Importance of *Quercus gilva* (イチイガシ) for the prehistoric periods in western Japan

NOSHIRO Shuichi[1], SASAKI Yuka[1], & MURAKAMI Yumiko[2]

ABSTRACT

Importance of an evergreen oak, Quercus gilva, from the Jomon to Kofun periods in western Japan is discussed based on plant macrofossils and wooden artefacts. Recent re-identification of plant macrofossils and wooden remains showed intensive use of the acorns of Quercus gilva during the Jomon to Yayoi periods and that of its wood during the Yayoi to Kofun periods in western Japan. In Kyushu the acorns of Quercus gilva occur most commonly in storage pits of the Jomon period and rather commonly even during the Yayoi period after the introduction of intensive rice agriculture into Japan. During the Yayoi to Kofun periods the wood of Quercus gilva was exclusively selected for agricultural tools of hoes and spades in western Japan and was replaced by that of other evergreen oaks of Quercus subgen. Cyclobalanopsis or deciduous oaks of Quercus sect. Aegilops in eastern Japan. These selection and use of Quercus gilva indicated its importance as food and wood resources from the Jomon to Kofun periods in western Japan in spite of a change in the subsistence system from hunting-gathering to agriculture, and the extent and origin of these selection and use are discussed.

KEYWORDS: acorns, hoes and spades, Jomon to Kofun periods, *Quercus gilva*, western Japan

1. Introduction and study objective

Quercus gilva is an evergreen oak with a straight bole that grows to 30 m tall and 200 cm in trunk diameter and is distributed from southern Kanto to Kyushu in Japan and in Jeju Island in Korea, southern China, and Taiwan (Figure 1; Kurata 1964; Huang *et al.* 1999; Ohba 2006; Fang *et al.* 2009; Iokawa 2016). The growth of *Quercus gilva* in western Japan since ca. 8000 years cal BP of the late phase of the initial Jomon period is confirmed by the fruits of *Quercus gilva* found at several sites in western Japan (Ishida *et al.* 2016) and a buried forest of the middle to final Jomon periods consisting of *Cinnamomum camphora* (クスノキ) and evergreen oaks including *Quercus gilva* found at the Tarumi-hyuga site, Hyogo (Noshiro *et al.* 2014). Thus, *Quercus gilva* was a common element of forest resources at least since ca. 8000 cal BP of the initial Jomon period in western Japan.

Common occurrence of plant macrofossils of *Quercus gilva* from archaeological sites

[1] *Center for Obsidian and Lithic Studies, Meiji University, 1–6–3 Kanda-sarugaku-cho, Chiyoda, Tokyo 101–0064, Japan (noshiro@meiji.ac.jp)*
[2] *The Kyoto University Museum, Yoshida-honmachi, Sakyo-ku, Kyoto, Kyoto 606–8501, Japan*
Category: Original Article Received: 7 August 2019; Accepted: 21 December 2020

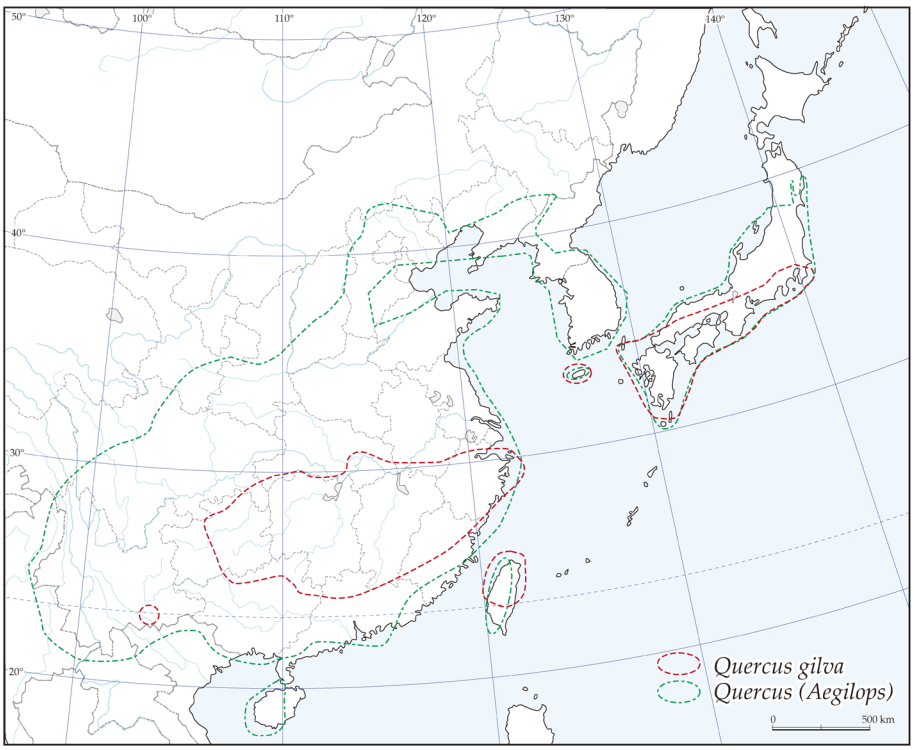

Figure 1. Present distribution of Quercus gilva and Quercus sect. Aegilops in East Asia (Kurata 1964; Fang et al. 2009). Among taxa used for hoes and spades during the Yayoi and Kofun periods, only deciduous Quercus acuta and Q. variabilis of sect. Aegilops grow in the Korean, Liaodong, and Shandong peninsulas thorough which rice agriculture and accompanying cultural elements came to Japan

in western Japan first attracted the attention of botanists in the 1970s when its acorns came to be reported, because *Quercus gilva* does not grow commonly in native forests outside Kyushu at present (Okamoto 1979). To confirm the botanical criteria for identifying the acorns and seeds of *Quercus gilva*, Okamoto (1979) studied the acorns and seeds of Japanese species of *Quercus* and showed that the acorns and seeds of *Quercus gilva* can be distinguished by the form of styles, stellate hairs on styles, and the capitate surfaces of stigmas, and by an impression of the placental axis and occasional anisocotyly, respectively (Figure 2). Based on these criteria, he identified acorns from the Kadota site, Fukuoka, and charred seeds from the Yuno site, Fukuoka, as *Quercus gilva*. Similarly, by studying acorns of *Quercus, Lithocarpus*, and *Castanopsis* mainly growing in Kyushu, Obata (2011) reconfirmed the morphological criteria of Okamoto (1979) and added other morphological criteria to identify acorns and seeds of *Quercus gilva*. By compiling the data mainly of

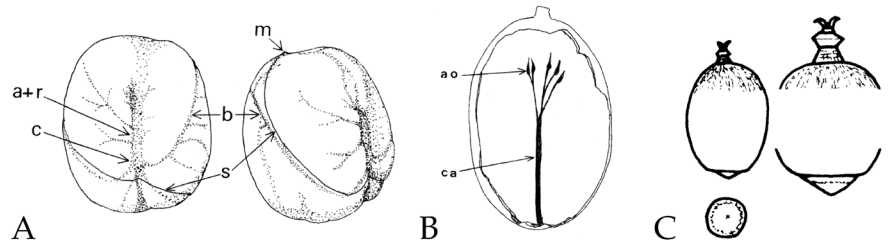

Figure 2. Characteristic features of seeds (A, B) and acorns (C) of Quercus gilva (A, B from Okamoto (1979), C from Obata (2011)). A: seeds has distinct heterocotyly as shown by the seam between two cotyledons (s), and the position of the radicle (m) is displaced from the top; an impression of the axile (a) elongates to the middle of fruits with an impressions of the raphe (r); impressions of charaza (c) and vascular bundles (b) can be seen also. B: axile (ca) elongates to the middle of fruits and has aborted ovules (ao) at the tips. C: acorns are ellipsoidal and have slender styles and sharply enlarged perianth bases similar to Japanese abacus beads in shape

acorns from archaeological sites in Kyushu, Obata (2011) showed that occurrence of deciduous oaks (*Quercus* subgen. *Lepidobalanus*) exceeds that of *Quercus gilva* during the incipient and initial Jomon periods, but use of *Quercus gilva* dominates during the early Jomon to Yayoi periods, constituting 88% and 63% of plant remains at 27 Jomon and 22 Yayoi sites, respectively.

Compared with plant macrofossils, wood remains of *Quercus gilva* have a longer history of research. In 1939 Onaka (1939) studied wooden artefacts of the Yayoi period from the Karako-kagi site, Nara, and indicated that three spades were made of *Quercus gilva*. His criteria for identifying oak wood based on his own collection of present wood specimens in the Kinki district was somehow neglected in later studies, and a recent compilation of archaeological wooden remains only reported that, of 4017 hoes and spades of the Yayoi to Kofun periods, 81% are made of species of evergreen oaks (*Quercus* subgen. *Cyclobalanopsis*)(Itoh & Yamada 2012). While studying hoes and spades from the Sorimachi site, Saitama, in the late 2000s, however, Noshiro & Sasaki (2011) reconfirmed the criteria of Onaka (1939) for identifying the wood of *Quercus gilva*, based on a larger number of specimens (Figure 3), and showed that hoes and spades of the Yayoi to Kofun periods were exclusively made with *Quercus gilva* in western Japan (Noshiro *et al.* 2012a, 2018).

These advances in identifying plant macrofossils and wooden remains of *Quercus gilva* from archaeological sites in western Japan indicated the importance of *Quercus gilva* for the prehistoric people in western Japan (Obata 2011; Noshiro *et al.* 2012a, 2018). However, the archaeological importance allotted to the fruits and wood of *Quercus gilva* have not been discussed so far. To evaluate the prehistoric importance of the fruits and wood of *Quercus gilva* in western Japan, we reviewed studies carried on archaeological plant

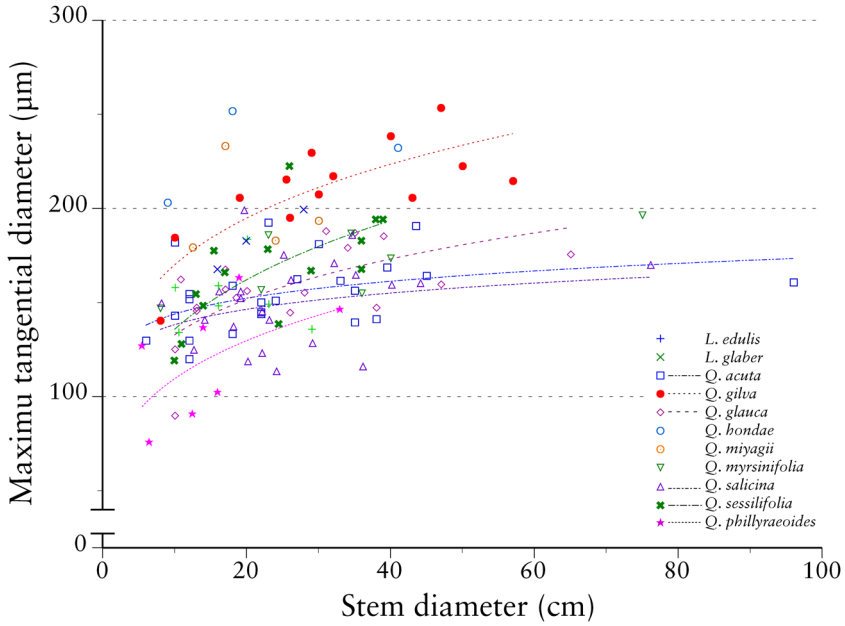

Figure 3. Distinction of Quercus gilva among Japanese species of Quercus from wood structure (Noshiro and Sasaki, 2011). In cross sections Quercus gilva has distinctly large vessels, and specimens having vessels larger than 220 μm in diameter can be identified as Quercus gilva, and those having vessels between 200–220 μm in diameter can be identified as probable Quercus gilva (shown as Quercus gilva? in this paper)

macrofossils and wooden remains of the Jomon to Kofun periods in western Japan (sites discussed in this paper are listed in Table 1). To evaluate the origin and spread of such evaluation for the fruits and wood of *Quercus gilva* in western Japan, we would like to test the following two hypotheses about the use of *Quercus gilva* in western Japan.

1. In western Japan the fruits of *Quercus gilva* were an indispensable element of food resources during the Jomon period and continued to be an important element of food resources even in the Yayoi to Kofun periods in spite of a change in the subsistence system from hunting-gathering during the Jomon period to agriculture during the Yayoi period.
2. The selection of *Quercus gilva* for wooden hoes and spades in the Yayoi period originated in western Japan, because, among oaks used for hoes and spades during the Yayoi to Kofun periods in Japan, only *Quercus* sect. *Aegilops* (i.e., *Quercus acuta* (クヌギ) and *Q. variabilis* (アベマキ)) grow in the Korean, Liaodong, and Shandong peninsulas, through which rice agriculture and accompanying cultural elements came to Japan (e.g., Ishikawa 2010; Miyamoto 2017).

Table 1. List of sites cited in this paper with plant remains of Quercus gilva

Site name	遺跡名	Location	Age	Plant remains of *Quercus gilva*
Anou site	穴太遺跡	Ohtsu, Shiga	late Jomon	fruits in storage pits
Higashimyo site	東名遺跡	Saga, Saga	initial Jomon	fruits in storage pits
Hiramine site	平峰遺跡	Miyakonojo, Miyazaki	middle Kofun	charred seeds in pit dwellings
Ichinokuchi site	一ノ口遺跡	Ogori, Fukuoka	middle Yayoi	fruits in storage pits
Kadota site	門田遺跡	Kasuga, Fukuoka	late Yayoi	fruits in storage pits
Kamishinano-nishikaneji site	上品野西金地遺跡	Seto, Aichi	late Jomon	fruits in storage pits
Karako-kagi site	唐古・鍵遺跡	Tawaramoto, Nara	early–late Yayoi	hoes, spades
Kuromaru site	黒丸遺跡	Oomura, Nagasaki	final Jomon	fruits in storage pits
Nabatake site	菜畑遺跡	Karatsu, Saga	initial–early Yayoi	hoe
Nagano-konishida site	長野小西田遺跡	Kitakyushu, Fukuoka	early–late Yayoi	fruits in storage pits
Nishikawazu site	西川津遺跡	Matsue, Shimane	early Yayoi–early Kofun	hoes, spades
Rokutanda site	六反田遺跡	Hikone, Shiga	late–final Jomon	fruits in storage pits
Shimogori-kuwanae site	下郡桑苗遺跡	Oita, Oita	early–middle Yayoi	hoes, spades
Shofukuji site	正福寺遺跡	Kurume, Fukuoka	late Jomon	fruits in storage pits
Sobata site	曽畑遺跡	Uto, Kumamoto	early Jomon	fruits in storage pits
Sorimachi site	反町遺跡	Higashimatsuyama, Saitama	early–late Kofun	hoes, spades
Tarumi-hyuga site	垂水・日向遺跡	Kobe, Hyogo	middle–final Jomon	buried forest with wood, fruits
Tsukuda site	佃遺跡	Awaji, Hyogo	middle Jomon	fruits in storage pits
Tsuyoshi site	津吉遺跡	Hirado, Nagasaki	early Yayoi	fruits in storage pits
Yuno site	湯納遺跡	Fukuoka, Fukuoka	final Jomon–initial Yayoi	fruits in storage pits

2. Botanical and archaeological background

In the Japanese archipelago stretching over 3000 km in mid latitudes, regional fauna and flora differ greatly from the north to the south. The central area of the Japanese archipelago consisting of Honshu, Shikoku, and Kyushu islands, where a large number of sites through the Jomon to Kofun periods have been excavated, is mostly covered by two types of forest

vegetation. The northeastern part of this area, referred to eastern Japan in this paper, is mostly covered by cool-temperate deciduous forests consisting of *Fagus crenata* (ブナ) and *Quercus crispula* (ミズナラ), and the southwestern part, referred to western Japan in this paper, is covered by warm-temperate evergreen forests consisting of evergreen oaks (カシ類, *Quercus* subgen. *Cyclobalanopsis*) and lauraceous trees (クスノキ科) (Fukushima 2017). This difference in forest vegetation between eastern and western Japan have greatly affected the subsistence of people through the Jomon to Kofun periods.

In eastern Japan covered by cool-temperate deciduous forests, recent studies showed that the Jomon people lived not as plain hunter-gathers, but managed and used plant resources around their settlements since around the early Jomon period (Noshiro & Sasaki 2013, 2014). This management system was centered on two kinds of arboreal resources, native *Castanea crenata* (クリ) and introduced *Toxicodendron vernicifluum* (ウルシ), and the people used not only the fruits of the former and the lacquer of the latter, but also their wood ingeniously. This management system came to include locally developed herbaceous cultigens such as *Glycine max* (ダイズ) and *Vigna angularis* (アズキ) in the middle Jomon period (Obata *et al.* 2007; Nakayama 2010; Obata 2011). Besides the use of such managed resources, people began to use seeds of *Aesculus turbinata* (トチノキ) that require complex processing during the late Jomon period by constructing processing facilities in the lowland (Sasaki *et al.* 2007; Sasaki & Noshiro 2018). Contrary to eastern Japan, use of plant resources during the Jomon period has been known only fragmentarily in western Japan, and their management has not been detected yet. Recent analyses of pottery types and settlement types of the late Jomon period indicated that difference in sedentism induced difference in the management and use of plant resources around settlements between eastern and western Japan (Fukunaga 2020). Even during the Yayoi to Kofun periods, only the employment of plant resources has been studied without considering the existence of their management (Noshiro 2016, 2019), and little information is available for the interaction with plant resources besides their use for agriculture and constructions during these periods.

Traditionally, the subsistence system from the Jomon to the Yayoi and Kofun periods has been regarded in a dichotomy of hunting-gathering Jomon people and Yayoi and Kofun agriculturists. This notion is reflected in the question posed by Matsui & Kanehara (2006) on the importance of the management of plant resources for the subsistence of the Jomon people, and they thought that the Jomon people were mainly foragers with a limited amount of cultivation and husbandry and that the subsistence changed drastically with the introduction of rice agriculture in the Yayoi period (Crawford 2008). Contrarily, by reviewing later finds of plant remains and studies of plant resource management during the Jomon period, Crawford (2011) places the Jomon subsistence system in the middle ground between hunting-gathering and agriculture, following the discussion of low-level

food production by Smith (2001). Because the management of plant resources during the Jomon period included resources other than food, he called the management system of the Jomon period as resource production rather than low-level food production. With the beginning of the Yayoi period, intensive agriculture was introduced in western Japan, but this new subsistence system did not spread to eastern Japan smoothly. In the northern Tohoku district, an interaction between the late to final Jomon and the Yayoi cultures continued in the Yayoi period and resulted in a culture called Tohoku Yayoi by Crawford and Takamiya (1990). Recently, by considering the continued existence of Jomon cultural items in the Tohoku district and the recent evaluation of the extent of the Yayoi culture, National Museum of Japanese History (2014) placed the northeastern border of the Yayoi culture along the Tone River running through the middle Kanto district on the Pacific side of central Japan. Thus, the dichotomy in the subsistence system has been taken to be the basic difference between the Jomon and Yayoi periods, and the subsistence systems for these periods are recognized not throughout the Japanese archipelago, but either in eastern or western Japan.

3. Analyses of plant macrofossils and wood remains of *Quercus gilva*

Occurrences of plant macrofossils and wood remains of *Quercus gilva* from the Jomon to Kofun periods will be reviewed first, based on Obata (2011), Minaki (1993), Momohara (1997), and Ishida *et al.* (2016) for plant macrofossils with our additional observations and on Noshiro *et al.* (2012a, 2018) for wooden remains.

3-1. Use of fruits of *Quercus gilva*

Acorns and leaves of *Quercus gilva* of the Jomon and Yayoi periods occur throughout the present distribution range of *Quercus gilva*, but also on the Japan Sea side of the Chugoku district (Figure 4). Acorns of *Quercus gilva* tended to occur in storage pits made in the lowland during the Jomon period and to occur in storage pits made around settlements on the upland during the Yayoi period (Obata 2011). Preservation of acorns of *Quercus gilva* in storage pits in the lowland can be typically seen at the Higashimyo site, Saga, at ca. 8000–7000 cal BP of the late phase of the initial Jomon period. At this site 155 pits were made in and around shell middens in the lowland, and 94 pits included basket remains that often included acorns inside them (Saga City Board of Education 2016a, 2016b). Acorns of *Quercus gilva* and *Q.* subgen. *Lepidobalanus* respectively accounted for 36% to 68% and 21% to 37% of the contents of pits and reflected the transition in the use of acorns detected by Obata (2011). Smilar storage of acorns of *Quercus gilva* inside baskets deposited in storage pits is found at the Sobata site, Kumamoto, at ca. 7000–5400 cal BP of the early

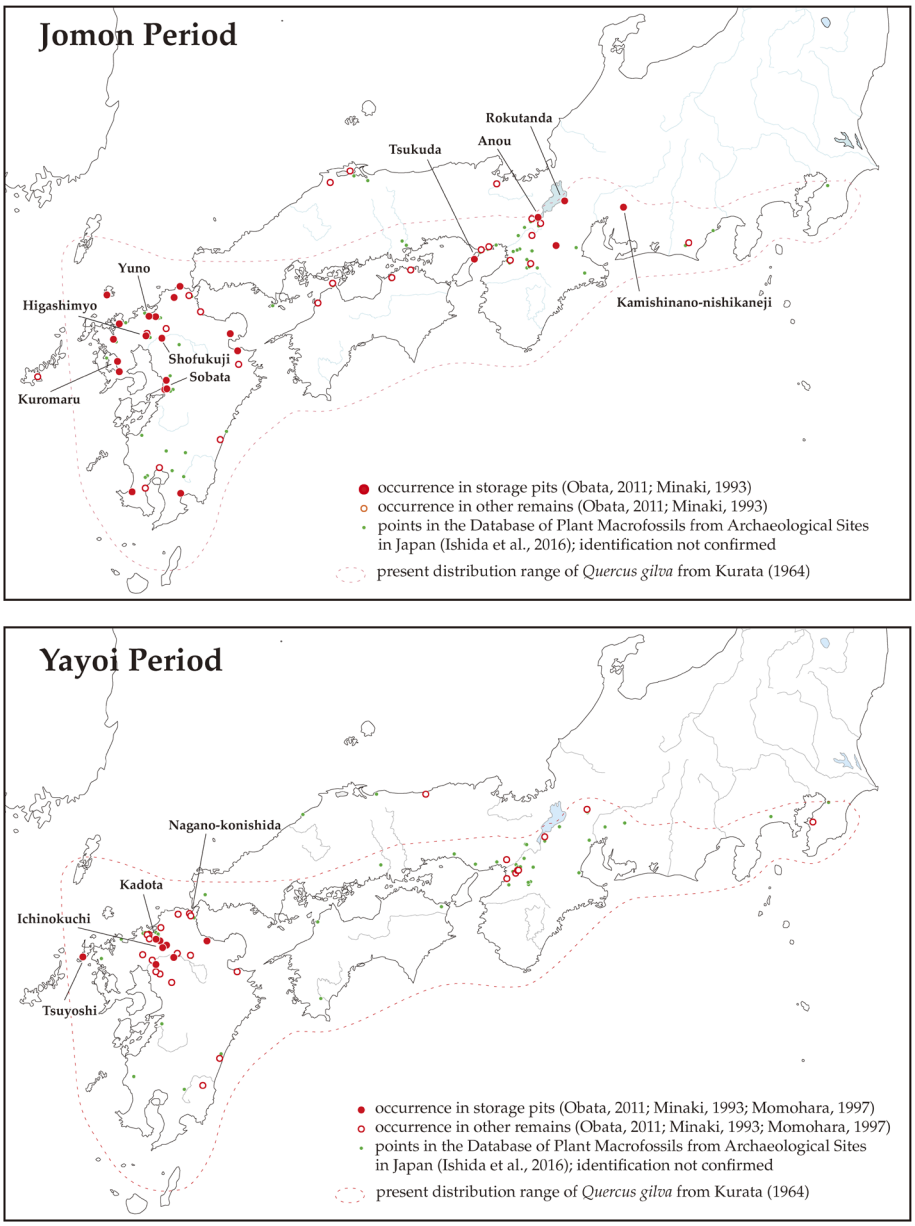

Figure 4. Occurrence of plant macrofossils of Quercus gilva during the Jomon and Yayoi periods in Japan based on Obata (2011), Minaki (1993), Momohara (1997) and Ishida et al. (2016) with our observations. During the Jomon period, fruits of Quercus gilva constituted the main contents of storage pits in Kyushu, but were a minor element even in storage pits outside Kyushu. Even in the Yayoi period, acorns of Quercus gilva were stored in storage pits of northern Kyushu

Jomon period (Kumamoto Prefectural Board of Education 1988) and the Shofukuji site, Fukuoka, at ca. 4500–3200 cal BP of the late Jomon period (Kurume City Board of Education 2017). In these later periods of the Jomon period, acorns of *Quercus gilva* came to be the only contents of storage pits at most sites. Because acorns of *Quercus gilva* are not astringent and edible without any processing, their storage in storage pits in the lowland during the Jomon period is considered as a method to kill weevils infecting the acorns with spring water seeped from pit walls or brackish water from the channel in the lowland (Saga City Board of Education 2016a). Outside Kyushu, however, fruits or seeds of *Quercus gilva* do not occur dominantly even in storage pits, but with astringent fruits of other taxa that needed bleaching to be used as food resources. For example, at the Anou site, Shiga, fruits of *Quercus gilva* occurred in storage pits of the late Jomon period that were dominated by fruits of *Aesculus turbinata* and *Quercus aliens* (ナラガシワ)(Shiga Prefectural Board of Education 1997), and, at the Kamishinano-nishikaneji site, Aichi, fruits of *Quercus gilva* occurred in a storage pit of the late Jomon period accompanied by such evergreen oaks as *Quercus sessilifolia* (ツクバネガシ), *Quercus acuta* (アカガシ), and *Quercus glauca* (アラカシ)(Aichi Prefectural Center for Archaeological Operations 2013). Contrarily, at the Rokutanda site, Shiga, 14 storage pits of the late phase of the late and the early phase of the final Jomon periods contained acorns of *Quercus gilva* and other evergreen oaks and fruits of *Aesculus turbinata* and *Trapa* (ヒシ属) variously, and storage pits dominated by acorns of *Quercus gilva* included astringent acorns of other evergreen oaks or fruits of *Aesculus turbinata* (Shiga Prefectural Board of Education 2013). The only exception outside Kyushu is storage pits of the late Jomon period found at the Tsukuda site, Hyogo, where ten storage pits exclusively included fruits of evergreen oaks, especially of *Quercus gilva*, similar to storage pits in Kyushu (Miyaji & Minaki, 1998). Thus, during the early to final Jomon periods, fruits of *Quercus gilva* constituted the main contents of storage pits in Kyushu, but were usually a minor element even when occurring in storage pits outside it.

Even in the Yayoi period after the introduction of rice agriculture, acorns of *Quercus gilva* occurred at over 30 sites, mostly in northern Kyushu, but also in southern Kyushu and Kinki districts (Figure 4). At the Ichinokuchi site, Fukuoka, 260 storage pits of the early to middle Yayoi periods were recovered on the top of a hill around pit dwellings, and three of the storage pits contained 42–644 charred seeds of *Quercus gilva*, excluding their fragments (Ogori City Board of Education 1994). At the Kadota site, Fukuoka, at ca. 1–250 AD of the final phase of the Yayoi period, 11 storage pits found in a valley contained acorns of *Quercus gilva* as much as 92 litre per storage pit (Kokawa 1979; Fukuoka Prefectural Board of Education 1979). At this site settlements were continually made through the Yayoi period, but storage pits were constructed only in the final phase of the Yayoi period. Because these storage pits were buried by fluvial deposits, acorns of *Quercus gilva* in storage pits at this site are thought to be special food to cope with a famine after a flooding

event. Continued use of acorns from the final phase of the early to the late phase of the late Yaoyi period is detected at the Nagano-konishida site, Fukuoka, where, beside two storage pits, 12 wooden frames used for storage of acorns and accumulations of acorns have been recovered (Kitakyushu City Foundation for Promoting Arts and Culture 2001). At this site, one storage pit and an acorn accumulation exclusively contained acorns of *Quercus gilva*, another storage pit and one wooden frame mainly contained acorns of *Quercus acuta*, accompanied by acorns of other evergreen oaks, and another acorn accumulation and deposits around a wooden frame mainly contained acorns of *Castanopsis cuspidata* (ツブラジイ). At this site, bleaching of astringent acorns and another kind of processing of non-astringent acorns were carried out within the same valley from the final phase of the early to the late phase of the late Yaoyi period. Thus, in Kyushu, fruits of *Quercus gilva* continued to be used even in the Yayoi period and were also used in the Kofun period. Charred seeds of *Quercus gilva* occurred with *Castanea crenata* and *Amygdalus persica* (モモ) from pit dwellings of the middle Kofun period at the Hiramine site, Miyazaki, showing their use as food even in the Kofun period (Sasaki & Bhandari 2012).

Outside Kyushu, fruits of *Quercus gilva* do not occur dominantly during the Yayoi to Kofun periods and occur with its young fruits and leaves, only indicating its growth nearby (Ishida *et al.* 2016).

3-2. Use of wood of *Quercus gilva*

Wooden artefacts made of *Quercus gilva* have so far been found only from archaeological sites of the Yayoi and Kofun periods in western Japan. The oldest artefact made of *Quercus gilva* is a hoe found at the Nabatake site, Saga, at ca. 950–600 cal BP of the initial to early Yayoi periods, and since then *Quercus gilva* came to be selected exclusively for hoes and spades in western Japan through the Yayoi period (Figure 5; Noshiro *et al.* 2012a, 2018). From Kyushu to Chiba on the Pacific side and to Shimane on the Japan Sea side, *Quercus gilva* and a putative one (*Quercus gilva?* in figures) were selected for 40% to 70% of hoes and spades of the Yayoi period, and other evergreen oaks mostly accounted for the remaining ones. In eastern Japan covered by cool-temperate deciduous forests, evergreen oaks other than *Quercus gilva* were the first choice in the southern part where other evergreen oaks grew, and *Quercus* sect. *Aegilops* (i.e., *Quercus acuta* and *Q. variabilis*) was selected in the northern part where even other evergreen oaks did not grow. This selection of *Quercus gilva* for hoes and spades in western Japan and that of *Quercus* sect. *Aegilops* in eastern Japan continued to the Kofun period (Figure 6). Although regional and periodical differences in hoe or spade types are being recognized (e.g., Higami 2010), the strict selection of *Quercus gilva* for their materials was carried out irrespective of the types of hoes or spades through the Yayoi and Kofun periods in western Japan.

This selection of *Quercus gilva* probably derives from the habit and wood quality of this

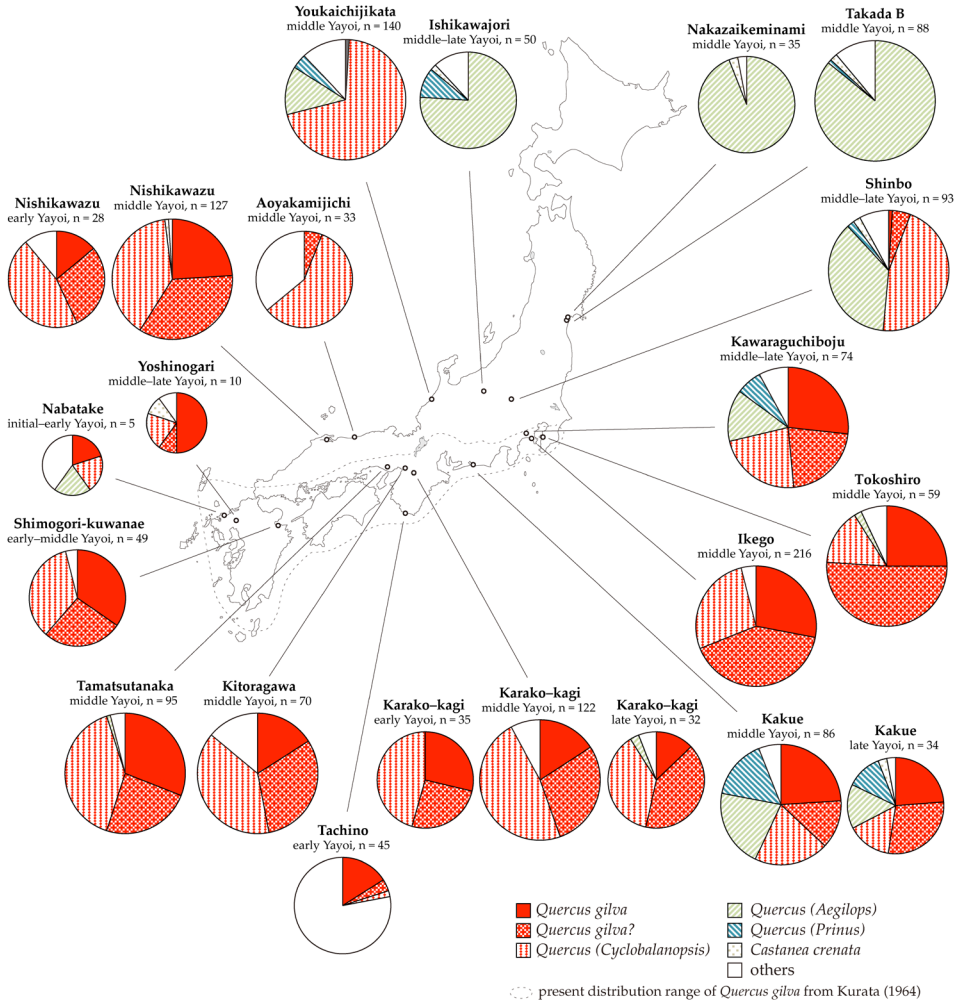

Figure 5. Taxonomic composition of finished and unfinished hoes and spades and their materials at 18 sites of the Yayoi period (modified from Noshiro et al. 2012a, 2018). During the Yayoi period Quercus gilva was exclusively selected for hoes and spades in western Japan, and Quercus sect. Aegilops was selected in eastern Japan. Small charts: up to 10 specimens, middle charts: 11–50 specimens, large charts: more than 50 specimens

tree. In Japan *Quercus gilva* is the largest evergreen oak, distinguished by having a straight bole up to 200 cm in trunk diameter (Kurata 1964; Ohba 2006; Iokawa 2016). Among evergreen oaks in Japan, the wood of *Quercus gilva* is weak in absolute strength, but is comparatively light, resilient, and sturdy (Mori & Sugiura 1922), and has been praised as materials for sculling oars of Japanese traditional boats, handles of hoes and spades, cart

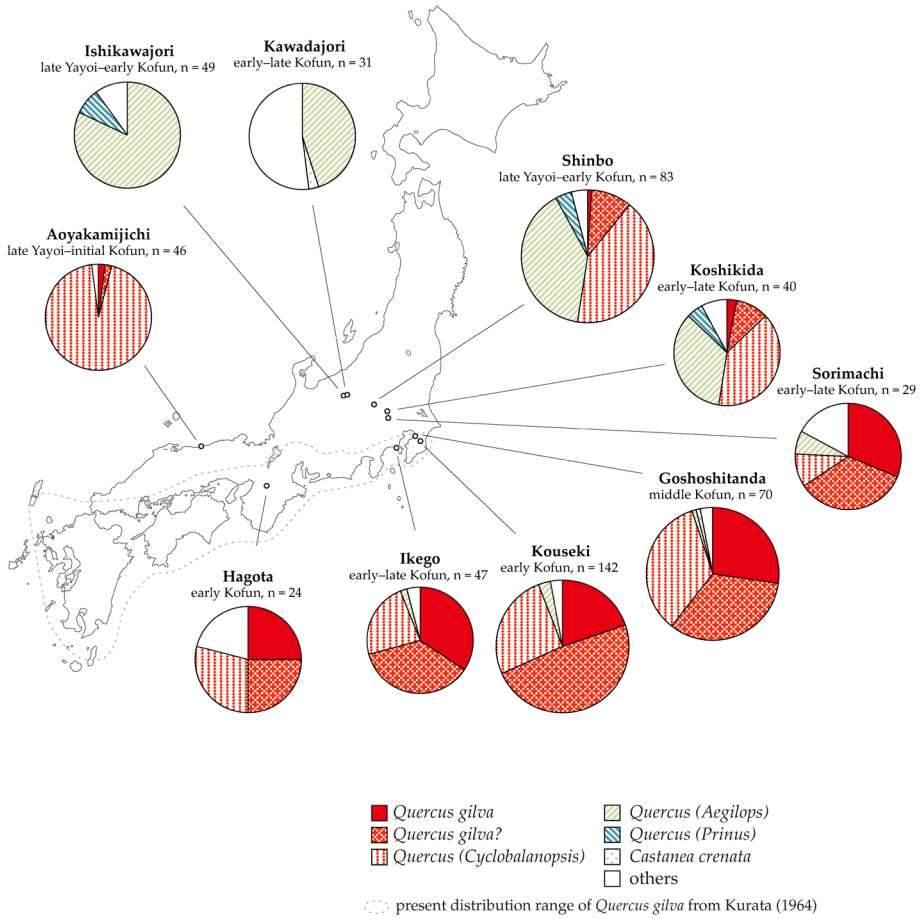

Figure 6. Taxonomic composition of finished and unfinished hoes and spades and their materials at 10 sites of the Kofun period (modified from Noshiro et al. 2012a, 2018). Selection of Quercus gilva for hoes and spades in western Japan and that of Quercus sect. Aegilops in eastern Japan continued to the Kofun period. Small charts: 11–50 specimens, large charts: more than 50 specimens

frames, and teeth of *geta* even in the modern period (Forest Bureau Ministry of Agriculture and Commerce 1912; Kumamoto Forest Bureau 1935). Compared with the wood of *Quercus gilva*, that of *Quercus* sect. *Aegilops* is comparatively heavy and less resilient (Wood Technology and Wood Utilization Division 1982; Hirai 1996). This wood quality of *Quercus gilva* must have been the reason for the exclusive selection of its wood for hoes and spades during the Yayoi to Kofun periods. Thus, choice of other evergreen oaks and *Quercus* sect. *Aegilops* instead of *Quercus gilva* for hoes and spades in eastern Japan seems to show an inevitable substitution for *Quercus gilva* outside the distribution range of

Quercus gilva.

Although the selection of *Quercus gilva* nearly conforms with the present distribution range of *Quercus gilva*, hoes and spades of *Quercus gilva* occurred at two areas outside the present distribution range, the northern part of the Kanto district and the Sannin district (Figures 5, 6). In the northern part of the Kanto district, occurrences of hoes and spades of *Quercus gilva* seem to show their transport from the southern part of this district (Noshiro *et al.* 2012a). In that area, *Quercus gilva* was found only as completed or nearly complete hoes and spades, whereas other evergreen oaks and *Quercus* sect. *Aegilops* were found not just as completed or nearly complete hoes and spades, but also as radially split boards considered as their materials (Noshiro *et al.* 2012a). In the southern part of the Kanto district, however, *Quercus gilva* was found as completed and nearly complete hoes and spades and radially split boards, which indicated that hoes and spades of *Quercus gilva* were made there. In the Sannin district, on the other hand, selection of materials for hoes and spades differs between Shimane and Tottori prefectures, and *Quercus gilva* was exclusively selected in Shimane prefecture, but other oaks were mostly used in Tottori prefecture (Figures 5, 6). Fruits of *Quercus gilva*, however, occur at three sites of the Jomon period in Shimane and Kyoto prefectures and at one site of the Yayoi period in Tottori prefecture (Figure 4). Thus, although native in the Sannin district since the Jomon period, *Quercus gilva* seems to have grown commonly eastward to Shimane prefecture, but rarely in the more eastern part of the Sannin district (Noshiro *et al.* 2018).

4. Discussion

Based on the occurrences of acorns, other plant macrofossils, and wooden remains, the importance of *Quercus gilva* in western Japan will be discussed from two aspects of the use of plant resources, food and wood.

4-1. Use of *Quercus gilva* as food resources in western Japan

The occurrence of plant macrofossils of *Quercus gilva* in western Japan indicated that regional differences existed in the use of the fruits of *Quercus gilva* between Kyushu and the area outside it. In Kyushu fruits of *Quercus gilva* were exclusively stored in storage pits during the Jomon to Yayoi periods and were consumed. In the area outside Kyushu, fruits of *Quercus gilva* occurred in storage pits usually dominated by astringent fruits. This lack of clear records of using fruits of *Quercus gilva* outside Kyushu seems to show that different storage or processing of acorns and nuts was carried out in this area. The scarcity of the plant macrofossils of *Quercus gilva* outside Kyushu may imply an existence of storage and processing of its fruits similar to the storage and processing of *Castanea crenata* fruits carried out in eastern Japan. In eastern Japan, although an ample use of the

wood of *Castanea crenata* in lowland structures indicated management of the resources of *Castanea crenata* around settlements since around the early Jomon period, its plant macrofossils occur far less than those of *Juglans mandshurica* var. *sachalinensis* (オニグルミ) and *Aesculus turbinata* whose fruits need processing with ample water and whose remains were left as middens in the lowland. Because fruits of *Castanea crenata* do not need processing with ample water and were probably prepared for food in an upland environment, few plant macrofossils of *Castanea crenata* tend to remain not only on the upland where only charred plant macrofossils remain, but even in the lowland where fresh plant macrofossils remain (Noshiro & Sasaki 2014). Even in Kyushu, fruits of *Quercus gilva* tend to have remained more in storage pits made in the lowland than in upland remains (Obata 2011). If the storage of the fruits of *Quercus gilva* in lowland storage pits is for killing weevils infecting them as considered at the Higashimyo site (Saga City Board of Education 2016a), the scarcity of fruits of *Quercus gilva* in storage pits outside Kyushu seem to imply an existence of another method of killing weevils in an upland environment and a different use of storage pits for bleaching astringent fruits, typically seen in the various use of storage pits at the Rokutanda site (Shiga Prefectural Board of Education 2013). The only exception to the exclusive storage of fruits of *Quercus gilva* in storage pits in Kyushu is a storage pit found at the Sobata site, Kumamoto, that was filled with fruits of *Quercus* sect. *Aegilops*, but, even at this site, the other 56 storage pits contained fruits of *Quercus gilva* exclusively (Kumamoto Prefectural Board of Education 1988). Thus, within western Japan, regional differences seem to have existed in the use and processing of plant resources between Kyushu and the area outside it.

On the other hand, exclusive occurrence of the fruits of *Quercus gilva* in storage pits of the early to final Jomon periods in Kyushu may exaggerate their importance as food resources in those periods. At the Higashimyo site, Saga, besides fruits of *Quercus gilva* and *Quercus* subgen. *Lepidobalanus* that dominated in lowland storage pits, broken nuts of *Juglans mandshurica* var. *sachalinensis* occurred as amply as acorns of *Quercus gilva* in the sediments of shell middens (Saga City Board of Education 2016a, 2016b). A large amount of broken acorns of *Castanopsis* discarded in a storage pit, and acorns and seeds of *Castanopsis cuspidata* found as pottery impressions also indicated ample use of *Castanopsis*. Because seeds of *Juglans mandshurica* var. *sachalinensis* and *Castanopsis cuspidata* are edible without bleaching similar to those of *Quercus gilva*, they must also have been important elements of food resources at this site. Beside the Higashimyo site, a storage pit of *Quercus* sect. *Aegilops* among 56 storage pits of *Quercus gilva* at the Sobata site (Kumamoto Prefectural Board of Education 1988) and a storage pit containing *Castanea crenata* among storage pits containing *Quercus gilva* at the Kuromaru site, Nagasaki, of the final Jomon period (Nagasaki Prefectural Board of Education 1997) are the only definite records of storage of plant resources other than *Quercus gilva* in Kyushu,

but they clearly show use of plant resources other than *Quercus gilva* in Kyushu during the Jomon period. Thus, although records are fragmentary, Jomon people must have used various plant resources other than *Quercus gilva* even in Kyushu.

During the Yayoi to Kofun periods, acorns of oaks, especially of *Quercus gilva*, continue to occur around upland settlements or in storage pits made within them in Kyushu, as found at the Ichinokuchi site, Fukuoka (Ogori City Board of Education 1994), and the subsistence system does not seem to have changed completely from hunting-gathering of the Jomon period to agriculture of the Yayoi period. Because of such continued occurrence of remains of *Quercus gilva* in an upland environment at 27 sites besides their occurrences in a lowland environment at 10 sites, Obata (2011) considers that the acorns of *Quercus gilva* still constituted an important element of food resources in Kyushu, probably aided by the good taste of these acorns, during the Yayoi to Kofun periods. Lowland storage pits similar to those of the Jomon period, however, did not disappear even during the Yayoi period and are found at the Nagano-konishida site, Fukuoka (Kitakyushu City Foundation for Promoting Arts and Culture 2001), the Kadota site, Fukuoka (Fukuoka Prefectural Board of Education 1979), and at the Tsuyoshi site, Nagasaki (Hirado City Board of Education 1986). Especially, at the Nagano-konishida site, occurrence of storage pits, wooden frames for acorn storage, and acorn accumulations together with hoes or spades used in rice agriculture indicated continued use of acorns along with rice agriculture. By citing the analysis of plant macrofossils by Maekawa (1978) at the Toro site, Shizuoka, and a review of food plants excavated from archaeological sites of the Yayoi period by Terasawa and Terasawa (1981), Ishikawa (2010) pointed out the importance of food plants other than rice as compensation for crop failures even in the Yayoi period and indicated that the multiplicity in the subsistence system of the Yayoi period was based on the use of various plant resources during the Jomon period that were available to the Jomon people. On the contrary, by comparing food plants excavated from Yayoi sites to those from *mumun* pottery sites in Korea, Goto (2006) showed that the number of sites yielding rice far exceeds that yielding other cultigens in Japan, but that rice usually occurs as much as other cultigens in southern Korea and becomes rare in northern Korea. However, contrary to the study by Terasawa and Terasawa (1981), Goto's comparison did not treat food plants other than cultigens in the analysis and does not seem to reflect the use of plant resources during the Yayoi period wholly. Thus, even after the introduction of rice agriculture, acorns of *Quercus gilva* must have been an important element of the subsistence system not only in Kyushu, but probably also in the area outside Kyushu.

The above analysis confirmed that fruits of *Quercus gilva* were an important element of food resources during the Jomon to Kofun periods in Kyushu. However, the weight that the fruits of *Quercus gilva* occupied in the prehistoric food resources could not be examined due to the scarcity of plant remains excavated outside storage pits. Thus, the first

hypothesis postulating the importance of fruits of *Quercus gilva* as food resources from the Jomon to the Yayoi to Kofun periods in spite of a change in the subsistence system has been supported in Kyushu, but was not supported outside it.

4-2. Origin of the selection of *Quercus gilva* for hoes and spades

While use of the wood of *Quercus gilva* has not been confirmed for the Jomon period, its wood came to occupy an important position during the Yayoi to Kofun periods in western Japan as the material for hoes and spades used in rice agriculture. This importance is reflected in the investment of labour for the manufacture of hoes and spades, and can be estimated from the size of wood being used, compared here with the radii of these wooden remains (Figure 7; Noshiro *et al.* 2012a, 2018). The radii of hoes and spades were larger than those of other tools and were as large as building materials, but were smaller that those of splash guards used with hoes. According to an felling experiment carried out with axes with steel blades reconstructed after Yayoi to Kofun remains, trees of *Castanea crenata* and *Quercus serrata* (コナラ) up to 20 cm in diameter could be felled within 10 minutes (Kudo 2004). Extrapolating from this result, it takes at least 40 minutes to fell down trees for hoes and spades with a diameter of ca. 40 cm, chopping without rest. Considering that the wood of oaks including *Quercus gilva* and *Quercus* sect. *Aegilops* is heavier and sturdier than that of other dicots and conifers and that several hoes or spades or splash boards needs trees up to 60 cm in diameter, it must have needed special effort to obtain materials for hoes, spades, and splash guards. The strict selection of materials for hoes and spades and the intensive labour invested for obtaining their materials seem to show the importance of hoes and spades in the subsistence of the Yayoi and Kofun people.

At present this selection of *Quercus gilva* for wooden hoes and spades seem to have originated in northern Kyushu at the beginning of the Yayoi period (Figure 5). The earliest selection of materials at the Nabatake site, Saga, is not clear, using *Quercus gilva*, another evergreen oak, *Quercus* sect. *Aegilops*, *Cinnamomum camphora*, and another dicot for each of the five hoes. In the early Yayoi period, the selection of *Quercus gilva* for wooden hoes and spades became prevalent in western Japan, being detected at the Shimogori-kuwanae site, Oita, the Nishikawazu site, Shimane, and the Karako-kagi site, Nara. Because detailed ages for the hoes and spades of these sites are unavailable, spread of the selection of *Quercus gilva* during the early Yayoi period cannot be traced at present. Thus, the value of the wood of *Quercus gilva* seems to have been recognized in northern Kyushu at the beginning of the Yayoi period. The present records of archaeological remains seem to indicate the following three possibilities.

1. *Quercus gilva* was selected for hoes and spades in western Japan, and *Quercus* sect. *Aegilops* was selected in eastern Japan.
2. Use of wooden tools for rice agriculture made of evergreen oaks is not known in the

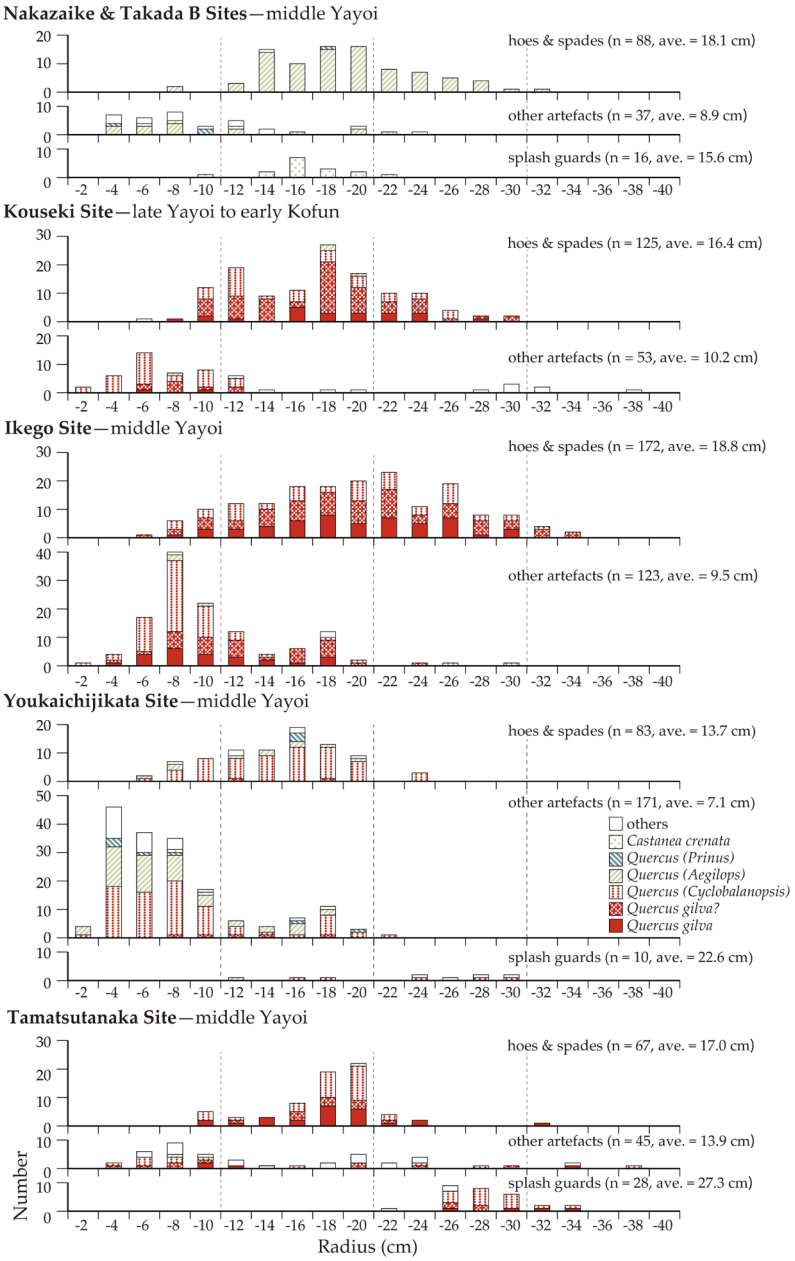

Figure 7. Radii of finished and unfinished hoes and spades and their materials for different taxa (modified from Noshiro et al. 2012a, 2018). Radii of hoes and spades were larger than those of other tools and were as large as building materials, but were smaller that those of splash guards. Intensive labour was invested for obtaining materials for hoes and spades in the Yayoi and Kofun periods

Korean, Liaodong, and Shandong peninsulas at present.

3. The selection of *Quercus gilva* for hoes and spades was carried out along with the use of its fruits in western Japan.

Thus, the second hypothesis postulating the origin of the selection of *Quercus gilva* for wooden hoes and spades in western Japan could not be supported due to the scarcity of comparative materials in East Asia.

5. Conclusion

Based on differences in the use of plant resources during the Jomon period, Sasaki (2011, 2014) proposed that two different cultural zones in the management and use of plant resources existed between eastern and western Japan during the Jomon period. In eastern Japan where the use of *Castanea crenata* and *Toxicodendron vernicifluum* characterizes the use of plant resources during the Jomon period, the management of plant resources has been critically studied, based on many examples (e.g., Noshiro 2016, 2019; Noshiro & Sasaki 2013, 2014; Sasaki & Noshiro 2018). In western Japan where the use of *Quercus gilva* characterizes the use of plant resources during the Jomon period, most examples have been obtained from Kyushu and solely from fruit remains. During the Yayoi to Kofun periods, on the contrary, the number of examples in western Japan exceeds that in eastern Japan, both in fruit and wood remains, and the western cultural zone proposed for the Jomon period by Sasaki (2011, 2014) came to be recognized throughout western Japan. Thus, in western Japan, *Quercus gilva* continued to be an important element of the subsistence from the Jomon to the Yayoi to Kofun periods. In eastern Japan, contrarily, the use of plant resources seems to have changned drastically during the Yayoi to Kofun periods and came to use *Quercus* sect. *Aegilops* intensively (Noshiro 2016, 2019). Thus, the use of plant resources differed between western and eastern Japan through the Jomon to Kofun periods, and a cultural continuum in the use of plant resources was maintained in western Japan, but not in eastern Japan.

The prehistoric use of plant resources centering on *Quercus gilva* in western Japan is queer from the present perspective. Within the present distribution range stretching in western Japan, *Quercus gilva* grows natively in evergreen forests only in Kyushu, on inland mountainous slopes from 15 to 750 m a.s.l. with rich well-drained soil (Ito *et al.* 2007). Due to a historical high demand for its timber, large trees of *Quercus gilva* are rarely found in mountainous forests of Kyushu, but are preserved in shrine forests, as typically seen at the Usa Shrine, Ooita, whose main shrine is at the top of a hill supporting a natural forest of *Quercus gilva*. Outside Kyushu, however, *Quercus gilva* now grows very sparsely, almost exclusively in shrine forests (e.g., Abe 1990; Science Museum Net, http://science-net.kahaku.go.jp, referred in 2018), and contradicts with the prevalent use of *Quercus gilva*

for hoes and spades during the Yayoi to Kofun periods. This discrepancy may be the results of intensive felling of *Quercus gilva* trees for hoes and spades and other tools during the historical periods, except in shrine forests, but this scenario cannot explain the present native growth of trees of *Quercus gilva* in the mountains of Kyushu. Thus, to examine the origin of such discrepancy in the present distribution of *Quercus gilva*, more studies about use of plant resources in historic periods seem necessary.

We did not discuss the management of plant resources during the Jomon to Kofun periods in western Japan due to the lack of such studies. However, even in western Japan, the management of plant resources may have been carried out since the Jomon people settled down, similar to modern *satoyama* managed around present villages. A recent study of wooden remains showed that, during the late Yayoi period, such management of *Castanea crenata* resources was carried out at Kagoshima in southern Kyushu near the southern border of its distribution (Noshiro 2016, 2019). Even in the initial Jomon period, the strict selection of basket materials at the Higashimyo site, Saga, using straight supple materials of uncommon arboreal species seemed to imply an existence of the management system of material plants for baskets around the settlement (Noshiro *et al.* 2019). By reviewing pottery types and settlement types of the late Jomon period, Fukunaga (2020), however, indicated that the society structure and sedentism during this period differed between western and eastern Japan and that intensive management of plant resources was not possible in western Japan. Contrarily, in the Yayoi period, with the introduction of rice agriculture and iron tools, *Quercus gilva* came to be used not only as food resources, but also as wood resources, and remained to be an important food plant for crop failures even in this period (Terasawa & Terasawa, 1981; Ishikawa (2010). This marked reliance on *Quercus gilva* both as food and wood resources in the Yayoi period seems to imply an existence of resources management of *Quercus gilva*, but no archaeobotanical proofs showing such management have been obtained so far. In western Japan outside Kyushu, ample use of *Quercus gilva* for hoes and spades through the Yayoi to Kofun period and the decline of its growth through historical periods resulting in its confinement into shrine forests at present also seem to imply management of *Quercus gilva* resources through the Yayoi to Kofun periods in this area. Although domestication of *Quercus gilva* has not been studied so far, domestication for its easily edible fruits may have existed since the initial Jomon period, similar to various tree species of the world (Fuller 2018), and a detailed study of the fruit and seed sizes of *Quercus gilva* may reveal such domestication or management of its resources. At present, it is difficult to discuss reasons why people in western Japan began to use the wood of *Quercus gilva* with the introduction of rice agriculture, due to the lack of any substantial records showing the prior use of timber resources during the Jomon period in this area (Itoh & Yamada 2012). However, use of the wood of evergreen oaks for baskets at the Nakamura cho site, Fukuoka, during the

early to middle Jomon period (Noshiro *et al.* 2012b) clearly shows that the Jomon people in this area already had enough technique and tools to freely process the hard, rigid wood of evergreen oaks into thin and slender basket splints. Thus, the apparent beginning in the use of the wood of *Quercus gilva* from the Yayoi period with the introduction of a new subsistence system seems to be an artifact caused by the lack of studies on the use of timber resources during the Jomon period in this area.

Acknowledgements

This study was partly supported by the JSPS KAKENHI (Nos. JP21300332, JP24240109, JP15H017779). We would like to thank Prof. Hideshi Ishikawa, Meiji University for valuable comments to the first draft of this manuscript and anonymous reviewers whose critical comments greatly helped in improving the manuscript.

References

Abe, K. 1990. *Flora of Tokushima Prefecture*. Tokushima: Kyoiku Shuppan Centre (in Japanese).

Aichi Prefectural Center for Archaeological Operations (ed.) 2013. *The Kamishinano-nishikaneji Site*. Yatomi: Aichi Prefectural Center for Archaeological Operations (in Japanese).

Crawford, G. W., 2008. The Jomon in early agriculture discourse: issues arising from Matsui, Kanehara and Pearson. *World Anthropology* 40: 445–464.

Crawford, G. W., 2011. Advances in understanding early agriculture in Japan. *Current Anthropology* 52: S331–S345.

Crawford, G. W. & H. Takamiya, 1990. The origins and implications of late prehistoric plant husbandry in northern Japan. *Antiquity* 64, 889–911.

Fang, J.-Y., Wang, Z.-H. & Tang, Z.-Y. (ed.) 2009. *Atlas of Woody Plants in China, vol. 1*. Beijing: Higher Education Press.

Forest Bureau Ministry of Agriculture and Commerce (ed.) 1912. *Industrial Use of Wood*. Tokyo: Dai-nippon-sanrin-kai (in Japanese).

Fukunaga, M., 2020. *Jomon Society in Eastern and Western Japan—Study of the Society Structure of the Late Jomon Period—*. Tokyo: Yuzankaku (in Japanese).

Fukuoka Prefectural Board of Education (ed.) 1979. *Excavation Report for the Construction of Sanyo Shinkansen, No. 11*. Fukuoka: Fukuoka Prefectural Board of Education (in Japanese).

Fukushima, T. (ed.) 2017. *Vegetation of Japan, 2nd ed*. Tokyo: Asakura Shoten (in Japanese).

Fuller, D. Q. 2018. Long and attenuated: comparative trends in the domestication of tree

fruits. *Vegetation History and Archaeobotany* 27: 167–176.
Goto, T. 2006. *Study of the Incipient Agricultural Society in the Korean Peninsula*. Tokyo: Doseisha (in Japanese).
Higami, N. 2010. *Regional Society Seen from Wooden Tools—From Yayoi to Kofun—*. Tokyo: Yuzan-kaku (in Japanese).
Hirado City Board of Education (ed.) 1986. *Excavation Report of the Tsuyoshi Site*. Hirado: Hirado City Board of Education (in Japanese).
Hirai, S. 1996. *Encyclopedia of Trees*. Tokyo: Asakura-shoten (in Japanese).
Huang, C.-J., Zhang, Y.-T. & Bartholomew, B. 1999. Fagaceae, in Z.-Y. Wu & P. H. Raven (ed.) *Flora of China*, *vol. 4, Cycadaceae through Fagaceae*: 314–400. Beijing: Science Press.
Iokawa, Y. 2016. Fagaceae, in H. Ohashi, Y. Kadota, J. Murata & K. Yonekura (ed.) *Wild Flowers of Japan. vol. 3*: 88–99. Tokyo: Heibonsha (in Japanese).
Ishida, I., Kudo, Y. & A. Momohara. 2016. Database of Plant Macrofossils from Archaeological Sites in Japan. *Japanese Journal of Historical Botany* 24: 18–24 (in Japanese).
Ishikawa, H. 2010. *Establishment of Agricultural Society.* Tokyo: Iwanami Shoten (in Japanese).
Ito, S., Ohtsuka, K. & T. Yamashita. 2007. Ecological distribution of seven evergreen *Quercus* species in southern and eastern Kyushu, Japan. *Vegetation Science* 24: 53–63.
Itoh, T. & M. Yamada (ed.) 2012. *Archaeological Woods in Japan: Database of Tree Species Used for Excavated Wooden Artifacts*. Ohtsu: Kaiseisha (in Japanese).
Kitakyushu City Foundation for Promoting Arts and Culture (ed.) 2001. *Nagano-konishida Site, 2*. Kitakyushu: Kitakyushu City Foundation for Promoting Arts and Culture (in Japanese).
Kokawa, S. 1979. Plant macrofossils from the valley of the Kadota site, Kamishiromizu, Kasuga City, in Fukuoka Prefectural Board of Education (ed.) *Excavation Report for the Construction of Sanyo Shinkansen, No. 11*: 155–159. Fukuoka: Fukuoka Prefectural Board of Education (in Japanese).
Kudo, Y. 2004. An experimental archaeological study of wood utilization during the Jomon period: experimental felling of trees with stone axes in the Kawatabi experimental farm of Tohoku University. *Japanese Journal of Historical Botany* 12: 15–28 (in Japanese).
Kumamoto Forest Bureau (ed.) 1935. *An Examination of Use and Sawing of Oak Timber in Kyushu*. Kumamoto: Kumamoto Forest Bureau (in Japanese).
Kumamoto Prefectural Board of Education (ed.) 1988. *Sobata—Excavation of Sobata Shell Midden and Lowland, Hanazono Machi, Uto City, Kumamoto—*. Kumamoto: Kumamoto Prefectural Board of Education (in Japanese).
Kurata, S. 1964. *Illustrated Important Forest Trees of Japan, vol. 1*. Tokyo: Chikyu-sha (in Japanese).
Kurume City Board of Education (ed.) 2017. *The Hiwatari Site Cluster, VII—Baskets from*

the 7th Excavation of the Shofukuji site. Kurume: Kurume City Board of Education (in Japanese).

Maekawa, F. 1978. Leaves, fruits, and seeds, in Japanese Archaeological Association (ed.) *Toro—Main Part*. Tokyo: Tokyo-do Shuppan (in Japanese).

Matsui, A. & M. Kanehara., 2006. The question of prehistoric plant husbandry during the Jomon period in Japan. *World Archaeology* 38: 259–273.

Minaki, M. 1993. Plant macrofossils recovered at the Eguchi shell midden, in Archeological Laboratory, Ehime University (ed.) *Eguchi Shell Midden, I—Middel Jomon Period*: 145–148. Matsuyama: Archeological Laboratory, Ehime University (in Japanese).

Miyaji, A. & Minaki, M. 1998. Plant macrofossils excavated at the Tsukuda site, in Hyogo Prefectural Board of Education (ed.) *Tsukuda Site*, vol. 2: 39–51. Kobe: Hyogo Prefectural Board of Education (in Japanese).

Miyamoto, K. 2017. *Early Agriculture in Northeast Asia and the Origin of Yayoi*. Tokyo: Doseisha (in Japanese).

Momohara, A. 1997. *Quercus gilva* forest in the middle part of Boso peninsula in the latest Yayoi – earliest Kofun period. *The Technical Bulletin of Faculty of Horticulture, Chiba University* No. 51: 127–136 (in Japanese).

Mori, S. & Y. Sugiura. 1922. Strength experiment of *Castanopsis*, *Machilus*, and *Cyclobalanopsis* wood. *Bulletin of the Government Forest Experiment Station* No. 22: 103–151 (in Japanese).

Nagasaki Prefectural Board of Education (ed.) 1997. *The Kuromaru Site, II*. Nagasaki: Nagasaki Prefectural Board of Education (in Japanese).

Nakayama, S. 2010. *Archaeobotany and Origin of Agriculture in Japan*. Tokyo: Dosei-sha (in Japanese).

National Museum of Japanese History (ed.) 2014. What is Yayoi Culture? Sakura: National Museum of Japanese History (in Japanese).

Noshiro, S. 2016. Change in the prehistoric use of arboreal resources in Japan—From sophisticated management of forest resources in the Jomon period to their intensive use in the Yayoi to Kofun periods. *Quaternary International* 397: 484–494.

Noshiro, S. 2019. Did the prehistoric use of arboreal resources in Japan change from sophisticated management in the Jomon period to intensive use in the Yayoi to Kofun periods? in S. Shoda (ed.), *Afro-Eurasian Archaeobotany: New perspectives, new approaches*: 163–179. Nara: Nara Cultural Properties Research Institute (in Japanese).

Noshiro, S., Minaki, M., Suzuki, M., Chigusa, H. & K. Maruyama. 2014. Forest vegetation of the initial and middle to final Jomon periods at the northern shore of the Osaka bay and appearance of *Quercus gilva* in this region. *Japanese Journal of Historical Botany* 22: 57–67 (in Japanese).

Noshiro, S., Murakami, Y., Sasaki, Y. & M. Suzuki. 2018. Intensive selection of *Quercus gilva* for hoes and spades of the Yayoi to Kofun periods in western Japan. *Japanese Journal of Historical Botany* 27: 3–15 (in Japanese).

Noshiro, S. & Y. Sasaki. 2011. Identification of Japanese species of evergreen *Quercus* and *Lithocarpus* (Fagaceae). *IAWA Journal* 32: 383–393.

Noshiro, S. & Y. Sasaki. 2013. Pre-agricultural management of plant resources during the Jomon period in Japan—a sophisticated subsistence system on plant resources. *Journal of Archaeological Science* 42: 93–106.

Noshiro, S. & Y. Sasaki. 2014. Management of forest resources during the Jomon period in Japan deduced from excavated plant remains. *Bulletin of the National Museum of Japanese History* No. 187: 15–47 (in Japanese).

Noshiro, S., Sasaki, Y., Kobayashi, K., Suzuki, M. & I. Nishida. 2019. Material selection and weaving techniques for the oldest basketry in Japan found at the Higashimyou site, Saga Prefecture. *Journal of Archaeological Science: Reports* 23: 12–24.

Noshiro, S., Sasaki, Y., Suzuki, M. & Y. Murakami. 2012a. Use of the timber resources of *Quercus gilva* in the Kanto district, central Japan, during the Yayoi to Kofun periods. *Japanese Journal of Historical Botany* 21: 29–40 (in Japanese).

Noshiro, S., Suzuki, M., Kobayashi, K. & Y. Sasaki. 2012b. Identification of materials used for baskets recovered in the fifth excavation of the Nakamuracho site, in Fukuoka City Board of Education (ed.) *Nakamuracho Site* 4: 46–49. Fukuoka: Fukuoka City Board of Education (in Japanese).

Obata, H. 2011. *Palaeo-ethnobotany in Northeastern Asia and Agriculture in the Jomon Period*. Tokyo: Dosei-sha (in Japanese).

Obata, H., Sasaki, Y., & Senba, Y. 2007. Impressions on pottery revealed cultivation of *Glycine max* subsp. *max* (soybean) in the late to latest Jomon periods in Kyushu Island. *Japanese Journal of Historical Botany* 15: 97–114 (in Japanese).

Ogori City Board of Education (ed.) 1994. *The Ichinokuchi Site, Location No. 1*. Ogori: Ogori City Board of Education (in Japanese).

Ohba, H. 2006. Fagaceae, in K. Iwatsuki, D.E. Boufford & H. Ohba (ed.) *Flora of Japan*, *vol. IIa* : 42–60. Tokyo: Kodansha.

Okamoto, Y. 1979. *Quercus gilva*, excavated in ancient human sites. *Bulletin of the Osaka Museum of Natural History* No. 32: 31–39 (in Japanese).

Onaka, F. 1939. On the ancient wooden implements of " Yayoi " type (over 2000 years ago) discovered at Karako, Yamato Province, Japan. *Japanese Journal of Forestry, Conference 1939*: 439–545 (in Japanese).

Saga City Board of Education (ed.) 2016a. *The Higashimyou Site Cluster, IV—The Higashimyou Site Cluster Synthesis Report—, vol. 1*. Saga: Saga City Board of Education (in Japanese).

Saga City Board of Education (ed.) 2016b. *The Higashimyou Site Cluster, IV—The Higashimyou Site Cluster Synthesis Report—, vol. 3*. Saga: Saga City Board of Education (in Japanese).

Sasaki, Y. 2011. Plant use and cultivation during the Jomon period, in *International Symposium: Achievement and Problems of Archaeobotany in East Asia*: 25–34. Seoul University, Kumamoto University (in Japanese).

Sasaki, Y. 2014. Regional differences in vegetation and use of plant resources. *Archaeology Quarterly, Special Issue* 21: 25–34. Seoul University, Kumamoto University (in Japanese).

Sasaki, Y. & S. Bhandari. 2012. Charred seeds and fruits recovered from the third excavation at the Hiramine site, in Miyazaki Prefecture Archaeological Center (ed.), *Hiramine Site, Third Excavation*: 84–86. Miyazaki: Miyazaki Prefecture Archaeological Center (in Japanese).

Sasaki, Y., Kudo, Y. & A. Momohara. 2007. Utilization of plant resources reconstructed from plant macrofossils during the latter half of the Jomon period at the Shimo-yakebe site, Tokyo. *Japanese Journal of Historical Botany* 15: 35–50 (in Japanese).

Sasaki, Y. & S. Noshiro. 2018. Did a cooling event in the middle to late Jomon periods induced change in the use of plant resources in Japan? *Quaternary International* 471: 369–384.

Shiga Prefectural Board of Education (ed.) 1997. *Excavation Report of the Anou Site 2*. Ohtsu: Shiga Prefectural Association for Cultural Heritage (in Japanese).

Shiga Prefectural Board of Education (ed.) 2013. *The Rokutanda Site, II*. Ohtsu: Shiga Prefectural Association for Cultural Heritage (in Japanese).

Smith, D. S. 2001. Low-level food production. *Journal of Archaeological Research* 9: 1–43.

Terasawa, T. & K. Terasawa. 1981. Study of the plant food of the Yayoi period—Premise for the study of the incipient agricultural society—. *Proceedings of the Kashiwara Archaeological Institute, Studies in Archaeology* No. 5: 1–129 (in Japanese).

Wood Technology and Wood Utilization Division. 1982. Properties of the important Japanese woods. *Bulletin of the Forestry & Forest Products Research Institute* No. 319: 85–126 (in Japanese).