

## CHAPTER 4

### SUCCESSION OF LARCH STANDS ON THE PERMAFROST

#### 4.1 Background

Boreal forest is subject to disturbances such as fire or cut. On the permafrost, such disturbances can induce irreversible vegetation changes (Section 2.1). To manage a wide area of such boreal forests appropriately, it is required to apply forest inventory and monitoring methods by means of remote sensing that are reliable and robust for the specific local vegetation and climate (Section 1.5). As the first step to developing such methods, the stand succession of the local vegetation, *i.e.* larch stands, are measured and analyzed in this Chapter. Remote sensing methods for the forest inventory and monitoring will be developed in the next Chapter. The area of interest is Central Yakutia, Russia.

In Central Yakutia, the structures of larch-dominated stands at different stages of succession have been studied by many authors (*e.g.* SHERBAKOV, 1979; KANAZAWA *et al.*, 1994; SCHULZE *et al.*, 1995; TSUNO *et al.*, 2001). In addition, there have been many literatures in Russian, however, they are rather difficult to access for foreigners (SCHULZE *et al.*, 1995). Many of them, especially by non-Russian authors, contained only few plots in each study, which were subjectively and intentionally chosen from the stands that had not been affected by any disturbances for relatively long period. In reality, though, disturbances occur frequently and a certain area of the forest is expected to be disturbed recently, especially in the vicinity of Yakutsk, the capital of the Republic of Sakha (Yakutia). If one considers managing all the forest stands in an area, all types of forest succession must be taken into account in the observation. This consideration leads to a strategy that the samples should be selected as many as the expedition allows, and they should be from as many types of stand as possible. In addition, data of those precedent studies should be utilized.

Relationships of the larch stand's mean individual sizes and stand parameters are the target to be clarified, so that in the following Chapter the succession stages or the mean individual sizes of stands are to be inversely estimated by the satellite

images whose resolution is as coarse as the stand-scale. It is often the case that there is a linear relationship between an individual dimension and the stand density of overcrowded even stands on the log-log space. REINEKE (1933) found empirically in even-aged conifer stands a linear relationship between the number of trees,  $N$  [trees/ha], and the quadratic mean of DBH (expected DBH of the mean basal area),  $D$  [cm], and named it the reference curve (4.1).

$$\log N = -1.605 \log D + k \quad (4.1)$$

where,  $k$  is a constant varying with species. He set  $-1.605$  as a universal coefficient, but SHIRAISHI (1985) advocated they depended on species.

Another relationship is the so-called “3/2 power law” (YODA *et al.*, 1963), which was found from analyses of the growths of homogeneous herbaceous stands, and is expressed as equation (4.2).

$$w = CN^{-3/2} \quad (4.2)$$

where,  $w$  [kg] is the mean plant dry weight and  $C$  is the coefficient depending on species. OGAWA (1980) yielded from dimension analysis that this law meant a constancy of the final biomass density in the occupied space by individuals. The “full-density curve” (SHIDEI, 1956) for arboreal species is equivalent to the 3/2 power law in form (YODA *et al.*, 1963; NAGUMO and MINOWA, 1990), though the assumptions are different from each other. TAKAO and MINOWA (1993) analyzed the individual tree growths in a stand with a consideration on the reduction of respiration in heartwood. They suggested that the 3/2 power law meant for arboreal species a constancy of the final surface area of individuals per occupied area, which allowed the tree biomass grow larger than grasses, and their suggestion was supported by their simulation. As for the larch stands on the permafrost, though, many authors suggested that their growths violated the 3/2 power law (SCHULZE *et al.*, 1995; OSAWA *et al.*, 2000).

Other stand parameters are two relative densities, that is, the basal area and

the relative spacing index (NAGUMO and MINOWA, 1990; NISHIZONO *et al.*, 2002). The relation between the basal area,  $G$  [m<sup>2</sup>/ha], and the stand density is mathematically equivalent to REINEKE's (1933) equation (4.1). From (4.1), one can yield an equation for the basal area as:

$$\log G = -0.246 \log N + k' \quad (4.3)$$

which suggests that the basal area increases little by little as the tree density reduces. The relative spacing index,  $S_r$  [dimensionless], is expressed as:

$$S_r = \frac{100}{h\sqrt{N}} \quad (4.4)$$

where  $h$  is the mean tree height. Under the assumption of the isometric tree growth (YODA *et al.*, 1963),  $S_r$  is expected to become constant in overcrowded stands regardless of  $h$  or  $N$  (KONDO *et al.*, 2001). However, NISHIZONO *et al.* (2002) found that  $S_r$  reduced as  $h$  grew for the conifer plantations of *Cryptomeria japonica* and *Chamaecyparis obtusa* in Japan.

As suggested by SCHULZE *et al.* (1995) and OSAWA *et al.* (2000), the relationships among these parameters of the larch stands in this region would supposedly not follow the ones derived from the other places on the earth. The objectives of this Chapter are:

- To describe the allometric relationships among the parameters of the overcrowded larch stands, and
- To derive the above-ground biomass estimation equation for both overcrowded and sparse larch stands.

## 4.2 Study Area

The study area is a suburb of the City of Yakutsk, Russia (Figure 4.1), within which the stands for measurement were selected. The terrain is characterized by flat

river terraces separated by gentle slopes or steep cliffs. The climate is severe; the minimum temperature reaches  $-55 - -60^{\circ}\text{C}$  in January while maximum  $+30 - +35^{\circ}\text{C}$  in July, and an annual precipitation is around 200 mm (ISAEV, 2001). In spite of the poor annual precipitation, the thawing of permafrost provides sufficient moisture for tree growth (BONAN and SHUGART, 1989).

Open grasslands and riparian deciduous bushes dominate on the lower terraces along Lena River. On the higher terraces that are about 100 m higher than the lower, Dahurian larch (*Larix cajanderi* Mayr.) dominates in almost pure stands. Pine (*Pinus sylvestris* Linn.) can be found on dry slopes on sandy soil. Birch (*Betula platyphylla* Sukatshev) is also found in mixed stands with larch (ISAEV, 2001). Depending on authors, *Larix cajanderi* is considered as a subspecies of *Larix gmelinii* Rupr. distributed in eastern part of Russia (MILYUTIN and VISHNEVETSKAIA, 1995). Thus, *Larix gmelinii* of Central Yakutia appeared in number of literatures refers the same species as *Larix cajanderi*. After the samplings described below, only larch-dominated stands in terms of basal area were to be analyzed in this study.

Some scenery of the forests, trees and forest fires are depicted in Photo 4.1 – 4.8.

### 4.3 Methods

#### 4.3.1 Stand Measurement and Biomass Estimation

A Landsat ETM+ image, acquired in 1999/10/30 (path/row = 122/016), over the study area was clipped then subdivided into about twenty classes using an unsupervised classification (TAKAO *et al.*, 2001). Tentatively a tree species (larches, pines or broadleaves) was given to each of forest classes in accordance with the knowledge from preliminary expeditions. 58 stands were selected in consideration of the proportion of the area of class, accessibility from roads, homogeneity of the stand class, as well as the time available for the measurements (TAKAO *et al.*, 2001). Selecting plots from vicinity of roads might introduce a bias in vegetation structure under anthropological influences, but the bias is considered minimal because the plots were placed not only along highways but also along small forest roads, which ran

throughout the forests in the suburb of Yakutsk.

The forest cruising was taken place in June and July, 2000. Point sampling (SHIVER and BORDERS, 1996) was applied at almost all stands, except those stands with presumed tree densities higher than ca. 40,000 trees per ha, where a plot of fixed area from 4 to 25 m<sup>2</sup> was set to measure the trees for each stand. The point sampling, originally developed by BITTERLICH (1984), estimates the basal area of a stand from a random point in the stand by counting the number of trees whose stem at breast height look larger than an arbitrary and constant horizontal angle. By measuring counted trees' DBH (diameter at breast height) and other tree parameters such as height, DBH or volume distribution of the stand can be estimated as well (NAGUMO and MINOWA, 1990). It is assumed that the method, originally applied to even-aged conifer plantations, could be applied to the forests of interest, which had almost evenly regenerated after disturbance.

Regarding the accuracy and efficiency of the point sampling, OHTOMO (1971) reported the percentages of error less than 10% in estimation of tree density, mean DBH, mean height, and *etc.* of conifer plantations in comparison with the plot sampling. KINASHI (1978) compared the plot and point samplings in a broadleaf forest and found that the correlations of standing volume estimations between the both methods were as high as from 0.67 to 0.75, which were almost equivalent level as the correlation of the estimations between the plot sampling and the aerial photograph interpretation.

DBHs of all counted trees were measured. Heights of about every tenth of the counted trees were measured by Impulse, a handheld laser range finder (Laser Tech, Inc., 1996). Stand or tree ages were not measured. A mean DBH – height curve for larch was derived by fitting a modified inverse formula (4.5) for the measured data using a non-linear regression model (S-PLUS2000, MathSoft, Inc., 1999).

$$h = \frac{a_1}{a_2/d + 1} + 1.3 \quad (4.5)$$

where  $h$  [m] and  $d$  [cm] are the height and DBH of a tree, respectively,  $a_1$  and

$a_2$  are constants which represent the maximum height – 1.3 and the DBH at which the height – 1.3 reaches a half of the maximum ( $a_1$ ), respectively.

The height of each measured tree of a stand was then estimated from the DBH by the curve with  $a_1$  adjusted for the stand by the linear regression using the measured pairs of DBH and height of the stand.

Out of the 58 measured stands, 26 stands at which larch was dominant in terms of the basal area were selected for further analyses as shown in Table 4.1 (Table 4.1 contains satellite image digital numbers (DN), which will be explained and used in Chapter 6). Dry weights of the stem, branches, and leaves of a tree were estimated by allometry. TSUNO *et al.* (2001) derived allometric relationships of the weights for each of their plots. Here, the combined relationships of their results (TSUNO, personal communication) are used for each of the weights as follows.

$$w_s = 0.0703(d^2 h)^{0.8237}, \quad R^2 = 0.9528, \quad n = 23 \quad (4.6)$$

$$w_b = 0.0174(d^2 h)^{0.7054}, \quad R^2 = 0.8885, \quad n = 23 \quad (4.7)$$

$$w_l = 0.0134(d^2 h)^{0.5858}, \quad R^2 = 0.9654, \quad n = 23 \quad (4.8)$$

$$w = w_s + w_b + w_l, \quad (4.9)$$

where  $w_s$ ,  $w_b$ ,  $w_l$ , and  $w$  [kg] are the dry weight of stem, branches, leaves, and total above-ground of a tree, respectively. Hereinafter,  $W_s$ ,  $W_b$ ,  $W_l$ , and  $W$  denote the corresponding weight per area [t/ha], *e.g.*  $W_s = N w_s/1000$ .

Underground (root) biomass was not estimated in this study. Some studies suggested the root biomass accounted for more than 40% of the total biomass in *Larix gmelinii* stands (KANAZAWA *et al.*, 1994; KAJIMOTO *et al.*, 1999), which were extremely larger than the trees in the other climate zones.

#### 4.3.2 Reference Data

Several literatures were referred for citing the biomass and stand parameters of the larch stands in Central Yakutia as reference. SHERBAKOV (1979) examined fire effects on Yakutian forests by comparing pairs of burned and control (unburned) plots, among which eight pairs (17 plots) of larch-dominated plots are used. KANAZAWA *et al.* (1994) estimated biomass and net primary production (NPP) of a stand in Spaskayapad Experimental Forest near Yakutsk. SCHULZE *et al.* (1995) measured biomass and nitrogen nutrition at six plots from five pristine larch stands. TSUNO *et al.* (2001) measured biomass at seven larch stands and NPP at three among them near Yakutsk. In total, there are 31 plots from the references (Table 4.1).

#### 4.3.3 Fitting Full Density Lines on the Scattergrams

From now on, the line fit to the overcrowded stands on any scattergrams on the log-log scale is referred as a full density line. A full density line is fit to the measured and the reference stands, separately, on each of the three scattergrams, *i.e.*  $N$  vs.  $D$  ( $N-D$ ) (note that  $N$  on x-axis, which is opposite to REINEKE's (1933)),  $N$  vs.  $W$  ( $N-W$ ), and  $N$  vs.  $S_r$  ( $N-S_r$ ), respectively. The reduced major axis (RMA) regression (NIKLAS, 1994; NISHIZONO *et al.*, 2002) is used for the fitting, which is equivalent to the principal component analysis of two parameters with the correlation matrix (*e.g.* OKUNO (ed), 1978).

There is no objective method to select the overcrowded plots solely from the cloud of stand data on scattergrams. However, on each log-log scattergram, majority of the stands seem aligned linearly. So, after removing the apparent outliers, whole the remaining stand data are assumed as the overcrowded and used for fitting a line, as YODA *et al.* (1963) did for tree species.

All of the reference stands except SHERBAKOV's (1979) burned plots are assumed as overcrowded. As for the measured stands, at first a line is fit to all the stands, then a stand with the largest residual is dropped and a next line is fit to the remaining data, and this procedure is repeated until all the outliers seemingly removed.

For each scattergram, two full density lines, the reference and the measured,

are derived. If the two can be merged into one line, the both stand data can be discussed as a whole. Following OKUNO (ed) (1978), the coefficient and offset of the two lines are tested and, if the two lines are not significantly different, the whole data are merged to fit a common line.

#### 4.3.4 AGB (Above-Ground Biomass) Estimation Equations

Each stand's AGB is estimated by summing the individuals' biomass as in equations (4.6 – 9). Good allometry between AGB and other easily measurable stand parameters would be helpful for both the insight of the stand structures and the operational uses. Several pairs of the parameters are fit to the AGB.

### 4.4 Results and Discussion

#### 4.4.1 Full Density Lines

For the  $N\text{-}D$ ,  $N\text{-}W$ , and  $N\text{-}S_r$  scattergrams, 12, 7, and 7 stands were removed as outliers, resulting 14, 19, and 19 stands used as the overcrowded stands to fit the full density lines, respectively. Each of two line fittings on each of three scattergrams were significant at  $p = .01$  level. The reference stand line and the measured stand line were not significantly different for  $N\text{-}D$  and  $N\text{-}W$  at  $p = .2$  for the coefficient and at  $p = .05$  for the offset (OKUNO (ed), 1978), so the reference and measured stands were merged to yield a line on each of the two scattergrams. As the results, the scattergrams and the result lines are shown in Figure 4.2. The full density lines yielded from the analysis are presented as below;

$$(N\text{-}D) \quad \log D = -0.515 \log N + 2.798, \quad R = .986, n = 35 \quad (4.10)$$

$$\text{or,} \quad \log N = -1.943 \log D + 5.437, \quad (\text{inverse of 4.10}) \quad (4.11)$$

$$(N\text{-}W) \quad \log W = -0.390 \log N + 3.252, \quad R = .807, n = 42 \quad (4.12)$$

$$(N\text{-}S_r, \text{ references}) \quad \log S_r = -0.152 \log N - 0.298, \quad R = .576, n = 22 \quad (4.13)$$

$$(N\text{-}S_r, \text{ measured}) \quad \log S_r = -0.113 \log N - 0.318, \quad R = .649, n = 19 \quad (4.14)$$

The stand density and the mean diameter had a strong correlation. The

coefficient of  $-1.943$  of equation (4.11) was significantly smaller than that of REINEKE's (1933) (4.1), which was opposite to SHIRAISHI's (1985) results, in which the coefficients were larger than (4.1) for *C. japonica* and *C. obtusa*. In addition, this value was not significantly different from  $-2$ , or the coefficient of  $-.515$  of (4.10) from  $-0.5$ , at  $p = .05$ , which suggested that the basal area per area,  $G$ , was constant regardless of the stand density. Actually,  $G$  itself did not show significant correlations with  $N$  or  $D$ . Thus, it can be supposed that when a stand comes to overcrowded its basal area comes to saturate at a certain level regardless of the mean tree size or the location. That is, the stands with the basal area around the level should be in the normal condition along the full density line, while the stands with less basal area should be out of the normal condition. The mean basal area of the overcrowded samples was  $25.0 \text{ m}^2/\text{ha}$ .

As for the AGB,  $W$ , the coefficient of  $-0.390$  of equation (4.12) was significantly larger than  $-0.5$ , the expected value from the  $3/2$  power law. This is, again, opposite to *e.g.* *C. japonica* or *L. leptolepis* (ANDO, 1968). This meant that AGB increased as the stand density decreased but more gradually than the forests of other places. This result supports the suggestions of SCHULZE *et al.* (1995) and OSAWA *et al.* (2000).

The relative spacing index,  $S_r$ , also behaved uniquely. Though the gradients of the fit lines were shallow, the coefficients of both (4.13) and (4.14) were significantly smaller than null at  $p = .01$ . They meant a stand grew, the stand density reduced and then the relative spacing index increased in either case of the references or the measured. The result agreed with neither the constancy under the isometric assumption (KONDO *et al.*, 2001) nor the reduction observed in *C. japonica* stands (NISHIZONO *et al.*, 2002). The inverse of squared  $S_r$  is proportional to the expected number of trees that looks taller than a fixed elevation angle when looking above from the forest floor (TAKAO *et al.*, 2001). Thus, the increment of  $S_r$  indicates that the forest canopy becomes relatively sparser as the trees grow.  $S_r$  of the references were smaller than those of the measured for a given stand density, which might indicated the references consisted of the stands with higher site index, if any, than the measured ones.

It is out of scope for the present study to find the reason why the forests on the

permafrost behave quite differently from those in other places. However, many authors have stated hypotheses. SCHULZE *et al.* (1995) suggested there should be a competition among individuals on, instead of the light, the nutrition that existed in a thin active layer on the permafrost. KAJIMOTO *et al.* (1999) suggested a heavier investment to the underground biomass rather than to the aboveground biomass, which resulted a very low T/R ratio. ABAIMOV and SOFRONOV (1996) stated that the tree mortality resulted from site conditions getting generally worse (as the trees grew), but not from self-thinning. Similar trend of growth were found for the pines (*P. sylvestris*). WIRTH *et al.* (2002) hypothesized that the apparent full density curve was not the real one but it was drawn by the forces of succession and frequent fires. If it is true, the supposedly overcrowded stands were not actually at the full density. Actually, there were not so many standing dead trees, an evidence of self-thinning (OSAWA, 1995), found in the supposedly overcrowded stands. However, SHERBAKOV (1979) pointed out that the larch trees could stop growing when the stand became too dense, then start growing again after thinning by fire. More investigations are required to mechanically explain the phenomenon.

#### 4.4.2 AGB (Above-Ground Biomass) Estimation

Allometric estimations of AGB were derived using an aggregated stand data of both the references and the measured, or both the overcrowded and the sparse (Figure 4.3). The equations are presented as below;

$$\log W = 1.382 \log G - 0.015, \quad R^2 = .74, n = 57 \quad (4.15)$$

$$\log W = 1.270 \log G + 0.462 \log H - 0.355, \quad R^2 = .84, n = 57 \quad (4.16)$$

$$\log W = 1.500 \log G - 1.670 \log N + 0.401, \quad R^2 = .82, n = 57 \quad (4.17)$$

The basal area alone could explain a major portion of the variance of AGB in the log-log space (4.15), but Figure 4.3(a) revealed that the measured stands were rather overestimated while the references were underestimated. As discussed in the previous section, this might be because the measured stands had lower stand height

than the reference stands. This problem was compensated by a term of the mean tree height (4.16), and a same level of compensation could be achieved by another term of the stand density (4.17) as well. The AGBs were well estimated at the full range of the value (both estimations got even slightly better correlations in the real-space). Equation (4.16) suggests a straightforward way of estimating AGB with a relascope and a height measurement device.

Comparison of equations (4.16) and (4.17) suggests a relationship between  $H$  and  $N$ .  $\log N$  and  $\log H$  has an  $R$  of .81, and better expressed with  $\log G$  as equation (4.18) and Figure 4.4;

$$\log N = 1.233 \log G - 2.216 \log N + 4.079, \quad R^2 = .85, n = 57 \quad (4.18)$$

This can be explained that the stand density is primarily determined by the mean tree height and then adjusted by the distance to the full density line by the basal area. Again, the references and the measured are separated on Figure 4.4. The stand age and the age after the last disturbance might be some among the important parameters that are not taken into account in the present study.

#### 4.5 Summary of Chapter

For developing a forest inventory method by remote sensing that are reliable and robust for the specific local vegetation and climate of Central Yakutia, the structure of the local larch stands were measured and analyzed in this Chapter. Although there have been several precedent studies, many of them have covered just the well-growing stands without recent disturbances. To observe all the existing forest stands, sample stands were collected by stratification of a satellite image, then measured mainly by point sampling.

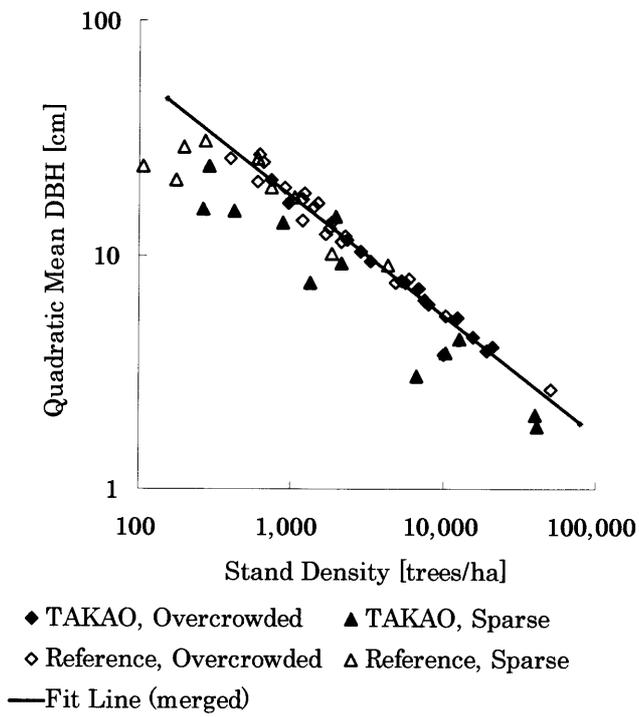
The analyses revealed that, as the trees grew, the basal area saturated at about 25 m<sup>2</sup>/ha regardless of mean DBH, the above-ground biomass increased gradually, and the relative spacing index increased. These phenomena are very different from the forests of the other places on the earth.

In addition, the straightforward methods of the above-ground biomass estimation were proposed. By the basal area and either the mean tree height or the stand density, the above-ground biomass was effectively estimated. From these relationships, it was found that the stand density was primarily determined by the mean tree height and then adjusted by the distance to the full density line by the basal area.

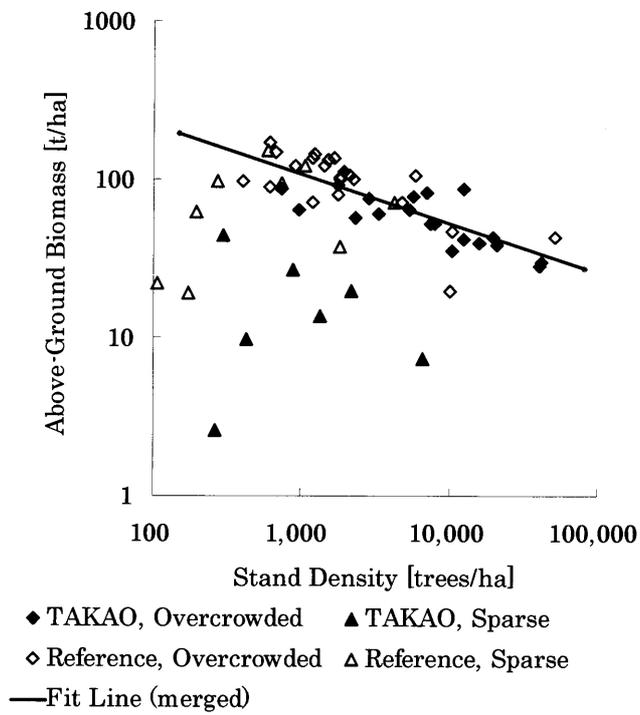
The analyses were successful to describe unique allometric relationships of the larch stand growth in Central Yakutia, which had not been explained in detail by the precedent studies. The results were to be utilized for the satellite image analysis in the next Chapter.



Figure 4.1 Study area

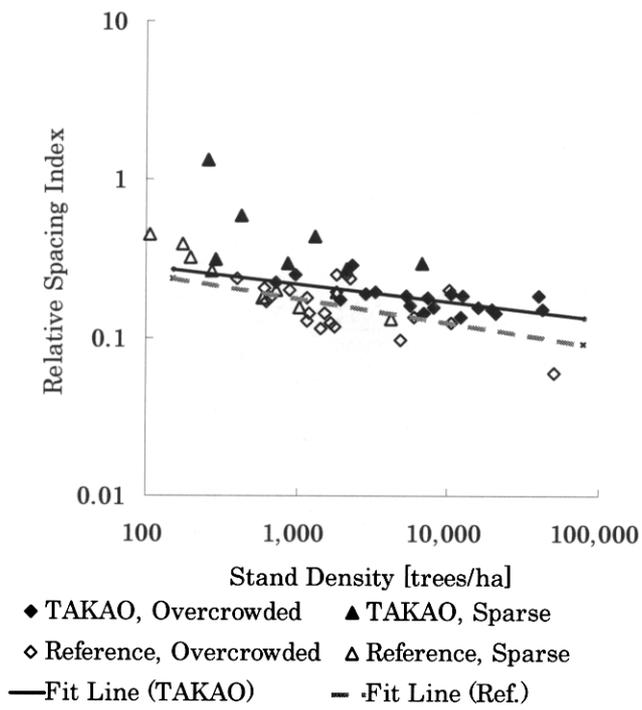


(a) Stand density vs. DBH



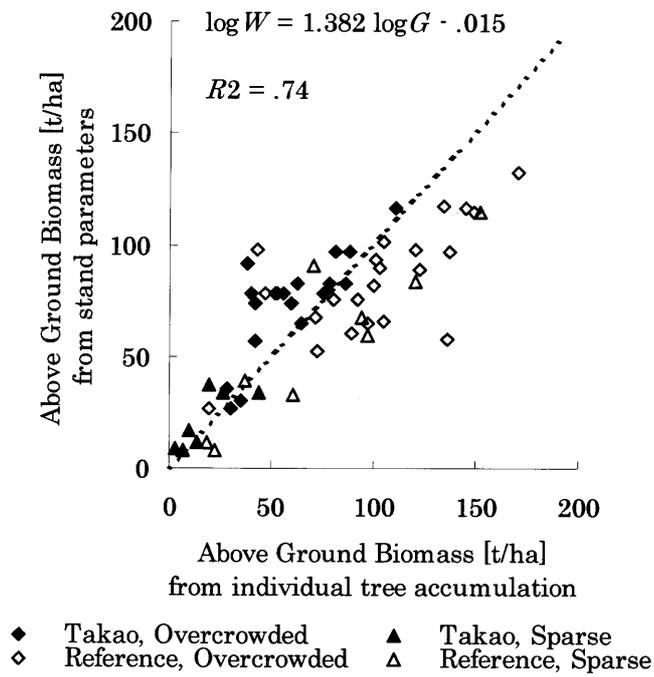
(b) Stand density vs. Above-Ground Biomass

Figure 4.2 Scattergrams and Full Density Lines for Stand Parameters

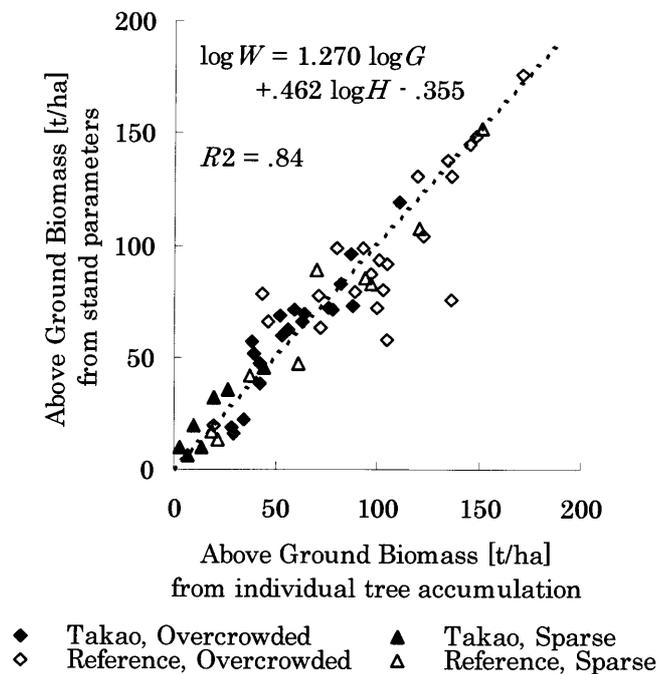


(c) Stand density vs. Relative Spacing Index

Figure 4.2 (continued)



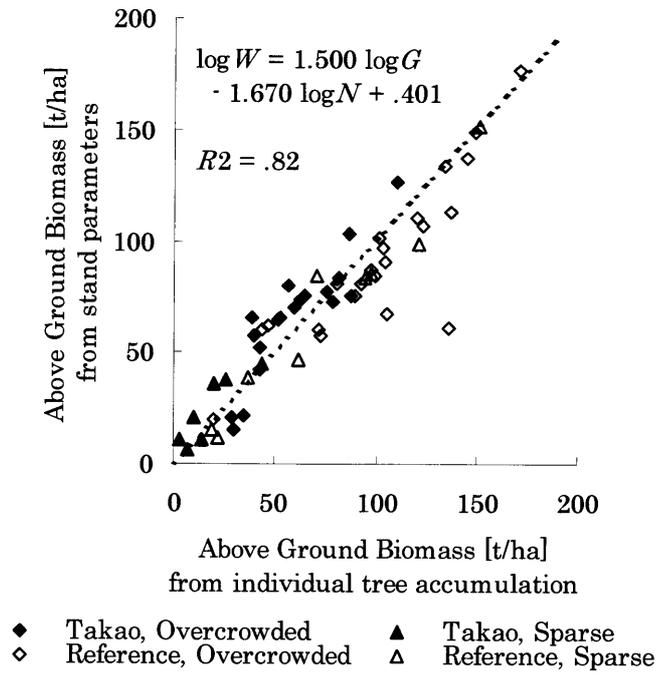
(a) By Basal Area



(b) By Basal Area + Mean Height

Figure 4.3 Above-Ground Biomass Estimation by Stand Parameters

$n = 57$  for all plots



(c) By Basal Area + Stand Density

Figure 4.3 (continued)

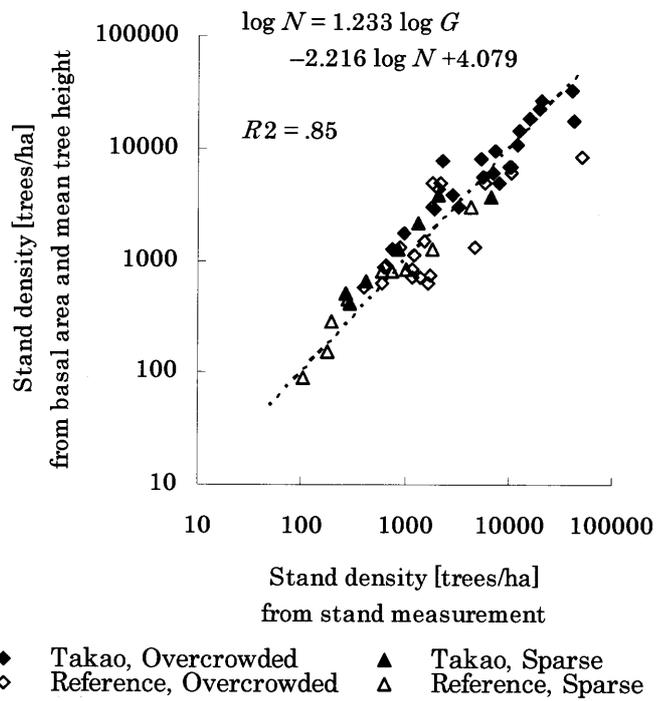


Figure 4.4 Stand density estimation by mean height and basal area

Table 4.1 Summary of Stands

Stand ID	Source	Original ID	Stand Age [year]	Mean DBH [cm]	Mean Height [m]	Stand Density [trees/ha]	Basal Area [m <sup>2</sup> /ha]	Relative Spacing Index [-]	Above-Ground Biomass [t/ha]	Leaf Area Index [-]	Satellite Imagery *2		
											Winter Band 2 [DN]	Winter Band 5 [DN]	Summer NDVI [-]
M1		2		10.5	7.2	2311	24.0	0.29	56.2	1.2	56.0	15.2	0.53
M2		4		1.6	3.2	42000	11.1	0.15	30.0	1.6	69.0	17.3	0.50
M3		9		3.4	5.1	10365	12.0	0.19	34.9	1.2			
M4		10		3.9	4.7	12656	19.0	0.18	42.4	1.4	66.6	18.2	0.50
M5		18		14.7	11.9	424	8.0	0.60	9.7	0.2	84.4	24.1	0.29
M6		22		7.1	8.5	5623	25.0	0.16	78.1	2.0	59.6	19.6	0.50
M7		23		3.5	4.3	20810	27.0	0.14	38.4	1.5	56.6	20.0	0.49
M8		28		23.8	19.2	292	13.0	0.31	44.1	0.6	57.2	17.1	0.51
M9		30		5.9	6.5	7463	24.0	0.18	53.0	1.5	56.3	21.8	0.53
M10		31		12.8	11.6	871	13.0	0.29	26.4	0.5	55.3	19.0	0.52
M11		33		8.2	7.3	2145	14.0	0.27	19.5	0.5			
M12		37		15.7	13.0	973	21.0	0.25	64.6	1.1	67.3	16.2	0.44
M13		38		15.4	10.1	261	5.0	1.34	2.6	0.1	88.8	22.4	0.35
M14		39		1.9	2.7	40000	13.5	0.19	28.6	1.6	55.1	24.9	0.49
M15		40		4.8	6.7	12353	28.0	0.13	87.9	2.6	52.7	21.8	0.55
M16		41		2.7	4.1	6683	4.8	0.29	7.3	0.3	75.1	19.1	0.43
M17		43		6.5	7.2	5288	25.0	0.18	63.1	1.5	49.4	19.6	0.57
M18		45		7.9	10.7	3321	23.0	0.20	59.8	1.1	57.0	17.7	0.54
M19		49		5.5	8.8	7997	24.0	0.15	52.2	1.3	54.4	15.3	0.53
M20		51		13.6	13.1	1943	32.0	0.17	110.5	1.9	58.3	15.0	0.54
M21		52		5.9	5.9	1322	6.0	0.44	13.8	0.3			
M22		53		6.5	8.7	6979	28.0	0.14	81.8	2.0	55.1	15.1	0.51
M23		54		9.6	9.8	2854	24.0	0.19	75.8	1.6	60.9	14.2	0.51
M24		55		20.4	16.5	736	25.0	0.22	86.7	1.3	54.7	16.0	0.53
M25		56		4.2	4.8	15683	24.0	0.15	40.0	1.5	54.6	21.1	0.56
M26		57		3.4	4.3	19505	23.0	0.15	42.6	1.5	52.3	19.0	0.56
R1		II	23	3.3	4.9	10200	11.1	0.20	19.8	1.3			
R2		V	121	7.4	9.7	5903	29.1	0.13	104.5	2.6			
R3		VI	230	9.3	9.0	2235	24.9	0.24	99.9	1.4			
R4		VII	230	12.8	11.9	1833	27.4	0.20	101.4	1.5			
R5		VIII		10.3	9.3	1816	26.6	0.25	103.1	1.3			
R6		X	170	8.7	8.6	2116	21.3	0.25	105.1	1.5			
R7		Young	49	2.3	7.5	50800	28.3	0.06	43.6	5.7			
R8		Pole	130	6.7	15.0	4800	21.7	0.10	71.7	1.7			
R9		Vaccinium1	125	11.2	20.5	1760	23.5	0.12	92.6	1.5			
R10		Vaccinium2	125	11.2	20.5	1760	23.5	0.12	80.6	1.4			
R11		Alnaster	125	13.3	23.0	1425	28.2	0.12	120.2	1.6			
R12		Ledum	131	12.8	16.5	1175	17.9	0.18	72.3	1.1			
R13		Lichen	380	16.3	20.0	607	19.9	0.20	89.1	1.0			
R14	*1	Spasskaya	169	18.0	16.9	900	26.3	0.20	123.0				
R15		11-K	220	28.0	22.0	664	31.7	0.18	148.8				
R16		11-I	220	31.4	23.0	272	19.7	0.26	97.0				
R17		12-K	176	28.0	23.8	620	35.2	0.17	171.0				
R18		12-1	176	26.0	23.2	600	31.7	0.18	151.7				
R19		21-K	104	17.7	20.1	1215	32.1	0.14	145.5				
R20		21-1	104	17.6	20.1	1040	25.3	0.15	121.0				
R21		22-K	280	17.5	17.8	1515	32.3	0.14	134.2				
R22		22-1	280	18.7	18.7	731	21.7	0.20	94.2				
R23		32-K	177	26.0	21.5	400	20.9	0.23	97.0				
R24		32-1	177	29.1	22.5	197	12.8	0.32	61.2				
R25		33-K	72	5.4	8.0	10400	24.1	0.12	46.6				
R26		33-1	72	9.0	11.6	4250	26.7	0.13	70.7				
R27		33-2	72	9.8	12.2	1830	14.5	0.19	37.2				
R28		15-K	180	23.7	23.0	1188	28.1	0.13	137.1				
R29		15-1	180	24.5	21.5	105	4.7	0.45	22.1				
R30		16-K	140	18.4	19.6	1670	19.4	0.12	136.6				
R31		16-1	140	18.0	19.5	174	6.0	0.39	18.8				

\*1 KANAZAWA *et al.*, 1994, \*2 Presented only values used in Chapter 5

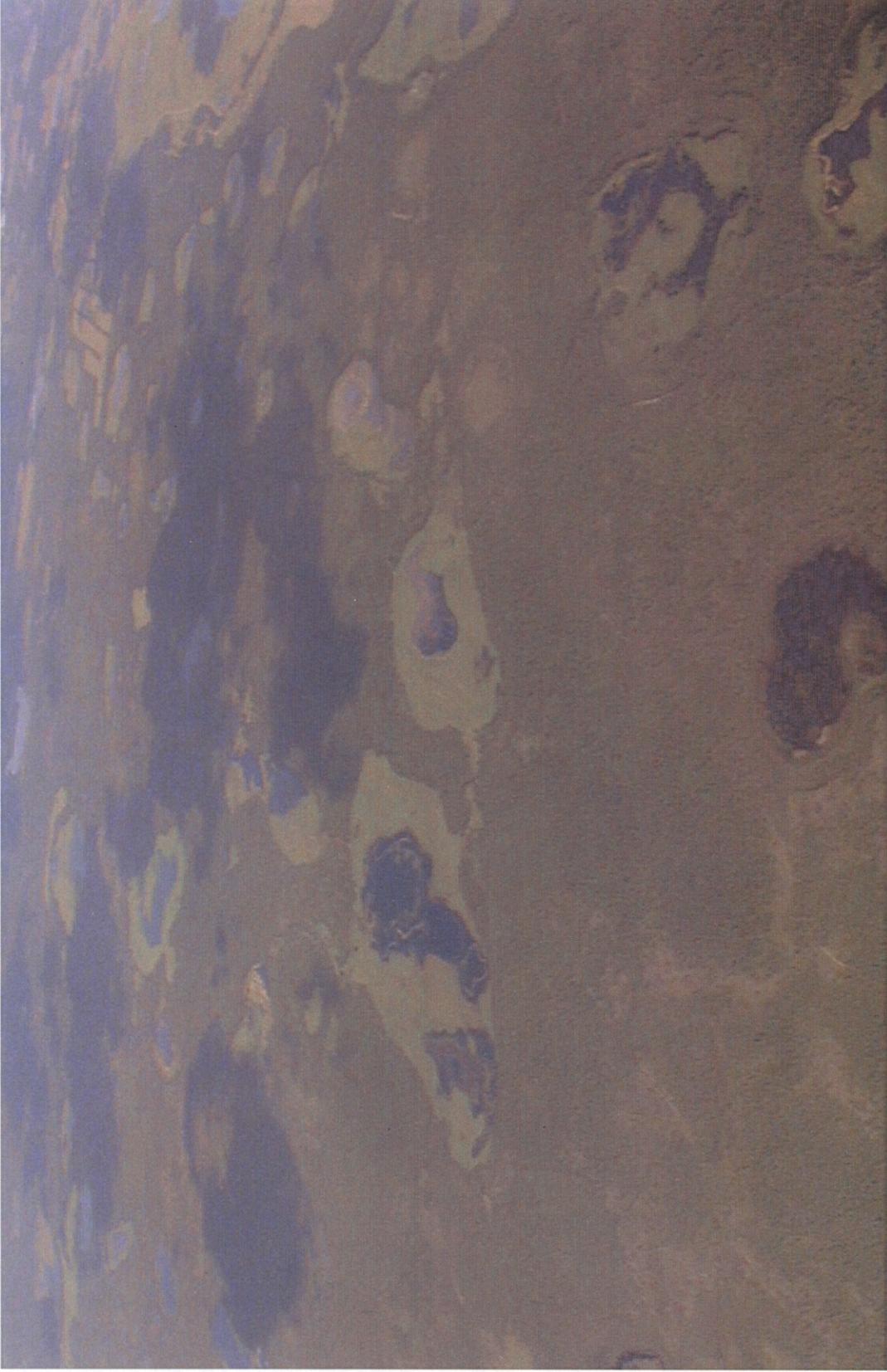


Photo 4.1 Aerial view of the forest in Central Yakutia  
'Alases' are scattered in the larch forest



Photo 4.2 Young and dense larch stand



Photo 4.3 Mature larch stand



Photo 4.4 Sparse larch stand after fire