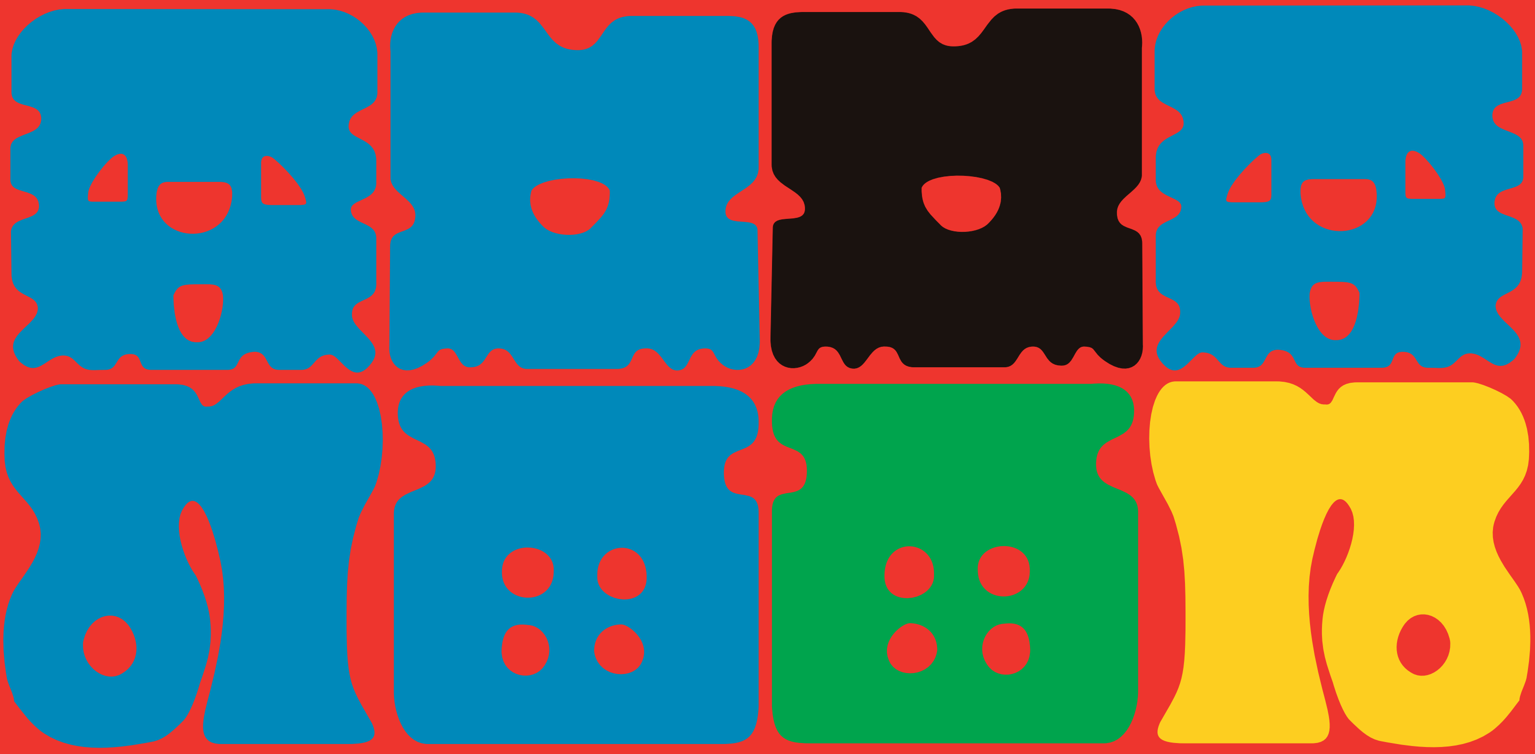
ISSN 1341-562X



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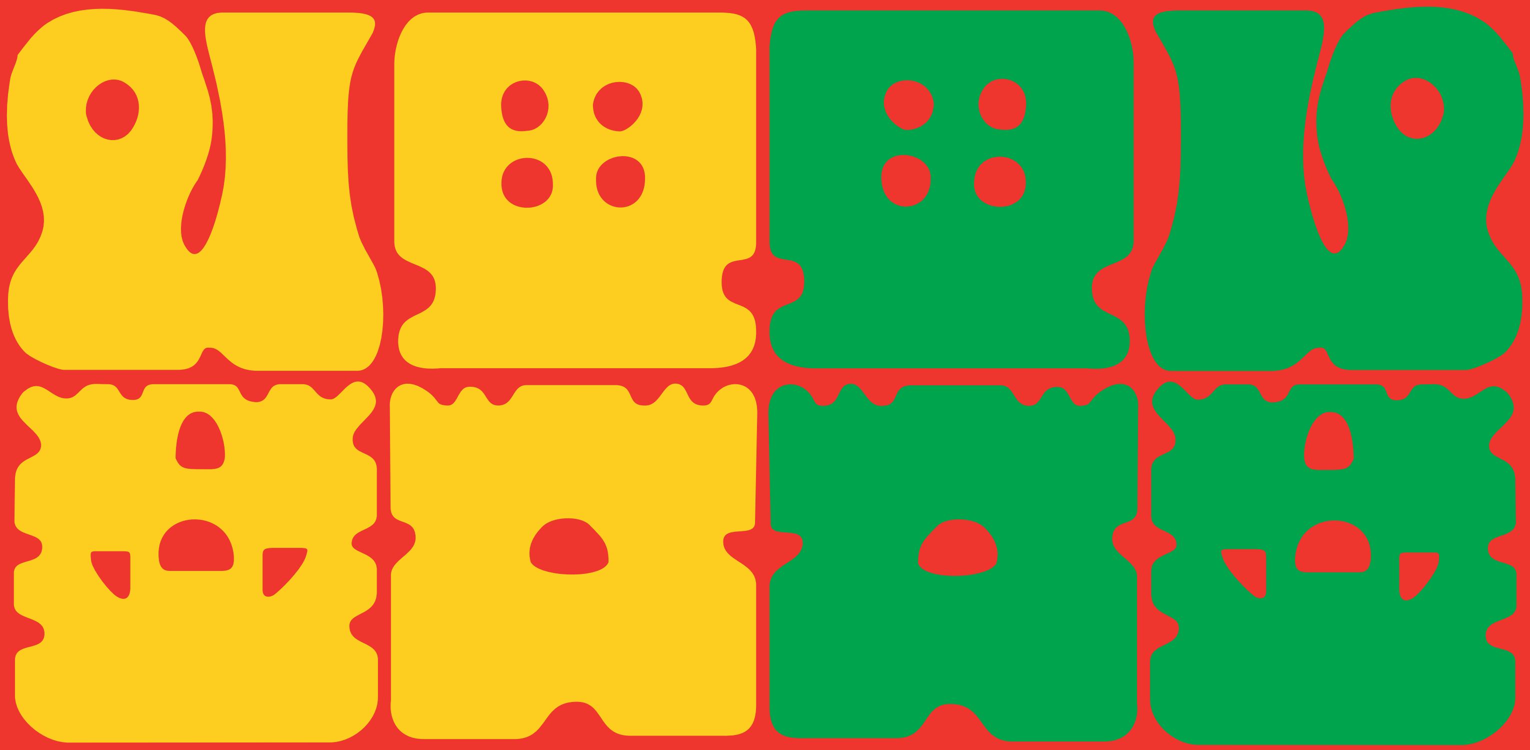

Japan Society of Forest Planning

Vol. 28
April, 2022

JOURNAL OF **FOREST PLANNING**

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Journal of Forest Planning is a peer-reviewed periodical that publishes articles, reviews, and short communications. It covers all aspects of forest management, modeling, and assessment such as forest inventory, growth and yield modeling, remote sensing and geospatial information technologies for forest management, forest management planning, forest zoning, evaluation of ecosystem services, managerial economics, and silvicultural systems. Manuscripts regarding forest policy, forest economics, forest environmental education, landscape management, climate change mitigation and adaptation strategies, and drone applications for forest management are welcome. The Journal aims to provide a forum for international communication among forest researchers and forestry practitioners who are interested in the above-mentioned fields.

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Journal of Forest Planning is published yearly. The subscription for 2021 is 2,500 yen. Subscription orders can be sent to the office of Japan Society of Forest Planning.

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JOURNAL OF

FOREST PLANNING

Vol.28, April, 2022

Japan Society of Forest Planning

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Articles

Article

Survival analyses of individual tree populations in natural forest stands to evaluate the maturity of forest stands: A case study of preserved forests in Northern Japan

Pavithra Rangani Wijenayake [1, *] and Takuya Hiroshima [2]

ABSTRACT

Most survival analyses in forest science have been applied to planted forests where tree age usually had no dispersal on one stand, while there have been few reports about the age-based survival analyses in natural forests. The purpose of this study was to perform survival analyses of individual tree populations in natural forest stands to evaluate the matured states of forest stands. We used a combination of tree-ring and census data from the three preserved permanent plots in pan-mixed and sub-boreal natural forests, Hokkaido, northern Japan. All the living trees (diameter at breast height ≥ 5 cm in 1989) were targeted to identify tree ages using a RESISTOGRAPH. Periodical tree age data with a 10-year age class were used during the observation periods of 1989–1999, 1999–2009, and 2009–2019, and all the changes (i.e., death and new ingrowth) during the periods were recorded. In the analyses, first, we applied survival analyses to find out multi-temporal age distributions and non-parametric estimates. Secondly, we applied parametric Weibull distributions to calculate age-related metrics such as mean lifetime and mean age of stands. Finally, we evaluated these calculated metrics from the viewpoints of matured states of forest stands. The results of non-parametric survival analyses showed the age distribution of multi-modal and exponential shapes. We also found the differences in survival probabilities among periods were not significant except for one plot. We also compared the relationship among estimated mean lifetime, biological lifetime, and mean age of stands derived from parametric survival analyses with the Weibull distribution and evaluated the matured states of stands considering all these aspects. It was implied that the study stands might not get enough matured yet, but some plots showed further progress toward the matured state than others.

Keywords: natural forest, survival analysis, the maturity of forest stand

INTRODUCTION

A survival analysis, time-to-event analysis, refers to a set of methods for analyzing the length of time until the occurrence of a well-defined endpoint of the event. It is common to use survival analysis in the fields of biology, medicine, engineering, marketing, social sciences, and behavioral sciences (Jung et al., 2012; Gross et al., 2014; Alvi et al., 2015; Ancarani et al., 2015; Buckley et al., 2016). In survival analysis, the covariates of "age" is one of the major parameters to analyze the mortality of target populations accurately (Kalblfeisch and Prentice, 1980; Kleinbaum and Klein, 2011). So, in the field of forest science, most of the survival analyses have been applied to planted forests, where tree age usually had no dispersal on one stand, i.e., no need to identify tree age. In the survival analysis of planted forests, the event is the clear-cut of the stands. Based on this endpoint, Suzuki (1959) has developed his original method to predict the harvesting behavior of planted forests called the Gentan probability theory in Japan. Some other survival analyses had also been applied to planted forests since then worldwide (Waters, 1969; Morse and Kulman, 1984; Amateis et al., 1997; Wyckoff and Clark, 2000).

When it comes to natural forests, the event is the mortality of individual trees. Woodall et al. (2005) carried out survival analyses in natural forests based on DBH instead of tree age. It is generally troublesome to detect tree ages of individual trees

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J. For. Plann. 28: 1–13 (2022) DOI: 10.20659/jfp.2021.003

in natural forests, particularly in large-scale inventories (Flewelling and Monserud, 2002; Nothdurft, 2013), so most of the researchers used stand metrics such as DBH, basal area, and height to analyze the mortality of trees not only in natural forests but also planted forests (Monserud, 1976; Tatsuhara and Minowa, 1988; Vanclay, 1995; Eid and Tuhus, 2001). In spite of the difficulty in tree age detection, one of the clear advantages in survival analyses with covariates of age, i.e., age-based survival analyses, is to analyze and evaluate the maturity of cohorts considering age distributions, mean age, mean lifetime, etc. In such circumstances, Hiroshima (2014) applied age-based survival analyses to a secondary natural forest in Japan. His study was the first case in natural forests to introduce a survival analysis based on the age of individual trees. He carried out the non-parametric and parametric analyses to illustrate the mortalities of the natural forest stand and tried to evaluate the maturity of stand based on the age-related metrics such as mean age and mean lifetime derived from the non-parametric and parametric estimates. This research was, however, based on only one plot and one-period measurement, so that it was not easy to make a clear general conclusion based on this case study since obtained survival probabilities could be site-specific. Besides, the targeted stand seemed immature, and the estimated survival probabilities seemed not stable over time. Given the current lack of age-based survival analysis, it is required to carry out more case studies of survival analyses, particularly in natural forests. Moreover, it is desirable to apply multi-temporal survival analyses to evaluate the matured states of stands considering the time-series changes in the above age-related metrics.

In this study, we took advantage of the long-term research site in a preserved area located in the University of Tokyo Hokkaido Forest (UTHF). The permanent plots of these sub-boreal forests were ideal for performing the tree age and mortality investigations in the long term because they had not been undergone human-induced disturbances for a long time.

Overall, the purpose of this study was to perform survival analyses of individual tree populations in natural forest stands within the pan-mixed and sub-boreal forests to evaluate the matured states of forest stands. First, we applied survival analysis techniques to study plots to find out multi-temporal age distributions and non-parametric estimates. Secondly, we applied parametric Weibull distributions to calculate age-related metrics such as mean lifetime and mean age of stands. Finally, we evaluated these calculated metrics from the viewpoints of matured states of forest stands. This study was the second case of applying age-based survival analyses for individual tree populations in natural forests in Japan.

MATERIALS AND METHODS

Study Site

The investigation was conducted in the permanent plots of the UTHF (43° 10'–21" N, 142° 23'–41" E), pan-mixed and sub-boreal forests in Hokkaido, Japan (The University of Tokyo Hokkaido Forest, 2019). This forest locates at the transition area from deciduous forests in the cool-temperate zone to coniferous forests in the sub-boreal zone (Kato, 1952) with a mean annual temperature and precipitation of 6.4 °C and 1,297 mm, respectively (The University of Tokyo Hokkaido Forest, 2019). The Stand-based Silvicultural Management System (SSMS), which is a unique natural forest management system conducting the single tree selection of over-matured and defective trees based on natural regenerations, has been practiced since 1958 (Takahashi 2001). Harvesting and management decisions are taken based on the long-term observation data in permanent plots. Among these permanent plots, a total of 25 plots locates in the preserved area, so we call them preserved permanent plots for convenience. These plot sizes range from 0.04 to 2.25 ha with an elevation range between 380–1290 m. Within these plots, DBH measurements of all trees with DBH $\geq$ 5 cm are performed by UTHF staff regularly, in most cases, 5-years interval. Other than these periodical measurements, basically, there is no human intervention in this preserved area for several decades.

This study chose three samples of preserved permanent plots #5203, 5225, and 5240 within elevation ranges around 600–700 m (Fig. 1 and Table 1). This middle elevation represents the range of similar species composition as well as stand structure with proximity to each other plot in the preserved area. Typical vegetation types in these plots are coniferous and broad-leaved mixed forest dominated by *Abies sachalinensis*, *Picea jezoensis* and *Acer* species (mainly *Acer urkrunduense*). The main soil types found in these plots were brown forest and podzolic soils (The University of Tokyo Hokkaido Forest, 2019). In addition, these three plots are classified as the same stand type of "coniferous selective cutting with poor regeneration" in UTHF, where we cannot expect sufficient new ingrowth trees continuously. All three plots also have similar slope aspects and slope angles (Table 1) though abiotic factors such as microtopography affected the mortality of trees in the three plots differently. Thus, the selected three plots facilitate the consistent analyses of the study objectives mentioned above.

Collection of Tree Age Data

We used the tree census data (species, DBH, state of alive or dead, cause of death, etc.) of the plots measured between 1989 and 2019. In line with the census data, we set three observation periods of 1989–1999 (period 1), 1999–2009 (period 2), and 2009–2019 (period 3). All the target trees were alive and had DBH $\geq$ 5 cm in 1989, though parts of these trees were already dead by 2019. We additionally collected the data of tree age after ingrowth (i.e., the number of annual rings from bark to pith in radius at breast height - 2.5 cm, if we set DBH = 5 cm as an ingrowth border) for every target tree. By considering the "age after ingrowth", we can ignore the impact of trees with DBH < 5 cm in the later survival analysis (Hiroshima, 2014). A semi non-destructive device called the RESISTOGRAPH was used to detect the annual rings of both the living and dead target trees (Hiroshima, 2014). The measurement data were then extracted via the DECOM software. Figure 2 depicts the annual

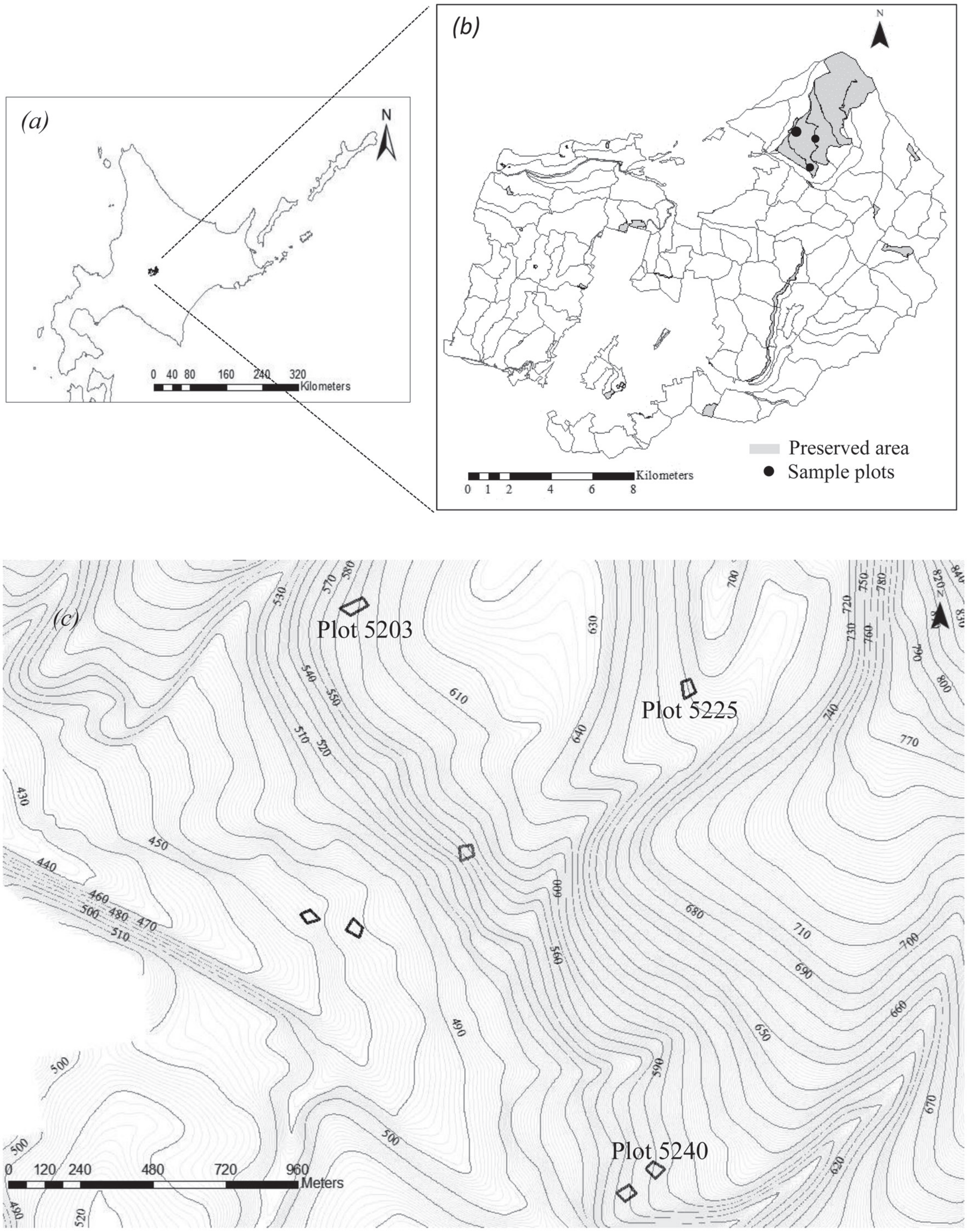

Fig. 1. Maps showing the locations of study area and sample plots. *(a)* UTHF of the Hokkaido island of Japan, *(b)* preserved area of the UTHF, *(c)* Contour map of the sampled three preserved permanent plots of UTHF.

rings detected in one of the alive *Abies* trees after deducting 2.5 cm from the pith using the DECOM^{TM} software. It can be used to mark tree ring limits automatically or manually based on the boundaries between early and latewood areas (Rinn et al., 1996). RESISTOGRAPH measurements were conducted for a total of 327, 237, and 214 trees in the plots 5203, 5225, and 5240 respectively in 2019 (the end of period 3), and the ages of target trees in period 3 were first identified, and then the ages in period 2 and 1 were calculated by deducting 10 and 20 from those in period 3.

It was not possible to apply the RESISTOGRAPH measurement to badly rotten trees. For those tree species that did not include living specimens, cross-sectional wood discs were collected from the stumps of felled healthy trees supplementally, and their ages were manually counted. Afterward, we estimated the regression equations for dominant tree species in the plots showing the relationship between the age after ingrowth (y) and

Table 1 Stand characteristics of selected plots

Plot #	Plot size (ha)	Elevation (m)	No. of target trees in period 3	Slope aspect	Mean slope angle (degrees)
5203	0.40	580	327	Southwest	15
5225	0.25	690	237	Southwest	20
5240	0.25	600	214	Southwest	25

Table 2 Developed regression models based on RESISTOGRAPH measurements

Tree species	Number of tree samples	Equation	Coefficient of determination
Abies sachalinensis	51	$y = -0.0000008w^3 + 0.0005w^2 + 0.1995w + 32.294$	0.8379
Picea jezoensis	59	$y = -0.000002w^3 + 0.0008w^2 + 0.2545w + 30.32$	0.8506
Acer urkrunduense	41	$y = -0.00001w^3 + 0.0043w^2 - 0.1416w + 41.991$	0.7668
Tilia japonica	32	$\mathrm{y} = 0.000002w^3 - 0.0012w^2 + 0.5815w + 13.189$	0.7803

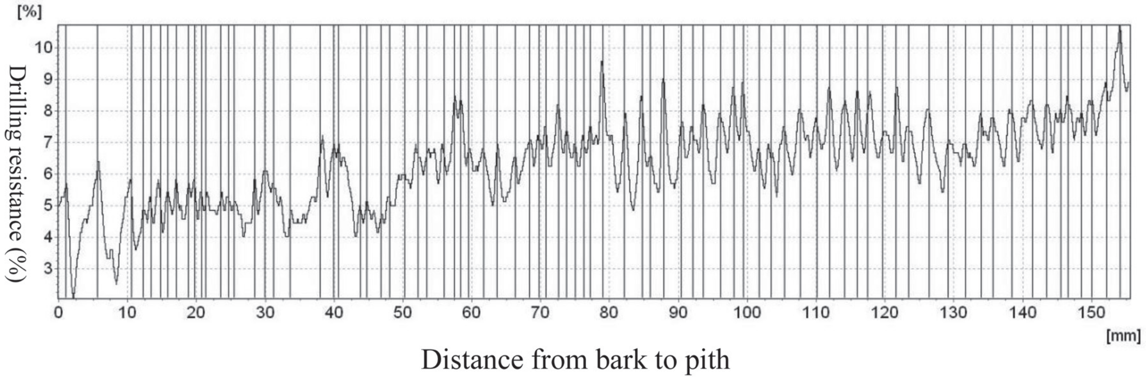

Fig. 2. DECOM$^{\mathrm{TM}}$ profile showing the drilling resistance of the annual wood growth rings. The differences in density between early and latewood were used to draw the vertical lines.

the radius - 2.5 cm (w) of trees by polynomial equations of third order fitted to scatter diagrams. Table 2 shows the number of samples for each species and the estimated equations with coefficients of determination values. The appropriateness of the estimated equations was validated with RESISTOGRAPH data of the plots. These equations were applied to estimate the ages after ingrowth of badly rotten dead trees and living trees of all three plots that were impossible to estimate the ages from RESISTOGRAPH data and census data.

For the subsequent survival analysis, we classified the tree ages into the age classes of ten year length for each.

Survival Analysis of Target Trees

The survival data demonstrated that there were both dead and living trees in the study plots at the end of the observation periods. In these instances, the survival time is described as "censored". Right censoring happens when a target leaves the study before an event occurs, or the follow-up ends before an event occurs. On the other hand, "truncation" is used when we do not know whether events occurred before a specific time for targets.

The survival probability functions were developed based on the previous studies (Kalblfeisch and Prentice, 1980; Cox and Oakes, 1984; Crowder et al., 1991; Klein and Moeschberger, 1997; Kleinbaum and Klein, 2011; Fujikake, 2000; Hiroshima, 2014). The tree mortality is introduced as a stochastic variable (T) unique for each target tree. Here, T indicates the age class after ingrowth and is defined as a continuous variable that is based on the probability density function $f(T)$. If a tree at the t-th age class dies, the conditional probability called the mortality rate (P_t) can be defined as follows:

$$\Pr(t - 1 < T \leq t \mid T > t - 1) = p_t \,. \tag{1}$$

If a tree survives the t-th age class during the observation period, the conditional probability is defined as follows:

$$\Pr(T > t | T > t-1) = 1 - p_t \,. \tag{2}$$

By following the methods of Fujikake (2003), Hiroshima (2006), and Tiryana et al. (2011), and considering Eqs. 1 and 2, we can describe the likelihood function (L) of the observation as follows:

$$L = \prod_t \Pr(t-1 < T \le t | T > t-1)^{d_t} \Pr(T > t | T > t-1)^{a_t}$$

$$= \prod_t \left(\frac{\int_{t-1}^{t} f(T)dT}{\int_{t-1}^{\infty} f(T)dT} \right)^{d_t} \left(\frac{\int_{t}^{\infty} f(T)dT}{\int_{t-1}^{\infty} f(T)dT} \right)^{a_t} \tag{3}$$

where d_t is the number of dead trees and a_t is the number of surviving trees at the t-th age class during the observation period. By employing the probability density function, the mortality probability (q_t) of new ingrowth trees at the t-th age class is defined as follows:

$$\Pr(t-1 < T \le t) = \int_{t-1}^{t} f(T)dT = q_t \,. \tag{4}$$

In addition, the survival probability (r_t) at the t-th age class is defined as follows:

$$\Pr(T > t-1) = \int_{t-1}^{\infty} f(T)dT = 1 - \int_{1}^{t-1} f(T)dT = r_t \,. \tag{5}$$

Therefore, based on Eq. 1, the mortality rate (P_t) can also be:

$$p_t = \frac{q_t}{r_t} \,. \tag{6}$$

Thus, Eq. 3 can be also expressed as:

$$L = \prod_t \left(\frac{\int_{t-1}^{t} f(T)dT}{\int_{t-1}^{\infty} f(T)dT} \right)^{d_t} \left(\frac{\int_{t}^{\infty} f(T)dT}{\int_{t-1}^{\infty} f(T)dT} \right)^{a_t}$$

$$= \prod_t \left(\frac{q_t}{r_t} \right)^{d_t} \left(1 - \frac{q_t}{r_t} \right) = \prod_t p_t^{d_t} (1 - p_t)^{a_t} \,. \tag{7}$$

The maximum likelihood estimators of P_t can be calculated by solving the first-order derivation equation of Eq. 3 as shown in Eq. 8:

$$\hat{\mathrm{p}}_t = \frac{d_t}{a_t + d_t} \,. \tag{8}$$

Moreover, considering Eq. 5 and Eq. 6 lead to

$$r_t - r_{t+1} = q_t \,, \tag{9}$$

the survival probability can be converted into

$$r_{t+1} = r_t - q_t = r_t \left(1 - \frac{q_t}{r_t} \right) = r_t (1 - p_t) \,. \tag{10}$$

This Eq. 10 can also be expressed as follows:

$$r_t = \prod_{k<t} (1 - p_k) \,. \tag{11}$$

Thus, the consistent estimator of r_t can be expressed as follows:

$$\hat{r}_t = \prod_{k<t} \left(1 - \hat{p}_k \right) = \prod_{k<t} \left(1 - \frac{d_k}{a_k + d_k} \right) . \tag{12}$$

This consistent estimator is called the Kaplan–Meier estimates (Kaplan and Meier, 1958), which describe the distribution of survival probabilities. The Kaplan–Meier curves represent the non-parametric expressions of survival probability distributions throughout the study period.

A comparison of the survival probabilities can be made using the log-rank test (Mantel, 1966). This tests a null hypothesis (i.e., no significant difference in survival between consecutive periods in this study) and the expectation of an equal number of deaths (E) for each of the two groups. The observed (real) number of deaths is indicated with O in the following equation:

$$\mathit{Log\ rank\ statistic} = (O - E)^2 / \mathit{Var}\ (O - E) \,. \tag{13}$$

One of the advantages in survival analyses with covariates of age, i.e., age-based survival analyses, is to analyze and evaluate the maturity of cohorts considering age distributions, mean age, mean lifetime, etc. Particularly, the calculation of mean lifetime requires the above-estimated mortality probability like the following:

$$\mathit{Mean\ lifetime} = \sum t q_t \Big/ \sum q_t \,. \tag{14}$$

In the case of this study, it is not proper to apply the non-parametric estimators of q_t in Eq. 14 when the dead trees are missing in some of the age classes because the denominator should be nearly equal to one. Otherwise, it is desirable to apply parametric survival analyses for mean lifetime calculations to smooth the stepwise non-parametric estimates. For that purpose, we apply the Weibull distribution for $f(T)$ with the parameters of m and k:

$$f(t; m, k) = \frac{k}{m^k} t^{k-1} e^{-\left(\frac{t}{m}\right)^k} \,. \tag{15}$$

The mean and variance of Weibull distribution are $m\Gamma(1/k+1)$ and $m^2 \left\{ \Gamma(2/k+1) - \Gamma^2(1/k+1) \right\}$ respectively, and the former represents the mean lifetime. The parameters can also be estimated by the maximum likelihood method with L in Eq. 3.

Table 3 Living and dead species composition of each plot of all the periods (1989–2019)

Species	Plot 5203			Plot 5225			Plot 5240		
	Total trees (dead trees)			Total trees (dead trees)			Total trees (dead trees)		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
Abies sachalinensis	91(7)	92(8)	94(20)	34(5)	45(2)	56(9)	50(5)	49(6)	63(4)
Picea jezoensis	62(10)	52(10)	42(10)	32(3)	31(1)	32(7)	42(0)	43(4)	40(3)
Picea glehnii	1(0)	1(1)	0(0)	1(0)	1(0)	1(0)	3(2)	1(1)	0(0)
Betura platyphylla	2(0)	3(0)	3(2)	6(1)	7(0)	9(2)	9(4)	5(0)	6(1)
Quercus crispula	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(0)	2(1)	1(0)
Ulmus laciniata	40(3)	38(7)	33(6)	7(1)	12(1)	11(1)	4(1)	3(0)	3(1)
Cercidiphyllum japonicum	1(0)	1(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Magnolia obovata	0(0)	0(0)	0(0)	1(1)	1(0)	1(1)	0(0)	0(0)	0(0)
Prunus maximowiczii	1(0)	1(0)	1(0)	0(0)	0(0)	0(0)	1(0)	1(0)	1(0)
prunus ssiori	4(0)	6(1)	6(0)	0(0)	1(0)	1(0)	7(0)	8(0)	8(1)
Sorbus commixta	3(0)	4(2)	2(0)	5(0)	8(2)	7(2)	29(3)	25(7)	23(6)
Sorbus alnifolia	1(0)	1(0)	1(0)	0(0)	0(0)	0(0)	2(0)	2(0)	2(0)
Phellodendron amurense	1(0)	1(0)	1(0)	0(0)	0(0)	0(0)	8(3)	5(1)	4(1)
Acer japonicum	10(2)	9(4)	11(2)	0(0)	2(0)	2(0)	9(2)	7(3)	4(0)
Acer ukurunduense	1(0)	1(1)	0(0)	28(8)	58(10)	69(19)	1(1)	0(0)	0(0)
Acer mono	6(0)	7(0)	8(1)	0(0)	0(0)	0(0)	9(0)	10(1)	9(2)
Acer mono var. *myrii*	19(2)	25(2)	27(1)	1(0)	1(0)	1(0)	12(1)	14(1)	13(1)
Tilia japonica	108(20)	110(35)	81(22)	21(3)	45(5)	45(8)	34(3)	32(7)	28(1)
Acanthopanax sciadophyloides	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	9(0)	9(1)	8(6)
Kalopanax pictus	8(0)	9(1)	8(0)	0(0)	0(0)	0(0)	1(0)	2(1)	1(0)
Aralia elata	0(0)	0(0)	1(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Fraxinus mandshurica var. japonica	4(0)	6(0)	7(2)	2(2)	2(0)	2(0)	0(0)	0(0)	0(0)
Total trees (dead trees)	363(44)	367(72)	327(67)	138(24)	214(21)	237(48)	232(25)	218(34)	214(27)
Dead tree %	**12.15**	**19.89**	**18.51**	**6.63**	**5.80**	**13.26**	**6.91**	**9.39**	**7.46**

RESULTS

Species Composition

The dead and living tree composition of three plots in three periods are listed in Table 3. In the plot 5203, the number of living trees for the period 1, 2 and 3 were 319, 295, and 260. Mortality percentage was 12.15%, 19.89%, and 18.51% for the three periods of 5203. *Tilia japonica* had the highest number of dead trees among all the species of 5203. Moreover, the highest percentage of 19.89% of tree mortalities among all three plots resulted from period 3 of 5203. For plot 5225, the number of living trees of three periods were 114, 193, and 189, respectively. The least tree mortality percentage of 5.80% among all the plots was from period 2 of 5225. In period 3 of 5225, *Acer urkrunduense* was the main dead species among all the species. Though *Acer urkrunduense* had a lower average tree height, it represented the highest number of tree mortalities during 5225. In the plot 5240, 207, 184, and 187 living trees were counted, and *Abies sachalinensis* and *Picea jezoensis* were the two major species. Dead tree percentages of 5240 were 6.91%, 9.39%, and 7.46% for the three periods accordingly. Considering differences in the species composition of living and dead trees among the three plots, we dealt with the three plots data separately in the following survival analyses.

Age Class Distribution

Tree age class distributions are presented for three plots in three periods (Fig. 3). Note that the number of trees in the first age class consisted of the aggregation of new ingrowth trees found in census data in previous periods and that the number of trees in the *t*-th age classes were equal to the number of living trees in the (t-1)-th age classes in previous periods (t = 2, 3, 4,…). In plot 5203 (Fig. 3*a*), the highest number of new ingrowths can be seen from the 1st age class of period 1, while the lowest number of ingrowths from period 3. Most of the dead trees concentrated in the 1st, 2nd, and 3rd age classes through the periods (Fig. 3*a*). The distribution of 5203 showed many young trees and few old trees in the shape of the bimodal distribution in each period.

In the plot 5225 (Fig. 3*b*), the highest number of new ingrowth trees were observed in the 1st age class of period 2. Period 3 had the highest number of dead trees among other periods.

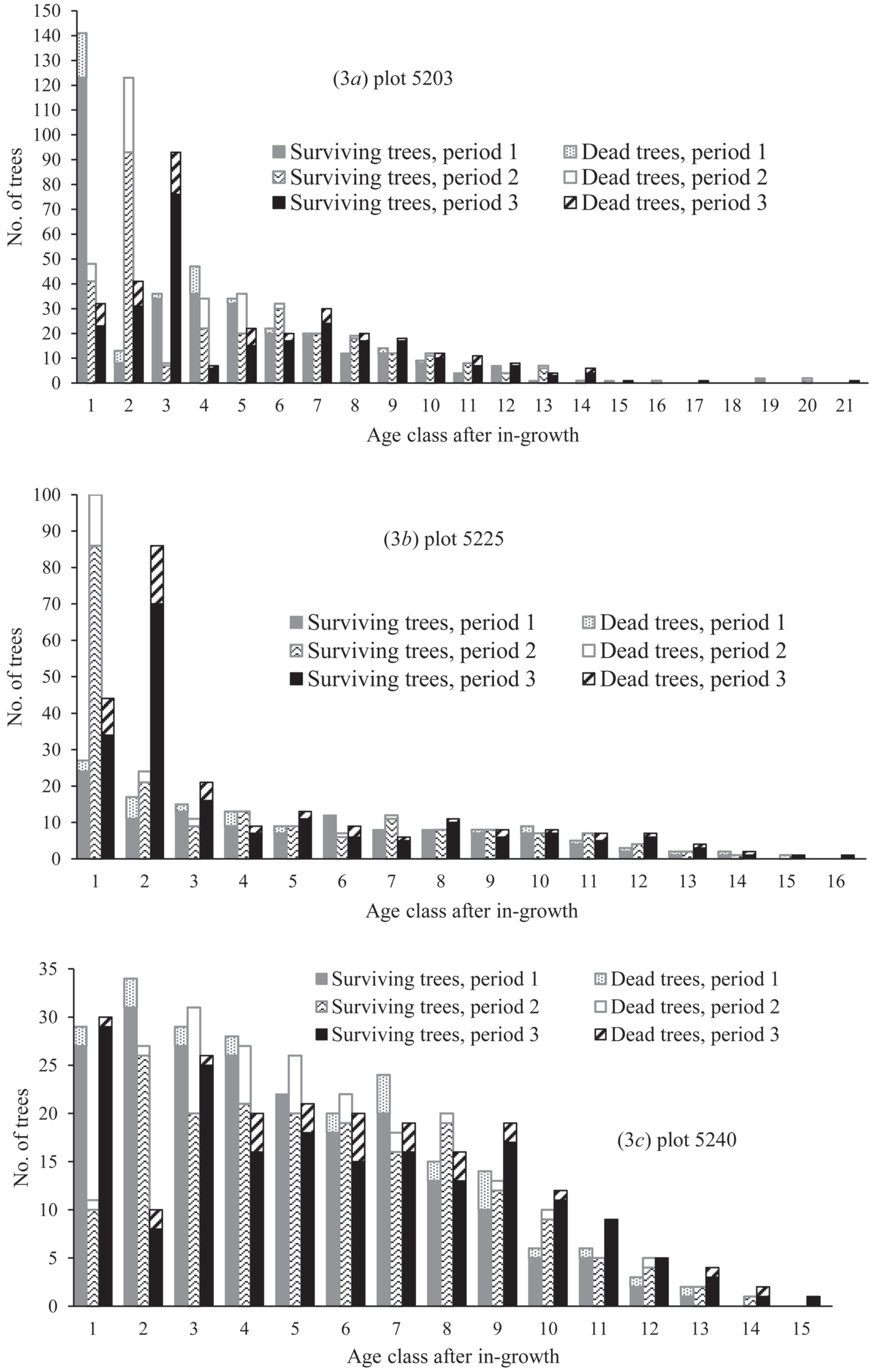

Fig. 3. Age class distribution of living and dead trees of 3 plots over the periods.

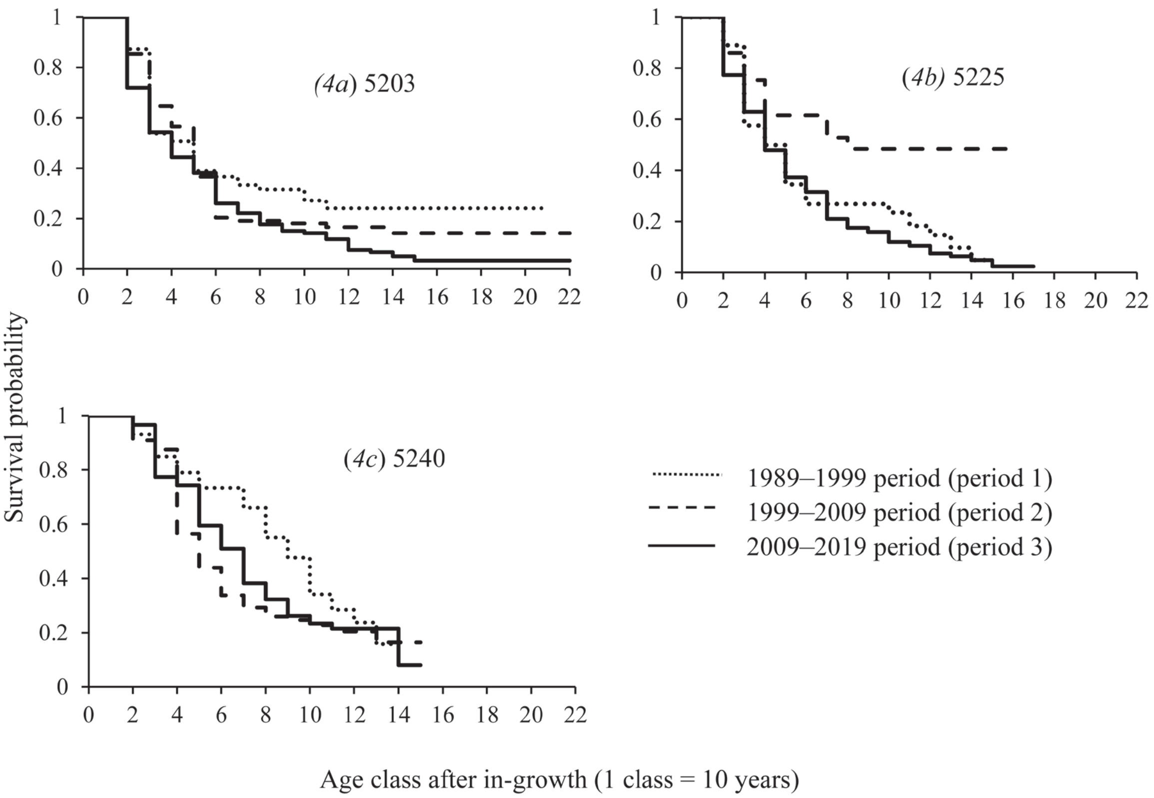

Fig. 4. Kaplan–Meier curves showing the tree survival probability during the three study periods.

Periods 1 and 2 showed an exponential type of age class distribution while 2nd age class of period 3 had a remarkably higher number of trees as an exception. Thus, the exponential pattern of age class distribution presented in the plot 5225 except for the 2nd age class of period 3.

In the plot 5240 (Fig.3*c*), the 2nd and 7th age classes of period 1 had a higher number of trees among all the age classes of period 1. The 1st age class of period 2 had a lower number of new ingrowths compared with other periods. It affected the 2nd age class of period 3 as well. The highest number of dead trees came from the 3rd age class of period 2 (Fig. 3*c*). Therefore, all three periods almost showed the shape of exponential type though they had some exceptions.

Thus, the age class distribution patterns varied among the plots, so further survival analyses were carried out separately, i.e., we did not compare Kaplan–Meier curves among three plots in the following log-rank tests. Besides, due to the insufficient number of dead trees for each species, further analyses were carried out without considering the difference of tree species, i.e., considering only one group of trees.

Kaplan–Meier Curves

Figure 4 shows the estimated Kaplan–Meier curves in the three plots during three periods. In this study, we compared the consecutive periods of period 1 with 2 and period 2 with 3. The stepwise fluctuations were inherent to Kaplan–Meier curves. In all the three periods of the plot 5203 (Fig. 4*a*), the curves declined considerably before the 3rd age class as a result of many young tree mortalities and decreased stepwise in the age classes in which trees died. In Figure 4*b* of the plot 5225, compared with period 2, the curves declined considerably during periods 1 and 3 owing to the deaths of both young and mature trees. No decline was observed in the curve of period 2 for the 8th or higher age classes since no dead trees were observed after the 8th age class. The plot 5240 (Fig. 4*c*) showed a similar Kaplan–Meier curve distribution with the plot 5203 though the highest age classes were younger. Generally, in all plots and all periods, none of the curves reached zero under the existing oldest age class. Overall, the differences in mortality among periods of 5225 were statistically significant. The other two plots did not show a statically significant difference when considering consecutive periods as mentioned above (Table 4).

Parametric Estimates

Mean lifetime could not be calculated based on the estimated Kaplan–Meier estimates in the plots due to the lack of dead trees in several age classes (Fig. 3). Therefore, the Weibull distributions were applied to all three plots for smoothing the stepwise values of non-parametric estimates. Table 5 shows the estimated parameters of *m* and *k* and the mean and standard deviation of the Weibull distributions. Figure 5 illustrates the results of estimated parametric distributions of mortality probability, mortality rate, and survival probability in the period 3 of three plots and, for reference, all three periods of the plot 5225. The meanings of mortality rate, mortality probability, and survival probability were explained, for instances, by assuming 100 trees in period 3

Table 4 Log-rank test results by comparing each period

Period	Plot 5203		Plot 5225		Plot 5240	
	p-value	Chi-squared value	*p*-value	Chi-squared value	*p*-value	Chi-squared value
1989-1999 and 1999-2009	0.1833	1.7707	0.04088*	4.1857	0.2167	1.5258
1999-2009 and 2009-2019	0.5577	0.3436	0.0068*	7.3295	0.6289	0.2336

Significant relationships ($p<0.05$) are with *.

Table 5 Probability distributions of the Weibull for each plot

	5203			5225			5240		
Weibull parameter	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
k	0.8767	0.8759	0.8566	1.0374	0.6042	0.9382	0.9825	0.9050	1.3522
m	8.3828	4.3157	3.8640	5.3051	20.7683	4.4234	8.6831	5.5414	7.8366
Mean	8.9517	4.6111	4.1836	5.2271	30.9680	4.5545	8.7497	5.8132	7.1840
Standard Deviation	10.24	5.28	4.90	5.04	53.97	4.86	8.91	6.43	5.37

m = scale parameter, k= shape parameter

of plot 5203 (Fig. 5*a*) like the followings: For the mortality probability of 0.05 at the 6th age class, if 100 new in-growth trees are produced now, 5 trees will die in the future at the 6th age class. For the mortality rates of 0.19 at the 6th age class, if 100 trees live in the 6th age class now, 19 trees will die at the 6th age class within this period. For the survival probability of 0.28 at the 6th age class, 28 trees will survive above the 6th age class among 100 new ingrowth trees.

Figure 5 showed that the shapes of probability distributions were determined by the so-called shape parameter of *k*, while mean longevity was determined by both *m* and *k* of Table 5. In period 3, the plots 5203 and 5225 (Fig. 5*a* and 5*c*) showed decreasing trends of mortality probabilities and survival probabilities along with age classes. Among them, Figure 5*a* represented the highest morality probability and mortality rate values in the 1st age class and fell mostly in the 2nd age class and then decreased monotonously with an increase in age. Period 3 of plot 5225 (Fig. 5*c*) maintained a slightly constant mortality rate throughout all the age classes. Interestedly, 5240 (Fig. 5*b*) showed a different pattern for the mortality rate, which was an increasing trend along with the age class, which came from the different range of shape parameters $k>1$ for the period 3 of 5240 among all the plots. In addition, period 2 of 5225 (light gray dots in Fig. 5*c*) showed remarkably higher survival probabilities and the highest mean of 30.97 with the lowest *k* of 0.60 while all the other plots have the means within 4.18–8.95 (Table 5).

Calculation of Age-related Indicators

We calculated the mean lifetimes, mean stand ages, and mean biological lifetimes for the purpose of evaluating the matured states of study stands.

According to the Weibull estimates in Table 5, the mean value represents the mean lifetime after ingrowth, and the mean lifetimes of the plot 5203 were about 90, 46, and 42 years old for periods 1, 2, and 3, respectively (Table 6). The lowest mean lifetime among the three plots was 42 years from period 3 of this plot 5203. The mean lifetimes of the plot 5225 were 52, 310, and 46 years old for three periods. Consistent with the Kaplan–Meier curve in Figure 4*b*, the highest mean and standard deviation values were found in the period 2 of plot 5225. Similarly, the mean lifetimes of the plot 5240 were 87, 58, and 72 years old for three periods.

The mean stand ages can be simply calculated as the weighted (i.e., the numbers of living trees in corresponding age classes are weights) means of tree ages in the study plots. These values ranged from 31 to 51 years old (Table 6).

The biological lifetimes of dominant species are reported as follows (Watanabe, 1970): *Abies sachalinensis*-127 years, *Picea jezoensis*-210 years, *Acer* spp.-178 years, and *Tilia japonica*-155 years. The mean biological lifetimes of study stands can be calculated as the weighted (i.e., the number of each species are weight) means of these biological lifetimes of the dominant species in the study plots. The mean biological lifespan of the study stands ranged from 161–169 years old (Table 6).

DISCUSSION

We discuss the matured state of stands from the viewpoints of age distribution, stable state of survival probability (KM curve), and comparison of age-related indicators referring to the previous studies.

Age Distribution

Matured forests can be viewed as aggregates of many patches in different stages of regeneration or cyclic succession, so that a wide variety of stand dynamics can lead to reverse-J shaped age distributions, particularly for natural stands composed of mixed tree species with different growth rates (Watt, 1947; Villalba and Veblen, 1997; Antos et al., 2000; Kuuluvainen et al., 2002; Worbes et al., 2003). In this study, the age distributions of all three plots declined gradually toward the older age classes resulting in two general shapes of the bimodal in the plot 5203 and the exponential (basically same meaning with the reverse J) in

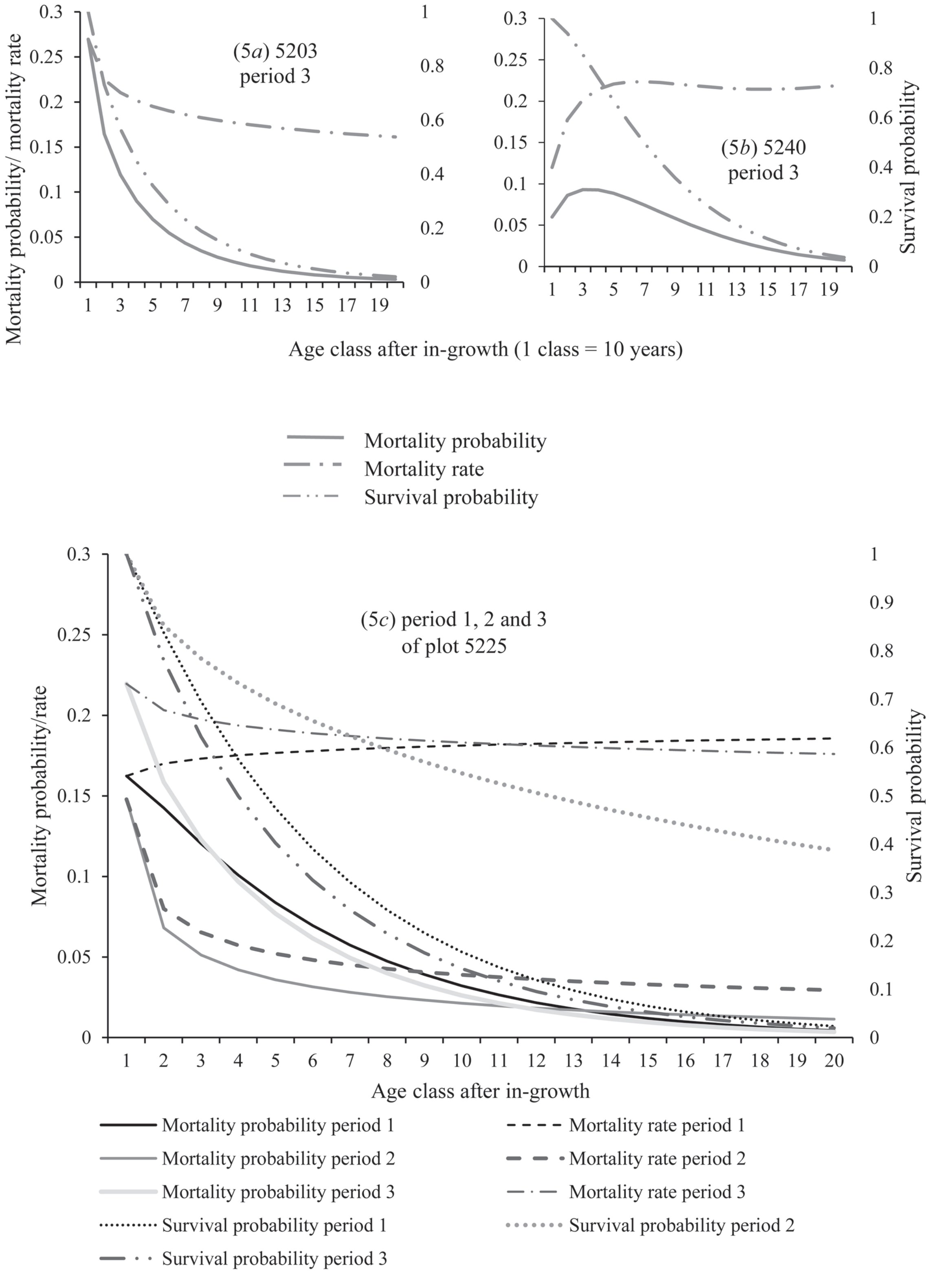

Fig. 5. Distribution of tree mortality probability, mortality rate, and survival probability based on Weibull distributions of three plots.

5225 and 5240 except for several specific age classes. Hiroshima (2014) suggested that reverse J-shaped age structures would be maintained in enough matured stands assuming continuous new ingrowth and dead trees in the older age classes. Because the three study plots were classified as the stand type of "coniferous selective cutting with poor regeneration" in UTHF, some of the stands may not maintain current exponential distributions in the future owing to a lack of an adequate number of new ingrowths

Table 6 Comparison of the mean lifetime, mean stand age, and mean biological lifetime of each plot

	Plot 5203			Plot 5225			Plot 5240		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Mean lifetime	90	46	42	52	310	46	87	58	72
Mean stand age	33	39	46	45	31	35	43	49	51
Mean biological lifetime	163	162	161	169	167	166	169	168	165

continuously. Considering these perspectives, moreover, Mosseler et al. (2003) discussed the critical aspects of old-growth forests and suggested that if new ingrowth trees were lacking, the stand moved to the old-growth stage with uneven multi-modal age structures as well as reverse J-shaped structures. Thus, the states of multi-modal age distributions could also be conceived as one characteristic of structural features in old-growth forests.

The Stable State of Survival Probability over Time

Hiroshima (2014) discussed the matured states of secondary natural forest stands and suggested that survival probability distributions, i.e., Kaplan–Meier curves, would converge into a stable state over time, referring to the generalized normal forest concept based on the Gentan probability theory (Suzuki, 1984) in enough matured stands such as natural forests in a climax stage of successions. Moreover, our findings suggested that the definition of "matured state" is based on two criteria; when there is no statistical difference among Kaplan–Meier curves over time and if the survival probabilities of old age classes reach nearly zero values. Therefore, the matured state of the forest stand can be evaluated based on the stable state of the survival probability over time.

In this study, significant differences were not found among Kaplan–Meier curves in consecutive two periods in the plot 5203 and 5240. Both plots showed no significant differences, but their KM curves shifted or fluctuated slightly from period to period. Particularly the time-series changes of 5203 were reasonable; with the increase of older dead trees in the later period (Fig. 3*a*), KM curves shifted downward in spite of no significant difference between each period (Fig. 4*a*), which looked certainly getting close to the stable state of a curve over time with the survival probability in the oldest age approaching to zero. Compared with the plot 5203, the curves of 5240 showed fluctuating in spite of no significant difference as well, which first shifted downward and then went upward. The KM curves of plot 5240, therefore, looked still on the way to converge (Fig. 4*c*). Incidentally, the KM curve of plot 5225 in period 2 showed the exceptional pattern (Fig. 4*b*) without older dead trees over 8th age classes (Fig. 3*b*).

Comparison of Mean Stand Age, Mean Biological Lifetime, and Mean Lifetime of Stands

Mosseler et al. (2003) summarized the aspects of old-growth forests like the followings: The mean age of predominant species reached almost half the maximum lifetime for the individual species, and some old trees were close to their maximum lifetime. In addition, when the stand remained in an old-growth stage without adequate new ingrowth continuously, the mean lifetime for the individual species would be getting higher, which was consistent with the suggestion by Hiroshima (2014). In our results, half of the mean biological lifetimes of study stands were around 80 years old and these 80 years old were still higher than the mean stand ages ranged 31 – 51 years old in all cases (Table 6). Meanwhile, some old trees were close to or even older than the mean biological stand lifetime of 160 years old in the study stands (Fig. 3), particularly the plot 5203 observed the maximum tree ages over 200 years old. The time-series changes in mean lifetimes in the study stands fluctuated, not showing the tendencies of getting older like Mosseler et al. (2003) insisted. Basically, the mean lifetime cannot be calculated correctly before the mortality probability converged in a stable manner; if there were not enough older dead trees in immature stands and survival probabilities remained higher values up to the maximum age classes, which simply led to the calculations resulted in a higher lifetime of stands. In this sense, if the plot 5203 was approaching to the stable state, the mean lifetime of around 40 years old in period 3 might be close to the intrinsic mean lifetime of the enough matured state of the stand.

Together with all the maturity level indicators, these facts could be summarized as follows: Firstly, the plot 5203 had the bimodal age class distribution, and 5225 and 5240 had the exponential shapes with a few exceptions of some age classes. These two kinds of age distributions were conceivable to be a matured state of stands to a certain extent and considering the inadequate new ingrowth continuously in these stands, the shape of multimodal distribution would be more general in enough matured stands. In this sense, the plot 5203 might be reaching a more matured state than 5225 and 5240. Secondly, the Kaplan–Meier curves were not significantly different over the periods in the plots except for the period 2 of 5225. These two stands were conceivable to be a matured state of stands to a certain extent, and particularly, the KM curves of 5203 looked gradually approaching to the stable state of a curve over time compared with the 5240 showing fluctuated behavior of curves. In this sense, the plot 5203 might Thirdly, the mean stand ages were still lower than the half value of mean stand biological lifetime in all cases, while some old trees were close to or even older than the mean biological stand lifetime, particularly in 5203. The mean lifetime of stands fluctuated and did not show clear aging tendencies, which indicated the study stands did not yet reach the enough matured states though there was a possibility that the mean lifetime of plot 5203 in period 3 was relatively close to the intrinsic mean lifetime of the enough matured stand. In these senses, the plot 5203 might be reaching the more matured state than 5225 and 5240. To sum up all these three aspects, it was consistently implied that the study stands might not get enough matured yet, but the plot 5203 showed further progress toward the matured state than 5225 and 5240.

CONCLUSION

In this study, we applied age-based survival analyses to the natural forest stands and estimated both non-parametric and parametric estimates of tree mortalities. Moreover, we evaluate the maturity of stands by comparing multi-temporal metrics such as age distributions, survival probabilities, mean age, and mean lifetime of stands. The analyses implied that the study stands might not get enough matured yet, but some plots showed further progress toward the matured state than others.

The mortality patterns and survival probabilities reported in this study would constitute a valuable reference for future studies to understand the stand dynamics of natural forests coherent to the morality of individual tree populations. However, for a better understanding of tree mortality and for reducing uncertainty in estimated survival probabilities, further research is needed. For instance, survival probabilities considering species differences can be more useful to identify the over-matured trees to harvest in the SSMS of UTHF.

ACKNOWLEDGMENTS

We thank the technical staff of the UTHF for their logistic support throughout the fieldwork and their help with the tree census data.

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(Received 18 February 2021)
(Accepted 10 May 2021)
(J-STAGE Advance Published 27 July 2021)

Article

Analysis of a Multi-stakeholder Process for Developing a Forest Certification Standard in Japan: A Case Study of FSC National Standard of Japan

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ABSTRACT

A fair, democratic standard development process is central to ensuring the credibility and legitimacy of forest certifications built on private governance. This study reports the implementation of the multi-stakeholder process for developing the FSC national forest stewardship standard of Japan and analyzes the factors affecting the discussion for collective decision making. In particular, this study highlights the issue of radiological safety and indigenous peoples' rights, on which the discussion for developing certification requirements especially contested due to considerable gaps between the international standards and the existing legal framework or practices in Japan. The overall discussion was characterized by the general conflict of opinions between certificate holders advocating for pragmatic requirements in line with existing practice and the civil society supporting robust standards. The factors that are considered to have affected the FSC national standard development in Japan include stakeholder relations, presence of competing scheme, governance structure, FSC's value proposition, and some personal leadership. Among them, the pre-set value proposition seems to be the most powerful factor that sets the priority in decision-making and determines the outcome. For this multi-stakeholder process, revisiting the shared value of FSC resulted in setting a priority on the certification's credibility over market uptake and many certification requirements at the level of international standards. In the future, comparison with other multi-stakeholder processes conducted in different contexts will further reveal factors affecting the deliberative and decision-making process and outcome.

keywords: forest certification, indigenous peoples, ionizing radiation, multi-stakeholder process, private forest governance

INTRODUCTION

The tide of globalization, accelerated by transnational corporations and globally stretched supply chains, increasingly undermines the governance by conventional regulatory framework bound by national borders (Meidinger, 2011; Mena and Palazzo, 2012; Soundararajan et al., 2019). Illegal logging and large-scale deforestation are prominent examples of such issues caused as a negative externality of globalized production. As conventional governmental and inter-governmental approaches have shown a limited effect in controlling the issues, forest certification emerged in the 1990s as a new, market-based tool to tackle the global forest issues (Bäckstrand, 2006; Cashore et al., 2008; Chan and Pattberg, 2008; Arts and Buizer, 2009; Meidinger, 2011). Since then, many forest certification schemes have been established worldwide at both local and international levels, framing the new paradigm of private governance based on multi-stakeholder dialogue and interactive policymaking (Cashore et al., 2008; Arts and Buizer, 2009; Meidinger, 2011).

Such initiatives of private governance, most commonly called multi-stakeholder initiatives (MSIs), are now present in almost every field and industry to fill the global regulatory gaps primarily by establishing 'soft law' standards imposed only on the parties who voluntarily participated (Bäckstrand, 2006; Chan and Pattberg, 2008; Mena and Palazzo, 2012; Moog et al., 2015). As a new form of rule-setter and transnational polity, however, MSIs lack the inherent regulatory power that the conventional government has. Since their power of influence is built on the voluntary engagement of supporters bound by their free will (Boström and Hallström, 2013), MSIs need to continually demonstrate their legitimacy and accountability through effective implementation of the multi-stakeholder process (MSP), a democratic rule-making process involving diverse stakeholders (Chan and Pattberg, 2008; Steffek, 2009). In forest certifications, MSP is central to the development of certification standards, and its implementation can directly impact the

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DOI: 10.20659/jfp.2022.001

certification schemes' credibility. However, while there are many studies on forest certification, there have not been many studies reporting MSP's implementation.

This study reports the implementation of the multi-stakeholder process for developing the Forest Stewardship Council (FSC) national forest stewardship standard of Japan and analyzes the factors affecting the discussion for collective decision making. In particular, this study highlights the issue of radiological safety and indigenous peoples' rights, on which the discussion for developing certification requirements was especially contested due to considerable gaps between the international standards and the existing legal framework or practices in Japan.

MATERIALS AND METHODS

Overview of FSC

Founded in 1994, FSC was one of the first MSIs established (Utting, 2002; Mena and Palazzo, 2012; Okereke and Stacewicz, 2018) and was the first global forest certification scheme. It has two kinds of certification: (1) forest management (FM) certification for forestry enterprises and (2) Chain-of-Custody (CoC) certification for entities processing or trading certified products. Only when all entities along the supply chain are certified, can the final product be labeled as certified. Organizations get certified by accredited third-party certification bodies only when they demonstrate that their operations meet the requirements set by relevant standards developed through MSP.

FSC's most fundamental standard of responsible forestry is the principles and criteria of forest stewardship (P&C). It consists of ten principles and seventy criteria that is globally applicable to all types and scales of forest (Forest Stewardship Council, 2015b). However, it cannot be used directly in the field without developing national or regional forest stewardship standards, which include more specific requirements as "indicators," that take into account local contexts. While the indicators used to be developed independently for each local standards, for the latest P&C (version 5), the International Generic Indicators (IGIs) have been developed globally as the common base to develop national standards to avoid inconsistencies between local standards. With the IGIs, the work of national standard development was reduced to deciding whether to adopt, adapt, or reject each IGI or to add a new indicator to address unique issues that are not covered by IGIs. The national standard development framework has been standardized and does not allow for much deviation from the prescribed process and structure of the standard.

Central to FSC's governance and its implementation of MSP in standard development is the chamber-balanced decision-making. FSC's members, either individuals or organizations, are divided into environmental, economic, and social chambers, each of which holds one-third of the weight in votes. At the global level, members are further divided into the North (developed countries) and South (developing countries), which are weighed equally in each chamber (Forest Stewardship Council, 2017).

Development Process of the Japan National Standard

The FSC forest stewardship standard of Japan was developed following the procedures prescribed in relevant FSC normative documents (Forest Stewardship Council, 2009; Forest Stewardship Council, 2015a) from 2015 to 2018. Prior to the establishment of the national standard, interim standards developed by certification bodies had been used for forest evaluations for FSC FM certifications in Japan.

After the publication of the International Generic Indicators (IGIs) version 1-0 in June 2015, a national Standard Development Group (SDG), a committee responsible for the process and the content, was established. The SDG of Japan consisted of three members in each of the three chambers (environment, economic, and social) and a non-voting chair, following the FSC's chamber-balanced governance requirement. Any decision as a group required support from all three chambers. The SDG members were mostly the same as FSC Japan Board members, who have demonstrated commitment to, understanding of and experience with FSC. Members included environmental NGOs, a forest consultant with FSC auditing experience, FM certificate holders, and researchers.

From September to October 2016, three open discussion sessions were held to invite major stakeholders and experts to exchange opinions to ensure their involvement at the early stage of the standard development. Based on the discussion sessions, the SDG developed the first draft standard. Working groups were organized for some contentious issues including radioactivity and indigenous peoples' rights. The working groups consulted external experts as necessary. The working groups compiled draft indicators, which were further discussed by the SDG.

The first draft of the standard was published for the public consultation from 7 June to 6 August 2016 for sixty days. During the consultation period, public hearing sessions were held in Tokyo, Hokkaido, and Osaka and collected approximately one hundred participants in total. Despite the efforts, only eight stakeholders submitted written comments, though many more comments were collected through the public hearing sessions.

After the first consultation, the first draft was tested for auditability in two certified forests in Hokkaido and Kochi. Hokkaido was selected for the necessity to test Principle 3 about indigenous peoples' rights, as the indigenous Ainu Peoples lived mostly in Hokkaido. The second site was selected for different geographical location, certificate type, and organizational type. The proposed indicators on radioactivity could not be tested because FSC Japan was unable to find any suitable forestry enterprise in the area affected by radioactivity willing to cooperate for a field test.

The results from the first public consultation and the field tests were discussed by the SDG and reflected in the second draft, which was then published for consultation from 1 March to 30 April 2017. Nine stakeholders submitted comments, which were considered for the final draft. The final draft was submitted to FSC International in December 2017 by the consensus of all SDG members. After five conditions raised by the FSC Policy and Standards Committee were addressed, the national standard was formally approved in November 2018. The approved standard and was made effective in February 2019 with one year for a transition from existing standards.

Analytical procedure

The information reported and used in this study is mostly based on the author's observation, records, and first-hand experience of the FSC national standard development process in Japan. As a policy and standards coordinator of FSC Japan, the author organized meetings of the national Standard Development Group (SDG) as well as working groups on specific topics, collected technical information relevant to the discussion theme, prepared materials for discussion, and kept meeting notes. The author also managed the field tests, public consultations, stakeholder communications, as well as communication with the FSC international. For each process, records were kept. Some of the records were published in FSC Japan website news, but most of them were shared only among the parties directly involved. The author was accessible to all the information due to her role in the process.

To find the general tendency of different stakeholder types (certificate holder, FSC staff, NGO, researcher, government, certification body, and others), opinions collected in the public consultations were categorized into three groups based on their content: 1) those suggesting more lenient standards; 2) those seeking more stringent standards; and 3) those that were neither, for each stakeholder group. For two major stakeholder groups, *i.e.* FM certificate holders and NGOs, Fisher's exact test was conducted to test the statistical significance on the difference in orientation of opinions. To find the overall tendency of discussion in relation to the original international generic indicators (IGIs), the number of IGIs that were adopted, adapted, or deleted, as well as new national indicators added, were counted in each stage of the standard development process. Then the discussion on radiation and indigenous peoples' rights was described in detail based on observation and record review, including major arguments from stakeholders. Some background information was also supplemented to better explain the arguments. For the contents of the discussion, there was no quantifiable data to be analyzed.

RESULTS

While there is some quantitative output presented, this section mainly provides the discussion conducted on specific topics in the course of the standard development, described as a result of the author's observation and record review. The topics highlighted were: ionizing radioactivity, which is further divided into workers' radiological safety and radiation safety of forest products; and indigenous peoples' rights. These topics demanded long, convoluted discussions, which would best illustrate how deliberations evolved to reach a conclusion.

Overall results

Leaving out duplicates, 89 people in actual participated in the stakeholder consultations. Participation by affiliation categories is: 21 (23.6%) from FSC FM certificate holders; 9 (10.1%) from CoC certificate holders; 15 (16.9%) from NGOs; 10 (11.2%) from national and local governments; 8 (9.0%) from academic institutions. While some CoC certificate holders participated in public hearing sessions, none of them expressed an opinion. FM certificate holders that participated included corporate forest owners, cooperatives of forest owners, and prefectural and municipal governments. NGOs included environmental NGOs and indigenous peoples' groups. Among the environmental NGOs, there were more international ones than domestic ones. Stakeholders with social interests were mostly those interested in indigenous issues, including indigenous people, scholars, and journalists. On the other hand, some stakeholder groups were missing from the process. There was no participation of groups explicitly representing the interests of women, forestry workers, local communities, and consumers. The involvement of the national government (Forestry Agency) was also minimal. Participation from the industry associations and relevant organizations was also largely missing. There was also no participation from stakeholders of contaminated forests around Fukushima.

During the public consultations, a total of 424 opinions were collected; 310 (73.1%) from FSC FM certificate holders, 58 (13.7%) from FSC staff, and 31 (7.3%) from NGOs, as shown in Table 1. Seventy-one percent of FM certificate holders' opinions sought more lenient standards, whereas 81% of NGOs' opinions proposed that standards should be more stringent. Fisher's exact test for these two groups' opinions yielded a p-value smaller than 0.01.

In the final, approved version of the FSC national standard of Japan, 77 IGIs were adopted, 119 adapted, 6 dropped, and 19 indicators were newly added. The number of dropped indicators and added ones did not change from the first draft to the final version. The number of adopted IGIs increased from 73 in the first draft to 74 in the second draft and 76 in the final version.

For the development of a national standard, FSC had set a guideline to reflect scale, intensity, and risk (SIR) of organizations in the requirements. This guideline allows for setting variances for indicators depending on the recognized potential impact (Forest Stewardship Council, 2015c; Forest Stewardship Council, 2016). Following the guideline, many SIR-specific indicators were proposed in the first draft. Yet, they were subsequently rejected with strong objections from a wide range of stakeholders, including both certificate holders and NGOs.

Corporate certificate holders protested against setting more stringent requirements for large forestry enterprises, pointing out that large-scale forest owners in Japan do not necessarily run profitable forestry businesses by conducting extractive forestry with high impacts. On the other hand, NGOs and some researchers objected to the proposals to soften requirements for smaller operations, arguing that the risk of adverse impacts is not necessarily proportional to the scale of operations. Due to their limitation in economic and technical resources, smaller entities also have a possibility of not being able to carry out sufficient management measures to control some inherent risk. In

Table 1. Counts of opinions collected from the public consultations.

	Lenient	Neither	Stringent	Total
FM certificate holder	220	89	1	310
FSC staff	3	51	4	58
NGO	0	6	25	31
Researcher	0	2	2	4
Government	0	1	0	1
Certification body	0	4	0	4
Others	1	13	2	16
Total	224	166	34	424

"Lenient" means opinions suggesting more lenient standard. "Stringent" are those supporting more stringent standards. Categorized in "Neither" are opinions that are neutral in that they do not support more lenient nor stringent standards.

the end, opinions from both ends found the point of agreement in not making SIR-specific variants for indicators in the Japanese standard.

While the standard covered various aspects of forest management comprehensively, comments from stakeholders and discussion in the SDG were concentrated on some specific issues such as radioactivity, occupational health and safety, a living wage, indigenous peoples' rights, definition of natural forests and plantation, pesticide use, and setting aside a certain proportion of forests for conservation. The following sub-sections describe the contents of the discussion on indigenous peoples' rights and radioactivity, which is further divided into workers' radiological safety and product safety. The basic information and discussion for these topics are summarized in Table 2.

Forestry Workers' Radiological Safety

Because there was no IGI on radioactivity to set the base as a certification requirement, the discussion on radioactivity started from scratch. The discussion on radioactivity focused on ^{137}Cs among various radionuclides, as it is the only kind of long-lived radionuclide released in significant quantity from the accident of Fukushima Daiichi Nuclear Power Plant (FDNPP) in March 2011. In discussing workers' radiological safety, opinions advocating mere legal compliance initially prevailed in the SDG. However, an SDG member from an environmental NGO pointed out that applicable Japanese laws do not provide sufficient protection for forestry workers to the level recommended by the international standards and advocated for adding more stringent requirements to provide additional protection for forestry workers. To examine the claim, relevant Japanese regulations and the international standards on radiological safety were examined and compared.

The Japanese laws on occupational radiological safety are based on the 1990 Recommendation of the International Commission on Radiological Protection (ICRP) which provides an average effective dose of 20 mSv per year over five years and a maximum of 50 mSv in any single year as the limit for occupational exposure (ICRP, 1991). However, such laws are not necessarily applicable to forest workers. In addition, ICRP provides a more stringent standard, a maximum of 1 mSv/y, as the limit for public exposure. The delegate from the environmental NGO argued that the limit for the public exposure should be applied to forestry workers, for they are exposed to radiation as general citizens, not as workers who have accepted the risk in exchange for wage. In the radiation-contaminated areas around Fukushima, the laws and regulations applicable to forestry workers include: 1) the evacuation order, which prohibits residence and associated activities in areas with the annual integrated dose exceeding 20 mSv/y; 2) "Guidelines for Work under Specified Doses" issued by the Ministry of Health, Labor, and Welfare; and 3) "Guideline for Transporting Trees Logged in Non-state Forests in Fukushima Prefecture" issued by the Forest Management Department of Fukushima Prefecture. The second one, Guidelines for Work under Specified Doses encourages people to work in areas under the air dose rate of 2.5 μSv/h. However, considering that the limit is equivalent to 21.9 mSv/y by simple conversion and areas exceeding 20 mSv/y are already under the evacuation order, this guideline may not provide additional protection. The third guideline from Fukushima Prefecture provides that "harvesting and removal of trees are permitted where the air dose rate does not exceed 0.50 μSv/h" (Forest Management Division of Agriculture, Forestry and Fishery Department, Fukushima Prefecture, 2014). The limit was established to prevent the occurrence of bark that requires treatment as special waste, and but not from the perspective of ensuring workers' safety. Thus, it does not provide restrictions on general forest management activities other than harvesting.

To ensure the international consistency of FSC requirements, the SDG also studied the situation in countries around Chernobyl. All the examined standards used in FSC FM certification in Chernobyl-surrounding countries referred to the relevant national law for radiation-related requirements (FSC Russian National Office, 2012; NEPCon, 2014a; NEPCon, 2014b; SGS Qualifor, 2015a; SGS Qualifor, 2015b). It was found that in countries around Chernobyl, activities are more strictly restricted in radiation-affected areas. The regulatory zoning of contaminated areas in Japan and countries around Chernobyl is summarized in Figure 1. Ukraine, Belarus, and Russia, along with other republics of the former USSR, define contaminated areas as areas with radiation exceeding 1 mSv/y, in line with the ICRP recommendation's dose limit for public exposure (Nesterenko and Nesterenko, 2009; Anisimov and Ryzhenkov, 2016). Either vol-

Table 2. Summary of points in contested issues

	workers' radiological safety	Radiation safety of forest products	Indigenous peoples' rights
International standard	·50 mSv/y and 100 mSv per 5 years for occupational exposure 1 mSv/y for public exposure	Not available	·UNDRIP ·ILO Convention 169
Legal requirement in Japan	·50 mSv/y and 100 mSv per 5 years for occupational exposure 20 mSv/y by the evacuation order	·100 Bq/kg for general food ·Not available for general wood ·40 Bq/kg for fuelwood	·None as indigenous rights ·Ainu cultural promotion
NGO side	·Establish a robust requirement with a stringent limit of radiation. ·Keep the internationally recommended level of assurance at a minimum. A more robust requirement is desirable. ·Certifying business-as-usual practice is meaningless. As a most trusted forest certification, FSC should keep the credibility by establishing robust requirements.		·Protect indigenous peoples' rights in line with UNDRIP. ·Provide more specifics to define actions to be taken by forest enterprises.
Business side	·Establish pragmatic indicators based on the actual situation of the Japanese forestry industry that the forestry business is not profitable and the forest certification does not provide much economic benefit. Object to requirements that impose the work of measuring radiation even in low-risk areas. ·Requirements that are too robust will only prevent the uptake of FSC certification by the industry. ·Setting a strict limit on radioactivity will preclude contaminated areas around Fukushima from the certification and may invite criticism that FSC is not supporting the reconstruction of the affected areas.		·Requirements that are too robust based on a model case will only prevent the uptake of FSC certification by the industry. ·The issue is not relevant to one's forest management (most certificate holders outside Hokkaido)
Other opinions	·FSC should not establish a requirement on radiological safety as it lacks expertise.	·A requirement for radiation safety of products should not be established because FSC is not a certification of product quality.	
Point of agreement	·Require the process of consultation to ensure radiological safety in area above the limit for public exposure.	·Avoid harvesting of forest products in area above the limit for public exposure.	·Keep the original requirements and add information or explanation to help implement the requirement.

untary or obligatory, people resettled from the contaminated area are provided with various compensation and benefits (Matsko and Imanaka, 1997; Ryabtsev and Imanaka, 1997; Nasvit and Imanaka, 1998; Takahara et al., 2010; Anisimov and Ryzhenkov, 2016). Moreover, forestry activities are forbidden in the exclusion zone within 30 km from Chernobyl Nuclear Power Plant and the obligatory resettlement zone, where a radiation dose can exceed 5 mSv/y (Nesterenko et al., 2009). Even in less contaminated guaranteed voluntary resettlement areas, forestry operations are restricted mainly to fire prevention, forest protection, monitoring, and pest control (Ipatyev, 2001; Shibata, 2013). In addition, workers' dose of exposure is monitored to ensure that the accumulative dose stays less than 1 mSv/y (Shibata, 2013). Such practices and legal framework altogether keep the exposure of forestry workers within the ICRP recommended dose limit for the public. As such, private certification standards can ensure the workers' protection to the internationally recommended level by simply referring to the legal requirements.

The opinion to adopt the dose limit for public exposure in the national standard eventually won other SDG members' support, though discussion continued regarding specific wording of the requirement. The NGO delegate advocated for a requirement that is even stricter than the internationally recommended dose limit for public exposure, but other members were reluctant to make requirements more stringent than necessary. While the working group on radiation, which consisted of three SDG members and the SDG chair, consulted several experts, their opinions varied widely depending on their perspectives and standpoint. Unable to agree on a single indicator, three different indicators shown in Table 3 were proposed in the first draft to collect opinions from stakeholders through the public consultation. The proposed indicators were not mutually exclusive as they represent different perspectives.

In the public consultation, radioactivity was one of the most contested issues. Yet, there was little feedback on the proposed indicators. Common comments from certificate holders included those opposing setting requirements on radioactivity, pointing out FSC's lack of expertise on the issue or arguing that such a

Table 3. Indicators of workers' radiological safety proposed in the first draft

Number	Proposed indicator	Rationale
2.3.12A	For the health and safety of workers in relation to the radioactive contamination of forests, it is ensured that radiation exposure of workers does not exceed 1 mSv/y in the effective dose.	One mSv/y is an annual dose limit for the general public according to 1990 Recommendations of the ICRP. Under this limit, the impact of exposure to radiation is considered negligible.
2.3.12B	Workers work in the area where the average air dose rate does not exceed 0.11μSv/h.	0.11μSv/h is equivalent to 1 mSv/y by simple conversion. The annual dose limit of 1 mSv per year (ICRP Recommendation for public exposure) is difficult to monitor and measure. In the field, it is more practical to ensure safety by limiting forestry operations to areas where radiation does not exceed the limit. Note that the Japanese government uses 0.23 μSv/h as equivalent to 1 mSv/y, assuming eight hours of work and reduced exposure during the off-time, but a more conservative number by simple conversion is used for this proposed requirement.
2.3.12C	Workers work in areas where the radioactive Cesium contamination density on the soil and tree surface does not exceed 0.4 Bq/cm2.	It is desirable to prevent internal exposure by monitoring the concentration of radioactive materials in the air as well as in soil and bark. However, as the clearance level in surface contamination has not been established, a voluntary standard needs to be established. Ordinance on Prevention of Ionizing Radiation Hazards provides 40 Bq/cm^2 as the surface contamination density limit, and 4 Bq/cm^2 as the limit for designation of radiation controlled area, the density limit to take things out of the controlled area, as well as the limit for radiation workers to go out of the area. The radioactivity for the general public is often managed in 1/100 of the occupational setting. Thus 1/100 of the surface contamination density limit (40 Bq/cm^2) was proposed as the voluntary standard here.

rule-setting should be left to the government. Certificate holders and auditors of certification bodies also raised concerns that the new requirement with a specific reference level would necessitate all certificate holders to measure radioactivity in order to demonstrate conformance, regardless of the actual risk of radioactivity in their forests. They argued that the new standard should not impose unnecessary work to certificate holders in uncontaminated areas.

There were also opinions from stakeholders pointing out the heterogeneous distribution of radionuclides as a practical challenge in monitoring radiation. It is known that radioactive cesium tends to be carried down along with litters and accumulate at the bottom of hillslope and depression (Koarashi et al., 2014), though once adsorbed to soil particles, it tends to be fixed and stay in place (Takahashi, 2013; Kaneko and Tsuboyama, 2014). Thus even when the publicly available information indicates a low aerial dose around an area, specific measurements at hotspots may exceed the established limit. Keeping the exposure dose under a specific limit may be difficult in the undulating terrain where Japanese forestry typically occurs.

Some SDG members and stakeholders also expressed another general concern about the broader implication of the new requirement for the promotion of FSC in Japan. Developing a rigorous radiological safety requirement will preclude contaminated forests around Fukushima from FSC certification, potentially inviting criticism against FSC for not supporting Fukushima's economic reconstruction. Amid various nation-wide campaigns to support Fukushima's revival, it would not be strategically wise to take the risk, especially when the competing domestic forest certification scheme had been rapidly expanding and FSC had been struggling to win more support from the industry. On the other hand, SDG members from environmental NGOs maintained that contaminated forests were better left undisturbed as source and sink of radionuclides for public health even considering its negative impact on Fukushima's local economy.

The intense discussion between those supporting stringent requirement in line with the internationally recommended dose limit for public exposure and those accepting the ongoing practice in contaminated areas continued until the SDG revisited the FSC's value proposition and clarified the priority in the standard-setting. The SDG agreed that FSC's value proposition is in its credibility as the most trusted international forest certification and that keeping the reputation is the priority. The commitment expressed by a leading forester in the economic chamber played a role in unifying the opinions under the shared FSC value. The SDG eventually settled on the following points: 1) a requirement on radioactivity should be added to the standard as an indicator; 2) the new indicator requirement should refer to 1 mSv/y, the ICRP-recommended dose limit for public exposure; 3) the requirement should not necessitate measurements of radiation

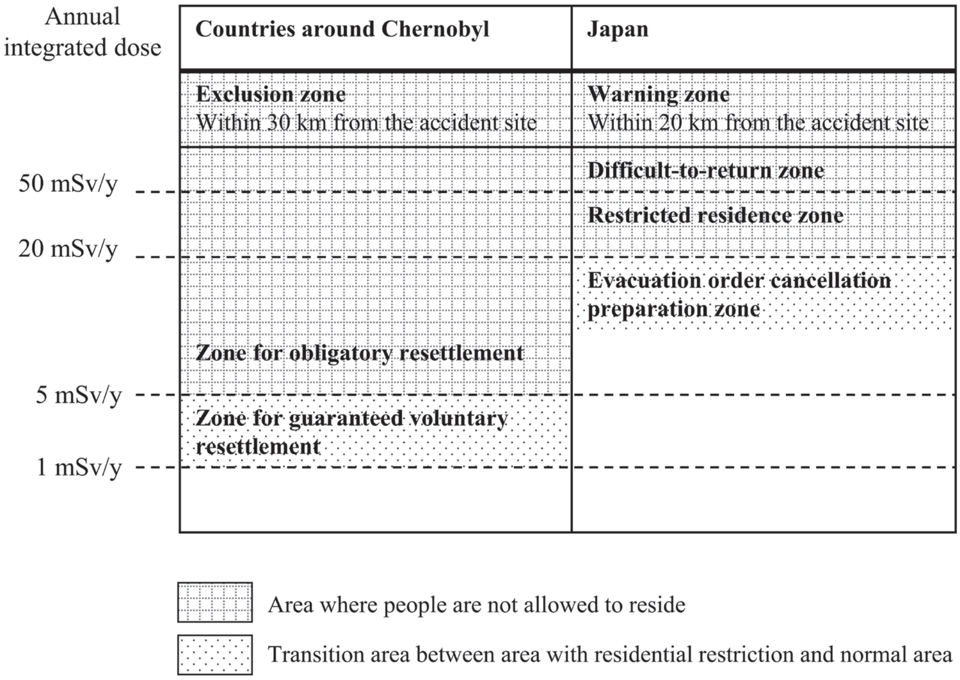

Fig. 1. Regulatory zonation of radiation-contaminated areas in Japan and countries around Chernobyl (Ukraine, Belarus, and Russia). Based on Matsko and Imanaka (1997), Nasvit and Imanaka (1998), Ryabtsev and Imanaka (1997).

in low-risk areas; and 4) the issue needs to be discussed continuously, especially among the affected workers themselves, to reflect the latest information and scientific findings. In the end, the SDG reached a conclusion to require an engagement with stakeholders, especially affected workers, to ensure the radiological safety of forestry workers in areas with more than the effective dose of 1 mSv/y. Because it requires a process of ensuring safety but not a direct adherence to the specific dose limit, it does not necessarily ensure workers' radiological safety to the desired level. Still, it was supported by the SDG's consensus as the best compromise among various perspectives. The indicator was proposed in the second draft, and it was maintained till the approved standard, as no comments with new perspectives were submitted during the second consultation.

Radiation Safety of Forest Products

For the radiation safety of forest products, there has been an argument that product safety is not the scope of FSC certification from the beginning. Still, it was inconceivable to leave the issue undiscussed considering the reputational risk to FSC when highly radioactively contaminated forest products are sold as certified. Thus, similar to the issue of workers' radiological safety, international standards, legal requirements, and the existing situations on the radiation safety of forest products were reviewed as a starting point for the discussion.

With regards to forest products' radiation safety, unlike the radiation dose for people, there is no single, internationally agreed reference level for commodities. Different authorities set different reference level for various commodities that are often categorized differently with varying definitions (See Table 4). However, the reference level is not always available for wood. The Japanese government has established the limit for wood related to food, e.g., firewood, logs for mushroom cultivation, charcoal for cooking, but not for lumber, despite the repeated requests by Fukushima Prefecture to the national government (Hayajiri, 2015). Wood for construction is considered relatively safe because most radionuclides in trees are removed with bark (Panfilov and Uspenskaya, 2002; Takahashi, 2015), and studies have indicated that construction wood has negligible risk to human health (Tonosaki, 2013). In the absence of an official regulatory limit for wood, a volunteer standard of a maximum permissible level for lumber established by Fukushima Prefecture Wood Cooperatives Union has become the practical safety standard for wood in Fukushima (Fukushima Prefecture Wood Cooperatives Union, 2012). The limit is based on the maximum allowable radiation level of materials to be taken out of radiation-controlled areas, as specified by the Regulation on Prevention of Ionizing Radiation Hazards.

On the other hand, the reference level for general food established by the Japanese government, 100 Bq/kg, is among the most robust internationally (See Table 4). Contrarily to wood, both around Fukushima and Chernobyl, some edible NTFP species accumulate high level of radionuclides (Neda, 2014; Kiyono and Akama, 2017), and continue to pose high health risk to local people who collect them for private consumption even years after radioactive accidents (Kashparov, 2016; Labunska et al., 2016; Forestry Agency, 2020; Ministry of Agriculture, Forestry and Fisheries, 2020).

To reflect the contrasting situations for wood and edible NTFPs, in the first draft, certification requirements were proposed for the two product categories separately, as shown in Table 5. For both categories, multiple candidate indicators with differ-

Table 4. Maximum permissible levels of ^{137}Cs (Bq/kg) set by various countries/ institution

	Russia	Ukraine	Belarus	NIS countries after 2002	Japan	EU	Codex Alimentarius Commission
Forest products							
Roundwood			1480	11100			
Barked wood for sawed products			1850	3100			
Wood products for household processing				2200			
Firewood			740	1400	40		
Construction wood			740	370			
Logs for mushroom cultivation					50		
Charcoal for cooking					280		
Mushrooms (fresh weight)		500	370	500	100		
Wild berries (fresh weight)		500	185	160	100		
Game meat			500		100		
Main food[*1]	370	6-500[*2]	185-592[*2]		100	1250	1000
Other food	600	600	592	100	100	1250	1000
Infant food	185	40	37		50	400	1000
drinking water		2	18.5		10	1000	

*1: Including milk and dairy products, bread, grains, sugar, vegetables, oils, etc.
*2: Specific limits are established for various categories of food
Source: Russia: (Ryabtsev and Imanaka, 1997); Ukraine: (Nasvit and Imanaka, 1998); Belarus: (Matsko and Imanaka, 1997; Shibata, 2013); New Independent State (NIS) countries: (Fesenko et al., 2005); Japan: (Research Center for Food Safety, 2012) ; EU: (Council Regulation (Euratom) no. 2218/89 of 18 July 1989); Codex Alimentarius, 2011). Codex Alimentarius is a collection of standards, guidelines and codes of practice adopted by the Codex Alimentarius Commission, a joint organization of the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO).

ent limits were proposed, reflecting the contentious discussion that did not settle on one conclusion. The indicators establishing more stringent limits (8.5.5 A3 and B2 in Table 5) were proposed by an environmental NGO delegate. Similar to the workers' safety, the primary concerns raised by stakeholders were the necessity of measuring the radioactivity of forest products and the heterogeneity of radionuclides' distribution that makes conformance to a specific limit challenging. A very few stakeholders commented on the limit values in the proposed indicators. In the second draft, the SDG adopted 40 Bq/kg, the limit for fuelwood established by the Forestry Agency, as a limit for all forest products. The limit was the most stringent among all the limit values proposed for wood and stricter than the legal reference value established for general food.

However, after the second consultation, the reference to a specific value was removed altogether, reflecting stakeholders' concerns that establishing a specific limit would necessitate measurement of radioactivity and add an undue load of work to many certificate holders. The indicator was rewritten to generally require ensuring a low risk of radioactive contamination of forest products, with a note that harvesting forest products from areas with a high risk of radioactive contamination should be avoided. The area with a high risk of radioactive contamination was defined as the area not exceeding 1 mSv/y, consistent with the new requirement for workers' radiological safety. This indicator made it unnecessary for most certificate holders to measure radiation levels to demonstrate conformity unless their forests are located in high-risk areas. At the same time, by focusing on the forest management activity rather than the product, the indicator also incorporated the persisting opinion that questions establishing a requirement for product quality. Although this requirement does not directly limit the radiation level of certified products, it was considered sufficient to control the risk of certified forest products to human health, for NTFPs, which pose high health risks, are controlled by the established legal limit that is considered internationally robust.

Indigenous Peoples' Rights

Indigenous peoples' issues are among the most frequently contested issues in forest certification worldwide (Hysing, 2009; Irvine, 2000; Teitelbaum et al., 2019; Wyatt and Teitelbaum, 2020). FSC is considered the most robust forest certification scheme in addressing indigenous peoples' rights, having Principle 3 dedicated to indigenous issues (Overdevest, 2010; Teitelbaum and Wyatt, 2013; Smith and Perreault, 2017). The requirements in FSC's Principle 3 include: identification and upholding of indigenous peoples' legal and customary rights; implementing Free, Prior, and Informed Consent (FPIC) for delegation of control over indigenous peoples' resources and territories; upholding of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP); protection of significant sites; and protection of traditional knowledge.

The discussion for Principle 3 started with the most fundamental issue: to whom the Principle should be applied. In other words, who should be considered indigenous in Japan. The United Nations recognizes two indigenous peoples in Japan: Ainu Peoples and Ryukyu Peoples, while the Japanese government only recognizes the former. However, in FSC, which is independent of any government, any groups that meet the FSC's definition of indigenous peoples should be treated as such regard-

Table 5. Indicators on radiological safety of forest products proposed in the first draft

Indicator Number	Proposed requirement	Rationale
8.5.5 A1	Forest products have been harvested from areas with the average air dose rate not exceeding 0.11 μSv/h.	The air dose rate of 0.11 μSv/h is equivalent to the exposure dose limit of 1mSv/y recommended by ICRP for the general public by simple conversion.
8.5.5 A2	The radioactivity concentration of forest products does not exceed 100 Bq/kg.	Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors set 100 Bq/kg as the clearance level for radioactive wastes based on international recommendations and guidelines. 100 Bq/kg is also the reference level for the general food, including edible NTFPs.
8.5.5 A3	The radioactive Cesium concentration of forest products is less than 40 Bq/kg, and their surface concentration of radioactive contamination is less than 0.4 Bq/cm^2.	40 Bq/kg is the reference level established by the Forestry Agency for fuelwood. Ordinance on Prevention of Ionizing Radiation Hazards sets 40 Bq/cm^2 as the surface contamination density limit. According to the NGO that proposed this indicator, the radioactivity for the general public is often managed at 1/100 of the occupational setting. Thus, as a voluntary standard, 1/100 of the limit under occupational setting was proposed.
8.5.5 A4	The information of radioactivity of forest products, including methods and results of measurement, is publicly available.	This indicator supplements either requirement from A1 to A3 to ensure transparency of the way conformance is demonstrated.
8.5.5 B1	The radioactivity concentration of edible forest products such as mushroom and wild plants do not exceed 100 Bq/kg.	100 Bq/kg is the safety standard for general foods established by the Ministry of Health, Labour, and Welfare so that the effective dose of exposure does not exceed the annual maximum permissible dose of 1 mSv/y for all age classes.
8.5.5 B2	The radioactivity of edible non-timber forest products such as mushrooms and wild plants is less than 10 Bq/kg.	10 Bq/kg is based on the voluntary standard of Green Co-op, which is considered one of the most stringent standards.

less of official recognition by the government. For this reason, whether the principle should be applied to Ryukyuans remained a matter of controversy.

For a long time, the Japanese government did not recognize the existence of any indigenous peoples in Japan, maintaining the position that the country is ethnically homogeneous (Oguma, 1998). Yet, under the growing international pressure, the Diet adopted the Resolution Calling for the Recognition of the Ainu People as Indigenous People in the Diet in 2008 (McGrogan, 2010). Still, it was not until 2019 that Ainu's status as indigenous peoples was formally written into laws with the enactment of a new law on Ainu. Nevertheless, the new law's scope was limited to cultural promotion, as was the previous law it replaced, without a mention of other rights as indigenous peoples. On the other hand, the Japanese government has never changed its position of not recognizing Ryukyu Peoples as indigenous. Ryukyu Peoples' status as indigenous peoples is controversial even among themselves, as evidenced by some local NGO's and municipal governments' protest against the UN's recommendation (Okinawa Times, 2016; Ginowan City Council, Okinawa Prefecture, 2019; Okinawa Policy Research Forum of Japan, 2019). For this reason, it was not clear whether Ryukyu Peoples satisfy the indigenous peoples' key characteristics of self-identification. No opinion was raised from Ryukyu Peoples or their groups about this issue during the consultations, mostly because advocates of Ryukyu Peoples' indigenous rights were rather limited and the interest in forest certification was generally low in Okinawa, reflecting the forestry industry's limited scale in Okinawa (Forestry Agency, 2021). In the end, the SDG reached a conclusion that it was not suitable to explicitly require the application of Principle 3 to Ryukyuans in the national standard, but the possibility should be left open on a case-by-case basis. A note was added at the principle level to clarify the view.

In the absence of a Ryukyuan stakeholder interested in the forest certification, stakeholders for the discussion for Principle 3 were limited to those concerning Ainu Peoples (including researchers) and certificate holders in Hokkaido. Accordingly, the rough draft of indicators relevant to indigenous issues was first prepared jointly by delegates of the Ainu Association of Hokkaido (AAH), the biggest Ainu organization, and an SDG member specializing in indigenous issues, considering cases related to Ainu Peoples. The draft was then examined in the working group comprised of the AAH delegate and three SDG members representing the three chambers of the SDG. The rough draft contained proposed changes to the IGIs not only in Principle 3 but also in other principles, but other members of the working group maintained that requirements on indigenous peoples' rights should be limited to Principle 3. The discussion focused on how to implement the requirements provided by IGIs, assuming the acceptance of IGIs. Among various requirements, discussions contested especially on identification of Ainu peoples and implementation of UNDRIP.

Identifying Ainu peoples is not easy because Ainu peoples are not distinguishable by appearance or any legal, documented status. The Japanese official family registry does not recognize any ethnicity. As a result of the long history of intermarriage and the assimilation policy, many Ainu descendants do not necessarily have the identity of Ainu or even know their ancestry. As there is hardly anyone with pure Ainu blood today, self-recognition as Ainu seems to be a matter of personal identity than blood. A field test conducted in Hokkaido also highlighted the issue's sensitivity, as a worker that the audit team tried to interview refused to be identified as Ainu. As a solution, the AAH delegate proposed using the organization's registry of Ainu people, which has been used as a basis for implementing various public policies for Ainu Peoples. Following the suggestion, a note was added to indicators to provide a practical guideline that certificate holders or applicants should inquire AAH in case they cannot identify local Ainu stakeholders.

The requirement of upholding UNDRIP also demanded discussion because of the wide scope of UNDRIP and the huge gap between the declaration's sublime philosophy and the reality in Japan as well as the limitation of forest management. While the Japanese government adopted the non-binding declaration in 2007, implementation has been limited to Ainu cultural promotion. Many of the rights provided in UNDRIP are beyond the capacity of forestry enterprises, as they necessitate an underlying legal and social framework, which needs to be addressed by the government. Thus the question was which rights are applicable in the forest certification and how it should be implemented through forest management. Among the rights prescribed in UNDRIP, protection of culturally significant sites has been widely accepted as a certification requirement and implemented in the field, as it has been covered not only in Principle 3 but also in Principle 9 on High Conservation Value (HCV) since previous standards. Other rights, such as the rights to lands and resources are more problematic, as their implementation faces various constraints.

In developing certification requirements, existing cases and issues with implementing indigenous peoples' rights in the field was taken for consideration. However, there have not been many cases of implementing indigenous rights both inside and outside the forest certification's framework. FSC-certified Mitsui & Co., Ltd.'s agreement with a local Ainu association in 2010 to provide forest resources for producing cultural objects was a rare case of forest management involving indigenous peoples (Mitsui & Co., unknown). Such an initiative was followed by Hokkaido Forest Management Bureau's similar arrangement with local Ainu organizations for the state-owned forests (Hokkaido Forest Management Bureau, 2014). On the other hand, salmon fishing for traditional ceremonies has been an issue of contention as the prefectural regulation only allows Ainu traditional fishing with prior approval, while some Ainu activists advocate their indigenous rights to fish freely. Because the actual cases concerning Ainu peoples' rights to lands and resources in forests were limited in number and scope, the discussion in the working group stayed rather theoretical. In the end, in the first draft, the working group mostly adopted IGIs by adding some notes that identify relevant rights to be considered and that provide examples of possible actions for implementation.

Many Ainu stakeholders participated in the public hearing session held in Hokkaido during the first public consultation period. However, their comments and questions mainly concerned the accountability of the certification system, not the specifics of the proposed indicators. On the other hand, researchers and NGOs demanded adding more specifics to relevant indicators to define actions to be taken by forestry enterprises. Such proposals were in direct opposition with opinions of certificate holders in Hokkaido that making the standard too prescriptive will put an undue burden to certificate holders. The certificate holders also expressed a general concern that using Mitsui & Co., Ltd.'s case as a model will make the standard too strict and prevent the diffusion of the certification in the industry. While the issue attracted many stakeholders' attention in Hokkaido, certificate holders outside of Hokkaido stayed indifferent to the issue as the requirements did not apply to them.

In considering various inputs from stakeholders in Principle 3, the SDG prioritized maintaining FSC's value as the most credible forest certification by adhering to the IGIs. Most comments from NGOs and Ainu stakeholders were incorporated, while certificate holders' perspectives were reflected by removing redundancy in requirements to make the standard simpler and adding notes to help implementation. In the second public consultation, there were hardly any opinions with new insights. As a result, the finalized contents of Principle 3 were founded on what was initially agreed with AAH in the working group, with more input from civil society than economic stakeholders reflected.

DISCUSSION

While the discussion for FSC national standard development covered a wide range of topics, discussions contested on some specific topics where there is a considerable gap between FSC's international requirements or international standards and the existing practice in the Japanese forestry industry. Overall, the discussion for the standard development was characterized by the opposing structure of certificate holders and civil society, including environmental NGOs and indigenous peoples groups. Certificate holders opted to seek down-to-earth indicators in line with the existing practices, stressing the challenging economic reality that the Japanese forestry industry had been facing for years. On the other hand, civil society advocated for more rigorous requirements, with international standards as the minimum, grounded on the view that the value of FSC is in the highest standard of forest management. Researchers varied greatly in their position. While researchers in indigenous peoples' issues unanimously advocated the indigenous peoples' rights together with NGOs, in the discussion of radioactivity, some researchers stood by the government or the business operators.

In the course of the standard development process, the two opposing views of the business sector and civil society tended to converge to adherence to the minimum international standards. Neither proposals by civil society stakeholders to establish more stringent requirements nor certificate holders' opinion to make requirements in line with the existing practice lower than the IGIs were accepted by the other side. Such a trend is reflected in the increased number of indicators adopting IGIs in the final draft as compared with the earlier drafts. In some cases, the pragmatic perspective was taken into account by adding notes and explanations that would help the implementation or by requiring processes instead of results. In a sense, IGIs served not only as a starting point for debate but also as a point of compromise for the opposing opinions.

Reconciling the conflict between the business sector and civil society is a common challenge to MSI governance. Ever since its foundation, FSC has been struggling to balance market impacts and robust standards. At the time of FSC's founding, there was an intense debate regarding the priority: whether to set stringent environmental standards or to achieve wide recognition of FSC labels in the market by making them more accessible to enterprises (Moog et al., 2015). Prioritizing the integrity of standards will limit the uptake of the certification while achieving a broader impact in the market would necessitate bringing in major enterprises into allies by making certification standards more in line with their views. In the end, global recognition for the label won the priority. Since then, FSC has grown by employing a series of controversial strategies to cater to business needs, including certification of plantations, use of recycled materials, and introduction of Controlled Wood and FSC Mix labels, which altogether led to a gradual decline in FSC's legitimacy (Moog et al., 2015). Such a development of FSC is typical to MSIs; as an MSI grows, it tends to attract new members of lower sustainability performance, who add downward pressure on loosening standards (Zeyen et al., 2016). As a result, MSIs are prone to be caught in a downward spiral of inclusive membership growth and lowering standards.

While opinions from certificate holders with business considerations were dominant in number among opinions collected from stakeholders, such views were not dominant throughout the deliberation and the decision-making process in the SDG. Rather, the resulting standard reflected civil society's perspectives more strongly. Needless to say, the pre-defined chamber-balanced framework of the FSC's governance played a significant role in controlling the power balance and determining the outcome. The outcome would have been different if more decision-making power had been allocated for economic stakeholders, as is the case in the other competing certification scheme (Overdevest, 2010). The two-tier approval process at the national and international level may also have prevented the national SDG from making requirements more lenient, as the FSC International would not allow much deviation from the pre-determined IGIs.

The discussion on the radiation issues, for which there was no IGI, best demonstrated how parties make negotiations to find an agreeable point of compromise. The issue of radiation was complex, and the discussion showed no sign of convergence with many conflicting opinions for a long time. Yet when the SDG revisited the value proposition of FSC certification, they found common ground for an agreement: the objective and the priority of standard-setting is to protect and enhance FSC's value. Decision-makers, i.e. the SDG members, were in consensus that the credibility as an international certification with the highest standard of responsible forestry shapes both the value and identity of FSC, and that protecting the trust in the brand is the top priority. In other words, they agreed that the diffusion of certification to the market can be compromised in order to protect the value. The resulting requirements reflected more perspectives of civil society than industry, despite a large number of comments submitted by certificate holders.

It has to be mentioned that some personal effects also might have played a role in unifying opinions. In the face of an intense dispute over the radiation issue, an SDG member, who is a leading forester and the first FSC FM certificate holder in Japan, maintained that FSC should remain a gold brand of sustainable forestry, which requires proactive management beyond the usual practices of the industry. Supported with his demonstrated, unparalleled contribution to the development of FSC in Japan, his words were persuasive and effectively united the group in upholding high standards as an embodiment of FSC value and identity. The fact that the opinion came from a significant figure in the economic chamber also had a significant impact on the outcome. However, this is different from authoritative, top-down decision-making by a top decision-maker. Unlike many political or business settings, the decision-makers in this process, i.e., nine members of the SDG, were free from organizational hierarchy and other interests or pressure to take a certain position. They were all volunteers independent from each other and had equal power by design. Since the decision was made by consensus by the free-will of the members, the personal effect does not undermine the integrity of the process or legitimacy of the collective decision. Still, this case suggests that although the influence of individuals may not be an ideal factor in a democratic, collaborative decision-making process, personal leadership can play an important role in resolving contention.

It was notable that all the SDG members in the economic chamber, who were certificate holders themselves, also agreed with the decision that compromised the business interest in order to uphold FSC's value. Considering that SDG members had been selected for their demonstrated commitment to FSC, this may not be a surprise. However, it was also possible that the certificate holders who participated in FSC standard development process were limited to those who embrace the non-economic value of FSC from the beginning. A study found that FSC FM certificate holders had chosen FSC over Sustainable Green Ecosystem Council (SGEC), a Japanese domestic forest certification schema, for "credibility" and "outside appeal," and because it was an "international scheme" (Sugiura and Oki, 2018). On the other hand, it reported that Japanese FM certificate holders, of both FSC and domestic scheme SGEC, generally do not perceive the economic benefits of the forest certifications. Unlike SGEC, FSC is not supported by industrial associations and government-affiliated organizations, thus it is not very likely that FSC certificate holders choose FSC out of external pressure. These findings suggest that the forestry enterprises that chose and stayed with FSC, especially those who engaged in the FSC national standard development, tend to embrace FSC's non-economic value, and were more predisposed to accept stringent requirements embodying sustainable forestry ideology than the average enterprises in the industry. In a sense, FSC in Japan has not yet matured to the stage where the certification attracts a large number of enterprises with strong business interests to the degree to threaten the organizational ideology.

It is also noteworthy that throughout the standard development process, there were not many disagreements among certificate holders in their perspectives, especially between industry forest owners and private forest owners or their associations, unlike some cases reported abroad. For example, in British Columbia, Canada, a clash between the industrial forest enterprises and the woodlot community resulted in the approval of the FSC regional standard in the complete lack of industry support (McDermott, 2012). Even worse, in Sweden, a heightened conflict between industrial forestry owners in the North and small-scale private forest owners in the South led the latter to withdraw support from FSC entirely (Hysing, 2009). The private forest owners' coalition subsequently established an alternative certification scheme, which eventually evolved into a competing global forest certification scheme: PEFC (Hysing, 2009; Schlyter et al., 2009). In the US, though they were not in conflict with each other, different perspectives and needs of private forest owners and industry forestry enterprises gave rise to two domestic certification schemes: the American Tree Farm System (ATFS) and Sustainable Forest Initiative (SFI), both of which have been endorsed by PEFC. On the contrary, as claimed by themselves during the public consultation, the Japanese forestry players shared a common predicament regardless of organizational scale and types, such as the low price of timber and heavy reliance on government subsidies. As certificate holders shared many issues in common, the stakeholder relations were considered relatively simple and manageable in this MSP. It can be said that such situations altogether had contributed to a consensual or collaborative orientation of stakeholders, which is considered vital for an MSP (Mena and Palazzo, 2012; Soundararajan et al., 2019).

Soundararajan et al. (2019) argue that the deliberative capacity of MSIs can be enhanced through collaborative stakeholder orientation focusing on overlapping values and shared responsibility. Indeed, this case study of FSC national standard development in Japan reconfirmed the importance of the shared value in directing the discussion to reach a consensus. In FSC national standard development, the shared value was clear from the beginning: environmentally appropriate, socially beneficial, and economically viable forest management that FSC envisages. Still, the assumed embraced value and the process's goal were obscured as the discussion revolved around specific details. Attempts to resort to scientific information or expert opinion in the hope of finding an objective solution were not very helpful. In the radiation issue, expert opinions varied depending on their standpoints. On the other hand, in the issue of indigenous peoples' rights, although experts unanimously advocated for the indigenous peoples' rights, certificate holders could not accept their perspectives unconditionally. After all, there is no purely objective opinion, and any information and opinions need to be interpreted in a given context to achieve a goal. Instead, revisiting the agreed value as a common ground and focusing on the shared goal was found to be a more reliable approach in consensus-building.

Overall, FSC national standard development in Japan presented in this case study was rather a simple case of an MSP implementation, with the pre-defined framework and the baseline for the discussion and limited stakeholder participation. It certainly had many shortcomings, including a lack of participation of some key stakeholders on the contested issue, such as stakeholders in Fukushima, and a failure to conduct a field test in the area of dispute: radiation-contaminated forests. Still, the insight gained from this case study should be relevant to other MSIs, as stakeholder participation is never uniform across all sectors, and many MSIs also face constraints arising from the competition with competing schemes. In addition, in any MSIs, stakeholders' engagement with an MSI is based on a shared value and a common goal, which is central to the MSI's existence.

Studies reporting the implementation of MSPs are still limited. In the future, as MSIs keep prevailing in various fields worldwide, more experiences will be shared. MSIs vary significantly in their value proposition, reflected in the governance structures, decision-making procedures, and power balance between business and non-commercial stakeholders (McDermott, 2013). Comparison with other cases of MSPs implemented by different institutions and in different contexts will further reveal the factors and conditions affecting this critical process underlying the MSI's legitimacy, contributing to further discussion on MSIs.

CONCLUSION

The FSC national stewardship standard development in Japan conducted from 2015 to 2018 was a simple case of MSP with limited stakeholder participation, pre-defined procedures, and International Generic Indicators that set the starting point of discussion. Throughout the process, the discussion was characterized by the conflict between civil society advocating for stringent requirements and certificate holders seeking pragmatic requirements in line with the existing practice. Discussions were especially contested in some issues, such as radiological safety and indigenous peoples' rights, on which there were gaps between the international standards and the legal framework or existing practices in Japan. Factors that are considered to have affected the process include stakeholder relations, presence of a competing scheme, governance structure, MSI's value proposition, and some personal effects. MSI's value proposition seemed especially powerful in determining the outcome; when discussions were contested, reconfirming the FSC's value helped set the discussion orientation to reach an agreement. In the future, comparisons with other MSPs conducted in different settings will provide more insights into the effective MSP implementation that underlies the legitimacy of MSIs.

ACKNOWLEDGEMENTS

The author would like to express the deepest gratitude to Professor Norihiko Shiraishi, Dr. Satoshi Tatsuhara, and Dr. Tohru Nakajima for their constructive advice and guidance in completing this research. The author also would like to thank FSC Japan, including colleagues and Board members, who provided unlimited support and understanding for the project and in publishing this paper. The author is also grateful to the two anonymous reviewers who provided much practical advice to improve this paper. Finally, the author is deeply indebted to her family. Without their warm, generous support, this work could not have been completed.

CONFLICTS OF INTEREST

The author declares the conflict of interest with the subject of the study, FSC. The author has been employed by FSC Japan and coordinated the national standard development process reported in this paper.

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(Received 18 November 2020)
(Accepted 16 November 2021)
(J-STAGE Published 15 April 2022)

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