

SPECIAL FEATURE

Listen to the voices of local beech forests: An ecological and evolutionary conception of beech under phylogenetic and environmental constraints

Optimizing species selection for the structural timbers of traditional farmhouses in a snowy rural area of northeastern Japan

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Abstract

Vernacular houses constructed using local woods contain information about forest-resource use. To clarify how timber was used to construct wooden farmhouses, we identified the timber species composition of 11 houses built between 1845 and about 1940 in Tadami, a snowy rural area in northeastern Japan, and interviewed 70 residents. We recorded 2004 timber parts (99–308 parts per house) and 171.2 m³ (1828 parts) of known species (14 taxa). *Cryptomeria japonica* (cedar) and *Pinus parviflora* var. *pentaphylla* (white pine) were used for all essential structural parts and accounted for 44% and 39% of the total timber volume, respectively. *Fagus crenata* (beech) was the third most commonly used species (7%), for roof supports, beams, and girders. The interviews revealed that the timber was typically sourced from local private or common woodlands within 1 km and that local craftsmen selected and hauled the trees. Considering the region's unique and complex vegetation, as land-cover distribution is strongly influenced by frequent avalanches, the timber was likely managed within local stands of tall trees, and the most available species would have been cedar (although whether native or planted is unknown), followed by native white pine on mountain ridges around settlements. In comparison, beech stands that could supply sufficient amounts of timber might have been limited. Based on the characteristics of the trees used as house timber in Tadami, we conclude that despite the surrounding harsh, snowy conditions, locally available species of tall trees were historically selected for timbers.

KEYWORDS

forest-resource use, Japanese wooden house, timber species choice, traditional ecological knowledge, vernacular architecture

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1 | INTRODUCTION

Vernacular houses are constructed using local natural resources and are adapted to the local climate and geographic features. Such houses are the product of a transfer of knowledge pertaining to restoration and improvement over generations. Applying such local knowledge is essential to develop sustainable, resilient social, and ecological systems (Kim et al., 2017; Takeuchi, 2010). In particular, the tree species and use of timbers in traditional wooden structures, which are rapidly disappearing worldwide, reflect the past vegetation landscape as well as regional utilization of forest resources. Therefore, clarifying the species, quantities, sizes, dendrochronology, and parts of timber used have great significance for revealing the history of forest-resource management (Haneca et al., 2009; Rackham, 1972).

In Japan, traditional vernacular houses are timber-framed. In rural areas, farmhouse construction using local wood resources employed a variety of tree species, in line with the diversity of forest vegetation across the Japanese Archipelago (Kawashima, 1986; Nunotani & Nakao, 1986). Japanese farmhouses generally contain ecological information about the tree species that provided timbers, and thus the woodlands or other landscapes in which those trees grew, as well as on the past use of such trees as a forest resource (Ida, 2017). The value of traditional Japanese architectural craftsmanship in timber-framed structures is recognized worldwide, as evidenced by their inclusion in the Intangible Cultural Heritage List of the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2020). Unfortunately, due to socioeconomic conditions, that is, depopulation, an aging population, and changes in industrial structure, demolition of traditional structures is progressing rapidly across Japan, and the number of elders and craftspeople with essential knowledge about forest-resource use is decreasing. Therefore, identifying and evaluating diverse information sources in surviving traditional farmhouses is urgently needed to support the sustainable use and management of local natural resources. In addition, such efforts may provide important basic information for local stakeholders involved in the conservation of local cultural heritage.

Most studies of wooden houses worldwide have aimed to determine their value and assess their historical and cultural significance from the perspectives of architecture (form, technique, material, or design), ethnology, and anthropology (Cobancaoglu, 2001; Esin & Yükses, 2010; Karahan & Davardoust, 2020; Karaman & Zeren, 2013; Morel et al., 2001; Wang et al., 2021), with few investigating the manner in which wood was used for construction and associated historical forest-resource utilization (Duguma &

Hager, 2010; Grabner et al., 2017; Klein & Grabner, 2015). Even in Japan, few studies have examined wooden construction in terms of forest-resource use (Ida, 2017; Ida et al., 2010; Nunotani & Nakao, 1986; Oku et al., 2009).

In previous studies, we investigated traditional farmhouses from the mid-18th century to early 20th century that were built in a rural area in central Japan that receives heavy snowfall (Ida, 2017; Ida et al., 2010; Nakama et al., 2016), and we found that their structural timbers were mainly composed of Siebold's beech (*Fagus crenata*, beech hereafter), Japanese oak species (*Quercus crispula* var. *crispula* or *Quercus serrata*, oak), and Japanese cedar (*Cryptomeria japonica*, cedar). Beech may have been selectively used for structural elements that bore heavy snow loads because beech trees form dominant stands in regions with heavy snowfall along the Sea of Japan (Sasaki, 1970) and due to their sturdiness and adaptation to remain upright under heavy loads (Homma, 1997). Although beech has been used as a structural timber in temples and farmhouses in mountainous areas dominated by beech forests (Kitajima, 1933), little is known about whether such usage was a local tradition or only an occasional choice. Beech is currently considered unsuitable for building construction due to its tendency to twist and rot. As the use of beech as house timber may be only a local tradition, studies should examine whether similar usage occurred in other areas that are similar to the present study area with large beech resources.

The purpose of this study was to clarify the manner in which timber was used as a forest resource for constructing traditional wooden buildings in landscapes where the harsh natural environment placed restrictions on people's way of life and the growth of trees. Specifically, we focused on the timber species used in a settlement surrounded by beech forest that has some of the heaviest snowfalls worldwide, determined the species used for structural timbers, and systematized traditional knowledge about species choice in light of local forest vegetation. This re-evaluation of traditional timber use has important implications for the development of modern communities adapted to their local natural environment.

2 | MATERIALS AND METHODS

2.1 | Study sites

This study was conducted in Tadami Town (747.53 km²; 350.0–1819.9 m asl; Figure 1), a rural municipality in Fukushima Prefecture, northeastern Honshu, Japan, designated as a Biosphere Reserve under UNESCO's Man and the Biosphere Programme. At Tadami meteorological station (37°20.6'N, 139°18.8'E, 377.0 m asl), the mean

residential areas, including cultivated land, is 2.3%. These values were calculated from a 1:25,000 vegetation map made by the Japanese Ministry of the Environment (Biodiversity Center of Japan, 2019).

2.2 | Investigated farmhouses

In Tadami, 157 traditional farmhouses were standing in 2017 according to our preliminary local report (Ida, 2020). Of these, 11 farmhouses (built from 1845 to around 1940) at elevations of 370–518 m asl in 11 villages were analyzed (Figure 1), including data for four houses (Figure 2b,d,h,j) in addition to the seven houses (Figure 2a,c,e,f,g,i,k) assessed in the local report cited above. Although these houses had been extended and renovated to some extent to accommodate modern lifestyles, the basic framework remained unchanged. The architectural forms include a cruck-framing structure (a Japanese traditional roof truss) and a thatched roof and are distinctively characterized by features known as *chumon tsukuri* (L- or T-shaped plan) (Tsukidate & Noguchi, 2000). The convex part of a *chumon tsukuri* was typically the entrance hall, with a stable and storage. One house (Figure 2d) had been reduced to the *chumon* (convex) portion. At present, their original thatched roofs have been covered with tin to allow accumulated snow to slide down naturally.

2.3 | Size measurement and species identification of timber parts

Between 2015 and 2021, the length, thickness (the long and short sides of squared timbers or the diameter of logs), and the species of timber parts used in the farmhouses were recorded. With the permission of the owners, each of the timber parts was investigated individually as far as possible, excluding parts that were difficult to access for structural or safety reasons; thus, the number of roof trusses, foundations, and fixture elements inspected varied substantially among the surveyed houses. Relatively few timber parts were investigated in currently occupied houses.

The procedure for identifying timber species was previously detailed by Ida (2017). In brief, species were determined by observing the anatomical features of three thin sections (end, edge, and flat grains) of wood tissue prepared from each timber under a microscope in the laboratory. As the two pine species (red and white pine) could be identified only to the subgenus level (*Pinus* subg. *Diploxylon* sp. and *P.* subg. *Strobus* sp., respectively) by observing wood tissues, we determined the species from the status of the present vegetation, and through interviewing residents about the traditional timber species.

The timber parts were defined as diagonal elements (crucks in structured roofs), transverse elements (beams, girders, joints, lintel, doorsill, roof purlins, bracket, and ridge-poles), longitudinal elements (pillars and short supports),

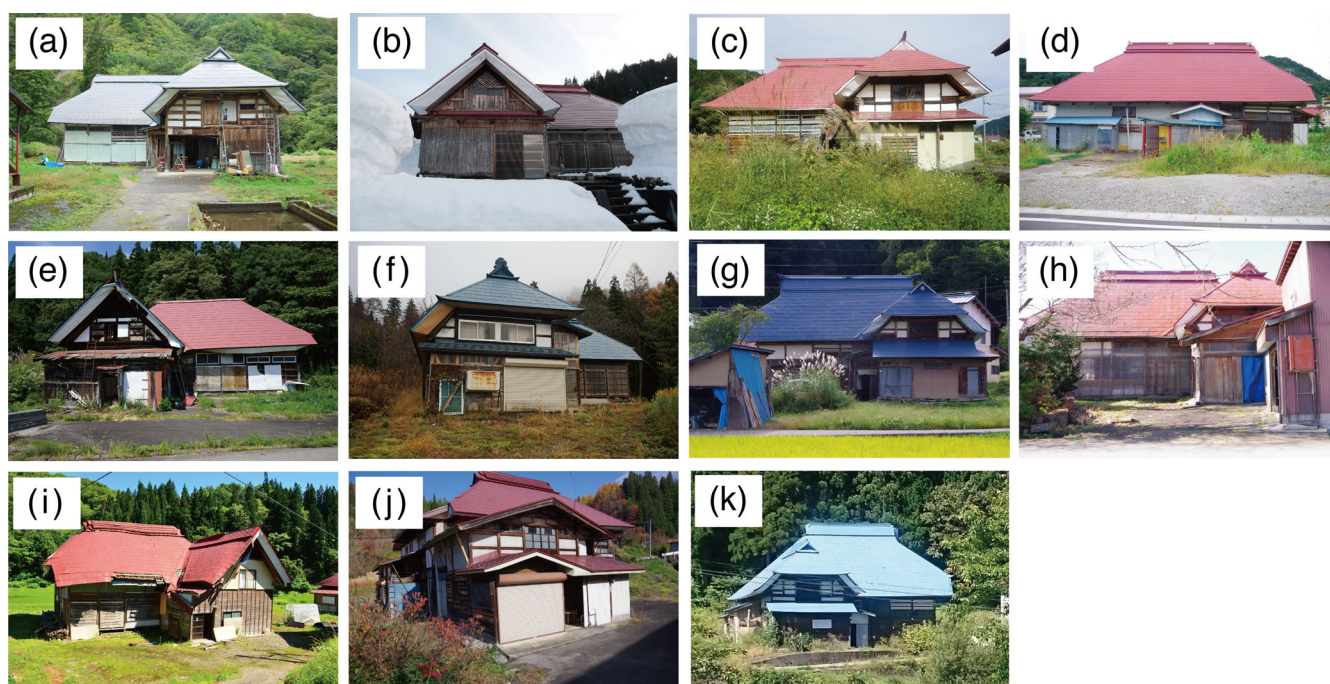


FIGURE 2 The farmhouses in Tadami investigated in this study. Data for four houses (b,d,h,j) were added to the seven houses (a,c,e,f,g,i,k) assessed in the local report of Ida (2020). Each location can be shown in the bottom map in Figure 1. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

TABLE 1 Farmhouse descriptions, number of timbers with identified species for each farmhouse, and summed volume of species-identified timbers for 11 houses investigated in Tadami, northeastern Japan.

Farmhouse ID Floor area (m ²) Elevation of location (m)	a	b	c	d	e	f	g	h	i	j	k	Total				Summed volume of species-identified timbers					
												number of species- identified timbers					n	%	n	m ³	%
												1845	1853	1868– 1869	1887						
Construction year (<i>italics indicate estimated years</i>)	1845	1853	1868– 1869	1887	1890	1900– 1926	1915	1900– 1920	1932	1920– 1940	1920– 1940										
Timber species (<i>common name used in the present study</i>)																					
<i>Cryptomeria japonica</i> (cedar)	37	97	16	222	104	18	1	157	35	167	46			900	44.9	812	75.9	44.4			
<i>Pinus parviflora</i> var. <i>pentaphylla</i> (white pine)	95	36	107	65	42	48	121	84	51	7	159			815	40.7	751	66.9	39.1			
<i>Fagus crenata</i> (beech)	—	34	—	3	—	15	4	—	12	—	13			81	4.0	80	11.6	6.8			
<i>Pinus densiflora</i> (red pine)	—	—	2	1	4	5	4	9	—	11	13			49	2.4	46	6.1	3.6			
<i>Castanea crenata</i> (chestnut)	3	3	1	3	4	5	4	17	6	1	9			56	2.8	48	3.9	2.3			
<i>Zelkova serrata</i> (zelkova)	4	—	—	5	3	—	—	1	13	6	1			33	1.6	27	3.1	1.8			
<i>Phellodendron amurense</i> var. <i>amurense</i>	—	1	—	—	—	—	—	—	1	1	2			5	0.2	4	1.1	0.6			
<i>Thuja standishii</i>	—	2	1	—	1	8	—	—	—	—	—			12	0.6	12	0.9	0.5			
<i>Magnolia obovata</i>	3	1	—	7	—	—	—	22	3	—	—			36	1.8	31	0.8	0.5			
<i>Larix kaempferi</i> (larch)	—	1	—	—	—	—	—	3	—	4	—			8	0.4	8	0.6	0.3			
<i>Cerasus</i> spp.	—	—	—	—	—	—	—	—	—	3	—			3	0.1	3	0.2	0.1			
<i>Quercus</i> spp. (<i>Quercus crispula</i> var. <i>crispula</i> or <i>Quercus serrata</i>) (oak)	—	—	—	2	—	—	—	—	—	2	—			4	0.2	4	0.1	0.1			
<i>Acer</i> spp.	—	—	—	—	—	—	—	—	—	1	—			1	< 0.1	1	0.1	< 0.1			
<i>Abies</i> spp.	—	1	—	—	—	—	—	—	—	—	—			1	< 0.1	1	< 0.1	< 0.1			
Total number of species-identified timbers	142	176	127	308	158	99	134	293	121	203	243			2004	100.0	—	—	—			
Total number of timbers used in the volume calculation	110	140	121	308	147	99	133	293	71	176	230			—	—	1828	—	—			
Summed volume of species-identified timbers (m ³)	11.2	12.8	17.0	23.2	16.8	9.5	11.3	17.0	10.1	20.1	22.1			—	—	—	171.2	100.0			

Note: Data for four houses (b, d, h, j) were added to our original data from Ida (2020).

foundation elements (groundsill, sleepers, and joists), and fixture elements (interior finishing and installation materials).

To compare timber size (length, thickness [long side or diameter], cross-sectional area, and volume) among major timber species (cedar, white pine, and beech), the Kruskal–Wallis nonparametric test was used, followed by the Steel–Dwass multiple-comparison test, as homogeneity of variance was not confirmed by Bartlett's test for all datasets. All analyses were performed in R 4.2.2 (R Core Team, 2022). To calculate timber volume, we used parts for which length and thickness had been measured and the species identified. The size structure of major species was examined in essential structural parts, namely crucks (equal to the diagonal elements), beams/girders (extracted from transverse elements), and pillars (extracted from longitudinal elements).

2.4 | Interview survey

Residents who live in, manage, or previously lived in such farmhouses were interviewed regarding the traditional use of forest resources associated with housing in Tadami. Between June 2015 and November 2020, we visited homes and conducted on-site interviews lasting approximately 1–2 h with a total of 70 households, including those noted above. We summarized the 43 households included in the survey in a preliminary local report (Ida, 2020). In the present study, we summarized the results of all interviews regarding the timber species used in the farmhouses, the source of the timber, the means of transporting the timber (logged trees), craftsmen such as timber selectors and carpenters, and any associated information. For some timber species, scientific names were determined from local names.

3 | RESULTS

3.1 | Species composition of timber parts

We recorded 2004 timber parts of known species (14 taxa), ranging from 99 to 308 parts per house (Table 1). The number of species ranged from 5 to 10 per house. Cedar, white pine, and chestnut were used in all 11 houses. We found red pine, zelkova, beech, and *Magnolia obovata* in eight, seven, six, and five houses, respectively, *Phellodendron amurense* var. *amurense* and *Thuja standishii* in four houses each, larch in three, oak in two, and *Cerasus* sp., *Acer* sp., and *Abies* sp. in one house each.

Cedar (45% of the total number of timbers from identified species) and white pine (41% of the total number) accounted for 44% and 39% of the total timber volume (171.2 m³, $n = 1828$), respectively. Beech (4% of the total

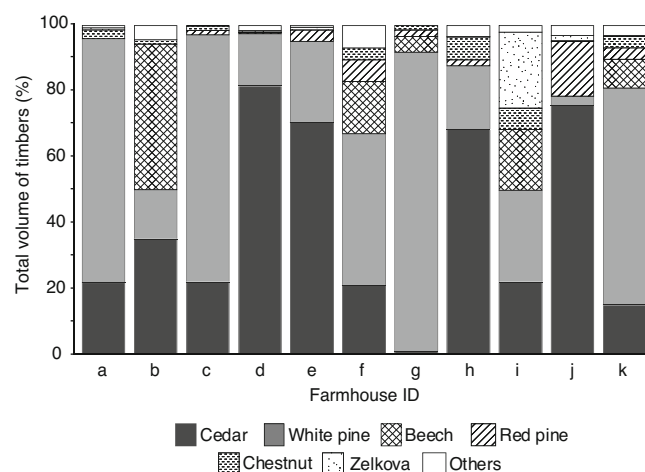


FIGURE 3 Timber species composition in each house based on volume. Data for four houses (b,d,h,j) were added to the seven houses (a,c,e,f,g,i,k) assessed in the local report of Ida (2020). The total volumes of timbers for each house can be shown in Table 1.

number) was the third most commonly used species in terms of volume (accounting for 7% of the total volume). Each of the other species accounted for <3% of the total number and 4% of the total volume of timbers.

The species composition of timbers by volume in each house shows that cedar was dominant in four houses (Figure 3d,e,h,j; 68%–82%), while white pine dominated four houses (Figure 3a,c,g,k; 66%–91%). The cedar-dominated houses (except for Figure 3j) were on terraces alongside a large river, while the white-pine-dominated houses (except for Figure 3k) were in narrow valley settlements on the south side of the river (Figure 1). Beech was relatively abundant, accounting for 16%–44% of timbers in the other three houses (Figure 3b,f,i), and zelkova was most abundant in Figure 3i (23%) among all houses. Red pine accounted for 17% of timber volume in Figure 3j, which was its highest abundance among all houses. All other species accounted for ≤7% per house.

The element composition of timber volume for each major species showed that cedar and white pine were used in diverse elements (Figures 4 and 5), including in a small number of fixtures (white pine only; $n = 3$). Beech was found only in diagonal and transverse elements. Chestnut was frequently used for foundation elements. Red pine tended to be selected for transverse timbers and zelkova for longitudinal timbers; these elements had large diameters.

3.2 | Size structure of major species used as timber

The size structure of all timber parts for the three major species (cedar, white pine, and beech) indicated that

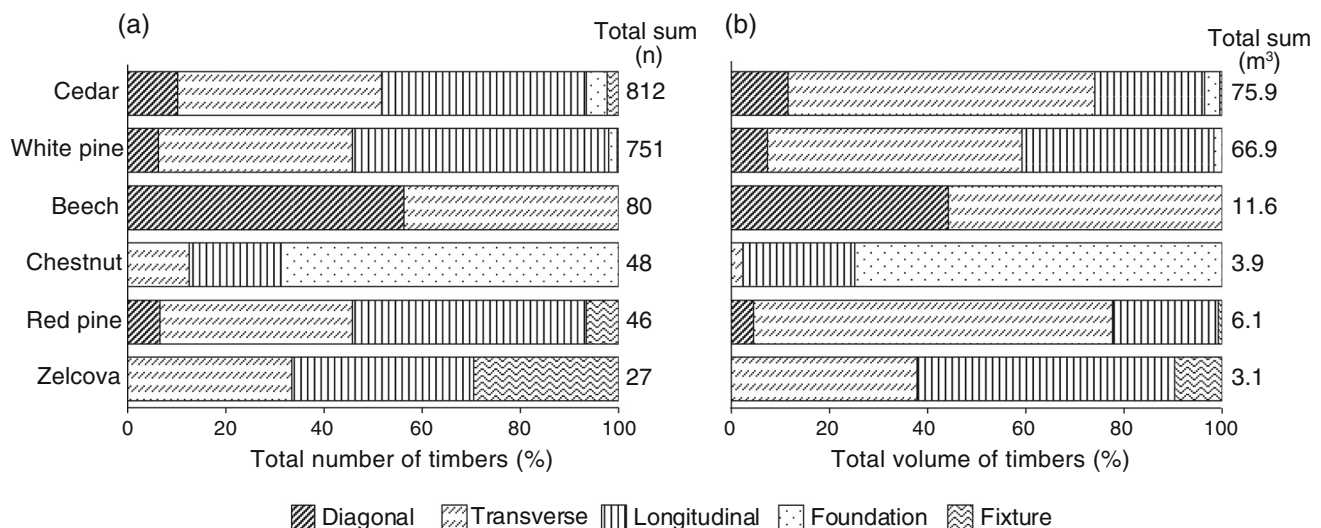


FIGURE 4 Element composition of the timber from each major species in (a) number and (b) volume used in the 11 farmhouses investigated in Tadami. Data for four houses were added to the report of Ida (2020).

beech timbers had the greatest thickness, cross-sectional area, and volume, followed by white pine and cedar ($p < 0.05$), implying that beech timbers were used exclusively for long, thick parts. No significant difference in length was found between white pine and cedar (Figure 6). Among the essential elements, crucks commonly consisted of timbers 10–20 cm in thickness and 4–8 m in length, with beech being the better-represented species in this size class (Table 2). A wide range of beam and girder sizes was observed, and timbers 10–20 cm in thickness and 4–8 m in length were most common for all species. Larger timbers (≥ 30 cm in thickness and ≥ 8 m in length) were comprised of cedar and beech. The greatest lengths were 14.58 and 10.07 m for cedar and beech, respectively, and the greatest respective thicknesses were 48 cm (estimated) and 40 cm. The pillar sizes of both cedar and white pine ranged widely, but timbers 10–20 cm in thickness and 2–4 m in length were the most common. Pillar sizes appeared to be more standardized than beam and girder sizes. Moreover, white pine accounted for more pillars greater than 20 cm in thickness than cedar.

3.3 | Interviews regarding the building histories of farmhouses

In the interviews with 70 households in Tadami, 12 species names were mentioned by 60 households regarding the timber species used in traditional farmhouses: cedar (44 responses), zelcova (26), chestnut (25), white pine (18), red pine (16), beech (11), *Magnolia obovata* (4),

Aesculus turbinata (4), *Q. crispula* var. *crispula* (4), *Phellodendron amurense* var. *amurense* (2), *Kalopanax septemlobus* (1), and *Styphnolobium japonicum* (1, used as an ornamental part in a *tokonoma*, Japanese-style alcove). Most respondents indicated that oak, beech, or both were also commonly used as fuelwoods.

Thirty-seven households responded regarding the source of the timber, which in all cases was woodland in the local neighborhood. Of these responses, 10 households stated that they or their relatives owned the woodlands, and three stated that the woodlands were managed jointly by villages. The logged trees had been brought down from the mountains by sleds on snow (10 responses), by rafts on a river (13), or both (1). The exact location of the woodland source of timbers was identified in only one case. For that house (Figure 2a, built in 1845), the owner stated that white pine timbers were sourced from a private stand on the ridgeline located about 1 km away and about 150 m higher; these were cut down by *motoyama* (see below) during the winter (mainly in February) and transported on sleds over snow.

Twenty-eight households recognized the former presence of timber selectors as craftsmen. They were local people (13 responses), followed by *motoyama* (11), which is the local name for craftsmen who specialize in selecting, logging, hauling out, and sawing timber. The *motoyama* craftsmen selected trees suitable for house timber in the woodlands designated by the client based on the carpenter's master design (Tadami Town History Compilation Committee, 1993). According to an elder person familiar with the local history, there used to be

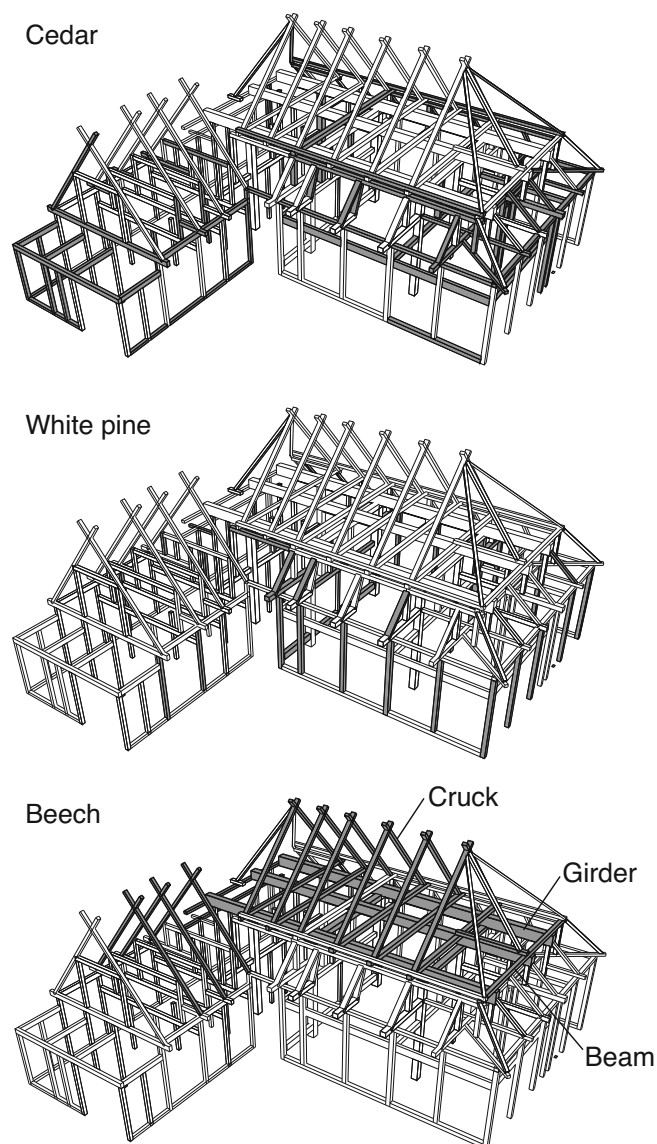


FIGURE 5 Example framework showing the major species and their utilization (shaded area) in farmhouse b in Tadami.

one or two *motoyama* in each village. Some residents noted that trees logged from woodlands in the spring were immediately used to construct houses, implying that timber would have been sawn and used for houses without being sufficiently dried.

Thirty-two households responded to the question about the origin of carpenters who built the houses by referring to *Echigo-daiku* carpenters (17 responses), who were migrant workers from Echigo, the former provincial name of the central region of Niigata Prefecture (Figure 1), which is adjacent to the northwest part of Tadami, and local carpenters (15), including the apprentices of Echigo carpenters. These carpenters sometimes reused timber parts from demolished houses for houses in other villages.

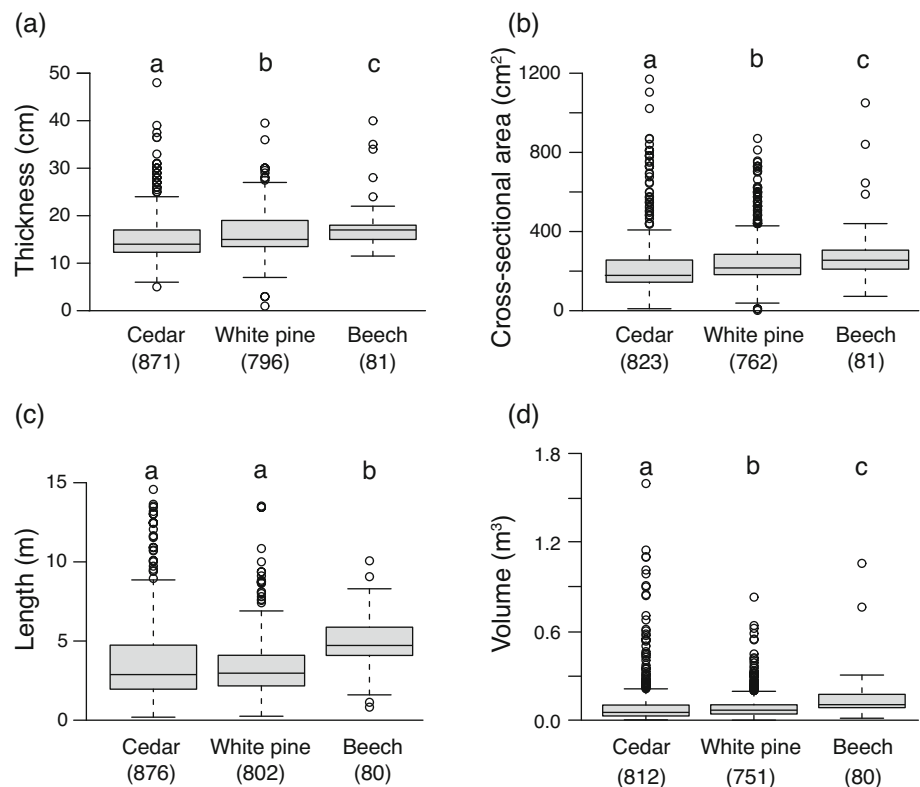
4 | DISCUSSION

4.1 | Relationship between vegetation and timber species

In Tadami, cedar and white pine constituted the majority of timbers used in all of the farmhouses surveyed, and beech was also used in approximately half of the houses (Table 1, Figure 3). The tree species identified fell into 14 taxa, all of which are currently distributed in this region. The interviews revealed that the timber was typically sourced from private or common woodlands located within about 1 km of a given settlement. In addition, craftsmen known as *motoyama* selected and logged trees from the woodlands and transported them over the snow on sleds.

The cedar timber used most extensively in the houses is thought to have been sourced locally; however, there was no evidence to indicate whether it had originated from planted or natural sources, and no statements made during the interviews clarified this issue. Most existing cedar plantations are likely unrelated to the original house timbers, instead being the result of expansive afforestation after World War II. These plantations were established in areas where old-growth beech stands had been clear-cut, or where semi-natural *Miscanthus sinensis* grasslands had been used to produce roofing thatch, hay, and fertilizer (Tadami Town History Compilation Committee, 2001). These land-use changes were confirmed by our interviews with residents. Although cedar silviculture was actively practiced in the early 20th century in Tadami, no large cedar plantations were observed at that time (Miyamoto et al., 2014), implying that planting was conducted in small patches or units of a few trees before then. In Iiyama, which is in the northern part of Nagano Prefecture (shown in Figure 1) and has heavy snowfall similar to Tadami, individual cedar trees were planted around houses in commemoration of the birth of a child, to use for future repairs (H. Ida, personal communication). Currently, few native cedar stands are present in Tadami, except in a mountain area near the eastern border with Kaneyama (Kimura et al., 2014). This site was a common woodland where large-diameter cedars were supplied for sake barrels before the end of the Edo period (in 1869); however, residents prohibited logging in 1902 due to overuse (Nakamoto & Watabe, 1959). Traditional artificial planting of cedar began on common land used by farmers throughout Japan during the late 17th and 18th centuries (Iwamoto, 2002; Totman, 1989). Although planted cedar does not grow well in mountainous areas with heavy snowfall (Masaki et al., 2004; Yokoi & Yamaguchi, 2000), by analyzing documents from 1844 and 1863 found in a

FIGURE 6 Comparison of timber size in (a) thickness, (b) cross-sectional area, (c) length, and (d) volume among the major species used in farmhouses in Tadami. Different letters represent significant differences among species (Steel–Dwass multiple-comparison test, $p < 0.05$). Numbers in parentheses indicate the numbers of timbers used in the calculations.



snowy rural site in central Japan, Aoyagi et al. (2018) determined that jointly managed cedar plantations supplied the house timbers. Because the cedar-dominated houses in Tadami were mostly on terraces alongside a large river, cedar was likely planted on these terraces for timber use. The origin of the cedar timbers requires further investigation.

White pine, which was the second most frequently used species in the farmhouses investigated, grows naturally in rows along ridgelines that have poorly developed soil due to erosion caused by avalanches (Shimokawa, 1981). Although the forest coverage of white pine is far smaller than the beech forest area (Figure 1), the distribution of ridgeline stands has been reported in this district since at least the early 20th century (Miyamoto et al., 2014). Native white pine stands are too narrow to be represented on vegetation maps, but they remain common on the mountains behind settlements (Figure 7). They have been described as having a horse-mane appearance and are still recognized by local residents as a major feature of the regional landscape in Tadami. The white pine tree is straight, thick, easy to saw and dry, and has little distortion (Wood Technological Association of Japan, 1989), making it ideal for structural timber. Our interviews revealed that white pine timbers were obtained from the ridgeline stands. According to our interviews, white pine was not afforested on the ridges but rather was maintained or regenerated through

selective logging for timber use. Within the white pine population, we observed wide ranges in diameter at breast height and height (Ida, 2020), as well as juveniles (Ida et al. unpubl. data), implying that white pine regenerates and maintains dominance along the narrow ridge-line. It is essential to examine the relationship between the usage practices and regeneration dynamics of these white pine stands, because they played an important role in supplying timber.

Beech was used in 6 of 11 farmhouses surveyed, and the numbers and volumes of beech timbers used varied widely among houses, from 3 to 34 and <1% to 44%, respectively (Table 1, Figure 3). Why did beech not predominate as a house timber given that beech forests dominate in Tadami? Considering that timber was sourced locally, the number of villages with beech stands that could supply sufficient timber is assumed to have been limited. The most suitable habitat for beech stands in Tadami is on gentle slopes formed by sediment deposited on lower-slope areas after erosion due to avalanches (Suzuki et al., 2016), but some may have been replaced by cedar plantations after World War II. These beech stands have historically been used to produce fuelwood and are thinly distributed in the neighborhood of settlements (Suzuki et al., 2013, 2014; Suzuki & Nakano, 2013). Suzuki et al. (2014) demonstrated that the greatest diameter at breast height class was 50–70 cm in a 70- and 80-year-old secondary stand and 100–110 cm

TABLE 2 Frequency distribution of the thickness and length of timbers for the major species by each element used in farmhouses in Tadami.

Elements	Species	Length class (m)	Thickness class (cm)			
			<10	≥10	≥20	≥30
Cruck	Cedar	≥8		13		
		≥4		36	6	
		≥2		16		
		<2	1	11		
	White pine	≥8		1		
		≥4	2	21	3	
		≥2		12	2	
		<2		5		
	Beech	≥8		3		
		≥4		35	2	
		≥2		4		
		<2		1		
Beam/girder	Cedar	≥8		15	20	9
		≥4		62	19	5
		≥2		49	16	1
		<2		33	15	
	White pine	≥8		6	9	
		≥4		33	30	
		≥2		23	10	
		<2	1	21	6	
	Beech	≥8				1
		≥4		12	7	
		≥2		3	2	
		<2		4		
Pillar	Cedar	≥8				
		≥4		50	3	
		≥2	6	187	2	
		<2	2	70		
	White pine	≥8				
		≥4		52	11	
		≥2		255	10	
		<2		61	4	

Note: No beech was found in the pillar.

in an old-growth stand remaining in the neighborhood of settlements. The beech trunks in these stands are straight, providing the long timbers required for building materials (the largest beech timber identified in this study was 10.07 m long and 40 cm thick). Therefore, despite their limited location and stand size, in villages where beech stands occurred in the neighborhood, large-diameter beech trees generated during fuelwood production could have been selectively used as building materials.

4.2 | Timber species selection

Among structural timbers, we found that beech was selected only for roof supports (crucks) and transverse elements (beams and girders) (Figures 4 and 5). There was also a tendency to use longer or thicker beech compared with cedar and white pine (Table 2 and Figure 6), implying that long, thick beech timbers were chosen for crucks, beams, and girders. Thatched-roof farmhouses in snowy areas such as Tadami must resist heavy snow



FIGURE 7 Current vegetation landscape showing native ridgeline white pine stands behind the farmhouse e in Tadami (November 14, 2022). [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

loads. Beams and girders support the entire roof and have to be extremely strong (Horie & Yagi, 1997); thus, timbers with large cross-sections are generally selected. Crucks typically require long, straight timbers, and high bending strength is needed in snowy regions with heavy snow loads on roofs (Tsukidate & Ito, 1991). The bending strength of the timbers in the traditional farmhouses located in a snowy rural region showed that beech was superior to cedar and oak (Hamasaki et al., 2016), reflecting the high snow-pressure tolerance of living beech trees (Homma, 1997; Miyashita et al., 2020). Some local reports have noted the use of beech for roof structures, beams, and girders in the heavy-snowfall area along the Sea of Japan on Honshu (Chiba, 1990; Fukamachi et al., 1998; Ida, 2017; Mifune, 2003); this was confirmed empirically in the present study. In addition, cedar (Itagaki et al., 2005) and white pine were typically used for all essential structural parts in Tadami, indicating that timber species selection depended on tall tree stands (and occasionally individuals) in and around settlements.

The results of the timber species analysis conducted in the farmhouses of Tadami support a local document (Tadami Town History Compilation Committee, 1993) reporting interviews with five residents born between 1905 and 1924 in three villages. The interviews concerned the timber species selected by *motoyama* craftsmen, and detailed that cedar and white and red pine were chosen for beams, girders, and pillars in all three villages, while beech was chosen for crucks in one village. We found that, for one farmhouse (Figure 2i, built in 1932), beech was used for crucks.

Red pine, which was present in 8 of the 11 houses surveyed in this study, is a representative species of secondary rural forest with a large range in Japan. It is commonly used for transverse timber in traditional houses (Tanaka et al., 2022). In Tadami, red pine is often mixed with white pine on the ridgeline; such individuals were likely logged for timbers. *Thuja standishii* was present in some houses, and also occurs in white pine stands; this implies a similar source to red pine. Chestnut, which is distributed throughout Japan as a major component of secondary stands together with red pine and oak, also occurs in white pine stands (Ida, unpubl. data). Because chestnut is generally resistant to moisture, this species was commonly used for the foundations of traditional wooden houses. Similar use of a member of the same genus, European chestnut (*Castanea sativa*), has been reported in Turkish vernacular houses (Cobancaoglu, 2001). Zelkova has traditionally been considered a valuable wood in Japan due to its strength and unique grain, and may have been selected for important features such as the main pillar or alcove post for design reasons. The larch used in a few houses was afforested in this area during the same period of expansive cedar afforestation, and shows little natural growth in Tadami (Tadami Town History Compilation Committee, 2001). The larch timbers found in the houses in this study were associated with additions and renovations, implying that post-war plantation-origin timber was used for that purpose. Other timber species, including zelkova, appear to have been harvested as large-diameter trees from deciduous forests, such as beech forests and riparian stands.

In conclusion, given the snowy and harsh environment of Tadami, tall individuals of various local tree species were selected and used as house timbers based on their unique characteristics. In addition, farmhouses are an important element of the landscape and provide information on the history of local forest-resource use. However, most of the residents interviewed who knew about the traditional use of local wood were more than 70 years old (born before around 1950), indicating a risk of breakdown and loss of these traditions. Such local indigenous traditional knowledge will likely remain untapped in various regions throughout the world. Our results are expected to promote further ecological research concerning wood construction.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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