Article

Forest Resources Management to Support the Japan's "Culture of Wood"

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ABSTRACT

Timber-frame building is a symbol of Japan's "Culture of wood" which makes use of renewable natural resources for construction. We face the global issue of limited natural resources, it is to this Japanese tradition of timber-frame building that we should turn to in to guide us to an important future course. 90 percent of cultural buildings designated by Japanese government are made of wood. The purpose of this paper is to estimate total material amount for timber cultural buildings and the forest resources needed to maintain wooden cultural assets and to propose social systems in order to secure forest resource for long-term more than one hundred years. About 40 percent of building parts are commonly replaced and at times requiring complete dismantlement. Total material amount of timber cultural buildings for government-designated structures was estimated approximately 300,000 m³, annually a volume of 2,220 m³ in standing trees was needed to secure 600 m³ of repair materials. The average amount of wood used per square meter in timber-framed cultural buildings is on the order of 0.5 m³. This means that these structures fix about 10 times the carbon as ordinary forest. For society as a whole to support the maintenance of cultural assets, it is necessary to disperse these risks as much as possible. Additionally, technical support measures are needed for forest owners to grow high-quality, large-diameter trees, and measures are needed to effectively use and raise the market value of timber that is produced but is not suitable for cultural asset repairs. That makes it necessary to increase the building of large-dimensional timber structures using large-diameter timbers, thereby inducing change in the manner of timber construction so that large-diameter timbers are primary. This will make it possible to log plantation trees at larger diameters and provide for longer rotation cycles.

Keywords: culture of wood, forest resources management, timber-framed cultural building, large scale timber

INTRODUCTION

The diverse functions of forests are regarded positively: In addition to conserving the land and recharging aquifers, they have "cultural functions" (SCIENCE COUNCIL OF JAPAN, 2001). Yet, these cultural functions are insufficiently analyzed. While the spiritual influence on people living in the present has been researched, it would be hard to say that the cultural value of forests across vast expanses of time has been sufficiently as-

essed. In other words, there is insufficient analysis of the fact that forests formed in a warm and moist climate produce trees of excellent quality, which have over many years become the materials for cultural structures. Indeed, what kind of forests supplied the materials for the buildings constructed in the Asuka and Nara periods (7th and 8th centuries)? Where and to what extent do such forests still exist in Japan? We do not have enough information to adequately answer such questions. I want to find out how much material is needed, and what kind of forests must be maintained, in order to maintain valuable cultural properties. Showing the specific tree species and standards that are considered necessary to maintain cultural properties would be a valuable source of information for locating wood from forests all over Japan for cultural asset repairs. In this paper, I estimated the total material amount for timber cultural buildings and the forest resources needed to maintain wooden cultural assets using examples of the Ise Shrine and domestic repairing reports, and then I proposed

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social systems in order to secure forest resource for long-term more than one hundred years.

Ninety percent of Japan's important cultural structures are wooden (EZURA, 2000), and nearly half of them have roofs covered with plant-based materials. These timber buildings and buildings with plant-based roofing materials cannot avoid weathering and rotting due to wind and rain, and each building needs periodic repairs. Currently, at least 240 timber cultural properties all over Japan are repaired annually (EZURA, 2000). These repairs are essential for cultural asset preservation, and will need to continue long into the future. They require high-quality lumber and plant-based materials. However, owing to changes in social circumstances and the economic situation in recent years, there has been a precipitous decrease in the domestic production of large-diameter wood, high-quality wood, and hardwood trees such as *Zelkova serrata* and Japanese chestnut (*Castanea crenata*), which are essential for repairs to cultural property structures, making it urgent to secure a stable supply of repair materials for cultural property structures. A questionnaire survey of cultural asset repair technicians found that 80% of them have at some time been unable to obtain the needed materials and have substituted something else (EZURA, 2000). They report that this situation has been pronounced for about 30 years, and that it is becoming gradually more serious year by year. Additionally, 90% of them are concerned about the availability of future repair material. These facts show that the insufficiency of materials will make it difficult to perform the needed cultural asset repairs. To ensure that timber cultural properties are maintained, information must be shared by people who repair cultural properties and those who manage forests, and the necessary systems must be put in place.

The International Council on Monuments and Sites (ICOMOS), which is under the United Nations Educational, Scientific and Cultural Organization (UNESCO), has "Principles for the Preservation of Historic Timber Structures" that require the "same species of wood", "same grading", and "same technology". Therefore maintaining Japan's traditional timber structures requires that we accurately ascertain what type of wood and how much is used. We also need to ascertain the extent of required large, long, and high-quality timbers that are hard to obtain on the market, and how much is available. However, in approaching the problem of securing materials for the repair of cultural property structures, there has so far not been enough exchange of, on one hand, information from cultural asset people on the needed quantity and quality of materials, and on the other hand, information from forestry people on how much timber meeting the requirements for cultural asset materials can be supplied and sustainably produced. For that reason, currently no one can accurately answer questions on how much and what kinds of wood are needed for maintaining cultural buildings.

So, the purpose of this study is to achieve mutual understandings of the situation between cultural asset people and

forestry people on preservation for traditional timber-frame buildings.

ESTIMATING THE AMOUNT OF TIMBER USED IN CULTURAL BUILDINGS

Let us begin with trying to estimate how much material is needed annually. According to the timber purchase breakdown in a report on structural cultural asset repairs on national treasures and important cultural properties over the 25 years from 1976 to 2000, the average amount used annually is 517 m³ (SHIMIZU, 2005). However, because of the large individual differences in structure size, state of damage, and other characteristics of structures to be repaired, some elements of uncertainty remain in applying this figure as is.

For that reason I will try predicting repair material demand from a different perspective. The average amounts of materials used according to building type (Buddhist temples, Shinto shrines, castles, dwellings, and folk housing) were determined from an analysis of repair reports to date (MURATA, 2000). These amounts were then multiplied by the number of structures designated as national treasures and important cultural properties. In this way, the total material amount for timber cultural buildings was estimated to be approximately 300,000 m³ (Table 1). It is a rough method, but in view of the information available at this time, it is presently the only conceivable method. It is reasonable to assume that the true amount of material will be between 50% and 200% of this figure. In a comparison of material amount per square meter of eaves-to-eaves area, it is 0.7 m³ for temples, 0.4 m³ for shrines, and 0.2 m³ for folk housing, but it will be necessary to get still more data and improve the estimation accuracy of material amount per unit eaves-to-eaves area for each type of building (Table 2).

Next is predicting annual demand. There is great disparity in the time intervals for dismantling and repair, depending on building size and environmental conditions. However, investigating the example of Buddhist temples, which account for most of the material, indicates that even for Horyuji Temple, which has a history of 1,300 years, the structures have so far

Table 1 Total material amounts in cultural buildings

	No. of structures	Average volume (m ³)	Total volume (m ³)
Shrines	1,183	22	26,026
Temples	1,253	187	234,311
Castles	250	40	10,000
Dwellings	168	44	7,392
Folk housing	680	28	19,040
Totals	3,534	84	296,769

Note; Average volume is quotation from MURATA (2000).

Table 2 Amounts of materials and replacement rates per unit eaves-to-eaves area

	Volume (m ³) per eaves-to-eaves area (m ²)			Replacement rate (%)		
	Dressed lumber	Rough lumber	Totals	Dressed lumber	Rough lumber	Overall
Shrine average	0.290	0.103	0.393	52.2	90.8	62.3
Temple average	0.389	0.311	0.700	31.1	52.7	40.7
Folk housing average	0.107	0.060	0.199	55.1	42.0	50.4

Note; plane area for folk housing, quotation from MURATA (2000).

been maintained by major repairs performed at intervals of about 300 years (OSAWA *et al.*, 2005). From the standpoint of sound maintenance of structures, here I will assume the dismantling and repair interval to be 200 years. Judging from the historical data on repairs given above, the average material replacement rate for temples is set at 40%. This figure could swing considerably either way depending on factors such as structure size and state of damage, and for shrines, the average material replacement rate is over 60%. For dressed timber, of which much is large-diameter and long, the figure is about 30%, while for rough lumber, which is often yard lumber, it is over 50%, but the percentage found from currently available data is the above 40%. Lumber 5 m or longer or 36 cm or wider is estimated to be about 40% of that.

Dividing the total material amount of 300,000 m³ by the repair interval of 200 years and multiplying by the 40% replacement rate yielded an annual amount of 600 m³. This value almost agreed Shimizu's report. However, because this is the final amount used, one must work backward to find the amount needed in the forest. At the first stage, one must estimate about 30% carpentry waste produced when cutting lumber at the repair site, and therefore lumber delivered to the site will be 1.3 times this amount. At the second stage, the lumber yield when processing lumber is less efficient than for yard lumber, making for an estimated 50%. For that reason, one will need a quantity of logs twice the required amount of finished lumber. These estimates of carpentry waste and lumber yield are based on interviews with sawmillers. At the third stage, one needs to examine the yield between standing timber and logs, which is generally estimated at 70%. Thus, when working backward from the materials used, the volume of standing timber actually needed in the forest was 3.7 times the amount of materials used in buildings. Accordingly, annually a volume of 2,220 m³ in standing trees was needed to secure 600 m³ of repair materials. But to provide the wood species and quality of the material actually sought, 2,220 m³ of wood in the forest will not be enough. Because wood is carefully selected from among diverse trees, far more forest resources are needed. Additionally, as the above figures are for only

government-designated structures, we must also consider cultural properties designated by municipalities.

What is more, because the required materials also include large-diameter and long timbers, this is not just a matter of volume. One must also carefully consider restrictive conditions related to diameter and length. In a literature study on the lengths and diameters of 278 members making up 22 cultural buildings dating before the 8th century, YUMOTO (2005) found that the longest is the 32-m central pillar of the 5-story pagoda at Horyuji Temple, and the second is the 16.6-m central pillar of the East Tower at Yakushiji Temple. Nationally, there are 18 members more than 10 m long. For diameter, the largest are the members used in the doors of the main building of Todaiji Temple, some of which are 1.3 m in diameter. There are 5 members exceeding a diameter of 1 m. It is necessary to carry out a broad study of such large timbers, and examine the possibility of procuring the forest resources.

Also to be considered is quality. According to the previously cited repair report, amounts used for replacement are 27% cypress, 21% cedar, and 19% pine (SHIMIZU, 2005). The top 3 conifer species account for over 2/3 of the materials used in repairs. Other major species are *Thujosis dolabrata* and *Tsuga sieboldii*. Securing large-diameter pine is now difficult because of the damage to pine forests in Japan by the pine wood nematode (*Bursaphelenchus xylophilus*). During the Showa era (1926–1989) Taiwan cypress is used, accounting for some 2%, but its logging is now banned, and consideration of how to secure large-diameter cypress timbers is needed. With respect to grades of the 3 species most used, the percentages of knotless timbers and those with fine small knots are 27% for cypress, 23% for cedar, and 25% for pine, which are exceedingly high percentages of high-quality materials compared with general building materials (SHIMIZU, 2005).

Since the 1930's, more than 1,600 reports have been prepared on repairs thus far performed, but as there is not necessarily a certain way in which reports must be written, in many instances the total amounts of materials in buildings is not known. The Great South Gate of Todaiji Temple, a national treasure, was repaired in 1930, and its repair report is the

oldest. Because it records the standards and numbers of all materials used, we know that the building uses 1,044 m³ of materials, that its 18 pillars account for 20%, and that there were 112 m³ of supplementary materials. The reason for the low replacement rate of 10.7% would seem to be the large proportion of large-diameter members. Owing to the 25.5-m height of this building, its amount of wood used per unit area is twice the average for temples. Toshodaiji Temple's Golden Hall, which is now being dismantled and repaired, uses 621 m³ of materials. The estimated amounts of wood in the buildings making up Horyuji Temple's Sai-in area are 289 m³ in the gallery, 251 m³ in the Golden Hall, and 252 m³ in the Great Teaching Hall (YAMAMOTO, 2006). Estimated on the basis of the material amounts used per unit eaves-to-eaves area, mentioned above, the average amount of wood used per square meter in timber-framed cultural buildings is on the order of 0.5 m³. This amounts to 5,000 m³ per hectare, which means that these structures fix about 10 times the carbon as ordinary forest, for at least several hundred years.

FOREST RESOURCES FOR MAINTAINING TIMBER-FRAME CULTURAL BUILDINGS

I shall now examine whether the supply capacity of Japan's forest resources can satisfy the demand for maintaining cultural buildings. The Forestry Agency's Planning Division (2002) states that cedar accounts for the biggest area of plantation forest in Japan at about 45%, followed by cypress at about 25% and pine at about 9%. Their stocks are 1.34 billion m³ of cedar, 490 million m³ of cypress, and 170 million m³ of pine. But if these are limited to aged trees at least 80 years old, which are in demand for repairing cultural buildings, then cedar plantation stock is 44.79 million m³, and cypress plantation stock is 19.62 million m³. Estimated stocks distributed in natural forests are 6.99 million m³ cedar and 7.92 million m³ cypress. While there are quantitatively sufficient stocks of cedar and cypress to meet demand, questions about quality need to be answered. Tabulated data on the current state of pine forests show an estimated 190 million m³ in natural forests, but that amount has plunged in recent years due to severe damage by pine wood nematodes, making recovery of pine resources difficult for the time being. Because there is little damage by this nematode in cold regions, securing pine forests in the northern Tohoku region and high-altitude regions is of vital importance. Demand for *Zelkova serrata* is also expected, but unlike cedar and cypress, there is no viable technique for growing *Zelkova serrata* in plantations. Although there are records of plantations having been created in the past, there are hardly any mature plantations, and it is estimated that there are about 220,000 m³ of natural trees. Many chestnut trees were planted in orchards, but none have attained large diameters, and natural trees are estimated to amount to about 480,000 m³. These hardwood trees rarely grow in groups within natural forests, and large-diameter trees are found scattered through-

out natural forests. Thus although there is sufficient stock to accommodate demand, but when it comes to actually supplying the trees, there are few sales of large-diameter trees, and a system to accommodate demand is lacking. As such, it seems there is a sense of tight supply.

On the state of cypress resources, for which there is the greatest demand, I noted above that cypress forests account for about 10% of Japan's forest resources in terms of both area and stock. Because most plantations have been planted since 1950, they are still young and cannot soon be used for cultural assets. Mature plantations that can be used for repairs are about 5% of the total; of that 5%, 3/4 are privately owned, and half of those privately owned plantations are concentrated in the prefectures of Gifu, Aichi, Nagano, Nara, and Kyoto. Natural trees, on the other hand, are distributed from Yakushima Island to Fukushima Prefecture. Distribution is concentrated mostly from Hakone westwards, in Nagano and Gifu prefectures, and from Kiso to Tono. Most is in the national forests stretching from Kiso to Tono.

The amount of cypress logged in Kiso-dani was verified on the basis of the Report on the Regional Cultural Asset Forest Initiative (JAPANESE ASSOCIATION FOR PROTECTION OF ARCHITECTURAL MONUMENTS, 2003). Although there are records of logging from the 14th century for shrine rebuilding and other reasons, heavy use is said to have started in the 16th century when cypress resources in Western Japan underwent a pronounced decline (Fig. 1). In the 17th century there was increased logging for temple construction and castle-building materials by the Owari Clan. There was a time when 300,000 m³ was logged annually, and it is thought that logging in this period engendered the natural regeneration that produced the current natural trees. But concerns about resource depletion in the 18th century led to subsequent strict protection policies, which meant less natural regeneration. Nevertheless, logging of between 50,000 and 80,000 m³ annually continued. With the Meiji Restoration, the cypress forests came under the new

Fig. 1 Logging amount of Kiso cypress prepared using Chubu Regional Forest Office data; quotation from JAPANESE ASSOCIATION FOR CONSERVATION OF ARCHITECTURAL MONUMENTS (2003).

government's jurisdiction, and for the establishment of imperial family assets, the forests were managed as an imperial estate from 1889 to 1947. During the Meiji period, logging was kept at a low level, but in 1916 forest railways were laid, and logging increased in the 1920s to about 200,000 m³ a year. At that time, the approach to forest management changed from the selective cutting practiced theretofore to clear cutting and blanket afforestation. However, around 1930, the approach to the management of imperial forests changed from expansive afforestation to selective cutting, and the amount of Kiso cypress supplied averaged 100,000 m³ yearly. In 1947, the forest was changed from an imperial family asset to a national forest. Beginning about 1960, Japan as a whole experienced a timber shortage. Forest policy changed, expansive afforestation was promoted, and logging increased. The logging of trees severely damaged by the Ise Bay typhoon resulted in increased logging, and brought the amount to 310,000 m³ in 1964. In 1973, logging policy for national forests again changed to selective cutting, and from 1975 the amount fell to 100,000 m³, and in FY2001 it was 20,000 m³. Under the Chubu Regional Forest Office's plan, with current stock of 3.7 million m³ as the resource base, it is possible for the time being to stably provide timber at an annual average level of 14,000 m³.

But while this plan responds to demand quantitatively, one must examine it to see whether it can sustain a qualitatively high level. According to 2001 data from the Chubu Regional Forest Office, half of the 20,000 m³ sold was knotty, and about 22% of the timber with small-end diameters of at least 40 cm was of good quality with few knots. What is more, good-quality, long timbers of 7 m or more in length accounted for about 3%. With these facts in mind, it will be necessary to consider, from the standpoint of quality, what level of quality to seek. It will be necessary to ascertain the demand for each tree species to find the quantities of long and large-diameter timbers needed.

SECURING SHRINE REBUILDING MATERIALS

The rebuilding of Ise Shrine started in 690 and the 62nd rebuilding is scheduled for 2013. A characteristic of shrine rebuilding is that the amount of needed wood and the time period are known in advance, allowing preparations to be made in a planned manner. On the occasion of the 58th rebuilding, the Ise Shrine Rebuilding Agency issued a breakdown of the 11,705 logs ordered from the Imperial Household Forestry Bureau by length and small-end diameter (KURATA, 1939). The volume of these logs exceeded 10,000 m³. The largest small-end diameter was 122 cm with a length of 4 m, the longest log was 13 m with a small-end diameter of 40 cm, and 25% of the needed logs, or 3,000 logs, were at least 6 m long or had small-end diameters of at least 30 cm. Of these, the large logs at least 6 m long and with small-end diameters of at least 50 cm accounted for 42% of the whole by volume. Combining these data with a cypress log taper table enables one to find the number of trees need-

ed by tree diameter at breast height (DBH). If all first-cut wood is used, then standing tree volume will be 4.5 times that of log volume, or 45,000 m³. When these are plotted by diameter, the result is Figure 2. The most numerous are logs with a DBH of 52 cm, but there were 613 logs measuring 70 cm or more.

Around 1930, an imperial forest technician used such data to calculate the area of shrine forest needed to secure wood for shrine rebuilding. Yoshio KURATA (1939), a technician at the Imperial Household Forestry Bureau, investigated the growth of natural trees and the percentage of dead standing trees on site, and calculated that 185,000 trees are needed to supply shrine reconstruction timber every 20 years. Further, assuming a suitable tree rate of 40% and a 2.5-fold safety factor, he calculated that 1,000 ha is needed to raise 461,000 trees, and then supplementing the trees cut for interim thinning, that 1,719 ha of pure natural forest is needed. Further assumptions he made included a 50% mixture of other tree species, and that 20% of the land would be unsuitable for producing large-diameter trees, and concluded that in total over 4,400 ha would be needed for shrine rebuilding forest (KURATA, 1939). But a 1934 management proposal set the shrine rebuilding forest at 8,228 ha comprising a total of 12 locations with permanent forest of 4,484 ha, temporary forest of 1,778 ha, and supplementary supply forest of 1,996 ha. This shrine forest system was established in 1904 to sustainably supply the timber needed for the periodic rebuilding of Ise Shrine. Under provisions of the day, cutting large cypress trees in the forests for a purpose other than shrine building was prohibited, and tree species other than cypress were cut to facilitate the natural regeneration of cypress. According to records, forest logging actually occurred around 1921 when 17,000 trees were cut for the 1929 reconstruction, and there was logging during the war for use in the 1949 reconstruction.

Since the transfer of the forests to the Forestry Agency after the war, it is no longer possible to manage them for Ise Shrine, but these forests now total 13,924 ha by combining a variety of management groups such as the "Kiso Cypress

Fig.2 Numbers of cypress trees by diameter needed to rebuild Ise Shrine

Selective-Cutting Multi-Storied Task Group for Cultural Assets and Other Purposes” and the “Kiso Cypress Large-Diameter Tree Selective-Cutting Production Group for Cultural Assets and Other Purposes.” The management program aims for sustainable timber production with a rotation cycle of 200 or 250 years.

It will take some time before we know if the expected natural regeneration goes well, but in general letting forests regenerate themselves will not go well unless about the same amount of time and effort is spent closely observing the forests as is used in clear cutting and blanket afforestation, and considerable energy is used (YAMAMOTO, 2005).

DISCUSSION AND CONCLUSIONS

If one knows in advance the amount of material needed and when, as with the Ise Shrine, it is possible to prepare the forests. However, for many cultural assets it is unknown when they will be repaired and, until actually dismantling them, it is not known how much material will be replaced, the wood species required, or the amounts and standards of each. The reality is that in these ways, the great element of uncertainty is a limiting factor that hinders the formation of a stable supply system. There may be instances in which materials are not used even if secured. If trees are cut after timber is ordered, sufficient dried timber cannot be provided. Therefore, lumber mills and distributors currently take on risk by stocking materials in advance. Doing so involves the risks of price fluctuations and timber deterioration, and it is also possible that when actually milling the timber it will not yield products of the expected quality. The challenge is to build a system which disperses these risks and links suppliers with consumers.

For the time being, to gain the cooperation of forest owners it will be necessary to create silviculture techniques for long-term rotation management of plantation forests, and set up a system to make effective use of the forest thinning of various standards generated in that process. From a long-term perspective, it will also be necessary to work on natural regeneration techniques for producing high-quality materials from natural forests.

So far I have discussed repair materials in terms of supply and demand, and while there is still room for consideration on the demand side about what extent of quality to seek, the prospects are good that many kinds of materials can be supplied in the desired quantities. It seems likely that stable supplies of materials can be secured by creating a system for their actual distribution. To begin with, we must define the scope of cultural assets for which materials must be obtained. There are (1) buildings that are designated and registered under the Cultural Properties Protection Act, mainly national treasures and important cultural properties, and (2) the cultural properties that are local temples and shrines maintained by communities, and the community activities that have sustained those temples and shrines. This discussion is limited to

the first. And with respect to the kinds of materials, we need to include not only special wood such as large-diameter, long timbers, but also other plant-based materials such as cypress bark and lacquer.

From the supply side, the character of forests intended to secure repair materials for national treasures, important cultural assets, and the like would be tree ages of at least 200 years, with priority tree species being cypress and pine, while *Zelkova serrata* and cedar must also be considered. At the very least the DBH must be 50 cm, and annual ring width must be under 2 mm. Fulfilling this ring width requirement is difficult with plantations instead of natural forests. But even if that is difficult near the center of a forest, it is possible on the periphery if tree density is properly managed. Yet, that is a tough objective for producers. Further, they must grow forests with many trees that have high lowest branch heights, few knots, and are straight. The ideal has been to use natural timber for replacement materials, but there are as yet no techniques to control natural forests as desired. Producers have not intentionally improved natural forests to meet these requirements, but rather have extracted appropriate materials from trees that just happened to be growing in natural forests. By maintaining natural forests it is possible that high-quality natural trees will grow, but it is not something that can be done on a planned basis. Therefore, from a long-term standpoint the use of plantation timber must be considered. That necessitates the preparation of long-rotation multi-storied forests with dense planting and frequent thinning. Regeneration by natural seeding must also be considered. Although the technical details will need further discussion, this will be the direction to take. And even if it is possible to raise high-quality trees in this manner, it will be necessary to also consider a social system that will put to good use the wood other than that used for cultural asset repairs, such as the semi-high-quality wood, general-use wood, culled trees, and other timber produced in the process of raising these forests.

When repairing cultural buildings, the amount of replacement materials needed is only known once a structure is dismantled. If something is not replaced in the present rebuilding, those materials are not used until the next repair 200 years in the future, and storing the materials until then presents difficulties. As such, preparing certain trees for those materials involves too many elements of uncertainty. For that reason, unless one assumes the probability of material replacement in advance and predicts the amount needed for a number of cultural buildings as a whole, a large amount of waste will arise on the supply side, which creates the problem of who will assume the burden.

Until now, much of that burden has been assumed by saw millers, distributors, and forest owners, and that has made these materials far more expensive than general-use timber. For society as a whole to support the maintenance of cultural assets, it will be necessary to disperse these risks as much as possible and take creative measures to hold down material

procurement costs. Additionally, technical support measures are needed for forest owners to grow high-quality, large-diameter trees, and measures are needed to effectively use and raise the market value of timber that is produced but is not suitable for cultural asset repairs. That in turn makes it necessary to increase the building of large-dimensional timber structures using large-diameter timbers, thereby inducing change in the manner of timber construction so that large-diameter timbers are primary. This will make it possible to log plantation trees at larger diameters and provide for longer rotation cycles.

One area of future research is to develop a technique to predict with some degree of accuracy the replacement materials required for a building to be repaired, before it is dismantled for repair.

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