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Current Utilization of Bamboo for Paper Making and its Potentialities in Kagoshima Prefecture

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ABSTRACT

This study aims to investigate the current utilization of bamboo for paper making and assess the potential of bamboo culm production in Kagoshima Prefecture. To fulfill the main objective, this research has been conducted to accomplish the specific objectives: (1) to clarify the bamboo resource utilization for paper, (2) to explore the relationship between bamboo distribution and bamboo chip production of bamboo chip companies, (3) to estimate above-ground biomass of Moso bamboo stands and estimate the area of utilized bamboo forest for bamboo chip production, (4) to estimate the potential amount of bamboo biomass. This study was conducted in Kagoshima Prefecture between March and April 2022. Data were collected through interviews with the manager of Chuetsu Pulp and Paper Company, the focal person of four chip companies, and bamboo shoot farmers. A spatial data from JAXA and forest statistics data of Kagoshima Prefecture were used to estimate the current bamboo distribution area. Field data were collected on bamboo stands in Satsuma Town and Akune City to study stand structure and estimate the above-ground biomass of Moso bamboo stands. An allometric model based on power function was used to predict the aboveground bamboo biomass. Chuetsu P.&P. Company established bamboo chips collection system using their partner chip factories in Kagoshima Prefecture, which have provided domestic wood chips. In 2020, nine chip factories provided the company with 5,794 ton dw bamboo chips. The amount of bamboo chips provided by each chip factory had the highest correlation (R^2=0.63) with the bamboo forest area within 10 km distance from each factory. Most of the bamboo chips were from old bamboo culms produced by the thinning operation of the bamboo farms. Farmers can produce 9.0 to 16.6 ton dw/ha thinned culms over 5 cm diameter and can sell them to chip factories 7,800 to 11,000 yen/ton fw, including the local government subsidies ranging from 0 to 3,300 yen/ton fw. The bamboo sector could promote the utilization of bamboo biomass used for value-added products, which also helps to improve and motivate bamboo chip providers because there are substantial unused resources and a high potential of biomass from bamboo stands. Recognition of farmers' motivation and improvement of subsidies amount in the management of bamboo forests will result in well-managed forests, favorable environmental conditions, and diversified biodiversity in the future.

Key Words: Moso bamboo, Above-ground biomass, paper making, abandoned bamboo stands, managed bamboo stands

စာတမ်းအကျဉ်း

ကာဂိုရှီးမားစီရင်စုရှိ စက္ကူပြုလုပ်ခြင်းအတွက် လက်ရှိဝါးအသုံးပြုမှုနှင့်၎င်း၏အလားအလာ

ဒေါ်ဖြူသွယ်ဝင်း၊ဦးစီးအရာရှိ (အပူပိုင်းဒေသစိမ်းလန်းစိုပြည်ရေးဦးစီးဌာန)

ဤသုတေသန၏ပြုလုပ်ရခြင်း၏ ရည်ရွယ်ချက်မှာ စက္ကူပြုလုပ်ရန်အတွက် လက်ရှိဝါးအရင်းအမြစ်များ သုံးစွဲမှုအခြေအနေအား ရှင်းလင်းတင်ပြရန်နှင့် ကာဂိုရှီးမားစီရင်စုရှိ ဝါးထွက်ရှိနိုင်ချေကို အကဲဖြတ်ရန် ဖြစ်ပါသည်။ အဓိကရည်ရွယ်ချက်ကို ဖြည့်ဆည်းပေးရန်အတွက် အောက်ဖော်ပြပါ ယေဘုယျ ရည်ရွယ်ချက်များကို ချမှတ်ခဲ့ပါသည်- (၁) စက္ကူအတွက် ဝါးရင်းမြစ် အသုံးချမှုကို ရှင်းလင်းရန်၊ (၂) ဝါးပျံ့နှံ့မှုနှင့် ဝါးချစ်ပ်ပြား ထုတ်လုပ်သည့် ကုမ္ပဏီများ၏ ဝါးထုတ်လုပ်မှု ဆက်စပ်မှုကို လေ့လာရန်၊ (၃)မိုဆိုဝါး၏ မြေပြင်အထက် ဇီဝဒြပ်ထုကို ခန့်မှန်းရန်နှင့် ဝါးချစ်ပ်ပြား ထုတ်လုပ်ရန် အတွက် အသုံးပြုထားသော ဝါးတောဧရိယာကို ခန့်မှန်းရန်၊ (၄) ဖြစ်နိုင်ခြေရှိသော ဝါးဇီဝလောင်စာ ပမာဏကို ခန့်မှန်းရန်။ ဤလေ့လာမှုအား ၂၀၂၂ ခုနှစ် မတ်လမှ ဧပြီလအတွင်း ကာဂိုရှီးမားစီရင်စုတွင် ပြုလုပ်ခဲ့ပါသည်။ Chuetsu Pulp and Paper Company ၏မန်နေဂျာ၊ ချစ်ပ်ကုမ္ပဏီလေးခု၏ အဓိကပုဂ္ဂိုလ်များ၊ မျှစ်စိုက်တောင်သူများနှင့် တွေ့ဆုံမေးမြန်းမှုများ မှတဆင့် ဒေတာအချက် အလက်များကို စုဆောင်းခဲ့ပါသည်။ JAXA မှ ဧရိယာဒေတာနှင့် ကာဂိုရှီးမားစီရင်စု၏ သစ်တော စာရင်းအင်း အချက်အလက်များကို လက်ရှိဝါးတော ဧရိယာကို ခန့်မှန်းရန် အသုံးပြုခဲ့ပါသည်။ Moso ဝါးပင်များ၏ မြေပြင်အထက် ဇီဝဒြပ်ထုနှင့် ဝါးတော အနေအထားကို ခန့်မှန်းရန် Satsuma မြို့နှင့် Akune မြို့ရှိ ဝါးတောများတွင် ကွင်းဆင်းလေ့လာပြီး စုဆောင်းရရှိခဲ့သည်။ Moso ဝါးပင်များ၏ မြေပြင်အထက် ဇီဝဒြပ်ထုခန့်မှန်းရန် power function ပေါ်အခြေခံသည့် allometric မော်ဒယ်ကို အသုံးပြုခဲ့သည်။Chuetsu P.&P. ကုမ္ပဏီသည် ပြည်တွင်းဝါးများကို ပံ့ပိုးပေးသည့် ကာဂိုရှီးမားစီရင်စုရှိ တစ်ခုတည်းသော ကုမ္ပဏီဖြစ်ပြီး ၎င်းတို့၏ လုပ်ဖော်ကိုင်ဖက် ချစ်ပ်ပြားစက်ရုံများကို အသုံးပြုကာ ဝါးချပ်စ်ပြားစုဆောင်းမှုစနစ်ကို တည်ထောင်ခဲ့သည်။ ၂၀၂၀ ခုနှစ် တွင် ချစ်ပ်စက်ရုံ ကိုးခုမှ Chuetsu P.&P. ကုမ္ပဏီအား ၅၇၉၄ တန် dw ဝါးချစ်ပ်များ ထောက်ပံ့ပေးခဲ့သည်။ ချစ်ပ်စက်ရုံတစ်ခုစီမှ ထုတ်လုပ်သော ဝါးချစ်ပ်များ ပမာဏသည် စက်ရုံတစ်ခုစီမှ ၁၀ ကီလိုမီတာ အကွာအဝေးအတွင်း ဝါးတော ဧရိယာနှင့် အမြင့်ဆုံးဆက်စပ်မှု (R^2=0.63) ရှိသည်။ ဝါးချစ်ပ်အများစုသည် ဝါးစိုက်ခင်းများ၏ ပင်ကြပ်နှုတ်ခြင်းမှ ထွက်လာသော ဝါးရင့်များဖြစ်သည်။ ဝါးစိုက်လယ်သမားများ သည် အချင်း ၅ စင်တီမီတာကျော် ပင်ကြပ်နှုတ်ထားသောဝါးမှ ဝါးချစ်ပ်ပြား ၉ တန် မှ ၁၆.၆ တန်(dry

weight) အထိ ထုတ်လုပ်နိုင်ပြီး ဒေသန္တရအစိုးရ၏ ထောက်ပံ့ကြေး ၀ မှ ၃၃၀၀ ယန်း/တန် (fresh weight) အပါအဝင် ဝါးချစ်ပ်ပြားများ ထုတ်လုပ်သည့်စက်ရုံများသို့ ဝါးအစိုတစ်တန်လျှင် ယန်း ၇,၈၀၀ မှ ၁၁,၀၀၀ ဖြင့် ရောင်းချနိုင်သည်။ ဝါးအရင်းအမြစ်များစွာရှိပြီး ဝါးပင်များမှ ဝါးထုတ်လုပ်နိုင်မှုပမာဏ အလားအလာ မြင့်မားသောကြောင့် ဝါးကဏ္ဍသည် ဝါးချစ်ပ်ပံ့ပိုးသူ ဝါးစိုက်တောင်သူများကို တိုးတက်စေရန်နှင့် ဆက်လက်လုပ်ကိုင်လိုစိတ်ကို လှုံ့ဆော်ပေးနိုင်ရန် တန်ဖိုးမြင့် ထုတ်ကုန်များအတွက် ဝါးဇီဝဒြပ်ထု အသုံးပြုမှုကို မြှင့်တင်သင့်ပါသည်။ ဝါးတောများကိုစီမံခန့်ခွဲရာတွင် လယ်သမားများအား လှုံ့ဆော်မှုနှင့် ထောက်ပံ့ငွေပမာဏကို မြှင့်တင်ခြင်းဖြင့် ကောင်းစွာစီမံခန့်ခွဲနိုင်သော သစ်တောများ၊ သာယာသော ပတ်ဝန်းကျင် အခြေအနေနှင့် အနာဂတ်တွင် ကွဲပြားသော ဇီဝမျိုးစုံမျိုးကွဲများကို ဖြစ်ပေါ်စေမည် ဖြစ်ပါသည်။

Current Utilization of Bamboo for Paper Making and its Potentialities in Kagoshima Prefecture

1. Introduction

Bamboo is a woody grass belonging to the subfamily Bambusoideae of the family Poaceae (Gramineae)(Troya Mera & Xu, 2014). There are about 1662 species under 121 genera of bamboo in the worldwide (Canavan et al., 2017). It is one of the fastest growing plants on earth (daily growth rate of 30–120 cm), reaching its final height of 5–25 m in a single, 2- to 4-month growing season. It is known as "poor man's timber" because it is sufficiently cheap and plentiful to meet the vast needs of humans, from the "child cradle to the dead man's bier" (Troya Mera & Xu, 2014).

About 2.5 billion people worldwide are already used economically on bamboo (Inbar, 1999), primarily for fiber and food in Asia(F. Borowski, 2019). However, bamboo may have potential as a bioenergy or fiber crop because bamboo has good fiber quality for paper-making and desirable fuel characteristics with certain other bioenergy feedstocks, such as low ash content and alkali index (F. Borowski, 2019). Moreover, bamboo is becoming popular as an excellent substitute for wood in paper industries, domestic commodities, cottage industries, board, and charcoal (Lobovikov, Paudel, Piazza, Ren, & Wu, 2007). Bamboo shoots are eaten as vegetables mostly in South-East and East Asian countries because about 200 species can provide edible and palatable bamboo shoots (Lobovikov et al., 2007). Bamboo has many values, and proper utilization and scientific management can benefit local, national, and global levels by providing livelihood and economic and environmental security for millions of rural people (Nath, et al., 2009).

Although bamboo is economically essential, some species have the potential to become invasive (Takano et al., 2017); e.g., Phyllostachys spp. are popular for their invasive habits (Lima et al., 2012). Like other invasive species, bamboos can extremely alter ecosystem dynamics through competitive exclusion and expansion of patches that form from clonal reproduction. A growing number of papers emphasized some of these issues, (Blundell et al. 2003; Kudo et al., 2011; Lima et al., 2012; Rother et al., 2016; Suzuki, 2015; Qing-Pei et al., 2015; Kobayashi, et al. 2015; Canavan et al., 2017).

Japan is one of the Asian countries where bamboo invasion is a concern(Xu et al., 2020). Japan has 167000 hectares of bamboo grove areas (Forest Agency, 2020) and experienced a recent, massive increase of Moso bamboo forest in some areas, e.g., in Ohgisu-Toshimo, Nasukarasuyama, and the Tochigi Prefecture (Akutsu et al.,2012, X u et al., 2020). From 1961 to 1978, the area covered by bamboo forests increased by 270% in the southwestern part of Tokyo (Okutomi, et al., 1996). At Mount Hachiman in the Ohmihachiman City of western Japan, Japan, Suzuki & Nakagoshi, 2008 reported an increase in bamboo forest area to 32.3 ha in 1985 from 25.1 ha in 1947, and finally to 42.4 ha in 2006. Moso bamboo forests expanded at an annual rate of about 2% in Chiba Prefecture, eastern Japan, and Hiroshima Prefecture, western Japan (Suzuki & Nakagoshi, 2008). In Sasaguri and Tachibana, the Fukuoka Prefecture of Japan, the area of bamboo stands increased 1.3 to 1.7-fold over about 30 years at a linear rate of about 1.1 to 1.6 m annually (Nishikawa, et al.,2005).

Japan has 13 genera and 670 species of bamboo, and the most important managed ones are Phyllostachys edulis, P. reticulata, and P. nigra. Most bamboo forests are privately owned and are managed by farmers. Areas are separately managed for culm production and edible shoot production (Union, 1980). Historically, Japanese people had mainly introduced and used two exotic bamboos (Poaceae), moso (Phyllostachys edulis) mainly for food and madake (P. bambusoides) mainly for handicrafts in managed plantations (Takano et al., 2017). However, lifestyle changes and a shift to fossil materials (Shibata, 2003, Shibata, 2015), cheaper bamboo imports, heavy labor costs, and the lack of successors and aging of the growers to bamboo plantations caused the Japanese bamboo industry to decline in the 1970s (Nakashima, 2001; Oizumi et al., 1974). Consequently, many bamboo plantations have been abandoned and are now left unmanaged, eventually invading the adjacent native vegetation (Okutomi et al., 1996; Nishikawa et al., 2005; Suzuki, 2015). In recent decades, the aggressive invasions of bamboo species into habitats that have experienced human interference have been increasingly relevant for biodiversity and ecosystem services (Kobayashi et al., 2015). Because of their rapid growth rate, bamboo plants are highly likely to prevent the growth of other plants and decrease species diversity (Chou & Yang, 1982; Larpkern, Moe, & Totland, 2011; Lin et al., 2014).

There has not been sufficient discussion on how to handle the abandoned bamboo stands, and a solution is being sought. Still, in the case of bamboo forests, annual maintenance such as adjusting the number of bamboo shoots, is required. In other words, much effort is needed to manage the bamboo stands. Thus, the mass consumption of bamboo in the paper industry is expected to solve this problem. Continuous use as a biomass resource is expected to lead to a promising solution to the abandoned bamboo stands problem. To use bamboo as a biomass resource, it is essential to understand the amount of resources that can be used in the future. Therefore, in this study, we further investigated the utilization of bamboo in a paper company, two abandoned Moso bamboo stands, and six managed bamboo stands in Kagoshima prefecture to clarify the biomass of the above-ground part and analyze the stand structure of Moso bamboo stands and potential amount of biomass from these stands.

2. Objectives

2.1 Main Objective

- To clarify the current situation of bamboo utilization of bamboo resources by Chuetsu Pulp and Paper Company, Kagoshima Prefecture.
- To assess the potential of bamboo culm production in Kagoshima Prefecture.

2.2 Specific Objective

- To clarify the bamboo resource utilization for paper
- To explore the relationship between bamboo distribution and bamboo chip production of bamboo chip companies
- To estimate above-ground biomass of Moso bamboo stands and estimate the area of utilized bamboo forest for bamboo chip production
- To estimate the potential amount of bamboo biomass

3. Materials and Methods

3.1 Study Area

The study area was selected in Kagoshima Prefecture, located in the southern part of Kyushu Island, Japan. It extends approximately 918800 ha, found in 31° 24′ 0″ N latitude and 130° 31′ 0″ E longitude. Kagoshima Prefecture has 43 municipalities. The average minimum and maximum temperature are from 14.9-22.8 °C, and the average annual precipitation is 2266 mm during ten years (1981-2010) (Statistic Bureau, 2020). The study site for bamboo sample plots was within Akune City and Satsuma town of Kagoshima Prefecture. Kagoshima Prefecture has the country's most largest area of bamboo forests among the 47 prefectures. According to Kagoshima Prefecture Forest and Forestry Statistics 2021, Kagoshima Prefecture had a bamboo forest area of 20158 ha, and the total accumulation of bamboo was 6236 senzoku (187080 tons). There were 23 processors, including 18 bamboo processing companies, one pulp utilization company, and four bamboo shoot-related companies (Shibata, Nukina, & Sun, 2019).

The study sites for field data collection and the location of Chuetsu Pulp and Paper Company are illustrated in Figure 1. The Chuetsu Pulp and Paper company was in Satsuma Sendai city. Four chip companies were located in Akune city, Satsuma Sendai city, Izumi city, Aira city, and Satsuma town. The study sites for bamboo sample plots were set out in Akune city and Satsuma town. Interviews to bamboo shoot farmers were conducted in Akune city, Izumi city, and Satsuma town.

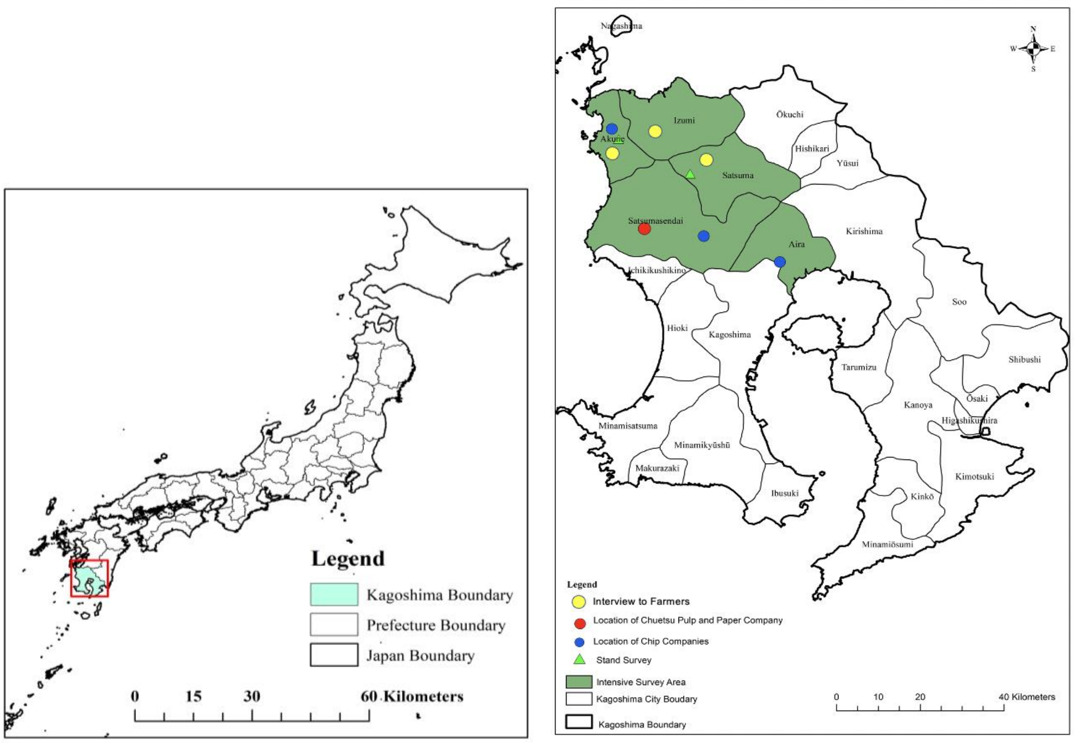

Figure 1 The study site for bamboo sample plots and location of Chuetsu Pulp and Paper Company

3.2 Key Informant Interview

Key informant interview was conducted with the manager of Chuetsu Pulp and Paper Company and focal person of Mori Mokuzai, Yoshino Mokuzai and Kunimoto Shokai chip companies, and Santomi Kogyo to clarify the current situation of bamboo utilization of bamboo resources by Chuetsu Pulp and Paper Company and to know the location of chip companies and bamboo supply process and subsidy system. The interview was conducted during the month of November 2021 and March 2022.

3.3 Spatial Data Analysis

For the bamboo distribution map of chip companies, the High-Resolution Land Use and Land Cover Map (10m x 10m) whole area of Japan for 2021 was downloaded from JAXA. From this, only bamboo classes were extracted, and the Kagoshima boundary area was clipped to this converted map. Then, the location of chip factories was inserted into this map.From using land use and land cover map (10 m x 10 m) of Japan from the Japan Aerospace Exploration Agency (JAXA) Earth Observation Research Center (EORC), total area and spatial distribution of the bamboo area of Kagoshima prefecture was created. That land use map was converted to shapefile in ArcGIS. The converted land use map was clipped by the Kagoshima boundary area. Then, land use classes data were exported, and calculated total area for each class in excel. The location of chip factories was collected from an interview survey of Chuetsu pulp and paper company. From this total land use map of Kagoshima prefecture, only bamboo class was extracted, and this converted map was clipped by the Kagoshima boundary area. Then, selecting each municipal area in the attribute table, exporting each into a dbase file, and calculating in excel was obtained bamboo distribution area of each municipal. By buffering 2 km,5 km,10 km, and 15 km around the 11 major chip factories, the bamboo area of each chip factory within buffer 2 km, 5 km, 10 km, and 15 km was calculated. Spatial analysis was done in Arc map version 10.5.

3.4. Field Data Collection

Field data collection was done during the month of April 2022. To study the condition of bamboo forest, circular plots with a radius 10 m were set up by using laser technology TruPulse 360/360B. The diameter at breast height (DBH) within plots was measured to estimate the culm production of Moso bamboo. For managed bamboo stands, two sample plots (P-1, P-2) in Satsuma town, and for intensively managed bamboo stands, four sample plots (P-3, P-4, P-5, P-6) in Akune city were randomly selected and set for the estimation of stand characteristics, where each plot had an area of 314 m^2 (0.0314 ha in horizontal area). The diameter and age of each bamboo culm were collected. But the age of some bamboo in Satsuma town could not be identified. For abandoned bamboo stands, one sample plot in Satsuma town (P-7) and one in Akune city(P-8) were randomly selected with an area of 314 m^2 (0.0314 ha in horizontal area). The diameter of each bamboo culm within plots was measured at breast height.

3.5. Selection of sample bamboos for biomass estimation

A total of 4 bamboo samples were obtained with DBH 8 cm,10.4 cm,12.3 cm, and 14.35, and analysis was based on diameter class. These bamboo samples were divided based on diameter 5,6,7 cm intervals to measure the biomass and the fresh weight of culms, and branches & leaves together were weighed separately. In order to determine biomass allocation, the weights of culms, branches & leaves of each bamboo of these four samples were immediately weighed after being separated in the field. These representative samples of each component from each sample were brought back to the laboratory, and oven-drying at 80°C for 2-3 weeks was used to obtain an absolute dry weight of each component. The process of biomass determination was based on the ratio of the oven-dried weight to the fresh weight of each component. The biomass of each component can be calculated from the fresh weight×(oven-dried weight / fresh weight). For instance, the culm biomass equals the culm fresh weight×(oven-dried weight of culms / fresh weight of culms). Likewise, the biomass of leaves& branches together was obtained using the same calculation process. Extending these samples to the laboratory, biomass allocation of all of the individual bamboo samples could be predicted. The detailed processes of biomass determination are described in a study by (Y. J. Lin et al., 2011) and (Yen & Lee, 2011)

4. Results

4.1 Bamboo Paper Production in Kagoshima

Chuetsu Pulp and Paper Company was founded in 1947 and the Sendai factory of this company was founded in 1954 and started negotiations with chip companies and farmers in 1998 for bamboo collection. Sendai Factory is located in Satsumasenai city, Kagoshima Prefecture. Firstly, bamboo lumber collection ended in 2010 because of differences in expenses, labor costs, chip quality as a paper clip, lumber collection system, setting prices, understanding the importance of using bamboo, etc. After that, bamboo pulp compounded products from around 1998, immediately after the start of efforts, 100% bamboo pulp products could produce from 2009. To increase the consumption of bamboo, Unicolor has been cooperating on developing products using bamboo paper made at the Sendai factory of Chuetsu Pulp & Paper Co. in the prefectural city of Satsumasendai since 2009. Chip companies do transportation, and bamboo collection is thinned bamboo that is regularly carried out by bamboo shoot farmers and bamboo from the abandoned bamboo grove.

There are five paper production lines, and 4 of these lines can produce bamboo paper. One of these four machines produced bamboo paper 2-3 times every month. The machine used for production is determined by the type of paper and the intended use. In addition, the production time varies from several hours/time to half a day/time to one day/time. The season is not fixed. Now, 10% bamboo pulp and 100% bamboo pulp can be produced by this company. Currently, Chuetsu P.&P. established the brand name Takegami (Bamboo Paper) and promotes the use of environmentally friendly materials and SDGs goals. Approximately 50,000 tons of 10% bamboo paper can be made from 20,000 tons of bamboo collected and 5000 tons of 100% bamboo paper from 20,000 tons of bamboo chip piled. Bamboo paper 100 natural (brown) has a smooth surface and a crisp texture. Bamboo paper 100 white (white) is characterized by a light and gentle texture, unlike natural characteristics. Bamboo paper is used in pamphlets of environmental groups and NPOs, corporate management reports, business cards, envelopes, etc. to emphasize their environmental concern (Mainichi 2020). The sale destination is all domestic and goes to a paper trading company, paper wholesaler, printing company, etc.

To promote bamboo utilization, in collaboration with local governments, local governments provide subsidies in Satsuma Sendai City 3,300 yen/ton, Satsuma Town 2,300 yen/ton, Akune City 1,500 yen/ton, Izumi City 2,500 yen/ton, etc. Chuetsu Pulp and Paper Chuetsu Pulp and Paper company accepts all amounts of bamboo chips shipped by chip companies.

4.2 Bamboo Chip Supply Process

Four bamboo chip companies used most bamboo species with diameters of 5 cm, 6 cm, and 7 cm and aged above two years because one-year bamboo has soft fibers and does not become chips. The price of the bamboo chip was about 7600 yen to 8300 yen per ton with a subsidy amount. The subsidy amount differed depending on the city; 1.5 yen/kg in Aira city, 2.3 inn/kg in Satsuma town, 2.5 yen/kg in Izumi city, and 3.3 yen/kg in Satsumasendai city Bamboo shoot farmers in each local government bring bamboo by their light truck to chip companies in their regions. Then, chip companies made a chipping process of bamboo and transported bamboo chips to Chuetsu pulp and paper company described in Figure 2. Based on the survey, three-chip companies, Mori Mokuzai, Yoshino Mokuzai, and Santomi Company, produced both wood chips and bamboo chips, except Kunimoto shokai had only bamboo chip purchase month was year-round, and it depended on the bamboo shoot farmers' thinning schedule. The number of bamboo shoot farmers joining in chipping company was about 550 on Kunimoto Shokai, 70-80 on Santomi, 300 on Mori Mokuzai, and 130 on Yoshino Mokuzai. Bamboo collection by bamboo shoots farmers was around the city where the chip company was located and the adjacent city. These chip companies started the process of bamboo chip production when they received a request from a paper company and cooperation from the local government. These companies said that bamboo chip production was not too much economic advantage, and these just contributed to social distribution and SGD and environmental conservation.

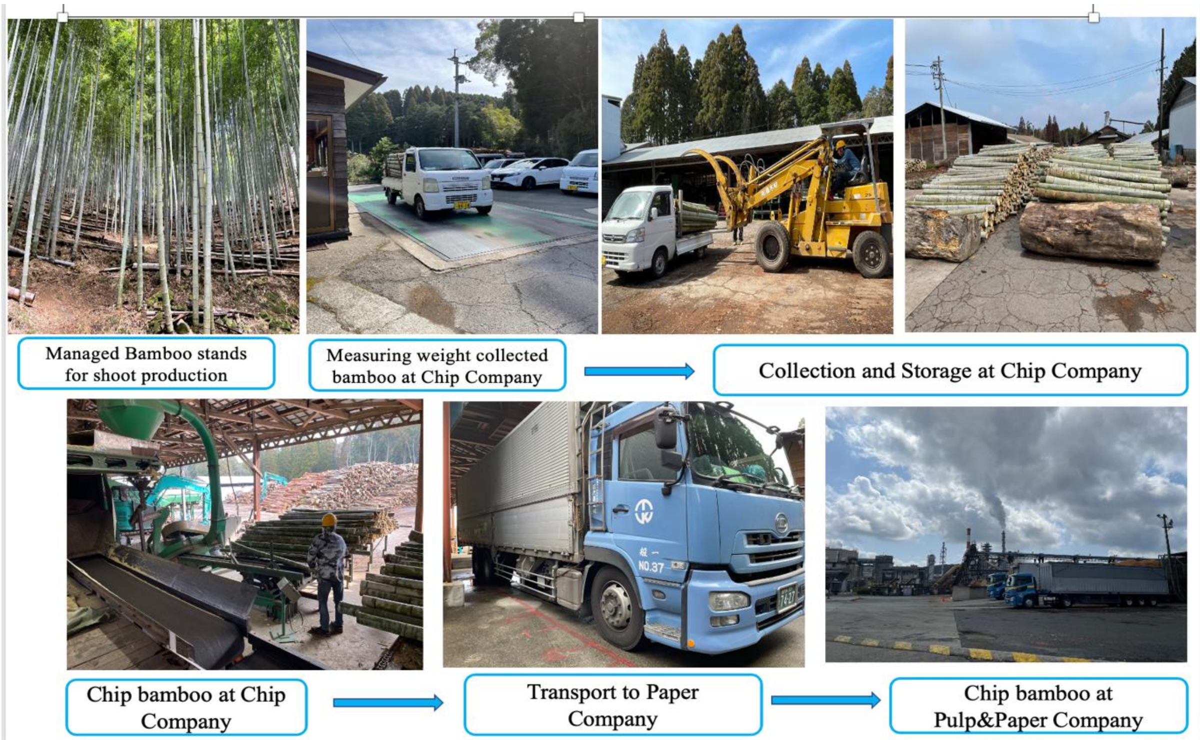

Figure 2 Bamboo supply process from bamboo shoot farmers to chip companies and pulp and paper company

4.3.Bamboo Chip Production from chip companies

Table 1 shows the bamboo chip production by 11 major chip companies in Kagoshima Prefecture from 2001 to 2020. This amount was purchased amount by Chuetsu Pulp and Paper Company. As the current year production in 2020, Yoshino Mokuzai in Akune city showed the largest display of the bamboo chip (1588 BDT) and the second was Santomi in Satsuma town (1439 BDT) and then Mori Mokuzai (1150 BDT) in Hiwaki area. Two chip companies, Kimotsuki Mokuzai in Kanoya city and Maeda Sangyo in Kirishima, had no production of bamboo chips since the fiscal year 2012. Showa Mokuzai in Minamikyushu city reproduced bamboo chips this year 2020 and had no production last four years ago. Miyoshi Sangyo was the only chip company that showed a significant increase in the production of bamboo chips from 2011 to 2020, except in decreasing some years. The total bamboo chip production in 2020 was about 5794 BDT, 8481 BDT in 2015, 6270 BDT in 2010, and 3370 BDT in 2005. Based on an average 10-year production (2011-2020), the yearly utilization amount of bamboo chips by Chuetsu Pulp and Paper Company was about 7238 BDT.

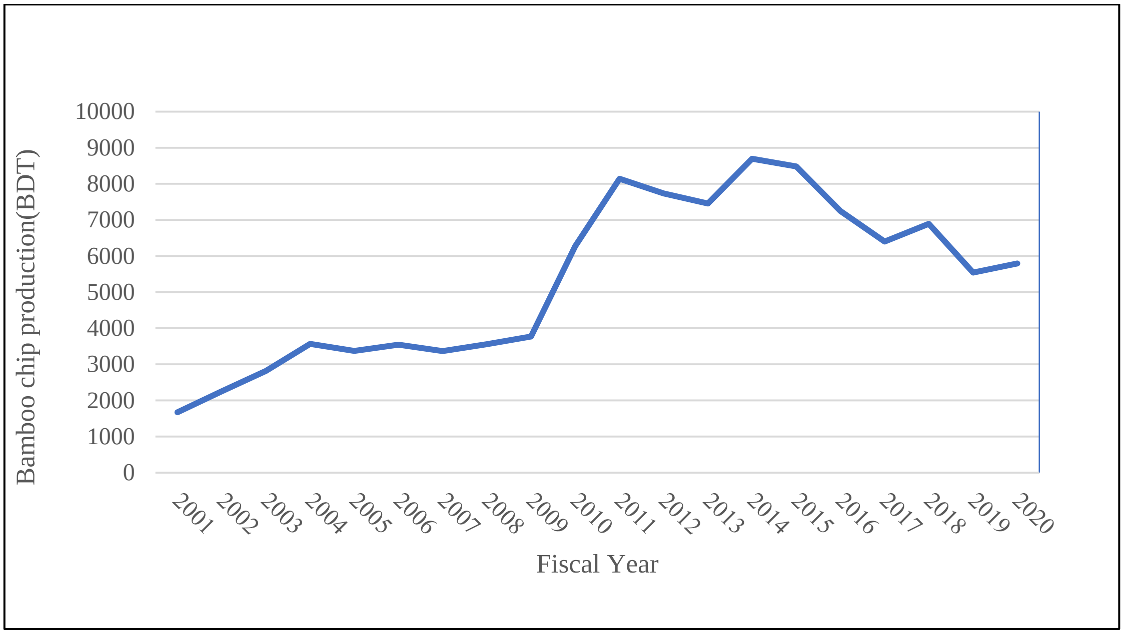

Figure 3. Bamboo chip production from 11 major chip companies. Figures are annual production from 2001 to 2020, and unit measurement is the absolute dry weight (Bone Dry Tone). The data provided by Chuetsu Pulp & Paper Co. Ltd.

Table 1. Bamboo chip production in 11 major chip factories. Figures are annual chip production in BDT (Bone Dry Ton). *The data provided by Chuetsu Pulp & Paper Co. L*

Area	Akune	Large mouth	Kushikino	Hiwaki	Nansatsu	Osumi	Hioki	Izumi	Satsuma	Kirishima	Aira	Total
Company Name/ Year	Yoshino Mokuzai	Hishikari Mokuzai	Furukawa Mokuzai	Mori Mokuzai	Showa Mokuzai	Kimotsuki Mokuzai	Forest Cooperative	Miyoshi Sangyo	Santomi Kogyo	Maeda Sangyo	Kunimoto Shokai	
2020	1588	148	8	1150	8	0	49	444	1439	0	960	5794
2019	1493	320	29	940	0	0	23	409	1489	0	836	5539
2018	1952	412	25	1132	0	0	41	449	1841	0	1038	6890
2017	1913	408	55	914	0	0	37	464	1656	0	955	6402
2016	2299	394	94	1008	0	0	84	587	1944	0	837	7247
2015	2165	506	30	1369	29	0	98	227	2804	0	1253	8481
2014	2167	612	56	1498	0	0	85	213	2845	0	1219	8695
2013	1816	655	98	1288	20	0	59	261	2426	0	831	7454
2012	1978	1095	94	1459	49.3	0	102	257	2183	0	515	7732.3
2011	2197	1296	89	2071	50	12	141	238	1992	10	46	8142
2010	2007	797	48	1762	48	24	132	271	1182	-	-	6271
2009	1190	500	22	1668	55	0	109	226	-	-	-	3770
2008	1065	620	43	1404	22	0	129	273	-	-	-	3556
2007	713	562	122	1223	196	0	96	455	-	-	-	3367
2006	631	820	101	978	314	0	136	565	-	-	-	3545
2005	763	773	170	912	231	0	108	413	-	-	-	3370
2004	1034	754	161	1040	121	13	104	340	-	-	-	3567
2003	712	451	134	1186	55	0	79	200	-	-	-	2817
2002	874	513	54	795	16	0	-	-	-	-	-	2252
2001	962	302	32	357	6	13	-	-	-	-	-	1672
Total	29519	11938	1465	24154	1220.3	62	1612	6292	21801	10	8490	106563.3

Note 1: The above chip acceptance quantity is the absolute dry weight (Bone Dry Ton). When the moisture content is about 50% to 55%, the air dry weight (Air Dry Ton) is almost doubled.

Source: Chuetsu Bussan Co., Ltd. Raw Materials Department, Raw Material section

4.4. Bamboo distribution area around chip companies

By using JAXA land use and land cover map and Japan administration boundary map, bamboo area within buffer 2 km, 5 km, 10 km, and 15 km from chip companies was obtained in Figure 4 and Table 2. To explore the relationship between bamboo area and bamboo chip production of bamboo chip companies, regression analysis was done by using average bamboo chip production and bamboo area within buffer 2 k, 5 km, 10 km, and 15 km from chip factories. Within 2 km and 5 km buffer, the largest bamboo area was observed (536.6379 ha and 2552.1446 ha) around Santomi Kogyo company in Satsuma town and the second was found around Yoshino Mokuzai in Akune city with bamboo area (503.2795 ha and 2305 ha). The lowest bamboo area existed with the amount (39.3808ha and 476.1986 ha) around Miyoshi Sangyo company in Izumi city and Showa Mokuzai showed the second lowest bamboo area (139.4830 ha and 855.4531 ha). Within 10 km buffer, the largest bamboo forest area (8195.6394 ha) was found around Santomi company, and the second largest bamboo area (7000.2306 ha) was around Mori Mokuzai company. The lowest bamboo area existed around Kimotsuki Mokuzai company (2817.6905 ha) and then Showa Mokuzai had shown with bamboo area (2858.0426 ha).

Table 2 Bamboo area within 2 km,5 km, 10 km, and 15 km from chip companies

Name of Chip Companies	**Bamboo area within**			
	2 km (hectares)	**5 km (hectares)**	**10 km (hectares)**	**15km (hectares)**
Yoshino Mokuzai	503	2305	5235	7199
Hishikari Mokuzai	280	1367	5261	10929
Furukawa Mokuzai	330	1202	3717	8183
Mori Mokuzai	385	2055	7000	15229
Showa Mokuzai	139	855	2858	4969
Kimotsuki Mokuzai	175	1117	2817	5642
Forestry Cooperative	248	1351	4429	9765
Miyoshi Sangyo	39	476	4222	7516
Santomi Kogyo	536	2552	8195	17751
Maeda Sangyo	221	1403	3694	7607
Kunimoto Shokai	174	1030	5118	10986

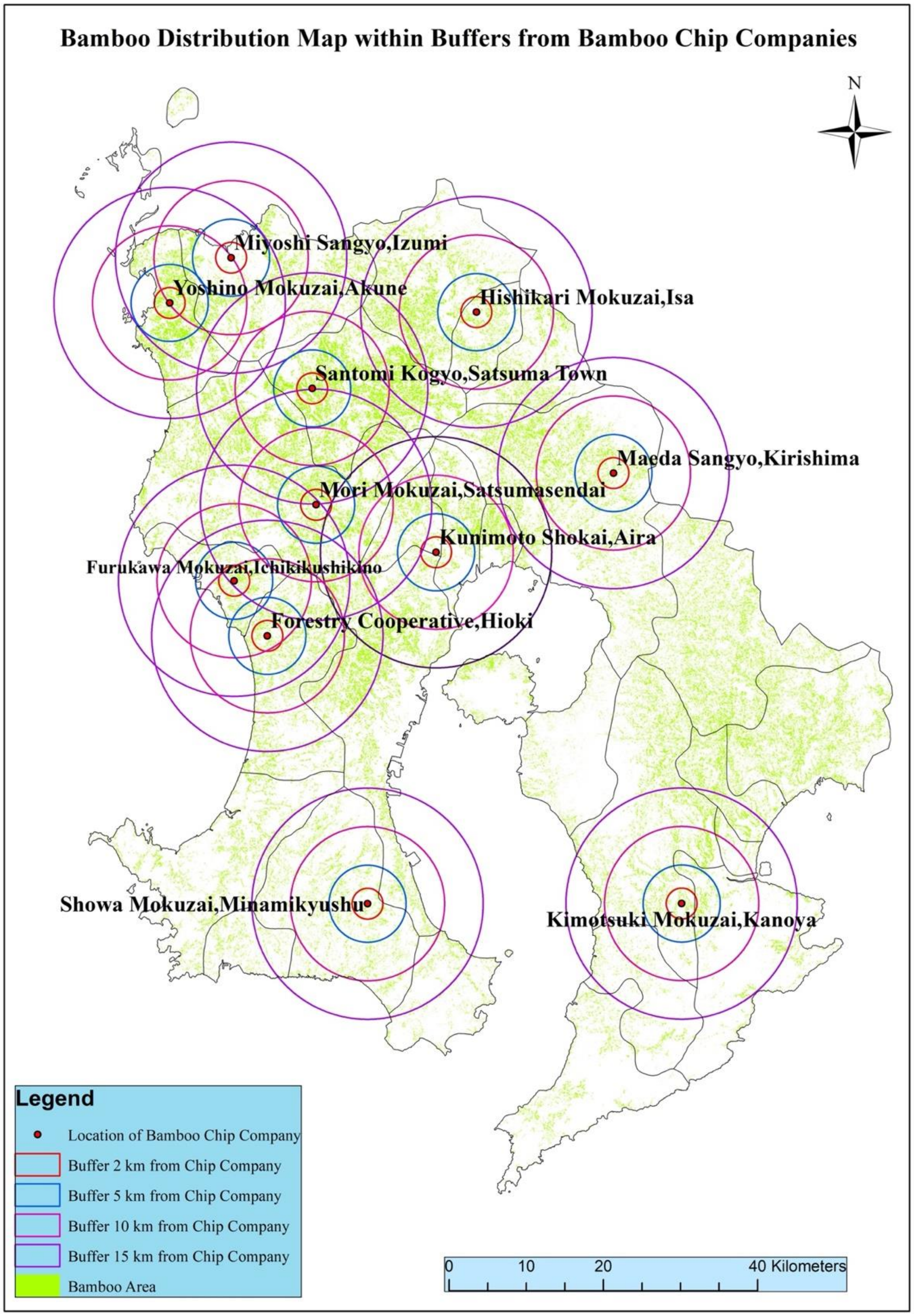

Figure 4 Bamboo distribution map around chip companies and buffer map from chip companies

All values in the coefficient of determination (R2) have been found to be strong enough for predicting bamboo chip production by its neighborhood area in Figure 6. The relationship between bamboo area and bamboo chip production was found to be more significant at 5 km with R2 values of 0.6291 in Figure 5 and 6. There was a significant relationship between neighborhood bamboo area and bamboo chip production of chip companies because the resulted value for coefficients of determination (R^2) was significant within 10 km. R^2 value peaked at a 10 km buffer area from chip companies in Figure 6.

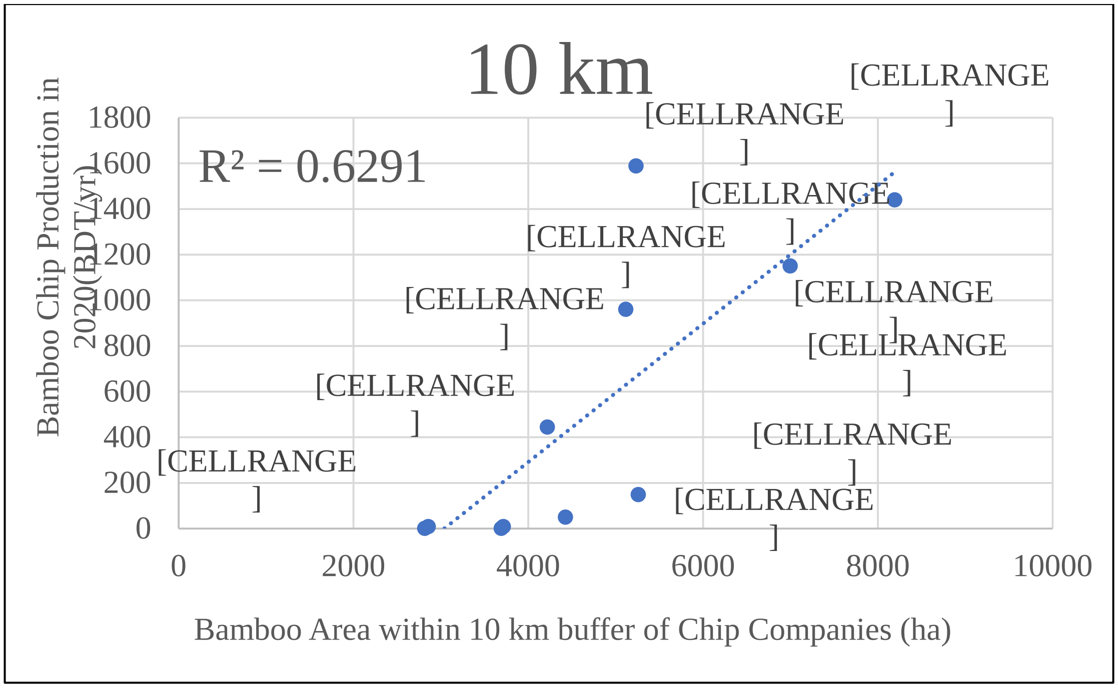

Figure 5 Relationship between Bamboo Area and Bamboo Chip Production within buffer 10km

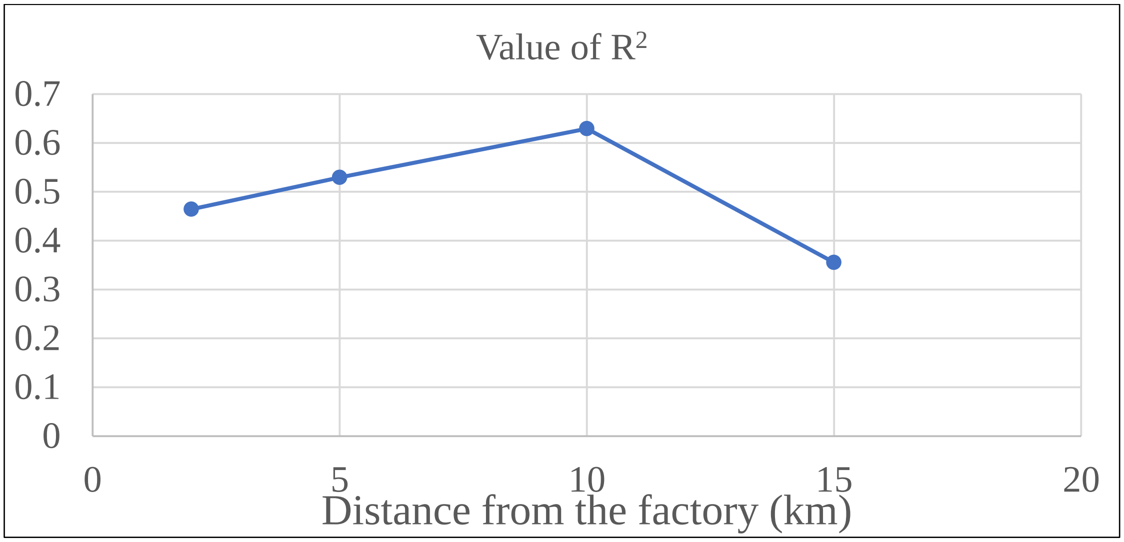

Figure 6 Value of R2

4.5 Findings from Interview

The incentive for Chuetsu P.&P. and chip companies is CSR and improving the corporation's image. Chuetsu P.&P. utilized its existing network of partner chipping companies for the bamboo chips collection. Each chip company has 70-550 registered farmers who potentially provide the bamboo. Many registered farmers have stopped bamboo forest management. Most of bamboo farmers are aging populations.

4.6 Culm Diameter Distribution

The mean DBH of culms per plot was distributed in the range of 10.85 to 13.18 cm, and the number of culms extremely far from the mean value of DBH was small except in Plot-7 and Plot-8, having outliers values described in Figure 7. There was no significant difference in the mean DBH for plots 1 to 4, and the variance of the mean DBH (difference between the minimum DBH and the maximum DBH) was almost within 0.47 cm. In the figure 7, DBH of most culm in P-1 range from 11 cm to 13.7 cm and in P-2 range from 11.3 cm to 13.5 cm and in P-3 range from 10.95 cm to 13.45 cm, and in P-4 range from 10.3 cm to 13.3 cm. Thus, it may be no significant difference in mean DBH for P-1 to P-4. In P-5 and P-6, DBH of most culm range from 10.5 cm to 12.5 cm and 9.25 cm to 12.4 cm, respectively. In P-7 and P-8, the DBH of most culms ranges from 12.075 cm to 14.6 cm and range from 12.025 cm to 14.475 cm, respectively. For all plots, 16.5 cm is the highest DBH in Plot-7 and 5.6 cm is the lowest DBH in Plot 8. In addition, the mean DBH and SD was 12.37±1.72 in Plot-1, 12.51±1.52 in Plot-2, 12.16±1.57 in Plot-3, 12.04±2.08 in Plot-4, 11.42±1.47 in Plot-5, 10.85±1.94 in Plot-6, 13.18±1.58 in Plot-7 and 13.09±1.98 in Plot-8. In all pots, SD does not have too much variation from the mean DBH valve except in Plot 4.

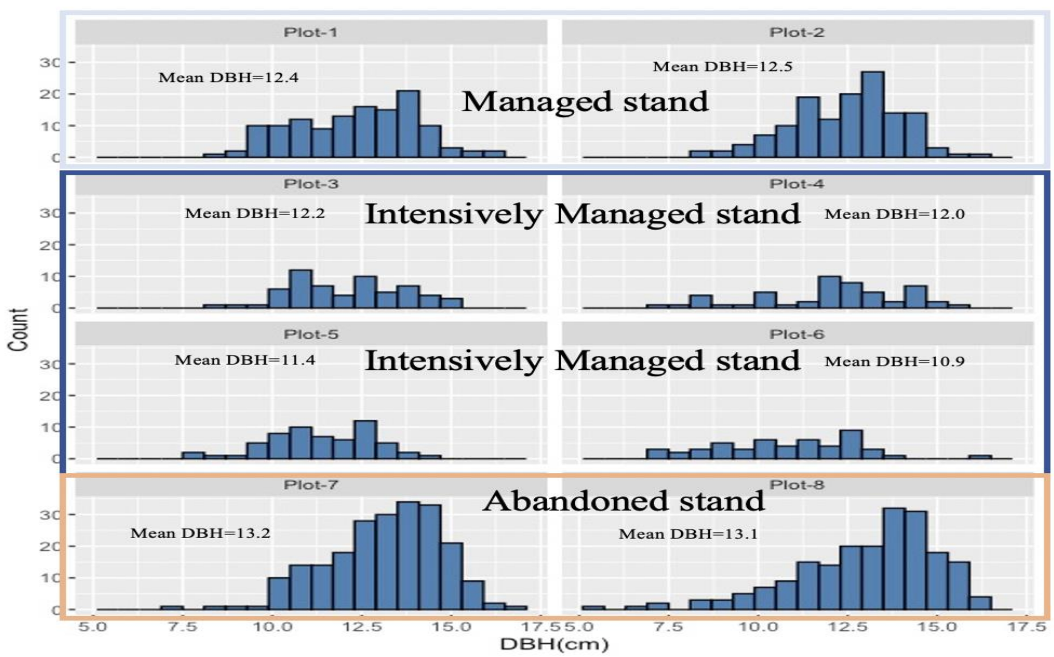

Figure 7 Diameter distribution in each sample plots

4.7 Existence of above-ground biomass and biomass of each component

Table.3 shows the weight of each component, above-ground biomass, and marketable weight of each plot. The biomass of each component was estimated by substituting the value of DBH from the vegetation survey into the regression equation in Table.3 and converting it per unit of land area. It was found that there was a strong relationship between the weight of each component of bamboo and diameter at breast height because the R2 valve was over 0.97 at a confidence interval of 95%.

For managed bamboo stands in Satsuma town, the above-ground biomass was 129.31 t / ha on P-1, 142.02 t / ha on P-2, and biomass of branch and leaves was 29.73 t/ha and 32.56 t/ha, respectively. In intensively managed bamboo stands in Akune City, the above-ground biomass was 60.19 t/ha on P-3,49.98 t/ha on P-4, 51.97 t/ha on P-5,39.63 t/ha on P-6, and biomass of branch and leaves of each plot was 14.00 t/ha, 11.59 t/ha, 12.51 t/ha and 9.71 t/ha respectively. The above-ground biomass of abandoned stand (P-7) in Satsuma town was 253.42 t/ha, P-8 in Akune city was 231.40 t/ha, and biomass of branch and leaves was 56.48 t/ha and 51.47 t/ha, respectively. The biomass of marketable culm over 6 cm diameter in each plot was 90.76 t/ha on P-1, 99.83 t/ha on P-2, 41.68 t/ha on P-3, 34.83 t/ha on P-4, 34.61 t/ha on P-5, 26.01 t/ha on P-6, 183.83 t/ha on P-7 and 168.52 t/ha on P-8. The above-ground biomass of abandoned stands was larger than managed stands, and intensively managed stands and the managed stands were larger than the intensively managed stands. Among plots, P-7 in Satsuma town had the largest quantity of biomass, and P-6 in Akune city had the lowest quantity of biomass.

Table 3 Biomass of each organ of Moso bamboo stands per hectare

Name	Culm Density (No/ha)	Mean DBH (cm)	Biomass of culm >5cm Diameter (ton/ha)	Biomass of culm >6cm diameter (ton/ha)	Biomass of culm >7cm diameter (ton/ha)	Biomass of culm (ton/ha)	Leaf& branch biomass (ton/ha)	Above ground biomass (ton/ha)
Plot 1	4012	12.37±1.72	94.64	90.76	85.87	99.54	29.73	129.31
Plot 2	4331	12.51±1.52	104.08	99.83	94.48	109.39	32.56	142.02
Plot 3	1943	12.16±1.57	43.62	41.68	39.09	46.15	14.00	60.19
Plot 4	1624	12.04±2.08	36.38	34.83	32.84	38.38	11.59	49.98
Plot 5	1911	11.42±1.47	36.60	34.61	31.66	39.37	12.51	51.97
Plot 6	1592	10.85±1.94	27.60	26.01	23.63	29.88	9.71	39.63
Plot 7	6943	13.18±1.58	190.06	183.83	177.45	197.08	56.48	253.42
Plot 8	6369	13.09±1.98	174.02	168.52	163.20	180.14	51.47	231.40

4.8. Culm Production from thinning operation

Bamboo shoot farmers did the annual culm production through thinning operations in managed bamboo stands. They sold bamboo culm to chip companies. The bamboo collection was done in October-November. In the case of managed stands (P-1 and P-2), five years old culms were thinned, and in the case of intensively managed stands (P-3, P-4, P-5, and P-6), four years old culm will be cut in October. In table 4, total annual culm production was about 99.4 tons/ha on managed stands, 36.1 ton/ha on intensively managed stands, and 182.0 ton/ha on abandoned stands. The allowable diameter size by chip companies was about 5 cm and over 5 cm. Thus, assuming the 1/6 of culm biomass in managed stands and 1/4 of culm biomass in intensively managed stands will be harvested by thinning operation and culm with a diameter >6cm, parts will be sold to chip factories. Based on the types of bamboo stands, the average annual culm production from thinning was about 16.6 ton/ha on managed stands, and 9.0 ton/ha on intensively managed stands.

Table 4 Estimation of annual culm production per hectare based on marketable culm biomass data and types of bamboo stands

Name	Biomass of culm ≥ 5 cm diameter (ton/ha)	Average annual culm production (ton/ha)	Annual Culm Production from thinning	Average Annual Culm Production from thinning (ton/ha)	Remarks
Plot 1	94.64	99.4	15.8	16.6	Managed Stands
Plot 2	104.08		17.3		
Plot 3	43.62	36.1	10.9	9.0	Intensively managed stands
Plot 4	36.38		9.1		
Plot 5	36.60		9.2		
Plot 6	27.60		6.9		
Plot 7	190.06	182.0	-	-	Abandoned
Plot 8	174.02		-		

4.9. Estimation of % utilized bamboo area based on forest statistics data

Table.5 illustrated the results of utilized bamboo area for sample four chip companies based on forest statistics data. In 2020 chip production data, most intensively bamboo was collected by four local governments in Izumi city, Akune city, Satsuma town, and Satsumasendai city. The bamboo chip factory in these areas was Yoshino Mokuzai, Miyoshi Sangyo, Mori Mokuzai, and Santomi Kogyo, and total bamboo chip production in 2020 was 4621 dw/yr. Based on forest registration data, the bamboo stand area in these four local governments was about 6541 ha. Potential annual culm production from thinning may be 58951 dw/yr based on intensively managed bamboo stands and 108317 dw/yr based on managed bamboo stands. The utilized area of these four bamboo chip companies ranged from 279.1-512.7 ha. By comparing potential chip production and actual chip production, % of utilized bamboo area by chip companies may be 4.3 % on managed stands and 7.8 % on intensively managed stands.

Table 5 Estimation of % of utilized bamboo area based on accessible areas (10 km) based on forest statistics data of Kagoshima

Municiple	Bamboo stand area (ha)	Chip factory	Bamboo chip production (BDT/yr)	Required area based on managed stand (ha)	Required area based on intensively managed stand (ha)	% Utilized area based on managed stand	% Utilized area based on Intensively managed stand
Akune City	1,021	Yoshino Mokuzai	1,588	95.9	176.2	9.4	17.3
Izumi City	899	Miyoshi Sangyo	444	26.8	49.3	3.0	5.5
Satsumasendai City	2,212	Mori Mokuzai	1,150	69.4	127.6	3.1	5.8
Satsuma Town	2,409	Santomi Kogyo	1,439	86.9	159.7	3.6	6.6
Total	6,541	Total	4,621	279.1	512.7	4.3	7.8

5. Discussion

Bamboo paper production by Chuetsu Pulp and paper company was founded by the cooperation of their chipping companies and bamboo shoot farmers. Currently, Chuetsu P.&P. established the brand name Takegami (Bamboo Paper) and promoted the use of environmentally friendly materials and SDGs goals. The production of bamboo chip depends on the managed bamboo area by bamboo shoot farmers because most of the bamboo chip comes from thinned bamboo. The price of the bamboo chip was about 7600 yen to 8300 yen per ton with a subsidy amount. The subsidy amount differed depending on the city; 1.5 yen/kg in Aira city, 2.3 inn/kg in Satsuma town, 2.5 yen/kg in Izumi city, and 3.3 yen/kg in Satsumasendai city. The number of bamboo shoot farmers providing to chip companies is different. The amount of chip production by chip companies varied, as shown in Table 1. The relationship between bamboo area and bamboo chip production was found to be more significant at 5 km with R2 values of 0.6291. Thus, the chip production of each company mostly depended on the availability of neighborhood bamboo resources. Other factors may be affected by bamboo chip production, such as transportation charges, the difference in subsidizing systems by local government, the number of bamboo shoot farmers joining chip companies, and managed bamboo forest percentage in each area. In the previous report (Kagoshima Prefecture Bamboo Biomass Energy Utilization Feasibility Study Report, 2019), one company responded that chipping within the bamboo groove considering local transportation costs, they would like to solve the problem of the abandoned bamboo groove by collecting roughly 10 km radius. Thus, the best distance of 10 km radius within chip companies was the same in this study. It may be the best distance for solving the collection problem of bamboo, but other factors will need to be considered. In figure 3, it showed that the amount of bamboo chips provided to Chuetsu P&P from 2001 to 2020. In 2009, they can produce 100% bamboo paper thus we can see amount of bamboo chip suddenly increased from this year. After that, bamboo chip production peaked in 2014, and then it was gradually decreasing. Currently, over five thousand tons of chips in dry weight are collected because the trend is decreasing it may be decreasing the number of registered bamboo farmers.

In this study, stand density and mean DBH of abandoned bamboo stands were higher than managed bamboo stands. The above-ground biomass of abandoned Moso bamboo stands was larger compared to the abandoned Moso bamboo forest in other areas in Table 6. According to (Shinohara et al., 2014), who compiled data from a nationwide tree-by-tree survey of 27 ha-1 mousseline forests, culm density averaged 6570 trees, DBH averaged 11.9 cm, and above-ground biomass was 149.0 Mgha-1. In comparison, it was revealed that the culm density of the abandoned Moso bamboo forest in this study was almost the same. Still, the mean DBH was slightly higher, so that the above-ground biomass in this study was large.

Compared to the previous study of the abandoned Moso bamboo forest in Kagoshima prefecture (Kumemura et al., 2009), the mean breast height diameter and culm density of the abandoned bamboo forest in this study was more because the mean DBH and culm density in this study was 13.09 to 13.18 cm and 6369-6943 culm/ha and there was in the previous survey with mean DBH (10.4 to 13.9cm) and culm density (5000-6130 culm/ha). Thus, the existing amount of the above-ground biomass in this study, 231.40-253.42 t/ha, was also considered higher than that of the previous study (83-147t/ha).

On the other hand, compared to different country, in the central Taiwan (Yen & Lee, 2011), the above-ground biomass and mean DBH of this study was found to be higher, and the stand density was almost the same. Compared to the above-ground biomass of abandoned Moso bamboo forest in Kyoto Prefecture (Isagi et al., 1997), this study's above-ground biomass was more than 100 tons/ha, and the stand density was almost the same. It may be because DBH in this study was higher than in Kyoto Prefecture (Isagi et al., 1997). Compared with another study in Kyoto Prefecture (Abe & Shibata, 2009), the stand density of this study was lower, and the mean DBH and above-ground biomass were slightly higher. Still, it can be considered to be the same amount. Compared to Aichi prefecture (Umemura & Takenaka, 2014), the culm density, mean DBH, and above-ground biomass in this study were obviously more. Thus, higher culm density and larger culm size in this study affect the greater above-ground biomass compared to other studies.

Table 6 Above-ground biomass in non-managed Phyllostachys pubescens forest from previous studies and this study.

Site	Culm density (No/ha)	Above ground biomass (ton/ha)	Mean DBH (cm)	Reference
Central Taiwan	6996 - 7188	81.6 - 96.8	8.66-8.87	(Yen & Lee, 2011)
Central Taiwan	5733-13067	34.8-60.4	5.5-6.3	(Chen, Wang, & Wang, 2016)
Kyoto Prefecture	7100	137.9	11.3	(Isagi et al., 1997)
Kyoto Prefecture	7967-8300	217-224	12-13	(Abe & Shibata, 2009)
Kyoto Prefecture	9765	182.1	10.03-10.52	(Fukushima, Usui, Ogawa, & Tokuchi, 2015)
Aichi Prefecture	2400-4790	31.4-107	8.2-11.2	(Umemura & Takenaka, 2014)
Gifu Prefecture	8125-16300	42.1-83.5	n.a	Goto et al. (2008)

Kagoshima Prefecture	5000-6130	82.8-146.6	10.4-13.9	(Kumemura et al, 2009)
Kagoshima Prefecture	6369-6943	231.40-253.42	13.09-13.18	This study

The above-ground biomass of managed Moso bamboo stands in this study was larger than compared to different country studies, Taiwan (Wang & Liu, 2010) and Korea (Baek, G.et al., 2017) in Table 7. The stand density of this study was smaller than that of Taiwan and Korea but larger in mean DBH. Compared to the previous report of the Satsuma Sendai City Bamboo Resources Survey (Basic Survey) Fiscal Year 2015 Business Report, the above-ground biomass of this study was slightly higher, and the stand density was almost the same. The mean DBH of this study was smaller than the previous study. Here, the above-ground biomass does not depend on stand density and mean DBH. It may be the site conditions of the study site.

Table 7 Above-ground biomass in managed Phyllostachys pubescens stands from previous studies, and this study

Site	Culm density (No/ha)	Above-ground biomass (ton/ha)	Mean DBH (cm)	Reference
Central Taiwan	7188±489	81.6±18.2	8.98.9±1.1	(Yen, 2016)
Taiwan	8867	68.6	6.8	(Wang & Liu, 2010)
Jinju, Korea	4633-6833	57.68-106.38	-	(Baek, G.et al., 2017)
Kagoshima	700-4400	14.4-97.0	10.5-13.9	(寺岡 & 伊佐治, 2016)
Kagoshima	1592-4331	39.63-142.02	10.9-12.5	This study

6. Conclusion

The main objective of this study is to clarify the current bamboo utilization of bamboo resources by Chuetsu Pulp and Paper Company, Kagoshima Prefecture and assess the potential of bamboo culm production in Kagoshima Prefecture.

First, bamboo paper production from chip companies and subsidy system and the bamboo supply process could be assessed. The current year's total bamboo chip production from chip companies found 5794 BDT in 2020, and the average yearly bamboo production from 2010-2020 found 7237 BDT. The trend of bamboo chip production results illustrates a decreasing trend from 2015 to 2020.

According to the bamboo stand structure, it was assumed as managed bamboo stands, intensively worked bamboo stands, and abandoned bamboo stands based on owner management policy. Abandoned bamboo stands showed greater diameter distribution and higher stand density than managed and intensively managed stands. Managed bamboo stands have been found to have higher stand density than intensively managed bamboo stands, but there was no significant difference in diameter distribution. The above-ground biomass ranges from 129.31 to 142.02 ton/ha on managed bamboo stands, from 39.63 to 60.19 ton/ha on intensively managed bamboo stands, and ranges from 231.40 to 253.42 ton/ha on abandoned bamboo stands. The above-ground biomass of bamboo stands depends on stand density and diameter size. The greater the stand density and diameter, the higher the above-ground biomass.

As an assessment of the utilized area by chip companies, the total bamboo chip utilization of Chuetsu Pulp and Paper company was about 5794 tons in 2020, and the total use of bamboo forest area by this paper company was around (349.9-642.9) ha yearly based on commercial culm production per hectare. By comparing potential chip production and actual chip production, % of utilized bamboo area by chip companies from forest registration data may be 4.3 % on managed stands and 7.8 % on intensively managed stands. Based on this, (2-10) % of bamboo forest area are managed and 90 % of bamboo forest area can be assumed to be left and abandoned stands.

This study pointed out the bamboo resource utilization of Kagoshima Prefecture and its potential for bamboo culm production. The bamboo sector should grasp new opportunities such as biomass use for value-added products, which also helps to improve bamboo chip providers. Moreover, the bamboo industry needs to be adjusted as a comprehensive system, from bamboo forest cultivation and logging to processing, storage, logistics, and so on, to obtain optimal performance by taking advantage of agglomeration effects. By managing the bamboo forests and utilizing bamboo products, we may be able to revitalize the deteriorating Satoyama production system and the local community. Moreover, it supports the management of bamboo forests; proper management of bamboo forests for quality and quantity is essential to the bamboo industry and local environmental problems. The realization of the proposal needs the cooperation of various stakeholders in the production of bamboo products. The priority in rebuilding Japan's depressed bamboo industry is to ensure stable farming incomes for bamboo shoot farmers and to give future job incentives to young generations. Recognition of farmers' motivation in the management of bamboo forests will result in well-managed forests, favorable environmental conditions, and diversified biodiversity in the future. This is one of Japan's most important and urgent tasks today (Shibata, 2015). There are many challenges to increasing the product, mainly the decreasing amount of bamboo chip supply and stopping management in bamboo farms. It needs to solve this challenge by improving subsidy amount by municipal governments, providing stable farming incomes for bamboo shoot farmers and future job incentives for young generations (Shibata, 2015).

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