RESEARCH NOTE

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# Dimensions and Conservation of Remnant Homestead Windbreaks on a Small Island

–A Case Study of Taketomi Island, Okinawa Prefecture, Japan–

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**Abstract:** To aid the conservation of vanishing old-growth fukugi trees (*Garcinia subelliptica*) in Okinawa Prefecture, this study aimed to compile an inventory of the dimensions and spatial distribution of such trees planted centuries ago as windbreaks along homestead borderlines. This paper reports our field survey results and findings from a small island, Taketomi Island, belonging to Yaeyama Island Group. We measured 1,194 fukugi trees with a minimum diameter at breast height (DBH) of 5 cm. Mean tree height, DBH, and estimated tree age are 6.05 m, 22.7 cm, and 90.8 years, respectively. Furthermore, almost 60% of the surveyed trees were planted on the east and north sides of homesteads to protect them from typhoons and monsoonal winds in the winter. Huge trees older than 250 years were distributed across 12 different homesteads. In addition to *G. subelliptica*, other useful tree species, namely *Podocarpus macrophyllus* and *Diospyros egbert-walkeri*, were commonly found as homestead windbreaks. Similar to other islands, the need for conservation initiatives and projects for these remnant old-growth trees is urgent, as they are vital parts of the scenic landscape for tourists on Taketomi Island.

## 1 Introduction

Islands are isolated from the mainland and hence are vulnerable to natural disasters. To protect houses and farmlands from strong winds in the coastal areas of Ryukyu Archipelago, tree belts were planted during the Ryukyu Kingdom Period (1429–1879) and have been maintained to this day. This landscape was established according to the Chinese *fengshui* concept. Before WWII, coastal forests and homestead windbreaks were prevalent on the Ryukyu Islands. These trees are still widely distributed in Ryukyuan villages (Chen and Nakama, 2011a, 2011b).

However, the majority of old trees/forests were destroyed by fires during WWII and as a result of land development projects to consolidate fragmented farmland in the 1960s. In recent land consolidation projects, many windbreaks were destroyed to facilitate agricultural mechanization and vehicular traffic. The old-growth trees of the traditional village landscape are vanishing, and it is vital to conserve them because of their historical and cultural value. The first step to conserve old-growth trees in the Ryukyu Islands is to inventory the locations and dimensions of existing trees.

In previous surveys, we inventoried remnant *Garcinia subelliptica* (fukugi trees) on Okinawa Island and other small islands nearby (Chen and Nakama, 2011a, 2011c) and explored their cultural and historical significance. We did the same in several villages on Okinawa Islands, such as Bise and Imadomari in the north, as well as Aguni Island and the Tonaki Islands (Chen and Nakama, 2011c). Recently, we extended our survey of remnant fukugi trees to the Yaeyama Island group, the southernmost islands in Okinawa Prefecture, with the aim of clarifying the dimensions and spatial distribution of remnant homestead trees on isolated islands and in coastal villages. Consequently, this paper reports our field survey results and findings from a small island, Taketomi Island, which is one of the most famous tourist destinations in Okinawa Prefecture.

## 2 Survey sites and methods

Taketomi Island is situated at 124°5′ E, 24°19′ N, 6 km from Ishigaki Island, the third biggest island in Okinawa Prefecture (Figure 1). Ishigaki Island harbors the City of Ishigaki and functions as the business and transport center of the Yaeyama Island group. Ishigaki Island has an area of 229.94 km$^2$ and a population of 47,660 as of October 2015 (Ishigaki City, 2016).

We selected Taketomi Island as our survey site as it harbors a village with some of the best-preserved fukugi treelines and is well-known as a “traditional landscape of red-tile roofed houses, stone walls, and sandy roads.” Taketomi Island is circular with an area of 0.05 km$^2$. It has been a popular tourist destination since the 1970s.

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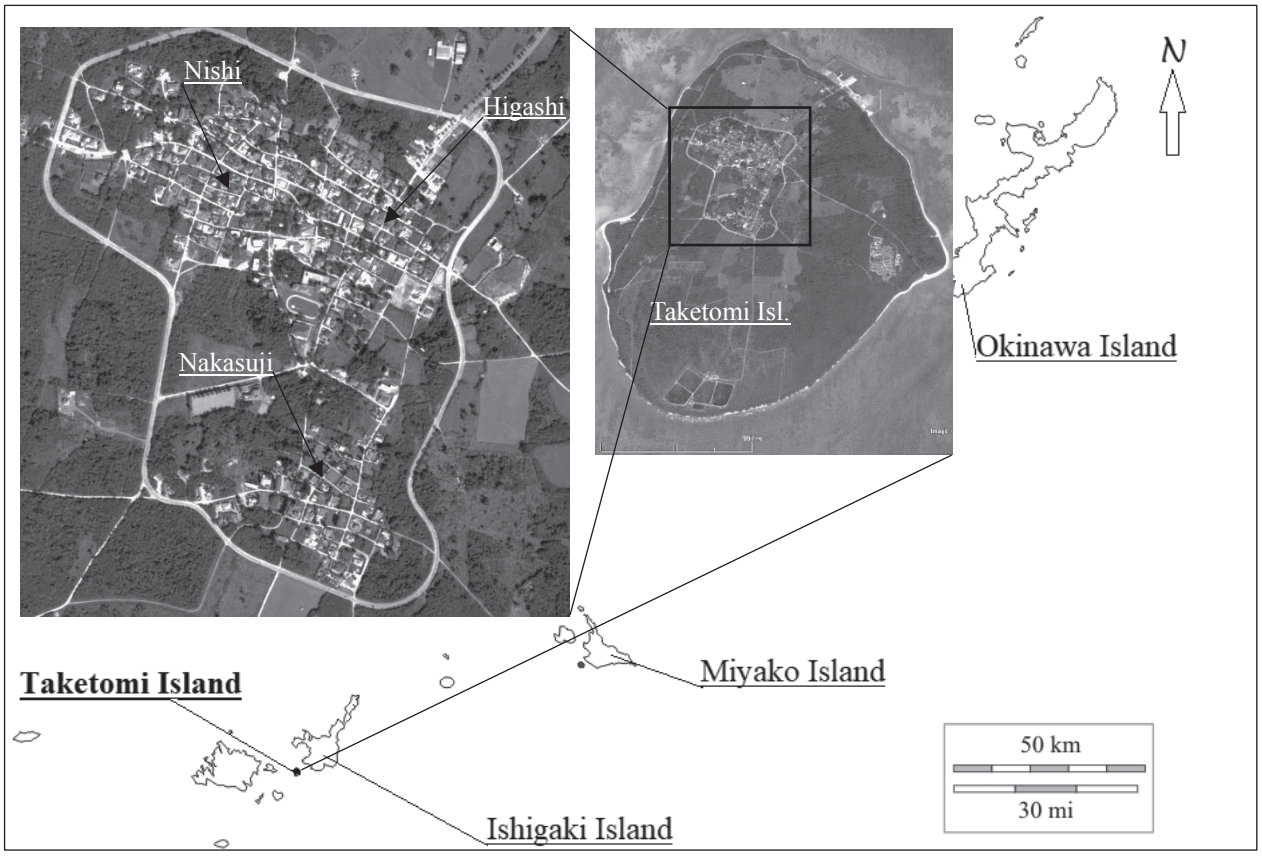


Figure 1: Location of Taketomi Island (Data source: aerial photo adopted from Google Earth)
Note: the village is the built-up area located in the center of the island.

There are three sub-hamlets on Taketomi Island, namely Higashi (*Ainota*), Nishi (*Innota*), and Nakasuji (*Naaji*). The island received a total of 513,328 tourists in 2017 (Taketomi Town, 2018). The population of Taketomi Island was 356 as of January 2018.

We measured and recorded trees following our previous methods (e.g., Chen et al., 2016). Field surveys were conducted to collect the following data relevant to each tree: diameter at breast height (DBH) measured at a height of 1.3 m, diameter measured at a height of 20–30 cm above the ground, and cardinal direction relative to the nearest homestead. All fukugi trees with a DBH of greater than 5 cm were surveyed in the village. Tree age was estimated based on DBH. All fukugi trees with a DBH of greater than 25 cm were estimated to be approximately 100 years old (Chen and Nakama, 2011c). A local volunteer team assisted in data collection in November 2017, followed by a supplementary survey by the first author conducted in March 2018.

There are two methods for estimating the age of fukugi trees: Equation (1) provided by Hirata (2006) and Equation (2) deduced by Nakama et al. (2014).

$$y = x_1 \div 2 \times 8 \quad (1)$$

$$y = x_2 \div 2 \times 6.2 \quad (2)$$

Where $y$ is the estimated tree age, $x_1$ is the DBH (cm) at 1.3 m above ground level, and $x_2$ is the diameter (cm) at approximately 0.2–0.3 m above ground level. We adopted Hirata's method (Equation (1)), because the DBH at 0.2–0.3 m above ground level for many trees was not available as the lower parts of their stems were surrounded and buried in stone fences. Considering a possible deviation in the tree's estimated age from its real age, age classes of 50 years were used in the analyses.

The locations of fukugi trees with DBH >5 cm at all surveyed homesteads were recorded on a residential map (Zenrin Co., LTD.).

Surveyed trees were classified into five groups according to their estimated ages: 100–149 years old, 150–199 years old, 200–249 years old, 250–300 years old, and over 300 years old. The distribution of tree age groups was mapped by homestead. The spatial distribution of the tallest fukugi trees within each property was also mapped. We assumed that house

owners selectively cut fukugi trees for specific purposes, e.g., timber, and that some trees may have died due to strong typhoons. However, the local population did not clear-cut all trees at once, in order to maintain windbreaks. This selective cutting allowed the oldest trees to survive, thereby providing historical data regarding residential land evolution. Tree belts of other tree species were also noted.

In addition, the leader of the village and knowledgeable people were interviewed to collect information on tree landscape conservation and potential use of trees. Interviews were conducted in September 2016 and March 2018. All survey data were analyzed with STATA software (15v.).

## 3 Results and discussion

### 3.1 DBH and tree height

A total of 1,194 fukugi trees was measured on Taketomi Island. The majority of surveyed trees were <10 m high or <200 years old (Figure 2). The mean and median tree heights were 6.05 m and 5.96 m, respectively (Table 1). The mean and median DBH were 22.7 cm and 21 cm, respectively. The mean and median tree ages were estimated to be 91 and 84 years, respectively. The smallest 5% of the surveyed trees were <2.3 m tall, had a DBH of <5.0 cm, and were <20 years old; the largest 25% were >8.2 m tall, had a DBH of >32.5 cm, and were >130 years old.

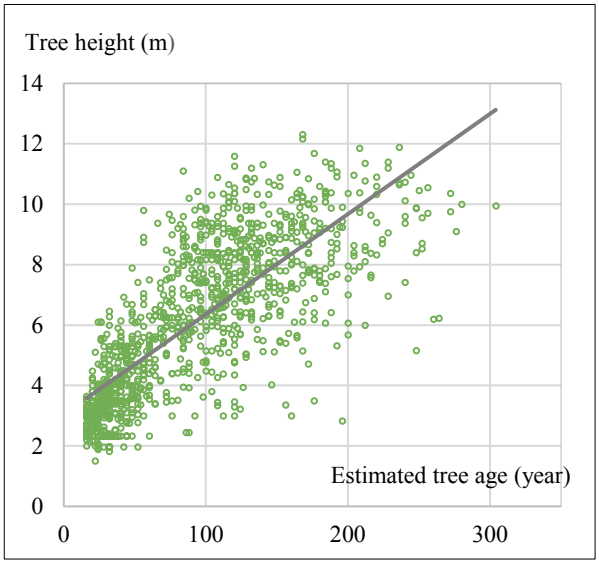


Figure 2: Distribution of age and height of fukugi trees on Taketomi Island

Table 1: Dimensions of fukugi trees on Taketomi Island
DBH: diameter at breast height

| | | Tree height (m) | DBH (cm) | Tree age (years) |
|---|---|---|---|---|
| Number of trees | Measured | 1,194 | 1,182 | 1,182 |
| | Not measured | 0 | 12 | 12 |
| Mean | | 6.05 | 22.7 | 90.8 |
| Median | | 5.96 | 21 | 84 |
| Std. deviation | | 2.55 | 14.9 | 59.5 |
| Minimum | | 1.5 | 2.0 | 16 |
| Maximum | | 12.31 | 76 | 304 |
| Percentiles | 5 | 2.33 | 5.0 | 20 |
| | 25 | 3.67 | 9.0 | 36 |
| | 50 | 5.96 | 21.0 | 84 |
| | 75 | 8.23 | 32.5 | 130 |

The largest tree on Taketomi Island has a DBH of 76 cm and was estimated to be approximately 304 years old. The DBH of fukugi trees surveyed on Taketomi Island does not differ much from other surveyed villages. The highest tree found in Taketomi Island is 12.3 m, which is much lower than that found at previous survey sites. For example, the tallest trees on Hateruma Island and Shiraho Village on Ishigaki Island are 17.7 m and 20.3 m, respectively, have a DBH of, and are >130 years old.

### 3.2 Cardinal direction of trees

The cardinal direction of the trees relative to homesteads were recorded based on the residential map (Figure 3). The four directions were approximated, and north does not necessarily refer to true north. Approximately 91% of trees were on the north, south, east, or west sides of each homestead. The other 9% of trees were located on the corners and were categorized as “Others.” Approximately 2.4%, 2.7%, 2.6%, and 1.2% faced north-east, north-west, south-east, and south-west, respectively.

Approximately one third of fukugi trees (29.7%) were found on the east side of homesteads, and 26.5% on the north side (Figure 3). South-facing trees had the lowest occurrence (14.8%), followed by west-facing trees (20.1%).

The trend of maintaining a dense tree belt on the east and north sides of homesteads is consistent with previous studies on Aguni Island (Ando et al., 2010a), Imadomari on Okinawa Island, Tonaki Island (Ando et al., 2010b), Hateruma Island, and Karimata on Miyako Island (Chen et al., 2016).

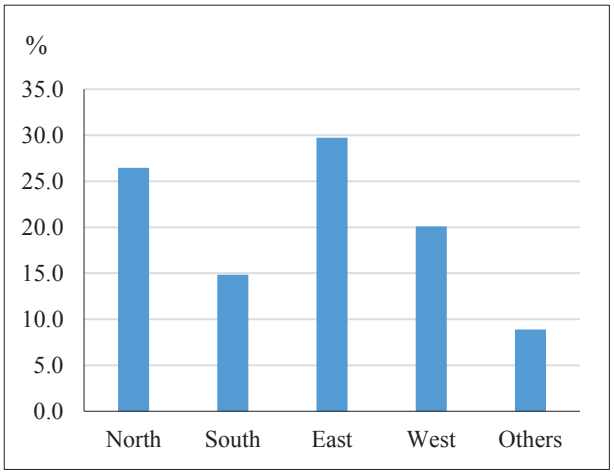


Figure 3: Fukugi tree distribution by cardinal direction relative to homesteads. “Others” refers to trees at the center or corners of homesteads.

### 3.3 Tree belt coverage and age distribution

Remnant tree belts surrounding the homesteads were surveyed and marked in different colors according to tree species (Figure 4).

Similar to many other villages on the Ryukyu Islands, fukugi trees are the most common tree species planted around homesteads on Taketomi Island. Two other common tree species are *Podocarpus macrophyllus* and *Diospyros egbert-walkeri;* other species, such as *Ficus microcarpa*, are also present (Figure 4). The former two species are viewed as useful trees by the local population. *D. egbert-walkeri* can be used to make a traditional musical instrument (*sanshin*); the wood, particularly, that produced in the Yaeyama Island Group, is considered the most suitable and highest quality wood to make a neck (*sao*) of *sanshin*. Unfortunately, at present it is forbidden by the Ishigaki Municipal Government to extract *D. egbert-walkeri* from mountain forests. *P. macrophyllus* is an important timber source used for pillars in traditional timber houses. In addition, old-growth *D. egbert-walkeri* was often seen, usually as individually standing trees. Among the tree species produced in Okinawa, *P. macrophyllus* contains the most termiticidal substance, and a local traditional method of wood preservation of soaking wood in sea water before use can greatly increase the termite-proof value of timber (Yaga, 1978).

On Taketomi Island, we measured 50 trees older than 200 years and 13 trees older than 250 years (Table 2). The oldest 13 trees were distributed in a wide range at 12 different homesteads (Figure 5). The volume of the oldest trees does not differ much from other survey sites in Okinawa Prefecture (Chen et al., 2016).

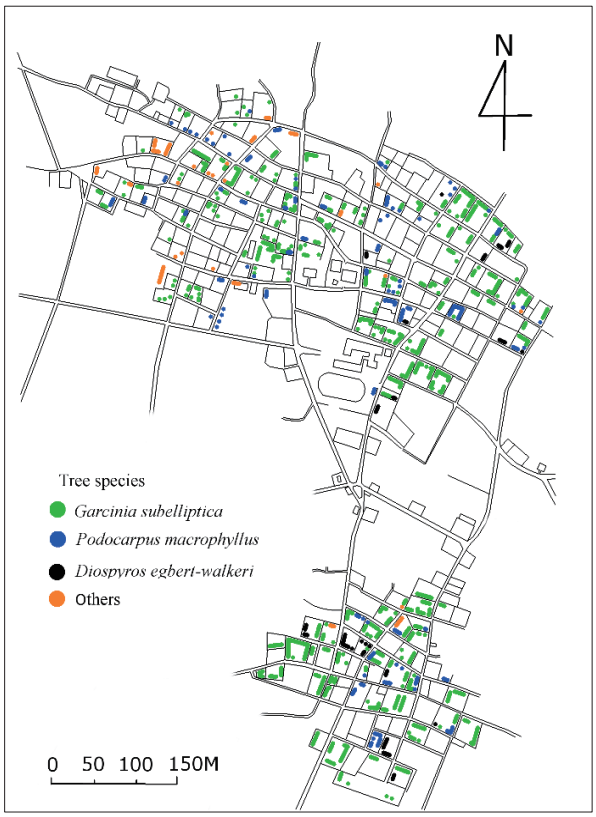


Figure 4: Distribution of trees surrounding homesteads in Taketomi Village

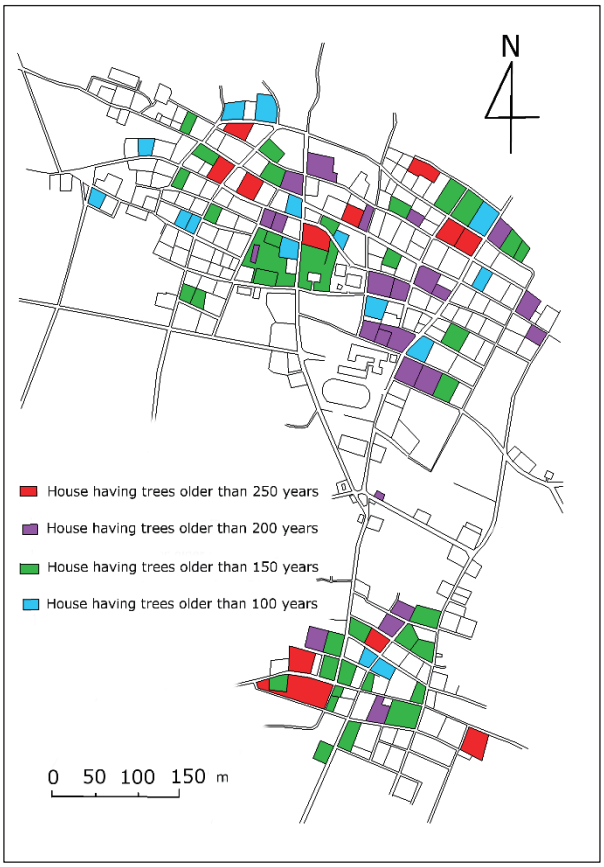


Figure 5: Spatial distribution of homesteads in Taketomi Village with old fukugi trees

Table 2: Descriptive data of fukugi trees by estimated age (year) on Taketomi Island

| Survey site | Total number | Tree number by estimated age (year) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0–49 | 50–99 | 100–149 | 150–199 | 200–249 | 250–299 |
| Taketomi Island | 1182* | 423 (36)** | 255 (22) | 298 (25) | 143 (12) | 50 (4) | 13 (1) |

Note: *Ages of 12 trees were not available during the survey
**Numbers in brackets are percentages

**3.4 Tree conservation and the tourism industry**

According to Mr. A. (male, 92 years old), homestead windbreaks were densely planted in the past. Many trees were removed during village infrastructure construction in the 1970s. Roadside tree lines were cut to widen roads to accommodate car transportation.

As a popular destination for both domestic and international tourists, the scenic landscape and traditional architecture on the island attract approximately 500,000 tourists annually (Taketomi Town, 2018). However, local people do not value fukugi trees as tourist attractions, as evidenced by the following quotation:

> *I have never considered fukugi trees in the village as tourist attractions. Foreigners also came to the island. Fukugi trees have been planted and maintained as windbreaks. If trees were cut, then house roofs would be blown away. The old people are cleaning the fallen leaves inside the village. People are used to helping clean their neighboring area*. (U., male, 60 years old.)

However, caution should be exercised in evaluation of the above statement as it may not represent the perception of the majority of residents towards fukugi treelines in terms of tourist attractiveness. We did not contact other residents for their opinions, so this statement exhibits research bias.

This finding that residents hardly value fukugi trees for tourist development in Taketomi Island is largely different from some other traditional villages that are also popular tourist destinations, e.g., Bise village in northern Okinawa Island. Tourists rated the amenity value of the fukugi tree landscape highly and appreciated naturalness and greening of the picturesque rural landscape (Chen et al., 2017). Consequently, there may exist a mismatch of perceptions of the local community in terms of tourist demand, an issue which should be clarified by further research.

Similar to other villages in Okinawa, tree management and maintenance has become an urgent issue due to the increasing number of immigrants. A community leader stressed that young residents, unlike the older generations, are unwilling to clean the fallen leaves, and some clear-cut the trees on their homesteads. Increasing immigration is also deemed problematic for traditional tree management methods.

**4 Conclusions**

We measured 1,194 fukugi trees with a minimum DBH of 5 cm on Taketomi Island. The mean tree height, DBH, and estimated tree age are 6.05 m, 22.7 cm, and 90.8 years, respectively. The three dimensions of fukugi trees do not differ much from those of other surveyed trees, e.g., on Hateruma Island and Shiraho Village in Ishigaki Island.

Over 50% of the surveyed fukugi trees are located on the east and north sides of homesteads. Thirteen remnant fukugi trees, with estimated ages of >250 years, were widely distributed across the village. As most of the trees were located on the east and north sides of homesteads, this suggests that tree orientation is determined by the direction of typhoons and monsoonal winds.

As a popular tourist destination, which accommodates approximately 500,000 tourists annually, Taketomi Island's traditional homestead woodlands are vital village landscapes for attracting tourists. Unfortunately, these trees, planted centuries ago, are deteriorating and being jeopardized by storms, typhoons, and diseases. Our survey results of remnant old-growth trees can be used as a baseline for future conservation on the island and further tourism development projects. Similar to other islands, conservation initiatives and projects are urgently needed on Taketomi Island. To this end, further research to clarify residents' perceptions of tree conservation and also tourists' attitudes toward the amenity value of fukugi tree lines is needed.

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