10th World Bamboo Conference

Bamboo Resources and Carbon storage in Taiwan

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Bamboo global horizontally distributed

Bamboo belongs to the Gramineae family with 90 genera over 1200 species globally.

Bamboo naturally distributed in the tropical and subtropical belt between 46^0 north and 47^0 south latitude.

Bamboo is commonly found in Africa(7%), Asia(65%), Central and South American(28%)

The ratio of bamboo to forest area in world is about 3.2% in 2005 (Lobovikov et al. 2007)

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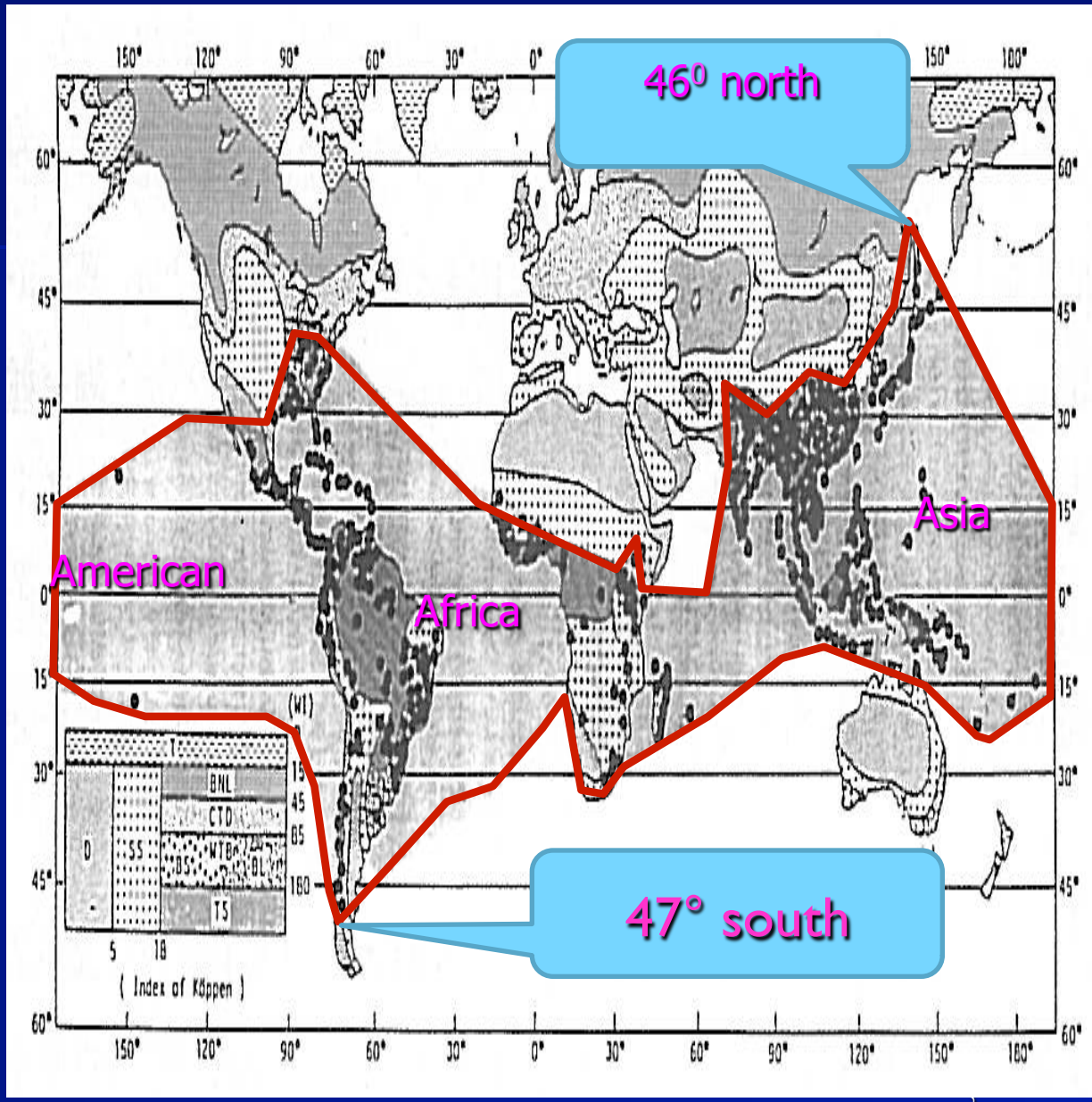


Introduction in Taiwan

Taipei City

Taichung City

Tinan County

Kaohsiung City

Basic information	
Latitude	21°45′N~25°56′ N
Longitude	119°18′E~126°E
Climate zone	Sub-tropical and tropical monsoon climate
Area	3,600,000 ha
Length of coastline	1,250 km
Highest altitude	3,952 m

Population **23,000,000**

Bamboo resources in Taiwan (I)

The total area of bamboo resources in Taiwan was 75,275 ha in 1962, 175,638 ha in 1971, 149,516 ha in 2000, and 221,991 ha in 2014.

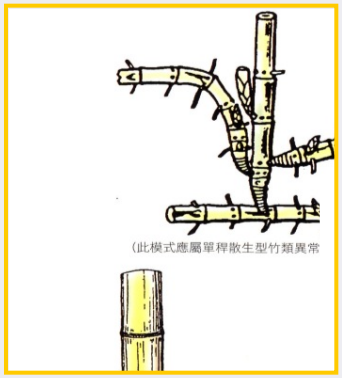
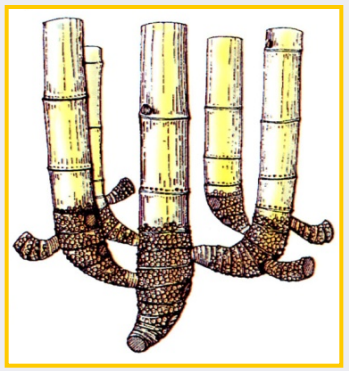
The ratio of bamboo to forest area in Taiwan is 10.2% in 2014

Bamboo species in Taiwan (II)

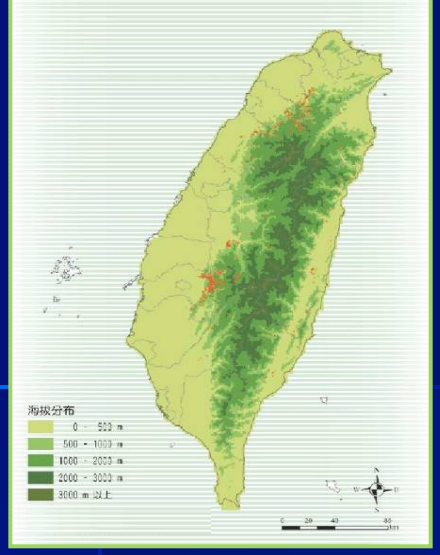
Due to the Tropic of Cancer across Taiwan and high elevations of central mountain range in Taiwan, different types of bamboo were found in Taiwan.

There are 85 species and varieties of bamboo in Taiwan, of which 24 are indigenous and 61 exotic (Lu 2001)

Type of the bamboo forests in Taiwan (six major bamboo species)

Type of rhizomes		Economic bamboo species	Management
Monopodial type		Makino Bamboo (*Phyllostachys makinoi* Hayata)	Mainly for bamboo timber, and also harvesting bamboo shoots.
		Moso Bamboo (*Phyllostachys pubescens* Mazel ex Houz.)	
Sympodial type		Ma Bamboo (*Dendrocalamus latiflorus* Munro)	Mainly for harvesting bamboo shoots, and also producing bamboo timbers.
		Green Bamboo (*Bambusa oldhamii* Munro)	
		Thorn Bamboo (*Bambusa stenostachya* Hackel)	Mainly for bamboo timbers, and focusing on the function of conservation.
		Long-Branch Bamboo (*Bambusa dolichoclada* Hayata)	

Makino Bamboo most plantation area (*Phyllostachys makinoi* Hayata)

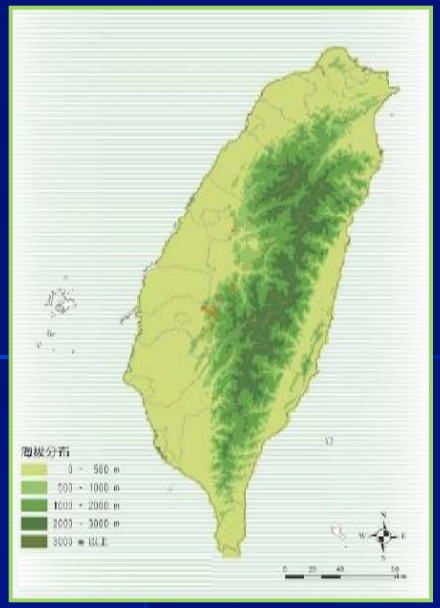


Endemic species in Taiwan. Widely distributed in the Northern and Central Taiwan with an elevation 100-1200 m 44,906 ha in total

Pure stands in large scale and expands the habitat annually.

The culm are about 5--15 m in height with a DBH of 0.2-1.5 cm in small size, and 5-8 cm in big size

Bamboo culm (chip) and fascine are used for sand stabilization in coastal areas.

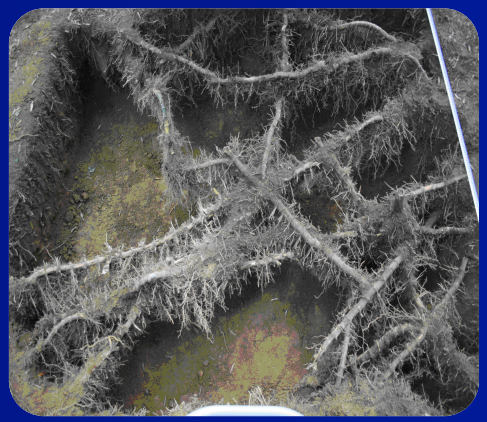


Moso Bamboo
(*Phyllostachys pubescens* Mazel ex Houz.)

Introduced from China
The culms are about 4-20 m in height with a DBH of 5-18 cm .

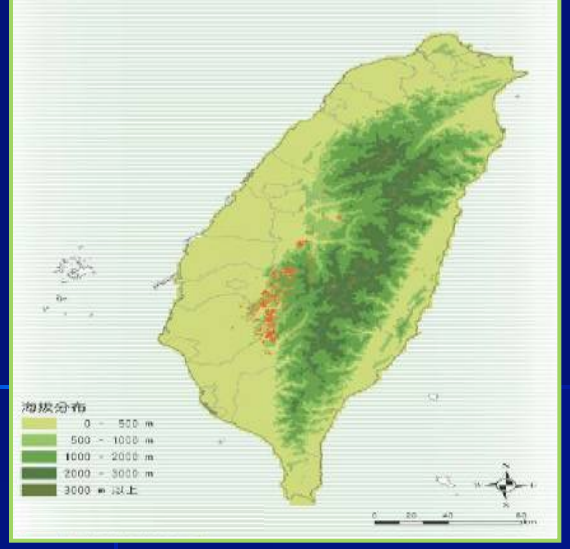
Cultivated for high quality culms and shoot.

Mainly distributed in central part of Taiwan.with an elevation 150-1600 m.



rhizomes distribution

wave-resistance



Ma Bamboo
(*Dendrocalamus latiflorus* Munro)

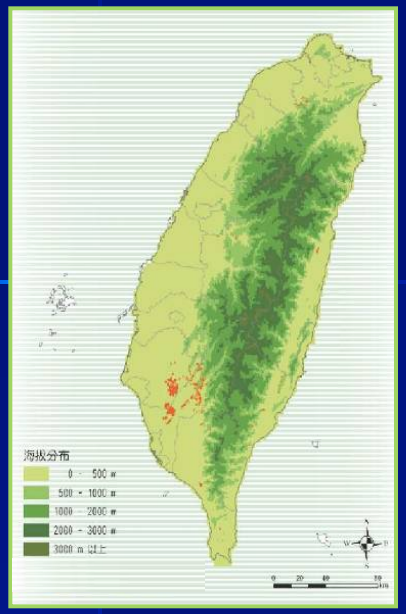
a giant clumping species introduced from China and planted widely with the majority in the Central-Southern Taiwan.

The elevations varies from plain to mountains with 1500 m.

DBH ranges 8-20 cm with culm height 14-25 m. The main bamboo's shoot product

Bamboo shoot

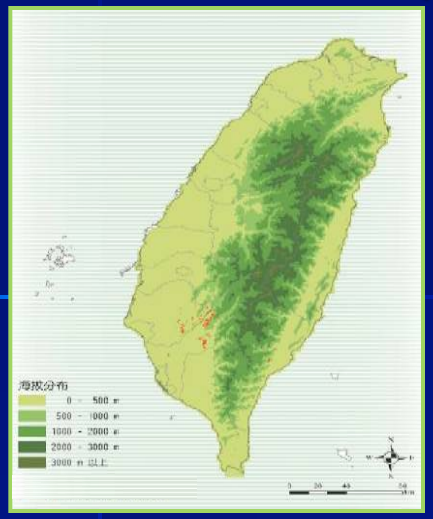
Green Bamboo (*Bambusa oldhamii* Munro)



- Cultivated for Bamboo shoot.
- Suitable to grow on high moisture soil and good fertility.
- Mainly distributed in southern part of Taiwan, but scatter planting along the riverside.

Bamboo shoot

Thorn Bamboo (*Bambusa stenostachya* Hackel)



Mudstone area

- endemic clumping species widely distributed at low elevation lands in Taiwan.
- cultivated as wind-break forests on the farm land.
- was culms dense per clump with culms over 16 m in height
- no economic usage nowadays.

a major species for forestation in the mudstone area

Culm used to be for paper pul

Bamboo area of four areas in Taiwan 2000

Total area 149,516 ha

Northern area 44,357 ha (29.7%), green bamboo, and makino bamboo

Central area 29,393 ha (19.7%) makino, moso and ma bamboo

Southern Area 61,143 ha (40.9%), ma, thorn and long-branch bamboo

Eastern area 13,948 ha (9.3%) ma and thorn bamboo

Bamboo distribution in Taiwan by elevation

Elevation above sea level (meters)	Bamboo species
Above 2000	*Yuahania niitakayamensis*
1000-2000	*Phyllostachys makinoi* *Phyllostachys pubesens* *Sinobambusa kunishii*
500-1000	*Bambusa dolichoclada* *Sinobambusa kunishii*
0-500	*Bambusa dolichoclada* *Bambusa oldhami* *Bambusa stenostachya*

Bamboo biomass and carbon storage assessment

- Bamboo biomass was estimated through the conventional procedure
- Bamboo biomass was separated into clum, branch and leaf parts, estimate each part individually, and summarize them to total biomass aboverground
- Carbon storage was estimated by multiplying biomass by percent carbon content
- Carbon sequestration was estimated by dividing carbon storage by number of years.

Bamboo resource and carbon storage

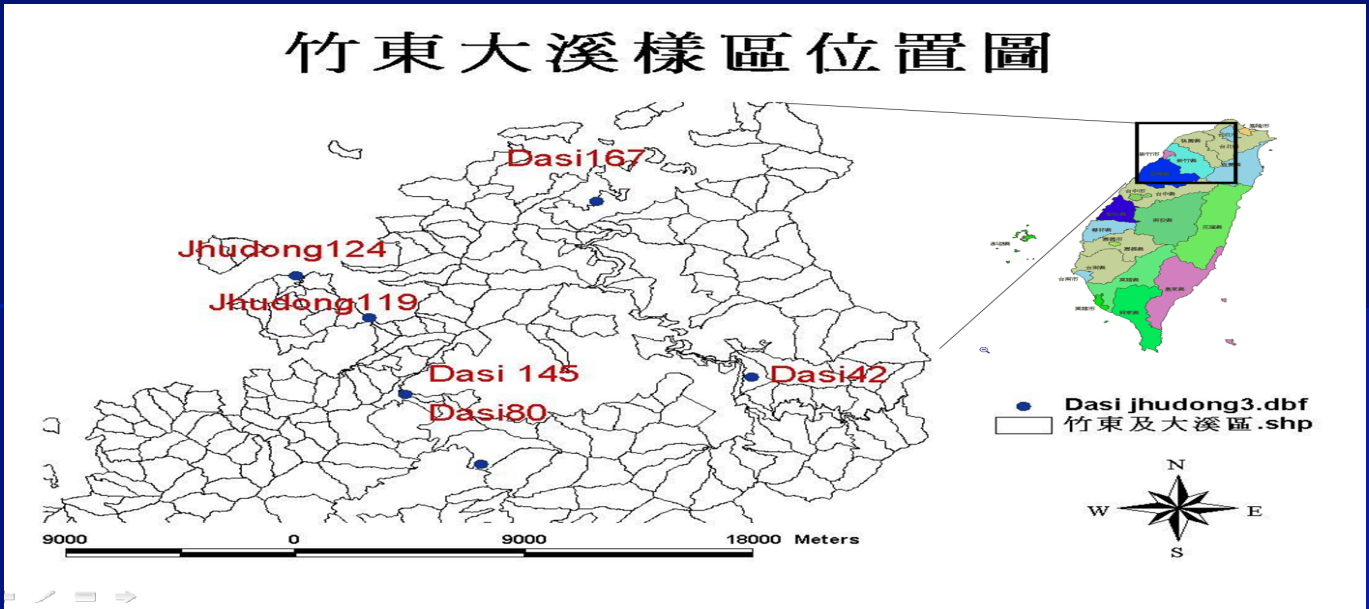
Species and environmental information for sites of cited references around Taiwan

Bamboo species	Site location	Elevation (m)	Temperature (℃)	Precipitation (mm yr^{-1})	reference
Phyllostachys makinoi	Northern Taiwan	405-1299	20	2350	Chen et al (2009)
Phyllostachys makinoi	Central Taiwan	450-550	15-23	1800-2400	Yen et al (2010)
Phyllostachys makinoi	Tung-Tou (Nan-ton County)	300-350	19.1	2249	Lu and Chen (1992)
Phyllostachys pubescens	Hui-sun (Nan-ton County)	667	20.3	3389	Wang et al. (2009)
Phyllostachys pubescens	Shi-zhuo (Cha-yi County)	1300	11.5	4616	Wang et al. (2009)
Denrdrocalamus latiflorus	Yue-Tzu village, Nan-ton County.	610	19.2	2404	Wang(2004)

Phyllostachys makinoi (Makinoi)

Northern Taiwan

Map of site locations in Shihmen Reservoir Watershed Area



Environment and characteristics of *makinoi* bamboo stands in Shihmen Reservoir Watershed Area

Site	Elevation (m)	Aspect	Slope (degree)	Density (culm ha^{-1})	DBH (cm)	Height (m)	Age (yr)
Dasi 80	1299	west	20	15700	5.2	10.2	5
Dasi 145	1256	east	20	16144	5.0	10.7	4
Jhudong 119	1220	west	10	17567	4.7	10.7	4
Dasi 42	1047	west	10	18767	5.9	11.1	5
Dasi 167	470	east	20	15800	5.4	10.8	4
Jhudong 124	405	east	25	11667	5.2	11.3	3

Biomass aboveground and belowground Makino stands at Shihmen Reservoir Watershed Area (Mg ha^{-1})

Site	leaf	shoot	Culm	Aboveground	Belowground	Total biomass
Dasi 80	4.34	6.74	14.9	53.08	164.37	217.45
Dasi 145	4.34	6.58	44.26	55.27	178.35	233.63
Jhudong 119	3.37	5.62	40.06	49.14	180.03	229.17
Dasi 42	8.07	10.02	63.45	81.68	190.1	271.78
Dasi 167	5.29	6.64	46.47	58.47	165.21	223.68
Jhudong 124	3.76	3.53	33.70	40.99	130.53	171.51
Average	4.86	6.52	44.97	56.44	168.1	224.54

Least density

Carbon storage aboveground and belowground Makino stands at Shihmen Reservoir Watershed Area (Mg ha^{-1})

Site	leaf	shoot	Culms	Aboveground	Belowground	Total biomass
Dasi 80	1.47	3.10	19.96	24.81	77.88	102.69
Dasi 145	1.74	3.03	21.09	25.86	84.50	110.36
Jhudong 119	1.35	2.59	19.9	23.03	85.30	108.330
Dasi 42	3.24	4.62	30.23	38.09	90.07	128.16
Dasi 167	2.12	3.06	22.14	27.32	78.28	105.60
Jhudong 124	1.51	1.63	16.06	19.19	61.84	81.04
Average	1.95	3.00	21.43	26.38	79.65	106.03

Comparison of Makino biomass aboveground and carbon storage at different area.

studies	Location	Biomass aboveground ($Mg\ ha^{-1}$)	Carbon storage ($Mg\ ha^{-1}$)	Carbon sequestration ($Mg\ ha^{-1}\ yr^{-1}$)
Chen et al (2009a)	Shihmen Reservoir Watershed Area	56.44	26.38	5.28
Yen et al (2010)	Chu-Shan Nan-Tou County	105.33	49.81	9.89
Lu and Chen (1992)	Tung-Tou Nan-Tou County	27.64	12.98	2.6
Ji (2008)	Chu-Shan Nan-Tou County	75.75	35.54	7.11
Yu(1995)	Hui-sun Experimental Forest Nan-Tou County	44.26	20.97	4.19

Shihmen is located in northern Taiwan

rests are in the central Taiwan

Phyllostachys pubescen (moso)

Husi-Sun central Taiwan

Shi-zhuo southern Taiwan

The stand structure and growth for Moso bamboo in two studies area

Site	Elevation (m)	Precipitation (mm yr^{-1})	Average temperature (℃)	Density (culm ha^{-1})	DBH (cm)	Height (m)
Hui-sun (Nan-ton County)	667	3389	20.3	7933	6.8	10.3
Shi-zhuo (Cha-yi County)	1300	4618	11.5	8344	10.6	21.4

The biomass, carbon storage and carbon sequestration in two studied area

Site	leaf (Mg ha^{-1})	Branch (Mg ha^{-1})	Culm (Mg ha^{-1})	Aboveground (Mg ha^{-1})	Carbon storage (Mg ha^{-1})	Carbon sequestration (Mg ha^{-1} yr^{-1})
Hui-sun (Nan-ton County)	3.6	9.7	43.1	57.9	26.4	5.3
Shi-zhuo (Cha-yi County)	4.4	12.0	151.7	171.3	82.9	16.58

Comparison Biomass, carbon storage and sequestration for 4 species in Taiwan

For a given species, the biomass aboveground varies at different sites

The biomasses aboveground of sympodial bamboos (S) are higher than those in monopodial types (M) because of the bigger size in culms in the sympodia and the major contribution of culm to biomass for both bamboo types

The trend of carbon storage is identical to the trend of biomass aboveground among species.

Bamboo species	Biomass aboveground	Carbon storage aboveground	Carbon sequestration
	(Mg ha^{-1})	(Mg ha^{-1})	(Mg ha^{-1} yr^{-1})
***Phyllostachys makinoi* (M)**	61.88	29.14	5.81
***Phyllostachys pubescen* (M)**	114.6	54.65	10.94
Denrdrocalamus latiflorus (S)	115.44	55.8	11.16
***Bambusa stenostachya*(S)**	243.8	114.51	22.90
Average	133.93	63.53	12.70

Comparison bamboo biomass between bamboo, natural forests and plantations (I)

The biomass and carbon storage in natural forests are greater than those in plantations because of more volume involved, but its carbon sequestration is in reverse. For example, in the 10 years period, the carbon sequestration in natural forests is only 0.67 Mg ha^{-1} yr^{-1} which is much less than carbon sequestration (2.66 ~5.23 Mg ha^{-1} yr^{-1}) in the Taiwan red cypress and Japanese cedar plantations.

The biomass aboveground in Makino bamboo (61.88 Mg ha^{-1}) is less than that in tree forests, for instance, 204 Mg ha^{-1} in *Taiwania cryptomerioides*, 170.99 Mg ha^{-1} in subtropical mixed deciduous broadleaf forests and 103.74 Mg ha^{-1} in subtropical broadleaf evergreen plantations , 99.5 Mg ha^{-1} in China fir , 68.5~96.81 Mg ha^{-1} in Taiwan red cypress, and 101.14~164.80 Mg ha^{-1} in Japanese cedar.

Comparison bamboo biomass between bamboo, natural forests and plantations (II)

But, due to the more rapid growth occurring in bamboo, the annual biomass growth in Makino bamboo forest is greater than that of *Taiwania cryptomerioides* (14.76 Mg $ha^{-1}yr^{-1}$ vs. 9.8 Mg $ha^{-1}yr^{-1}$).

Carbon sequestration contributions attributed to bamboo forest is obviously greater than that in tree forests.
Achieve the same amount of fixed carbon, bamboo only takes 1/3 to 1/2 of time required by trees.

Comparing to the tree forests, bamboo forests in Taiwan showed apparent superiority (average 12.70 Mg ha^{-1} yr^{-1}) to tree forests in the carbon sequestration capacity. Therefore, in order to reduce carbon dioxide emission, planting bamboo forest and taking a good management is a good way.

Calculate bamboo aboveground biomass and carbon storage in Taiwan

While we do not have exact data about bamboo forest area for key species in Taiwan, based on the average value for species discussed in this paper and the bamboo area of 221,911 ha in 2014, the total bamboo biomass aboveground and carbon storage in Taiwan Forests in 2014 can be roughly estimated to be 29.74 Tg and 14.10 Tg C, respectively.

Bamboo utilization in Taiwan

In the past, most of bamboo commercial products in Taiwan were baskets, chopsticks, toothpicks, bamboo shoots, skewers, blinds, joss stick, papers, and handicraft items.

Nowadays, the processing of bamboo in Taiwan is shifting from low-end crafts and utensils to high-end, value-added commodities such as laminated panels, boards, pulp, paper, mats, prefabricated houses, cloth, bio-fuel energy and artistic carvings.


東籬
書圖兩園翰墨
南華
秋水北苑春山
2015/05/28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Prospect of bamboo sustainable development in Taiwan

- Being a multi-purpose plant resource, bamboo is drawing an ever-increasing attention from different countries of the world including Taiwan and various international organizations. In the past decades, apparent advances have been achieved in scientific research, production, processing and trade in Taiwan bamboo industry.

- Under the prerequisite that sustainable management is quite essential to be maintained for bamboo resources for numerous reasons and benefits, in Taiwan, through a process of integration, coordination, and supporting of strategic policy and appropriate research and development programs, it is anticipated to (1) enhance the interests of the producers and consumers of bamboo, (2) to upgrade the capability and technical level of bamboo development institutions and services organizations at national level, and (3) to strengthen international collaboration among countries and regions.

Conclusion

Due to the great benefits associated with bamboo forest in multiple phrases, the importance of bamboo should be realized and intensive management should be taken for the sustainable bamboo resources management in Taiwan.

Thank you for Attention