Carbon Sequestration Capacity and Measurement of Eco-system of Moso Bamboo Forest

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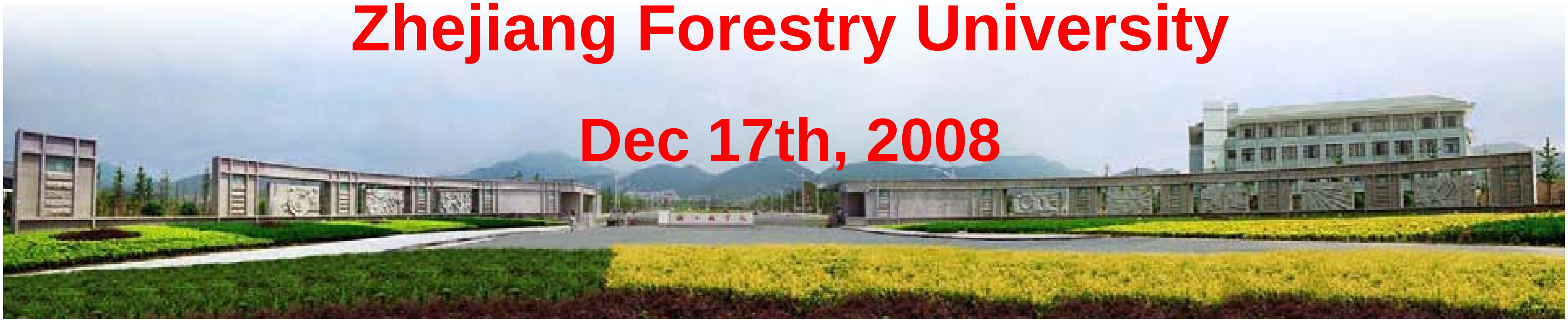


Outline

I. Characteristics of moso bamboo resource distribution and utilization

II. Carbon sequestration capacity of the eco-system of moso bamboo forest

III. Carbon sequestration measurement and monitoring of moso bamboo forest

IV. Thinking on carbon sequestration measurement technology for moso bamboo forest

I. Characteristics of moso bamboo resource distribution and utilization

Situation of world bamboo resources

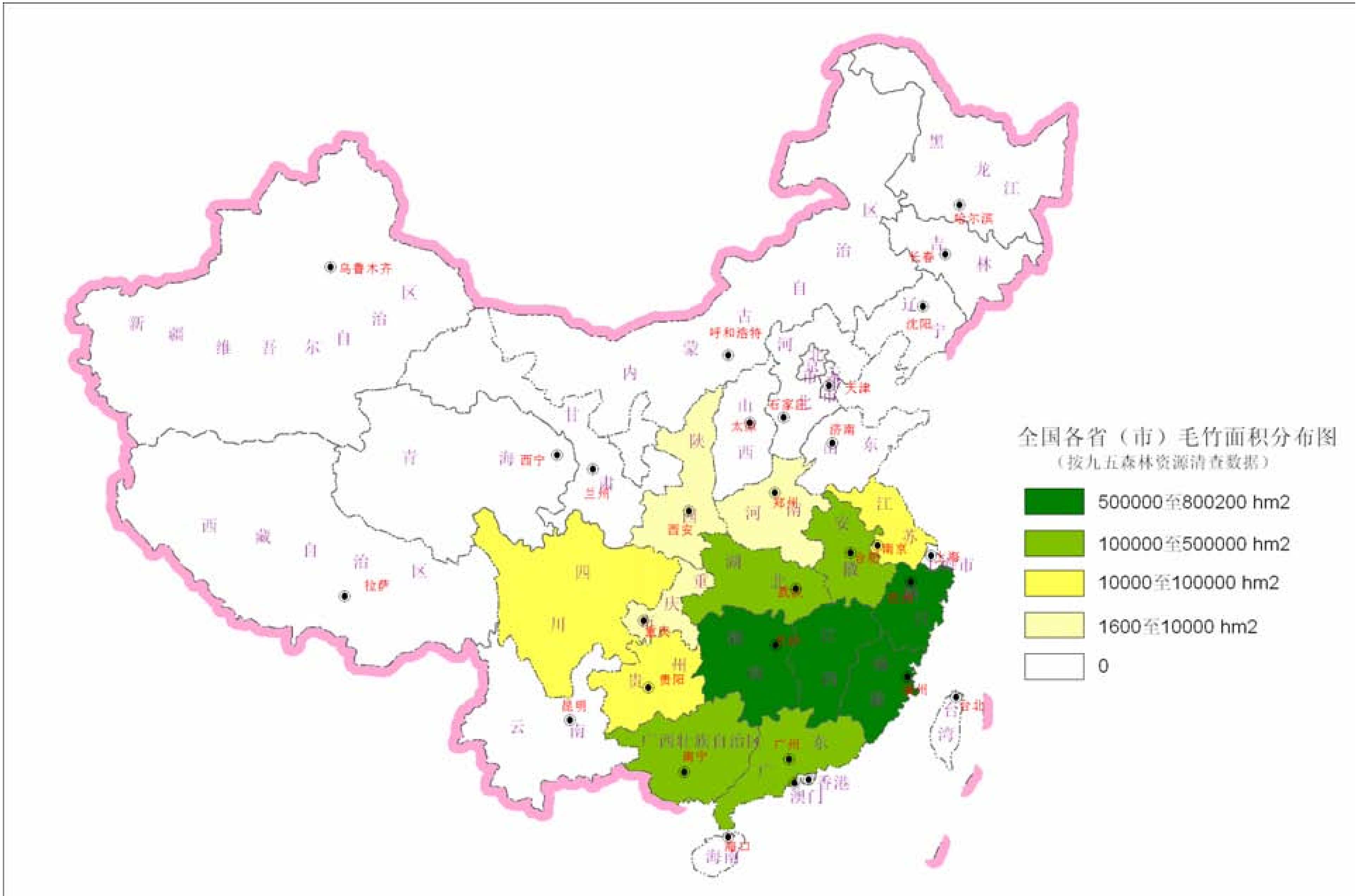
Bamboo belongs to gramineous bambusadea, with known 150 genus and 1,225 species worldwide; the bamboo forests cover 14 million ha.

- **Asian and Atlantic area: Bamboo forest area takes approximately 80% of the world bamboo forests**
- **American area: About 20 genus and 300 species of woody bamboos.**
- **African area: Comparatively the smallest in terms of size.**

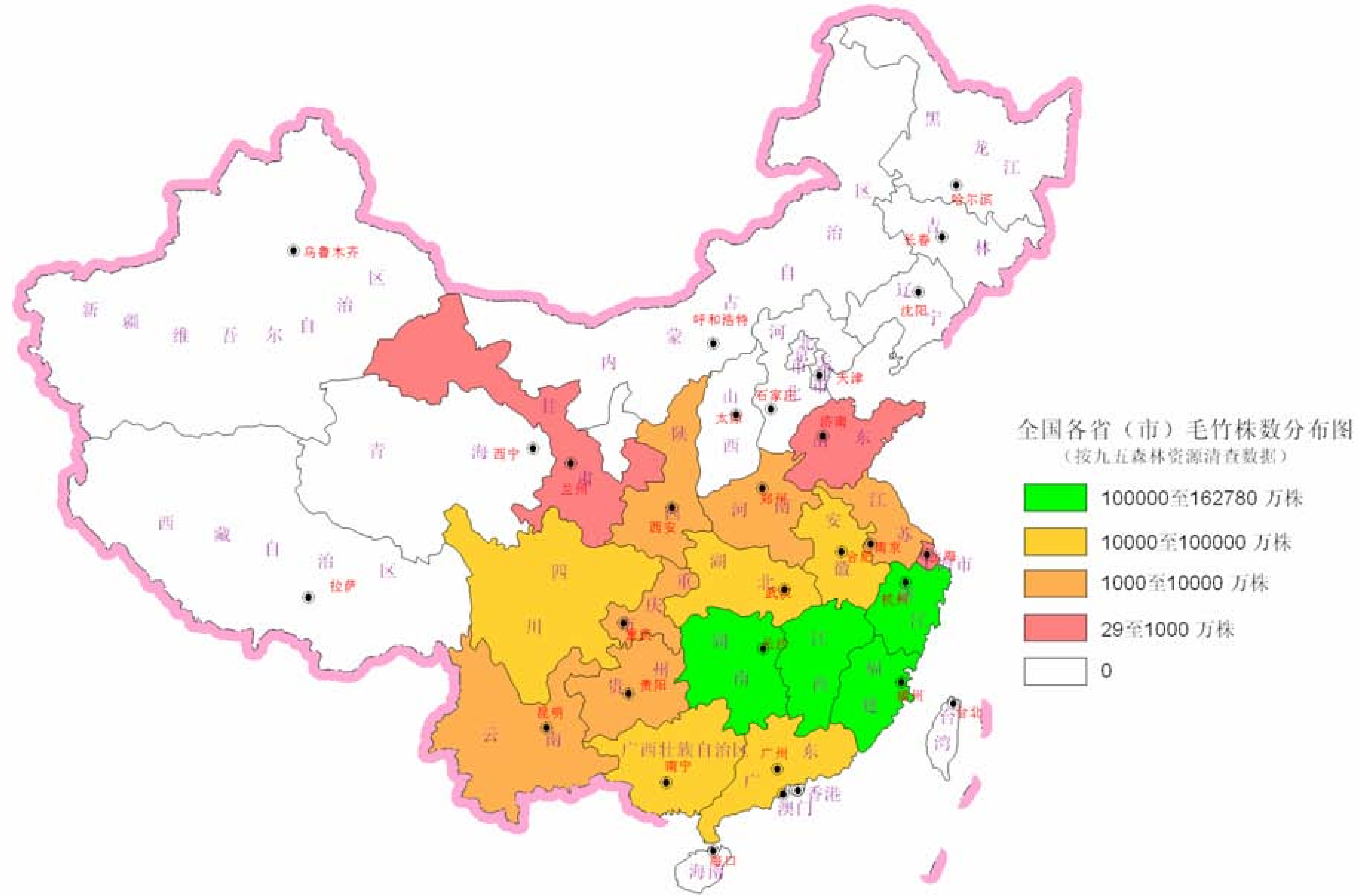
Bamboo Resource of China

China is locating at the heart of bamboo-distributed area with rich bamboo resources

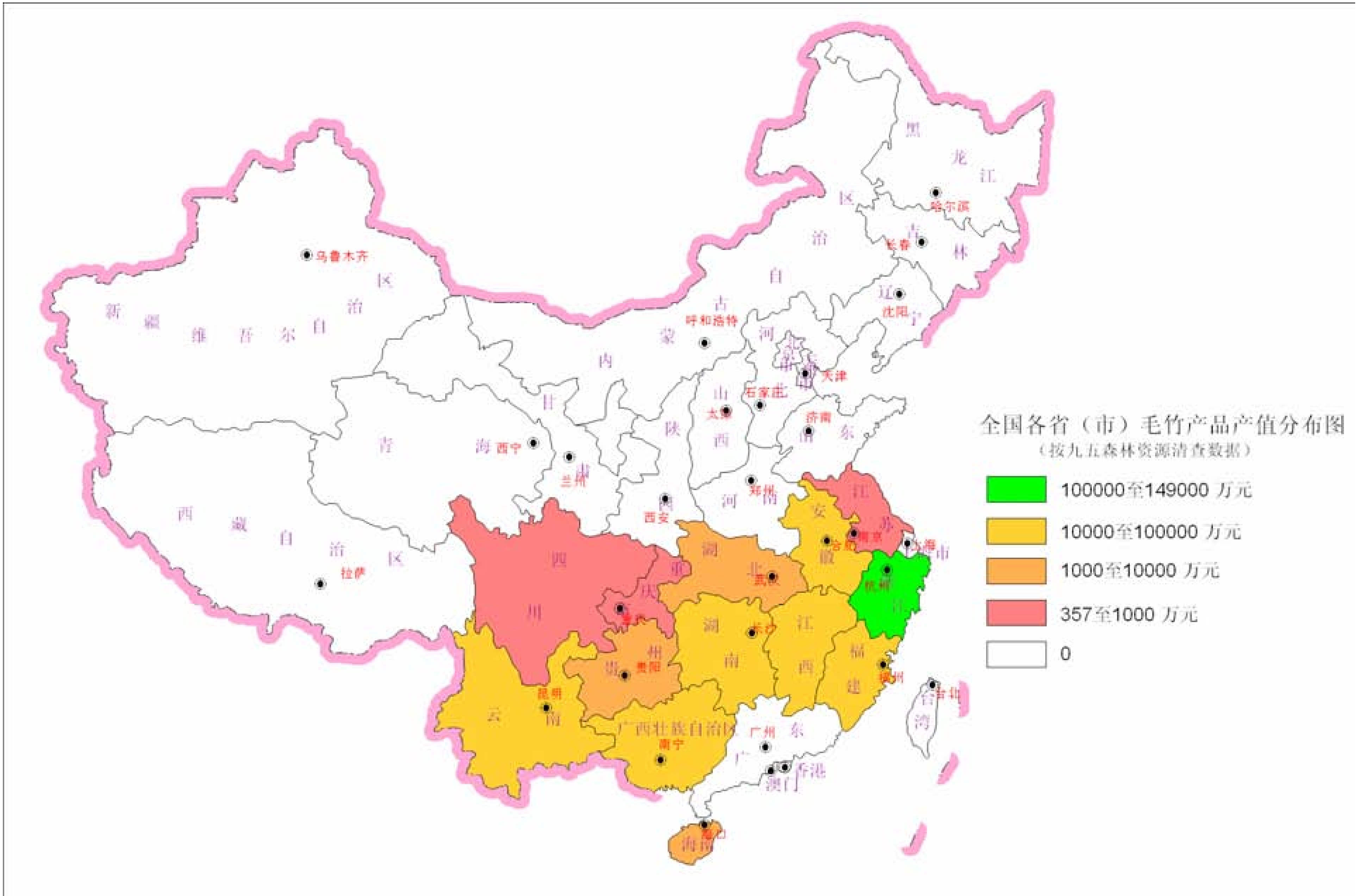
- **There are mainly 40 genus and over 400 species of bamboos in China.**
- **Bamboo forest area covers 8 million ha, taking 40% of the world bamboo forest area and 57% of that in Asia-Pacific area.**
- **The bamboos in China are mainly moso bamboo, taking 75% of the material forests and covering more than 6 million ha.**
- **The annual harvesting of moso bamboo nationwide is 400 million in 2006, 12 million tons, creating annual production of RMB17 billion yuan (including production RMB6.3 billion yuan from bamboo products processing)**



Layout of moso bamboo forests in each province (city)

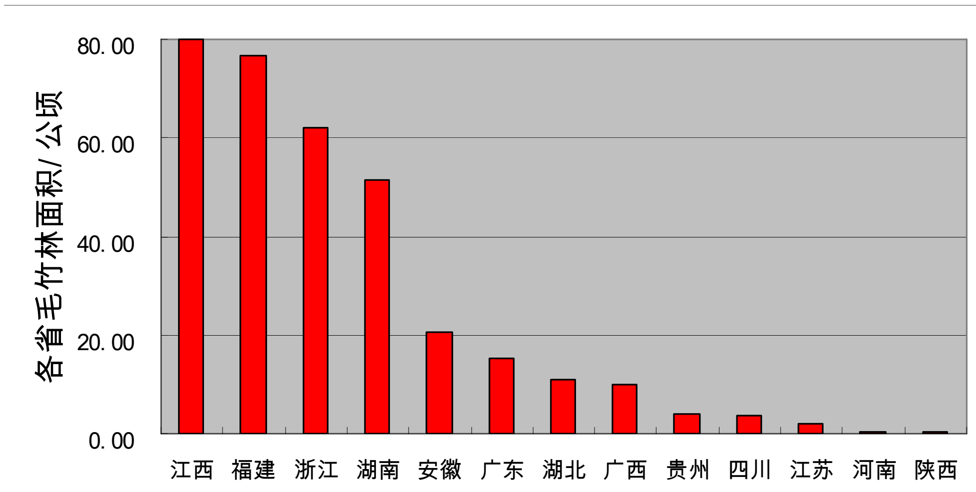


Layout of moso bamboo quantity in each province (city)

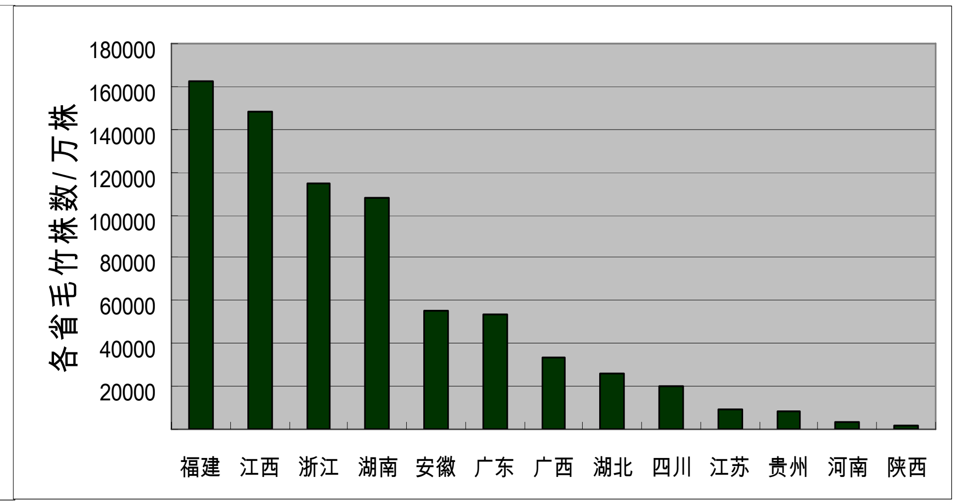


The production value of moso bamboo products in each province (city)

Distribution of moso bamboo forests in China



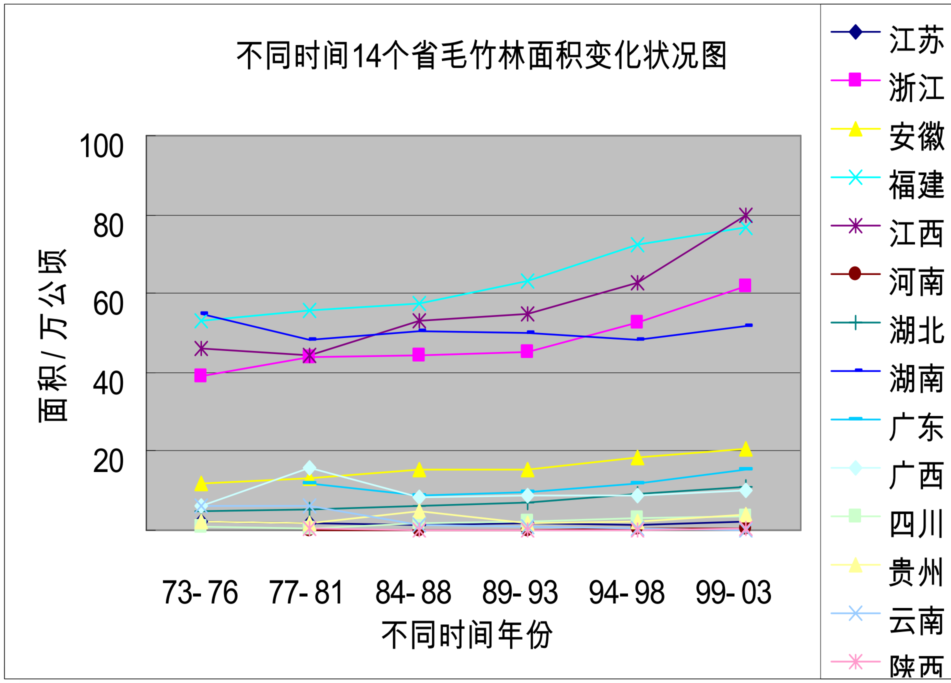
Moso bamboo area in each province

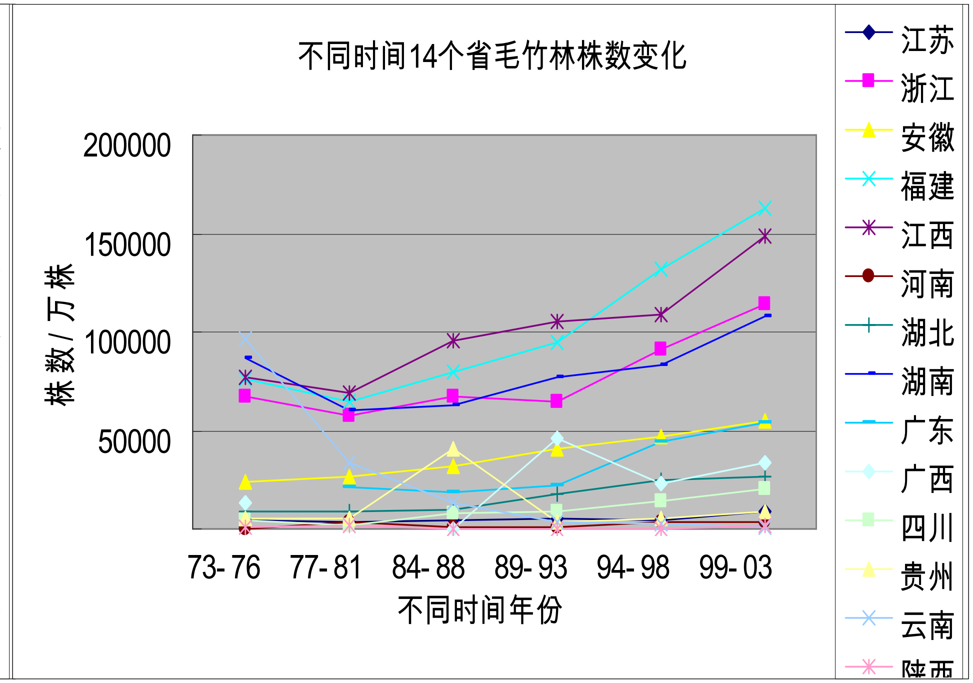


Moso bamboo quantity in each province

Source: The 6th Forest Resource Census in 1999-2003

The year-to-year size and yield change of main moso bamboo forest areas in China



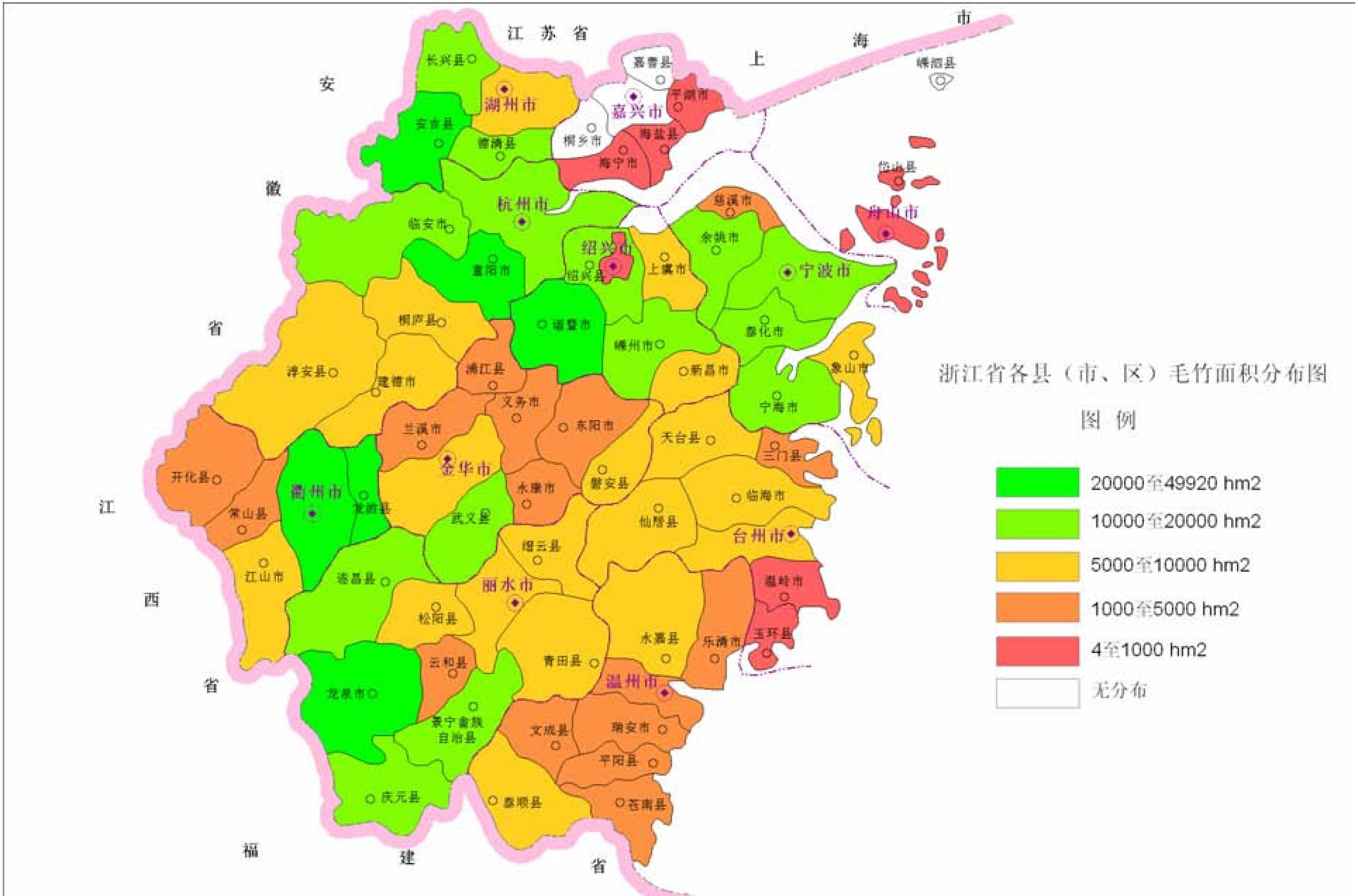


Area **Yield**

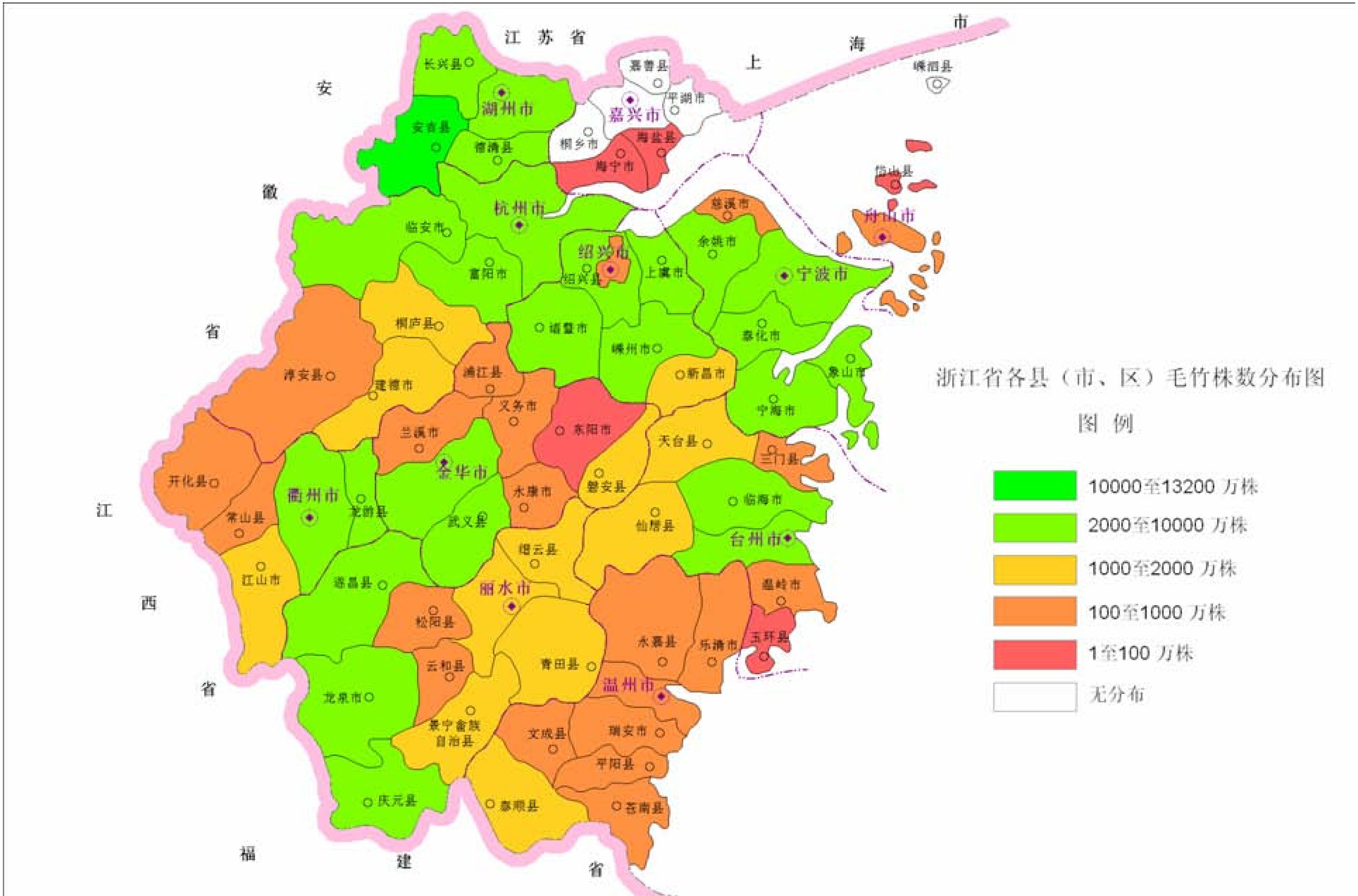
Moso bamboo resources in Zhejiang Province

Zhejiang Province is a typical original place of moso bamboo resource with moso bamboo forests widely distributing in all the counties (cities). The area, output and bamboo products value take very important places on Chinese market.

- Moso bamboo forest area in Zhejiang: 620,600 ha
- Quantity: 1.661 billion
- Production value: RMB1.481 billion yuan, taking 38% of the total national production (according to China Forestry Statistical Yearbook in 2006)



Layout of moso bamboo forests in each county (city, district) of Zhejiang Province



Layout of moso bamboo quantity in each county (city and district) of Zhejiang

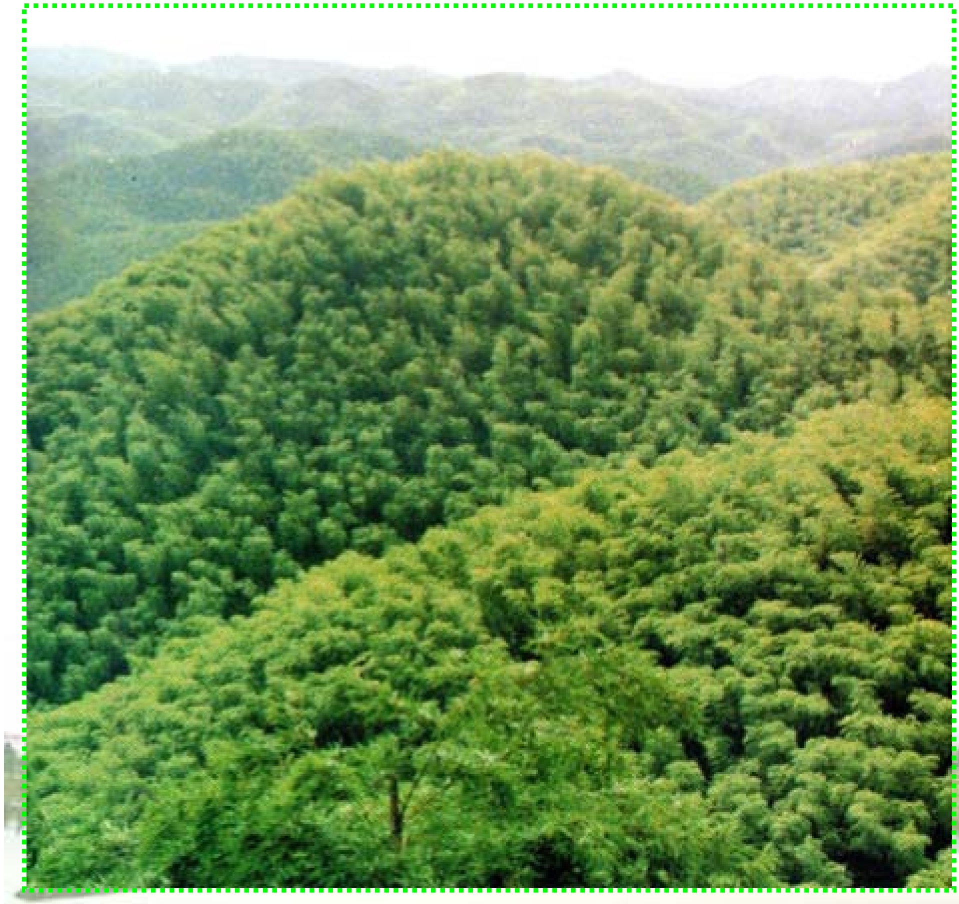
The growth features of moso bamboo

- **Moso bamboo forest is a typical uneven-aged forest**
- **Fast growth speed—Grow up in 50 days, after that bamboos do not grow any longer in terms of height and diameter**
- **After seven years, the forest can be continuously harvested every two years and sustainably used.**

Simulation of growth, harvesting and using of moso bamboo

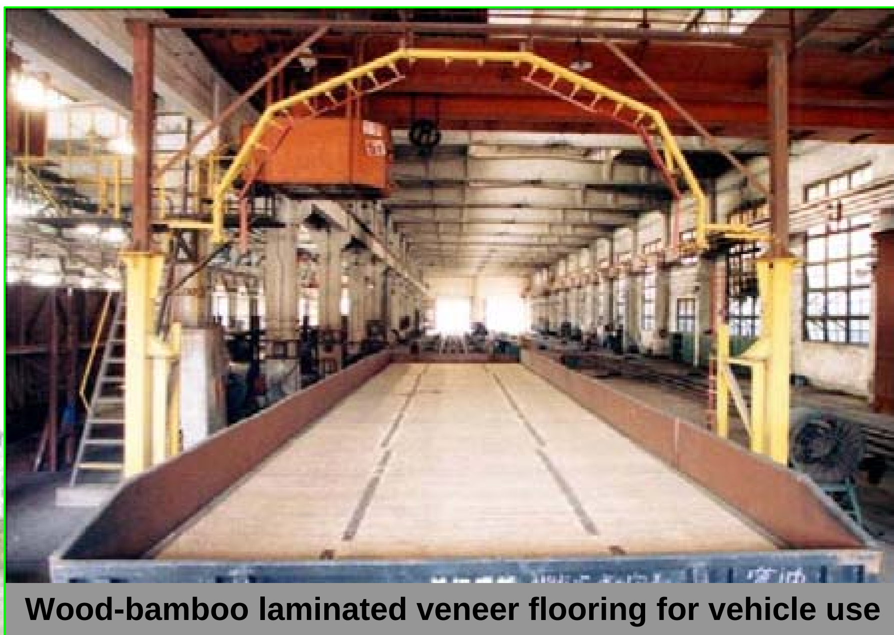
Use of moso bamboo

Bamboo can be widely used to: bamboo plywood, flooring, furniture, arts and crafts, charcoal, etc. It is of excellent economic benefit, but also gives full play to its carbon storage function.



“Wood-bamboo laminated veneer lumber

Bamboo curtain plywood



Wood-bamboo laminated veneer flooring for vehicle use

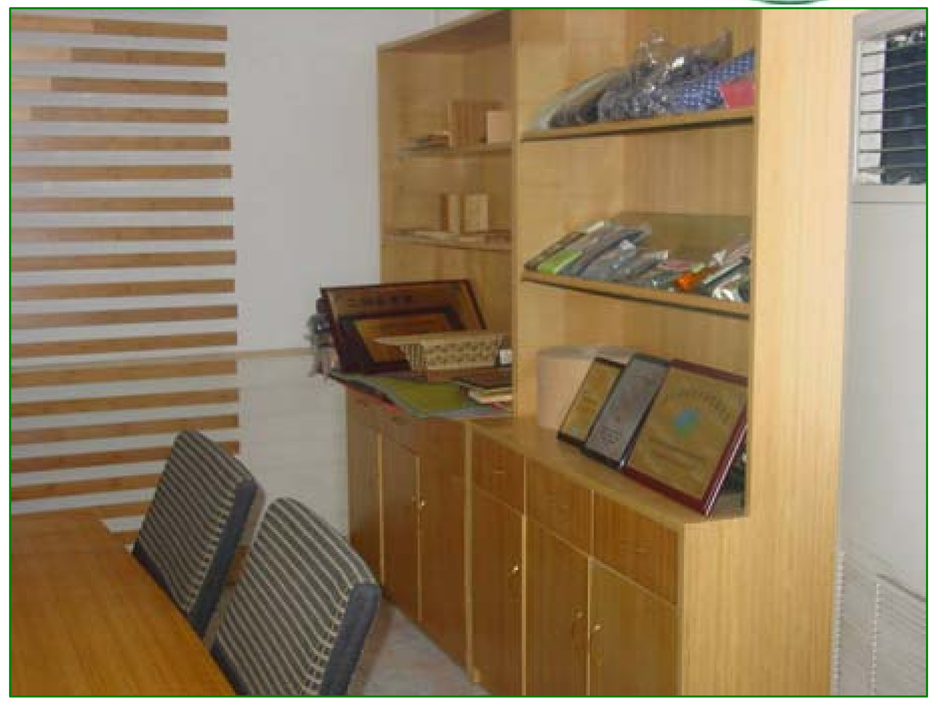
Rolling-bearing bamboo plank

Bamboo plywood used as the bottom board of vehicle

Bamboo flooring

Bamboo plywood used for reinforced concrete

Bamboo council board and bookcase



Bamboo plywood furniture

Raw bamboo charcoal

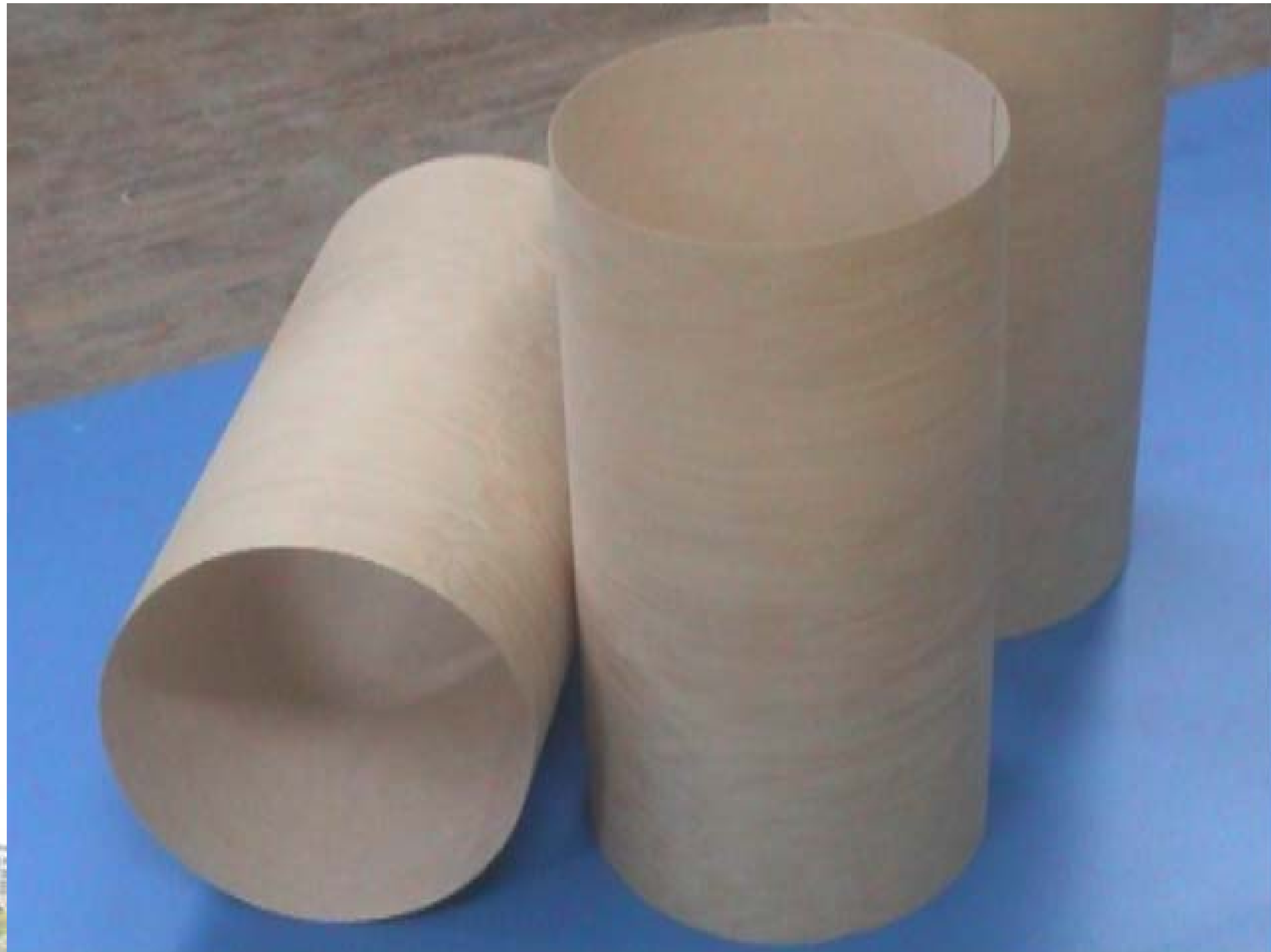
Bamboo charcoal pieces

Bamboo charcoal powder

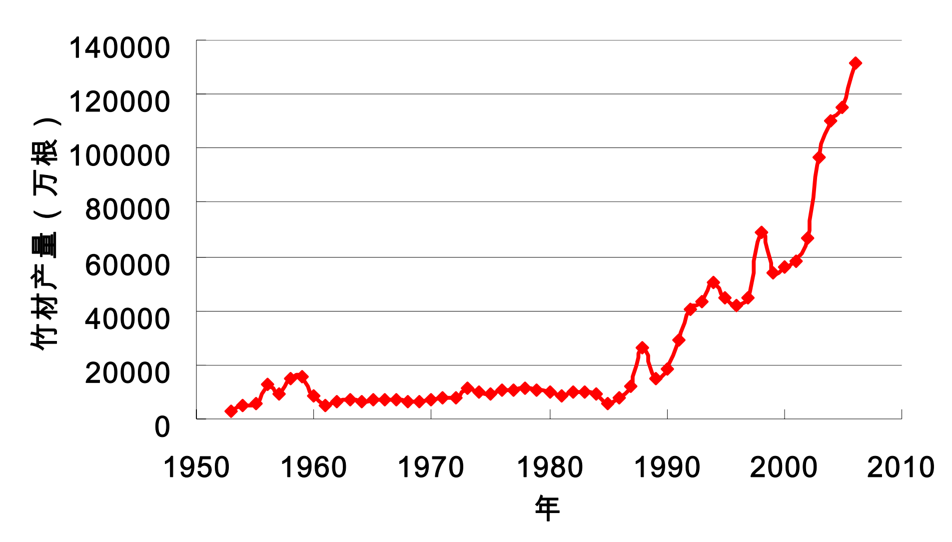
Bamboo weaving

Bamboo carving

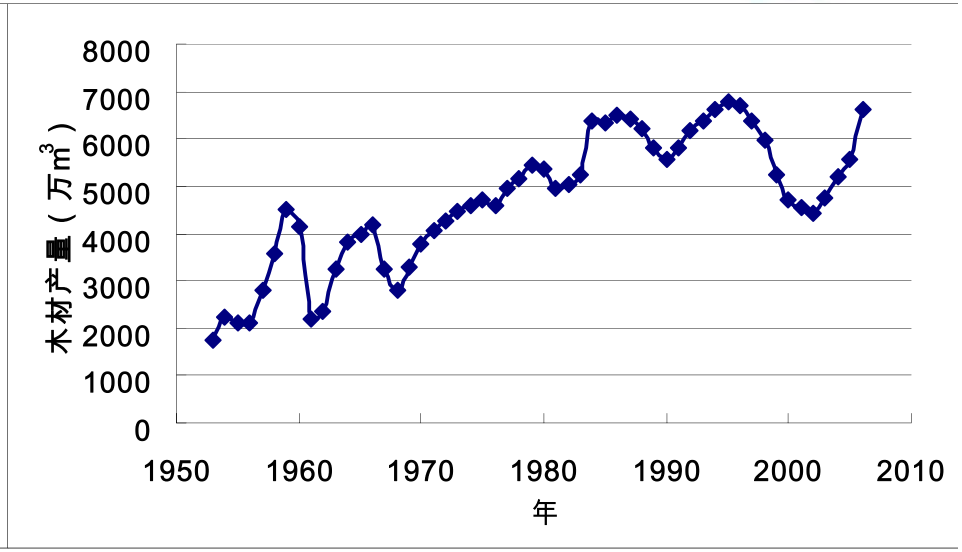
旋切竹单板



1953~2006 outputs of bamboos and timbers of China



Bamboo



Timber

After China took measures to restrict logging of natural forest, the bamboo output rapidly increased since 1990s, which has increased by six times in 2006 in contrast with that of 1990 and still has large development margin.

Moso bamboo's characteristics on upgrade and carbon sequestration

➢**Moso bamboo grows fast. The formed moso bamboo forest can be harvested every two years by 1/3 of existing quantity, while the bamboo forest stand remains balanced growth dynamics.**

➢**Moso bamboo has very developed and inter-weaving rhizome-root, leading to excellent water and soil conservation funciton.**

➢**Moso bamboo forest is of great CO_2 sequestration capacity, which is significant to balance the CO_2 in the atmosphere.**

II. The carbon sequestration capacity of the eco-system in moso bamboo forest

- For over 6 years since 2002, through field researches and pilot works on set points, we cut down 253 moso bamboo samples and collected 230 sampled lands where pure moso bamboo forest system exists.

- Systematically studied the carbon content, carbon storage and space layout, as well as dynamic change in the eco-system of moso bamboo forest on stalk, branch, leave, root and culm stump, as well as on arbor, shrub, grass, soil vegetation and soil, in addition to the dyanmic change of active organic carbon of soil in different management processes.

Rule of individual moso bamboo in carbon accumulation in growth

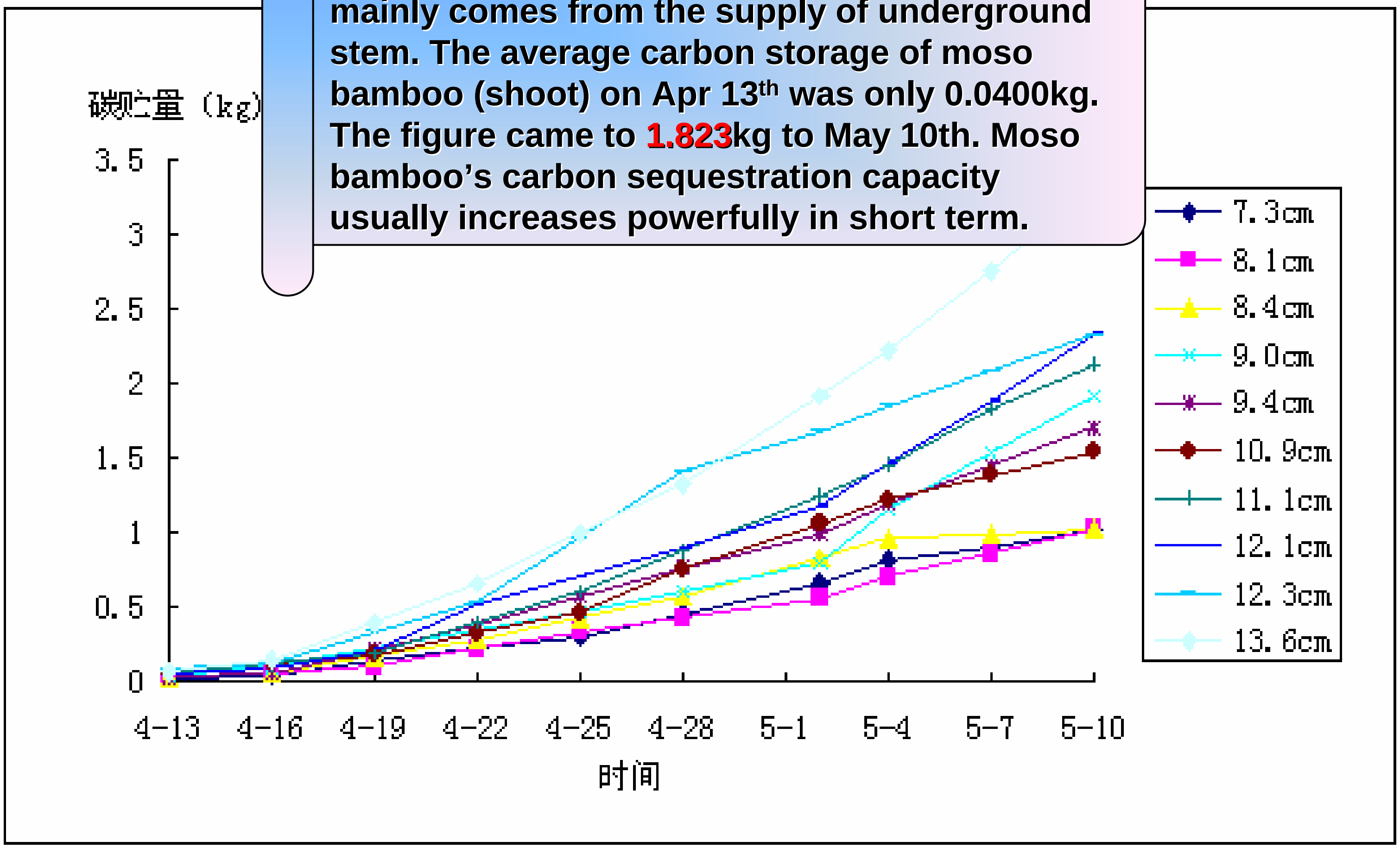
- **The growth of moso bamboo (shoot) takes a "S-shaped" curve in a "slow-fast-slow" trend. From shooting to young bamboo, only 35-40 days needed; In the following time, its height and size do not change dramatically, only substances stored continue accumulating.**

- **The accumulated fresh (dry) biomass in growth mainly depends on the ground diameter of moso bamboo, the larger the diameter is, the more the biomasses are.**

- **In the process of growth, the carbon content of moso bamboo may slightly increases, but should remain between 440 g• kg-1~ 460 g• kg-1; the carbon storage of individual bamboo (shoot) preliminarily averages at 0.0400kg, the carbon storage may increased to 45.5 times as the young bamboo grows up, averaging at 1.823kg.**

Dynamic change of carbon storage in different growth period

In the growth period, carbon accumulation mainly comes from the supply of underground stem. The average carbon storage of moso bamboo (shoot) on Apr 13th was only 0.0400kg. The figure came to 1.823kg to May 10th. Moso bamboo's carbon sequestration capacity usually increases powerfully in short term.



Dynamic change of carbon storage of moso bamboo with different ground diameters

Spatial layout of carbon in individual moso bamboo

- **Carbon content: The carbon content in different parts of moso bamboo fluctuates between 0.4683 ~ 0.5210, the order from high to low is root > stalk > culm stump > branch > scourage > leaf. The average carbon content in each part of moso bamboo is 0.5042.**

- **Carbon storage: Carbon storage reaches the highest point 50.97% in stalk, followed by root, taking 19.79%, the last one is leaf, only taking 4.87%.**

- **Comparison of carbon contents between moso bamboo and ordinary forest trees**

  - **The carbon content in different part of moso bamboo usually fluctuates between 0.4683 ~ 0.5210, which is similar to ordinary forest trees (China’s fast-growing fir, 18 a exotic pine, tropical rainforest).**
  - **Carbon content in different part is different from ordinary forest trees**
    - **Fir: The carbon content in leaf is larger than that in trunk, the figure in trunk is larger than that in root.**
    - **Oak forest in southern Jiangsu and exotic pine: The carbon content in leaf is larger than that in branch, trunk and root**

Rules of carbon accumulation in growth of moso bamboo forest

The intensive-managed moso bamboo forest accumulates 12.7496 t·hm^{-2} carbon in one year

- ✓ **New bamboo (within 1 year) accumulates 11.3890 t·hm^{-2} carbon (accounting for 89.33%)**
- ✓ **Old bamboo (3-5 years) accumulates 0.6481 t·hm^{-2} carbon in one year**
- ✓ **The withered parts accumulate 1.1725 t·hm^{-2}**
- ✓ **The withered parts release 0.4690 t·hm^{-2}**

- The extensively managed moso bamboo forest accumulates 8.1443t·hm^{-2} carbon in 1 year
  - ✓ New bamboo (within 1 year) accumulates 6.0563 t·hm^{-2} (accounting for 74.36%)
  - ✓ Old bamboo (3-5 years) accumulated carbon increases by 0.4211 t·hm^{-2} in average.
  - ✓ The undergrowth vegetation accumulates 0.5459 t·hm^{-2}
  - ✓ The withered parts accumulate 2.1558t·hm-2
  - ✓ The withered parts release 1.0348 t·hm^{-2}

The carbon accumulation in on-ground parts is 1.46 times of fast-growing fir, 1.33 times of tropical mountainous rainforest and 2.16 times of 27 a fir forest in southern Jiangsu.

- The carbon accumulation in eco-system of intensively managed moso bamboo forest (vegetation part) is 1.56 times of that of extensively-managed moso bamboo forest in 1 year.

Spatial layout of carbon storage in eco-system of moso bamboo forest

The carbon storage in eco-system of moso bamboo forest is 106.362 $t \cdot hm^{-2}$

The depth of soil is: 0 ~ 60cm

Level	Arbor	Shrub	Herbaceous	Withered litters	Soil
Carbon storage /$t \cdot hm^{-2}$	30.580	3.170	0.481	0.656	71.475
Percentage /%	28.75	2.98	0.45	0.62	67.20

Dynamic change of active organic carbon in soil of moso bamboo forest

- **After intensive management, the carbon contents in soil dropped, intensively manage 0-20cm soil of the bamboo forest, the organic carbon storage in 1 hm^2 soil may reduce by 4.475 tons.**
- **After intensive management, the organic carbon, micro-biomass carbon, water-soluble carbon and mineral carbon contents all significantly dropped ($P<0.05$).**
- **After intensive management, the organic carbon in soil drops continuously, and tends to be stable after it drops to 20a.**
- **Within 20 a from extensive management to intensive management, total organic carbon in soil drops by 34.70%，micro-biomass carbon drops by 49.35%**

III. Carbon sequestration measurement and monitoring of moso bamboo forest

Carbon sequestration project of moso bamboo in Lin’an

Overview of the project

The carbon sequestration project of moso bamboo forest in Lin’an was sponsored by China Green Carbon Fund, approved by the Carbon Sequestration Management Office of SFA and implemented by Zhejiang Forestry University, building 47.72 ha moso bamboo forest in Zaoxi Town, Lin’an City.

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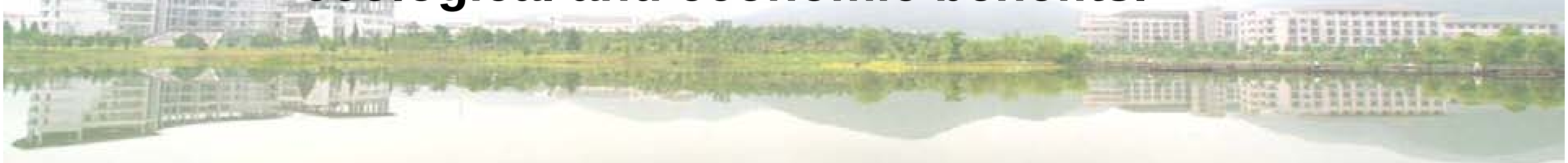
Significance of the Project

- The Project plays an important role in addressing global warming, innovating development mechanism of forestry, publicizing and demonstrating carbon sequestration, promoting local forestry construction.
- The Project is of excellent social, ecological and economic benefits.



Carbon sequestration measurement

- **Measurement principle**
- **Carbon pool selection**
- **Determination of GHG emission source**
- **Measurement method and result**

➢ Measurement principle

- **Conservation**

When choosing parameters, enable the increase of carbon storage under baseline conditions be overestimated, or increase of carbon storage under baseline conditions be underestimated or emission under project conditions be overestimated

- **Transparency**
- **Priority and comparability**
- **Reduce uncertainty**
- **Cost-effectiveness**

When choosing carbon measurement and monitoring method, including determining carbon pool and parameters, consider the accuracy and correctness of measurement and monitoring, plus cost factor and find a reasonable balance

Carbon pool selection

- **Total five carbon pools: On-ground biomass, underground biomass, withered litters, coarse wood litter and soil organism**
- **Select three carbon pools**：On-ground biomass, underground biomass and soil organism
- **Ignore two carbon pools**：Withered litters and coarse wood litters

Since this forest land has been bared for years before afforestation, the carbon storage in withered litters and coarse wood litters under baseline conditions will maintain the same or continue dropping.

Carbon pool	Choose or not	Reason for choosing or ignoring certain carbon pool
On-ground biomass	Yes	Compulsory
Underground biomass	Yes	Compulsory
Soil organic carbon	Yes	Changes are complicated and cannot be ignored
Withered litters	No	Base on conservation and cost-effectiveness
Coarse wood litters	No	Base on conservation and cost-effectiveness

➢Determination of GHG emission source

Afforestation activity may produce the following GHG emission sources (to be considered):

- **Transportation means: CO2 emission caused by fossil fuel consumption of transportation means**
- **The use of fuel mechanic equipments: e.g. land leveller and chain saw.**
- **The application of fertilizer: Direct N_2O emission caused by nitrogen-contained organic fertilizer in afforestation and forest management activities.**
- **Forest fire: CO2 emission caused by fire shall be considered in measurement and monitoring of carbon storage change, while non- CO_2 emission (N_2O and CH_4) shall be accounted as emission within the project boundary.**

➢ Measurement method and result

① **Layer division beforehand**

② **Change of carbon storage baseline**

③ **Change of carbon storage of the project**

④ **GHG emission within the project boundary**

⑤ **GHG leaker beyond the project boundary**

⑥ **Measurement formula and result of carbon sequestration**

① Layer division beforehand

- **Layer division of baseline beforehand and layer division of project beforehand**
- The layer division of baseline beforehand shall base on the vegetation status in the project area before afforestation, which mainly considers:
  - ✓ **Whether there are scattered trees and advantageous species, their ages: Used for estimation of carbon storage baseline changes**
  - ✓ **Coverage of non-forest-tree vegetation, especially the type and coverage of shrub vegetation: Used for estimating biomass loss of vegetation**
- Layer division of project beforehand mainly bases on afforestation and management model
  - ✓ **Main indexes include: Species, afforestation time, selective logging and rotation age**

Layer division of baseline beforehand

No. of baseline carbon layer beforehand	Scattered tree				Shrub		Herbage		Area ha
	Advantageous species	Quantity per ha	Average height diameter cm	Average height m	Average coverage	Average height m	Average coverage	Average height m	
BSL-1	Fir	480	5.2	3.0	25%	1.2	10%	0.7	33.66
BSL-2					35%	1.2	10%	0.7	14.06

Layer division of project beforehand

No. of project carbon layer beforehand	Afforestation species	Afforestation method	Mixed method	Initial density tree/hm^2	Farmyard manure Kg/hm^2	Area ha
PROJ-1	毛竹	散状匀栽	纯林	600	6000	15.4733
PROJ-2	毛竹	团状丛栽	纯林	720	7200	32.2467

② Change of carbon storage baseline

- **Under baseline, the carbon storage in the three carbon pools of soil, withered litters and coarse wood litters will remain constant or continue dropping. Conservatively assume the change is zero.**

- **Only consider the change of carbon storage in live biomass carbon pool caused by growth of scattered trees.**

$$\Delta C_{BSL,t} = \sum_{i=1}^{I}(\Delta C_{BSL,AB,i,t} + \Delta C_{BSL,BB,i,t}) \cdot 44/12$$

Calculation of carbon storage of on-ground and underground biomasses

$$C_{BSL,AB,i,t} = \sum_{j=1}^{J} (M_{ij,t} \cdot WD_j \cdot BEF_j \cdot CF_j) \cdot A_i$$

$$C_{BSL,BB,i,t} = C_{BSL,AB,i,t} \cdot R_j$$

Biomass expansion factor method

$C_{BSL,AB,i,t}$	Carbon storage of on-ground biomass, t C
$C_{BSL,BB,i,t}$	Carbon storage of under-ground biomass, t C
$M_{ij,t}$	Stock per ha at the t^{th} year, $m3.ha^{-1}$
WD_j	Timber density, dry weight per cubic meter (t d.m.m-3), fir is set at 0.307
BEF_j	Biomass expansion factor, no unit, fir is set as1.53×1.3
CF_j	Average carbon content, fir is set as 0.47
A_i	Area, ha
R_j	Ratio of biomass in root and stem, no unit, set as 0.22

③ Change of carbon storage of the Project

$$\Delta C_{PROJ,t} = \left[\begin{array}{l} \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}(\Delta C_{PROJ\_B,AB,ijk,t} + \Delta C_{PROJ\_B,BB,ijk,t}) \\ -\sum_{i=1}^{I}(\Delta C_{LOSS,AB,i,t} + \Delta C_{LOSS,BB,i,t}) \end{array} \right] . {}^{44}\!/\!_{12}$$

$\Delta C_{PROJ,t}$	Change of carbon storage of the project, t CO_2.a^{-1}
$\Delta C_{PROJ\_B,AB,ijk,t}$	Change of carbon storage of on-ground biomass in the bamboo forest, t C.a$_{-1}$
$\Delta C_{PROJ\_B,BB,ijk,t}$	Change of carbon storage of underground biomass in the bamboo forest, t C.a-1
$\Delta C_{LOSS,AB,i,t}$	Decrease of carbon storage of on-ground biomass of each baseline, t C.a^{-1}
$\Delta C_{LOSS,BB,i,t}$	Decrease of carbon storage of under-ground biomass of each baseline, t C.a^{-1}
t	Time, year
i, j, k	Carbon layer, species and forest age.

☞Change of carbon storage of biomass in the bamboo forest

Bamboo forest: **The planted forest is believed to remain a relatively stable state of biomass after the forest reaches certain age.**

$$\Delta C_{PROJ\_EBS,AB,ijk,t} = \frac{C_{PROJ\_EBS,AB,ij,Max}}{T_j} \cdot CF_j \cdot A_{ijk} = \frac{72}{6} \times 0.5042 \times 47.72 = 288.72$$

$$\Delta C_{PROJ\_EBS,BB,ijk,t} = \frac{C_{PROJ\_EBS,BB,ij,Max}}{T_j} \cdot CF_j \cdot A_{ijk} = \frac{23}{6} \times 0.4935 \times 47.72 = 90.27$$

☞Decrease of biomass in the original vegetation

$$C_{BSL,t=0} = \sum_{i=1}^{I} (C_{BSL,Tree,i,t=0} + C_{BSL,NTree,i,t=0}) \cdot 44/12$$

$C_{BSL,t=0}$	The original carbon storage in vegetations before the project (t=0), t CO_2
$C_{BSL,Tree,i,t=0}$	The original carbon storage in biomass of scattered trees before the project (t=0), t C
$C_{BSL,NTree,i,t=0}$	The original carbon storage in biomass of non-forest-tree vegetations before the project (t=0), t C

④ GHG emission within the project boundary

- Measurement of GHG emission within the project boundary only considers:
  - Direct N_2O emission caused by application of nitrogen-containing fertilizers
  - CO_2 emission caused by use of fuel-consuming machineries in the

$$GHG_{E,t} = E_{Equpment,t} + E_{N\_Fertilizer,t}$$

- GHG emission from forest fire cannot be measured beforehand, but shall be monitored and measured in the operation period of the project.

⑤ GHG emission beyond the Project boundary

Leakage mainly considers CO_2 emission from combustion of fossil fuel by transportation means.

$$LK_{Vehicle,t} = \sum_{f} (EF_{co_2,f} \cdot NCV_f \cdot FC_{f,t})$$

$$FC_{f,t} = \sum_{v=1}^{V} \sum_{i=1}^{I} n \cdot (MT_{f,v,i,t} / TL_{f,v,i}) \cdot AD_{f,v,i} \cdot SECk_{f,v,t}$$

⑥ Measurement formula and result of carbon sequestration

The **actual net carbon sequestration from the Project** **equals to the changed carbon storage of the Project minus the increased emission within the Project boundary, then minus the changed baseline carbon storage and again minus the leakage caused by afforestation project.**

$$C_{\Pr oj,t} = \Delta C_{\Pr oj,t} - GHG_{E,t} - LK_t - \Delta C_{BSL,t}$$

$C_{\Pr oj,t}$ Net carbon sequestration from the afforestation project, t CO2-e.a-1

$\Delta C_{\Pr oj,t}$ ange of carbon storage of the project, t CO2.a-1

$GHG_{E,t}$ IG emission increased within the Project boundary, t CO2-e.a-1

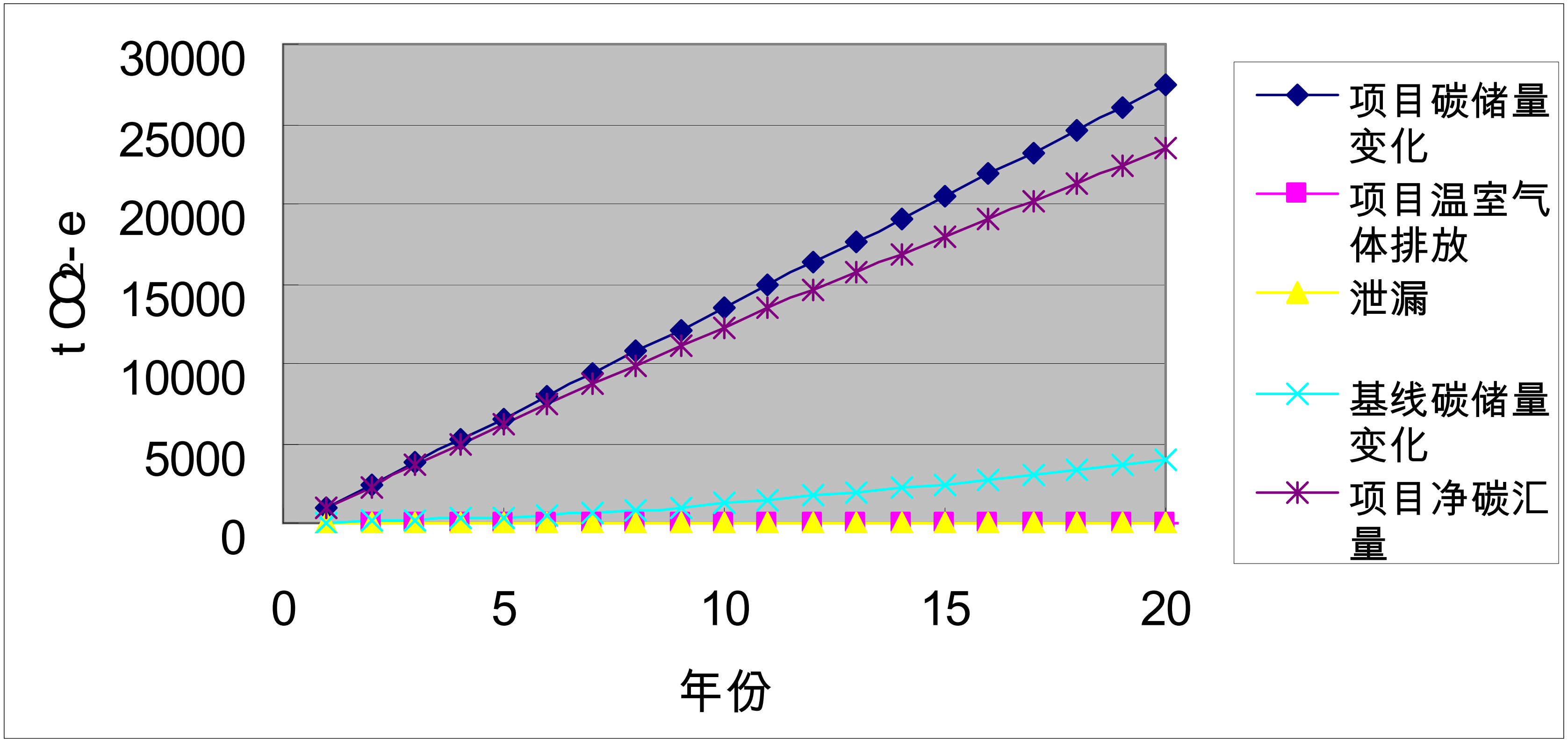
LK_t Leakage caused by afforestation project, t CO2-e.a-1

$\Delta C_{BSL,t}$ ange of baseline carbon storage, t CO2.a-1

Net carbon sequestration of the project

年份	项目碳储量变化		项目温室气体排放		泄漏		基线碳储量变化		项目净碳汇量	
	年变化 $tCO_2.a^{-1}$	累计 tCO_2	年排放 $tCO_2\text{-}e.a^{-1}$	累计 $tCO_2\text{-}e$	年排放 $tCO_2\text{-}e.a^{-1}$	累计$tCO_2\text{-}e$	年变化 $tCO_2.a^{-1}$	累计 tCO_2	年排放 $tCO_2\text{-}e.a^{-1}$	累计$tCO_2\text{-}e$
1	1007.3	1007.3	6.33	6.33	5.79	5.79	34.52	34.52	960.66	960.66
2	1389.63	2396.93		6.33	0	5.79	50.88	85.4	1338.75	2299.41
3	1389.63	3786.56	6.33	12.66	1.24	7.03	69.54	154.94	1312.52	3611.93
4	1389.63	5176.19		12.66	0	7.03	89.7	244.65	1299.93	4911.86
5	1389.63	6565.82	6.33	18.99	1.24	8.27	110.6	355.24	1271.46	6183.32
6	1389.63	7955.45		18.99	1.09	9.36	131.56	486.8	1256.98	7440.3
7	1389.63	9345.08	6.33	25.32	3.42	12.78	152.05	638.86	1227.83	8668.13
8	1389.63	10734.71		25.32	2.18	14.96	171.67	810.52	1215.78	9883.91
9	1389.63	12124.34		25.32	2.18	17.14	190.11	1000.64	1197.34	11081.25
10	1389.63	13513.97		25.32	2.18	19.32	207.2	1207.83	1180.25	12261.5
11	1389.63	14903.6		25.32	2.18	21.5	222.82	1430.65	1164.63	13426.13
12	1389.63	16293.23		25.32	2.18	23.68	236.92	1667.57	1150.53	14576.66
13	1389.63	17682.86		25.32	2.18	25.86	249.51	1917.08	1137.94	15714.6
14	1389.63	19072.49		25.32	2.18	28.04	260.63	2177.71	1126.82	16841.42
15	1389.63	20462.12		25.32	2.18	30.22	270.34	2448.04	1117.11	17958.53
16	1389.63	21851.75		25.32	2.18	32.4	278.71	2726.75	1108.74	19067.27
17	1389.63	23241.38		25.32	2.18	34.58	285.83	3012.58	1101.62	20168.89
18	1389.63	24631.01		25.32	2.18	36.76	291.79	3304.38	1095.66	21264.55
19	1389.63	26020.64		25.32	2.18	38.94	296.69	3601.07	1090.76	22355.31
20	1389.63	27410.27		25.32	2.18	41.12	300.62	3901.69	1086.83	23442.14
合计	27410.27		25.32		41.12		3901.69		23442.14	

Change of carbon sequestration produced in the Project



Carbon sequestration monitoring

- **Monitoring content and method**
- **Sampling design**
- **Monitoring of carbon storage change of the Project**
- **Emission and leakage monitoring of the Project**
- **Net carbon sequestration calculation of the Project**
- **Quality guarantee and control measures**

Monitoring content and method

- **Monitoring contents include:**

  - ✓ **Project activity and boundary change**
  - ✓ **Carbon storage change of the Project (key monitoring factor)**
  - ✓ **GHG emission and leakage**

- **Baseline carbon storage change shall be finished in the measurement stage of the Project and does not need monitoring**

- Consider the cost-effectiveness of measurement and monitoring, the monitoring of carbon storage change adopts **set-sample-based continuous measurement method**.

Sampling design

① Layer division of the Project afterwards

② Determine the quantity of sample lands

③ Method of sample land setting

④ Monitoring frequency and time

① Layer division of the Project afterwards

- **Base on different afforestation model (afforestation approach, planting density, fertilizer application in unit area) to divid the project into 2 carbon layers afterwards**
- **Use precise finite difference GPS to determine the boundary of each carbon layer of the Project and calculate the area**

No. of carbon layer of the Project afterwards	Species used for afforestation	Afforestation method	Mixed method	Initial density Tree/hm2	Farmyard manure Kg/hm2	Logging time	Area ha
PROJ-1	Moso bamboo	Scattered planting	Pure forest	600	6000	The 7th year	15.4733
PROJ-2	Moso bamboo	Clustered planting	Pure forest	720	7200	The 7th year	32.2467

② Determine the quantity of sample land

$$n = \frac{\left[\sum_{i=1}^{L} N_i \cdot st_i\right]^2}{\left(N \cdot \frac{E_1}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot = 3.82$$

$$n_1 = \frac{\left[\sum_{i=1}^{L} N_i st_i\right]}{\left(N \cdot \frac{E_1}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot N_1 \cdot st_1 = 1.24$$

$$n_2 = \frac{\left[\sum_{i=1}^{L} N_i st_i\right]}{\left(N \cdot \frac{E_1}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot N_2 \cdot st_2 = 2.58$$

$$N = 795$$

$$E_1 = Q_1 \cdot p = 7t.ha^{-1}$$

$$st_1 = st_2 = 7t.ha^{-1}$$

The quantity of sample land for Carbon layer PROJ-1 is set as 2,
The quantity of sample land for Carbon layer PROJ-2 is set as 3

③ Setting method of sample land

- **The set sample lands adopt systematic setting method with random starting point**
- **The monitored sample land is set as 0.06 ha, the shape is set as rectangular (30m×20m)**
- The sample land locates at the south or the north, and is set with **precise all-station meter**.
- Record of sample land: the administrative location, are coordinate, afforestation species, model and time.

④ Monitoring frequency and time

- **Frequency: every 5 years**
- **Monitored carbon pool: on-ground biomass, underground biomass, organic soil carbon pool**
- **First monitoring: 2009**
- **Monitoring period: August-September each year**

Monitoring of carbon storage change of the Project

- **Adopt sample-land-based continuous measurement method**
- **Key factors:**

☞ **On-ground and underground biomass of forest (bamboo forest)**

☞ **Organic carbon of soil**

☞Measurement of on-ground and underground biomass of forest (bamboo forest)

- **Conduct actual sample land measurement, calculate the carbon storage in on-ground and underground biomass of forest by individual bamboo**

- **Calculate with dual biomass allometric growth formula**

  First measure the height diameter and age of standing bamboo on the sample land one by one, then calculate the biomass of each standing bamboo with biomass allometric growth formula, then add them together to get the carbon storage in biomass in unit area of smaple land (t d.m.ha^{-1})

- **Calculation formula:**

$$C_{AB\_B,m,ijk,p} = \sum f_{AB\_B,j}(BD, BA) \cdot CF_j \cdot 10000/AP$$

$$C_{BB\_B,m,ijk,p} = \sum f_{BB\_B,j}(BD, BA) \cdot CF_j \cdot 10000/AP$$

或 $$C_{BB\_B,m,ijk,p} = C_{AB\_B,m,ijk,p} \cdot R_j$$

$f_{AB\_B,j}(BD, BA)$ Dual allometric growth formula for on-ground biomass of moso bamboo, t d.m.quantity^{-1}

$f_{BB\_B,j}(BD, BA)$ Dual allometric growth formula for underground biomass of moso bamboo, t d.m.quantity^{-1}

CF_j Average carbon content, no unit

R_j Ratio of biomass in root and stem, no unit

AP Area of sample land, m^2

Record of Investigation on Sample Bamboo Forest Land

Sample land No.____ Shape： Rectangular (north) Size: 0.06hm2（30m×20m）

Record of Measurement for Individual Bamboo on the Sample Land					
Standing Bamboo No.	Height diameter 0.1cm	Age	On-ground biomass kg	Underground-biomass kg	Remarks
1					
2					
3					
4					
…					
Total (kg)					
Carbon storage in on-ground biomass in unit area of sample land (t $C.ha^{-1}$)					
Carbon storage in under-ground biomass in unit area of sample land (t $C.ha^{-1}$)					

☞Measurement of organic carbon in soil

- Soil sampling and disposal
- Calculation of organic carbon storage in unit area of soil on sample land

$$C_{SOC,m,ijk,p} = \sum_{l=1}^{L} \left[SOCC_{m,ijk,p,l} \cdot BD_{m,ijk,p,l} \cdot (1 - F_{m,ijk,p,l}) \cdot Depth_l \right]$$

$C_{SOC,m,ijk,p}$	Organic carbon storage in unit area of soil on sample land, t $C.ha^{-1}$
$SOCC_{m,ijk,p,l}$	Organic carbon content in each soil layer, g C.(100g soil)$^{-1}$
$BD_{m,ijk,p,l}$	Unit weight of soil in each layer, $g.cm^{-3}$
$F_{m,ijk,p,l}$	Bulk percentage of stone with diameter above 2mm, root system and other dead organic residues, %
$Depth_l$	Depth of each soil layer, cm

➢ Emission and leakage monitoring of the Project

- **GHG emission within the project boundary mainly include:**
  - ✓ **Direct N_2O emission caused by application of fertilizer**
  - ✓ **CO_2 emission caused by combustion of fossil fuels**
  - ✓ **CO_2 emission caused by forest fire**
- **GHG emission beyond the project boundary is mainly caused by transportation means:**
  - ✓ **Fertilizer transportation**
  - ✓ **Seedling and tree transportation**
  - ✓ **Harvested bamboo transportation**
- **For above emission and leakage monitoring, the main works include design of all tables, arranging specific personnel to keep routine record and collect change data.**

Calculation of net carbon sequestration of the Project

$$C_{Proj,t} = \Delta C_{Proj,t} - GHG_{E,t} - LK_t - \Delta C_{BSL,t}$$

Year	Carbon storage change of the project		GHG emission of the project		Leakage		Baseline carbon storage change		Net carbon storage of the Project	
	Annual change $tCO_2.a^{-1}$	Accumulative, tCO_2	Annual emission, tCO_2-e.a^{-1}	Accumulative, tCO_2-e ）	Annual emission, tCO_2-e.a^{-1}	Accumulative, tCO_2-e	Annual change, tCO_2-e.a^{-1}	Accumulative, tCO_2-e	Annual emission, tCO_2-e.a^{-1}	Accumulative tCO_2-e
1										
2										
……										
20										
Total										

➢ Quality guarantee and control measures

To ensure the net carbon sequestration of the Project, especially the accuracy of measurement and monitoring of carbon storage change, the following quality guarantee and control measures shall be taken:

① **Ensure reliable field measurement result**

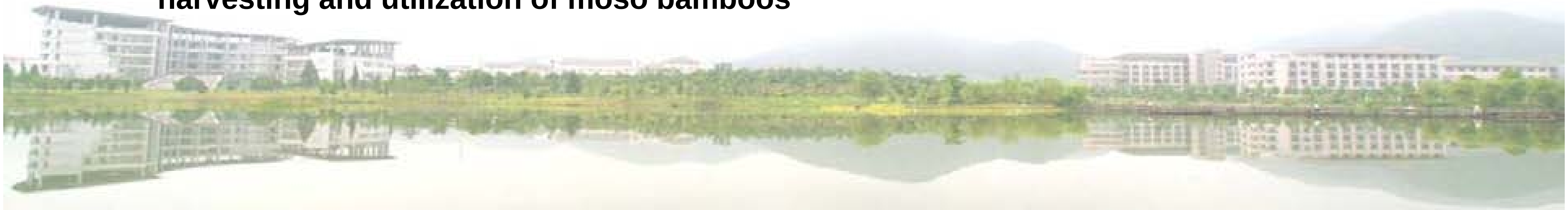
② **Implement verification and correction for data measured in field investigation**

③ **Recheck of data input and analysis of abnormal data**

④ **Carefully file and manage all the data**

IV. Consideration of carbon sequestration measurement technology of moso bamboo forest

- Improve the precision of sample land setting and project boundary determination, consider to use all-station meter and real-time dynamic differential GPS technology (precision: cm) to replace traditional compass and handheld GPS.
- Work out and optimize the biomass, carbon storage growth forecast formula of moso bamboo forest.
- Develop carbon absorption measurement method and evaluation model for eco-system of moso bamboo forest.
- Base on the carbon sequestration measurement and monitoring (small scale and scope) to reinforce large scale and scope measurement and monitoring study.
  - Make fully use of RS and GIS technology
  - Combine the continuous inventory system of forest resources
- Reinforce studies on carbon balance and conversion of bamboo products after harvesting and utilization of moso bamboos



Thank you!