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Article

Patterns and Determinants of Early-stage Vegetation Development in Abandoned Plantation Clearcut Sites in Kyushu, Japan: Toward Prioritizing Sites for Restoration

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ABSTRACT

The abandonment of plantation sites after clearcutting is increasing in Japan; there is concern that if vegetation fails to recover or develops too slowly after clearcutting, there will be a decline in forest ecosystem services. An appropriate management strategy for rectifying the situation might include predicting vegetation recovery for each abandoned site and prioritizing sites for restoration. Here, we present a regional-scale study that investigated a large number of abandoned plantation clearcut sites distributed across Kyushu Island. The objective was to develop a better general understanding of early-stage vegetation recovery patterns and their determinants, which will be useful in prioritizing sites for restoration. Four vegetation classes -grassland (*GL*), few pioneer trees (*FPT*), non-pioneer trees (*NPT*), and pioneer trees (*PT*)- were detected by a vegetation survey. Sites that were (1) affected by deer browsing, (2) had relatively young tree stands at the time of clearcutting, and (3) that had been clearcut recently most often recovered to *GL* or *FPT*. Under these site conditions, efforts should be directed toward reducing deer grazing to enhance vegetation recovery during the initial stages of regrowth. Restoration effort should be allocated to sites classified as *GL* even 5 years after clearcutting, which includes a relatively large proportion of the study area. *FPT*, *PT*, and *NPT* sites should be monitored over the long term. This monitoring effort should be used to determine (1) whether tree species recovery is successful in *FPT* sites and (2) whether *PT* or *NPT* sites will convert successfully to evergreen broad-leaved forests (lucidophyllous forests).

Keywords: forest management, restoration priority, simplified vegetation survey, deer browsing, tree species recovery

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INTRODUCTION

In Japan, there has been a substantial increase in the number of forest sites abandoned without replanting after clearcutting because of the prevailing unfavorable forestry conditions, such as falling timber prices, increased operational costs, and an aging and declining workforce. Abandonment after clearcutting is spreading through the nation (SAKAI, 2003; SAKAI *et al*., 2006; YAMAGAWA *et al*., 2006) and is indicative of an impending decline in domestic timber production. There is also concern that if vegetation fails to recover or develops too slowly after clearcutting, there will be a reduction in the capacity of the forests to influence soil, water, and biodiversity conservation (SAKAI, 2003; YOSHIDA, 2003; YAMAGAWA *et al*., 2006).

One appropriate management strategy to rectify these circumstances might include (1) predicting vegetation recovery for each abandoned site and (2) prioritizing sites

for restoration based upon the site-specific amount of effort needed to aid recovery. Vegetation stabilizes soil, and water-holding capacity increases through the progressive steps of plant community succession (FUJIMORI, 2004). Hence, restoration efforts may be preferentially allocated toward (1) sites where tree establishment is difficult, (2) sites where pioneer species become dominant, and (3) sites with non-pioneer/late successional species that are likely to develop into the ideal target vegetation of evergreen broad-leaved forest (lucidophyllous forest). Implementation of such a management strategy will require broad-scale interpretations of vegetation recovery patterns and its determinants.

In a previous study, we investigated the patterns and determinants of early-stage vegetation recovery in abandoned plantation clearcut sites in Oita prefecture (633,900 ha) in northeastern Kyushu (NAGASHIMA *et al*., 2009). We demonstrated that relatively small abandoned sites that had been clearcut many years prior to the study and were adjacent to evergreen broad-leaved forests were likely to allow invasion by evergreen tree species. Pioneer species tended to become dominant under adverse conditions. The presence of regenerative plant fragments (i.e., tree stumps) capable of sprouting new stems also markedly influenced (from the earliest stages) recovery of non-pioneer/late successional species (both evergreen and deciduous). Several other studies have shown that elevation and slope type can influence regeneration patterns in abandoned clearcut sites (SAKAI *et al*., 2006; YAMAGAWA *et al*., 2006), but these factors were not identified in our previous study.

The effects of deer browsing can be crucial for vegetation recovery. As in many areas of the world, deer populations in Japan have increased dramatically over recent decades and have hindered tree regeneration in many forests (TAKATSUKI and GORAI, 1994; NOMIYA *et al*., 2003; ITO and HINO, 2005). Sika deer (*Cervus nippon*) browsing decreases the number of seedlings and saplings in vegetation (TAKATSUKI and GORAI, 1994; TSUJINO and YUMOTO, 2004), retarding woodland successional development (GILL and BEARDALL, 2001). Few studies have evaluated the effects of deer browsing on abandoned plantation clearcut sites, and the extent to which deer browsing affects vegetation recovery are not well understood. Deer grazing was not considered in our previous study (NAGASHIMA *et al*., 2009) because there were few overt signs of browsing-related damage. Nevertheless, sika deer are widely distributed in the southern part of Kyushu Island (TSUNETA, 1998), where there are large numbers of abandoned plantation clearcut sites (YAMAMOTO, 2003). It is therefore possible that vegetation recovery patterns are now different from those during our previous study conducted in Oita prefecture. It is now obvious that a regional-scale approach is required to discern the generalities of vegetation recovery patterns in abandoned clearcut sites in warm-temperate regions.

Accordingly, we investigated a large number of abandoned clearcut sites distributed across Kyushu Island to analyze the relationship between recovered vegetation types and the putative determinants of variation among vegetation types. Our objective is to use this information in directing restoration efforts based on our previously mentioned priority ranking. To this end, we also applied a simplified vegetation survey exploring the coverage of pioneer or non-pioneer trees in a plot, instead of conducting a precise vegetation survey (i.e., tree census); this simplified method might be useful to determine the vegetation development status of extensively distributed abandoned plantation clearcut sites. Therefore, the validity of interpreting recovered vegetation based on this simplified vegetation survey is also discussed.

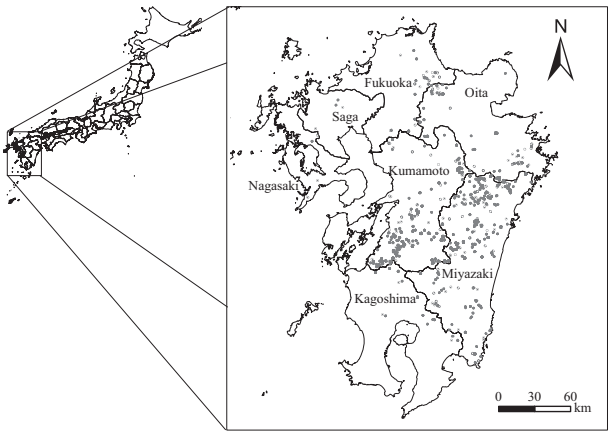

Fig. 1 Study area and distribution map of 671 abandoned clearcut sites of plantation

MATERIALS AND METHODS

Study Area

Kyushu, the third largest island in the Japanese archipelago, is located in the southeastern part of the country (Fig. 1). The island has a total area of approximately 4,217,810 ha. Sixty-three percent of the area (2,674,023 ha) is covered by forest (FORESTRY AGENCY OF JAPAN, 2009); the natural vegetation in most of the region is warm-temperate evergreen broad-leaved forest. However, above 1000 m elevation, the vegetation gradually changes to cool-temperate deciduous broad-leaved forest (MIYAWAKI, 1982). The island is one of the best-known active forestry regions in the country. Plantations occupy >50% of forested area (1,500,995 ha), mostly in the southern sectors of the island (Miyazaki, Kumamoto, and Kagoshima prefectures). This region is strongly impacted by difficulties currently facing the Japanese forestry industry. Plantations abandoned after clearcutting first appeared in the 1990s (OKAMORI, 2003) and have since expanded progressively year after year. A 1996 survey (OKAMORI, 2003) showed that

Table 1 Number of abandoned clearcut sites and investigated sites by prefecture

Prefectures	Abandoned sites	Investigated sites
Fukuoka	25	12
Saga	4	3
Nagasaki	4	4
Kumamoto	273	16
Oita	58	51
Miyazaki	287	81
Kagoshima	20	20
Total	671	187

Miyazaki (143 sites, 375 ha) and Kumamoto prefectures (105 sites, 278 ha) had the second- and third-largest number of abandoned clearcut sites after Hokkaido (295 sites, 865 ha). There are many of these sites in Oita prefecture (Nagashima *et al*., 2009), and this number is increasing (Okamori, 2003).

Field Survey

Among 671 abandoned clearcut sites found in Kyushu Island (Fig. 1; see Murakami *et al*., 2006 and 2007 for procedures to detect abandoned clearcut sites), 187 were selected for vegetation surveys. In prefectures that had a relatively small number of abandoned sites, nearly all were investigated, except those that were inaccessible (Table 1). In Miyazaki prefecture, we randomly selected 81 abandoned sites among >250. In Kumamoto prefecture, we selected 16 sites that were common to our survey and a 2005 survey conducted by the prefecture. The selected sites were distributed across varying elevations (50-1,050 m above sea level; median height, 500 m), had a wide range of clearcut areas (0.5-66.5 ha; median 3.35 ha), and had undergone clearcutting at different times before our study (from 1-12 years prior; median, 6 years).

We obtained field measurements in the period between 2005 and 2008. At each study site, 1 or 2 study plots measuring 10 × 10 m were set up; in some sites, 2-5 plots measuring 4 × 4 m were established. The total number of study plots was 218. The locations of study plots were chosen carefully to include vegetation typical of each site. We selected slopes rather than ridges or valleys; forest edges were avoided to exclude edge effects. We used both areas and abundances of typical vegetation types present to determine the number of plots established at each site. Specifically, 4 × 4 m study plots were established in clearcut plantations that were either large in area or had several typical vegetation types; in addition, these sites had recovered vegetation up to 4 m tall. We adopted different plot sizes to better understand characteristics of recovered vegetation in abandoned clearcut sites that are extensively distributed throughout Kyushu Island. We also hypothesized that since vegetation height is a parameter used to determine appropriate quadrant sizes (Suzuki, 1954), the ratio of vegetation cover should be equivalent when plot sizes are determined by vegetation height.

For conducting the simplified vegetation survey, a list of tree species categorized by their successional trends (pioneer/non-pioneer) was prepared using descriptions in illustrated guidebooks (Kitamura and Murata, 1979; Okuda, 1997; Mogi *et al*., 2000) and informed recommendations made by researchers with broad experience in vegetation survey in Kyushu Island (Appendix). Based on this list, we recorded coverage of pioneer and non-pioneer tree species at canopy and shrub layers in each plot; we also measured coverage in the herb layer. The dominant species in the canopy layer were also recorded. Vegetation was divided into shrub and canopy layers when 2-layered stratification was clearly observable at 1.5-2 m and >5 m above ground level. When there was (1) no clear differentiation between shrub and canopy layers and (2) trees covering the site to a height of 2-4 m, the tree layer was designated as the canopy layer. When there were few trees of <2 m high scattered throughout the site, the trees were included in the shrub layer, and the canopy layer coverage was recorded as zero. Herb layer coverage was described by the cover of herbaceous plants. We also recorded (1) physiographic features (including slope angle, slope aspect (N, NE, E, SE, S, SW, W, and NW), and slope form (convex, flat, and concave)), (2) extent of deer browsing (none, slight, moderate, and serious), and (3) presence/absence of adjacent natural broad-leaved forests. The extent of deer browsing was categorized as follows: none (no damage among any of the trees in the plot), slight (≤25% of trees damaged), moderate (26-75% of trees damaged), and serious (>75% of trees damaged).

Data Analysis

Recovered vegetation was classified by cluster analysis (squared Euclidian distance, Ward method), based on the coverage of pioneer and non-pioneer tree species in the canopy and shrub layers of each plot, using SPSS version 17.0 (SPSS, 2008). Using PC-ORD version 4 for Windows (McCune and Mefford, 1999), nonmetric multidimensional scaling ordination (NMS) was also carried out, based on the same data set used for cluster analysis. With these multivariate procedures, we explored our data to determine the vegetation classification best suited for accomplishing the objectives of this study. NMS was implemented using (1) squared Euclidian distance as the distance measure and (2) the "slow and thorough" autopilot mode (step length = 0.2, stability criterion = 0.00001, iterations = maximum of 400) to generate solutions; the lowest stress solution was adopted.

In order to interpret the factors underlying variation in vegetation types, we examined relationships between axes derived by NMS and site features by calculating Pearson's correlation coefficients for numerical attributes and Kendall's rank correlation coefficients for categorical attributes. In order to minimize the influence of outlier site areas, which greatly influenced the median, we excluded data for abandoned sites >25 ha when calculating correlation coefficients. Site features included slope aspect, slope angle, slope form, elevation, area, time passed since clearcutting, stand age at clearcutting, presence of adjacent natural broad-leaved forests, extent of deer browsing, and land use before plantation establishment. Data on slope aspect, slope angle, slope form, presence of adjacent natural broad-leaved forests, and extent of deer browsing were obtained by field surveys. Areas of abandoned sites were obtained from the forest register or were calculated from Geographic Information System (GIS)-based forest maps possessed by each prefecture. Time since clearcutting and the stand age at the time of clearcutting were obtained from the forest register or through interviews. We obtained elevation data by overlaying distribution maps of abandoned clearcut sites over a 1:25,000 scale topographical map and recording contour elevations of study plots at a resolution of 50 m. Land use before plantation establishment was determined from aerial images captured in the late 1940s by the US Army. Land uses were categorized as "nonforest," "plantation," "broad-leaved tree scattering," and "broad-leaved forest." In addition to the ordination analysis, the relationships between vegetation types and factors were examined by Kruskal-Wallis tests and adjusted Bonferroni multiple comparisons using Mann-Whitney *U* tests. Categorical attributes (slope

Table 2 The average tree species coverage of canopy and shrub layer and vegetation coverage of herb layer by vegetation type (unit: %)

Group	Vegetation type ※	Canopy layer			Shrub layer			Herb layer
		Pioneer species	Non-pioneer species	Total coverage	Pioneer species	Non-pioneer species	Total coverage	Grasses
A	*g*	1.62	11.42	13.04	1.76	2.88	4.64	58.20
B	*fpt*	21.59	9.59	31.17	1.59	9.59	11.17	39.63
C	*snp*	12.33	24.83	37.17	13.47	73.00	86.47	48.33
D	*cnp*	10.82	60.64	71.45	5.00	8.18	13.18	60.00
E	*np*	7.70	27.46	35.16	5.78	23.54	29.33	40.88
F	*p*	28.21	17.89	46.11	37.26	12.63	49.89	72.63
G	*cp*	59.42	10.17	69.58	14.30	19.96	34.26	52.42

※ *g* : grassland; *fpt* : a few pioneer trees; *snp* : shrub non-pioneer trees; *cnp* : canopy non-pioneer trees; *np* : non-pioneer trees; *p* : pioneer trees; *cp* :canopy pioneer trees.

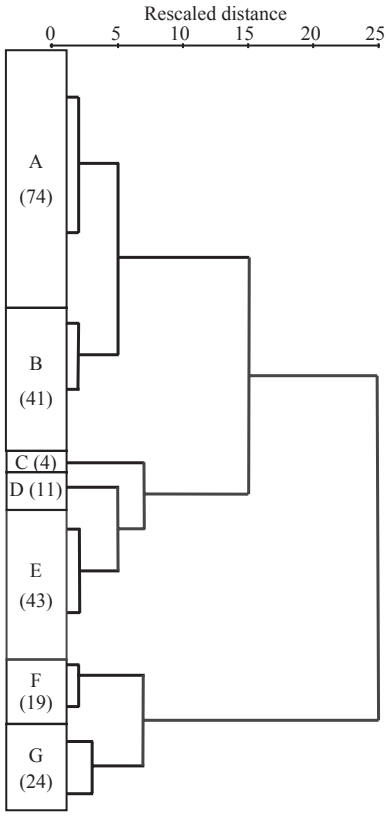

Fig. 2 Cluster analysis dendrogram of 218 plots

The parenthetic numbers correspond to the number of plots under each group.

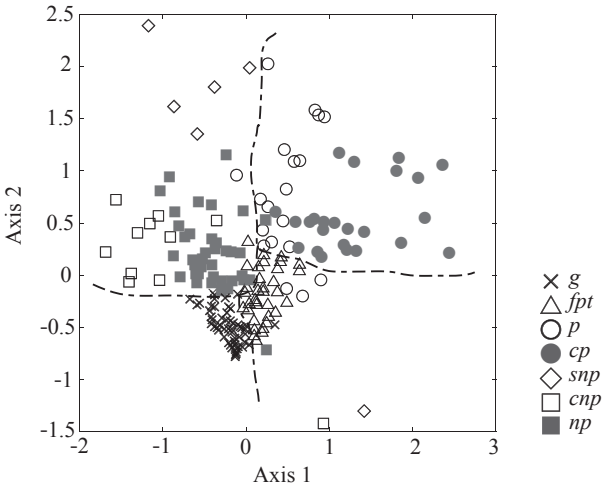

Fig. 3 Result of NMS ordination of 218 plots

g: grassland, *fpt*: a few pioneer trees, *p*: pioneer trees, *cp*: canopy pioneer trees, *snp*: shrub non-pioneer trees, *cnp*: canopy non-pioneer trees, *np*; non-pioneer trees.

aspect, slope form, presence of adjacent natural broad-leaved forest, extent of deer browsing, and land use before plantation establishment) were computed using dummy variables. Calculations of correlation coefficients, Kruskal-Wallis, and Mann-Whitney *U* tests were performed with SPSS 17.0 (SPSS, 2008).

RESULTS

Classification of Vegetation Types

Seven vegetation types were identified through cluster analysis (Fig. 2). Group A had little tree coverage at the canopy and shrub layers but high cover at the herb layer (Table 2); this group was designated "grassland (*g*)". Canopy layer coverage in group B was 30% and comprised mainly of pioneer species such as *Mallotus japonicus*, indicating that a few pioneer trees had recovered; this group was designated "a few pioneer trees (*fpt*)". Group C had very high coverage of non-pioneer trees (73%) such as *Quercus glauca* at the shrub layer; this group was designated "shrub non-pioneer trees (*snp*)". Group D had high coverage of non-pioneer trees in the canopy layer (60%) and was designated "canopy non-pioneer trees (*cnp*)". Group E had 20% coverage of non-pioneer tree species in both canopy and shrub layers; this group was designated "non-pioneer trees (*np*)". In Group F, 30% of both canopy and shrub layers comprised pioneer species; this group was designated "pioneer trees (*p*)". Group G had high mean pioneer species coverage (60%) at the canopy layer and was designated "canopy pioneer trees (*cp*)".

NMS ordination yielded a 2-dimensional depiction that explained 86.0% of variation in the data (Axis 1 = 57.8%, Axis 2 = 28.2%; final stress = 18.90; final instability = 0.02803). Axis 1 of the ordination (Fig. 3) had high scores for vegetation types dominated by pioneer species (*p* and *cp*) and lower scores for non-pioneer species (*snp*, *cnp*, and *np*). Axis 2 had low scores for vegetation types *g* and *fpt*, and high scores for remaining vegetation types dominated by tree species. Consequently, NMS ordination successfully separated plots designated "*g*"

Table 3 Main component species of each vegetation class*

Vegetation class	Main component species
NPT	*Quercus glauca* Thunb. Ex Murray
	Machilus thunbergii Sieb. et Zucc.
	Neolitsea sericea (Bl.) Koidz.
	Daphniphyllum macropodum Miq.
	Swida macrophylla (Wall.) Soj.
	Lindera erythrocarpa Makino
FPT and PT	*Mallotus japonicus* (Thunb. Ex Murray) Mueller-Arg.
	Zanthoxylum ailanthoides Sieb. et Zucc.
	Clerodendrum trichotomum Thunb.
	Aralia elata (Miq.) Seemann

* The component species of vegetation class *GL* were excluded because the dominant species of the herb layer were not investigated.

and "*fpt*". It also clearly divided the vegetation types dominated by pioneer species (including *p* and *cp*) and non-pioneer species (including *snp*, *cnp*, and *np*). We therefore concluded that the most appropriate vegetation classes for recognition in our study region were grassland (*GL*), few pioneer trees (*FPT*), non-pioneer species (*NPT*, including groups *snp*, *cnp*, and *np* identified by cluster analysis), and pioneer species (*PT*, including *p* and *cp*). Among the 218 abandoned clearcut sites, 74 were classified as *GL*, 41 as *FTP,* 43 as *PT*, and 60 as *NPT*. The major component species in each vegetation class are presented in Table 3.

Factors Affecting Early-stage Vegetation Recovery

A comparison of the site conditions among vegetation classes by Kruskal-Wallis and Mann-Whitney *U* tests revealed significant differences in elevation ($p = 0.026$), time since clearcutting ($p = 0.035$), slope form ($p = 0.018$), and extent of deer browsing ($p < 0.001$). Elevations increased in the following rank order of vegetation categories: *NPT* < *PT* < *GL* < *FPT*, which occurred mainly in the elevation range of 300-700 m (Fig. 4b). *GL* tended to establish on abandoned sites with a shorter time since clearcutting (Fig. 4d). *FPT* and *PT* had a tendency to establish on concave sites (Fig. 5b). The extent of deer browsing was greater in *GL* than in other vegetation classes (Fig. 5d). Vegetation categories were not related to slope aspect ($p = 0.083$), slope angle ($p = 0.936$), abandoned area ($p = 0.391$), stand age at time of clearcutting ($p = 0.685$), occurrence of adjacent natural broad-leaved forest ($p = 0.672$), and land use before plantation establishment ($p = 0.123$).

Analysis of the relationship between the derived NMS axes and site conditions demonstrated that Axis 1 was negatively correlated with slope angle ($r = -0.175$, $p = 0.011$),

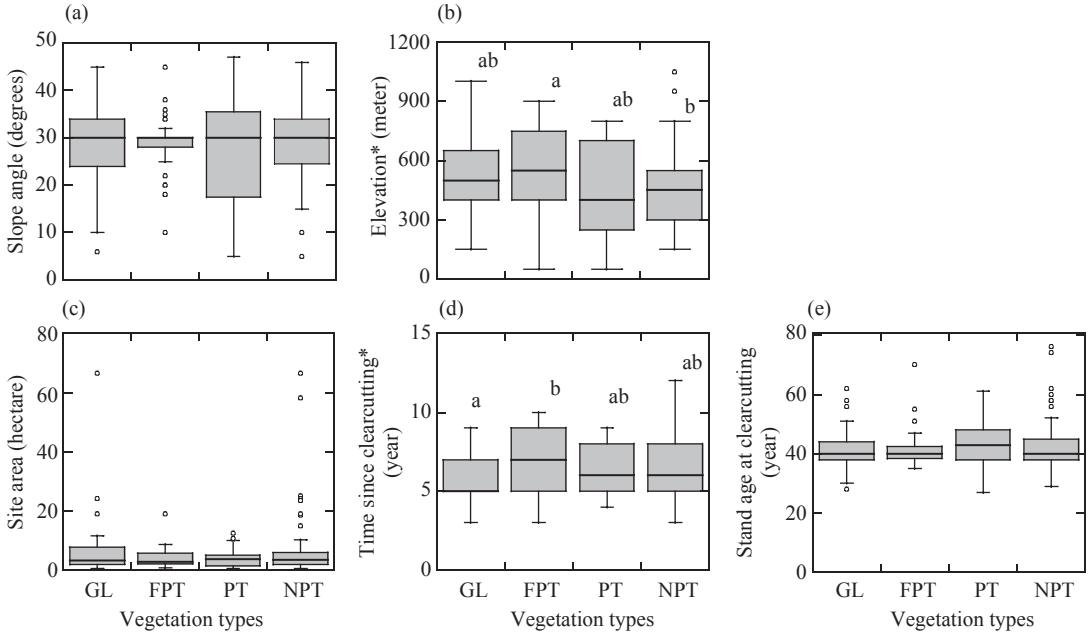

Fig. 4 Site characteristics of each vegetation class

Only numerical attributes are shown in this figure. * indicates the attribute showed significant differences as a result of Kruskal-Wallis test at the 5% level. Data marked with the same letter indicates no significant differences were detectedby Mann-Whitney *U* test at 5% level.

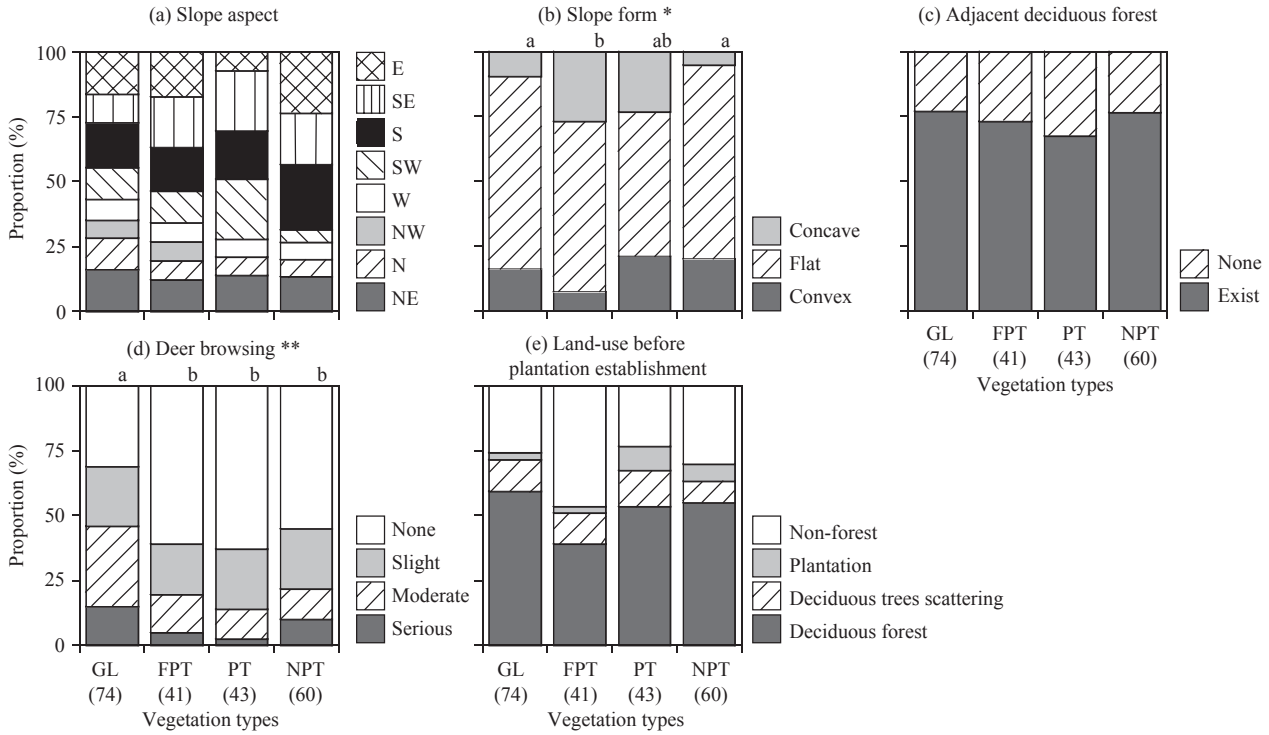

Fig. 5 Site characteristics of each vegetation class

Only categorical attributes are shown in this figure.* indicates the attribute showed significant differences as a result of Kruskal-Wallis test at the 5% level and ** indicates the attributes showed significant differences at the 1% level. Data marked with the same letter indicates no significant differences were detected by Mann-Whitney *U* test. The figure shows the relative percentage of the variables to make it easy to understand the differences among vegetation types. The Kruskal-Wallis test and Mann-Whitney *U* test were conducted by utilizing the dummy variables of each features and NOT the relative percentage.

slope form (r = -0.128, p = 0.016), and extent of deer browsing (r = -0.127, p = 0.016). Axis 2 was negatively correlated with extent of deer browsing (r = -0.261, p < 0.001) and positively correlated with stand age at time of clearcutting (r = 0.153, p = 0.033) and time since clearcutting (r = 0.139, p = 0.048).

DISCUSSION

Vegetation Classification Using the Data of Simplified Vegetation Surveys

Previous studies (SAKAI *et al*., 2006; YAMAGAWA *et al*., 2006; NAGASHIMA *et al*., 2009) have described the different recovery patterns of pioneer tree species and non-pioneer tree species at abandoned plantation clearcut sites: the former are likely to recover from the existing soil seed bank, while the latter can recover by resprouting. Therefore, valid methods of classifying vegetation should consider the prevalence of pioneer versus non-pioneer species in a given site. In addition, animal grazing can have a large impact upon vegetative regrowth (TAKATSUKI and GORAI, 1994; GILL and BEARDALL, 2001; TSUJINO and YUMOTO, 2004), and as such, these effects must be considered in any valid description of regrowth. Our analysis, based on the data of simplified vegetation surveys that recorded the coverage of pioneer and non-pioneer species, classified vegetation into four categories (*GL*, *FPT, PT*, and *NPT*); in this way, both the impact of animal (deer) grazing and the prevalence of pioneer vs. non-pioneer colonization were accounted for. As discussed below, this classification system also allows us to recommend the allocation of restoration efforts to sites based upon the following order of priorities: (1) sites in which tree establishment is difficult, (2) sites in which pioneer species tend to become dominant, and (3) sites comprised largely of non-pioneer/late-successional species. In summary, our simplified method of vegetation surveys can describe both the regrowth of pioneer/non-pioneer species and the effects of animal grazing at the canopy or shrub layer. The method is useful for evaluating the likelihood of vegetation recovery and therefore the urgency/necessity of human intervention into site recovery, as well as a measure of the potential efficacy of human intervention. The method should therefore be employed when determining the best management strategy for recovering clearcut sites.

Factors Influencing Tree Species Recovery

GL and *FPT* differentiated from *PT* and *NPT* on Axis 2 of the ordination diagram. Hence, this axis represents factors that influence tree species recovery. The extent of deer browsing was negatively correlated with Axis 2, while stand age at the time of clearcutting and time since clearcutting were positively correlated with this axis. Specifically, tree species recoveries became more difficult when (1) deer browsing pressure was elevated, (2) when stands were young at the time

of clearcutting, and (3) when clearcutting was recent. Under these circumstances, *GL* or *FPT* were often established. When conditions were adverse, tree species recovered steadily and *NPT* or *PT* became established. The Kruskal-Wallis and Mann-Whitney *U* tests also indicated that *GL* tended to establish itself on sites with serious deer browsing and shorter time since clearcutting. High densities of sika deer may result in loss of seedlings and saplings (Takatsuki and Gorai, 1994; Tsujino and Yumoto, 2004), preventing forest recovery (Gill and Beardall, 2001). Accordingly, abandoned clearcut sites classified as *GL* occurred in island sectors with large deer populations, particularly in the southern part of Kyushu Island (Tsuneta, 1998). At the same time, it is quite natural that the recovery of few tree species was observed at sites where only a few years had passed since clearcutting. Our previous study (Nagashima *et al.*, 2009) indicated that tree species recovered vigorously 5 years after clearcutting when deer browsing was negligible. Therefore, it might be important to pay attention to sites where tree species do not recover even 5 years after clearcutting, as the absence of trees could signal the presence of ongoing damage.

Abandoned clearcut sites that had high scores on Axis 2 had relatively old stands (age >45 years) at the time of clearcutting; thus, stand age at clearcutting influenced tree species recovery, even though there were no significant differences in stand age at clearcutting among vegetation classes. The stand age at clearcutting can reflect the quantity of regeneration sources such as regenerative plant fragments (i.e., tree stumps) and soil seed banks. Yamagawa *et al.* (2006) demonstrated better evergreen broad-leaved tree recovery after clearcutting of older plantations than after cutting younger stands. This age effect might relate to the richer understory tree flora in older plantations (Ito *et al.*, 2003). After felling, these trees leave stumps and other fragments, which are good sources of regenerating sprouts; these stumps are less frequent after cutting a young stand (Yamagawa *et al.*, 2006). Soil seed banks develop in plantations by frugivorous seed dispersal (Sato and Sakai, 2003). The older the stand age of a plantation became, the greater the amount of seeds that accumulate in the soil seed bank, which indicates a higher possibility of tree species recovery after clearcutting. In the same way, a protracted time after clearcutting may provide long-term opportunities for seed dispersal and propagation in felled areas, with consequently improved tree species recovery.

We expected elevation to influence tree species recovery because *GL* and *FPT* tended to occur at higher elevation sites according to the Mann-Whitney *U* test. However, this was not apparent from correlations on Axis 2 of the ordination. Because *GL* tends to occur at high-elevation sites with strong impacts of deer browsing, elevation can be considered as a factor influencing the occurrence of deer browsing (Sakai *et al.*, 2006; Tanaka *et al.*, 2008) but not affecting the recovery of tree species. These multivariate relationships should be investigated in future studies.

Factors Influencing Dominant Tree Species

PT and NPT were arrayed separately on Axis 1 of the ordination, which appears to express factors that influence the dominant tree species. Slope angle, slope form, and extent of deer browsing were negatively correlated with Axis 1. Thus, sites with steeper slopes, convex slopes, and elevated deer browsing effects tended to recover to *NPT*, and sites with adverse conditions tended to recover to *PT*; the same tendencies were also detected for the latter two factors by the Mann-Whitney *U* test. The effect of deer browsing was more closely related to Axis 2 than Axis 1, which indicates that browsing has less influence on selection of the dominant tree species than on tree species recovery. Deer browsing may be correlated with Axis 1 because *NPT* is established more easily than other vegetation classes (even under heavy deer browsing) due to rapid growth of sprouting shoots, which allows non-pioneer trees to grow to size categories that are less susceptible to browsing pressure (Shimoda *et al.*, 1994; Koda *et al.*, 2008). Distribution trends for late-successional species on ridges or steeper slopes and for pioneer species within valleys or lower slopes have been observed in several studies on the understories of sugi plantations and evergreen broad-leaved forests (Sakai and Ohsawa, 1994; Nakagawa *et al.*, 1998). Since a high proportion of non-pioneer trees recover by sprouting at plantation clearcut sites from the earliest stages of abandonment (Yamagawa and Ito, 2006; Nagashima *et al.*, 2009), the composition of recovered vegetation may be a reflection of the understory tree distribution prior to clearcutting. Therefore, topographic variation in understory tree species may influence the composition of recovered vegetation, as suggested by Yamagawa *et al.* (2006).

Implications for Abandoned Clearcut Site Management

According to our rank order of restoration priority, first efforts should be directed toward *GL*, a vegetation class mostly covered by herbs. The second priority should be toward *FPT*, a vegetation class in which a few tree species have recovered. Sites (1) impacted by deer browsing, (2) with young stands at the time of clearcutting, and (3) that were cut recently tend to recover to *GL* or *FPT*; hence, measures to eliminate deer browsing are likely key to enhancing vegetation recovery at such sites, particularly during the initial stages of recovery. In addition, special attention should be paid to sites classified as *GL* or *FPT* even 5 years after clearcutting, because within 5 years, tree species usually show steady recovery in the absence of deer browsing. The proportion of total plots classified as *GL* $\geq$5 years after clearcutting was relatively high (28%), indicating that restoration of this vegetation class will require considerable resources. Decisions regarding restoration of *GL* sites <5 years after clearcutting and *FPT* should be contingent on long-term recovery of tree species after clearcutting. This may require protracted monitoring of vegetation change. Although the vegetation classes *PT* and *NPT* have low priorities for immediate restoration, they will also require long-term monitoring to determine whether they will progress to the target lucidophyllous forest state. The climax stage of lucidophyllous forests contains *Q. acuta*, *Q. salicina*, *Q. gilva*, and *Distylium racemosum* (Nagamatsu *et al.*, 2002); this is the ideal target of vegetation recovery toward which we are striving. However, the main component species of *NPT* was *Q. glauca*, a tree that dominates the early stages of vegetation development (Tanouchi, 1990). Moreover, *NPT*

vegetation can easily regenerate by sprouting from stumps and other late-stage remnants after clearcutting (YAMAGAWA and ITO, 2006; YAMAGAWA *et al*., 2008; NAGASHIMA *et al*., 2009). Vegetative sprouting promotes successful early recovery of component species in lucidophyllous forests, but this reproductive process may simplify the species composition, slowing the progress toward climactic vegetative diversity (BOND and MIDGLEY, 2001; ITO *et al*., 2008; YAMAGAWA *et al*., 2008). In order to promote the succession to the climax stage of lucidophyllous forests, it might be necessary to allocate labor for manual manipulations that remove such impediments to natural succession, in the future.

Finally, it is important to mention that the management strategy and the rank order of restoration priority discussed in this paper is one useful approach for managing abandoned clearcut sites. The proposed management strategy takes into consideration the current unfavorable economic conditions, which make it difficult to reestablish plantation on abandoned clearcut sites. The objective is to avoid a reduction in the soil and water holding capacity of the forest, which might occur when the vegetation fails to recover or develops too slowly. Therefore, we give greater priority to sites where the vegetation recovers slowly. In order to enhance biodiversity, we selected evergreen broad-leaved forest as the target vegetation. However, we did not proceed to cover the all sites with evergreen broad-leaved forest as soon as possible; instead, we took a long-term view for biodiversity recovery, and gave sites with non-pioneer/late successional species a low priority in our rank order. If reestablishing plantation on certain sites is economically viable, then an alternative is to first prioritize sites well suited to plantation based on their site productivity and then apply our strategy to sites not favorable for plantation establishment. If biodiversity conservation is of greater priority, then the alternative is to suitably change the rank order and allocate labor to NPT. It is important to note that the decision regarding which strategy must be applied depends on the management objective and the target vegetation.

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Appendix: Tree species identified as pioneer species

Trees	*Albizia julibrissin* Durazz.
	Alnus firma Sieb. et Zucc.
	Alnus hirsuta Turcz.
	Alnus hirsuta Turcz.var. *sibirica* (Fischer) C.K. Schn.
	Alnus sieboldiana Matsumura
	Celtis jessoensis Koidz.
	Evodia meliifolia (Hance) Benth.
	Firmiana simplex (L.) W. F. Wight
	Idesia polycarpa Maxim.
	Mallotus japonicus (Thunb. ex Murray) Muell. Arg.
	Pinus densiflora Sieb. et Zucc.
	Platycarya strobilacea Sieb. et Zucc.
	Rhus succedanea L.
	Robinia pseudoacacia L.
	Zanthoxylum ailanthoides Sieb. et Zucc.
Shrubs	*Aralia elata* (Miq.) Seemann
	Boehmeria spicata Thunb.
	Broussonetia kazinoki Sieb.
	Caesalpinia decapetala (Roth) Alst. var. *japonica* (Sieb. et Zucc.) Ohashi
	Clerodendrum trichotomum Thunb.
	Deutzia crenata Sieb et Zucc.
	Deutzia scabra Thunb.
	Diplomorpha ganpi (Sieb. et Zucc.) Nakai
	Diplomorpha trichotoma (Thunb.) Nakai
	Hydrangea paniculata Sieb. et Zacc.
	Lespedeza bicolor Turcz.
	Litsea citriodora (Sieb. et Zucc.) Hatusima
	Oreocnide fruticosa (Gaudich.) Hand.-Mazz.
	Rhus japonica L. var. *roxburghii* (DC.) Rehd. et Wils.
	Rhus sylvestris Sieb. et Zucc.
	Rhus trichocarpa Miq.
	Rosa multiflora Thunb.
	Rosa onoei Makino
	Rosa wichuraiana Crépin
	Rubus crataegifolius Bunge
	Rubus hirsutus Thunb.
	Rubus palmatus Thunb. var. palmatus
	Rubus parvifolius L.
	Rubus sieboldii Bl.
	Rubus sumatranus Miq.
	Sambucus racemosa L. subsp. *sieboldiana* (Miq.) Hara
	Stachyurus praecox Sieb. Et Zucc.
	Weigela decola (Nakai) Nakai
	Weigela japonica Thunb.
	Zanthoxylum schinifolium Sieb. et Zucc.

Note: The appendix only shows the pioneer tree species. Other tree species observed in the abandoned plantation clearcut sites are recognized as non-pioneer species.

Short Communication

Variation in Form-factors for Stem Surface Area in Even-aged Pure Stands of Japanese Larch (*Larix kaempferi*)

Akio Inoue [*1]

ABSTRACT

Variation in the form-factors for stem surface area was studied in two even-aged pure stands of Japanese larch (*Larix kaempferi*). In the stands, all living trees were felled for stem analysis, and then the form-factors for stem surface area and stem volume at breast height and 0.7 and 0.5 in relative height, i.e., κ_b, $\kappa_{0.7}$, $\kappa_{0.5}$, λ_b, $\lambda_{0.7}$ and $\lambda_{0.5}$, were calculated. The coefficients of variation (CV) of $\kappa_{0.7}$ and $\kappa_{0.5}$ ranged from 3.2 to 7.4% and from 3.9 to 8.8%, respectively. On the other hand, CV of κ_b ranged from 9.1 to 15.4%, indicating that the variation in κ_b was comparatively larger than those in $\kappa_{0.7}$ and $\kappa_{0.5}$. The ratios of CV of form-factor for stem surface area to that for stem volume ranged from 0.3 to 0.6, indicating that the variation in the form-factors for stem surface area was smaller than that for stem volume. In conclusion, $\kappa_{0.7}$ and $\kappa_{0.5}$ would be effective form-factors in estimating the total stem surface area of a stand with the angle count sampling precisely.

Keywords: angle count sampling, even-aged pure stand, form-factor for stem surface area, Japanese larch, stem form

INTRODUCTION

The stem surface area represents the base for potential volume growth (LEXEN, 1943), stem respiration, and interception of radiation and rainfall (SCHREUDER *et al*., 1993). The stem surface area is also the habitat and food supply source for various insects, fungi, lichens and algae (SCHREUDER *et al*., 1993). Therefore, the stem surface area plays an important role in ecological and biological processes of trees or forests, and its efficient measurement or estimation is of inherent interest to ecologists and forest scientists. To measure the stem surface area, various methods have been proposed (HUSCH *et al*., 1972). However, it is difficult or often impossible to measure the stem surface area of standing trees directly, and hence alternative methods for estimating the surface area have been required.

Studies have shown that the normal form-factors for stem volume at 0.7 and 0.5 in relative height (tip: relative height = 0; base: relative height = 1) for coniferous trees are, respectively, almost steady at 0.7 and 1.0, independent of species, districts, growth stage and stand density control (e.g., KAJIHARA, 1969, 1985; UENO, 1978, 1983; WANG and UOZUMI, 2001). On the other hand, INOUE (2005) proposed a measure of the stem form in relation to the stem surface area and named the measure "form-factor for stem surface area". The measure is given by the ratio of the stem surface area to the side area of a column, of which diameter and height are equal to the diameter at a given height and total tree height, respectively. As INOUE (2005) suggested, if there is a universal value of the form-factor for stem surface area, the total stem surface area of a stand can be estimated with the angle count sampling. To estimate the universal values of form-factors for stem surface area from those for stem volume, INOUE (2006) derived the following model that describes the relationship between form-factors for stem volume, λ_i, and those for stem surface area, κ_i:

$$\kappa_i = k\lambda_i^{0.5} \quad (1)$$

where k is a coefficient. The model expressed the relationship between these form-factors for Japanese cedar (*Cryptomeria japonica* D. Don) and Japanese cypress (*Chamaecyparis obtusa* Endl.) trees.

Variation in the form-factors within a stand will affect the precision of the angle count sampling with form-factors. To estimate the stand volume with the angle count sampling, the variation in the form-factors for stem volume in a stand has been studied by several forest scientists (e.g., KAJIHARA, 1969, 1985; UENO, 1978, 1983; WANG and UOZUMI, 2001). However, a careful review of the literature revealed that the variation in the form-factors for stem surface area has not been studied. To estimate the total stem surface area per hectare with the angle count sampling, it is important to understand the change and variation in the form-factors for stem surface area in a stand.

The objective of the present study is thus to analyze the

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variation in the form-factors for stem surface area in even-aged pure stands of Japanese larch (*Larix kaempferi*). First, all living trees were felled for stem analysis in two larch stands, and then the form-factors for stem surface area and stem volume were computed. Second, the change and variation of the form-factors for stem surface area were analyzed. The variation in the form-factors for stem surface area was also compared with that for stem volume.

MATERIALS AND METHODS

Study Site

This study was conducted in two Japanese larch even-aged pure stands in the Hiruzen Experimental Forest of Tottori University, Okayama Prefecture, western Japan (35°18'N and 133°35'E). The annual average temperature, annual average precipitation and maximum snowfall of the Experimental Forest were 11.3℃, 2,140 mm and 2.1 m, respectively. The soils are mainly gray volcanic ash soils. The larch stands were located on gentle slopes with an average inclination of 5-10° at about 600-700 m asl. In these stands, larch seedlings were planted with a density of about 3,000 trees per hectare and no thinning regime was conducted after the planting. Attributes of each plot is summarized in Table 1.

Table 1 Attributes of each plot

Stand	A	B
Stand age (year)	36	30
Topographic position	Ridge	Middle slope
Slope direction	S	N
Average slope inclination (degree)	10	5
Mean DBH (cm)	15.5±5.1	17.1±5.0
Mean tree height (m)	15.6±3.7	15.3±2.2
Stand density (trees/ha)	1244	1244

*: Average±SD

Data

A square plot of 15 m×15 m was established for each larch stand, and then all living trees in the plot were felled for stem analysis. The number of sample trees was 28 for both plots. Stem disks were sampled from 0.2 m, 1.2 m and the upper portion at 2.0 m intervals, whereas only final disk at the highest position was taken at 1.0m interval. Each sample disk was measured along four different radii to determine ring width corresponding to growth intervals of three-years.

Analysis Methods

Using the stem analysis data of larch trees, the stem volume and surface area was computed with the sectional measurement method (HUSCH *et al.*, 1972), and the diameters at each relative height, i.e., 0.1, 0.2,…, 1.0, were also estimated with the linear interpolation. Then, the form-factors for stem surface area and volume at breast height and each relative height were calculated.

Studies have shown that the form-factors for stem volume at breast height and 0.7 and 0.5 in relative height, λ_b, $\lambda_{0.7}$ and $\lambda_{0.5}$, are effective in estimating stand volume with the angle count sampling (e.g., KAJIHARA, 1969, 1985; UENO, 1978, 1983; WANG and UOZUMI, 2001). These studies suggest that the form-factors for stem surface area at breast height and 0.7 and 0.5 in relative height, κ_b, $\kappa_{0.7}$ and $\kappa_{0.5}$, would also be effective in estimating total stem surface area with the angle count sampling (INOUE, 2006). The counting procedure of the angle count sampling will allow us to estimate the total stem surface area per hectare as well as the stand volume simultaneously. For these reasons, the variation in these six form-factors, i.e., λ_b, $\lambda_{0.7}$, $\lambda_{0.5}$, κ_b, $\kappa_{0.7}$ and $\kappa_{0.5}$, were analyzed, and other form-factors were excluded from the analysis of the variation in the normal form-factors. The coefficient of variation of each form-factor, i.e., CV(κ) and CV(λ), was then computed for each stand and age as a measure of variation in the form-factors. The ratio of the coefficient of variation of the form-factor for stem surface area to that for stem volume, CV(κ)/CV(λ), was also calculated.

Since Eq. 1 holds independent of the height position (INOUE, 2006), Eq. 1 was fitted to the relationship between form-factors for stem surface area at breast height and all relative heights and those for stem volume.

RESULTS

Fig. 1 indicates the changes in average form-factors for stem surface area with stand age in two even-aged pure stands of Japanese larch. The average form-factor for stem surface

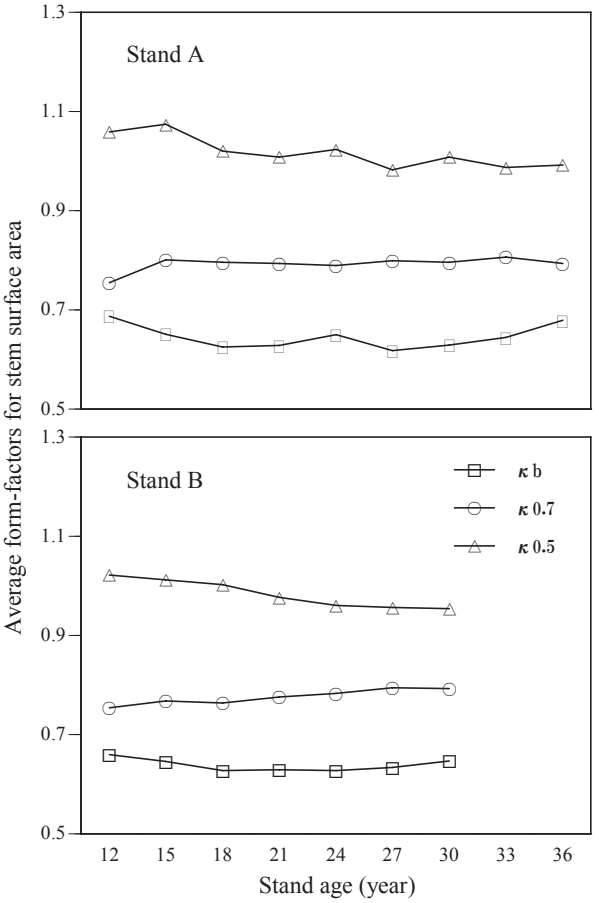

Fig. 1 Changes in average form-factors for stem surface area with stand age

area at breast height, κ_b, ranged from 0.618 to 0.687 for stand A and from 0.628 to 0.660 for stand B, and no remarkable change in the average κ_b with stand age was found for both stands. In stand A, the average form-factor for stem surface area at 0.7 in relative height, $\kappa_{0.7}$, increased from 0.755 in 12-year-old to 0.801 in 15-year-old, and then average $\kappa_{0.7}$ was almost steady at 0.800. In stand B, $\kappa_{0.7}$ was increased slightly from 0.754 to 0.793. The average form-factor for stem surface area at 0.5 in relative height, $\kappa_{0.5}$, was tended to be gradually decreased from 1.059 to 0.992 for stand A and from 1.022 to 0.954 for stand B.

Changes in the coefficients of variation of the form-factors for stem surface area with stand age are shown in Fig. 2. The coefficients of variation of κ_b, $\kappa_{0.7}$ and $\kappa_{0.5}$, CV(κ_b), CV($\kappa_{0.7}$) and CV($\kappa_{0.5}$), respectively, ranged from 8.933 to 15.436%, from 3.250 to 6.631% and from 5.360 to 8.782% for stand A and from 7.929 to 11.454%, from 3.322 to 6.407% and from 3.899 to 8.093% for stand B. For both stands and all stand ages, CV($\kappa_{0.7}$) was slightly smaller than CV($\kappa_{0.5}$), and CV(κ_b) was comparatively larger than CV($\kappa_{0.7}$) and CV($\kappa_{0.5}$).

Fig. 3 depicts the changes in the ratio of the coefficient of variation of the form-factor for stem surface area to that for stem volume, CV(κ)/CV(λ), with stand age. For both stands and all stand ages, CV(κ)/CV(λ) was less than unity, indicating that CV(κ) was smaller than CV(λ).

As shown in Fig. 4, Eq. 1 was well fitted to the relationship between form-factors for stem surface area, κ_i, and those for stem volume, λ_i, and the relationship could be expressed by the following equation:

$$\kappa_i = 0.885\ \lambda_i^{0.5} \qquad (r^2 = 0.996,\ P < 0.001) \qquad (2)$$

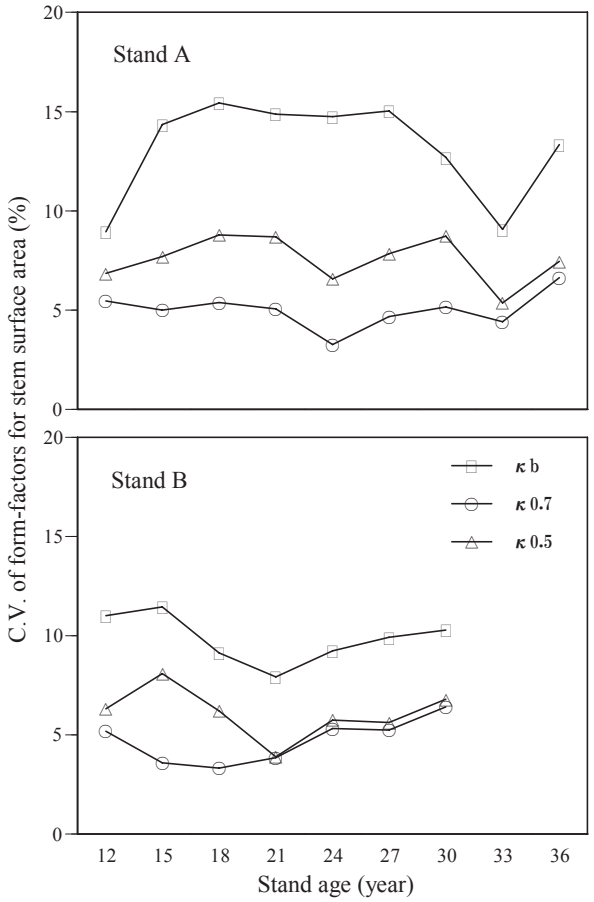

Fig. 2 Changes in coefficients of variation of the form-factors for stem surface area with stand age

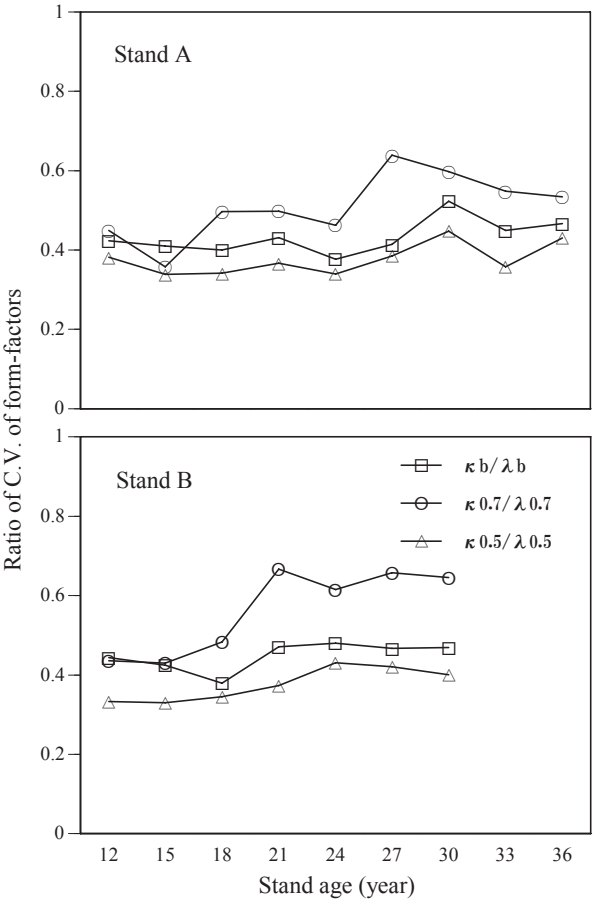

Fig. 3 Changes in the ratio of the coefficient of variation of the form-factor for stem surface area to that for stem volume

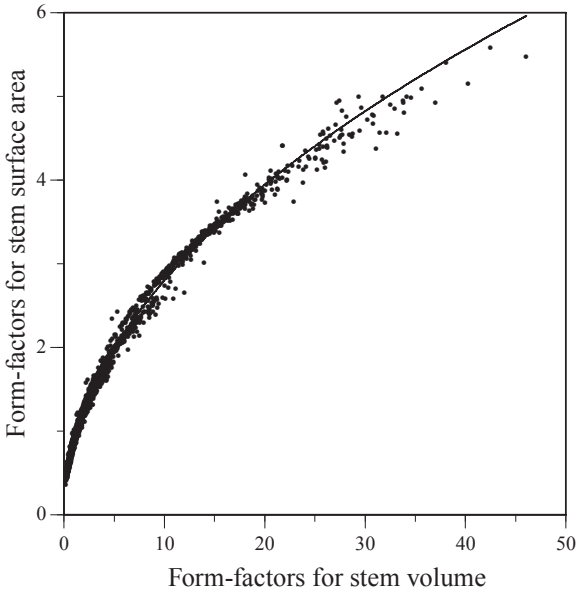

Fig. 4 Relationship between the form-factors for stem volume and those for stem surface area
The solid line indicates Eq. 2 in the text.

DISCUSSION

In a previous study, KAJIHARA (1969) analyzed the variations in λ_b and $\lambda_{0.5}$ in even-aged pure stands of Japanese cedar, and reported that CV(λ_b) and CV($\lambda_{0.5}$) ranged from 4.8 to 10.7 % and from 3.0 to 6.6 %, respectively. UENO (1978) investigated the variations in form-factors for stem volume in even-aged pure stands of Japanese cedar, and showed that CV(λ_b), CV($\lambda_{0.5}$) and CV($\lambda_{0.7}$) ranged from 7.9 to 10.7%, from 7.5 to 12.6% and from 6.2 to 6.3 %, respectively. UENO (1983) also analyzed the changes in CV(λ) with stand age in Japanese cedar stands and reported that CV($\lambda_{0.7}$) was less than 10% independent of the stand age. By contrast, when the stand age was less than 20-years, CV(λ_b) and CV($\lambda_{0.5}$) decreased from 30-40 to 20% sharply with the increase in stand age. However, when the age was over than 20-years, CV(λ_b) and CV($\lambda_{0.5}$) gradually decreased with age, and became 10-20% and less than 10%, respectively. KAJIHARA (1985) reported that CV($\lambda_{0.5}$) and CV($\lambda_{0.7}$) in Japanese cedar, Japanese cypress, Japanese red pine (*Pinus densiflora*) and Japanese larch stands ranged from 4.2 to 7.7% and from 4.0 to 6.6%, respectively. WANG and UOZUMI (2001) studied the changes in CV($\lambda_{0.5}$) and CV($\lambda_{0.7}$) with stand age in Japanese larch stands, and reported that CV($\lambda_{0.5}$) and CV($\lambda_{0.7}$) gradually decreased with stand age and became steady at about 5%.

These studies showed that CV(λ) was less than 10% except for the young stands, and suggested that the form-factors for stem volume enable us to estimate the stand volume with the angle count sampling precisely (KAJIHARA, 1969, 1985; UENO, 1978, 1983; WANG and UOZUMI, 2001). The result of this study indicated that CV(κ) was less than 10%, except for the form-factor for stem surface area at breast. The ratio of the coefficient of variation of form-factors for stem surface area to that for stem volume, CV(κ)/CV(λ), also ranged from 0.3 to 0.6 (see Fig. 2), indicating that the variation in form-factors for stem surface area was smaller than that for stem volume. These facts suggest that the form-factors for stem surface area allow us to estimate the total stem surface area in a stand with the angle count sampling precisely.

In this study, the data of stem analysis of all living trees within the un-thinned larch stands was used to examine the variations in the normal form-factors for stem surface area within the stands. Therefore, the dead trees due to the self-thinning process are excluded from our results. The average of the normal form-factors for stem surface area may vary with the inclusion of the dead trees. As show in Fig. 4, the normal form-factors for stem surface area are directly proportional to the root of those for stem volume. Generally, the exponent of the power equation is approximately equal to the ratio of the coefficient of variation of the two variables (e.g., INOUE, 2002), and thus Eq. 2 implies that ratio of the coefficient of variation of form-factors for stem surface area to that for stem volume, CV(κ)/CV(λ), would be approximately 0.5. The fact that the variation in form-factors for stem surface area was smaller than that for stem volume will be true, even if including the dead trees into the analysis. For these reasons, the normal form-factors for stem surface area enables us to estimate the total stem surface area per hectare with the angle count sampling precisely. However, we should pay an attention into the effect of the inclusion of dead trees on the average form-factors, which may produced the biased and inaccurate estimator of the total stem surface area with the angle count sampling.

INOUE (2006) applied Eq. 1 to Japanese cedar and Japanese cypress trees, and found that the coefficient k was 0.873 independent of species. Assuming that $\lambda_{0.7}$ and $\lambda_{0.5}$ were, respectively, steady at 0.7 and 1.0, INOUE (2006) also estimated the universal values of $\kappa_{0.7}$ and $\kappa_{0.5}$, i.e., $\kappa_{0.7}$ = 0.730 and $\kappa_{0.5}$ = 0.873. As shown in Fig. 4, the coefficient for the larch trees was 0.885, which results in the predicted normal form-factors, i.e., $\kappa_{0.7}$ = 0.740 and $\kappa_{0.5}$ = 0.885, with an assumption that $\lambda_{0.7}$ = 0.7 and $\lambda_{0.5}$ = 1.0. There are no clear differences in the predicted $\kappa_{0.7}$ and $\kappa_{0.5}$ among cedar, cypress (INOUE, 2006) and larch trees. However, our result indicated that both $\kappa_{0.7}$ and $\kappa_{0.5}$ for the larch trees were larger than these predicted values (see Fig. 1). The true cause of such inconsistency is unknown to me at present. The inconsistency may produce the biased estimator of the total stem surface area per hectare with the angle count sampling. There is a need for further studies on the variation in the average form-factors as well as the variation in the form-factors within the stand examined in this study.

CONCLUSIONS

In this study, the variation in the form-factors for stem surface area within the even-aged pure stands of Japanese larch was studied. The result indicated that CV($\kappa_{0.7}$) and CV($\kappa_{0.5}$) ranged from 3.2 to 7.4% and from 3.9 to 8.8%, respectively, and the variations in $\kappa_{0.7}$ and $\kappa_{0.5}$ were comparatively smaller than that in κ_b. It was found that the variation in the form-factors for stem surface area was smaller than that for stem volume. In conclusion, $\kappa_{0.7}$ and $\kappa_{0.5}$ would be effective form-factors in estimating the total stem surface area of a stand with the angle count sam pling precisely.

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Abstract Proceedings of FORCOM2011

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EDITOR
NAOTO MATSUMURA

Preface: Abstract Proceedings FORCOM2011

The second IUFRO International Symposium on Sustainable Forest Resource Management -FORCOM2011- was held September 25-30, 2011 at Mie University, Japan. The symposium was organized by the Japan Society of Forest Planning, in cooperation with Mie Prefecture and IUFRO Division IV. The purpose of the conference was to present state-of-the-art research results and techniques relating to the management and analysis of forest resources. The organizers wanted to bring together scientists from different regions, providing a platform for sharing information and experience. On behalf of the organizing committee, it is my pleasure to present this collection of abstracts from oral and poster presentations. These abstracts represent significant research contributions from forest scientists and students. Though they have not gone through the Japan Society of Forest Planning's traditional review process, I believe these papers contribute much to the development of sustainable forest resource management. I would like to extend my sincere appreciation to all the symposium participants. In total, sixty-three people from four countries, primarily representing Asia presented fourteen oral and nineteen poster presentations. They covered a wide range of forest management topics, including the philosophy of forest resource management, silvicultural systems, carbon issues, national forest inventory, mathematical modeling, GIS and remote sensing, social and community forestry, and general topics in forest planning and forest economics. I also want to thank all the members of the organizing and scientific- committees, including session moderators Dr. Naoko MATSUO, Dr. Akemi ITAYA, Dr. Yasushi MITSUDA, Mr. Eiji KODANI, Dr. Fumiaki KITAHARA, and Dr. Masayoshi TAKAHASHI. Also, my thanks to Dr. Atsushi YOSHIMOTO and Mr. Ryo AKAISHI for their assistance arranging the symposium, and to Dr. Satoshi TSUYUKI for his help designing the symposium logos. Finally, I would like to thank IUFRO-J for their financial support of the symposium, and TOYOTA MOTOR CORPORATION, Toyota Biotechnology & Afforestation Division and Ise Jingu Shrine for their assistance with the field excursions.

Naoto MATSUMURA
Professor, Graduate School of Bioresources, Mie University

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WELCOME ADDRESS

Motoi YOSHIOKA (*Dean, Graduate School of Bioresources, Mie University*)

On behalf of the Faculty of Bioresources at Mie University, it is my pleasure to give these opening remarks and host the FORCOM 2011 symposium. First of all, let me express my warmest welcome to the distinguished participants, especially to the speakers who came from abroad. For the Faculty of Bioresources, where our research activities focus on international perspectives of agriculture, forestry, fisheries and food, it is quite an honor that our campus and university forest have been selected as venues for this conference. The United Nations has designated 2011 the International Year of Forests. Many related events have been, and will be, held in Japan. Research on comprehensive theory and technology related to forests is needed to make full use of the materials and environmental resources provided by forests. This includes such topics as forest ecosystems, tree physiology, sustainable control and management, and evaluation of scenery. The topics and programs listed for this conference, forest planning, resource assessment, and GIS, to name a few support these research needs, and are just right for the International Year of Forests. Personally, I have become very interested in the term "e-forest," or, forest information systems, in the recent ICT era. Several days ago, a large typhoon made landfall in Japan, severely damaging forests in Mie and neighboring Nara and Wakayama Prefectures. Our university forest was no exception. Professor MATSUMURA, who is head of the forest station, is working with other staff members to implement recovery measures for the university forest. What we human beings can do for nature is limited, but I believe the best forest planning measures will lead to the most sustainable use of forest resources. Finally, I will conclude my opening remarks here: I look forward to fruitful discussion during this three-day conference that includes two field excursions to Odai-town and the Ise Shrine. Thank you very much for your kind attention.

WELCOME ADDRESS

Fumio NISHIMURA (*Deputy Director General of Forest and forestry section, Department of Environment and Forestry, Mie Prefectural Government Office*)

Thank you for the introduction. My name is Fumio NISHIMURA, and I am the Deputy Director General of the Forest and Forestry Section, Department of Environment and Forestry, Mie Prefectural Government Office. It is a pleasure to speak to you and open this International FORCOM2011 Conference. I am pleased to say, "Welcome to Mie Prefecture!" I would like to thank Dr. MATSUMURA and the organizing committee members for the work they have done to hold this conference at Mie University. Afforestation has been encouraged in the Mie Prefecture since the Edo period. Furthermore, intensive forest management practices like pruning and thinning have been successfully used to produce fine sugi and hinoki wood products. As a result, the proportion of plantation forest in the Mie Prefecture is about 60%, higher than the mean value for Japan. The United Nations has proclaimed 2011 the International Year of Forests. Additionally, "the first year of forestry revitalization" has been selected as a key theme of the International Year of Forests in Japan. Last year, the government released "The Forestry Revitalization Plan," which set the target for timber self-sufficiency at over 50% in the next decade. To achieve this goal, in April of this year forest laws were changed to reflect a new forest planning system. In the Mie Prefecture, it is a priority that sustainable forest management practices are used to increase timber production. Therefore, we need the best possible information to guide our efforts. This conference is deeply significant and timely. Scientists, researchers, and students will once again gather, to exchange information and discuss various topics about sustainable forest resources management. I hope this conference brings lively discussion and fruitful discourse. Thank you for your attention.

KEYNOTE SPEECH

Philosophy and Techniques for Forest Resource Management: Follow up and New Challenges for Coming Generations

Naoto MATSUMURA, Yutaka YURUGI and Shinya NUMAMOTO (*Mie University, Japan*)

Ensuring the sustainability of forest resources for future generations has been a central concern for scientists and managers who have been engaged with the science and practice of forest management. Forest resources provide innumerable ecosystem services that benefit society and the environment. Effective and innovative scientific and practical methods have been developed and implemented to protect important ecosystem functions while meeting increased demands for forest products. Changing societal values demand innovative and/or integrated approaches to forest management that meet social, ecological, and economic goals. New monitoring approaches involving continuous evaluation of harvest-induced and human-induced changes in forest structure and/or function are needed. Additionally, new approaches to forest management, as well as innovative political measures, are needed to encourage the most efficient and effective use of resources. The objective of this conference is to gather state-of-the-art research results and techniques relating to the management and analysis of forest resources. The organizers would like to welcome and invite those who intend to share their ideas and thoughts about current problems in forest management with others from different regions and research areas.

A Perspective on Forest Registration for the Next Generation in the Era of GIS

Kazuhiro TANAKA (*Kyoto Prefectural University, Japan*)

Data of forest registration managed by prefecture are used as attribute data of forest GIS in Japan. There are some issues of data of forest registration as follows: Inadequate data on forest operation records, discrepancies with actual forest condition, insufficient data on public interest, slow pace of update, not open to the public because of private information protection, and

so on. To overcome the above problems, required conditions of forest registration for the next generation are discussed in this paper. We need various information in forest planning, not only data of forest registration but also data of other organizations. By using spatial analysis function of GIS, we analyze various types of data such as, polygon data of forest compartment, raster data of remote sensing, point data of GPS, DEM and DSM by aircraft laser profiler. Consequently, it is recommended to keep forest data as thematic map in GIS. Present data of forest registration should be segmentalised into some thematic maps. Minimum basic data in forest GIS would be thematic map of forest physiognomy. Historical data of each forest stand would be link with forest GIS by hyperlink. Fundamental scheme of forest registration for the next generation is GIS-based structure which means that we use forest GIS as a tool of spatial analysis, not as a database.
Additional keywords: forest registration, database, forest GIS, thematic map, spatial analysis

ORAL SESSION

Monitoring of Peat Swamp Forest using PALSAR Data: A Trial of Double Bounce Correction

Yoshio AWAYA (*Gifu University, Japan*)

Reduction of Deforestation and Forest Degradation (REDD) is an international political issue, since about 20% of human-induced carbon emission is estimated to be caused by deforestation in the tropics. Monitoring deforestation is an important activity, since it provides basic information in REDD. Satellite remote sensing makes the monitoring possible in a large area. However, clouds disturb clear forest observation by optical sensors in tropics. Synthetic Aperture Rader (SAR) can observe the earth surface under overcastted condition from the space. Therefore SAR would provide valuable information about forest. Huge peat land forest area has been developed for rice production since latter 1990s in Central Kalimantan, Indonesia. The project caused the greatest impacts on deforestation and forest degradation in that area. There are numerous forests under declining by forest fires and reclamation still now. We aim at monitoring the peat swamp forest using ALOS/PALSAR data to demonstrate possibility of monitoring forest area by reducing the effects of double bounce on PALSAR data in open swamp forests and fire scars. Our study reviled that degradation and fragmentation continues, however, water levels in the swamp area suffered forest monitoring using PALSAR data. Although we succeeded in reducing effects of double bounce and monitoring forest changes, stand biomass was not estimated accurately. However, it would be possible to classify vegetation into about 5 classes according to biomass and to monitor deforestation.
Additional keywords: forest fire, mega rice project, backscattering coefficient

Estimation of LAI and Related Metrics using Small-footprint Airborne LiDAR without a Digital Terrain Model

Kazukiyo YAMAMOTO, Naoto KONDO (*Nagoya University/CREST, Japan*), Yoshiyuki TAKAICHI, Masashi TSUZUKI and Naoaki MURATE (*Nakanihon Air Service Co., Ltd., Japan*)

The relationship between canopy structure and temporal and spatial distribution of incident understory light has been used with particular interest for evaluating the effects of silvicultural prescriptions on the survival, pattern, and diversity of understory plants and trees. Although numerous ground-based optical tools and techniques have been developed to measure various attributes of forest canopy structure and understory light environment, it is difficult to measure these attributes around the vast forested area using the ground-based methods. In our previous studies, we presented a new methodology that did not require a digital terrain model (DTM) to estimate mean tree height using small-footprint airborne LiDAR data. In this study, we applied this method to estimate the leaf area index (*LAI*: m^2/m^2) and the related metrics concerning the light environment within the forest, i.e. canopy openness (*CO*: %) and sky factor (*SF*: %). Using the hemispherical images taken at 161 points (hereafter called for "Photo Points") within the hinoki cypress plantations and the LiDAR data, we investigated the relationship between the metrics calculated from hemispherical image (*LAI*, *CO* and *SF*) and the laser interception ratio (*LIR*: %) calculated from LiDAR data using the method presented in our previous study. In addition, because the LiDAR-drivened metrics would be more or less scale-dependent as suggested by previous researchers, we thus compared the LIR calculated from the range R (5 m to 60 m in 5 m intervals) in diameters centered on a Photo Point for investigating the optimal scale to estimate the *LAI*, *CO* and *SF* from LiDAR data.
Additional keywords: airborne LiDAR, *LAI*, canopy openness, sky factor, DTM

Estimating Total Biomass Carbon Stock and Carbon Absorption in Manmade Coniferous Forest Stands by Combining Low Density LiDAR and Yield Table

Eiji KODANI (*Tohoku Research Center, Forestry and Forest Products Research Institute, Japan*) , Tomohiro NISHIZONO (*Forestry and Forest Products Research Institute, Japan*) and Yoshio AWAYA (*Gifu University, Japan*)

We developed a method to estimate total biomass carbon stock and carbon absorption in manmade coniferous forest stands by combining low-density LiDAR and yield table. We established a transect 20-km long and 100-m wide that traverses the western part of Shikoku Island, Japan. Airborne LiDAR data for the transect were obtained in September 2002 by the Asahi-koyo Corporation. We set plots within the transect. The plots included non-forest areas and small to large forest stands of manmade coniferous forest of Sugi (*Cryptomeria japonica*) and Hinoki (*Chamaecyparis obtusa*),(n = 24). A linear regression analysis was performed between the LiDAR indices and the total biomass carbon stock. The total biomass carbon stock had the strongest relationship with the index of the last pulse average (r^2 = 0.89, p = 0.000). We estimated the total biomass carbon stock using the airborne LiDAR data and the regression line. Forest stand carbon absorption was estimated using a yield table (empirical growth model) with input variables of stand age from forest GIS, site index, and stand volume from the low-density LiDAR.

Additional keywords: LiDAR, total biomass carbon stock, carbon absorption

Analysis of High School Students' Perceptions of the Functions Served by Forests

Mari KAWASE (*Kyoto University, Japan*)

Understanding young people's perceptions of the functions of forests is important in developing forest-management strategies. This study investigated factors associated with high school students' perceptions of the functions of forests, particularly as related to their knowledge of forests and experience of visiting forests. Questionnaires were distributed to first-year students at a public high school in Kobe, Japan, in 2009, yielding 285 responses (response rate of 97.6%). Nine functions (e.g., carbon storage, timber production) were suggested in the questions. The students' perceptions of forests were compared among three types of forest described by the terms "forest," "artificial forest," and "natural forest." The results allowed for a clear understanding of the student's perceptions of forests, revealing the following:

1. The function of carbon storage was highly rated in all types of forest.
2. Knowledge of forest management could be divided into three categories: management by people, harm caused by nature, and substitutes for wood products.
3. Experience visiting forests was determined largely by grade. Students visited forests most when they were in elementary school. However, whether the students visited forests at present had no significant influence on their responses to the questionnaire.

Additional keywords: questionnaire, high school students, knowledge of forests, visit to forests, function of carbon storage, logit model

Forest and Human Development: Analysis of Socio-economic Factors Affecting Global Forest Area Changes

Tetsuya MICHINAKA and Motoe MIYAMOTO (*Forestry and Forest Products Research Institute, Japan*)

World forest area has been decreasing, but different countries witness different changes. In order to clarify the main socio-economic factors affecting changes in forest areas, cluster analysis is firstly undertaken to 206 countries by their levels of per capita GDP and rate of rural population, and three clusters are obtained, i.e., Cluster 1, consisting of 80 countries with high level of rate of rural population but low level of per capita GDP, Cluster 2, consisting of 87 countries with lower rate of rural population but higher per capita GDP, and Cluster 3, consisting of 39 countries with low rate of rural population but high per capita GDP. Secondly, panel data analysis is undertaken to these three clusters separately. The following six factors are considered in the model specification: life expectancy, adult literacy rate, gross national income per capita, total population, rate of rural population, and agriculture gross production value. Total population and Gross national income per capita are significant in all these clusters, but have different coefficients and signs. It is found that countries in Clusters 1 and 2 face pressure from population growth, while forest area will increase in countries in Cluster 3 if population increases. It also shows that increase in income will help to increase forest resources but in different scale. Forest area faces pressure when adult literacy rate increases in Cluster 1, but increases in adult literacy rate in Cluster 2 is good for increases in forest area. The rate of rural population is important for countries in Cluster 3 to maintain forest resources. It finds that in different levels of human development, humans have different relationships with forest resources.

Additional keywords: deforestation

Assessment of Forest Carbon Stocks in Cambodia

Nophea SASAKI (*University of Hyogo, Japan*), Kimsun CHHENG (*Forestry Administration, Cambodia*), Nobuya MIZOUE (*Kyushu University, Japan*), Dana KAO and Vathana KHUN (*Forestry Administration, Cambodia*)

While intensive discussions on REDD+ mechanism and its roles for multiple benefits have been going on, how carbon emission reductions can be achieved depending on how well we understand the current carbon stocks in the forests where REDD+ projects will be implemented. Using data from many sample plots in various forest types in Cambodia, here we attempted to estimate carbon stocks by province by forest type in Cambodia. Our results showed that total carbon stocks in Cambodia decreased from 1052.5 TgC in 2002 to 1020.0 TgC in 2006, resulting in emissions of about 27.9 $TgCO_2$ $year^{-1}$. The following provinces had the highest carbon stocks in Cambodia: Preah Vihear, Mondulkiri, Stung Treng, Kratie, and Koh Kong. Provinces responsible for the highest carbon emissions in Cambodia were Battambang (18.2% of the total annual emissions), Banteay Meanchey (14.9%), Otdar Meanchey (11.6%), Siem Reap (11.4%), and Krong Pailin (10.2%). In contrast, Koh Kong and Mondulkiri provinces increased carbon stocks at about -0.7 $TgCO_2$ and -0.8 $TgCO_2$ $year^{-1}$ over the same period. Our results suggested REDD projects in the northwestern provinces are likely to achieve huge carbon credits but such projects require strong government commitment and law enforcement. If retrospective trend is chosen as reference emission level, Cambodia would generate carbon revenues of US$ 69.7 million $year^{-1}$ at the price of \$5 tCO_2^{-1} if 50% of the current emissions are reduced.

Additional keywords: deciduous forest, evergreen forest, mixed forest, REDD+, stand volume

Variations of Carbon Stocks in Mixed Forests in 3 Northeastern Provinces in Cambodia

Kimsun CHHENG (*Forestry Administration, Cambodia*) and Nophea SASAKI (*University of Hyogo, Japan*)

Understanding forest carbon stocks is prerequisite for implementing and achieving the goal of the anticipated REDD+ mechanism of the United Nations Framework Convention on Climate Change. Nevertheless, study on carbon stocks in Cambodia is very

limited. In 2007-2008, Forestry Administration conducted forest inventory and logging experiments in 2007 and 2008 in Northeastern Cambodia. Here, we analyzed data from 159 sample plots of 25 m × 40 m size in mixed forests in Kratie, Stung Treng, and Rattanakiri provinces to study the variations of carbon stocks. On average per hectare, carbon stocks were estimated at 77.2±4.1 MgC (± refers to standard error), 69.8±3.5 MgC, and 68.2±3.9 MgC in Kratie, Stung Treng, and Rattanakiri, respectively. Average carbon stocks for the three provinces were 71.7±2.2 MgC ha^{-1}. Highest carbon stocks were observed in Stung Treng site where the stocks were 227.2 MgC ha^{-1}, while lowest carbon stocks were also observed in Stung Treng (18.1 MgC) suggesting that logging intensity has taken place at various scales. By using this average number (71.7 MgC ha^{-1}) as a default value, forest carbon stocks in mixed forests in Cambodia were estimated at 104.3 TgC with a decreasing rate of 1.7 TgC $year^{-1}$ between 2002 and 2006. If 50% of carbon emissions can be reduced, revenues from avoided deforestation in mixed forests alone are about $16 million annually at a price of $5 $MgCO_2^{-1}$.
Additional keywords: carbon stocks, carbon revenues, reduced emissions, REDD+, forest management

Impacts of Reduced Impact Logging on Stand Structures in Mixed Forests in 3 Northeastern Provinces in Cambodia
Kimsun CHHENG (*Forestry Administration, Cambodia*) and Nophea SASAKI (*University of Hyogo, Japan*)
Sustainable forest management (SFM) is an important component of the 2009 Copenhagen Accord, in which the REDD+ policy was highly recognized by the parties to the United Nations Framework Convention on Climate Change. Previous studies suggested that SFM cannot be achieved under the conventional logging commonly practiced in the tropics. Alternative but sound logging practice is therefore needed in order to achieve the REDD+ policy. Reduced impact logging (RIL) was recently found to be promising because of its ability to reduce damages to residual stands and wood wastes. Although RIL experiments have been conducted in some countries in the tropics, our study was very first RIL experiments conducted in mixed forests in Cambodia's Kratie, Stung Treng, and Rattanakiri provinces in 2007-2008. Here, we analyzed data from 179 sample plots by DBH classes and according to three damage classes, namely slightly damage (A), moderately damage (B), and severely damage or dead (C) on stem density, basal area, and stand volume. On average, damages were estimated at 67.3 trees ha^{-1} or about 20.3% of the total stem density in all three sites (DBH ≧ 10 cm). Of the 67.3 trees, 17%, 21%, and 63% were damages in class A, B, and C, respectively, and about 57.1% were trees in DBH class of 10-19 cm suggesting that small trees were largely affected by logging. In terms of stand volumes, 26.8 m^3 ha^{-1} (about 13.3 MgC) or 18.6% of the total stand volume. Our findings suggest that RIL could significantly reduce damages to residual stands, and thus carbon stocks. RIL should be adopted for achieving SFM under the REDD+ policy.
Additional keywords: basal area, logging damages, stem density, stand volume, carbon stocks

Developing a National-level System for Simulating the Forest Carbon Dynamics of Hinoki Planted Forests in Japan
Yasushi MITSUDA, Hidesato KANOMATA and Mitsuo MATSUMOTO (*Forestry and Forest Products Research Institute, Japan*)
Systems for simulating the forest carbon dynamics at the national level are useful for drawing up forest policies on climate change. We developed a national-level system for simulating the forest carbon dynamics of Hinoki planted forests in Japan, consisting of a forest database and a stand-level carbon cycle model. The system is based on a 1-km resolution forest database containing data on age, species, size, density and biomass of four pools (foliage, branch, stem, and root) of stands. We developed a process-based stand-level carbon cycle model to simulate carbon dynamics under various climatic conditions and forestry regimes. In our simulation system, this model was applied to each stand recorded in the forest database using climatic values (radiation, temperature and vapor pressure deficit) and forest operation schedules (clear cutting and thinning) as inputs. We simulated the carbon dynamics of planted forests for the whole of Japan from 2005 to 2050 for several scenarios of forest policy. These simulations yielded time-series trajectories of total living stock biomass, annual change in biomass, and spatial distributions of both, enabling us to compare the effects of forest policy on national-level carbon dynamics in the near future.
Additional keywords: growth model, permanent plot

Forest Management Guidelines based on Biodiversity and Impact of Operation for Uneven-aged Forests in Hokkaido, Japan
Masayoshi TAKAHASHI, Satoshi ISHIBASHI, Shigeo KURAMOTO, Shozo SASAKI, Shigeo IIDA, Takehiro YAMAGUCHI, Akira UEDA, Shin Abe and Yoshimi SASAKI (*Hokkaido Research Center, Forestry and Forest Products Research Institute, Japan*)
Selection cutting system has been considered as one of an advanced way to minimize the impacts of cutting operation. Over a period of several decades, most of natural forests in Hokkaido have been managed by selection cutting and as a result, they had been produced high quality timbers. However, some of the managed forests were considered as degraded forests both qualitatively and quantitatively. We analyzed biodiversity of managed forests and evaluated the impacts of silvicultural practices. Sometimes, recruit trees were dramatically decreased and regeneration of trees were very difficult by direct impact of logging operations and dense dwarf bamboo species due to variation of light condition. Adequate supplemental planting and regeneration operations are needed. Skidding operation might lead both qualitative and quantitative stand damages. Group selection cutting and careful logging technique should be applied. Fallen logs including nurse logs were decreased by logging operations that threaten the biodiversity. A certain amount of fallen logs and dead trees must be preserved in the management forests. To harmonize the logging operations and preservation of fallen and dead trees, we proposed new classification system. GPS and GIS should be important tools to deal with the appropriate management activities.

The Sustainable Forest Management and Planning of Jingu Forest: A Case Study for Periodic Rebuilding of a Traditional Japanese Shrine

Tohru NAKAJIMA, Satoshi TATSUHARA, Satoshi TSUYUKI and Norihiko SHIRAISHI (*The University of Tokyo, Japan*)

The Jingu Shrine is a traditional Japanese shrine, located in Mie Prefecture. The "Shikinen Sengu Ceremony", the periodic rebuilding of the shrine, has been carried out every 20 years since the seventh century using timber harvested from natural forests outside Mie Prefecture. However, the Forest Administration Department of Jingu Shrine has decided to obtain its own supply for the next Shikinen Sengu Ceremony in 2013. To obtain a self-supply of large timbers for rebuilding the Jingu Shrine, it is necessary to develop a harvesting plan for plantations that allows the sustainable use of forest resources. Then, we spatially allocated the optimum clear cutting area calculated by previous study in Jingu Shrine forests. Using local area wind energy prediction system, we predicted the wind speed in the study site with the digital elevation model (DEM) and climate data in Jingu Shrine forest. We also calculated the average wind speed per wind hazard area. Based on the wind speed calculated in the disturbed stands, we estimated the wind hazard probability. Finally, we analyzed the difference in wind hazard risk among harvesting strategies based on the dynamic programming. As a result, the optimum clear cutting area would reduce the expectation value of the stand volume that will suffer from wind hazard to less than approximately 50%. This study proved that it is possible to suggest spatial-temporal sustainable forest management strategies to improve the supply rate of timber given a situation where the demand for forest resources is fixed, on a regular, quantitative basis.

Additional keywords: air flow simulation, growth model, Shikinen Sengu Ceremony, sustainable timber production

Structural Equation Modeling in Analyzing the Relationship between Urban Forest and Medical Care Use

Kwangsoo LEE *(Eulji University, Korea*)

This study evaluated whether urban forests had relationship with medical care use in respiratory disease. Data were obtained from (1) forest information from the Korean Forest Service, (2) air pollution data from the Ministry of Environment, and (3) medical care use for respiratory disease, population information, and medical care provider information from the Korean Statistical Information Service. Study dataset comprised 143 cities and administrative districts in seven metropolitan areas in Korea. A structural equation modeling was applied to test whether the extent of urban forest is negatively related to medical care use for respiratory disease after controlling the effects of degree of air pollution, population, and availability of health care providers. Forest extent and medical care use showed significant negative associations (estimates = -0.07, p-value = 0.00). The structural equation model showed good model fit to the sample data. Urban areas with larger forests had direct significant effects on medical care use. These study findings supports that urban city forests could mediate harmful effects of the external environment and improve health status.

Additional keywords; forest and human health, urban forest, medical care use, structural equation model

POSTER PRESENTATION

A: General issues in forest planning

Clarifying the Condition Determining the Applicability of Airflow Model to Wind Hazard Risk Assessment

Naota TANIGAWA, Tsuyoshi KAJISA, Shigejiro YOSHIDA, Tetsuji OTA and Nobuya MIZOUE *(Kyushu University, Japan*)

Wind hazard in forest is one of critical risks of forest management in Europe, the U.S. and Japan. For efficiently and effectively coping with wind hazard in forest, it is necessary to assess the wind hazard risk in each forest land in advance. Application of an airflow model to the wind hazard risk assessment is expected these days. Therefore we studied the condition that determines the applicability of the airflow model to the wind hazard risk assessment. We constructed the wind hazard prediction models using airflow model for the wind hazard caused by typhoon 19 in 1991 in Oita Prefecture and that caused by low pressure system in 2006 in Hokkaido, respectively, and discussed the causes that influence the applicability of the airflow model. It is implied that the difference of factors mainly causing wind hazard strongly influences the applicability. We considered that the airflow model can be applied to the risk assessment of wind hazards triggered by rare and stronger storms and it is difficult to apply the airflow model to wind hazards triggered by the poor resistance of forests to strong winds.

Additional keyword: wind hazard, risk assessment, airflow model, typhoon

Growth and Volume Distribution Analysis of *Robinia pseudoacasia* Riparian Forests along the Chikumagawa River in Japan

Keisuke TOYAMA (*The University of Tokyo, Japan*)

We investigated the growth of riparian forests of nonnative *Robinia pseudoacacia* along the Chikumagawa River in Japan assuming their use as biomass resources, and analyzed the volume distribution among trees or within one tree. Stem analysis in 4 plots with total 0.4 ha showed that the growth speed of stand stem volume was high when the stand age was ca. 15 years or more. Volume distribution among trees indicated that targeting only larger trees will easily increase the average volume of harvested trees. Genetic analysis showed that there were cases where DBH of trees of genets with bigger population were significantly larger. The volume of branches often occupied considerably large ration of the whole standing tree volume. The definition of wood part available as biomass resources seems to be important for appropriate volume measurement.

Additional keywords: *Robinia pseudoacacia*, growth analysis

A Study of Natural Forest Type Classification for Japanese National Forest Inventory Data

Fumiaki KITAHARA, Yasushi MITSUDA (*Shikoku Research Center, Forestry and Forest Products Research Institute, Japan*) and Tsuyoshi KAJISA (*Kyushu University, Japan*)

The National Forest Inventory (NFI) started in Japan in 1999 with the aim of understanding the state and dynamics of various aspects in forests such as wood production and biodiversity throughout the country. Forest type is one of the important component from which many indicators of forest biodiversity can be estimated. In Japan, the forest register (shinrinbo) records information on the stand status of all private and national forest land including species, age, DBH and stand height. However, natural forests (not planted forest) are recorded as "mixed" in the forest register. Currently data from NFI is expected to classify the natural forest and to estimate the total area of natural forest with the model or satellite image. There are several definition, classification and identification methods for forest type. Moreover, most researchers define or classify the species assemblages and identify indicator subjectively. The objectives of this study were to classify forest types of the natural NFI stands for carbon stock model and to develop the classification method with reproducible way.

Additional keywords: forest type classification, NFI

Forest Management and Native People's Use of Forest Resources in Nature Reserve of Hainan Island, China

Yuanjun CHEN and Seiji ISHIBASHI (*The University of Tokyo, Japan*)

In Hainan Island, China, natural tropical forest remains in mountain region and it is managed in order to leave its plentiful nature for the future in nature reserve. However, there are native people such as the Li and the Miao have lived in this area for several hundred years. It is a big problem how to adjust their use of forest resources and forest management in the nature reserve. On previous measures, emigration of the native people or restriction of the use of the natural resources has done. But they are not effective for this problem. Today, some new methods have been tried, for example the employment to native peoples to manage the nature reserve and eco-tourism, but the effect of these attempts is unknown. On this research, we try to examine the native people's use of forest resources and thought about nature reserve, and discuss how to manage forests of the nature reserve for adjustment of native people's use and conservation of the nature reserve. We interviewed to the Li living in Daoyin village, Yinggeling Nature Reserve, Hainan. As a result, we could say traditional use of forest resources is definite. On the other hand people are eager to cultivate market crops such as rubber trees to get more income. Some methods like eco-tourism are tried to conserve the nature reserve. However, it is considered that some systems are the key to compensate them with getting income by cultivating market crops and to prevent them from overusing of forest resources.

Additional keywords: eco-tourism, tropical forest, immigration, rubber tree

Growth Prediction of *Acacia Mangium* in Western Java, Indonesia

Shin INOUE and Naoto MATSUMURA (*Mie University, Japan*)

According to FRA2010, around 13 million hectares of world forest were converted to other uses or lost through natural causes each year in the last decade. Emissions from deforestation are very serious, they are estimated to represent more than ca. 20% of global emissions. Especially, tropical forest is sharply decreasing, it is necessary to reduce emissions from deforestation and forest degradation in tropical area to prevent global warming. The life of the local people is deeply connected with tropical forest, and the forest management obtained understanding of local people is needed. In this study, yield table of *Acacia Mangium* planted by local people in western Java area, Indonesia. This yield table was divided into three categories of Site Index. Furthermore, total volume and absorbed amount of Green house gas were calculated, and disparity of income founded on Site Index was estimated to consider possibility given incentive to local people.

Additional keywords: community-based forestry, agroforestry, yield table, B/C ratio

Determinants of Spatial Stratification Decisions in Natural Forest Management in Central Hokkaido, Japan

Toshiaki OWARI, Yuji NAKAGAWA and Hiroshi INUKAI (*The University of Tokyo, Japan*)

Spatial stratification is an essential planning technique in Hokkaido, northernmost Japan, to manage natural forest that exhibits a structural heterogeneity. Operationally, a forest planner makes a stratification decision on-site, based on his empirical skills and knowledge gained through the long-term work experiences. Although general guidelines for stratification practices exist, little is explicitly known on how stratification decisions are actually made by experienced forest planners. The purpose of this study was to determine factors affecting spatial stratification decisions for managing a natural forest in central Hokkaido. A case analysis was conducted at the University of Tokyo (UT) Hokkaido Forest. We used a total of 930 sample plots that had established within 4 major stratification options (softwood selection harvest, hardwood selection harvest, pre-harvest, and regeneration activity required) during 2005-2009. Tree species and diameter at breast height (DBH) for all living trees with DBH $\geqq$ 5 cm were recorded in each plot. The number of juveniles ($\geqq$ 1.3 m in height and < 5 cm in DBH) by tree species was also recorded. We examined differences in stand structure between the stratification options and performed a classification tree model to derive the decision rules of spatial stratification administered by forest planners. Results indicated that the dominance (represented by the sum of basal areas) of marketable coniferous and broad-leaved trees (25 cm $\leqq$ DBH < 59 cm) and the density of young growth broad-leaved trees ($\geqq$ 1.3 m in height and < 25 cm in DBH) had significant effect on stratification decisions.

Additional keywords: classification tree model, forest management planning, natural forest management, spatial stratification technique, stand structure

B: Remote sensing and GIS

Estimation of Forest Biomass using Remotely-sensed Data and *k*-Nearest Neighbor Algorithm

Jungsoo LEE (*Kangwon National University, Korea*)

This study purposed to estimate the forest biomass using *k*-Nearest Neighbor (*kNN*) algorithm. Multiple data sources were used for the analysis such as 5th forest type map, field survey data and Landsat TM data. Forest biomass accuracy was evaluated with the forest stratification, horizontal reference area (HRA) and modal filtering. Forests were divided into 3 types such as conifers, Hardwoods and *Pinus koraiensis*. The applied radii of HRA were 3 km, 4 km, 5 km and 10 km, respectively. The estimated forest biomass of conifers forest was 255 ton/ha when the value of *k* was 9, the radius of HRA was 4 km, and 5 by 5 modal was filtered. The estimated biomass of Hardwoods was 210 ton/ha when the value of *k* was 6, the radius of HRA was 4 km, radius and 3 by 3 modal was filtered. The estimated forest biomass of *Pinus koraiensis* was 276 ton/ha when the value of *k* was 3, the radius of HRA was 11 km. The estimated total carbon stock by *kNN* method was 234 ton/ha. The estimated total biomass by *kNN* method was about 20 ton/ha less than that of filed survey data. This study was carried out with the support of 'Forest Science & Technology Projects (Project No. S120911L010110)' provided by Korea Forest Service.

Additional keywords: forest biomass, *k*-nearest neighbor algorithm, Landsat TM

Vegetation Map using Object-oriented Image Classification with Ensemble Learning

Shota MOCHIZUKI and Takuhiko MURAKAMI (*Niigata University, Japan*)

Vegetation map is the basic information for forest management. In the remote sensing, creation of the accurate vegetation map is an important subject. Recently, the research using the object-oriented image classification technique or hyper spectral data have increased in the image classification by remote sensing data. Therefore, classifying image with the feature of multi-dimension is an important subject. In particular, in a linear model such as the maximum likelihood method in a pixel base classification, the pattern or relation of multi-dimension data are not characterized. In the classification of multi-dimension data, data mining and ensemble learning is effective. Ensemble learning is the method of raising accuracy and flexibility by combining two or more results. In this study, the object-oriented image classification using Random Forest (RF) advocated by Breiman was employed. Moreover, Nearest Neighbor (NN) method and Classification and Regression Tree (CART) were used as the candidate for comparison of classification accuracy. Our study area is Sado Island in Niigata Prefecture, Japan. SPOT/HRG imagery (June, 2007) was used for vegetation mapping. Our classification target was broad-leaved deciduous forest, coniferous forest, Japanese red pine, and bamboo forest. As the result, the accuracy of the vegetation map using RF and NN was high. Especially RF method was the most accurate within three techniques of image classification. We propose the effective classification technique in vegetation map creation using multi-dimensional data.

Additional keywords: image classification, random forest, Nearest Neighbor, CART, remote sensing

Development of Method to Estimate Understory Vegetation Coverage using Two Digital Cameras

Yasuhisa MURASE, Kazukiyo YAMAMOTO, Chisato TAKENAKA (*Nagoya University-CREST, Japan*), Toshiro NONODA (*Mie Prefecture Forestry Research Institute, Japan*), Norio YUBA (*Hiroshima Prefecture, Japan*)

In Japan, conifer plantations were established for timber production after intensive clear-cutting of natural forests, particularly from the 1950s through the 1970s. However, these plantations have become overstocked during the past decades mainly due to lack of adequate management resulting from high labor costs and low wood value in the country. Presently, from the increasing interest in public benefit such as soil and water conservation brought by forest, the unsoundness of these overstocked forests poses a social problem with rapid increase of the belated thinning forest. Although thinning would open the canopy and lead to increased species diversity and understory vegetation coverage in these overstocked forest, the evaluation of the effects obtained by thinning have required significant time and labor. In this study, we therefore presented a method to estimate understory vegetation coverage using two digital cameras for investigating recovery of understory vegetation after the thinning of conifer plantation. For evaluating the accuracy of the method presented in this study, we established the 27 plots of 5 m $\times$ 5 m in size within the three hinoki cypress forests. We then compared the understory vegetation coverage directly measured in the field (UVCo: %) and that estimated using the method presented in this study (UVCe: %). The UVCe was significantly correlated with UVCo and the root mean square error of regression line of UVCo against UVCe was approximately 8%. Thus, the method presented in this study would be a useful method for measuring the understory vegetation coverage easily.

A Comparison of Stem Density Estimation Techniques using Very High Resolution Imagery

Tetsuji OTA, Nobuya MIZOUE and Shigejiro YOSHIDA (*Kyushu University, Japan*)

For sustainable forest management, we need precise forest information from periodic and systematic measurements. Remote sensing could be a powerful tool for getting forest information for sustainable forest management. Several techniques for retrieving forest information from very high resolution imagery (VHRI) now exist. In this study, we compared stem density estimation techniques using VHRI. We used QuickBird imagery as VHRI. The study site consisted of even-aged plantations of Japanese cedar (*Cryptomeria japonica*) and hinoki cypress (*Chamaecyparis obtusa*). Two techniques using regression analysis and two techniques using individual tree counting were compared. RMSE was between 377 and 409, regression analysis methods being used. RMSE was between 450 and 1242, individual tree counting methods being used. RMSE of individual tree counting methods were strongly influenced by window size. Additionally, one reason suggested for individual tree counting error is the

limited spatial resolution of QuickBird imagery. The main conclusion of this study is that regression analysis methods were better accuracy than individual tree counting methods in terms of RMSE. However, individual tree counting methods have the advantage that there is no need to collecting training samples. Further research using much higher resolution imagery is required.
Additional keywords: stem density, very high resolution imagery, texture, local maximum filter

Factors Causing the Expansion of Japanese Oak Wilt Disease on the Outskirts of Kyoto City
Yuu YOSHII, Takashi NOGUCHI and Masahide KOBAYASHI(*Kyoto Prefectural University, Japan*)
Japanese oak wilt disease (JOW), associated with *Platypus quercivorus*, an ambrosia beetle, is widespread in Japan. To prevent JOW, it is essential to locate all killed trees without exception. An aerial helicopter survey to locate killed trees has been ongoing in Kyoto City since 2005. To learn where JOW tends to occur, we analyzed topographic conditions in places where JOW occurred using the helicopter survey data. The analysis used geographic information system (GIS) technology. The probability of JOW occurring was calculated using Jacob's index. In particular, to understand where JOW tends to occur first, we focused on trees that developed damage earlier, at least 6 km from trees killed the previous year. Our results indicate that although JOW occurred frequently at altitudes of 100 to 300 m each year, trees that developed damage earlier were found at lower altitudes. Although a clear tendency was not observed for the angle of inclination, trees that developed damage earlier were less likely to occur in steep areas. Aspect analysis indicated that in 2005-2006, JOW occurred frequently on the southwest-facing slope of Mt. Higashiyama, in the east part of Kyoto City. JOW then occurred at all aspects as the damage expanded. We also classified landforms into five classes and analyzed their relationship with JOW. The results show that trees that developed damage earlier were less likely to occur in steep valleys and on steep ridges. Moreover, we analyzed whether solar radiation, power pylons, and lightning strikes had an influence on JOW.
Additional keywords: JOW, *Platypus quercivorus*, helicopter survey, GIS

The Development of Risk Assessment Model for Snow Damage using GIS
Takashi NOGUCHI, Masahide KOBAYASHI (*Kyoto Prefectural University, Japan*), Satoshi SAITO (*Forestry and Forest Products Research Institute, Japan)* and Kazuhiro TANAKA(*Kyoto Prefectural University, Japan*)
Serious snow damage occurred in Miyama-cho, Kyoto Prefecture in January 2009. We identified that some trees that had survived being damaged by wind during Typhoon 23 in 2004 had cracked along their annual rings. Trees weakened in this way later suffered snow damage. Similar damage will occur frequently in Japan in the future, because strong typhoons and heavy damp snow are likely to increase with climate change. In this study, we predicted where snow damage tends to occur by adopting topographical features (altitude, angle of inclination, water flow accumulation, and so on) and wind speed as factors influencing snow damage. In this prediction, we used wind flow simulation software (RIAM-COMPACT) to compute the wind speed in a given location during Typhoon 23. We divided Miyama-cho into 13,070 cells (10 m in every direction), randomly extracted training data from these cells, then predicted snow damage using three models: logistic regression, classification and regression tree (CART), and random forest analysis. To determine which of these three was the optimal model, we randomly extracted 6,535 cells for verification from different training data, then computed the discriminant hitting ratio (the number of cells in which predictions and actual conditions agree divided by the total number of cells used for verification). The results showed random forest to be the optimal model, as it had the highest discriminant hitting ratio (92.6%). We conclude that the random forest model can predict snow damage, because the hazard map based on this model agrees with actual conditions.
Additional keywords: snow damage, wind damage, GIS, RIAM-COMPACT, random forest

Extraction of Suitable Sites for Japanese Cypress (*Chamaecyparis obtusa*) Plantation in Odai-cho, Mie Prefecture: The Growth and Insect Damage Tendency by Site Condition
Ryota TSUCHIDA, Keiko NAGASHIMA *(Kyoto Prefectural University, Japan*), Kenichi TANAKA(*Center for Restoration of Regional Nature, Japan*), Hiroyuki OKAMOTO (*Miyagawa Forestry Association, Japan*) and Kazuhiro TANAKA (*Kyoto Prefectural University, Japan*)
This study aims to examining the relationship of site conditions and the growth of Japanese cypress (*Chamaecyparis obtusa*) at abandoned plantation sites of Odai-cho in Mie Prefecture for clarifying sites suitable or unsuitable for cypress plantation. The relationship between site conditions and the damage by *Anaglyptus subfasciatus* was also interpreted and used for evaluating the site suitability. Sixty-six plots were established for field survey and the site conditions were interpreted based on their parent material, types of deposition (residual/creeping/colluvial), slope angle, slope type, and soil particle size at each plot. The data of tree height, diameter at breast height (DBH), and insect damage were also investigated. Cluster analysis was conducted by using the data of tree height and DBH in order to divide the site conditions into several location groups with the same growth tendency. Using the insect damage data, site conditions were also divided into several location groups with the same damage tendency. The whole abandoned plantation area was then divided based on each location groups by using GIS. As a result, concave sites with colluvial deposits were fast-growing but tended to show serious insect damage. Convex sites with residual deposits and clay were slow-growing sites but showed little insect damage. As the insect damage is the main factor influencing the timber value, we concluded the latter sites as suitable sites for cypress plantation. Other sites might be better to convert to other forest types such as broad-leaved forest which might contribute to diversify the forests in the region.
Additional keywords: site condition, GIS, *Chamaecyparis obtusa*, suitable sites

Procedure for Suitability Analysis of Forestry for Sustainable Forest Management: A Case Study in Odai Town, Mie Prefecture

Yasuhiko HAYASHI(*Kyoto Prefectural University, Japan*) and Naoto MATSUMURA*(Mie University, Japan*)

Abandoned forests have been increasing in Japan, because the willingness of forest management has been declining with the falling log price caused by mass imports of timber. Forest zoning for suitable and sustainable forest management came to be carried out in Japan with the establishment of Forest and Forestry Basic Act in 2001 as turning point. This study aimed to propose a method for evaluating suitable sites for forestry by comparing various thematic maps created from the data of forest register book such as slope and existence of road network using GIS in Odai Town, Mie Prefecture, Japan. Suitable sites for forestry were distributed in the eastern part of the town, where young well-managed forest were distributed and forest road networks were well-developed. In contrast, the western part of the town was considered as unsuitable sites for forestry because the area had steep slopes which result in the difficulty of road network development. Accordingly, many elderly forests were not managed well in this area. If areas with high possibility of slope failure were identified, forest road network might be able to construct either in the western area and the situation of forest management in the area will be improved. Presentation of the results of forest zoning by using GIS will be effectively useful in sharing knowledge and mutual understanding.

Additional keywords: forest zoning

C:Forest information systems, e-forest

The Introduction of the Research Project: Development and Demonstration of Forest Management System, "e-forest", which Supports Revitalization of Forest and Promotion of Utilization of Unused Forest Resources

Toshiro NONODA (*Mie Prefecture Forestry Research Institute, Japan*)

The artificial forest in Japan created by expansive afforestation since the 1950s has reached its cutting period. However, at present, the thinned wood in the forest is being underutilized and left because of reduced forestry profitability. To solve this problem, efficient forest management aimed at improvement in forestry productivity and effective utilization of thinned wood are important. Based on this present state, we will study the following problems in this research project: (1) Construction of forest resource databases for formulating an effective forest management plan, (2) Development of a forest analysis system that can evaluate the effect of forest operation, (3) Evaluation of the possibility of thinned wood utilization, and (4) Development and implementation of the forest management system "e-forest." The development and implementation of "e-forest," which is the goal of this research project, supports a forest manager and forester, who are in charge of finding a solution of following problems: (1) Proposal of thinning methods and forest revitalization techniques for adapting to various forest conditions, especially to the artificial forest that is in a state of devastation, (2) Decision making with regard to creating an efficient forest management plan for realizing the management goal, and (3) Promotion of forest management that enables the coexistence of forest improvement and effective utilization of thinned wood. In this presentation, we outline our research project and present the current state of the challenge.

Additional keywords: forest management system, revitalization of forest, utilization of unused forest resources

Estimation of Crown Closure Rate in Sugi and Hinoki Stands after Heavy Thinning

Toshiro NONODA, Hiromasa SHIMADA(*Mie Prefecture Forestry Research Institute, Japan*), Masayuki NISHISE, Masaki TANI and Yasuhiro NAKATA (*Oodai Town Hall, Japan*)

Recently, there have been increasing number of stands in which thinning is not carried out at the right time and overpopulated because of reduced forestry profitability. In overpopulated artificial forests, there are some stands in which thinning has never been carried out, even if the forest is a middle-aged one. In such forests, heavy thinning should be carried out to resolve the overpopulation problem. Heavy thinning in overpopulated artificial forest is occurred large gaps in closed crown and changed environment in stands extensively. Although it is apprehended that the environment change after heavy thinning affect crown extension related growth increment of stand as inhibiting factors, the effect is not always apparent. Therefore, to estimate crown closure rate, the plots were set at stands where heavy thinning were carried out and differed the number of years after thinning, and stand density, breast-height diameter, tree height, crown height, and branch spread in 4 directions were investigated. The total number of stands evaluated was 54: 32 hinoki stands (37-60 years old) and 22 sugi stands (34-68 years old). Using factors such as the number of years after thinning, thinning rate based on the number of trees, basal area, mean tree height, and crown density of stands were estimated using multiple regression analysis. Our study showed that the crown closure rate was almost similar to the rate of crown closure caused by general thinning.

Additional keywords: crown closure rate, heavy thinning, overpopulated forest

Modeling Structural Development of Plantation Forests Addressing Diagnosis System of Forest Management

Yukihiro CHIBA (*Forestry and Forest Products Research Institute, Japan*)

With considerable large area of plantation forests in Japan, viable measures are required to dissolve several issues on forest management: e.g. how to recover over-crowded plantation forests, how to shift to long-rotation forestry. To meet the requests particularly on silviculturally technical problems, it is needed to evolve scientifically based criteria for forest health and needs of thinning, and prediction technics of forest growth. Now the project is going on to develop a portable laser scanning equipment and data processing software for measuring forest structure, and forest management system, e-forest. The following quantitative

analyses were made to model structural development of plantation forests, which could be preprogramed in "e-forest". (1) The vertical distributions of leaves and branches of individual trees were reconstructed by quantifying tree architecture with branch recession pattern. (2) The developmental change of horizontal crown projection in a forest was simulated by simplistically assuming the crown shape as octagon, which is needed to understand canopy closure after thinning. (3) The forest stand growth model for younger to older forests was improved by introducing "self-thinning" and "crown shyness" processes. (4) Since the "e-forest" includes technical support system for a variety of forest management such as long-rotation forestry, the modeling of structural development of forest stands could be essential approach for "e-forest".
Additional keywords: thinning effect, canopy closure, tree architecture

Three Dimensional Map Building for Mountain Forest Structure Analysis using a Small-sized Laser Scanner
Keiko SHIOZAWA (*FOREST Revitalization Systems Co. Ltd., Japan*)
A portable laser scanning equipment and data processing software for measuring forest structure are developed. It will contribute to introducing Information Technologies (IT) into forestry field where manual measurements have been carried out so far. The equipment consists of a small-sized laser scanner and a rotating mechanism for the scanner. 3D point clouds which are a set of points between the scanner and measured coordinates on the scanned surface of trees, leaves, branches and ground are obtained by rotating the scanner at several measuring locations. The point clouds are processed to reconstruct 3D map and parameters such as DBH, Height, etc, which are necessary for forest maintenance are extracted. As scanning depth is limited, every scanned data for different measuring location must be integrated in one large map. An algorithm for the integration is developed based on the iterative closest point (ICP) algorithm. After the integration, a circle is fitted onto every tree by least square method and its radius can be measured at a human chest height. We plan to put a laser scanner, camera, accelerometer, data processing terminal and battery altogether in portable manner for measurement convenience.
Additional keywords: 3D SLAM, ICP, forest measurements, a small-sized laser scanner

Utilization Possibility Evaluation of Thinning Timbers
Akiko MOCHIZUKI (*FOREST Revitalization Systems Co. Ltd., Japan*)
A new measuring method for forest resource by belt sampling is well adapted to realization of forest structure in Odai-town of Mie Prefecture which has 393 km^2 of total area and 220 km^2 of Sugi (*Cryptomeria japonica*) and Hinoki (*Chamaecyparis obtusa*) plantation forest. Moreover, the appropriate estimation for the harvest possibility from the total forest is developed by using Ortho-photo and GIS with sampling results and effective forest road density. While on the other hand, the aim of this study is realization of cascade use of total harvest timbers by thinning. Therefore, several system of the gathering timbers beside of forest roads are examined, and possibility test of using 0 to 10 years dumping timbers on stands for the co-combustion fuel at coal-fired thermal power station is also done. These tests achieve actual proof like the confirmation of using dumping and thinning timbers beside of forest roads by harvest simple system. This study is cooperated by three companies; FOREST Revitalization Systems Corp. for the possibility of total forest use, TOYOTA MOTOR Corp. for the development of thinning timbers harvest system beside of forest roads and CHUBU Electric Power Co., Inc. for the examination of using dumping timbers on stands for the co-combustion fuel at coal-fired thermal power plant.

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(May, 2001)
(revised September, 2002)
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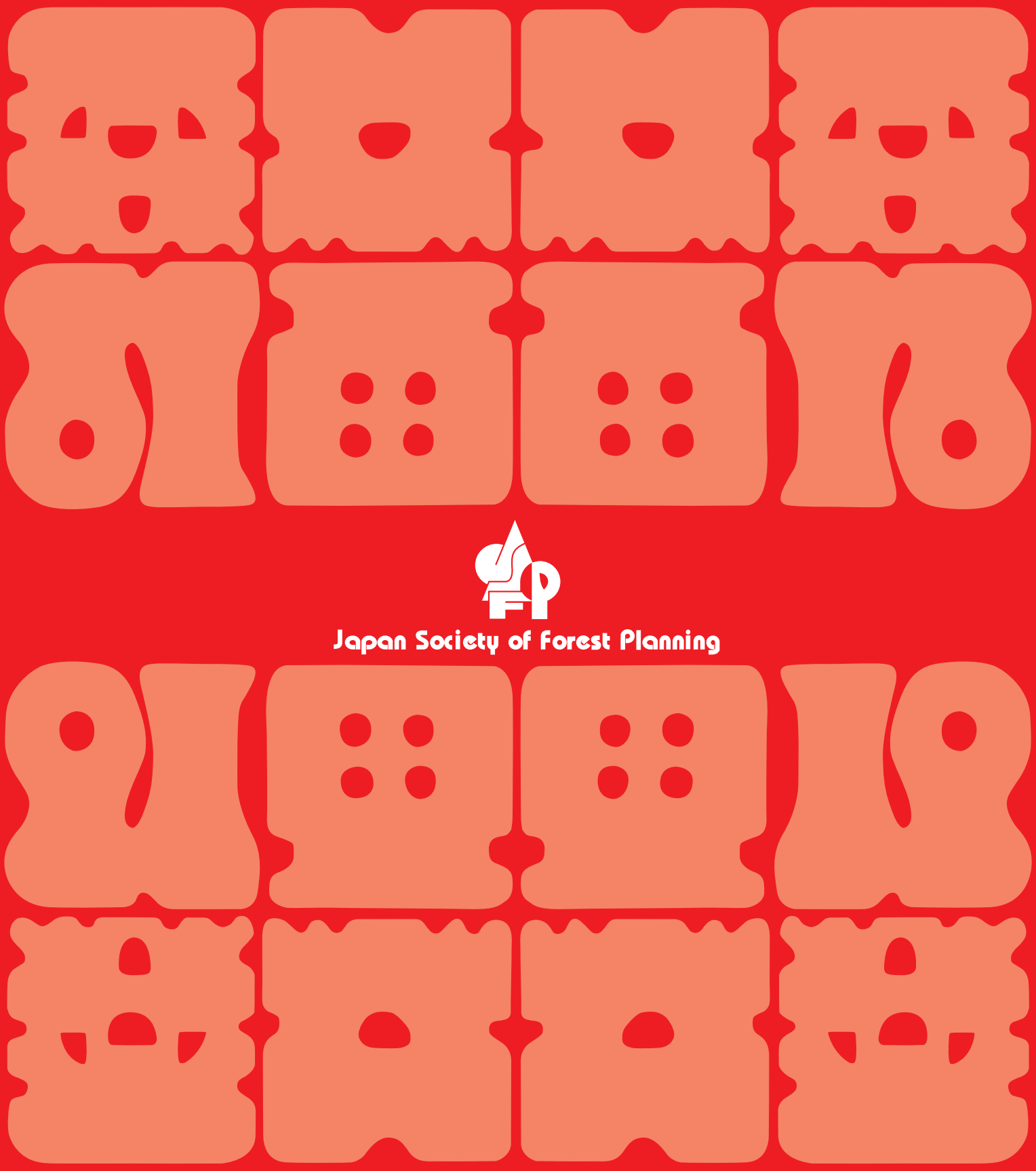

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