Theory and Practice of Forest restoration at landscape level in PR. of China
– Report of Case Study

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Outline

1. Forestry History towards FLR and multi-functional management in China

2. A case study of ECTF in Chinese tropical region

3. Theory and techniques in FLR practice in China

4. Case study of FLR in other regions

5. Conclusion: China is already on its way of FLR

1. Forestry History towards FLR and multi-functional management in China

•Natural forest harvest, – 1998. Spec.
•Afforestation efforts for plantation, since 1949 – now, established more than 60 mill. Ha plantation
• Strategy of Classifying management, since 1992.

•胡锦涛主席于2009年提出"到2020年森林面积比2005年增加4000万公顷、森林蓄积量增加13亿立方米"的战略目标，已经作为约束性指标纳入国家"十二五规划。

•Multi-functional forest management, since 2011

第一，加强林业建设。

第二，发挥森林多种功能。我们应该妥善处理发展和保护、产业和生态的关系，充分发挥森林在经济、社会、生态、文化等方面的多种效益，实现平衡发展。要合理利用森林资源，发展林业产业，壮大绿色经济，扩大就业，消除贫困。要挖掘林业潜力，发展木本粮油和生物质能源，维护粮食安全和能源安全。要加强生物多样性保护，涵养水源，防治荒漠化，增加森林碳吸收，应对气候变化，维护区域和全球生态安全。

加强区域合作　实现绿色增长
—在首届亚太经合组织林业部长级会议上的致辞
（2011年9月6日）
胡锦涛

Current status of forest and land restoration in China

1. covering approximately 9.6 million square kilometres with a diverse physical environment.

2. over 27,000 species of higher plants (including ferns) belonging to 353 families and 3184 genera, of which more than 7000 species are woody plants.

3. forest area is about 195 million ha, and timber volume of 13,721 million m^3 (SFA 2010).

4. Uneven forests distribution, more than half of the forest area lies in the northeast and southwest, where the land area accounts for only one-fifth of total Chinese territory (Fig. right),

5. coverage of forest is low (20.36%),

6. Due to degradation the forest quality is not good with average unit-volume of 85.88 m3/ha), average growth of 4.5 m3/ha•yr,

7. pressure of land protection and management was increasing.
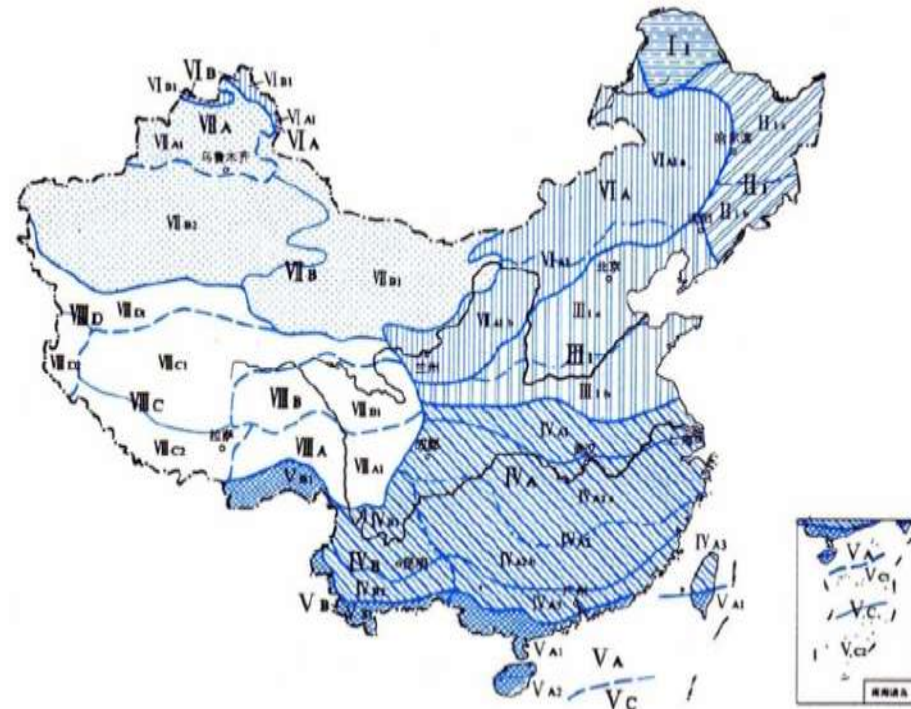
Fig.1 The distribution of major forest types in China.
Ⅰ: Cold temperate coniferous forest, Ⅱ: Temperate coniferous and broad-leaved mixed forest, Ⅲ:Warm temperate deciduous broad-leaved forest, Ⅳ: Subtropical evergreen broad-leaved forest, Ⅴ: Tropical rainforest and monsoon forest, Ⅵ:Qinghai Tibet Plateau alpine vegetation. Revised from the Editorial Board of Vegetation of China (1980)

The concept of FLR and contents in Chinese practice

FLP Concept:

Forest landscape restoration (FLR) is defined as "a planned process to regain ecological integrity and enhance human well-being in deforested or degraded landscapes". (cited from http://en.wikipedia.org/wiki/Forest_landscape_restoration)

It comprises tools and procedures to integrate site-level forest restoration actions with desirable landscape-level objectives, which are decided upon via various participatory mechanisms among stakeholders. The concept has grown out of collaboration among some of the world's major international conservation organizations including the International Union for Conservation of Nature (IUCN), the World Wide Fund for Nature (WWF) and the International Tropical Timber Organization (ITTO).

Experiences of FLR practice in China:

Multi-functional Forest Management (MFFM): by restoring a range of forest functions at the landscape level.

Improving Spatial Planning Techniques (SPT）: combining forest functions in FM plan to insure ecological integrity of forests at landscape level.

Close-to-natural Forest management options (CNFM): technical supports for MFFM to strengthen the resilience and ecological integrity of forests.

Developing New Forestry Polices (FP): giving services and conditions for the participation of local communities and organizations in FLR , and shaping the benefits from restored forest resources.

Concept of Multi-Function Forest Management and its Desirable Outcomes

Forest Function classification:

（1）Production function 供给功能：从森林生态系统中获得的各种产品，如木材、食物、燃料、纤维、饮用水，以及生物遗传资源等的直接需求；

（2）regulating function 调节功能：通过森林生态系统自然生长和调节作用中获得的效益，如维持空气质量、降雨调节、侵蚀控制、自然灾害缓冲、人类疾病控制、水源保持及净化等功能对社会经济发展的支持效益；

（3）Cultural Service 文化功能：通过丰富人们的精神生活、发展认知、大脑思考、生态教育、休闲游憩、消遣娱乐、美学欣赏以及景观美化等方式，而使人类从生态系统获得的体力恢复和精神升华等非物质的服务效益；

（4）Life supporting function 支持功能：森林生态系统生产和支撑其它服务功能的基础功能，如物质循环、能量吸收、制造氧气、初级物质生产、形成土壤等对生存环境的支持效益。

Desirable Outcomes :
① a reliable supply of clean water, environmental protection such as reduced soil erosion, lower landslide risk, flood/drought mitigation etc.,
② a sustainable supply of a diverse range of forest products including foods, medicines, firewood etc.
③ Monetary income from various sources e.g. ecotourism, carbon trade, and other cultural services,
④ creating opportunities of job or payments for other environmental services of forests.

中国多功能林业
发展道路探索

中国林业科学研究院"多功能林业"编写组

中国林业出版社
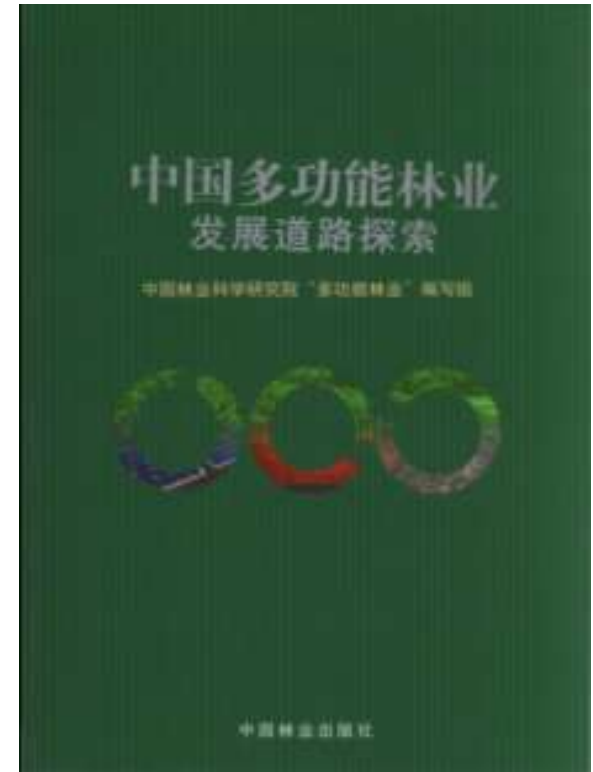
Report of 《Multi-functional Forestry in China：looking for a new development way》 2010.

2. Case study: FLR in Experimental Centre of Tropical Forest (ECTF)

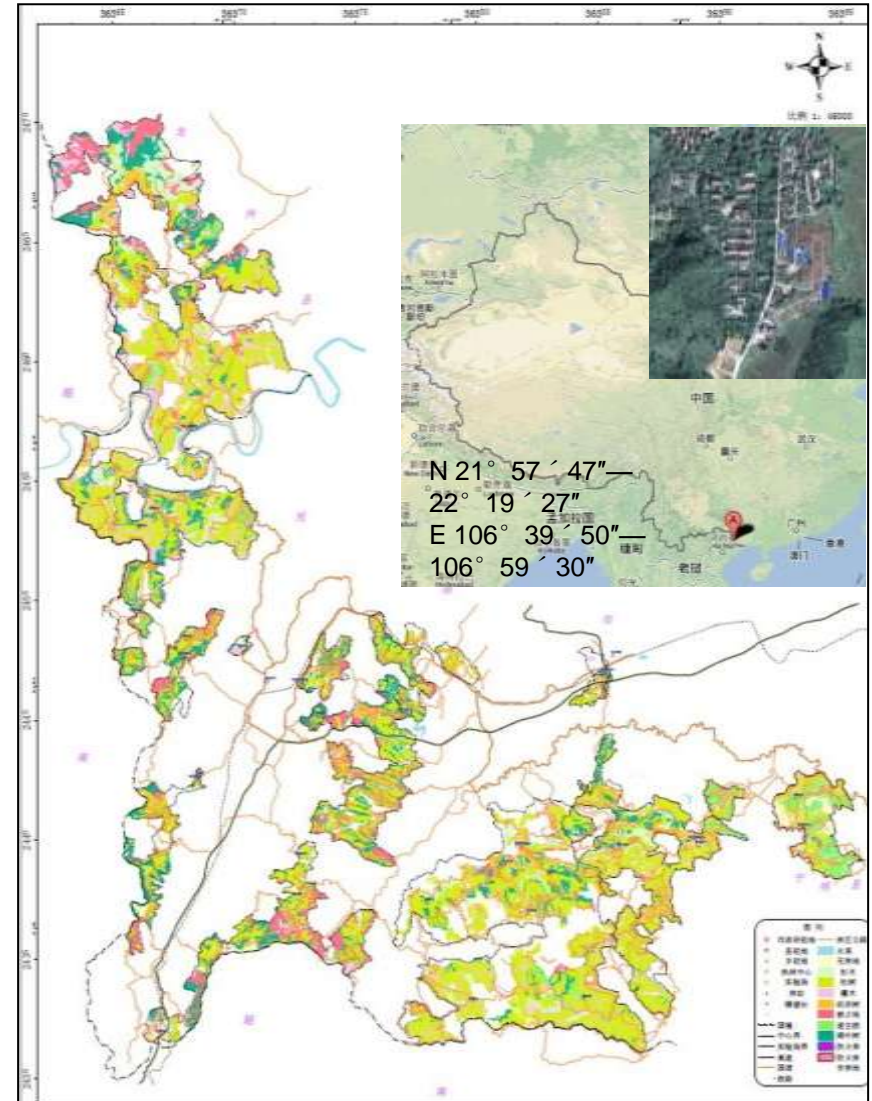■ **Ecosystem type**

Tropical mountain ecosystem with multi-species forest as potential natural vegetation.

Situation before
1975

Natural reserve
at the region

N 21° 57´ 47″—
22° 19´ 27″
E 106° 39´ 50″—
106° 59´ 30″

2.1 History, Problems and threats

(1) Barren mountain or degraded secondary forests was dominated in the region **before the establishment of ECTF on 1979,** after establishment it has devoted to afforestation to restore landscape forest cover with **mainly pines** （*Pinus massoniana*） **and Chinese fir** *(Cunninghamia Lanceolata).*

(2) The forest area of ECTF is about 19,000 ha with forest volume of 1,390,000 m^3.

(3) However, Poor quality stems, decline in yield and soil fertility were observed due to single-species plantation, short rotation with clear-cut .

(4) after year of 2000, ECTF changes its strategy from rotation plantation to CCFM under the goal of multi-functional development.

(5) The success of plantation transformation from pure forest to uneven, mixed forest was achieved up to now.

(6) This achievement was reported by *Science* in 2009.

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Problems and threats

- Multi-generation afforestation with pure *Pinus massoniana* or *Cunninghamia Lanceolata* and simple operation types (short rotation and clear cutting) caused a series of problems:

- 1. simple function, bad stability and serious diseases and pests;

- 2. decline of soil fertility and stand quality;

- 3. Other problems such as forest health, vitality, productivity, and lower return on investment etc. which causing various contradictions between land utilization, society and environment.

Pests damage on *Pinus massoniana* plantation happens every year.

Low quality and yield CuLa forest

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2.2 Project description and activities
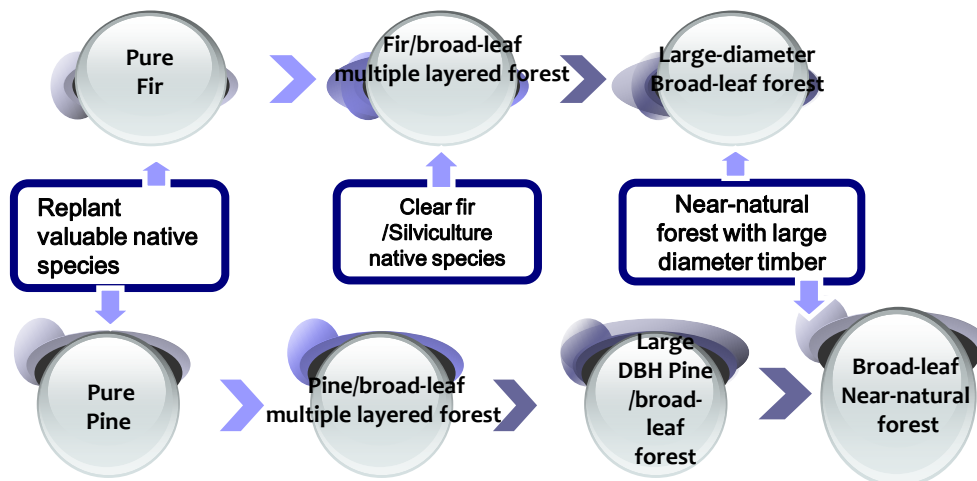
- **10.5 Planning period (2001-2006)：**

 1. National Project of research and demonstration of valuable tree species management；

 2. Arboretum for the conservation and utilization of germplasm resources.

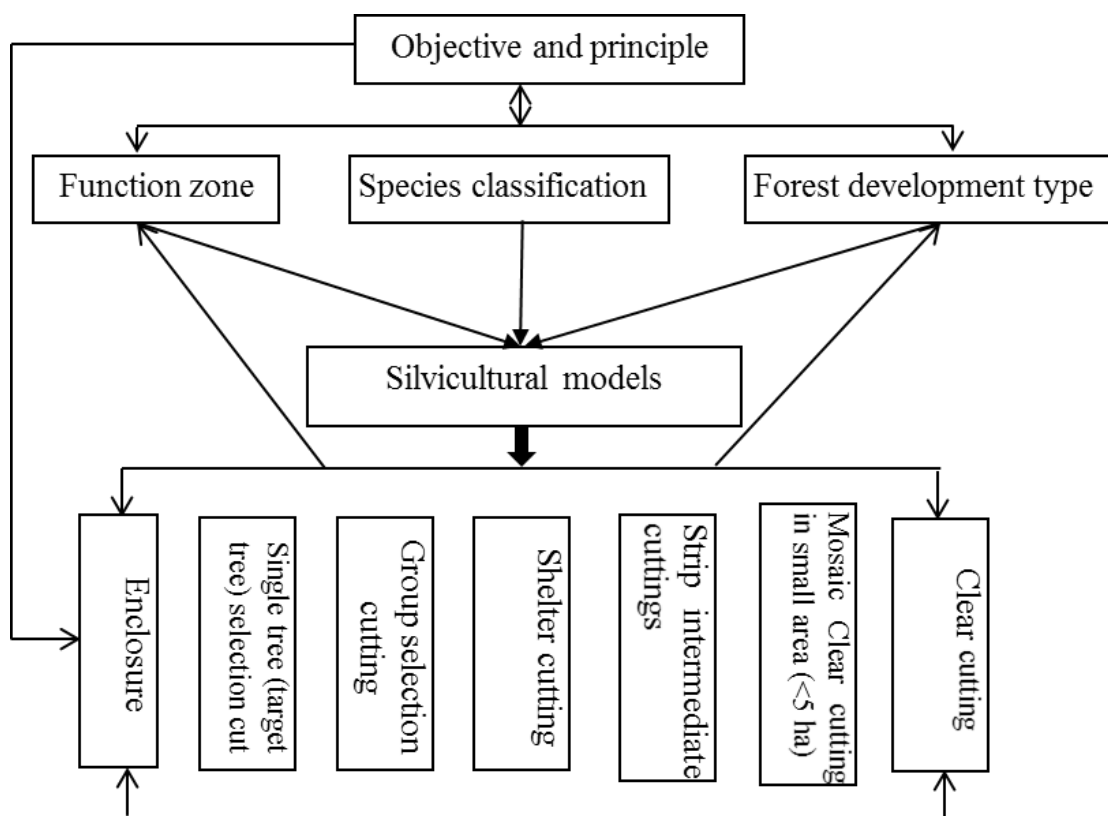- **11.5 Planning period (2006-2011)：**

 1. national Project of close-to-natural transformation of *Pinus massoniana* and *Cunninghamia Lanceolata* plantation；

 2. Study on silviculture regime of valuable tree species large-diameter timber fores；

- **12.5 Planning period (2011- 2015)：**

 1. Study on multi-functional forest management planning and operation models.

 2. Innovative techniques for multipurpose management of new forests - with a focus on carbon sequestration and climate change adaptation (Sino-German joint study)

Pure Fir → Fir/broad-leaf multiple layered forest → Large-diameter Broad-leaf forest

Replant valuable native species

Clear fir /Silviculture native species

Near-natural forest with large diameter timber

Pure Pine → Pine/broad-leaf multiple layered forest → Large DBH Pine /broad-leaf forest → Broad-leaf Near-natural forest

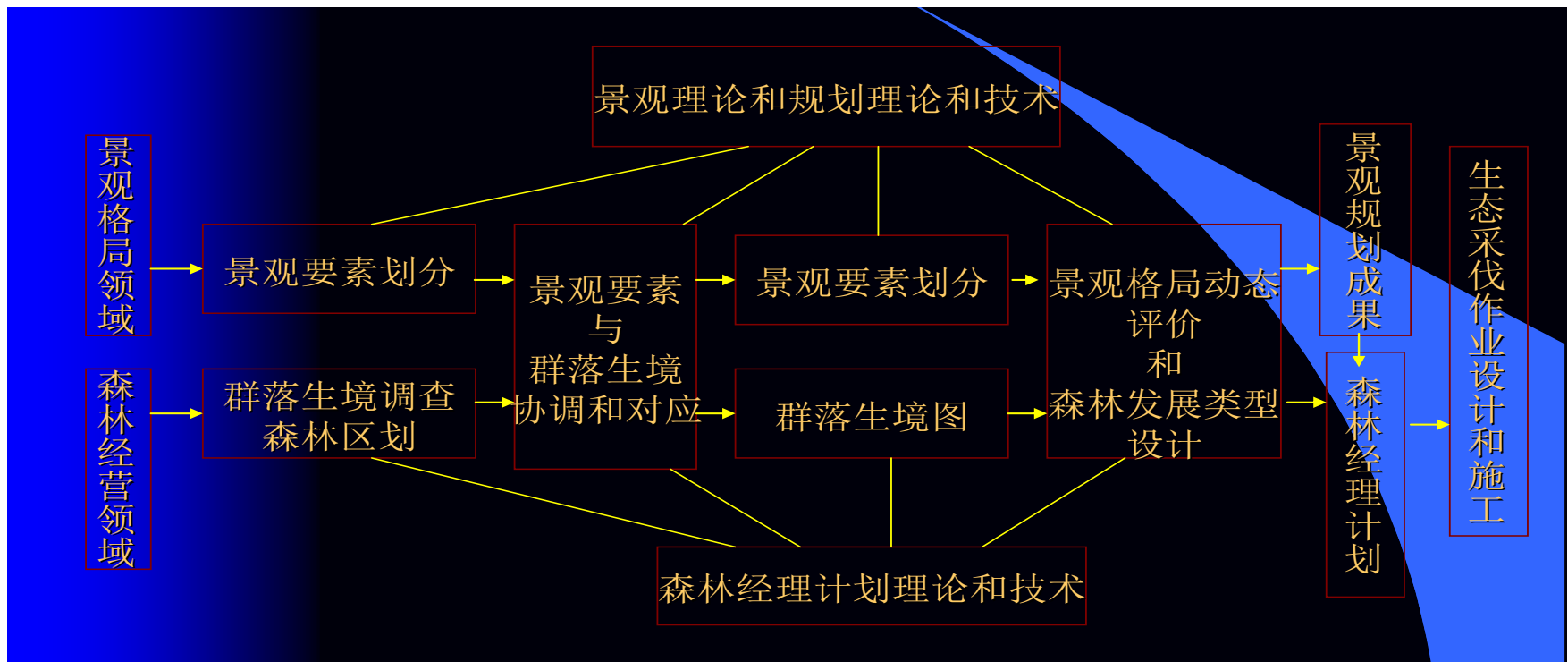# 2.3 ECTF: Technical framework MF Forest management plan

Example: Grope design of close-to-natural management on eucalyptus plantation:

(1) Fast-growing forest management model of eucalyptus mixed with acacia rachii (*Acacia confuse*);

(2) Target to medium size timber production and improving soil fertility management model of Eucalyptus dominated, *Mytilaria* (*Mytilaria laosensis*) co-dominated and sweet gum (*Liquidambar formosana*) as accompanying species ;

(3) Succession dynamic and intensive management model of enrichment planting dalbergia odorifera (*Dalbergia odorifera*) under eucalyptus canopy.

2.4 Spatial planning techniques (SPT) supported with landscape character assessment and RS-GIS-GPS application

- Combination of landscape character classification with forest management planning

景观理论和规划理论和技术

景观格局领域 → 景观要素划分 → 景观要素 与 群落生境 协调和对应 → 景观要素划分 → 景观格局动态评价 和 森林发展类型设计 → 景观规划成果 森林经理计划 → 生态采伐作业设计和施工

森林经营领域 → 群落生境调查 森林区划 → 群落生境图

森林经理计划理论和技术

Multi-function zoning 森林多功能区划技术

区划基础信息   多功能经营分区图

海拔高度图层

坡度图层

河流缓冲区图层

道路缓冲区图层

旅游景点和保护区
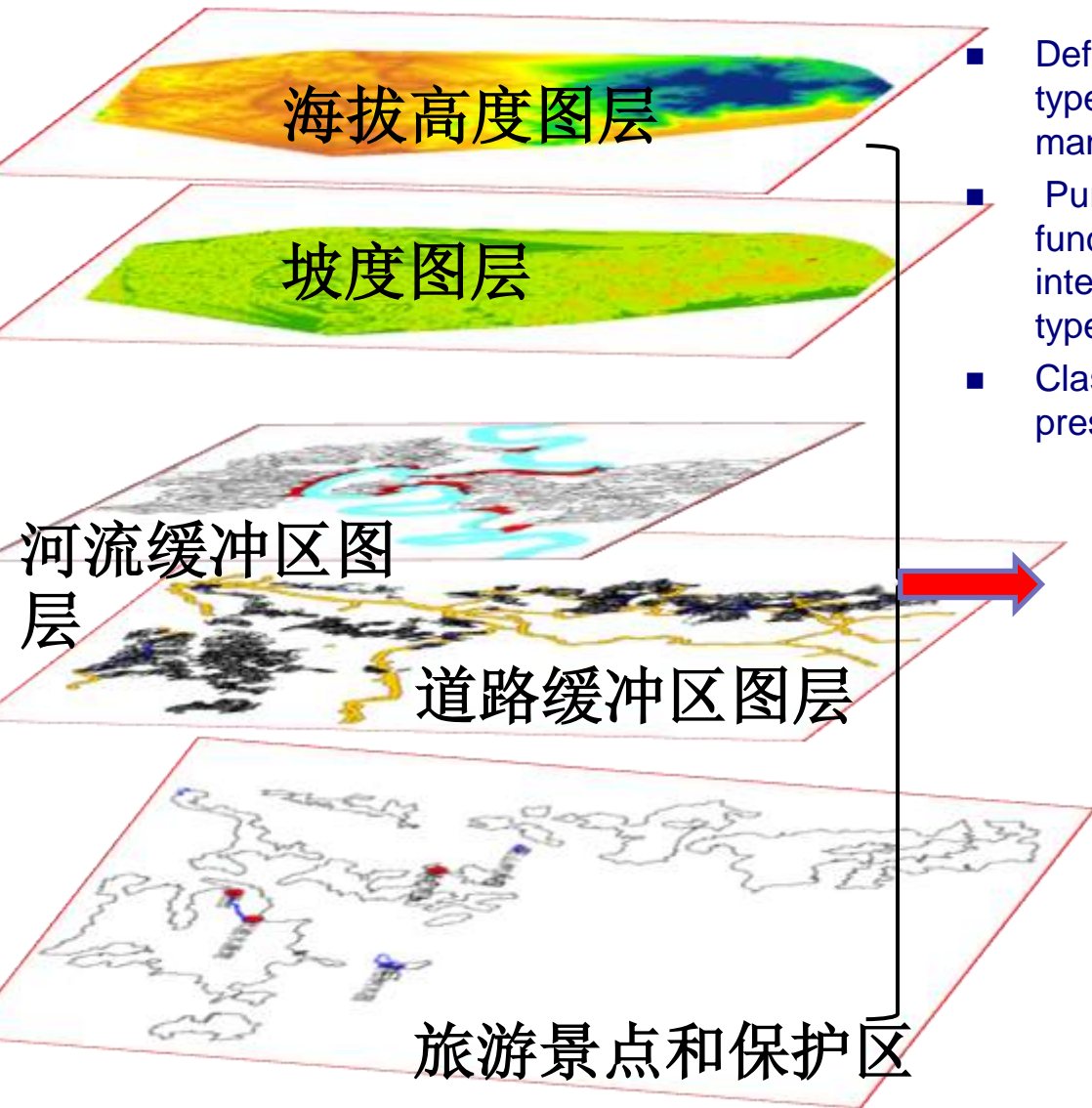
- Definition: Divide the forest into different function types following regulation standards in the management unit.
- Purpose: Realize the classification of multi-function forest management and use different intensity operations in corresponding function types.
- Classification based on geographical, site, biotope, preservation area etc.
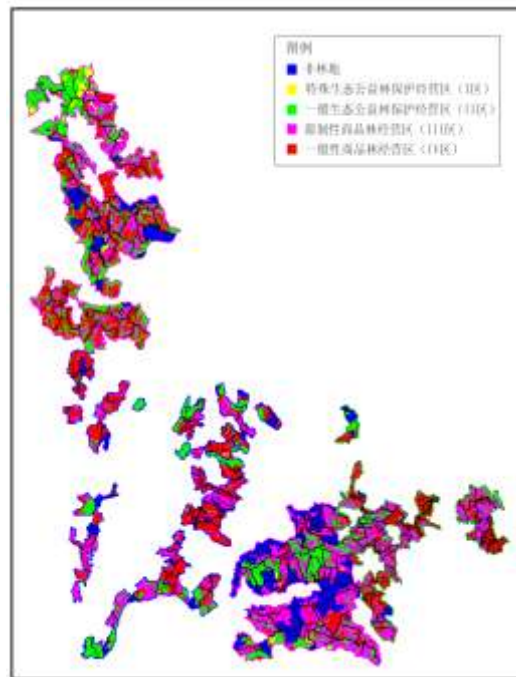
Operation steps of Function Regionalization

图形数据准备　　属性数据准备

基础图层制作

海拔图层　坡度图层　道路图层　河流图层　国防林　自然保护区　旅游、试验林

限制条件图层　　功能区划图

经营强度图

River buffer zone

Tourism points and area
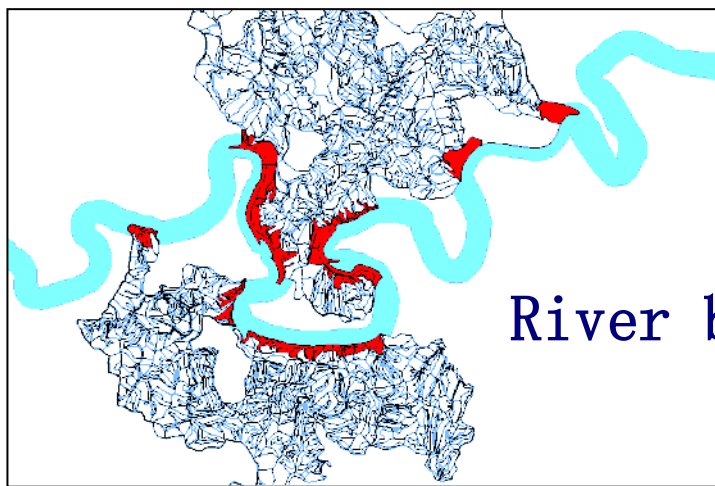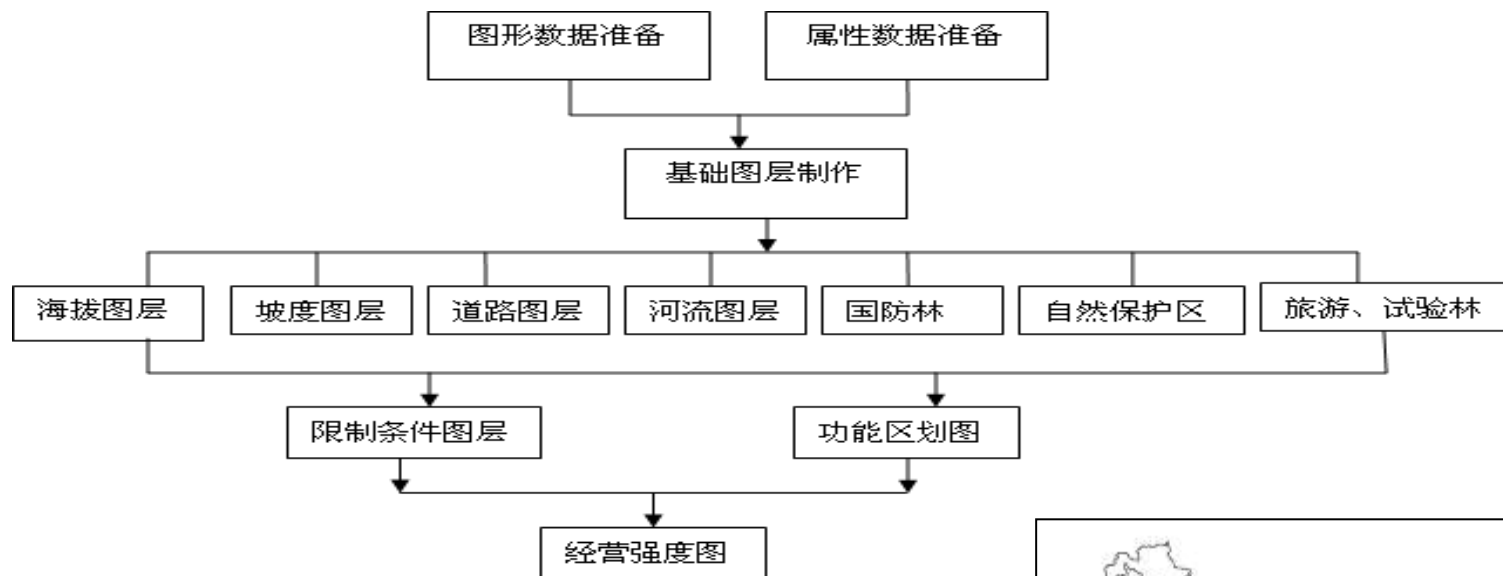
Results: Multi-functional FM plan at MU level-
Function Zoning as pre-condition of stand model design

Results:

- 4 function types in Experimental center of tropical forestry (ECTF) :

I: ecological forest zone with special protection: forests have special function and value, need strict protect, felling is forbidden.

II: ecological forest zone with some optimization tending, low intensity operation activity.

III: Commercial forest zone with restricted felling, low intensity felling for timber production, clear-cutting is forbidden.

IV: Commercial forest zone: timber production without restriction of operation intensity.

伏波分场森林经营区划图

图 例

非林地等
特殊生态公益林
限制性商品林
一般生态公益林
一般性商品林

陆元昌   中国林业科学研究院**(CAF)**，北京**100091**
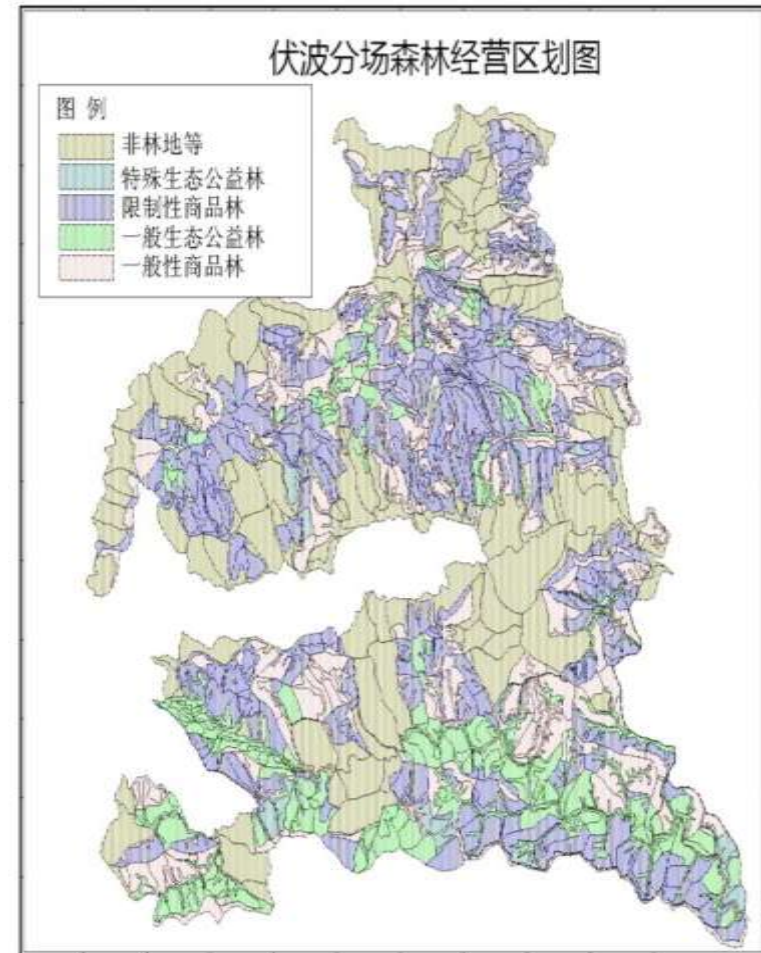
2.5 ECTF : MF Forest management and operation guidelines at stand level

1. Under the new concept of plantation，a series of forest types from Simple Structured fast-growing plantation to complex structured forest are involved in MFFM．

2. In a systematic consideration of MFFM based on the control of operation intensity，7 key silvicultural models are difined to meet the need of rich form of plantation management．
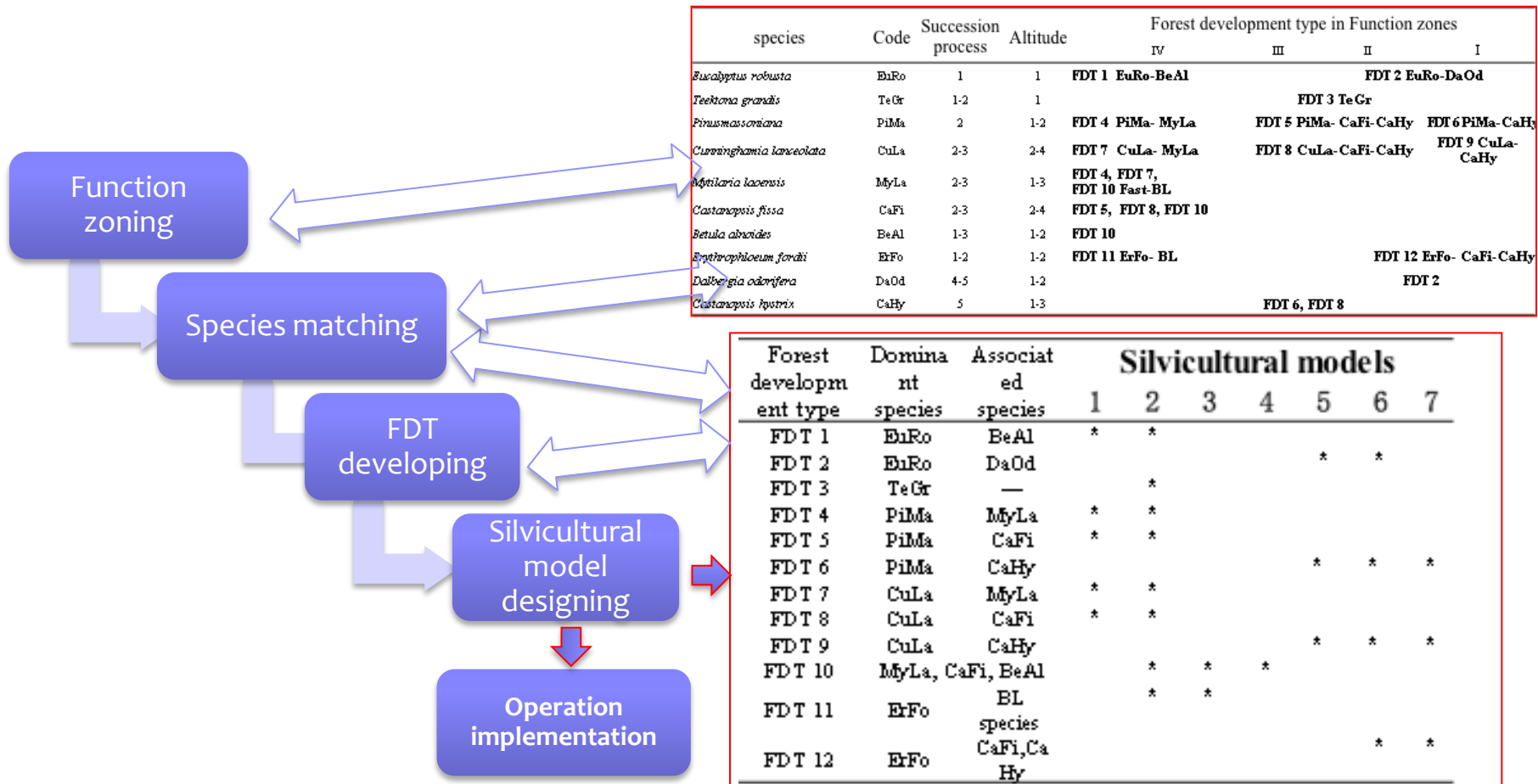
species	Code	Succession process	Altitude	Forest development type in Function zones			
				IV	III	II	I
Eucalyptus robusta	EuRo	1	1	FDT 1 EuRo-BeAl		FDT 2 EuRo-DaOd	
Teektona grandis	TeGr	1-2	1		FDT 3 TeGr		
Pinus massoniana	PiMa	2	1-2	FDT 4 PiMa- MyLa	FDT 5 PiMa- CaFi- CaHy	FDT 6 PiMa-CaHy	
Cunninghamia lanceolata	CuLa	2-3	2-4	FDT 7 CuLa- MyLa	FDT 8 CuLa-CaFi-CaHy		FDT 9 CuLa-CaHy
Mytilaria laoensis	MyLa	2-3	1-3	FDT 4, FDT 7, FDT 10 Fast-BL			
Castanopsis fissa	CaFi	2-3	2-4	FDT 5, FDT 8, FDT 10			
Betula alnoides	BeAl	1-3	1-2	FDT 10			
Erythrophloeum fordii	ErFo	1-2	1-2	FDT 11 ErFo- BL		FDT 12 ErFo- CaFi-CaHy	
Dalbergia odorifera	DaOd	4-5	1-2			FDT 2	
Castanopsis hystrix	CaHy	5	1-3		FDT 6, FDT 8		

Forest development type	Dominant species	Associated species	Silvicultural models						
			1	2	3	4	5	6	7
FDT 1	EuRo	BeAl	*	*					
FDT 2	EuRo	DaOd					*	*	
FDT 3	TeGr	—		*					
FDT 4	PiMa	MyLa	*	*					
FDT 5	PiMa	CaFi	*	*					
FDT 6	PiMa	CaHy					*	*	*
FDT 7	CuLa	MyLa	*	*					
FDT 8	CuLa	CaFi	*	*					
FDT 9	CuLa	CaHy					*	*	*
FDT 10	MyLa, CaFi, BeAl			*	*	*			
FDT 11	ErFo	BL species	*	*					
FDT 12	ErFo	CaFi,CaHy						*	*

- Function zoning
- Species matching
- FDT developing
- Silvicultural model designing
- Operation implementation

- **Stand silvicultural models:**
  M2: Mosaic clear cutting小面积皆伐作业

Concept:

Mosaic clear cutting, and the cutting area is less than 5 hectares. The largest width and length of cutting banding are100 and 500 meters when the gradient is more than 15°. Reforestation in the cutting blocks should be finished in two years after the felling.
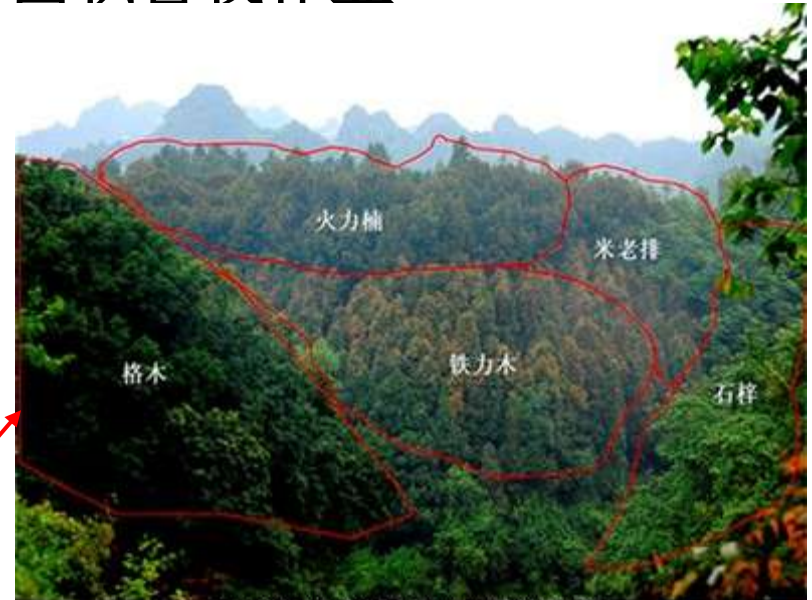
多树种块状配置的森林景观恢复
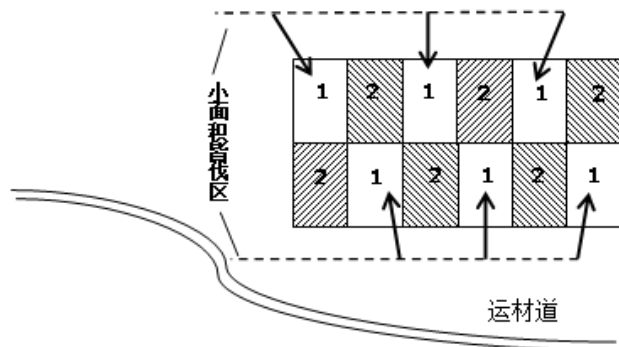
镶嵌式小面积皆伐区：1）第一次采伐带；2）第二次采伐带

- ■ the cut area is strict less than 5 hectares.
- ■ The cutting blocks should be arranged like mosaic grids, and the regeneration (artificial or natural) in the cutting blocks can be protected by the adjacent stands (Figure).
- ■ The width of retained banding is more than the average stand height; the boundary of cutting block should be selected where stands have better wind resistance.

An Example for SM5:Silvicultural models application

1）Subcompartment analysis

Afforestation time：1993.

Forest type：*Pinus massoniana* immature timber

Average DBH:19.7cm

Average tree height:14.2 m

Accumulation: 83.3m^3

Density: 600N/hm^2，

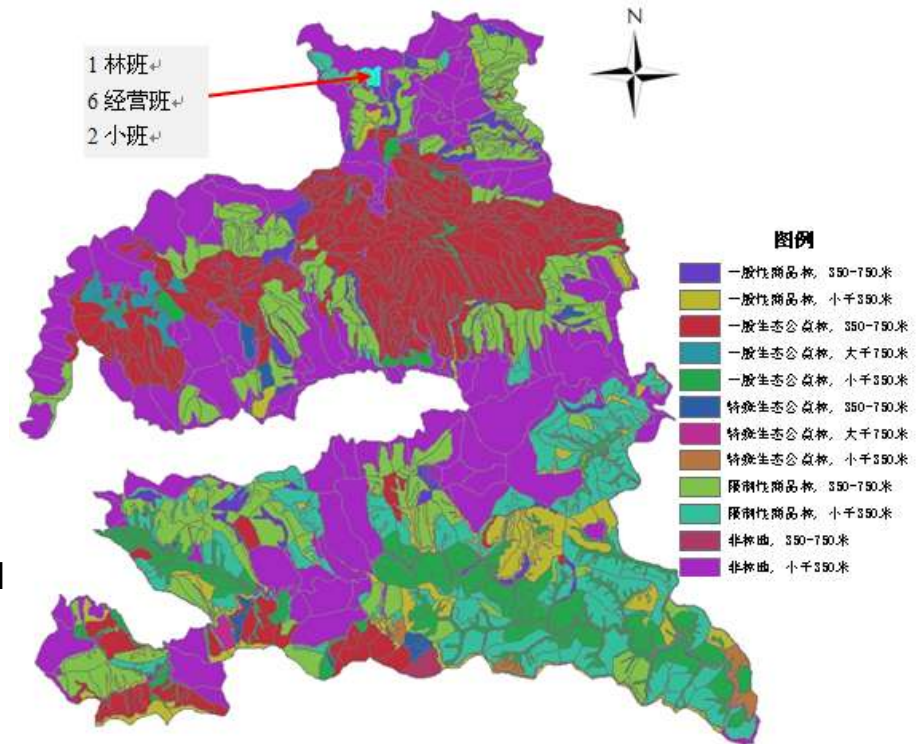Elevation: 401 meter,

Gradient: 30°,

Soil thickness: 150 cm,

Mother rock and soil : magmatic rock, latosolic red soil.

2）function regionalization

Type III: Commercial forest zone with restricted felling, low intensity felling for timber production, clear-cutting is forbidden.

3）Target analysis

 "timber production—landscape—ecological consideration"

4）Species configuration and FDT
   FDT 5 PiMa- CaFi-CaHy

5）Silvicultural model
   Group selection cutting

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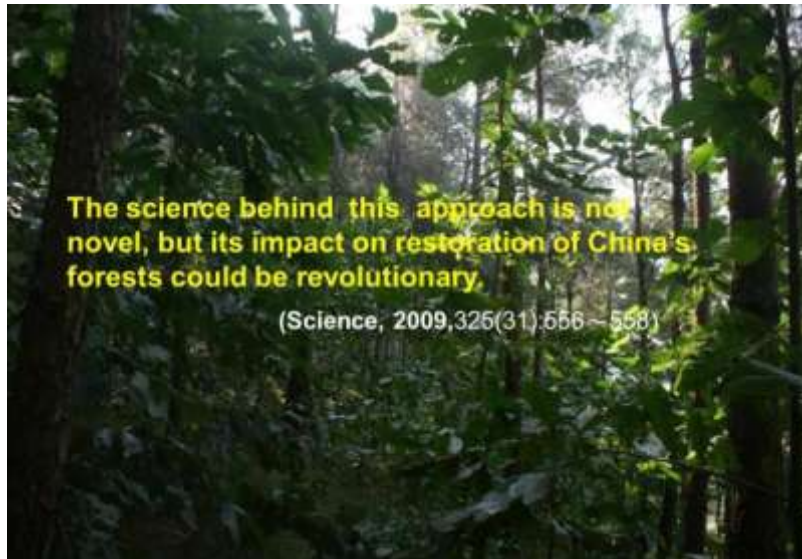# 2.6 Tentative results of plantation close-to natural transformation

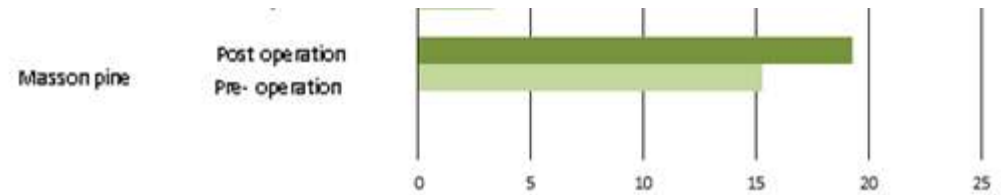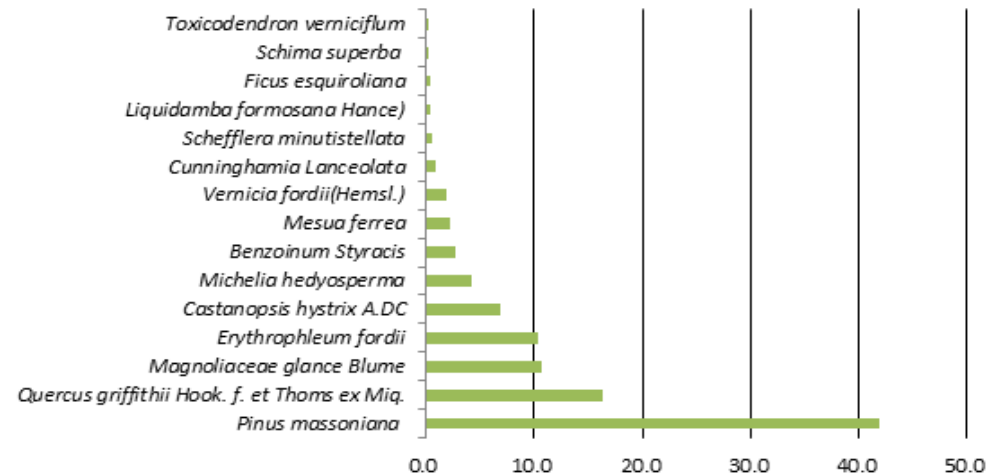Fig. 1 Standing volume increment 5 years after operation (m3/ha.yr)

Fig. 2 Tree species composition per hectare N (%)

First overall influence Results after Transformation

Impact on environment, biodiversity

1. BL deciduous   is 5864 kg·hm^{-2} per year;
2. Thickness of soil humus increase 10%;
3. Carbon reserve of topsoil（0 - 10 cm）is 33 t·hm^{-2}，increase 11%;
4. Soil maximum water-holding capacity increase 27.1%, total porosity increase 8.0%, drain ability increase 5.92%.
5. Effect of biodiversity see Tab. 1

Socio-economic benefits, including livelihoods：

1. Production value increase 356.4 %;

2. Harvest increasing than Rotation plantation, see Tab.2

3. Average Family Livelihood in ECTF increase from 2300 to over 5000 RMB now (2012).

Tab. 1 Change of biodiversity in operation and contrast forest stands

Main species	Operation	layer	Species kinds		Shannon-wiener index		Piener index	
			2007	2012	2007	2012	2007	2012
Pinus Massoniana	Controled	Tree	1	9	0	1.14		0.82
		Shrub	34	47	1.31	2.78	0.81	0.89
		Grass	11	15	0.86	1.46	0.78	0.70
	reference	Tree	1	1	0	0		
		Shrub	31	33	1.42	1.93	0.79	0.75
		Grass	12	10	0.91	1.29	0.66	0.72
CuLa (Chinese fir)	Controled	Tree	1	13	0	1.37		0.76
		Shrub	35	45	1.44	2.58	0.69	0.80
		Grass	15	18	1.12	1.82	0.81	0.79
	reference	Tree	1	1	0	0		
		Shrub	34	33	1.53	2.01	0.74	0.74
		Grass	12	12	1.07	1.51	0.66	0.73

Tab. 2 Harvests in operation and contrast forest stands

	reference	Control ed		
	Pinus massoniana (30 a)	*Pinus massoniana (50 a)*	*Castanopsis hystrix and hv species*	Total
N/ha	525	45	375	420
Average H(m)	18.5	22.8	24.5	
Aver DBH(cm)	26.5	60.2	28.5	
Volume(m^3/ha)	228	109.5	267	376.5
Value(RMB/ha)	111,150	106,762	400,500	507,262

3. Theory and techniques in FLR practice in China

- 3.1 Spatial Planning Techniques (SPT)

  ECTF example

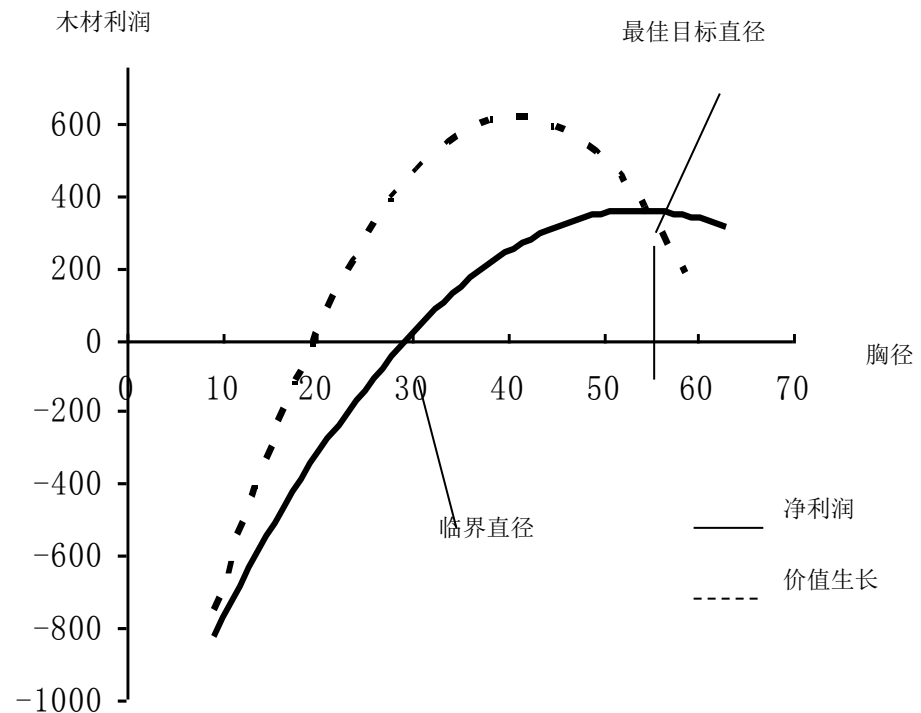- 3.2 Close-to-natural Forest management (CNFM)

- 3.3 Release New Forestry Polices (FP)

3.2 Close-to-natural Forest management (CNFM)

The CNFM regime profit such non-market benefits, but how about the market value of forest ?

German experience: CNFM is marked with Series products and high valuable timber

木材利润

最佳目标直径

| 600 |
| 400 |
| 200 |
| 0 |

0 10 20 30 40 50 60 70   胸径

−200
−400
−600
−800
−1000

临界直径

净利润 ——

价值生长 -----

Principles of close-to-natural forest management:
a general view suitable for restoration of degraded forest
近自然森林经营的基本原则

■ **What is a forest? Principle of bio-rationalization in silviculture – the first principle of close-to-natural forest management**

什么是森林？ 经营森林的生物合理性原则-近自然森林经营的第一个基本原则

■ **What could be omitted? Hiring the force of natural automation - the second principle of close-to-natural forest management**

可以不做什么？ 利用自然自动力原则 - 近自然森林经营的第二个基本原则

■ **Why we do it? Natural response promotion- the third principle of close-to-natural forest management**

为什么要这样做？ 促进森林反应能力原则-近自然森林经营的第三个基本原则

Systematical consideration of Silvicultural Operation Design at stand level

The first dimension: Logical consideration based on natural succession process for silviculture planning 近自然经营技术主导的第一维度：基于演替进程的经营计划考虑

- Based on natural succession process, the CNFM process is divided into 5 stages with structural and operational parameters:

1. 森林建群阶段 **Forest establishment stage:** ranges from establishment/afforestation and additional natural regeneration with indigenous tree species till canopy closure begins.

2. 竞争生长阶段 **Competition differentiation stage:** begins at forest canopy closure until obvious main canopy of storey constructed, all established trees develop their heights to compete for sunlight in a way of supporting to each other. In some natural situations, indigenous pioneer species can dominant the stand species composition, under the canopy the brush-plants and grass begin to die, and some shade tolerant trees from natural regeneration begin to grow.

3. 质量选择阶段 **Dominant Selection stage:** Dominant trees in main canopy are clearly differentiated in competition position, quality and vitality. The selection of the best trees for the different function in the stands are clear, and is the beginning of the single tree management. Natural regeneration begins to grow into the main canopy, especially in the gaps.

4. 近自然森林阶段 **Close-to-nature (pre-mature) stage:** There is clear differentiation in terms of multi layers of the trees until the forest becomes mature (Target diameter reached). In this stage, less vigorous or poor quality trees will lag behind the development of more vital trees, the ground vegetation changes to typical herbs of the forest and the shrub-vegetation develops weakly. The natural regeneration is dominant more by shade tolerant, indigenous tree species with high growing rate shows a better productivity as the first afforestation generation.

5. 恒续林阶段 **Naturalness permanent forest stage (mature forest):** This stage starts when the forest meets maturity standards. Forests planted for timber purpose can be naturally regenerated to recover the losses in tree numbers as well as timber volume during the years of exploitation. Forest with nut, fruit, or resin trees are producing nuts, fruits, or resin at maximum outputs.

The second dimension: Classifying the main canopy structure of current stand

☐ The canopy structure can be divided into: 1) pure or mixed forest composed by indigenous broadleaf tree species; 2) mixed conifer and broadleaf forest; 3) pure coniferous forest; 4) forests with degraded canopy. No matter what succession stage the current forest is, canopy structure is the most important factors by determining forest management activities.

☐ 无论那个演替阶段的森林，其主林层的结构状态和树种是决定当前经营处理措施的重要因素。主要划分为4种类型：

（1）由乡土阔叶树种构成的纯林或混交林，canopy composed by indigenous broadleaf tree species,

（2）针阔混交林，canopy mixed with needle and broadleaf tree species,

（3）针叶纯林，canopy with pure needle species,

（4）主林层退化的森林，main canopy degraded。

The third dimension: Silvicultural grouping of tree species based on characteristics of light competition

☐ Tree species can be sequentially classified into 5 types according to their characteristics of light competition:

typical pioneer, long-life pioneer, opportunist or neutrals, sub-climax, and climax species.

☐ **Usage of this knowledge:**

☐ Tree species in the later sequence can be enriching planted and survive under canopy of the former ones but the opposite sequence is not reasonable.

■ **Example: 5 types of species in ECTF :**

1) pioneer tree species (*Eucalyptus robusta, Mytilaria laoensis*),

2) long-life pioneer tree species(*Pinusmassoniana, Cupressus sempervirens*),

3) opportunist tree species(*Toona sinensis , Styrax roseus*),

4) sub-climax tree species(*Schima superha, Erythrophloeumfordii*),

5) climax tree species(*Dalbergia odorifera, Castanopsis hystrix*).

The fourth dimension: Individuals differentiation and competition

第四维度： 林木个体差异和竞争关系

Concentrated on high vitality and quality individuals
:

- （1）Target tree 目标树：目标树是处于优势木或主林层的个体，生活力旺盛（有良好生长趋势的冠型） ，干形通直完满，没有明显的损伤和病虫害痕迹，特别是在树干的基部不能出现各种因素导致的损伤情况等。

- （2）Disturbing tree干扰树：是直接影响目标树生长的、需要在本次经理计划期内采伐利用的林木，记为"B"类（德语Bedranger）；干扰树一般也是生长势头较强的林木，作为抚育采伐的对象，使得在抚育经营的过程中有一定的木材收获。

- （3）Special function tree 特殊目标树：为增加混交树种、保持林分结构或生物多样性、保持鸟类和动物生境等目标服务的林木，记为"S"类；在国家和地方保护树种名录上的树种一定要列为特殊目标树加以保护。

- （4）Other rest tree 一般林木：不作特别标记。特殊情况下可在抚育过程中按需要采伐利用一定数量以满足当地的用材需求。

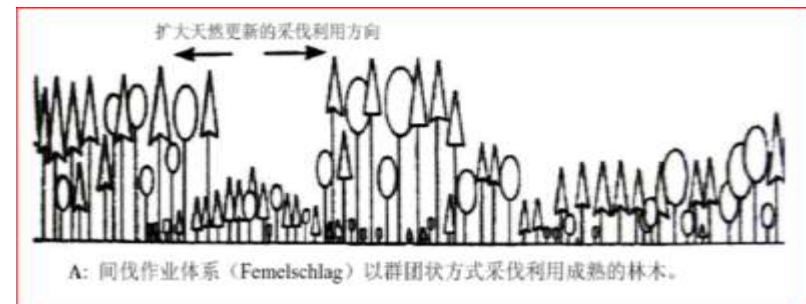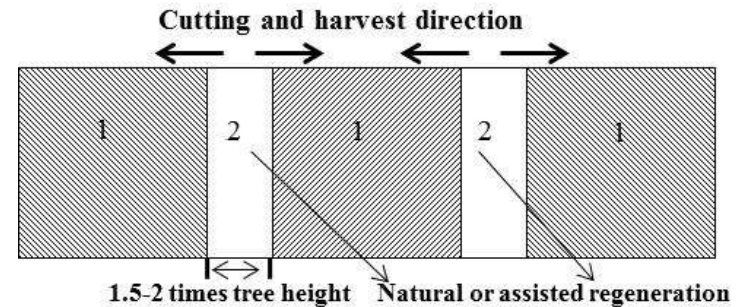# Designing a complete series of stand Silvicultural models
林分作业法设计

作业法是根据各类森林发展类型的树种特征（耐阴性和速生性等）、经营利用特征（功能类型）和生长环境特征（群落生境和立地条件）开展的林分作业技术设计。

① 根据林分的功能类型和经营强度特征确定的作业法序列
1. 皆伐作业 **Clear-cutting**
2. 镶嵌式小面积皆伐作业 **Mosaic clear cutting**
3. 带状间伐作业 **Mosaic clear cutting**
4. 四次抚育渐伐作业 **Shelter cutting**
5. 群团状择伐作业 **Group selection cutting**
6. 目标树单株择伐作业
   Single tree(target tree) selection cut
7. 封育保护经营 **Enclosure and protection**

② 针对具体小班或地段的林分作业法设计

● 发展类型

● 林分作业法

● 近期作业措施

Cutting and harvest direction

1.5-2 times tree height   Natural or assisted regeneration

扩大天然更新的采伐利用方向

A: 间伐作业体系（Femelschlag）以群团状方式采伐利用成熟的林木。

Standardized silvicultural operation options
标准化的经营作业措施

- Options:

人工林多功能经营的作业措施是指为实现森林发展类型的经营过程制定的包括采伐收获、林下补植、更新造林和保护以及施肥浇水、割灌除草等一系列经营活动的统称。包括林分抚育采伐、主伐收获、林下补植、混交造林、保护和促进天然更新等作业措施。

- Preconditions:

措施制定必须围绕具体的经营对象的功能限制、结构特征和过程模式设计进行，使各个作业技术要素互相联系、互为补充、承上启下地贯穿于整个经营技术系统始终，以保证所有措施对于系统目标的有效性，形成科学完备的技术体系。

3.3 Release New Forestry Polices (FP)

Policy and strategy for restoration of degraded forest ecosystems at national level includes:

① Classification of forest areas: Conservation of biodiversity and establishment of nature reserves, limiting management intensity of forests with main function of ecological and public benefit protection.

② Supporting all marketing activities deal with forest silviculture and resources improvement, like taxi free products, free interest of bank loan in FLR, release controlling for tending cut in forest, license for forest land tenancy management, etc.

③ Increasing state investment for silvicutural operations based on the new National Code of Forest Tending.

④ Improving road and traffic condition in forest area by governmental supports.

⑤ Strengthen technical training, capability development and scientific supports.

4. Case study of FLR in other regions
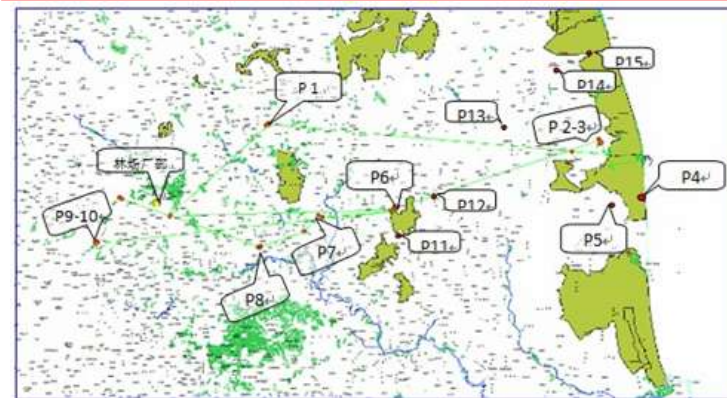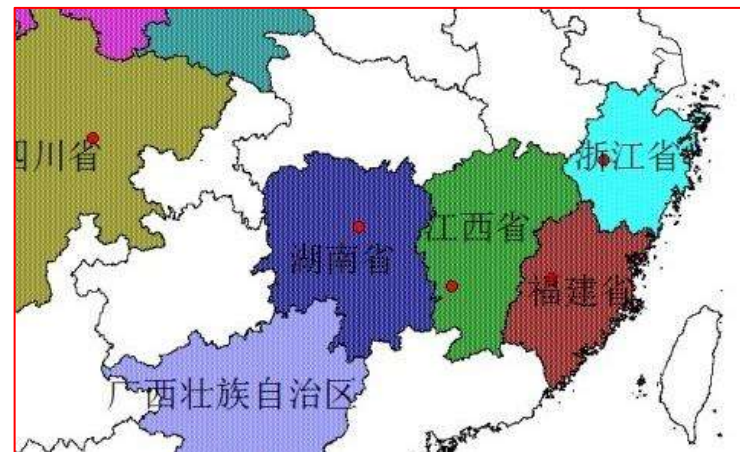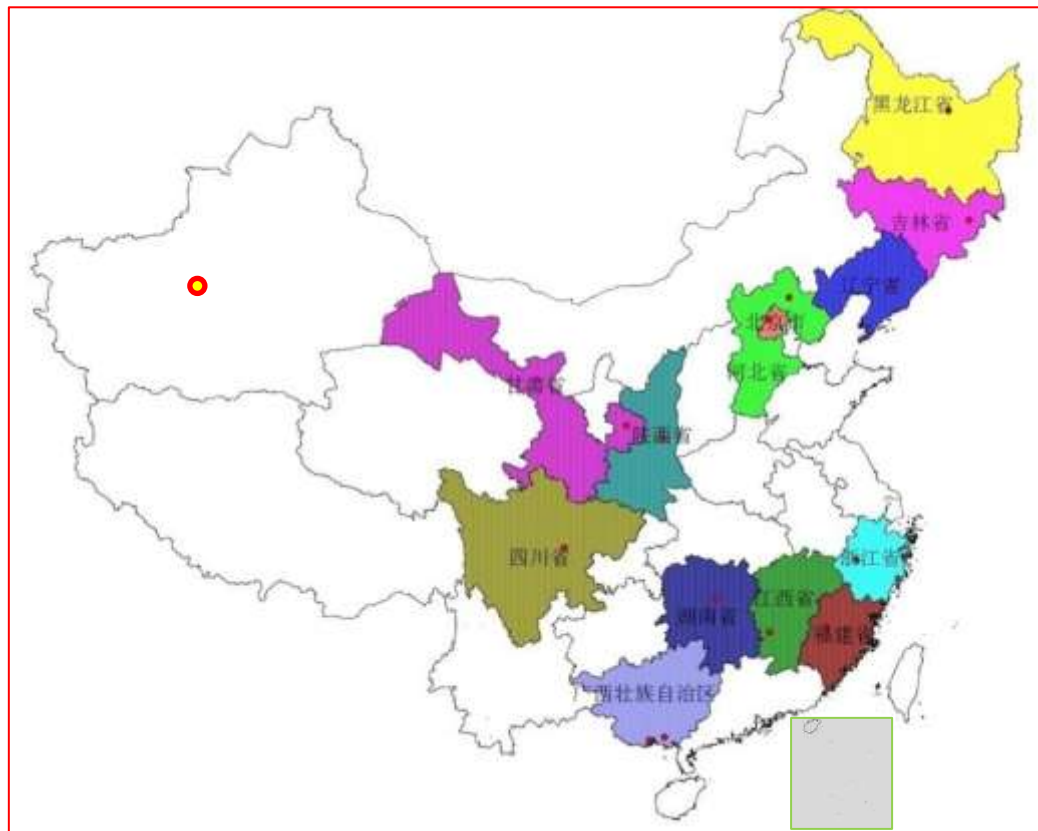
Case study 2: large scale forest restoration of damaged forests by the extreme ice-storm in 22 counties in Hunan Province

In the extreme ice-storm happened in early 2008, forestry suffered huge losses in Hunan province. The forestry direct loss was 16.5 billion Yuan; affected population in the forestland area was 9.236 million. The forest resources in Hunan suffered large losses and the forest ecosystem was badly damaged. The affected forest accounts for 35.28 percent of the total forest area and 43.19% of the total growing stock volume in Hunan.


杉木

毛竹

The 8 Models of MFFM for the project region

湖南省森林生态恢复和发展项目

技术设计建议

—森林恢复经营模型和实施技术指南
（框架）

陆元昌　　David Lamb

2011 年 6 月

Table 3 Design table of forest restoration management models

forest management type	TSP&dominant species	suitable site conditions and stand situation	available other mixed species	main operation measures	affore statin deman	impro ving regen	future stand operation method	ecological function	inverstmen t intensity
1. MM1: conifer + broadleaf management model									
1	CuLa-SaFz-LiHa-Qusp	degenerated forest in foothills and lower part of mountains at middle-high altitude,canopy density of plantation damaged in ice storm<	chinese fir and common broadleaf species	seedings, soil preparation, afforestation,	100		Target tree management , Cluster	continuous vitality and protective	strong
2	PiMa-LiHa-ScSu-SaFz	degenerated forest in foothills and lower part of mountains at middle-high altitude, canopy density of plantation damaged in ice storm<	masson pine and common broadleaf species	seedings, soil preparation, afforestation,	100		Target tree management , Cluster	continuous vitality and protective	strong
3	PiEn-LiHa-ChBu-ScSu	degeneration forest in plat and hilly area at low altitude , canopy density of plantation damaged in ice storm< 0.2	slash pine and common broadleaf species	seedings, soil preparation, afforestation, young trees	100		Target tree management , Cluster selective	continuous vitality and protective function	strong
4	PiMa-ScSu-SaFz	degeneration forest in foothills and hillsides at middle-low altitude with canopy density of plantation damaged in ice storm< 0.2	schima, Acer elegantulum , Toona sinensis Roem, Choerospondias	seedings, soil preparation, afforestation, young trees	100		target tree management , gathering and utilization	continuous protective functions, non-timber	strong
2、MM2: Conifer + precious broadleaf management model									
5	CuLa-PhZh-LiCh-Qusp	middle and upper part of hillsides at middle-hig	chinese fir and precious	seedings, soil preparation, afforestation, young trees	100		Target tree management , single tree selective function	continuous vitality and protective function	strong
6	PiMa-ZeSc-CiCa-Qusp	middle,upper and rigde of hillsides, canopy density of plantation damaged in ice storm< 0.2	masson pine and precio	seedings, soil preparation, afforestation, young trees	100		Target tree management , single tree selective	continuous vitality and protective function	strong
7	Cufu-RoPs-AlJud	degenerated forest in upper hillsides or ridges, in limestone or purple rock site conditions, canopy density of plantation	cypress, Cyclobalanopsis glaua, C.henryi Rehd.＆Wils,	seedings, soil preparation, afforestation,	100		Target tree management , single tree	continuous vitality and protective	strong
8	LaKa-Ch-LiCh	degenerated forest ,canopy density of plantation damaged in ice storm< 0.2, at high altitude	larch and precious broad	seedings, soil preparation, afforestation, young trees	100		Target tree management , single tree selective function	continuous vitality and protective	strong
9	Multi-specie mixture in groups	places with landscape remaining or ecological importance, having special demand for lanscape educational and cultural service	conifer and broadleaf species as rich as possible		100		measures for biodiversity and	landscape recreationa l,	strong
3、MM3: Mixed or pure broadleaf management model									
10	LiHa- AlJu-MaOl	foothills at low altitude, lower part, degenerated forest, broadleaf pure forest	soft broadleaf species	seedings, soil preparation,	100		Cluster or selective	continuous vitality and	strong
11	BeWi-AcEl-PoPs	lower part or whole hillside, middle-high altitude, conifer or broadleaf forest with canopy density of plantation damaged in ice	soft broadleaf species	seedings, soil preparation, afforestation	100		Cluster or selective cutting	continuous vitality and protective	strong
4、MM4：Precious and high value broadleaf management model)									
12	CiCa-PhZh-LiCh	low altitude, leeward and adret slope, good water and fertilizer condition, red soil, canopy density of plantation damaged in ice storm< 0.2, residue broadleadf forest	Reserve and promote ot	seedings, soil preparation, afforestation, young trees	90-100	0-10	Target tree management , single tree selective	continuous vitality and protective function,	strong, special technology
13	PhZh-CaEy-broadleaf	high altitude, slope over 25°，damange forest, have braodleaf trees	Reserve and promote ot	seedings, soil preparation, afforestation, young trees protection	90-100	0-10	Target tree management , single tree selective cutting	continuous vitality and protective function, forest	strong, special technology
5、MM5：Improving and Enrichment with Conifer + Broadleaf Model									
14	CuLa- SaFz-LiHa-Qusp	barren-middle site conditions at high altitude, canopy density 0.2-0.5, middle aged forest damaged in the ice storm, existing good	common broadleaf spec	measures to promote natural regeneration +	<50	>50	Target tree management , single tree selective	continuous vitality and protective	moderate
15	PiMa-LiHa-ScSu-SaFz	low-middle altitude,canopy density 0.2-0.5, middle aged forest damaged in the ice storm, existing good natural regeneration seedlings.	common broadleaf spec	measures to promote natural regeneration +	<50	>50	Target tree management , Cluster	continuous vitality and protective	moderate
		low altitude, flat and hilly area, canopy density aged forest damaged in the ing good natural regeneration	common broadleaf spec	measures to promote natural regeneration +	<50	>50	Target tree management , Cluster	continuous vitality and protective	moderate
		recious broadleaf							
		tions at high altitude,canopy , middle aged forest damaged , existing good natural seedlings.	enrich precious broadlea	measures to promote natural regeneration + enrichment	<50	>50	Target tree management , single tree selective	continuous vitality and protective function,	moderate
		tions in foothill or middle-lower ns at middle-low altitude, 0.2-0.5, middle aged forest e ice storm, existing good	other evergreen preciou	measures to promote natural regeneration + enrichment	<50	>50	Target tree management , single tree selective	continuous vitality and protective function,	moderate
		y by ice strom, thin soil, steep es easily to have landslide, rosion.	enrich shade tolerant and deep rooted arbor tree species like chinese fir,Taxus	bamboo forest management method, including	75-150/ha		single tree selective cutting	medium vitality and protective function	low
		a intervention							
		with poor site conditions and ere dominant layer was nged but natural regeneration 000 trees/ha,	selectively remian natural regeneration or high value or dominant species, enrich 10-30%	measures to promote natural regeneration	0	>70	selective cutting	continuous vitality and protective function	low
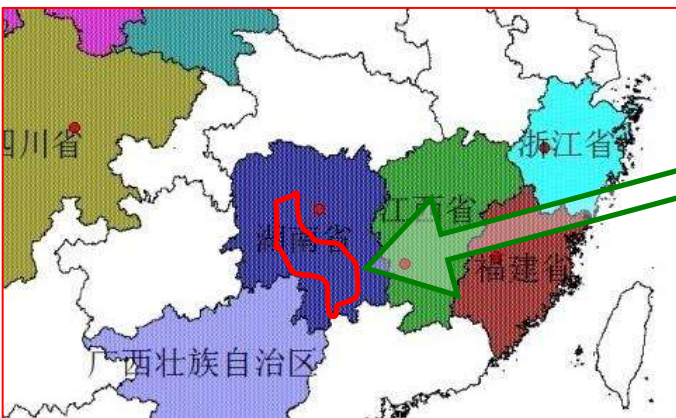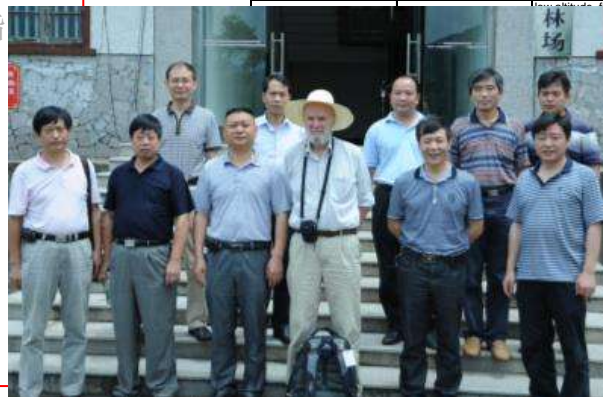
- Mission member Mr. Hans Thiel, Senior Forestry Specialist (FAO) and Prof. Y.Lu in fieldwork of project region.

TSP   5a: CuLa- SaFz-LiHa-Qus large-diameter mixed forest enrichment planting cultivation type

The target function mainly focuses on low temperature and snow disaster resistance. It is distributed in south and northwestern area of Hunan.

The **TSP** is a multi-layer mixed forest of Chinese fir, sassafras, liquidamber and oaks with a target diameter of 50cm and has natural regeneration layer in groups underneath.

It will be planted on vertical belt above 400m, barren to middle site conditions at high altitude Degraded Chinese fir forest with good natural regeneration where the has 800-1200 natural regeneration seedlings inside.   By enrichment planting of climax communities such as sassafras, liquidamber and oaks in small groups underneath, do beating up by 10 50% of original density, change the forest operation direction into precious native broadlea forest.

This 3 species can grow very well in this area with good resistance of early shadow and strong subsequent growing ability to grow up to 30 meters high, which is the primary choice for improve the degraded forestland which has been planted with Chinese fir for generations It can achieve good wood-fostering goal as soon as possible on the premise of better site condition.

Plant in groups or in cutover land according to a working system of individual target tree tending operation, the target diameter is50 cm, cultivation period is 30 years. After choosing the target trees, to foster growing of the target forest, tending and logging activity shall be performed every 10 year until the trees reach their target diameter, which can be regarded as a management cycle.

THE PEOPLE'S REPUBLIC OF CHINA

HUNAN FOREST RESTORATION AND DEVELOPMENT PROJECT

Supervision Mission Aide Memoire

**(September 23 to 30, 2013)**

I.   INTRODUCTION

1.   A World Bank mission[1] visited Hunan Province from September 23 to 30, 2013 to review the implementation progress of Hunan Forest Restoration and Development Project (HFRDP). The mission visited the planting sites and interviewed participating planting entities and farmers in Shuangpai, Leiyang and Ningxiang Counties. The mission also met with the Hunan Provincial Forestry Bureau, the Provincial Finance Department and the Provincial Academy Forestry Sciences, as well as visited county project agencies.

2.   The objective of the mission was to review and assess the progress of project implementation, make necessary recommendations for further improvement of the project management and ensure the achievement of project's development objectives and its intended impacts. The main tasks of the mission included the review of project on-lending arrangements, implementation of technical design, project operation and management, financial and procurement management, as well as social and environment safeguards compliance.

3.   On September 30, 2013, the mission held a wrap up meeting with the project management agencies. The major findings and recommendations are summarized below. The recommendations and agreements are subject to the World Bank (the Bank management review and confirmation. The Bank mission wishes to express its sincere appreciation to Hunan Forestry Bureau and other relevant project agencies for their collaboration and warm hospitality.

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[1] The mission comprised Messrs./Mmes. Liu Jin, Mission Leader;   Feng Yiren, Senior Environment Specialist; Liu Yunlong, Procurement Specialist; Hans Thiel, Senior Forestry Specialist (FAO),   Lu Yuanchang, Senior Forest Ecologist, Jieli Bai, Program Assistant, and Jianxin Chen, interpreter.

Case study 3: Forest restoration of degraded plantation in tropical coastal zone
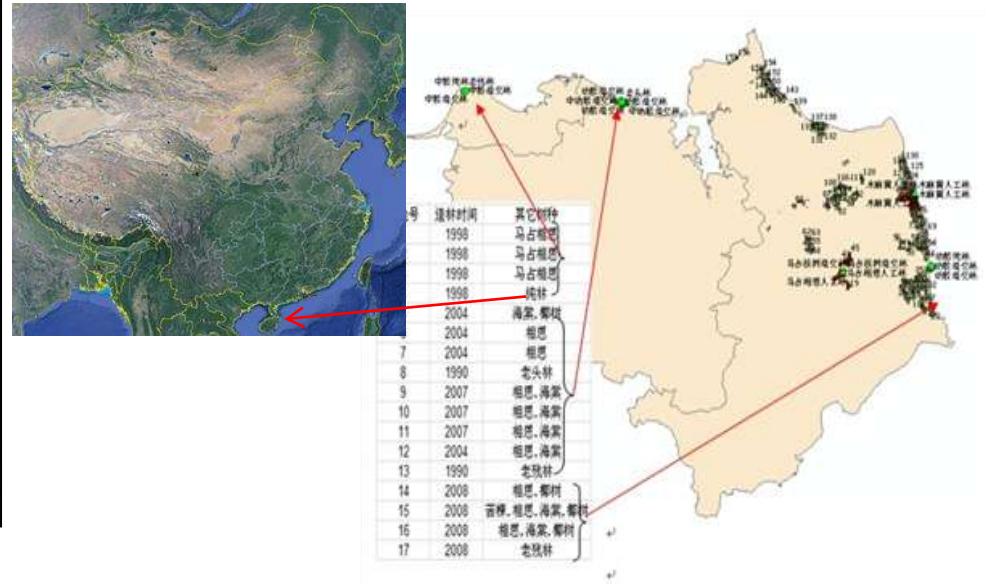
Casuarina equisetifolia is the only afforestation tree species in tropical coastal zone in Hainan, China;

Machine-cultivated afforestation and short rotation with monocultures of *C. equisetifolia* was the sole management approach for protecting coastal forests;

This approach destroyed the composition and structure of the original community along with the soil seed bank, causing native species to disappear from reforested lands;

Problems：Canopy damaged, Productivity and diversity declined, Soil nutrient declined, forest landscape in the tropical coastal zone was degraded by the lack of native species.

Approach to the problem: Establishment of a steady ecosystem with native species: silvicultural design

- The first model was to adjust the spatial and non-spatial structure in coastal protection forest which its main storey was degraded. Tree species with better tolerance and visual effects (such as *Melia azedarach*, *Cocos nucifera*, *Schefflera octophylla*) were replanted in degraded forest. With a series of nursing and tending operation, this forest development type (FDT) was aiming to drive *C. equisetifolia* monoculture forest to multi-function forest with high biodiversity, stability, protection and landscape recreation characters.

Table 3: site and forest development types

Site type	Present stand type	Leading function type		
		1. Eco- and landscape forest	2. multi-functional forest	3. improved timber plantation
1. coastal sand soil Includs: fine sand soil after Titanium mining sandstone Soil land	1.1 pure stand of Casuarina 200m to the coastline within the shelterbelt stripe shelterbelt	**FDT1:** CaEq-MeAz-multi-species (shore) protection and tourism landscape forest within 50-100m stripe wide along coastline	not referred	**FDT12:** **Casuarina equisetifolia plantation**
	1.3 pure stand of Casuarian coastal sandy soil, sandy land after mining timber forest	**FDT2:** CaEq-LiCh-Artocarpus heterophyllus Mixed forest	**FDT3:** CaEq-AcCo-HoHa mixed stand; mixed with precious and fast growing broadleaf species	**FDT4:** CaEq-AcMa Plantation for large size timber production FDT: CaEq-MeAz Plantation for large size timber production
	1.3 pure stand of Eucalyptus coastal sandy land, timber forest	in a few forest area, badly growing; not SFM-modus, only improvement in Eucalyptus stand	not referred	not referred
2. shallow sea sediment sand soil including:shallow sea sediment sand soil land	2.1 Pinus eliottii plantation	**FDT6:** Pinus elliottii/ precious broadleaf species mixed forest	**FDT7:** PiEl(PiCa) - AcMa - EndospermumCh mixture stand	FDT 13: **Pinus sp. plantation**
3 Juvenile brick red soil	pure stand of Casuarina	**FDT7:** CaEq-LiCh-Artocarpus heterophyllus Mixed forest	**FDT8: CaEq-Noble BL multi-functional Forest**	
	pure stand of Acacia mangium	not referred	**FTP9:** uneven-aged Acasia stand tending + selective cutting operation modus in uneven-aged mixed forest	FDT 11: Acacia mangium plantation
	pure stand of Pinus caribaea	not referred	**FTP10: PiCa-Noble BL multi-functional Forest**	
	pure stand of	not referred		Clear-cutting

Hypothesis: series arrangement with typical pioneer-opportunity- climax species makes a fast development towards steady coastal ecosystem.

Start point   **Enrich planted**   **One year after**   **two years after**

- ## 林分平均生长和林木优势生长

1. 马占相思与木麻黄初植混交比例（1:1），幼龄阶段混交林内相思受干扰明显，株数比例小于0.3，随林分生长，混交林内相思的相对比例逐渐提高；

2. 幼龄林阶段混交林内木麻黄单种平均增长量与林分平均增长量差异不明显（P=0.88），进入中龄阶段林分，由于马占相思的生长优势，林分平均生长量高于木麻黄单种和木麻黄纯林的平均生长量（P=0.164），并在近熟林阶段差异显著（P=0.018）；

3. 相思比例越大，林分年均生长量与木麻黄单种年平均生长量的差距越大（图3-1）；

4. 随林分生长相思个体生长优势凸显（表3-1）；

表 3-1 优势木（最大个体）组和劣势木（最小个体）组木麻黄的构成比例和生长情况

Table 3-1 the ratio and growth of *Casuarina equisetifolia* individual in dominate inferior groups

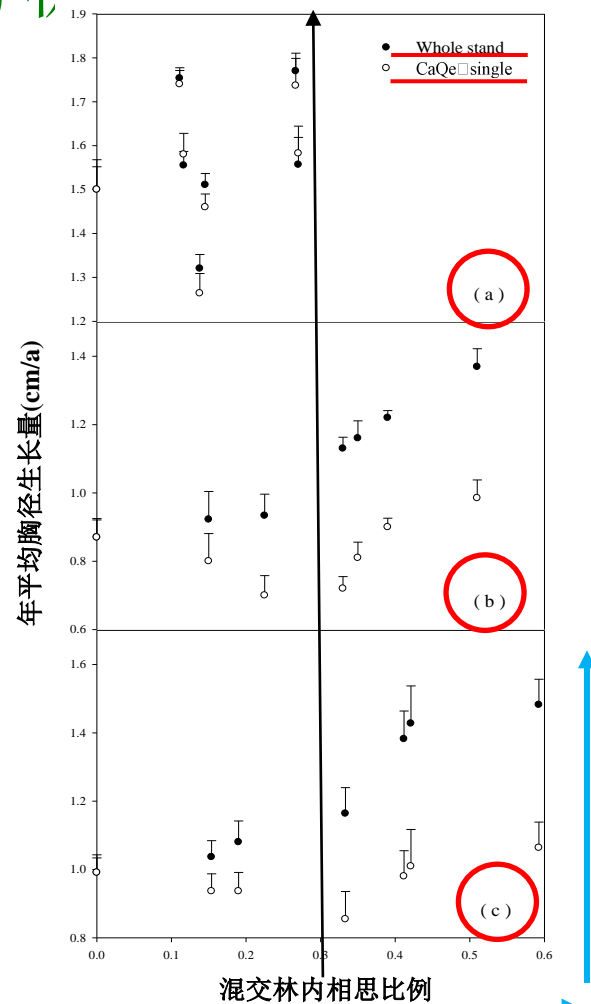| 分组	生长阶段	数量	木麻黄比例 (%)	混交林平均胸径 (cm)	纯林平均胸径 (cm)	胸径差 (cm)
最小个体	幼龄林	18	67	4.37	4.32	0.05
	中龄林	18	83	5.14	5.02	0.12
	近熟林	18	94	6.10	5.78	0.32
最大个体	幼龄林	18	67	7.92	6.52	1.40
	中龄林	18	28	11.81	10.3	1.78
	近熟林	18	22	22.27	16.72	5.55**

* 显著 0.05, ** 极显著 0.01

图3-1 木麻黄混交林个体和林分年平均生长量差异情况 **(a)** 幼龄林 **(b)** 中龄林. **(c)** 近熟林

tentative results

- Both the two operation models showed a good growth effect after two years management.

- The survival rate of different replanted seedlings kept a high level (average 70%) in August 2013.

- *Schefflera octophylla* had the largest retain proportion (86%).

- Although the survival rate of *Dalbergia odorifera*, *Homalium hainanense* was a little low, both of them really kept a satisfied level (above 50%) in the degraded forest.

- Both the height and diameter got a good growth effect.

- As the pioneer tree species, *Melia azedarach* had the largest increment (DBH=1.66 cm per year; Height=1.73 m per year), the growth of *Schefflera octophylla* was also got a satisfied effect (DBH=1.56 cm per year; Height=0.87 m per year).

- After the mixed afforestation the diversity of tree species increased obviously, the Shannon-wiener index in 2011 was only 0.05, but it increased to 0.86 in 2013.

- Both the two forest development types could drive tropical coastal forest to a stable and healthy tropical coastal forest community with multi-function value.

Case study 4: Release and implement of the new National Forest Tending Regulations

- In Sept. 2013 the new National Forest Tending Regulations with MFFM concept is issued and first training program is also conducted. The implementation in Chinese public benefit dominant forests is support with financial support of about 60 milliard RMB per year since 2013. its influences will be greater with time.
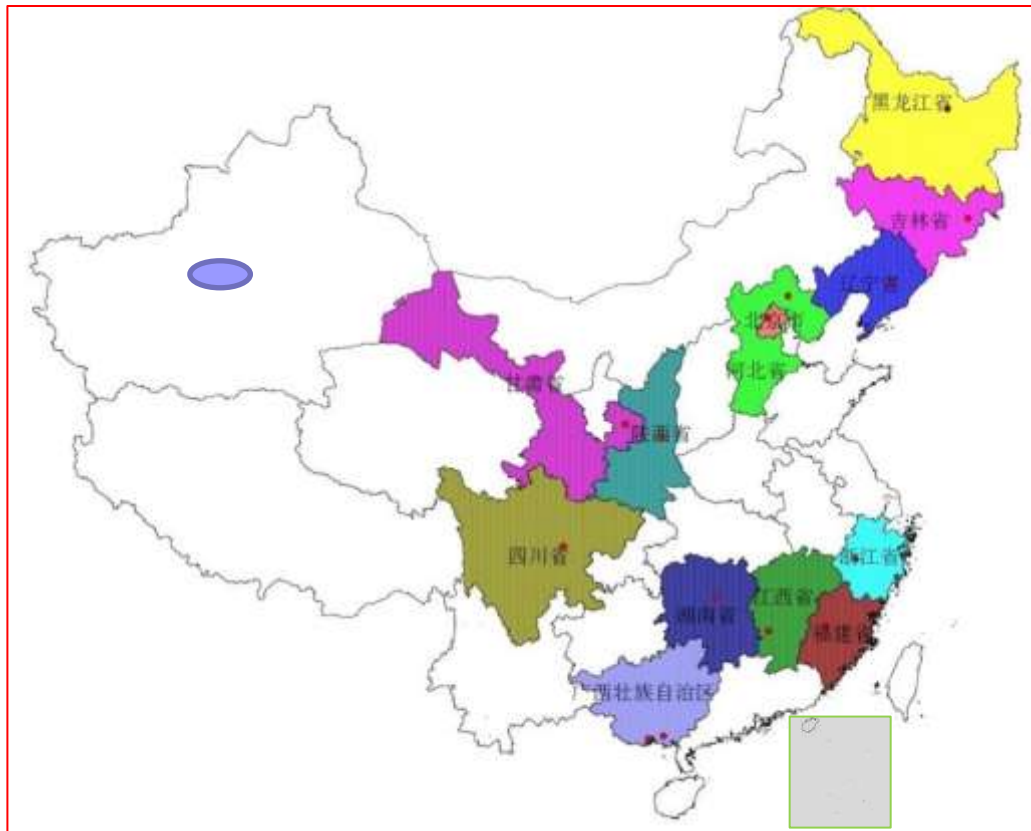

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Case study 5: National project of study on MFFM theory and techniques with 15 demonstration pilot area (management unit) in different Provinces

- The national project will start by year of 2014

图例

■	北京市西山实验林场XiShan Forest Farm
■	福建省永安市YongAn City
■	甘肃省小陇山林业实验局XiaoLongShan Forest Bureau
■	广西壮族自治区国有高峰林场GaoFeng Forest Farm
■	广西壮族自治区中国林科院热带林业实验中心Experimental Center of Tropica Forestry
■	河北省塞罕坝机械林场SaiHanBa Forest Farm
■	黑龙江省大兴安岭林业集团公司松岭林业局SongLing Forest Bureau
■	黑龙江省哈尔滨市丹清河实验林场DanQingHe Forest Farm
■	湖南省永州市金洞林场JinDong Forest Farm
■	吉林省汪清林业局WangQing Forest Bureau
■	江西省崇义县ChongYi County
■	辽宁省清原县QingYuan County
■	陕西省延安市黄龙山林业局HuangLongShan Forest Bureau
■	四川省洪雅林场HongYa Forest Farm
■	浙江省建德市JianDe City

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5. Conclusion: China is already on its way of FLR

■ Enhance the desirable outcomes to contribute the national and global sustainable development!

① a reliable supply of clean water, environmental protection such as reduced soil erosion, lower landslide risk, flood/drought mitigation etc.,

② a sustainable supply of a diverse range of forest products including foods, medicines, firewood etc.

③ Monetary income from various sources e.g. ecotourism, carbon trade, and other cultural services,

④ creating opportunities of job or payments for other environmental services of forests.

The science behind this approach is not novel, but its impact on restoration of China's forests could be revolutionary.
(Science, 2009,325(31):556～558)

谢谢！

Thank you for your attention!