Utilization of Bamboo Forest for a District Energy Resource : an Example of Phyllostachys Pubescens

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Utilization of bamboo forest for a district energy resource: an example of Phyllostachys pubescens

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Abstract: Once bamboo trees, particularly Phyllostachys pubescens is the most commonly seen kind in Japan, were planted near villages, and used to be utilized for construction materials or a seasonal provision. However, most of those bamboo forests are now abandoned since economic and social situations have been changed. Without human control, bamboo forests have enlarged their propagation area by their unique asexual reproduction system, which uses rhizomes, and consequently it has depreciated the value of both artificial and natural forests planted beside those bamboo forests. For those reasons, today bamboo forests are often treated with a serious social issue. Our research team has aimed at Phyllostachys pubescens's biological characteristics, thrusting speed and asexual reproduction system, and proposes to use bamboo as a sustainable energy resource for the local industry and life. In order to use Phyllostachys pubescens for a sustainable districts energy resource, it is an urgent matter to develop the efficient reproduction and management system as well as to verify the quality, economical feasibility, and convenience of Phyllostachys pubescens for the energy resource. Meanwhile, because appropriately controlled bamboo forests have much faster assimilation potential of carbon dioxide than other popularly seen kinds of tree in Japan, it is assumed that utilization of bamboo trees for the district energy will contribute to the resolution of the global warming not only in Japan, but also in China, south eastern Asia, and Latin American countries where bamboo kinds are popularly grown.

Keywords: Phyllostachys pubescens, sustainable district energy resource, assimilation of carbon dioxide

1. Introduction

1.1. Utilization of bamboo tree in Japan

In Japan, bamboo tree was considered as an indispensable natural resource for the life of Japanese people. It was used as a useful material for a variety of tools under different circumstances, such as construction, handwork, musical instruments, ritual implement, and weapon. Also, bamboo was recognized as a necessity for their daily lives. For instance, it was often grown in their backyard for food, medicine, fuel, and ornamental plant. However, as the economy rapidly grew after the second war, most of the products which were used to be made of bamboo were replaced by the plastic products which enable industries mass production and cost efficiency. Meanwhile, culinary bamboo shoot products which mostly made in China and had higher price competitiveness started to dominate the market. This has discouraged the landowners from managing their bamboo forests. With other factors such as drain problem on the labor force and aging problem in the countryside, bamboo forest has been abandoned.

Today, most of those abandoned forests have become an over-density forest since nobody has been taken care of them. Besides, those which were abandoned have expanded their territory into other kinds of forests and dominated other kinds of plants quickly. Consequently, this has caused a loss in quality and value of forests, particularly seen in younger artificial forests. This situation is often picked up by mass media as a social problem. Most people no longer appreciate the value of bamboo forest as a natural resource, though they may consider that bamboo forest is worse than useless.

1.2. Biological characteristics of Phyllostachys pubescens

Phyllostachys pubescens known as Mousou bamboo in Japan is the largest and the strongest kind in terms of propagation. It is considered that Mousou bamboo was originally imported for a provision from China in 17th century. It has an asexual reproduction system and spreads out their territories by growing rhizomes, horizontal stem, and clums, vertical stem. Mousou bamboo has much higher reproductive power than other kinds of bamboo seen in Japan. Their rhizomes grow as much as 4 meters in a year. It takes only 2 to 3 months to complete the growth of clum. It is not so unusual to see the clum to grow more than 1 meter in one day. The size of clum will not get bigger after the completion of growth. The diameter of clum becomes between 9 to 20 centimeters and the length of clum will be 12 to 20 meters.

Because of its vigorous reproduction power, the bamboo forest which lacks density management by people often becomes too dense. It causes the loss of biodiversity by interfering sunshine to reach the forest floor as well as the erosion of the forest floor. These forests are under serious conditions in terms of environment and disaster prevention. Also, invading the surrounding forests, particularly toward the younger artificial forests, has become a big problem. Therefore, it is an urgent matter to develop the management system for those abandoned bamboo forests.

2. Objectives and expected effects

2.1. Objectives

We focus on the reproduction system and the incredible growth speed of Mousou bamboo. In this paper, we aim at improving the regional energy self-sufficiency ratio as well as promoting the maintenance of bamboo forest by developing the sustainable utilization system of regional bamboo forests. In this plan, the energy will supply to the horticulture farmer for heating their greenhouses.

2.2. Expected effects

It is expected to increase the stability of local industry and economy as well as the public utility of bamboo forest due to the development of sustainable bamboo energy utilization system.

2.2.1. Increase in the public utility of bamboo forest

It is expected that Carbon dioxide Capture and Storage (CCS) function of bamboo forest will increase by reducing the proportion of old bamboo trees due to the maintenance of the forest. At the same time, sunshine will be able to reach the forest floor by appropriately managing forest, and consequently it enables understory vegetation to grow. Thus, it is also expected that developing the utilization system of bamboo forest will contribute to the preservation of biodiversity.

Because bamboo forest has higher soil binding power than other types of forest (figure 1) due to their highly dense underground network of rhizomes, bamboo trees were often planted for stabilizing the riverside and the slopes of hillside, where risks of landslide is considered to be higher. However, it is assumed that abandoned bamboo forest cannot work properly as a disaster prevention function since the activity of rhizomes decline. For this problem, it is considered that developing the utilization system of bamboo forest will able to increase the soil binding power of forest by enabling them to reproduce the new rhizomes as well as to increase the public utility of the bamboo forest.

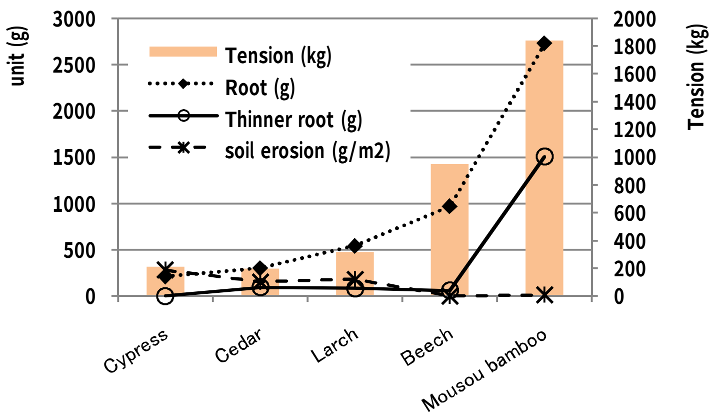

Figure 1. Comparison of soil binding power[1]

2.2.2. Contribution to the stability of local industry and economy

For another effects of applying the regional utilization system of bamboo forest, it is expected to provide stability for the local industry and economy.

In addition to the increase in the regional energy self sufficiency by procuring and consuming energy within the region, contribution to the local economy is also expected. Because in this system, the energy cost which used to be going to outside the region is going to circulate inside the region.

For example, the greenhouse horticulture in Geisei village, which is our current research field, spent 4 hundred million yen to purchase 4,500 kiloliters of crude oil last year. This is equivalent to 15% of the annual budget of this village. If able to develop the closed system where the energy costs circulate within the village, this will bring huge effects on the local economy. At the same time, the village will able to develop the stable industrial structure which is hardly influenced by the fluctuation of the national and international energy market.

3. Evaluation of bamboo as an energy resource

[1] drawn based on the information below http://www.pref.ehime.jp/060nourinsuisan/080ringyou/00001461021016/5_guide/take.pdf

3.1. Heating value of bamboo

There are many stories regarding energy of bamboo. For instance, the fire made from bamboo fuel makes a hole in the bottom of the kettle. This story explains that the heating value of bamboo is quite high. We made pellet fuels from different kinds of raw materials and examined the heating value and ash contents of each sample. (Figure 2)

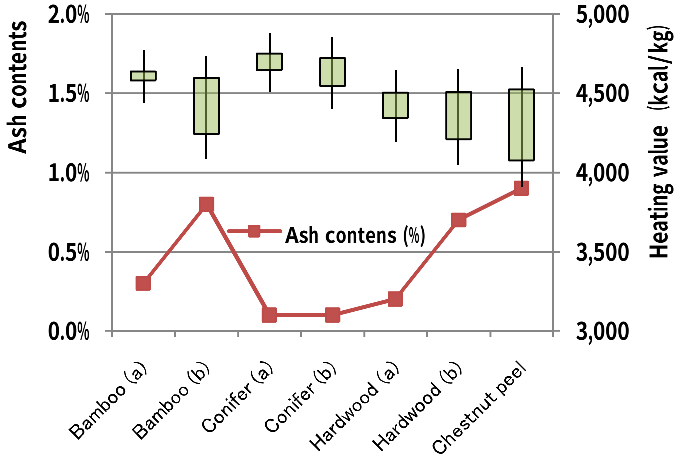

Figure 2. Comparison of heating value and ash contents in different raw materials

Heating value of both bamboo pellet (a) and (b) have 4,600 to 4,800kcal/kg at complete dry-base, which is quite similar result to conifer trees and hardwoods. However, bamboo pellets have 0.3 to 0.8% of ash contents, which is several times higher than the conifer pellets we tested. For this result, we consider that bamboo has quite high heating value which is sufficient for energy use. However, because of the relatively higher ash contents, bamboo may not suit for solid fuel under a certain circumstance.

3.2. Distribution and amount of bamboo resource in Japan

Propagation of bamboo forest in Japan distributes broader range from Okinawa to Iwate prefecture. Because bamboo tree particularly prefers mild climate, bamboo forests in Kyushu, Shikoku, and

Chugoku region account for 70% of the total area (Table 1).

Table 1. Distribution of bamboo forest in Japan

Region		Area (ha)	Ratio (%)
North	Hokkaido	0	0.0
	Tohoku	3,798	2.4
	Kanto	12,068	7.6
	Chubu	18,319	11.5
	Kinki	15,217	9.6
	Chugoku	32,764	20.6
	Shikoku	13,959	8.8
South	Kyusyu/Okinawa	63,078	39.6
	Total	159,203	100.0

According to the statistics by Forest Agency (2007), there are total amount of approximately 160,000 hectares of bamboo forest in Japan, which is less than 1% of whole forest in Japan. It is considered that these bamboo forests have at least 100 to 150 ton of dry-base weight per 1 hectare. Thus, there are approximately 16 to 24 million ton of dry-base weight in Japan.

When we use bamboo forests for local energy, we must distinguish the available and unavailable amount based on the economy, environment, and disaster prevention.

3.3. Re-productivity of bamboo forest

The attraction of bamboo for energy use is obviously its growth speed. Table 2 shows that the productivity of different forests. As the table shows, well-controlled Mousou bamboo forest has 6 to 11 times higher productivity than artificial cedar and cypress forests. Besides, bamboo tree can reproduce the new tree by asexual production system, it is not necessary to replant the seedlings and therefore, it is able to lower the maintenance costs.

Table 2. Amount of biomass and productivity of different kinds of forests

Forest type	Number of standings (/ha)	age (year)	amount of biomass (dry-t/ha)	annual production (dry-t/ha)
Mousou bamboo	7,000	5	100-150	20—30
Cedar (artificial)	3,000	50	168.7	3.37
Cypress (aretificial)	3,000	50	136.7	2.73

4. Possibility of bamboo forest as Carbon dioxide Capture and Storage (CCS) function

In Kyoto protocol, bamboo forest is not allowed to count as a CCS forest. Bamboo forests account for only 1.13% of whole forests in the world. It seems that it is insignificant to consider bamboo forests. However, most of those bamboo forests distribute in developing countries such as China and India which so far are not so positive to the global agreement for the reduction of carbon dioxide. If the utilization and management system of bamboo as well as the market are established, it is considered that the significance of bamboo tree will be recognized better in many ways.

According to a research, Madake bamboo, *Phyllostachys pubescens*, has as much as 1.7 times higher assimilation function than evergreen broad-leaved tree in temperate zone. Because of the fact that Mousou bamboo grows bigger than Madake bamboo, it is assumed that well-managed Mousou bamboo forest has higher assimilation potential. On the other hand, emission of carbon dioxide may exceed assimilation in abandoned Mousou forest. For this matter, we consider that defining the assimilation and emission functions of bamboo forest in the protocol is necessary and it will increase the significance of bamboo trees as well as to create opportunities of bamboo business.

5. Utilization of bamboo tree as an energy for heating greenhouse

5.1. Combustion test of bamboo pellets by wood pellet heating system

5.1.1. Outline of the experiment

In order to investigate the feasibility of bamboo tree as an energy resource for heating greenhouse, we carried out the combustion test of two different kinds of bamboo pellets. Table 3 shows the outline of the experiment.

Table 3. Outline of the combustion test

Fuel	Bamboo pellet A	Bamboo pellet B
Raw material	Mousou bamboo clums	Mousou bamboo clums, branches, and leaves
Diameter	ϕ6mm	ϕ7mm
Burner	Wood pellet heating burner MN-12F (Soai co,.ltd)	
Output	120,000 kcal/h	96,000 kcal/h
Fuel charge	248g/charge	255g/charge
Combustion period	2hrs. 23min.	2hrs. 26min.
Temperature measurement points	① Furnace ② Chimney ③ Hot air vent	

5.1.2. Results of the experiment

After the both combustion tests, we waited for 30 minutes and then opened the furnace for the inspection. In the case of combustion test with bamboo pellet A, some ash remaining in the furnace was observed. (Picture 1) However, the amount of ash accounted for only 0.54% of total fuel consumption, which is relatively a little bit higher than the conifer white pellets, but still in the permissible range. On the contrary, in the case of combustion test with bamboo pellet B, a large amount of sediments which were still burning were observed. (Picture 2) Because bamboo pellet B was made of not only clums, but also branches and leaves, it is assumed that it had a lot of ash contents. Therefore, a large amount of ash was produced during the combustion. The ash produced during the combustion was burned at very high temperature and finally became the clinker which consequently interfered the air circulation in the furnace. (Picture 3)

Picture 1. After the combustion of bamboo pellet A

Picture 2. After the combustion of bamboo pellet B

Picture 3. Clinker adhered to the ceramic rostle

During the experiments, the changes in temperature at several points were recorded. Figure 3 shows that the changes in temperature of the hot air came from the vent of heat exchanger. During the experiment of bamboo pellet A, the average temperature of hot air was 63.5 degree which is quite high. Meanwhile, the average temperature of hot air in the experiment of bamboo pellet B resulted in 44.2 degree which is almost 20 degree lower than pellet A. Figure 4 shows the temperature in the furnace during both experiments. In the case of pellet A, the temperature in the furnace consistently kept around 600 degree. On the other hand, in the case of pellet B, a decline in the temperature is observed at 1 hour passed from the beginning, and then, the temperature made a sudden upturn when 2 hours passed from the beginning. Finally, the temperature reached at almost 1,000 degree. It is considered that these differences in the temperature between two experiments were also caused by the difference of the raw materials.

It is necessary to control the ash produced during the combustion if the bamboo pellet which contains branches and leaves is used for fuel. The pellet heating unit we used in this experiment is not suitable for using this kind of fuel. Therefore, it is necessary to remove the branches and leaves from bamboo tree before processing the fuel.

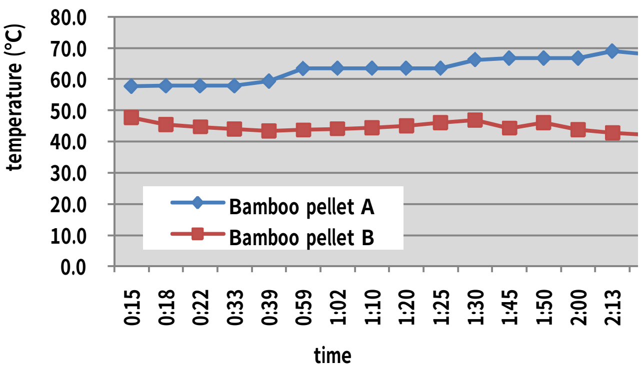

Figure 3. Changes in temperature of the hot air

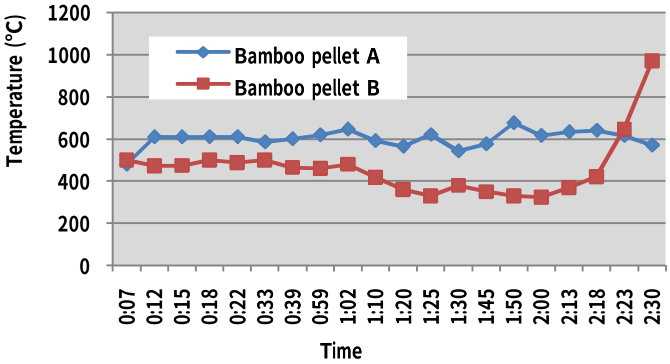

Figure 4. Changes in temperature in the furnace

5.2. Energy demand and amount of resources in a model region

Geisei village which is our research field is a small municipality. It has a population of 4,000 people and the greenhouse horticulture is the key industry of this village. Currently, 5 farmers in this village have introduced 7 pellet heating system. (Picture 4)

Picture 4. Outward of the greenhouse which uses pellet heating system

In their greenhouses, green pepper or flowers, both require the greenhouse to keep the temperature relatively higher than other kind of products such as eggplant (Table 4), are grown since it is more cost effective. Therefore, it is expected that the number of greenhouse which introduce the pellet heating system is going to increase based among those greenhouses which require higher temperature.

Table 4. Energy consumption by greenhouse products

		Eggplant	Flowers	Green pepper
Cultivation area	ha	32	13	10
Consumption of crude oil per10a	l/y	3,000 - 4,000	10,000 - 12,000	15,000
Annual consumption	kl/y	960 - 1,280	1,300 – 1,560	1,500

Currently, there are 10 hectare of greenhouse where green pepper is grown in Geisei village and it is estimated that the amount of crude oil consumed in those greenhouse is 1,500 kiloliters per year.

According to the statistics by Kochi prefecture, there are 89 hectare of bamboo forest in Geisei village and most of them are distributed around the central village. We have carried out the investigation of those bamboo forests in the field after getting the permission by the landowner. (Table 5)

Table 5. the amount of bamboo forest resources in Geisei village

Number of standings in 100m2		89		
Average diameter		10.0		cm
Average height		14.2		m
Dry-based weight per clum	14.1	-	15.5	kg
Dry-based weight per ha	125.3	-	137.7	t
Bamboo forest in Geisei		89		ha
Amount of bamboo in Geisei	11,152	-	12,255	t

Based on our field research, it is estimated that there are about 12,000 tons in dry-base of bamboo in Geisei village. If harvesting cycle of every 5 years or 20% of thinning every year has been done to the bamboo forest in Geisei village, 2,400 tons of bamboo pellets are able to produce from bamboo forest in this village. This is equivalent to 80% of energy for heating all of the green pepper growing greenhouse. Even if all of the flower growing farmers in this village also decide to switch the heating system to pellet heating, more than 40% of their energy consumption can be covered by their bamboo resources.

Today, there are about 50 pellet-production plants in Japan. However, only 3 of them produce more than 3,000 tons of pellets in a year and only one of them supply their products to the market. This is because most of the plants have problem with procurement of the resource for the energy consistently as well as the insufficient market development. Utilization of bamboo forest for the local energy can contribute for solving these problems and giving these business a sustainability and stability,

6. Conclusion

It is necessary to develop the management system that can sustainably control the bamboo forest by local people in order to solve the enlargement of abandoned bamboo forests.

In this paper, we discussed the utility of bamboo forest for the regional energy use and evaluated its feasibility for using greenhouse horticulture as an energy resource. However, there are still several issues to be solved such as economic feasibility and environmental aspects.