58	0.88	0.45	1.91
	31	*Polyspora balansae*	0.58	0.88	0.44	1.90
	32	*Erythropsis. colorata*	0.58	0.88	0.43	1.90
	33	*Sarcosperma laurinum*	0.58	0.88	0.42	1.88
	34	*Codiaeum variegatum*	0.58	0.88	0.28	1.75
	35	*Cryptocarya densiflora*	0.58	0.88	0.21	1.67
	36	*Altingia obovata*	0.58	0.88	0.18	1.65
	37	*Bischoffia javanica*	0.58	0.88	0.15	1.62
	38	*Diospyros howii*	0.58	0.88	0.14	1.60
	39	*Litchi chinensis*	0.58	0.88	0.11	1.57
	40	*Toxicodendron vernicifluum*	0.58	0.88	0.11	1.57
	41	*Viburnum odoratissimum*	0.58	0.88	0.10	1.57
	42	*Rhus succedanea*	0.58	0.88	0.03	1.50
Community 2: *Engelhardtia roxburghiana - Garcinia oblongifolia*	1	*Engelhardtia roxburghiana*	24.62	14.71	31.62	70.94
	2	*Garcinia oblongifolia*	22.31	11.76	21.14	55.21
	3	*Ixonanthes chinensis*	10.00	11.76	13.73	35.50
	4	*Symplocos lancifolia*	5.38	5.88	3.78	15.04
	5	*Lithocarpus pseudovestitus*	4.62	5.88	2.57	13.07
	6	*Sarcosperma laurinum*	3.85	4.41	4.01	12.27
	7	*Ficus microcarpa*	3.85	4.41	3.16	11.42
	8	*Dalbergia hainanensis*	2.31	4.41	3.81	10.53
	9	*Diospyros potingensis*	3.08	5.88	1.53	10.49

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	10	*Dalbergia odorifera*	3.85	2.94	3.67	10.46
	11	*Radermachera hainanensis*	2.31	2.94	1.74	6.99
	12	*Canarium album*	2.31	2.94	1.34	6.59
	13	*Lannea coromandelica*	1.54	2.94	0.89	5.37
	14	*Liquidambar formosana*	0.77	1.47	2.93	5.17
	15	*Schima crenata*	0.77	1.47	0.65	2.89
	16	*Photinia benthamiana*	0.77	1.47	0.60	2.84
	17	*Bischoffia javanica*	0.77	1.47	0.51	2.75
	18	*Suregada glomerulata*	0.77	1.47	0.46	2.70
	19	*Acronychia oligophlebia*	0.77	1.47	0.45	2.69
	20	*Sterculia lanceolata* Cav.	0.77	1.47	0.33	2.57
	21	*Gonocaryum lobbianum*	0.77	1.47	0.30	2.54
	22	*Polyspora balansae*	0.77	1.47	0.22	2.46
	23	*Syzygium rysopodum*	0.77	1.47	0.18	2.42
	24	*Glochidion dasyphyllum*	0.77	1.47	0.18	2.42
	25	*Elytranthe cochinchinensis*	0.77	1.47	0.14	2.38
	26	*Sindora glabra*	0.77	1.47	0.03	2.27
Community 3: *Amesidodendron chinense - Garcinia oblongifolia*	1	*Amesidodendron chinense*	14.29	12.12	21.75	48.16
	2	*Garcinia oblongifolia*	17.01	14.14	10.99	42.14
	3	*Engelhardtia roxburghiana*	4.76	6.06	7.63	18.45
	4	*Lithocarpus pseudovestitus*	5.44	4.04	7.23	16.71
	5	*Gonocaryum lobbianum*	6.12	4.04	6.4	16.56
	6	*Polyspora balansae*	6.12	6.06	4.18	16.36
	7	*Symplocos lancifolia*	5.44	7.07	3.16	15.67
	8	*Cleistocalyx conspersipunctatus*	1.36	2.02	7.12	10.50
	9	*Ficus microcarpa*	4.08	3.03	2.47	9.58
	10	*Radermachera hainanensis*	3.4	3.03	2.85	9.28
	11	*Hopea exalata*	3.4	4.04	0.75	8.19
	12	*Canarium album*	2.72	3.03	0.94	6.69
	13	*Litsea lancilimba*	2.72	2.02	1.7	6.44
	14	*Ixonanthes chinensis*	2.04	2.02	1.03	5.09
	15	*Sarcosperma laurinum*	2.04	2.02	0.66	4.72
	16	*Machilus chinensis*	0.68	1.01	1.45	3.14
	17	*Lindera playfairii*	1.36	1.01	0.51	2.88
	18	*Machilus nakao*	0.68	1.01	1.03	2.72
	19	*Pentaphylax euryoides*	1.36	1.01	0.23	2.6
	20	*Ehretia acuminata*	0.68	1.01	0.85	2.54
	21	*Toxicodendron vernicifluum*	0.68	1.01	0.73	2.42
	22	*Bischoffia javanica*	0.68	1.01	0.63	2.32
	23	*Pithecellobium clypearia*	0.68	1.01	0.6	2.29
	24	*Diospyros potingensis*	0.68	1.01	0.48	2.17
	25	*Sindora glabra*	0.68	1.01	0.36	2.05
	26	*Photinia benthamiana*	0.68	1.01	0.36	2.05
	27	*Eriobotrya deflexa*	0.68	1.01	0.36	2.05
	28	*Piptanthus laburnifolius*	0.68	1.01	0.33	2.02
	29	*Phoebe hungmaoensis*	0.68	1.01	0.21	1.9
	30	*Litchi chinensis*	0.68	1.01	0.19	1.88
	31	*Caryota mitis*	0.68	1.01	0.17	1.86
	32	*Peltophorum tonkinense*	0.68	1.01	0.16	1.85
	33	*Ficus auriculata*	0.68	1.01	0.16	1.85
	34	*Acronychia oligophlebia*	0.68	1.01	0.1	1.79
	35	*Pterospermum heterophyllum*	0.68	1.01	0.1	1.79

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community 4: *Sarcosperma laurinum*, *Dalbergia hainanensis* - *Polyalthia laui*	1	*Sarcosperma laurinum*	12.82	12.90	7.49	33.21
	2	*Dalbergia hainanensis*	5.13	6.45	17.99	29.57
	3	*Polyalthia laui*	12.82	9.68	3.43	25.93
	4	*Elaeocarpus sylvestris*	5.13	3.23	16.74	25.10
	5	*Diospyros susarticulata*	5.13	6.45	9.66	21.24
	6	*Antirhea chinensis*	5.13	6.45	4.72	16.30
	7	*Garcinia oblongifolia*	7.69	6.45	1.65	15.80
	8	*Cratoxylum cochinchinense*	2.56	3.23	8.88	14.67
	9	*Wendlandia merrilliana*	5.13	6.45	2.27	13.85
	10	*Ficus variolosa*	7.69	3.23	2.64	13.56
	11	*Lithocarpus elmerrillii*	2.56	3.23	7.02	12.81
	12	*Ormosia pinnata*	2.56	3.23	4.04	9.83
	13	*Lithocarpus corneus*	5.13	3.23	1.19	9.55
	14	*Syzygium buxifolium*	2.56	3.23	2.85	8.64
	15	*Vitex tripinnata*	2.56	3.23	2.85	8.64
	16	*Suregada glomerulata*	2.56	3.23	1.75	7.54
	17	*Acronychia oligophlebia*	2.56	3.23	1.56	7.35
	18	*Engelhardtia roxburghiana*	2.56	3.23	1.22	7.01
	19	*Goniothalamus howii*	2.56	3.23	0.99	6.78
	20	*Neolitsea obtusifolia*	2.56	3.23	0.74	6.53
	21	*Phoebe henryi*	2.56	3.23	0.30	6.09

9.1.2 Community structure

The community of degraded primary forest had the structure of stratified uneven-aged forest, composed by arbor storey, shrub storey and grass storey, and the canopy density is 1.0. The arbor storey can be classified as two sub-storeys, one with H (tree height) larger than 8 m while the other with H less than 8 m. Most of valuable trees in the sub-storey I in arbor storey have been used while there are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey had rich species, such as *Dalbergia odorifera*, *Sarcosperma laurinum*, *Ormosia pinnata*, *Lithocarpus elmerrillii*, *Dolichandrone cauda-felina*, *Cryptocarya densiflora*, *Engelhardtia roxburghiana* and other tree saplings, as well as *Ervatamia officinalis*, *Aporosa chinensis* and other shrub species. Species in grass storey were *Psychotria rubra*, *Elaeocarpus petiolatus*, *Garcinia oblongifolia*, *Livistona chinensis*, *Aporosa chinensis* and other seedlings, and grass species as *Indocalamus latifolius* and *Chrysopogon aciculatus*. In addition, the community of degraded primary forest has rich vines, such as *Smilax china*, *Piper hainanense* and *Abrus mollis*. Thus shrub storey and grass storey in each forest stand still have valuable tree saplings and seedlings.

9.1.3 Species diversity of arbor storey

Species diversity of arbor storey in different communities of degraded primary forest in the demonstration area was shown in Table 9.2. Species Richness (R) of communities 1-4 were 42, 26, 35 and 21respectively. Diversity index (SW) were 4.46, 3.61, 4.28 and 4.14 respectively. The Evenness (E) of communities were 0.81, 0.77, 0.81 and 0.94 while Ecological Dominance (ED) were 0.07, 0.13, 0.07 and 0.04 respectively.

On the whole, Species Richness (R) in arbor storey of degraded primary forest was lower than that of adjacent tropical lowland rainforest in Baishui forestry farm and Nanxi forestry farm located in Diaoluoshan Nature Reserve (Huang K Y, 2007). Diversity index was close to that of low-elevation tropical forest in Diaoluoshan Nature Reserve (4.04 - 4.17), but less than that of tropical primary forest in Jianfengling Mountain (5.78 - 6.28) (Li Y D, 1997; Xu H, et al, 2009).

Table 9.2 *Species diversity in tree stratum of degraded primary forests*

Community	Forest storey	R	SW	ED	E
Community 1	Arbor storey	42	4.46	0.07	0.81
	Sub storey Ⅰ	30	4.39	0.06	0.89
	Sub storey Ⅱ	29	3.89	0.10	0.80
Community 2	Arbor storey	26	3.61	0.13	0.77
	Sub storey Ⅰ	12	2.83	0.18	0.79
	Sub storey Ⅱ	24	3.73	0.11	0.81
Community 3	Arbor storey	35	4.28	0.07	0.81
	Sub storey Ⅰ	25	3.93	0.08	0.85
	Sub storey Ⅱ	27	2.60	0.10	0.55
Community 4	Arbor storey	21	4.14	0.04	0.94
	Sub storey Ⅰ	6	2.50	0.07	0.97
	Sub storey Ⅱ	15	3.64	0.06	0.93

9.1.4 Stand growth

Degraded primary forest stand growth was shown in Table 9.3. The average DBH of arbor storey of 4 communities was 10.2 - 14.3 cm and the average height was 8.50 - 13.39 m. The average volume per unit area was 142.51 - 199.44 m^3/ ha, significantly lower than that of mountain rainforest in Bawangling, Hainan Island (Jiang Y X and Lu J P, 1991; Huang Q L, 2001; Huang Q L et al, 2002). Stand density was 2,321 - 3,545N/ ha, higher than that of primary forest of mountain rainforest in Bawangling. Trees were mostly in sub storey Ⅱ and the number of trees in sub storey Ⅱ accounted for 48.30 - 79.49% of the total number of trees in degraded primary forest communities. However, the volume of trees in sub storey Ⅰ accounted for 67.11 - 91.38% of the total volume.

Table 9.3 *Forest mensuration factors of degraded primary forests*

Community	Forest storey	Average DBH (cm)	Average Height (m)	Stand density		Volume	
				Density (N/ha)	Percentage (%)	Volume (m^3/ha)	Percentage (%)
Community 1	Arbor storey	12.68	12.33	2,595	100	191.55	100
	Sub storey Ⅰ	17.65	14.23	1,005	38.73	164.28	85.77
	Sub storey Ⅱ	8.09	6.60	1,590	61.27	27.27	14.23
Community 2	Arbor storey	10.20	10.05	3,545	100	142.51	100
	Sub storey Ⅰ	14.29	12.22	1,091	30.77	103.30	72.48
	Sub storey Ⅱ	7.71	6.75	2,455	69.23	39.21	27.52
Community 3	Arbor storey	13.16	13.39	2,321	100	199.44	100
	Sub storey Ⅰ	16.79	14.62	1,200	51.70	183.17	91.38
	Sub storey Ⅱ	7.52	6.83	1,121	48.30	17.27	8.62
Community 4	Arbor storey	14.30	8.50	2,925	100	195.12	100
	Sub storey Ⅰ	24.06	10.29	600	20.51	130.94	67.11
	Sub storey Ⅱ	10.74	6.18	2,325	79.49	64.18	32.89

9.1.5 DBH distribution

As shown in Table 9.4 and Figure 9.1, the DBH distribution range of degraded primary forests was 4 - 48 cm and the maximum diameter was 46.30 cm. The number of trees in diameter class 4cm didn't include trees with DBH of 2 - 4.9 cm, so the number of trees in diameter class 4 cm was lower than that of diameter class 8 cm significantly. The DBH distribution of each degraded primary forest community showed the inverse J shape.

Table 9.4 *The DHB distribution of degraded primary forests*

Diameter class (cm)	The percent of trees in each diameter class (%)			
	Community 1	Community 2	Community 3	Community 4
4	20	17	11	11
8	35	48	36	37
12	24	21	30	23
16	10	7	12	14
20	6	6	5	7
24	3	1	2	4
28	1	0	1	3
32	0	0	2	2
36	0	0	1	0
40	0	0	1	0
44	1	0	0	0
48	1	0	0	0

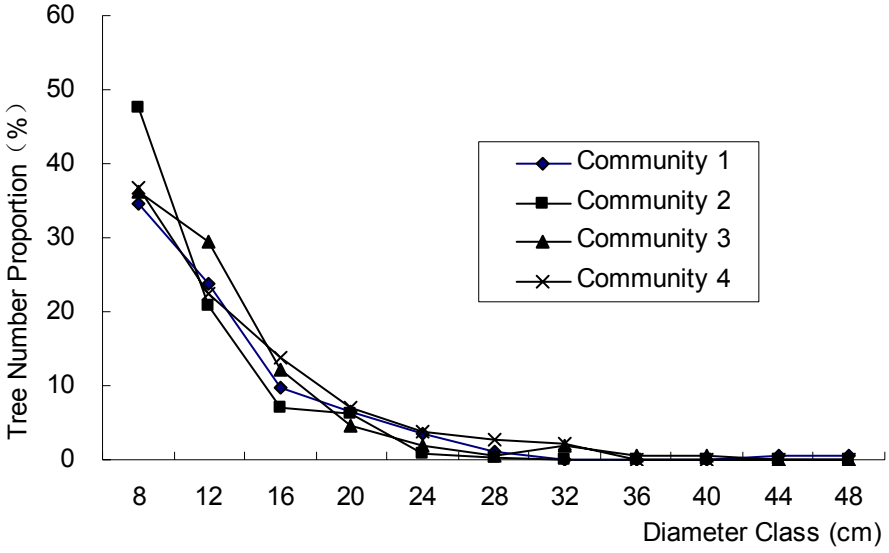


Figure 9.1 *The DHB distribution of degraded primary forests*

9.2 Characteristics of secondary forest

9.2.1 Dominant species

Importance value of plants in arbor storey of secondary forest in Dagan demonstration area was shown in Table 9.5. Relative dominance was calculated using Ground Diameter other than DBH for the importance value calculation of community *Symplocos laurina- Radermachera hainanensis* and community *Lithocarpus pseudovestitus*. There were totally 25 tree species in arbor storey of community *Aporosa chinensis*. The importance value of *Aporosa chinensis* was 60.32%, which was the biggest one. Followed by *Lithocarpus corneus* and *Garcinia oblongifolia*, the importance values were 23.58% and 22.38% respectively. The importance values of *Liquidambar formosana*, *Lithocarpus howii*, *Artocarpus tonkinensis*, *Castanopsis hainanensis*, *Syzygium buxifolium*, *Ormosia pinnata, Ellipanthus glabrifolius* and *Sapium discolor* ranked 4 - 11 respectively while those of other 14 species were less than 10%. There were totally 6 tree species in arbor storey of community *Trema tomentosa* and species *Trema tomentosa* had the biggest importance value, which was up to 195.09%. The importance values of *Indigofera galegoides*, *Helicteres hirsuta*, *Ellipanthus glabrifolius*, *Evodla meliaefolia* and *Aporosa chinensis* decreased in turns. There were totally 12 tree species in arbor storey of community *Symplocos laurina- Radermachera hainanensis*. The important value of *Symplocos laurina* was 78.39%, which was the biggest one. Followed by *Radermachera hainanensis* withan importance value of 58.75%. The importance values of *Photinia benthamiana*, *Chukrasia tabularis* and *Lannea coromandelica* ranked 3 - 5 respectively. There were totally 32 tree species in arbor storey of community *Lithocarpus pseudovestitus*. The importance value of *Lithocarpus pseudovestitus* was 48.67%, which was the biggest one. Followed by *Sterculia lanceolata* with an importance value of 20.50%. The importance values of *Sapium discolor*, *Canarium album*, *Memecylon ligustrifolium*, *Glochidion dasyphyllum*, *Sindora glabra*, *Suregada glomerulata* and *Glochidion wrightii* ranked 3 - 9 respectively while those of other 23 species were less than 10%.

Table 9.5 *Importance value of plant species in different secondary forest communities*

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community 1: *Aporosa chinensis*	1	*Aporosa chinensis*	30.77	12.50	17.05	60.32
	2	*Lithocarpus corneus*	8.97	6.25	8.36	23.58
	3	*Garcinia oblongifolia*	10.26	6.25	5.87	22.38
	4	*Liquidambar formosana*	2.56	3.13	13.01	18.70
	5	*Lithocarpus howii*	7.69	3.13	4.72	15.54
	6	*Artocarpus tonkinensis*	2.56	3.13	9.74	15.43
	7	*Castanopsis hainanensis*	2.56	6.25	3.93	12.74
	8	*Syzygium buxifolium*	1.28	3.13	7.71	12.12
	9	*Ormosia pinnata*	2.56	6.25	2.90	11.71
	10	*Ellipanthus glabrifolius*	3.85	3.13	4.10	11.07
	11	*Sapium discolor*	1.28	3.13	5.71	10.12
	12	*Ormosia fordiana*	2.56	3.13	3.90	9.59
	13	*Indigofera galegoides*	3.85	3.13	1.95	8.92
	14	*Cratoxylum. cochinchinense*	2.56	3.13	1.54	7.23
	15	*Wrightia pubescens*	2.56	3.13	1.12	6.80
	16	*Beilschmiedia intermadida*	2.56	3.13	1.01	6.70
	17	*Lannea coromandelica*	1.28	3.13	1.78	6.19
	18	*Lithocarpus elmerrillii*	1.28	3.13	1.23	5.63
	19	*Memecylon ligustrifolium*	1.28	3.13	1.07	5.48
	20	*Acronychia oligophlebia*	1.28	3.13	0.93	5.34
	21	*Dalbergia hainanensis*	1.28	3.13	0.87	5.27
	22	*Glochidion puberum*	1.28	3.13	0.45	4.85
	23	*Psychotria rubra*	1.28	3.13	0.38	4.79
	24	*Radermachera frondosa*	1.28	3.13	0.36	4.76
	25	*Aodoratissima*	1.28	3.13	0.32	4.72
Community 2: *Trema tomentosa*	1	*Trema tomentosa*	77.27	37.50	80.32	195.09
	2	*Indigofera galegoides*	9.09	12.50	10.10	31.69
	3	*Helicteres hirsuta*	9.09	12.50	3.68	25.27
	4	*Ellipanthus glabrifolius*	1.52	12.50	4.02	18.03
	5	*Evodla meliaefolia*	1.52	12.50	1.21	15.22
	6	*Aporosa chinensis*	1.52	12.50	0.68	14.69
Community 3: *Symplocos Laurina - Radermacher a hainanensis*	1	*Symplocos laurina*	29.67	20.00	28.72	78.39
	2	*Radermachera hainanensis*	23.08	10.00	25.67	58.75
	3	*Photinia benthamiana*	9.89	5.00	11.00	25.89
	4	*Chukrasia tabularis*	7.69	15.00	2.37	25.06
	5	*Lannea coromandelica*	6.59	10.00	5.35	21.94
	6	*Glochidion wrightii*	4.40	10.00	5.27	19.67
	7	*Suregada glomerulata*	8.79	5.00	5.50	19.29
	8	*Parapyrenaria multisepala*	2.20	5.00	9.78	16.98
	9	*Euodia lepta*	3.30	5.00	2.06	10.36
	10	*Glochidion dasyphyllum*	2.20	5.00	2.44	9.64
	11	*Radermachera frondosa*	1.10	5.00	1.22	7.32
	12	*Sindora glabra*	1.10	5.00	0.61	6.71
Community 4: *Lithocarpus pseudovestitus*	1	*Lithocarpus pseudovestitus*	19.63	5.66	23.38	48.67
	2	*Sterculia lanceolata*	8.59	5.66	6.25	20.50
	3	*Sapium discolor*	8.59	3.77	5.27	17.63
	4	*Canarium album*	3.68	3.77	6.71	14.16
	5	*Memecylon ligustrifolium*	4.29	1.89	7.58	13.76
	6	*Glochidion dasyphyllum*	4.29	3.77	4.42	12.48
	7	*Sindora glabra*	4.29	5.66	1.16	11.12

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	8	*Suregada glomerulata*	3.07	3.77	3.89	10.73
	9	*Glochidion wrightii*	2.45	3.77	3.90	10.13
	10	*Ormosia pinnata*	3.68	5.66	0.64	9.98
	11	*Psychotria rubra*	3.68	5.66	0.55	9.89
	12	*Commersonia bartramia*	3.68	3.77	2.06	9.51
	13	*Garcinia oblongifolia*	0.61	1.89	6.77	9.27
	14	*Sarcosperma laurinum*	2.45	1.89	4.55	8.89
	15	*Wrightia pubescens*	1.84	3.77	3.20	8.81
	16	*Glochidion puberum*	3.07	3.77	1.44	8.28
	17	*Dolichandrone cauda-felina*	1.84	1.89	2.85	6.58
	18	*Ficus microcarpa*	1.84	3.77	0.97	6.58
	19	*Lannea coromandelica*	2.45	1.89	1.69	6.03
	20	*Engelhardtia roxburghiana*	1.84	3.77	0.32	5.94
	21	*Cinnamomum parthenoxylon*	1.23	3.77	0.53	5.53
	22	*Alangium chinense*	1.23	1.89	2.41	5.52
	23	*Symplocos laurina*	1.23	1.89	2.41	5.52
	24	*Euodia lepta*	1.23	1.89	1.90	5.02
	25	*Elaeocarpus petiolatus*	2.45	1.89	0.42	4.76
	26	*Evodla meliaefolia*	0.61	1.89	1.69	4.19
	27	*Radermachera hainanensis*	1.23	1.89	1.02	4.14
	28	*Amesidodendron chinense*	1.84	1.89	0.07	3.80
	29	*Pterospermum heterophyllum*	0.61	1.89	1.08	3.58
	30	*Artocarpus lingnanensis*	1.23	1.89	0.08	3.19
	31	*Chukrasia tabularis*	0.61	1.89	0.66	3.16
	32	*Cryptocarya densiflora*	0.61	1.89	0.15	2.65

Tree species in arbor storey of 4 communities are mainly from families as Euphorbiaceae, Fagaceae, Ulmaceae, Bignoniaceae, Sterculiaceae and Papilionaceae. There were some valuable native species in Hainan Province, such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, and important species for commercial forest in Hainan Province, such as *Trema tomentosa*, as well as afforestation species like *Dolichandrone cauda-felina*, etc.

9.2.2 Community structure

The community of secondary forest had the simple structure and the canopy density was 1.0. Compared to degraded primary forests, structure of secondary forest communities was less significantly differentiated and only community *Aporosa chinensis* and community *Trema tomentosa* had obvious arbor storey and shrub storey. On the whole, communities of secondary forest had arbor species such as *Aporosa chinensis*, *Lithocarpus corneus*, *Liquidambar formosana*, *Artocarpus tonkinensis*, *Trema tomentosa*, *Radermachera hainanensis*, *Lithocarpus pseudovestitus* and *Sterculia lanceolata*, as well as *Helicteres hirsute*, *Glochidion dasyphyllum*, *Dolichandrone cauda-felina*, *Glochidion wrightii*, *Psychotria rubra*, *Cratoxylum*, *Cochinchinense* and other shrub species. Grass storey had rich species and the coverage was 100%. There are *Aporosa chinensis*, *Euodia lepta*, *Psychotria rubra*, *Trema tomentosa*, *Ormosia pinnata*, *Diospyros strigosa*, *Flacourtia indica*, *Acronychia oligophlebia*, *Arytera littoralis*, *Wrightia pubescens*, *Phoebe henryi* and other tress seedlings, and herbaceous plants such as *Chrysopogon aciculatus*, *Kyllinga brevifolia* etc. In addition, the community of secondary forest has rich vines, such as *Smilax china*,

Papilionaceae, *Pueraria lobata* and *Abrus mollis*. Thus communities of secondary forest still have valuable tree saplings and seedlings.

9.2.3 Species diversity of arbor storey

As shown in Table 9.6, there are significant differences in species diversity of arbor storey among different communities of secondary forest in the demonstration area. Species Richness (R) of secondary forest communities were 25, 6, 24 and 32 respectively. Diversity index (SW) were 3.79, 1.19, 2.94 and 4.41 respectively. The Evenness (E) of communities were 0.82, 0.46, 0.82 and 0.88 while Ecological Dominance (ED) were 0.12, 1.00, 0.16 and 0.07respectively. Compared to degraded primary forest, secondary forest showed much lower species richness and higher ecological dominance.

Table 9.6 *Characters of secondary forests in arbor storey*

Factors	Community 1	community *2*	Community *3*	Community *4*
Species Richness (R)	25	6	24	32
Diversity Index (SW)	3.79	1.19	2.94	4.41
Evenness (E)	0.82	0.46	0.82	0.88
Ecological Dominance (ED)	0.12	1.00	0.16	0.07
Average (DBH) /cm	6.44	4.48	-	-
Average Height (H)/m	5.23	4.74	-	-
Average Density (N) /N·hm^{-2}	5,850	6,600	6,828	8,300
Average Volume (V)/m^3·hm^{-2}	10.12	26.09	-	-

Note: DBH of trees in *Symplocos laurina* community and *Lithocarpus pseudovestitus* community were not inventoried.

9.2.4 Stand growth

Stand growth of secondary forest was shown in Table 9.6. The average DBH of arbor storey of community *Aporosa chinensis* and community *Trema tomentosa* were 6.44 cm and 4.48 cm while the average height were 5.23 m and 4.74 m respectively. The average volume were 10.12 m^3/ ha and 26.09 m^3/ ha, significantly lower than that of degraded primary forest. The stand density of 4 secondary forest communities was between 5,850 - 8,300 N/ ha, higher than that of degraded primary forest.

9.2.5 DBH distribution

The DBH distribution of secondary forest in demonstration area was described by analysis of DBH distribution of community *Aporosa chinensis* and community *Trema tomentosa* (see Figure 9.2). The DBH distribution range of secondary forests was 2 - 16 cm, showing the inverse J shape and the maximum diameter was 15.80 cm.

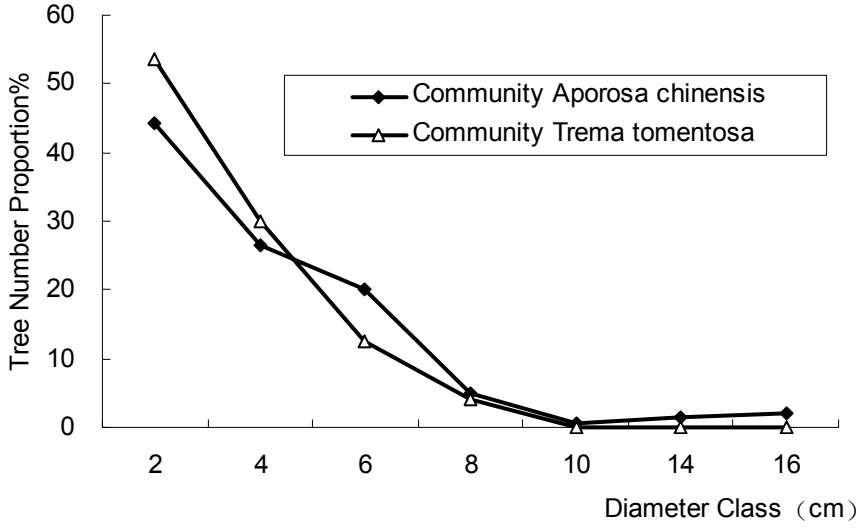


Figure 9.2 *The DHB distribution of secondary forests*

9.3 Characteristics of degraded forest land

One community of degraded forest land in the demonstration area was inventoried in March, 2009. A strip plot was set up with an area of 360 m^2 composed of 10 quadrats (6 m ×6 m) for the community. Tree species and height in each quadrat were measured and the results showed that there were few arbor species and shrub species in degraded forest land (see Table 9.7) and the heights were between 0.5 m and 2 m.

Table9.7 *Main species in degraded lands*

No.	Species	Remarks	No.	Species	Remarks
1	*Aporosa chinensis*	arbor species	13	*Antirhea chinensis*	shrub species
2	*Sterculia lanceolata*	arbor species	14	*Smilax corbularia*	shrub species
3	*Bridelia monoica*	arbor species	15	*Micromelum falcatum*	shrub species
4	*Flacourtia indica*	arbor species	16	*Licuala spinosa*	shrub species
5	*Ficus virens*	arbor species	17	*Gonocaryum lobbianum*	arbor species
6	*Sterculia hainanensis*	arbor species	18	*Microcos paniculata*	arbor species
7	*Arytera littoralis*	arbor species	19	*Diospyros strigosa*	arbor species
8	*Randia sinensis*	shrub species	20	*Cratoxylum. cochinchinense*	arbor species
9	*Ervatamia hainanensis*	shrub species	21	*Macaranga hemsleyana*	arbor species
10	*Croton laui*	shrub species	22	*Caryota mitis*	arbor species
11	*Randia depauperata*	shrub species	23	*Salacia hainanensis*	vine species
12	*Acronychia pedunculata*	shrub species		-	

9.4 Site level restoration strategies

9.4.1 Restoration of degraded primary forest

Degraded primary forest in Dagan demonstration area was formed from repeated use of primary forest, mainly at the peak of hills in the southern and southeastern areas. Analysis of characteristics showed that Degraded primary forests still retain the main characteristics of the original forest, such as species composition, soil structure and stand structure, capacity of natural regeneration, and an important function of ecological protection, so a basic management principle of forest restoration is to remove the causes for further disturbance and degradation, and promote restoration through natural succession.

It is the key to identify the forest stands or sites to be protected, which should have seed, wildlings or seed sources in neighborhood to ensure the success of natural restoration. The community of degraded primary forest had a stratified uneven-age structure, composed by arbor storey, shrub storey and grass storey, and the canopy density was is 1.0. There are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* in arbor storey. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings, such species as *Dalbergia odorifera*, *Sarcosperma laurinum*, *Ormosia pinnata*, *Lithocarpus elmerrillii*, *Dolichandrone cauda-felina*, *Cryptocarya densiflora*, *Engelhardtia roxburghiana* and other tree species, *Ervatamia officinalis*, *Aporosa chinensis* and other shrub species, as well as *Indocalamus latifolius* and *Chrysopogon aciculatus*. Therefore, degraded primary forest has the capability of natural regeneration and this type of forest can be restored as managed primary forest, even converted to primary forest by protecting the site from further disturbance or stress factors such as deforestation, over harvesting of timber and non-timber forest products, slash and burn, etc. to restore biodiversity, structure, function and productivity of ecosystem by allowing natural regeneration and succession. This strategy is sometimes called “passive restoration” (Grieser J A, 1997) and is particularly suited to situations where the financial resources for FLR activities are limited. This strategy is probably one of the interventions with low cost and can be extended in many areas. Another measure to promote the protection of degraded primary forest is to plant live fence. Planting *Acacia mangium*, *Eucalyptus* and other fast-growing species as live fence in the boundary among planted forest, degraded forest land and agricultural land can protect degraded primary forest from further human disturbance.

9.4.2 Management of secondary forest

There are two types of ownerships of secondary forest in Dagan demonstration area: one is collective ownership with which the forest was originated from clear-cutting of degraded primary forest, and the other is individual ownership with which the forest was regenerated through a natural process after more than 10 years’ abandonment. Forest stands with different ownerships should balance different conflicts and should be restored using different interventions.

Collective owned secondary forest, such as community *Symplocos laurina- Radermachera hainanensis* and community *Lithocarpus pseudovestitus*, its arbor storey has valuable native trees such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, etc. So this type of secondary forest should take

the same forest restoration measures as that of degraded primary forest, protective “decompression ", that is to achieve natural recovery with use of existing saplings, seedlings by establishing live fence and avoiding human disturbances as much as possible. Individual owned secondary forest, such as community *Aporosa chinensis* and community *Trema tomentosa*, having important timber production species such as *Trema tomentosa* and species like *Dolichandrone cauda-felina* which can be used for afforestation, but lack of valuable native species, should take management strategies of protection and enrichment planting to improve ecological integrity and community benefits by using existing tree seedlings and saplings for protective restoration, together with plantings of valuable native species to restore forest communities with trees of high commercial values.

Species selection is the basis for forest restoration. It is crucial to select species of economic, ecological or social interest for the success of enrichment planting. Selecting species to be planted needs to consult local villagers. Ranking of favorite tree species was defined by the process of public participation: *Dalbergia odorifera*, *Aquilaria sinensis* and *Acacia mangium*, etc. So *Dalbergia odorifera* and *Aquilaria sinensis* were selected as species to be planted in the demonstration area because they are valuable native species. The two most common enrichment planting options are line plantings and gap plantings. The choice of method depends primarily on the condition of the forest stand, the restoration objective and the species used. The gap planting method is generally recommended in degraded, over-logged forests while line planting is more suitable if the surrounding trees in the stand are small (less than 10 cm diameter at breast height).

The biggest conflict for restoration of collective owned forest is to avoid the disturbances caused by plantation expanding. Individual family could not be negotiated for the implementation of restoration interventions, e.g. the species selection, but should be made understanding of the ecological function of this type of forest and thereby abide by the "logging ban" requirement. The biggest conflict for restoration of individual owned secondary forest is to protect or develop this type of forest to planted economic forest. Local villagers are the decision makers for this conflict, which means the secondary forest is facing human interventions of converting to other uses all the time. Therefore, forest owners should be consulted about specific restoration activities such as tree species selection. It is a principle to select acceptable native species to balance economic benefit and ecological services, that is to meet the “double filter” condition of FLR.

In order to reflect diversity of secondary forest management, collective owned forest has no specific conflict stakeholders so that this type of forest should be managed for providing environment services and forest products only used for firewood. Individual owned secondary forest has conflict of economic benefit and ecological services during restoration process so that this type of forest could be managed with preference to economic benefits, restoring ecological integrity and enhance income of villagers at the same time.

9.4.3 Rehabilitation of degrade forest land

The rehabilitation for degraded forest land focused primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Analysis of characteristics showed that the degraded forest land had better soil condition, but had few trees seedlings and saplings. Afforestation is the main rehabilitation strategy because restoration relying on protection will take a long time. As degraded forest land with characteristics of low soil fertility and poor soil structure, soil erosion and subjected to frequent human disturbance, restoration activities are better focused on the recovery and maintenance of primary

processes. First select pioneer trees as nurse crop, important silvicutrual characteristics for species suitable for nurse crop include fast-growing, tolerance to drought and diseases, if necessary, select exotic species, such as *Eucalyptus*, *Acacia mangium*, etc. Then valuable native species are planted understory, such as *Dalbergia odorifera*, *Aquilaria sinensis*. Forest will be logged in a few years to increase the light intensity needed by native species. In this way, both rehabilitation of degraded forest ecosystem and income of local villagers will be improved.

10 Application of PRA

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used in the FLR planning of the county.

FLR makes use of collaborative approaches to harmonize the many land-use decisions of stakeholders with the aims of restoring ecological integrity and enhancing the development of local communities and national economies. Implied in the word “process” are three key principles: (1) It is participatory; (2) It is based on adaptive management and thus responsive to social, economic and environmental change; and (3) It requires a clear and consistent evaluation and learning framework. “Participatory” continues throughout the life of the initiative, from the data collection, landscape dynamics and driving forces analysis to identifying priority sites. As one of the important differences between FLR and many other restoration-oriented technical responses, meaningful public participation is the basis and prerequisite of implementing FLR and the key for the successful implementation of forest landscape restoration.

Taking Dagan FLR demonstration area as a case, this chapter studied the application of PRA methods in FLR initiative through the use of the PRA tools, combined with community-level FLR planning and implementation process.

10.1 Using PRA tools

FLR initiatives at community level is a process that stakeholders in the community analyze the problems in forest landscapes and make FLR plan together so as to restore the community ecological integrity and improve the human well-being of the residents.

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used here and this chapter focuses primarily on the use of Community Workshop, Field Survey, Participatory Forest Inventory, Semi-structured Interview, and Matrix and Ranking in the community FLR.

10.1.1 Community Workshop

Community workshops were held in Dagan FLR demonstration area in May 2008, March 2009 and May 2009 respectively. The main purpose of the first community workshop was to make the villagers understand FLR initiative, encourage their active participation and to identify the key difficulties and the solution that villagers think in the current community development. The first community workshop was held on May 14, 2008 with the help from Qunying Town leaders and there were totally 171 participants (at least one person per family), including 68 women. The following items were presented to villagers: (1) Introduction to purpose, background and content of FLR initiative at community level; (2) Introduction of the FLR work group; (3) Description of the purpose, task and activity arrangement of FLR work group; (4) How to collaborate and participate for villagers; (5) Help villagers to elect village representatives to implement FLR initiative. The second community workshop were held in March 24, 2009 after field survey and participatory forest inventory (Subcompartment division and subcompartment inventory), aiming at verifying the

boundaries and ownership (householder) of subcompartments and getting feedback of FLR draft planning from villagers to correct the plan timely. As the priority sites need to be identified in this meeting, most sites are collectively owned degraded primary forest and secondary forest, there were totally 421 participants, including 156 women, meeting the request of 2/3 of the villagers to participate in the meeting. The community workshop were held in 3 villages respectively because of the large number of participants. Problems, causes and solutions in Dagan FLR denonstration area, ranking of favorite tree species, verifying maps of landscape mosaic, and identifying the ownership of priority sites were presented in the meeting. The third community workshop was held in May 26, 2009 before implement site level restoration measures and aimed at getting the feedback of site level restoration interventions, passing community FLR Plan by vote and signing contracts related to implementing restoration measures. There were 154 villagers participated in the meeting, at least one person per family, including 53 women.

10.1.2 Field survey

Based on topographic maps, cadastral maps and interpreted RS images, land-use, ownership, management history and the future land use of each patch was identified through field visits, direct observation and villagers' interview. Field survey was conducted during November, December 2008 and March, April 2009, aiming at identifying the patch boundaries with different ownerships or different landscape element types. The following steps were included in the field survey: (1) To find acquainted informants who are willing to cooperate, such as the leaders of villages, the former Ranger, etc.; (2) To identify survey route after discussions with key informants; (3) To conduct survey and to communicate, discuss with villagers; (4) To draw the patch boundaries together with key informants and to indicate the specific information of each patch combined with villager interviews; (5) To check the patch boundaries and to draw maps of landscape mosaic in different periods.

10.1.3 Participatory forest inventory

Subcompartment division and subcompartment cruise were conducted in Dagan FLR demonstration area. Community characteristics and forest measuration characteristics of degraded primary forest and secondary forest in demonstration area were also inventoried. Investigators should include at least one key informants (or villager representatives),so as to take advantage of local knowledge and help the villagers understand the importance of biodiversity conservation and sustainable use of existing forest resources, thereby assisting villagers to analyze the problems and possible countermeasures of current forest management activities. Experience shows that local residents are very concerned about how to use forest to maintain and improve their daily lives, and the ability, security to benefit from the use of forest resources. There is no conflict on the use of forest in community because of local rules and regulations. The main conflicts on forest resources are between government and community, as well as forest users of different communities.

10.1.4 Semi-structured interview

Individual farmers were interviewed on the topic of forest degradation and restoration based on the problems found in field survey and forest inventory by means of semi-structured interview. This tool were used in four parts: determination of patch boundaries and ownerships, analysis of the driving forces of landscape changes, analysis of problems and solutions of forest management, and consultations of

restoration measures for priority sites. Semi-structured interview was also important tool for collecting socio-economic conditions of residents.

10.1.5 Matrix and ranking

Enough information and a lot of problems have been obtained from community workshops, forest inventories, semi-structured interviews, group discussions, participatory mapping and other steps. The intrinsic relationship and possible results were found by classification and analysis the information and materials collected. Then the problems were ranked and strategies and methods were analyzed preliminarily. Different people have different views on the same thing because of differences on preferences, knowledge, and experience. The purpose of matrix and ranking was to collect the different perspectives on tree species selection, problems and development planning of community and other issues so as to make decisions representing the majority. Matrix and ranking was mainly used during comunity workshops.

10.2 Results analysis

10.2.1 Natural resources

Dagan FLR demonstration area is located in the Qunying town, with the area of 399.48 ha. Landforms of the areas are mostly low mountains, hills, with a landform pattern of lowering down from South to North, and from East and West to the Central with an elevation of 30-340 m. Species diversity of the region is rich. Major soil is brown-yellow soil. The site is suited for the growth of variable tropical cash crops because of full rainfall, good light and temperature conditions and suitable climate. There are totally 5 reservoirs and one stream throughout the demonstration area, providing irrigation water for agriculture and forestry development. Forest resources were rich twenty years ago. The natural forest has reduced sharply due to deforestation, slash and burn and conversion to rubber plantations. Intact degraded primary forest and secondary forest can only be found in the hill peaks and remote areas not accessible by human activities while areas in the foot of hills, close to human settlements and with access to water were replaced by rubber trees, cassava, litchi, and mango plantation.

There are 89.61ha natural forests and 240.30 ha plantation now in Dagan FLR demonstration area. The areas of degraded primary forest and secondary forest were 42.06 ha and 47.55 ha respectively. There are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* in degraded primary forest communities. Secondary forest communities have also some valuable native species in Hainan Province, such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, and important species for commercial forest in Hainan Province, such as *Trema tomentosa*, as well as afforestation species like *Dolichandrone cauda-felina*, etc. Species used for plantation are *Areca catechu*, rubber tree, *Eucalyptus*, with the area of 166.36 ha, 45.86 ha and 10.02 ha respectively. The area of plantation less than 5 years old is 151.70 ha while those more than 5 years old is 57.70 ha.

Natural forest has diverse non-timer products, medicinal plant such as *Bridelia tomentosa*, *Sapium discolor* and *Pueraria lobata* can be used for microbial resistance, *Millettia speciosa* can be used for treatment of nervous system diseases and enhancement of immune function, *Sterculia lanceolata*, *Papilionaceae* can

be used for treatment of bruises, fruits such as longan, *Cleistocalyx conspersipunctattum* and *Canthiun horridum*, aromatic plant such as *Chukrasia tabularis*, as well as ornamental plant *Caryota ochlandra*.

10.2.2 Socio-economic aspects

Dagan FLR demonstration area, including three villages (Dagan, Fenyou and Fenjie village), is a typical minority nationality habitat, belonging to the Li minority area, economic development lags behind the county average, The total number of families in the demonstration area is 134 in 2009 with a total population of 586 (Li nationality), including 348 men and 259 women. There are 64 families, 228 people with 151 labors in Fenyou village, 40 families, and 186 people with 110 labors in Fenjie village while there are 60 families, 224 people with 153 labors in Dagan village. The annual per capita net income is about 110 US$ (see Figure 10.1). In 2009, there are totally 134 migrant workers, most of which are young people.

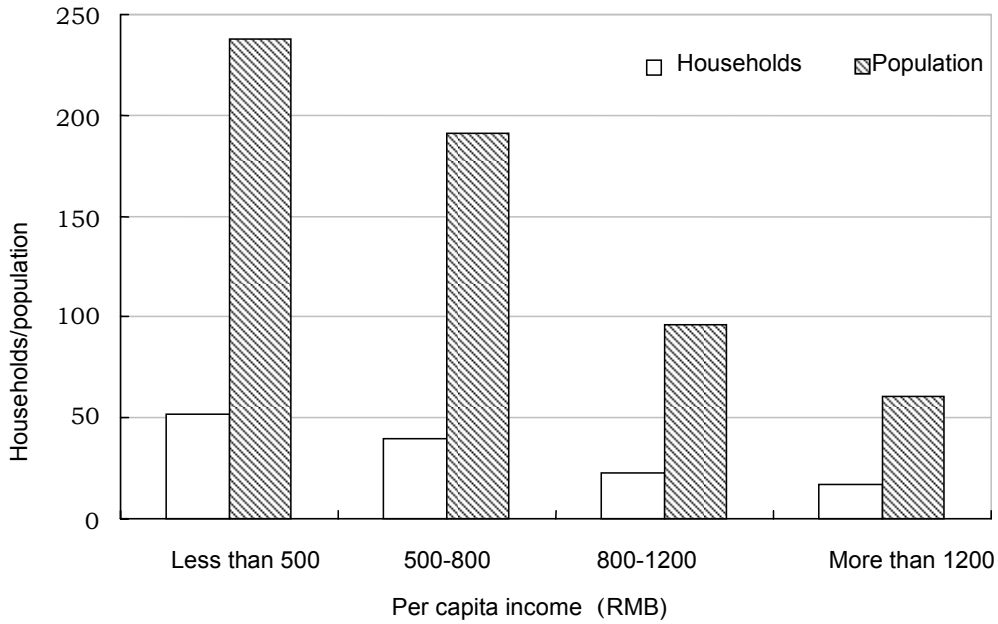


Figure 10.1 *Per capita annual income of residents in* Dagan FLR demonstration area

The main crops are rice, supplemented by corn and sweet potatoes. Rice can be harvested once or twice a year. However, reduction of land cover and land conversion due to sandy soil and caused by human disturbance, such as slash and burn, management and investment, make the soil erosion even severe in rainy season. In addition, pond-deposit caused by soil erosion and combined with uneven seasonal rainfall also makes frequent drought in the area, such as the original fields for autumn rice can not be planted in spring due to lack of water. Rice can plant in June and July even if it is the rainy season. At present, non-paddy field are clearly defined, most are used for cassava cultivation.

The arrangement of agricultural activities in Dagan FLR demonstration area was shown in Table 10.1.

Table10.1 *Seasonal Calendar of* Dagan FLR demonstration area

Crops	Jan.	Feb.	Mar.	Apr.	May	Jun.
Sweet potato		Planting				
Rubber tree	Weeding	Fertilizing	Weeding	Tapping	Tapping	Tapping
Betel nut				Flowering		
Early rice	Fertilize		Fertilizing	Harvesting		
Late rice					Planting	Fertilizing
Mango	Flowering				Harvesting & Pruning	Weeding
Cassava				Planting		
Corn				Planting		Harvesting
Melon & vegetable		Harvesting	Harvesting			

Crops	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Sweet potato		Harvesting	Harvesting			
Rubber tree	Tapping	Tapping	Tapping	Tapping	Tapping	Fertilizing
Betel nut				Harvesting	Harvesting	Fertilizing
Early rice						Planting
Late rice		Fertilizing	Harvesting			
Mango	Fertilizing					
Cassava						Harvesting
Corn	Harvesting					
Melon & vegetable					Planting	Fertilizing & irrigating

Dagan FLR demonstration area is impassable in terms of transportation and the only rural road to the county town is in poor condition, providing no benefit to the transportation of agricultural products, technology and information. The road constructed in January 2010 by the local government after implementing ITTO FLR project. The main transport tool is motorcycle (one per household). The education level of residents is uneven, people under the age of 35 have junior high school education and there are only two in the demonstration area who have got college education (see Figure 10.2).

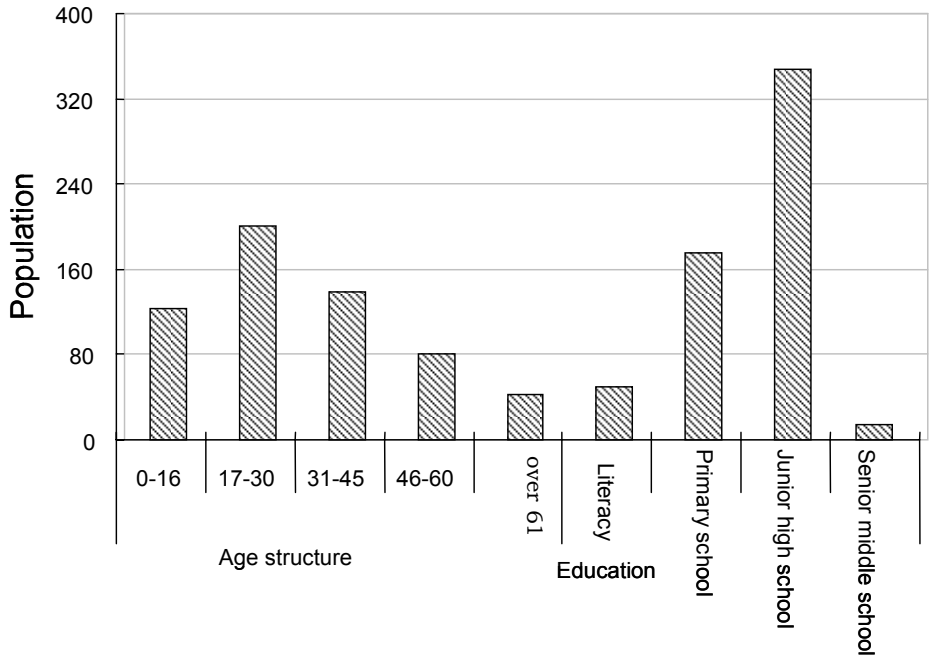


Figure 10.2 *Age structure and educational level of residents in* Dagan FLR demonstration area

School-age children go to school in the local town while children in high income families go to school in the county town. There is no professional medical staff in the demonstration area and villagers have to go to town health centers, clinic in Nanping farm and hospitals of the county to see a doctor.

As to energy structure, fuelwood is the major energy source and biogas is only used in five families. Sample survey on fuelwood consumption of 60 families has shown that the average daily consumption of fuelwood per household was 28 kg, per capita consumption of fuelwood was 5.5 kg (see Figure 10.3). Firewood are mainly used for daily life, such as cooking, bathing and pig feeding. The survey found that concept of "reflects environment everyday" were deeply rooted in the Dagan FLR demonstration area so that firewood was the natural choice in the community. However, this energy use is more extensive and residents generally use stove with lower energy efficiency. Rice cooker, induction cooker have not been in wide use, only 15 families were using electricity for cooking. Fuelwood were mainly from natural forests surrounding the community, mainly are dead trees or shrubs. Fuelwood collection on natural forests has caused some damages. The implementation of forest landscape restoration measures will inevitably affect the natural choice. Therefore, coal, gas, electricity and other alternatives should be encouraged in order to reduce the consumption of forest resources. As these alternatives are not conducive to extend because the price of these energy alternatives are higher than that of firewood, the government and relevant government agencies should adopt some poverty reduction polices, such as subsidizing construction costs of methane tank.

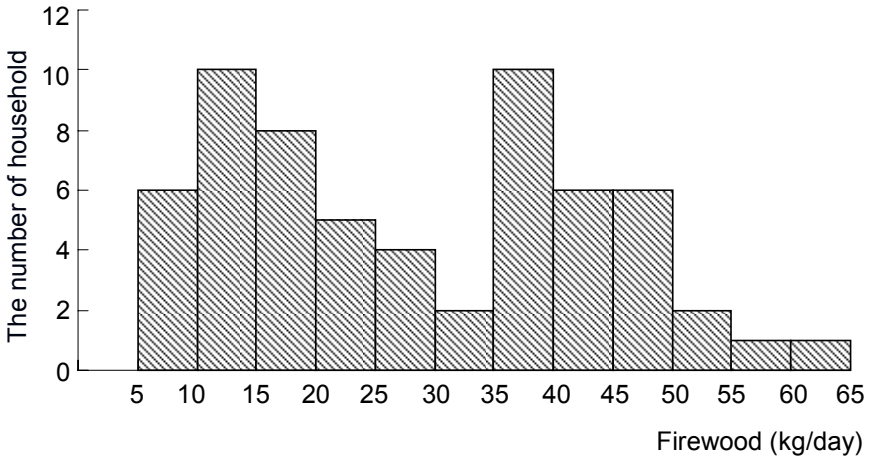


Figure 10.3 *Distribution of families of daily firewood consumption in Dagan FLR demonstration area*

10.2.3 Ranking of problems

Problems, causes and solutions of Dagan FLR demonstration area were shown in Table 10.2. It should be noted that all the problems can't be solved in the short term just relying on FLR. FLR aims to restore ecological integrity and human well beings of the community, there would be no problem in the long term if the human well being is improved. The key problems need to be solved in FLR plan in Dagan FLR demonstration area are the difficulties that can be solved in short term by communication and cooperation among different stakeholders, such as problem 1, 2, and 5 listed in Table 10.2. Other problems can be solved after human well being are improved and community income are enhanced, as the fundamental reason for these problems is poverty and lack of funds.

Poor roads, traffic inconvenience were agreed as the most urgent problem for current FLR demonstration area and the most important solution is government-funded road construction because of high cost and limited funds raised by villagers. As the main infrastructure construction in Dagan FLR demonstration area recently, roads sclerosis is an important part of the community FLR plan. The road construction would be conducted under support from the existing national policy of stimulating domestic demand (the road construction has been finished in January 2010). Villagers believe that lack of irrigation water is the second major problem and hope to increase the capacity of reservoirs and construct ditches by government fund. Meanwhile, the villagers have realized the role of natural forest for the protection of the reservoirs. This problem can be solved by incorporating water conservancy facilities into water project planning of the Department Water Resources of the government. Difficulty of going to toilet and taking a bath for women can be solved by the construction of biogas digesters. Materials after fermentation could also provide fertilizers for rubber and betel nut growing.

Table10.2 *Ranking of problems in Dagan FLR* demonstration area

Rank	Problems	Causes	Solutions
1	Poor roads, traffic inconvenience	Poverty, no funds	(1) Government-funded road construction (2) Villagers can put labor (3) Increasing revenue after rubber tapping
2	Lack of irrigation water	Less water in reservoirs, no funds to repair the ditch	(1) increasing the height of reservoirs by government funds (2) Repairing the ditch by government funds (3) Protecing the reservoirs by tree planting
3	Lack of fertilizer for betel nut and rubber trees	Betel nut and rubber are too young to harvest, low income, Large-scale cultivation, no money to buy fertilizer	(1) Integrated into government poverty reduction policy (2) Cassava planting (3) Raising pigs to get Organic fertilizer (4) Loans to buy fertilizer
4	Lack of housing	Low income	(1) Government grants received (2) Increasing revenue after rubber tapping (3) Saving money by work outside
5	Difficulty of going to toilet and taking a bath for women	Lack of bathrooms	(1) Subsidies for bathroom building by government (2) Methane tank construction (3) Public toilets building by raising funds
6	Powdery mildew	Lack of pesticides and techniques	(1) Guidance by forestry stations (2) Government-issued pesticide (3) Technical training

10.2.4 Status and causes for forest degradation

The status of and causes for forest degradation in Dagan FLR demonstration area were analyzed using the problem tree method. Problem tree can help outsiders and locals to find and analyze the impact of an event, the flow of resources and activities by expressing the causes, effects and linkages between the causes for the problem so as to find the intrinsic link and key reasons. Reasons for natural forest deforestation, degradation and fragmentation in community were analyzed through PRA tools, such as community workshops, and interviews with farmers, as shown in Figure 10.4. The areas of degraded primary forest and secondary forest in Dagan FLR demonstration area were 42.06 ha and 47.55 ha respectively, only distributed in south-eastern part of the community. But the forests were widely distributed 30 years ago, covering almost all the hills. The area of degraded primary forest was still 97.64 ha in 1990. Degraded primary forest has reduced by 55.58 ha during the period of 1990-2009, which resulted in the forest fragmentation. As shown in the problem tree, the main causes for natural forest reduction were natural forest deforestation by basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices.

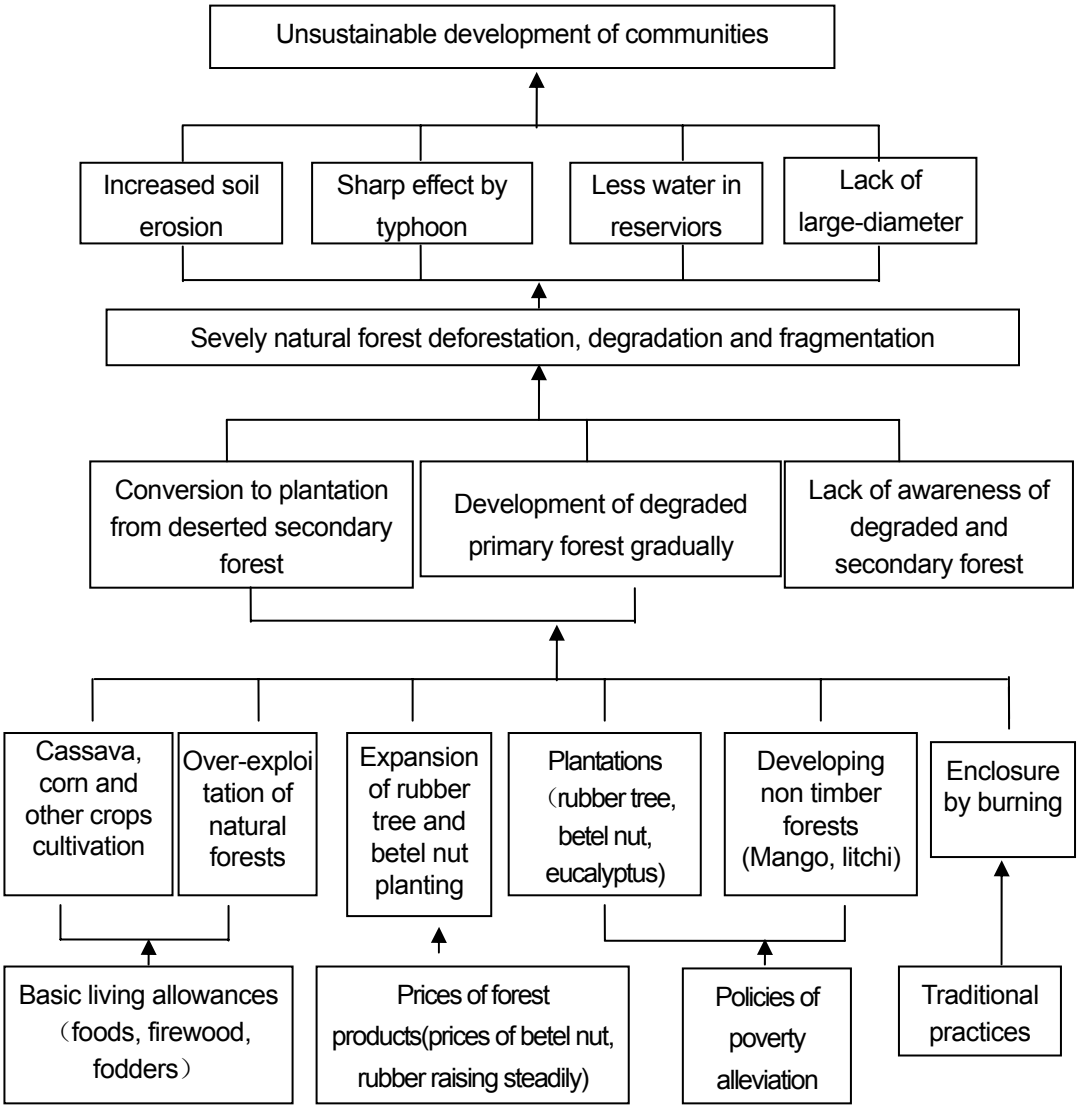


Figure10.4 *Problem tree for causes for forest degradation in Dagan FLR* demonstration area

10.2.5 Identifying priority sites and tree species

Priority sites and restoration measures, favorite tree species were identified by using Matrix and Ranking in village workshop (see Table 10.3 and Table 10.4). Site-level restoration measures should take advice of local residents and should be implemented by them, and that will contribute to the successful implementation. It should be noted that residents made decisions on restoration measures and planting tree species from their own economic interests, some choices do not meet the double-filters of FLR, for example, *Acacia mangium* was generally agreed as the best windbreak species, but field survey found that most of *Acacia mangium* trees which have been planted along the ridge of hills were break down by typhoon. So conflicts between different restoration measures should be coordinated timely to find the compromise between economic and ecological benefits.

Table10.3 *Priority sites and restoration interventions*

Priority sites	Interventions	Reasons
Sites along roads	Planting urban tree species, such as Coconut Tree	Beautify the environment, sunshade
Sites along streams	Planting native species	Protecting the ditch, pond
Deraded forest land in flat area	Planting rubber tree instead of Areca catechu	Improving income, enough Areca catechu
Deraded forest land in hill peaks	Planting wind-break trees (Acacia mangium), eucalyptus	Wind-breaking, improving income,
Forest lands	Protection	Wind-breaking, protecing rubber trees

Table10.4 *Ranking of favorit tree species*

Species	Advantages	Disadvantages	Rank
Rubber tree	Rubber tapping 5 years later, planting for 50 years	Powdery mildew	1
Eucalyptus	Fast-growing, high survival rate	Harvest 5 years later, lack of water	2
Dalbergia odorifera	Valuable	Slow growth	3
Aquilaria sinensis	Valuable, air purification	Slow growth	4
Acacia mangium	Against typhoons, planting around the houses	--	5

10.2.6 Skills for PRA tools application

Not all the tools and methods of PRA will be used during the development of FLR plan at community level. PRA methods can be enriched and developed according to local conditions. The following items need to be given attention during community workshops: speaking local languages as far as possible and simplify the questions to let all villagers understand; putting the emphasis on introduction in the first community workshop for low participation; using PRA tools in variety of ways after villagers are willing to ask, discuss and share information; guiding the meeting in a positive direction to avoid a few people dominate the meeting; every discussion, analysis should have results or conclusions and should be recorded, feed backing to villagers next meeting so as to correct timely, selecting appropriate meeting time and place, 1-2 hours is suitable.

Experiences in semi-structured interviews in Dagan FLR demonstration area showed as follows. (1) Selecting team members, topic design and identifying interview objects should be fully prepared before the interview. Team of semi-structured interview included one translator because there was barrier for FLR

team to communicate with local residents. (2) Interview time is critical and should be fixed based on daily work and life of local laws, seasonal farming activities, work habits, climate, local customs, etc. (3) Interviews should be started from family structure (family member, name, age, educational level, etc.), land ownership, crop cultivation, livestock breeding species and the number. It could enable farmers to increase their self-confidence on the one hand. On the other hand, it would help to obtain valuable information from conversation to guide the sub topics. (4) FLR working team should not give villagers hints or promises that they would get any benefits in the future in order to get reasonable and reliable answers. (5) Answers given by villagers should not be exposed and kept private. (6) Taking notes should be agreed by interviewees and don't use tape recorders. (7) The interview time should be kept in one hour, thank the respondents at the end of the interview and ask them if there is any question.

Matrix and ranking can fully reflect the participation of villagers, especially community in rural area. Using symbols that villagers can understand to express the contents of matrix and ranking could motivate villagers' enthusiasm and achieve the survey objective.

Moreover, FLR working team should pay attention to the role of government departments and make full use of indigenous knowledge, especially traditional knowledge of farmers.

11 Conclusions and recommendations

11.1 Conclusions

Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this technical report constructed the systematic approach to FLR from the view of regional-level. Key techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies were put forward. The main conclusions are as follows.

11.1.1 The systematic approach to FLR

FLR initiatives should be implemented according to the following steps: analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in the steps. The "double filter", public participation and adaptive management are the principles that must be followed in the whole process. These methods, principles and steps above constitute the systematic approach to FLR.

Stakeholders can be analyzed from characteristics, needs, interests, potentials, degree of participation and other aspects. Building support for FLR is to build the support of stakeholders for FLR initiatives. Forest mosaic and dynamics can be analyzed according to the following steps: landscape elements classification, data collection and processing, landscape pattern analysis, landscape dynamics analysis and prediction, driving forces analysis. Data of Forest Management Inventory, RS image information extraction and sampling inventory are methods for regional level baseline data collection. Community-level data has been obtained by participatory subcompartment division and inventory.

The variety of ecological conditions and diversity of stakeholder views mean it may not be possible to restore forest at all sites in a landscape. However, by strategically targeting areas for various kinds of reforestation, these interventions will collectively improve key ecological processes (e.g. hydrological functions, nutrient cycling etc), restore biodiversity and thereby improve livelihoods across the landscape. Applicable principles for identifying priority restoration sites can be put forward based on ecological and socioeconomic conditions and diversity of stakeholder views. Site level restoration strategies should be developed on the basis of analysis of characteristics of degraded and secondary forests combined with participatory survey, including restoration of degraded primary forest, management of secondary forest, rehabilitation of degraded forest land and restoring forest functions of agriculture lands. Forest landscape restoration planning is to arrange restoration interventions for priority sites from the perspectives of time and space and to implement the planning relying on stakeholders. Monitoring and evaluation is the basis and foundation of adaptive management in FLR and the key is to establish a set of indictors to evaluate the context and implementation of FLR.

11.1.2 Landscape pattern at region level

In view of forest restoration and rehabilitation, system of forest landscape element types of Lingshui County was set up, including primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* Plantation, trees around villages, other plantations, other forest lands, residential quarters land, garden plots, agricultural land and other lands. RS data in three yeas (in 1991, 1999 and 2008) are the source of baseline information in landscape pattern analysis of Lingshui Li Autonomous County. Landscape pattern and dynamics of the study area were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The results showed that the area proportions of Primary Forest, Degraded Primary Forest and Secondary Forest were 4.74%, 6.29% and 22.80% respectively. During the period of 1991 to 2008, primary forest has been kept stable. The areas of Degraded Primary Forest and Secondary Forest have decreased while Patch Density (PD) and Edge Density (ED) have increased, indicating the patch shape tended to be more complex and thereby they become more fragmented.

11.1.3 Landscape pattern at community level

System of forest landscape element types for landscape pattern analysis at community level was set up, including Degraded Primary Forest, Secondary Forest, Degraded Forest Land, Plantation, Non-paddy Cropland, Paddy Field, Human Settlement, Reservoir or Pond. Based on RS information extraction, participatory subcompartment division and inventory were used to obtain 3 maps of landscape mosaic (in 1990, 1999 and 2009) of Dagan demonstration area. Landscape pattern and dynamics were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The results showed that the demonstration area was a heterogeneous forest landscape in which Plantation was the matrix (accounting for 60.15% of the total area) and other types was scattered among the matrix in 2009. The area proportions of Secondary Forest and Degraded Primary Forest were 11.90% and 10.53% respectively. Overall, Non-paddy Field and Degraded Primary Forest were the matrix of the demonstration area in 1990, and then with the reduction of Degraded Primary Forest and Secondary Forest and the increase of Plantation, Non-paddy Field and Degraded Primary Forest had become the main types in the landscape resulting in a high heterogeneous landscape in 1999, and in 2009 the landscape pattern has become that Plantation was the dominant type and other types was scattered among the Plantation during the period of 1990-2009. Prediction of landscape dynamics showed that degraded primary forest would reduce sharply while secondary forest, degraded forest land and plantation would increase slightly, therefore resulting in the decrease of landscape heterogeneity.

11.1.4 Driving forces of landscape dynamics

Driving forces of forest landscape dynamics can be analyzed preliminary by transition probability matrix constructed by Markov model. Transition probability matrix and participatory survey method can be used to study the factors for forest landscape dynamics both at region level and at community level.

The results showed that forestry policies and key programs were the dominant factors which cause the increase of forest quantity and quality during the period of 1991 to 2008 in Lingshui Li Autonomous County.

Reducing rural poverty through development is an important factors in the changes on forest landscape in western hills area and northern middle hills region. Livelihood development was important factor in the changes on forest landscape in the whole hills area and middle hills region. Village greening and farm-shelterbelt forest were important factors in the changes of forest landscape in central plain terrain. Sand excavation, pond fishery and tourism development are important driving forces for changes in forest landscape in coastal area.

Forest landscape dynamics during 1990 to 2009 in Dagan FLR demonstration area was the joint results caused by several driving forces, such as the basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices. In order to solve the problem of food and cloth shortages, local residents developed degraded primary forest and secondary forest into cassava fields in the 1990s, especially during the period of 1990 - 1999. Policies of poverty alleviation and prices of forest products caused the conversion to plantation from degraded primary forest and agricultural land, which resulted in the sharp expansion of rubber tree plantation, betel nuts tree plantation, etc.

11.1.5 Characteristics and restoration strategies of degraded and secondary forests

Analysis of characteristics of degraded and secondary forest in Dagan demonstration area showed that degraded primary forest has an integral community structure. Most valuable trees in the sub-storey I in arbor storey have been harvested while there were many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey.

Site-level restoration strategies: degraded primary forest in Dagan FLR demonstration area was formed from repeated use of primary forest. The basic restoration strategy for degraded primary forest is to protect the site from further disturbance or stress factors such as deforestation, over harvesting of timber and non-timber forest products, slash and burn, and to restore biodiversity, structure, function and productivity of ecosystem by allowing natural regeneration and succession. Protection and enrichment planting are the management strategies for secondary forest. Protective "decompression" is the main strategy for collective-owned secondary forest while enrichment planting combined with protection is the suitable strategy for individual-owned secondary forest. Species for enrichment planting should be valuable native trees, such as *Dalbergia odorifera*, *Hopea exalata*. The rehabilitation strategy for degraded forest land focuses primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Planting live green fence is one of the effective measures for protection of degraded and secondary forests.

11.2 Recommendations

The FLR concept is still being refined and redefined, involving knowledge of multiple disciplines, such as landscape ecology, restoration ecology, stakeholder theory, public participation mechanisms, adaptive management and forest management. This report studied the systematic approach of FLR, and key

techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies, but the following areas need to be studied in the future.

Techniques of FLR

As to Monitoring & evaluation, indicator system needs to be rich and refined and thereby used to study the monitoring and evaluation of FLR. In terms of site-level restoration strategies, site-level strategies for plantation management and the function of plantation in FLR need to be studied further.

Conflict and balance between restoring ecological integrity and enhancing human well-being

The double-filter principle states that the trade-offs between the economic interests and social, protective values is unavoidable, but the landscape-level sum of all site-level actions should attempt to balance the economic, social and environmental benefits, that is to balance the two objectives of enhancing human well-being and restoring ecological integrity. There is prominent conflict between restoring ecological integrity and improving human well-being in forest-dependent poor communities. Multifunction of landscape has not emerged, especially the economic benefits, so developing alternative industries become the effective measures to improve income of local inhabitants. For example, alternative industries including breeding in forest, beekeeping, off-season vegetables growing, etc. can be developed in Dagan FLR demonstration area during the implementation of FLR initiatives. However, development of alternative industries and community capacity-building require the resources superiority of surrounding communities and the region. Therefore, it needs to study further for balancing the conflict between restoring ecological integrity and improving human well-being in poor communities within the development of community.

Incentive mechanism

Degraded and secondary forest can be classified into two categories according to forest function: production forest and protection forest. Degraded and secondary production forests are widely distributed in surrounding areas of forest-dependent communities and play an important part in community development. While degraded and secondary protection forests are in well protection and restoration because of implementing the Scheme of Forest Ecological Benefit Compensation Fund for Non-commercial Forests, the degraded and secondary production forests are gradually converted to crop-trees and degrading in most forest-dependent communities mainly due to lack of PES (Payment for Ecosystem Services) scheme. So study on scheme of payment for environment services derived from degraded and secondary production forests can help improve the incentive mechanism for FLR and thereby promoting the successful implementation of FLR.

Bibliography

Aldrich M, Sandeep S. *Forest landscape restoration - seeing the bigger picture*. Arborvitae - IUCN/WWF Forest Conservation Newsletter. 2005. 28, 8-9.

Bakker V J, Doak D F. *Population viability management: ecological standards to guide adaptive management for rare species*. Frontiers in Ecology and the Environment. 2008, 7. (3): 158-165.

Banerjee A. Rehabilitation of Degraded Forests in Asia. World Bank Technical Paper No 270. World Bank, Washington, DC, USA. 1995.

Bao W K, Liu Z G, Liu Q. *Ecological Restoration and Rehabilitation: Development, Researching Features and Existing Major Problems* (in Chinese). World Sci. Tech R&D. 2001,1: 44-47.

Barrow E, Timmer D, White S. et al. Forest landscape restoration: building assets for people and nature – experience from East Africa. IUCN, Cambridge, UK. 2002.

Berkes F. *Evolution of co-management: Role of knowledge generation, bridging organizations and social learning.* Journal of Environmental Management. 2009, 90. (5): 1692-1702.

Cao Y, Xiao D N, Ouyang H, et al. *Analysis of landscape change drivers in the Ejina natural oasis* (in Chinese). Acta Ecologica Sinica. 2004, 24(9): 1895-1902.

Cassano C R; Schroth G; Faria D, et al. *Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil*. Biodiversity and Conservation. 2009, 18 (3): 577-603.

Castillo-Campos G, Halffter G, Moreno C E. *Primary and secondary vegetation patches as contributors to floristic diversity in a tropical deciduous forest landscape*. Biodiversity and Conservation. 2008, 17 (7): 1701-1714.

Chambers R. *The origins and practices of participatory rural appraisal*. World Development, 1994, 23 (7): 953-969.

Chazdon R L. *Beyond deforestation: Restoring forests and ecosystem services on degraded lands*. Science. 2008, 320 (5882): 1458-1460.

Chen P L, Huang Q L. *Analysis of Land Use Situation and Forecast of Its Development Tendency in Fujian Province by Markov Chain* (in Chinese). Journal of Natural Resources.1992, 7 (1): 35-42.

Chen W B, Xiao D N, Zheng J, et al. *Forest landscape change and its driving force during past ten years in Bilahe forest region,Inner Mongolia* (in Chinese). Chinese Journal of Applied Ecology. 2004,15(5): 741-747.

CIFOR. *Adaptive Collaborative Management* website: http://www. cifor.cgiar.org/acm.

Daisy N, Laura N, Carlos O. *Forests and water: The value of native temperate forests in supplying water for human consumption*, Ecological Economics. 2006, 58: 606-616.

Ding Y. Study on Recovery *Ecology of the degraded tropical forest vegetation in Hainan Island, South China* (in Chinese). Ph.D. dissertation: Chinese Academy of Forestry. 2007, 53-72.

Duckert DR; Morris D M; DeugoD, et al. *Developing site disturbance standards in Ontario: Linking science to forest policy within an adaptive management framework*. Canadian Journal of Soil Science. 2009, 89(1): 13-23.

Dudley M. *Forest Landscape Restoration: a national perspective of a Global Partnership*. EFI Proceedings. 2005. 53, 21-24.

Ecott T. *Forest Landscape Restoration: working examples from 5 ecoregions*. WWF International June. Avenue du Mont-Blanc 1196 Gland Switzerland. 2002.

Elliott S, Kirby J, Blakesley D, et al. *Forest restoration for wildlife conservation. Proceedings of a workshop.* Chiang Mai (Thailand): University of Chiang Mai, Forest restoration research unit. 2000.

Etter A; McAlpine C; Pullar D; et al. *Modeling the age of tropical moist forest fragments in heavily-cleared lowland landscapes of Colombia*. Forest Ecology and Management. 2005, 208(1-3): 249-260.

Fisher R J, Rachel D, Kham Keonuchan K. *Socioeconomic baseline study and evaluation methodology*. Consultants' Report 2/96, NTFP Project. Vientiane: Department of Forestry and IUCN. 1996.

Gilmour D A, Nguyen V S, Xing Tsechalicha. *Rehabilitation of degraded forest ecosystems in Cambodia, Lao PDR, Thailand and Vietnam*. IUCN, Gland, Switzerland. 2000.

Grieser Johns A. *Timber production and biodiversity conservation in tropical rain forests*. Cambridge studies in applied ecology and resource management. Cambridge University Press, Cambridge, UK. 1997.

Guo J P, Zhang Y X. *Studies on the Dynamics and Distribution Pattern of Landscape Elements in the Forest Landscape Restoration Process in Guandi-shan Forest Region* (in Chinese). Acta Ecologica Sinica. 2002, 22 (12): 2021-2029.

Guo X M, Niu S K, Liu Y Q, et al. *The Vegetation Restoration and Reconstruction of Different Types of Degraded Barren Ecosystems In Jiangxi* (in Chinese). Acta Ecologica Sinica. 2002, 22 (6): 878-884.

He B X, Zeng L H, Xue L, et al. *The Study on the Tropical Forests and the Management of Secondary Forests* (in Chinese). Gangdong Forestry Science and Technology.2008.24 (1):1-9.

Hobbs R J, Norton D A. *Towards a conceptual framework for restoration ecology*. Restoration Ecology. 1996, 4:93-110.

Hou Y Z, Chen T A. *The Strategic Benefits of Developing Precious Commercial Tree Species Integrated with Secondary Forest Management in China* (in Chinese). World Forestry Research. 2008,21(2):49-52.

Hou Y Z. Distribution, *Types and Characteristics of China's Tropical Forest* (in Chinese). World Forestry Research. 2003, 16 (3): 47-51.

Huang K Y, Liao W B, Jin J H, et al. *Analysis of plant community characteristics and species diversity of Diaoluo Mountain, Hainan Island* (in Chinese). Ecology and Environment. 2007, 16 (3): 900-905.

Huang Q L, Chen Y F, Yang X S. *Study on the Characters of Tree Stratum of Pinus latteri Forest in Bawangling Forestry Area of Hainan Province* (in Chinese). Forest Research. 2002, 15(6):74-745.

Huang Q L. *Types and characteristics of tropical natural forest in Hainan Province* [A]. In: Chen Y F, Yang X S. Sustainable forest management of tropical natural forest in Hainan Island, China (in Chinese). Beijing: Science and Technology Press. 2001, 177-192.

Huang S N, Wang B S. *Study on Community Dynamics of Secondary Tropical Forests:Review and Prospects* (in Chinese). World Forestry Research. 2000,13(6):8-13.

ITTO, IUCN. *Restoring forest landscapes: an introduction to the art and science of forest landscape restoration*. ITTO Policy Development Series No 23. ITTO, Yokohama, Japan. 2005.

ITTO. *ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests*. ITTO Policy Development Series No 13. ITTO, Yokohama, Japan. 2002.

IUCN, WWF. *Arborvitae*. The IUCN/WWF Forest Conservation Newsletter. 2005a.
IUCN. *Forest Landscape Restoration to meet Ghana's deforestation challenges*. http://www. iucn. org/forest/. 2006.
IUCN. *Forest landscape restoration: broadening the vision of West African forests*. IUCN, Gland, Switzerland and Cambridge, UK. 2005b.
Jia L S. *Overview on Forest Landscape Restoration*. http://www.kfbg.org/download/ livingforest11 /29-33.pdf. 2006.
Jiang Y X, Lu J P. *The tropical forest ecosystems in Jianfengling, Hainan Island, China* (in Chinese). Beijing: Science Press. 1991, 29-42.
Jiang Z H. *Ecological Landscape Restoration of Degraded Lands and Degraded forests in China* (in Chinese). Forestry Economy. 2005: 4-5.
Kerr J. *Sharing the benefits of watershed management in Sukhomajri, India*. Selling forest environmental services—market-based mechanisms for conservation and development. Earthscan, London, UK. 2002.
Lamb D, Erskine D P, Parrotta A J. *Restoration of Degraded Tropical Forest Landscapes*. Science. 2005,310 (5754): 1628–1632.
Lamb D, Gilmour D. *Rehabilitation and restoration of degraded forests*. IUCN, Gland, Switzerland and Cambridge, UK and WWF, Gland, Switzerland. 2003.
Larson K L, Lach D. *Participants and non-participants of place-based groups: An assessment of attitudes and implications for public participation in water resource management*. Journal of Environmental Management, 2008, 88(4): 817-830.
Li J G, He C Y, Shi D P, et al. *Change Process of Cultivated Land and Its Driving Forces in Northern China during 1983-2001* (in Chinese). Acta Geographica Sinica, 2004, 59 (2):274-282.
Li Wenhua. 2004. *Degradation and restoration of forest ecosystems in China*. Forest Ecology and Management 201: 33-41.
Li X Z, Bu R C, Chang Y, et al. *The response of landscape metrics against pattern scenarios* (in Chinese). Acta Ecologica Sinica. 2004, 24(1) : 123-134.
Li Y D. *Community characteristics of tropical mountain rainforest in Jianfengling, Hainan Island* (in Chinese). Journal of Tropical and Subtropical Botany. 1997, 5 (1): 18-26.
Linkov I, Satterstrom F K, Kiker G, et al. *From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications*. Environment International. 2006, 32(8): 1072-1093.
Liu G H, Fu B J, Chen L D, et al. *Characteristics and distributions of degraded ecological types in China* (in Chinese). Acta Ecologica Sinica.2002, 20(1):13-19.
Liu J Y, LIU M L, Zhuang D F, et al. Spatial pattern analysis of land use in recent China (in Chinese). China Science (Series D).2002, 32(12) : 1031-1040.
Liu M, Hu Y M, Bu R C, et al. *Landscape change in Kangbao County of Hebei Province* (in Chinese). Chinese Journal of Applied Ecology. 2005, 16(9):1729-1734.
Liu M, Hu Y M, Chang Y, et al. *Landscape change and its spatial driving force of farmlands in Wenchuan County of Minjiang River upper reaches* (in Chinese). Chinese Journal of Applied Ecology. 2007, 18 (3):567-574.
Long J N. *Emulating natural disturbance regimes as a basis for forest management: A North American view*. Forest Ecology and Management. 2009, 257(9): 1868-1873.
Lu L, Cheng G D, Li X. *Analysis on the landscape structure of the Heihe River Basin, Northwest*

China (in Chinese). Acta Ecologica Sinica.2001, 12(1):68-74.
Ma R H, Jia J H, Hu M C, et al. *Analysis of vegetation change based on RS and GIS in Hainan* (in Chinese). Journal of Beijing Forestry University. 2001, 23(1):6-9.
Maginnis S, *Jackson W. Balancing restoration and development*. ITTO Tropical Forest Update. 2005, 15: 4-6.
Maginnis S, Jackson W. *Restoring forest landscapes*. ITTO Tropical Forest Update. 2002, 12(4): 9-11.
Maginnis S, Jackson W. *The role of planted forests in Forest Landscape Restoration*. UNFF Intersessional Experts Meeting on the Role of Planted Forests in Sustainable Forest Management New Zealand. 2003.
Maginnis S. *What is Forest Landscape Restoration?* EFI Proceedings. European Forest Institute, Joensuu, Finland. 2005, 53:25-26.
Malley Z J U, Semoka J M R, Kamasho J A, et al. *Participatory assessment of soil degradation in uplands of southwestern Tanzania: Implications of sustainable agriculture and rural livelihoods*. International Journal of Sustainable Development and World Ecology. 2006, 13(3):183-197.
Mansourian S, Vallauri D, Dudley N. *Forest restoration in landscapes: beyond planting trees*. Springer, USA. 2005.
Marghescu T. *Restoration of degraded forestland in Thailand: the case of Khao Ko*. Unasylva 207 Vol 52. FAO, Rome, Italy. 2001.
Mcshea W J; Stewart C; Peterson L, et al. *The importance of secondary forest blocks for terrestrial mammals within an Acacia/secondary forest matrix in Sarawak, Malaysia.* Biological Conservation. 2009, 142（12）：3108-3119.
Meng X Y. *Forest Measuration* (in Chinese). China Forestry Publishing House, Beijing, 1996，45-65.
Monela G C, Chamshama S A O, Mwaipopo R. et al. *A Study on the Social, Economic and Environmental Impacts of Forest Landscape Restoration in Shinyanga Region, Tanzania*. IUCN, Gland, Switzerland and Cambridge, UK. 2005.
Omeja P A, Chapman C A; Obua J. *Enrichment planting does not improve tree restoration when compared with natural regeneration in a former pine plantation in Kibale* National Park, Uganda. African Journal of Ecology. 2009, 47(4): 650-657.
Orsi F, Geneletti D. *Identifying priority areas for Forest Landscape Restoration in Chiapas (Mexico): An operational approach combining ecological and socioeconomic criteria*. Landscape and Urban Planning. 2010, 94(1): 20-30.
Radeloff V C, Mladenoff D J, Manies K L, et al. *Analyzing forest landscape restoration potential: pre-settlement and current distribution of oak in the northwest Wisconsin Pine Barrens*. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 1998, 86: 189-206.
Robert L. *Designs on life*. New Scientist. 1993, 140: 37.
Rodrigues R R. *On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest*. Biological Conservation. 2009, 142(6): 1242-1251.
Rroyo-Rodriguez V, Pineda E, Escobar F, et al. *Value of Small Patches in the Conservation of Plant-Species Diversity in Highly Fragmented Rainforest. Conservation* Biology. 2009. 23(3): 729-739.
Sayer J, Campbell B. *The science of sustainable development: local livelihoods and the global environment*. Cambridge University Press, Cambridge, UK. 2004.

Setty R S, Bawa K, Ticktin T, et al. *Evaluation of a Participatory Resource Monitoring System for Nontimber Forest Products: the Case of Amla (Phyllanthus spp.)* Fruit Harvest by Soligas in South India. Ecology and Society. 2008, 13(2).

Shono K, Cadaweng E A, Durs t P B. *Application of assisted natural regeneration to restore degraded tropical forestlands*. Restoration Ecology. 2007, 15 (4): 620-626.

Sisk D T, Prather W J, Hampton M H, et al. *Participatory landscape analysis to guide restoration of ponderosa pine ecosystems in the American Southwest*. Landscape and Urban Planning. 2006, 78(4): 300-310.

Song D M, Xiao D N. et al. *Landscape changes of Minqin oasis in Gansu Province and its driving force* (in Chinese). Chinese Journal of Applied Ecology. 2003, 14(4):535-539.

Soutsas K, Tampakis S, Arabatzis G, et al. *The concept of forest landscape restoration in the mediterranean basin*. NEW MEDIT. 2004, 3(4): 57-62.

Stanturf J A, Goodrick S L, Outcalt K W. *Disturbance and coastal forests: A strategic approach to forest management in hurricane impact zones*. Forest Ecology and Management. 2007, 250(1): 119-135.

Thomas P T. *Balancing development and conservation objectives in the tropical forest*. http://www.asb.cgiar.org.2005.

Veltheim T, Pajari B. *Forest Landscape Restoration in central and northern Europe*. EFI Proceedings NO. 53. Gummerus Printing Saarijarvi, Finland. 2005.

Wang B S, Yu S X, Peng S L et al. *Experimental manual for plant community* (in Chinese). Publishing House of Higher Education of Guangdong Province, Guangzhou, 1996, 1-22，100-106.

Wang B S, Yu S X, Peng S L, et al. *Plant Community Experiment Manual* (in Chinese). Guangzhou: Guangdong Higher Education Press. 1996: 1-22,100-106.

Wang H F, Zeng L H. *Discussions on Sustainable Management of Secondary Forest in Tropical China* (in Chinese). World Forestry Research, 2008, 21(4): 48-52.

Xie H L, Lin B. *Driving forces analysis of land-use pattern changes based on logistic regression model in the farming-pastoral zone: A case study of Ongiud Banner, Inner Mongolia* (in Chinese). Geographical Research. 2008, 21(4): 48-52.

Xu G Z. *Community Forestry* (in Chinese). Beijing: Chinese Forestry Press, 2002.

Xu H, Li Y D, Luo T S, et al. *Community Structure Characteristics of Tropical Montane Rain Forests with Different Regeneration Types in Jianfengling* (in Chinese). Forestry Science.2009, 45(1):14-25.

Xu X L, Liu J Y, Zhuang D F, et al. *Spatial-temporal characteristics and driving forces of wood resource changes in China* (in Chinese). Journal of Beijing Forestry University. 2004, 26(1): 41-46.

Yang Y C, Zhang W Y, Lin R C, et al. *Study on Structure and Species Diversity in Post Harvested Tropical Montane Rainforest Dominated by Dacridium pierrii in Bawangling,Hainan Island* (in Chinese). Forestry Science Research. 2008, 21(1): 37-43.

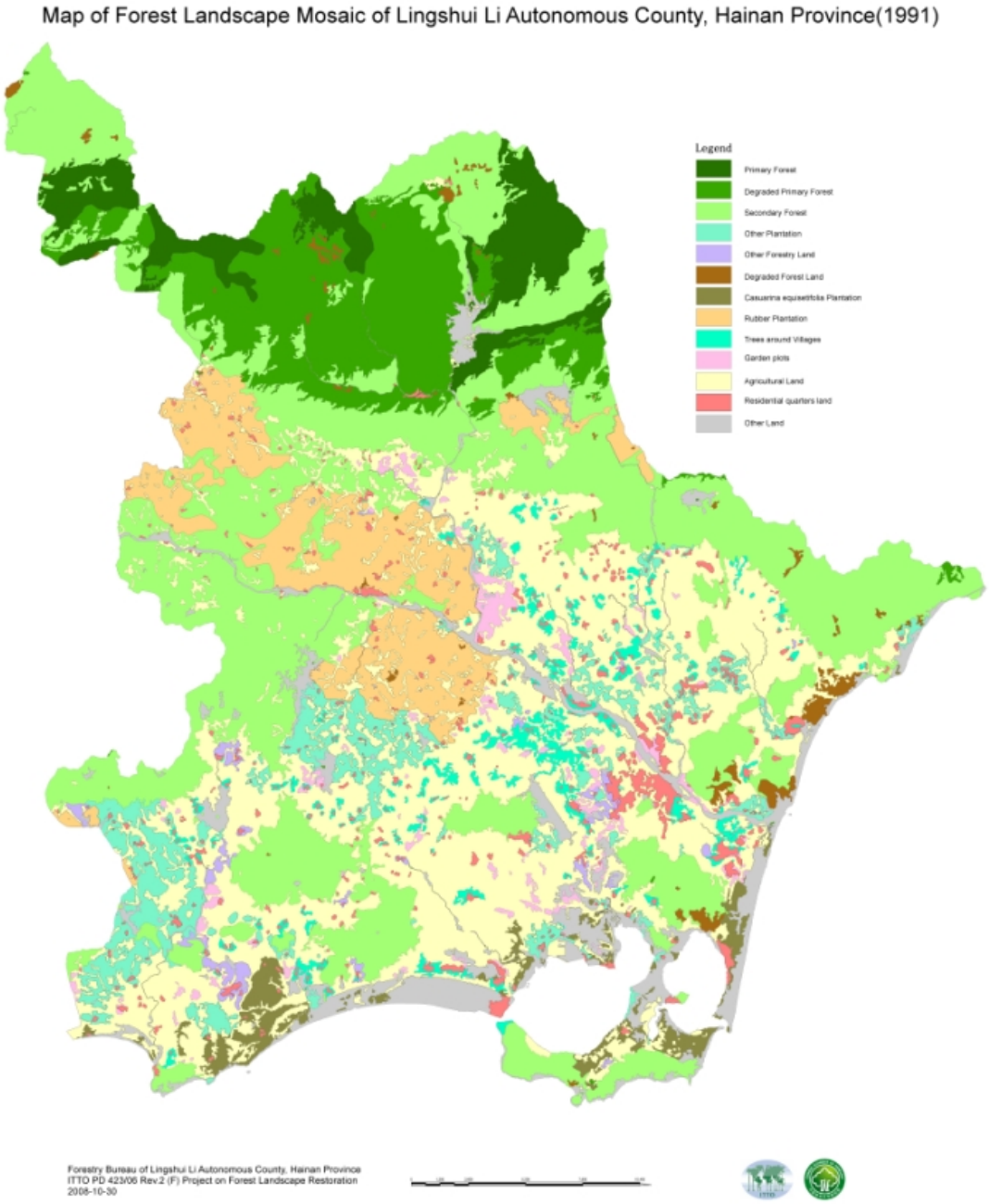
Zang R G, Liu J Y. *Gap dynamics of forest biodiversity* (in Chinese). Beijing: Chinese Forestry Press. 1998.

Zang R G, Yang Y Cg, Jiang Y X. *Community structure and tree species diversity characteristics in a tropical mountain rainforest in Bawangling nature reserve, Hainan Island* (in Chinese). Acta Phytoecologica Sinica. 2001, 25 (3):270-275.

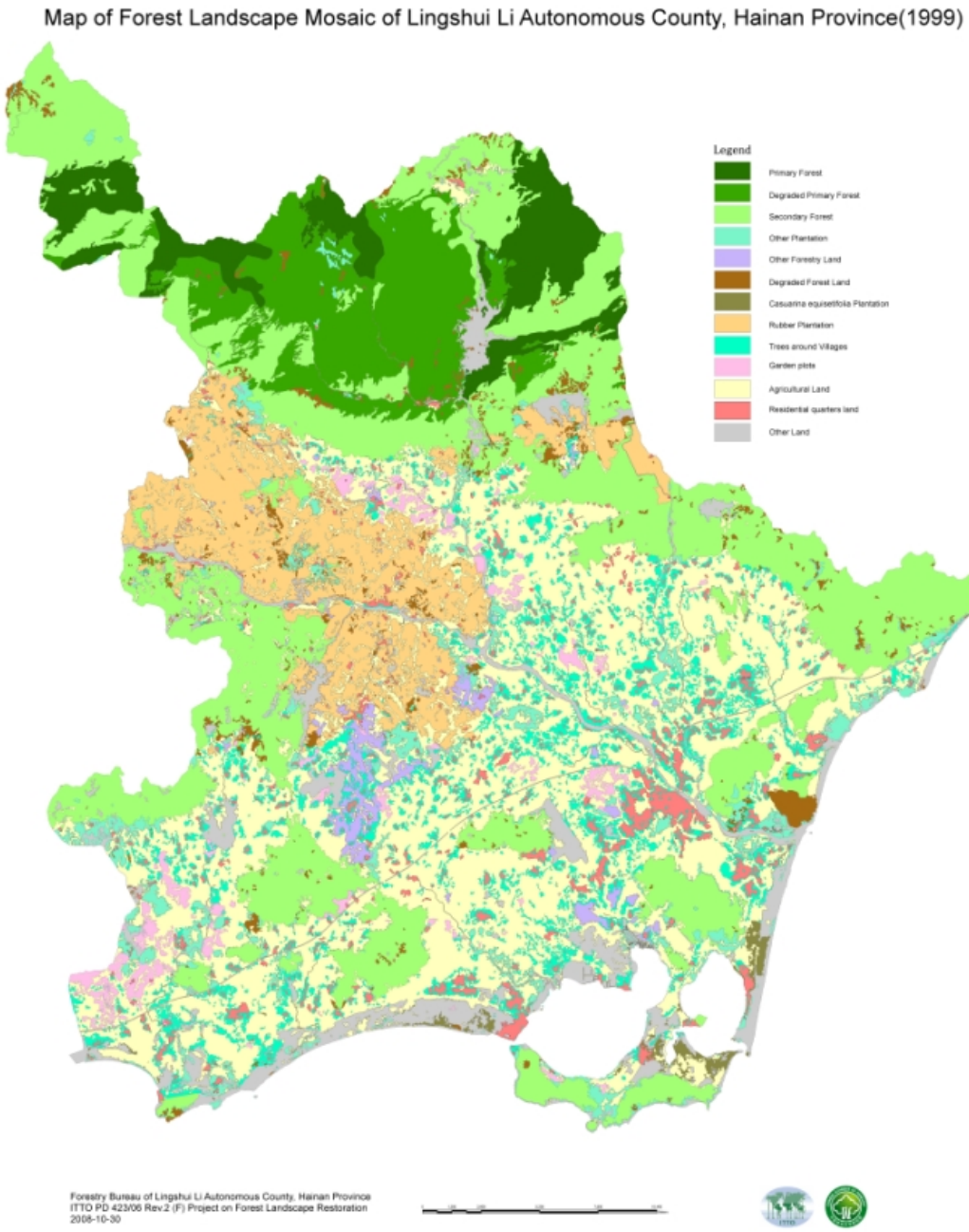
Zhang X H, Huang Q L, Zhang C. *Review on the Research of Forest Landscape Restoration* (in Chinese). World Forestry Research. 2007, 20(1):22-28.

Zhang X H, Huang Q L, Zhang C. *Analysis of forest landscape dynamics based on Forest Landscape Restoration: a case study of Yong'an city, Fujian Province, China*. European Journal of Forest Research, 2010, 129 (5): 975-980

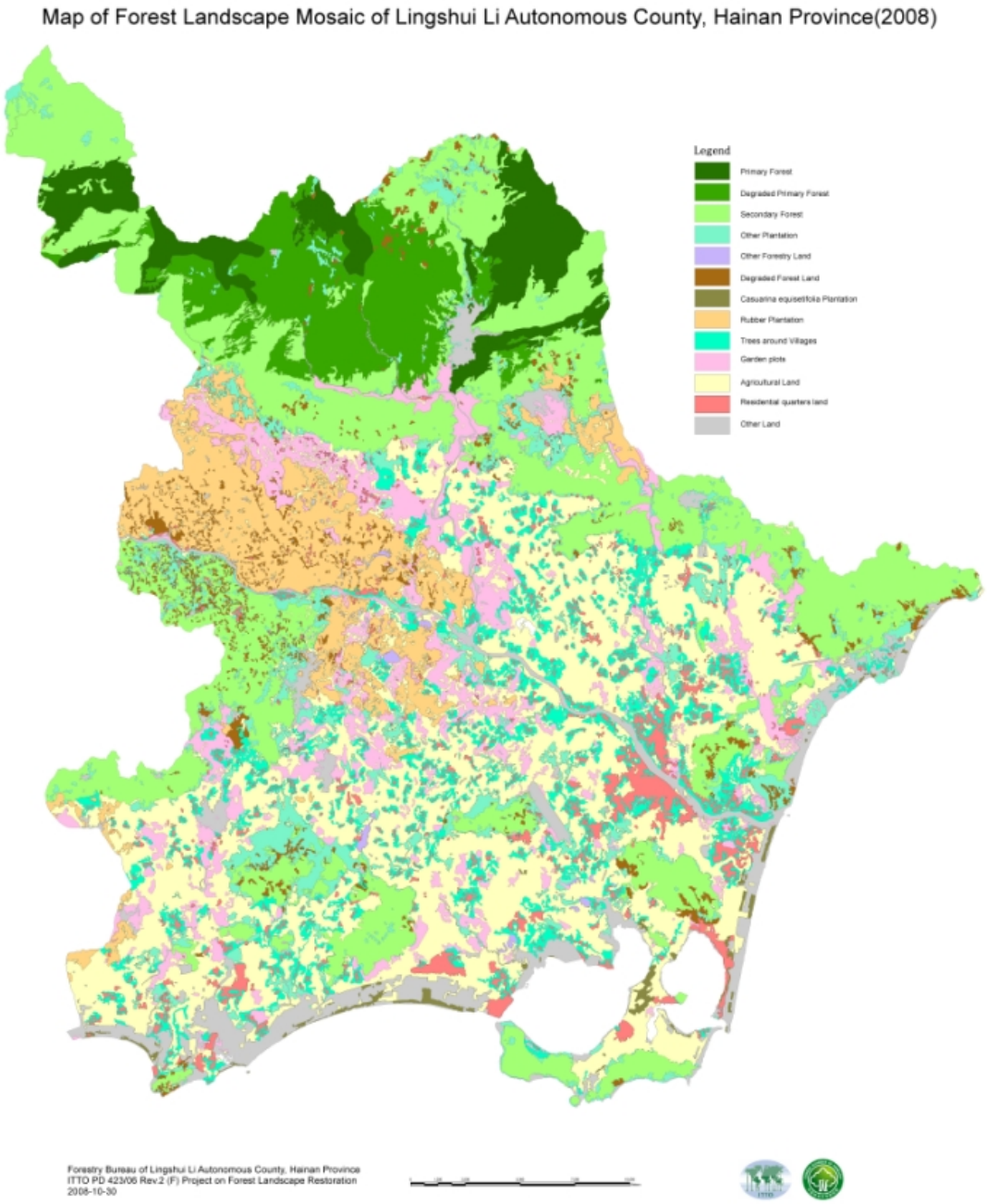
ANNEX 1: Map of Forest Landscape Mosaic of Lingshui Li Autonomous County, Hainan Province (1991)



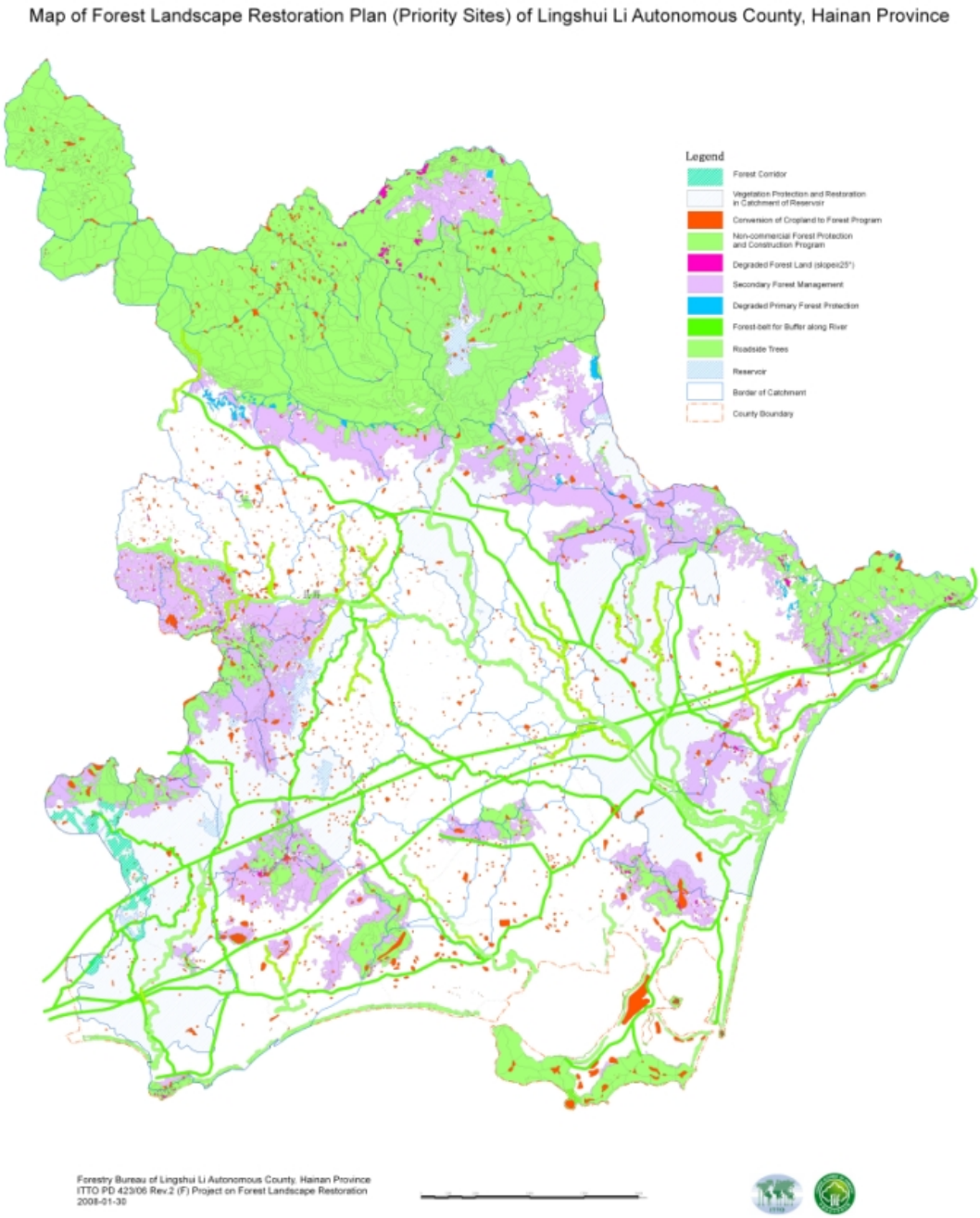
ANNEX 2: Map of Forest Landscape Mosaic of Lingshui Li Autonomous County, Hainan Province (1999)



ANNEX 3: Map of Forest Landscape Mosaic of Lingshui Li Autonomous County, Hainan Province (2008)

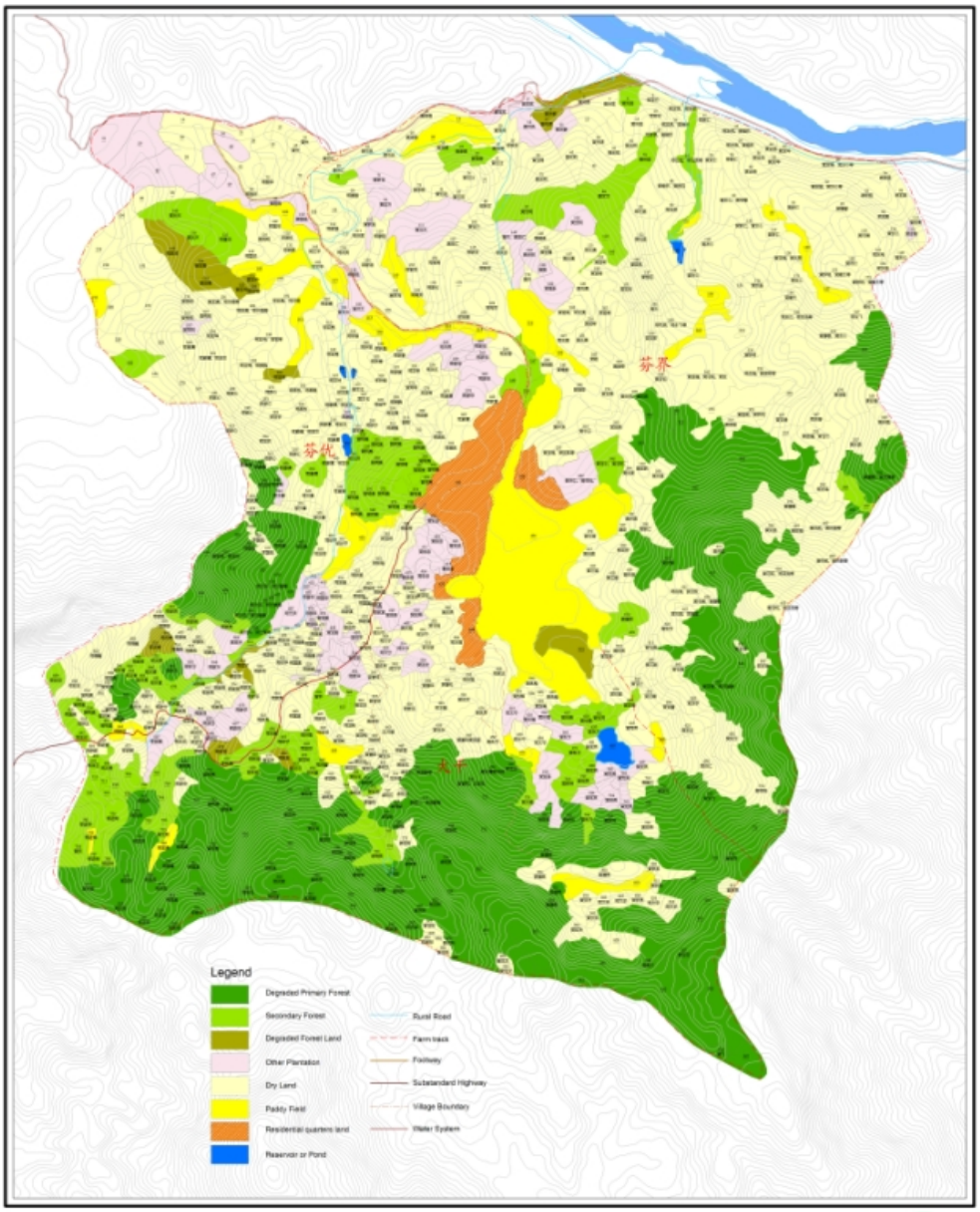


ANNEX 4: Map of FLR Plan (Priority Sites) of Lingshui Li Autonomous County, Hainan Province



ANNEX 5: Map of Forest Landscape Mosaic of Dagan FLR Demonstration Area (1990)

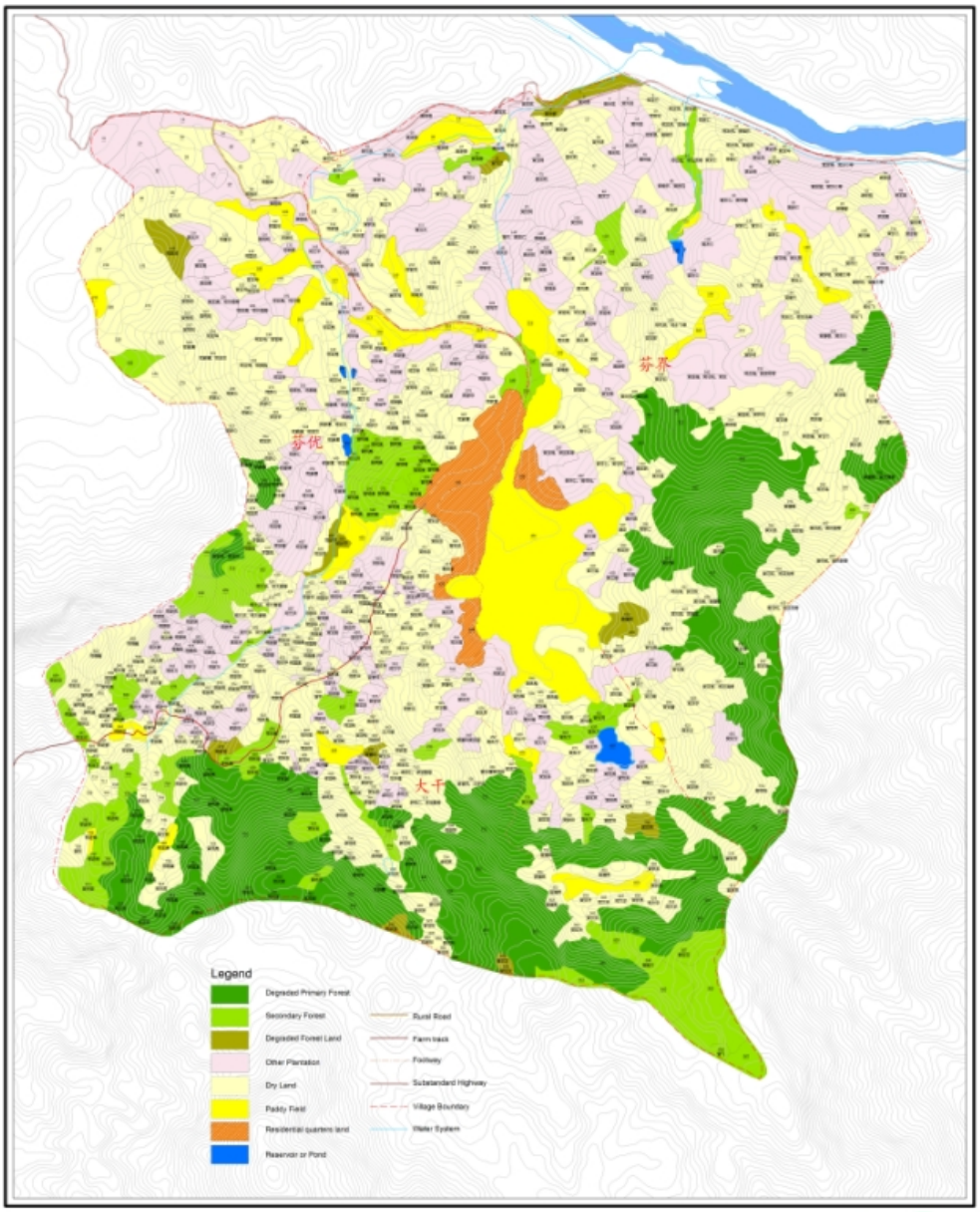
Map of Forest Landscape Mosaic of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province in 1990



Forestry Bureau of Lingshui Li Autonomous County, Hainan Province
ITTO PD 423/06 Rev.2 (F)
ITTO PD 423/06 Rev.2 (F) Project on Forest Landscape Restoration
2009-01-30

ANNEX 6: Map of Forest Landscape Mosaic of Dagan FLR Demonstration Area (1999)

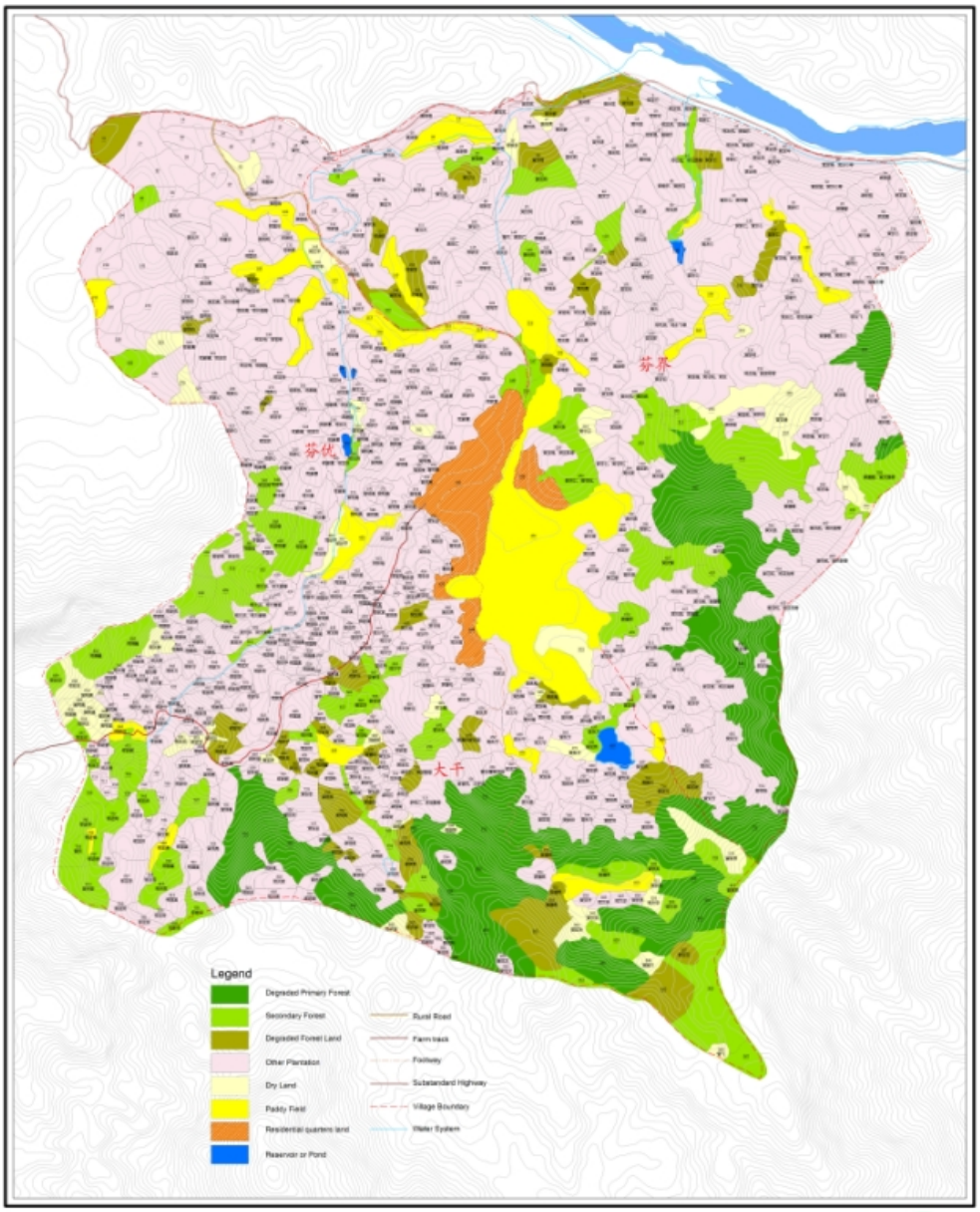
Map of Forest Landscape Mosaic of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province in 1999



Forestry Bureau of Lingshui Li Autonomous County, Hainan Province
ITTO PD 423/06 Rev.2 (F)
ITTO PD 423/06 Rev.2 (F) Project on Forest Landscape Restoration
2009-01-30

ANNEX 7: Map of Forest Landscape Mosaic of Dagan FLR Demonstration Area (2009)

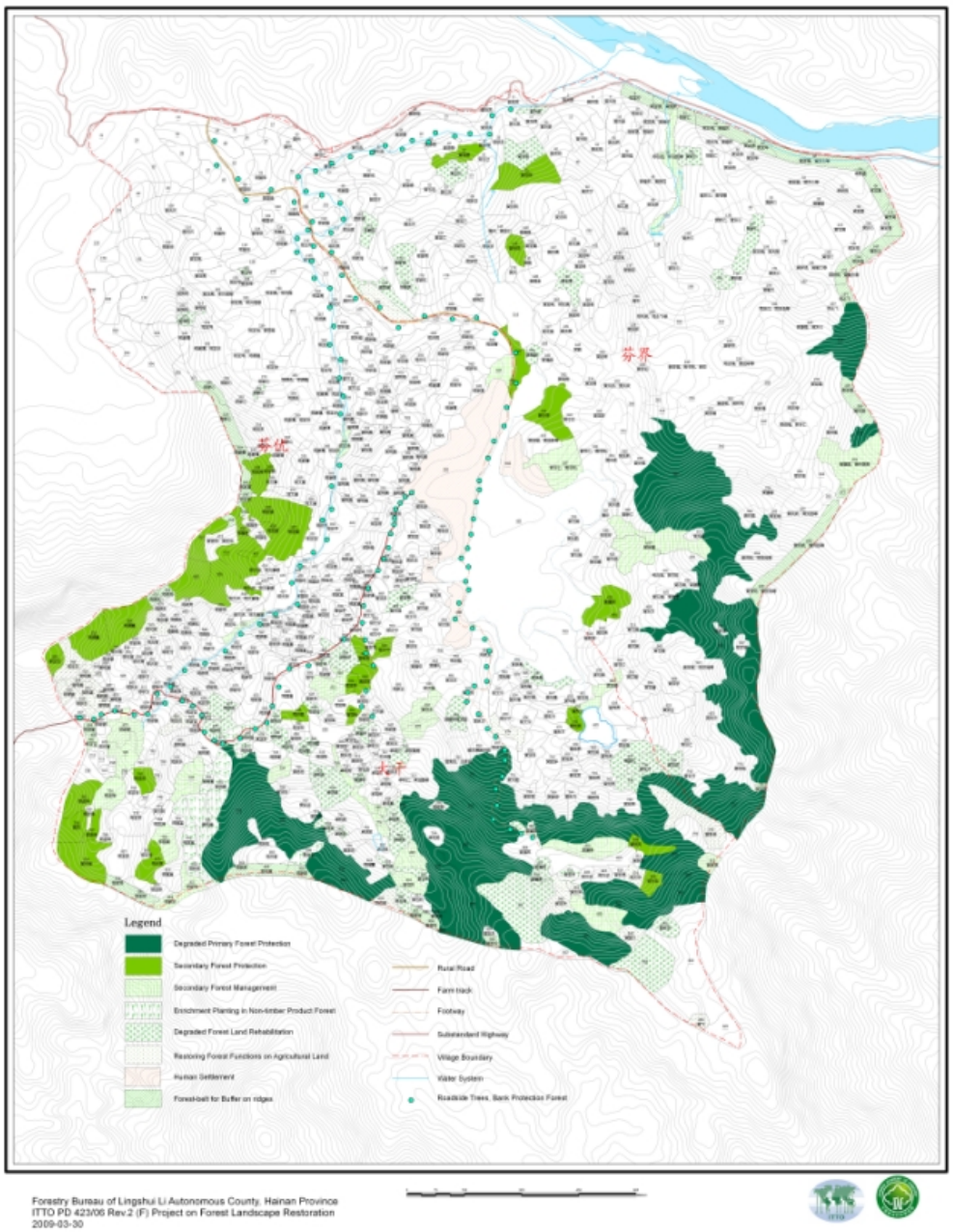
Map of Forest Landscape Mosaic of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province in 2009



Forestry Bureau of Lingshui Li Autonomous County, Hainan Province
ITTO PD 423/06 Rev.2 (F)
ITTO PD 423/06 Rev.2 (F) Project on Forest Landscape Restoration
2009-01-30

ANNEX 8: Map of FLR Plan (Priority Sites) of Dagan FLR Demonstration Area

Map of Priority Sites of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province



Forestry Bureau of Lingshui Li Autonomous County, Hainan Province
ITTO PD 423/06 Rev.2 (F) Project on Forest Landscape Restoration
2009-03-30

ANNEX 9: World-view Image of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province (2008/12/09)

World-view Image of FLR Demonstration Area （Dagan） in Lingshui Li Autonomous County, Hainan Province(2008/12/09)

Forestry Bureau of Lingshui Li Autonomous County, Hainan Province
ITTO PD 423/06 Rev.2 (F) Project on Forest Landscape Restoration
2009-01-01