BAMBOO ECOSYSTEM AND CARBON DIOXIDE SEQUESTRATION

1 Preface

Population growth and elevation of living standards are placing a greater stress upon the natural environment. The burning of vast quantities of fossil fuels, the large- scale devastation of tropical forest and land-use change have resulted in a gradual increase of atmospheric Greenhouse gas concentration which in turn have led to global warming. Carbon dioxide and other trace gases in atmosphere have a strong absorbency on infrared radiation, which absorb long-wave radiation from the earth and emit part of long-wave radiation to the earth, thus causing the warming of the earth's surface and globe climate. These potential serious problems have evoked many concerns not only from the general public and experts, but also from governments which have taken effective measures to reduce the emission of greenhouse gases in 1992, about 166 counties have signed in The United Nations Framework Convention on Climate Chang (UNFCCC) in the Earth Summit of Rio de Janeiro. In 1997, Kyoto Protocol has developed In Japan and responsibility and obligation of reducing of Greenhouse gases have drafted Because of gas concentration, many studies have showed that Greenhouse effect has resulted in elevation of atmosphere temperature and seawater temperature, thus affecting the global precipitation and soil moisture. In the last one hundred years or so, atmosphere temperatures have already crept up to 0.3 – 0.6 degrees Celsius Based on the model forecast, Greenhouse gas concentration will double in 2050 and the ground temperature will be 1.5 -4 5 degrees C higher. According to evaluation reports of the United Nations Intergovernmental Panel on Climate Change (IPCC) , if no measures are taken , by the end of the 21st century , the sea level will have risen up to 15 - 95 cm ; weather systems will be chaotic and severe rams , storms or droughts will occur In many places ; water resource allocation will be uneven , with low ground inundated , while shift ocean currents will relocate fishing grounds Carbon dioxide concentration has some great Influence on energy transform and the biological carbon cycle. The elevation of carbon dioxide concentration will accelerate the Bamboo Ecosystem and Carbon dioxide Sequestration 83 growth of plants to some degree and will change vegetation types and terrestrial ecosystems, agricultural product pattern, forest distribution, terrestrial vegetation, pole ice biosphere and frozen earth, seriously affecting the climate.

2 Bamboo Ecosystem Roles in Carbon Dioxide Sequestration

There are three carbon Inventories globally , which are ocean , atmosphere and terrestrial ecosystems So far , we know little about the carbon cycle between ocean and atmosphere. Because we live in this terrestrial ecosystem, which is complex and bigness , we know much about the carbon cycle between atmosphere and terrestrial ecosystem In the terrestrial ecosystem , forest is the largest carbon Inventory and it deposits 1146 x 10^{15} g carbon which occupies 56 percent of the carbon inventory of the total terrestrial ecosystem Bamboo

ecosystem is an Important part of forest ecosystem and an important carbon source and carbon sinks on the earth In this system , bamboo biomass , bamboo litter and bamboo soil are carbon sinks , whale respiration of organisms and decomposers degrading the dropping or carcasses of animals and plants are the greatest carbon sources on the earth If the amount of bamboo carbon fixation is larger than that of the decomposition, bamboo ecosystem is a carbon sink , otherwise it is a carbon source. In the global carbon cycle , the bamboo ecosystem is regarded as an carbon sink , but due to the bamboo ecosystem destruction , degradation and other interfering factors , bamboo forest ecosystem will become carbon sources , thus contributing to cause degradation of environment and exasperation of Greenhouse In bamboo ecosystem , through the mechanism of photosynthesis , bamboo turn carbon dioxide into organic carbon and stores It as their structures (G_p : gross of plant) Respiration of plant will emit part of carbon (R_a) Part of organic carbon will store in the litters and forest soil and part of which will gradually decompose , rot and return to the atmosphere (R_h) . The Net Primary Production (NPP) of bamboo forest may be formulated as : $NPP = G_p - R_a - R_h$ In the natural situation , the Net Primary Production of bamboo forest is positive , but due to the disturbance by human beings , NPP is negative. So we must take measures to protect the bamboo forest from being a carbon source and to mitigate the Greenhouse effects through carbon storage and emission from bamboo stands, litters, bamboo forest soil and bamboo products, the bamboo ecosystem participates in the carbon cycle between bamboo forest and atmosphere.

2.1 Bamboo Forest Biomass

Bamboo forest biomass stores a large quantity of carbon. With a carbon percentage of 40% - 45%, nearly half of the total biomass is carbon. The biomass of bamboo ecosystem in south China is listed in the following Table 1, also In comparison with the biomass of other forest ecosystems. The biomass of Indosasa sinica, Maozhu high and middle yield stands are higher than those of Pinus massoniana stand, Cunninghamia lanceolata stand and natural secondly stands , but lower than those of conifer-broad leaf mixed stands and ever-green broad leaf stands The biomass of Neosinocalamus affinit stand is higher than that of Cunninghamia lanceolata stand (Chinese fir) . These data show that the bamboo ecosystem possesses a great capacity for carbon dioxide sequestration.

Table 1 Biomass Comparison between Bamboo Forest and Other Ecosystems (t/ha)

Ecosystem Types	Stock	Branch	Leaf	Root	Total	Rank
Maozhu high yield stand	98.89	13.05	4.3	53.13	169.37	4
Maozhu middle yield stand	41.99	8.213	2.886	61.9	114.989	6
Neosinocalamus affinit	38.35	8.46	4.6	10.93	62.34	10
Bambusa rigida	57.49	8.6	5.3	11.6	82.99	9
Dendrocalamus latiflorus	24.82	8.45	5.92		39.19	12
Phyllostachys nidularia cv. Smoth sheath	7.771	4.17		11.941	13	
Acidosasa edutis Wen	5.353	4.8		10.153	14	
Indosasa sinica (better site condition)	143.68	20.07	18.338		182.088	3
Indosasa sinica (poor site condition)	100.66	15.037	11.205		126.902	5
conifer-broad leaf mixed stand	174.938	94.145	22.601	85.839	377.523	2
ever-green broad leaf stand	201.151	58.325	25.921	113.174	398.571	1
Pinus massoniana	70.31	22.7	10.73	5.03	108.77	8
Cunninghamia lanceolata	32.374	6.235	4.968	10.904	54.481	11
Natural secondly stands	56.058	32.412	9.287	16.274	114.031	7

2.2 Bamboo Products

The bamboo culm has its special features of high strength, flexibility, hardness compared with timbers, so it is an ideal raw material for many projects and widely utilized in construction, handicraft, and agriculture and fish industry. Because of the high cellulose content, it is suitable for bamboo paper-making, especially for top grade paper. Due to the different production types of bamboo, the length of growing time and also the emission by carbon dioxide after consumption varies. According to production longevity, bamboo products may be classified as short-term products and as medium-term products, for example, fuel and paper pulp belong to short-term products, while bamboo boards and bamboo furniture may be medium-term products. Carbon storage in fuel bamboo may emit in 1 - 2 years; carbon storage in paper and bamboo board may last 5 years or 100 years respectively. Longevity of bamboo products may determine the carbon sink function to a great degree. It is important to decrease the byproduct proportion and to produce durable and medium- longevity products during bamboo processing. Other measures such as bamboo culm modification and bamboo preservation may improve the bamboo products longevity. In a word, utilization of medium-longevity bamboo products may alleviate the emission of carbon dioxide and slow down the increase of carbon dioxide in the global atmosphere.

Table 2 Litter Comparison between Bamboo and Other Ecosystems (t/ha)

Ecosystem Types	Litter	Rank
Maozhu stands	7.440	3
Neosinocalamus affinit	2.76	8
Bambusa rigida	2.556	11
Dendrocalamus latiflorus	3.93	7
Dendrocalamus brandisii	2.58	10
Dendrocalamus oldhami	2.62	9
Indosasa sinica (better site condition)	37.00	1
conifer-broad leaf mixed stand	7.66	2
ever-green broad leaf stand	6.9	4
Pinus massoniana	1.79	12
Cunninghamia lanceolata	4.841	5
Natural secondly stands	4.003	6

2.3 Bamboo Litters

Part of bamboo plants are shed and fallen to the ground as litter. A portion of this litter will decompose and rot, and its carbon re-emitted back into the atmosphere, while other portions will become part of the soil organic material. This part of carbon inventory occupies only a little proportion of the total ecosystem, but can not be neglected. To decrease the decomposition may play some role in carbon sequestration The main ecosystem litters in China are listed in the following Table 2 From the table , we may see that the latter of Indosasa sinica stands is 5 times larger than that of a conifer-broad leaf mixed stand , and the latter of Maozhu stand is higher than those of Cunninghamia lanceolate, Natural secondly stands and ever-green broad leaf stands.

2.4 Bamboo soil

Bamboo SOC (soil organic carbon) is a most important part of soil organic material (SOM), which affects soil structure, root depth, soil profile characteristics, soil available water and soil biodiversity, etc. The loss of SOC will damage the formation of soil aggregation and its stability. The balance level of SOC is a symbol of the system. In this system , only the carbon flux maintains a suitable level , can It maintain and improve its productivity Soil is the largest carbon sink in bamboo ecosystem and SOC vanes in different bamboo ecosystems In a Maozhu stand , the SOC content is about 2. 0% (0 - 40cm below the soil surface), while in a Neosinocalamus affinit stand, the SOC content is more than 3%. Generally speaking, the SOC content of Bamboo is lower than in conifer-broad-leaved stand, ever-green stands and natural secondly stands, but higher than in a Pinus massoniana stand and Cunninghamia lanceolata stand See Table 3.

Table 3 The Carbon Storage of Chinese Major Forest Ecosystems and Bamboo Ecosystems (10^8t)

Ecosystem Types	Vegetation	Soil	Litter	Total
Larix forests	5.83	16.13	1.95	23.91
Picea-Abies forests	6.2	27.28	1.57	35.05
Pinus sylvestries var. *mongolica* forests	0.2	0.85	0.04	1.09
Pinus koraiensis forests	1.36	3.7	0.19	5.25
Temperate coniferous forests	1.85	8.12	0.49	10.46
Warm temperate forests	14.17	32.58	1.64	48.39
Coniferous mixed/coniferous and broad-leaved mixed forests	0.86	4.47	0.1	5.43
Deciduous broad-leaved forests	17.24	75.4	2.11	94.75
Sclerophyllous broad-leaved forests	4.02	8.19	0.13	12.34
Evergreen/evergreen-decidous broad-leaved forests	9.29	32.48	0.68	42.45
Tropical forests	0.98	1.03	0.03	2.04
Total	62.00	210.23	8.92	281.16
Bamboo forests	2.511	8.516	0.361	11.388

3 The Dynamic Change of Soil Organic Carbon Storage

3.1 Biomass Carbon

As trees grow up, the biomass is enhanced, thus the storage of carbon increases gradually. The rate of carbon accumulation depends on the relationship between plant photosynthesis, respiration of animals and microorganisms, and death of organisms. These have a close relation with forest types, forest productivity, and growth stage of forest and climate condition. Respiration of organisms has a positive relation with forest biomass. As the forest is aging, the

biomass increases, but debris increases also, so the respiration of organisms increases. The undisturbed virgin forest (climax stage) absorbs a large amount of carbon dioxide, but due to the intensive respiration by the vegetation, animals and microorganisms, the decomposed organic material releases carbon dioxide greatly. The absorption and the respiration of the climax forest will stay in a balance Anyway the virgin forest stores a large a- mount of carbon in the biomass and soil.

Based on the forest biomass and forest resource survey, Canadian scientists estimated the carbon storage and dynamic changes. They collected the forest biomass data and draw the growth curve of forests, according to climate zones, forest types, productivity scale and forest growth stage According to one proportion, forest cumulating conversed into forest biomass and carbon storage is calculated by forest biomass time's carbon conversion Index

3.2 Forest Soil Carbon

Researchers have divided SOC into three parts, quick turnover, middle turnover and slow turnover Different parts of SOC determine their different remaining time in the soil the half life of the quick turnover carbon ranges from 3 to 20 years, and are composed of dead leafs and branches with a diameter less than 10 cm. The half life of the middle turnover carbon ranges from 20 to 100 years, composed of dead branches and stocks, above 10 cm. The half life of the slow turnover carbon exceeds 1|0 years and exists as organic material. According to the analysts, 17 percent of the quick and the middle turnover carbon are converted into slow turnover carbon stock, while 83 percent are emitted into the atmosphere as carbon dioxide The soil carbon stock depends on the input of organic material, output of decompose and loss of waders, which is also closely related with climate, disturbance factors and change of vegetation biomass. By modeling decomposing rate, disturbance factors and biomass change, soil carbon stock is estimated.

3.3 Disturbance Factors on Forest Carbon Balance

Forest cutting, land-use change, forest fire, forest plant diseases and insect pests can greatly affect the forest carbon storage. After forest cutting, the biomass and carbon storage is reduced. lf reforestation follows after forest cutting, there is little change about soil organic carbon; but if no reforestation follows, the remains of forest cutting will decompose in ten years later In general, soil organic carbon remains at a lower level after 25 years forest cutting After forest cutting, the land becomes arable land or ley, as the biomass reduce, the SOC stay a lower level. Soil cultivation will increase the carbon release from soil, so that destruction of forests increases carbon dioxide in the air. If forest plant diseases and insect pests break out, the growth of forest will be affected and carbon storage will decrease. Forest fire will burn the vegetation and emit the carbon dioxide into the air, which were amassed over a long time. Therefore expanding a forestation and forest protection are effective measures to mitigate the rising of car- in dioxide in the atmosphere.

4 Review on Forest Ecosystem Carbon Cycle in China

As the people in the world pay more and more attention to the global warming, caused by Greenhouse effect, China has also conducted some carbon balance study, especially in forest ecosystem carbon Inventory. Besides the studies by forest experimental stations , such as tropical Forest experimental station in Hainan province and artificial forest experimental station in south China , researchers have surveyed the space distribution of forest carbon , based on the statistic data, plot survey and GIS. All these work has established foundation for forest carbon cycle studies in China Today the forest coverage in China is 18. 21%, and as reforestation steps quicken up and forest management level is Improved, in 2050 the forest coverage will reach 27% Without question, enhancement of forest area will surely Improve the forest absorption on carbon dioxide In the air and Chinese forest will have a carbon sink roles In the global carbon balance. There are still many efforts needed to settle Chinese carbon cycle in the future.

To strengthen the fundamental studies on the forest ecosystem in forest experimental stations In order to reinforce the data on forest ecosystems In China; to study the different vegetarians in order to survey the carbon stock and carbon cycle on different forest ecosystems, considering the vast territory and complex vegetarians in China; To estimate the benefits of forest carbon sink.

5 The Future of Bamboo Ecosystems in Carbon Dioxide Sequestration

China has the richest bamboo resource in the world and is one of the bamboo origins and center distributions. The broad natural geographical environment from tropical, sub-tropical and warm temperate zones has provided 39 genera of more than 500 bamboo species with a favorable growing situation. The total bamboo area is more than 4.4 million ha, which occupies 3. 6% of the total forest land and plays an important role In conserving soil and water, modulating climate and improving environment Their large amount of biomass determines their important function In carbon dioxide sequestration People in the world have reached an agreement in improving soil carbon storage , alleviating enhancement of carbon dioxide , protecting soil from being degraded , Improving soil quality and productivity and conserving biodiversity It is estimated that in future 25 years, 14 +- 7 x 10^{15} carbon will be stored If the degraded land in the world be reestablished and if vegetation reestablishment and pasture intensive management are taken into account , carbon dioxide sequestra-15 non will be 0. 58 - 0. 80 x 10^{15} g yearly , which will be 9% - 12% percent of carbon dioxide emission from human activities So carbon sequestration projects as an available and economic measure are carried out in many countries in the world to cut down Greenhouse gas content , to Improve soil quality and to conserve environment.

For example, in United States, four measures are put forward to alleviate carbon dioxide emission, including soil erosion management, land use change and resume, producing bio-fuel

to reduce the amount of fossil fuel utilization and Intensive arable land management all of these measures have resulted already in marked ecological benefits.

Bamboo has its features of fast growth, high output, and annually renewable and harvestable vegetable if managed in an intelligent way after planting it is an important forest resource in tropical and subtropical zones. Its high-resistance and lower demand on site condition determines that it can grow widely, so it is one of the most-selected species in national grain for green projects. The project aims are to reestablish forestry, to Improve carbon absorption of vegetation and soil, to reduce the emission of carbon and to enhance the SOC and to extend the storage time of carbon in soil The enumerate branches and leaves, evergreen, and the excellent conservation of soil and water show that bamboo provides an integration of economical, ecological, and view functions. With the development of national gram for been project and natural forest conservation project, bamboo will surely play ever- greater roles in the future.