

Basic Data for CO_2 Flux Monitoring of a Young Larch Plantation

— Current Status of a Mature, Mixed Conifer-Broadleaf Forest Stand —

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Abstract

A yearly increase in atmospheric CO_2 is leading to global warming. To moderate global greenhouse conditions, forest ecosystems are expected to act as CO_2 sinks. The forest stand structure of a mixed conifer-broadleaf forest was analyzed to gather the basic information needed to evaluate the CO_2 sink capacity of the stand. The total area of the Teshio Experimental Forest of Hokkaido University, located in northern Hokkaido near the border between Japan and the Russian Far East (45°N, 142°E), was 13.71ha. A forest area of 0.25 ha (50m x 50m) was selected for this study. In the site, there were a number of individual species, 2 species of conifers and 13 species of deciduous hardwoods. The frequency distribution of the diameter of breast height (DBH) of the trees exhibited an L-shape. Oak and fir were distributed uniformly while willow and magnolia showed a clump distribution. The total number of trees in the selected area was 155 and the total volume was $52.23m^3$. There were 19 evergreen conifers and 136 deciduous broadleaf trees with total volumes of $11.69m^3$ $40.54m^3$, respectively. Dominant species in the order of volume were oak ($16.4m^3$), fir, mountain birch, kalopanax, white birch, willow and maple ($2.5m^3$). There was a positive correlation between DBH and crown projection area (CPA). The increment of regression line between DBH and CPA was steeper in the early- and late-successional species than that in the increment of gap-phase species and conifers. However, the largest DBH was 41cm for early successional species and 60-67cm for late successional species and conifers. Based on the specific gravity of each species, at present, the amount of CO_2 stored in stems was estimated to be 1702.9ton (124.2ton $CO_2 \cdot ha^{-1}$; 84.5ton $\cdot ha^{-1}$ for aboveground biomass). The need for further studies to estimate biomass of *Sasa* sp. and net ecosystem production are discussed.

Key words: CO_2 flux monitoring, mixed conifer-broadleaf forest, northern Japan, biomass

Introduction

The atmospheric concentration of CO_2 is increasing at a rate of 1.5ppm per year (IPCC 1995). During the past 30 years, it has increased from 300ppm to 355ppm. After the international meeting for global CO_2 stabilization in 1997 (the COP3 meeting, sometimes referred to as Kyoto Protocol or Kyoto Forest), we expect that forest would be CO_2 sink. However, we don't have enough data to evaluate the real capacity of a forest to act as a CO_2 sink.

According to the Kyoto Protocol (IGBP 1998), seedlings planted in afforestation projects will be regarded as new CO_2 sinks. In Hokkaido, a prefecture in northern Japan, larch and fir plantations were intensively started around 1960 (Hokkaido Region Government 1987, Koike *et al.* 2000). These larch plantations have replaced from many private hardwood forests because of their high biomass productivity in larch species.

On the eastern Eurasian continent where permafrost is the defining geographic feature, the dominant tree species are the genus *Larix* (Gower and Richards 1990, Schmidt and McDonald 1995, Koike *et al.* 1998, 2000). It is urgent that we evaluate the

(Received; Oct. 23, 2000: Accepted; Jan. 17, 2001) * Corresponding author: tkoike@exfor.agr.hokudai.ac.jp

CO_2 sink capacity of these larch forests to judge their ability to moderate global warming through CO_2 fixation and storage in the forest ecosystems. However, it is very difficult for us to get reliable data on the CO_2 sink capacity of larch ecosystems on the eastern Eurasian continent because of its huge area and the numerous political and transportation difficulties involved. Therefore, we would like to use data from a larch stand in northern Japan to create a model for CO_2 fixation and storage capacity that can be applied to the eastern Eurasian continent.

The final goal of this project is to estimate the CO_2 sink capacity of a young larch plantation at northern Japan. For approaching this goal, we are preparing to establish a research site for CO_2 flux monitoring in the Laoschen Experimental Forest Plantation (LEFP) of the Northeast Forestry University (NEFU), China located on the southern edge of a discontinuous permafrost region (Shi *et al.* 2001).

We will establish a monitoring site for estimation of net ecosystem production (NEP) so as to ascertain the carbon balance in the watershed. Prior to establishing this new study site, we have evaluated the present status of CO_2 fixation and the storage capacity of a mixed conifer-broadleaf forest to use as baseline data.

Materials and Methods

1) Location and topography: The study site is located in the Compartment No.151 of Katoh 51 Forest Compartment of Teshio Experimental Forest of Hokkaido University Forests in northern Hokkaido near the border of Japan and the Russian Far East (45°N, 142°E, 20-580m a.s.l.; Fig. 1). The study site is situated on a gentle slope on a ridge located in the "Yatsumeno-Sawa" watershed. There are a few small streams in the study site. So, we can monitor the carbon dynamics of a watershed (Fig. 2). Bedrock is the sedimentary rock of the Cretaceous period (Takaoka and Sasa 1996a, b). The total study area was 13.71ha, and we selected a 0.25ha (50m × 50m) area for detailed study in the center of the Compartment No. 151 of Teshio Experimental Forests.

2) Meteorological survey: All meteorological data were collected by an auto-sampling meteorological

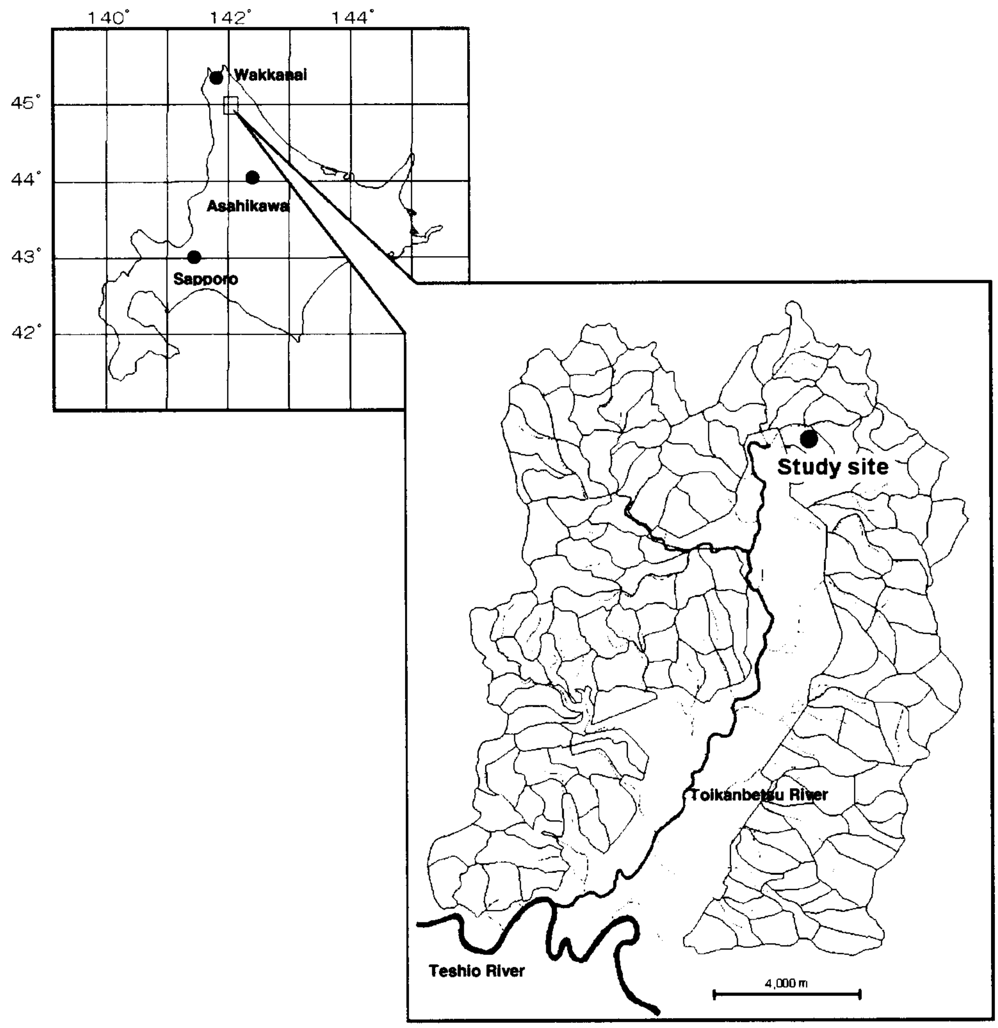

Fig. 1. Location of the study site in the Teshio Experimental Forests.

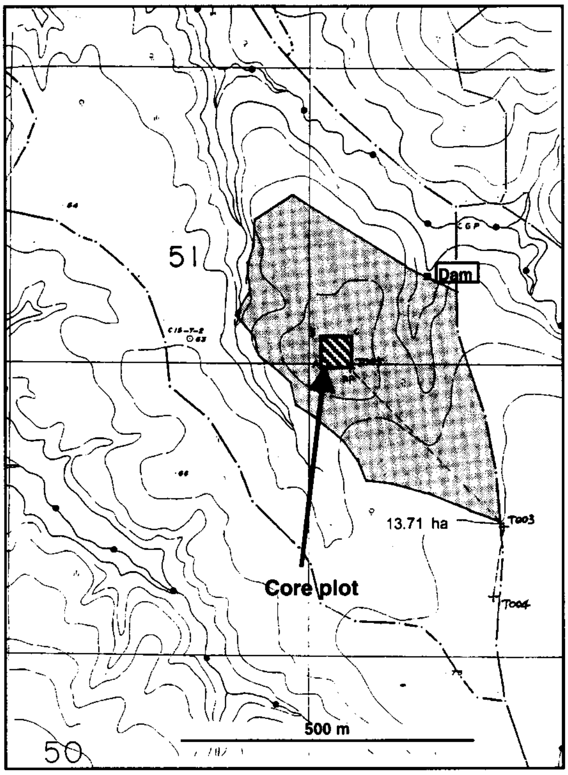

Fig. 2. Topography and road map of the study site.

equipment. Annual precipitation (Precipitation meter, KONA system, Sapporo), mean temperature (HMP45D, Vaaisala, Finland), wind speed and direction (Model 05103, Young Co. with KADEC-KAZE, KONA system, Sapporo) were monitored on the meteorological balcony near the main building of the Teshio Experimental Forest in Toikanbetsu Town.

3) Stand characteristics: The study site was belonging to the preserved stands after the fire occurred in 1929 (Takaoka and Sasa 1996 b). The 0.25ha study site was established in 1999 and a biomass estimate was carried out during April 26 when deep snow covered the ground vegetation of Sasa bamboo (Photo. 1 and 2). The position of individual trees (tree distribution map), species identification, number of trees (alive and dead) and size distribution were surveyed. We estimated the biomass of the stand according to the harvesting table (Nakajima 1958; Table 1),.

The crown projection area (CPA) was estimated using the following equation;

$$CPA = ((R_1+R_2+R_3+R_4)/4)^2 \times \pi$$

where $R_{1\sim4}$ is the radius of the tree crown in each direction (north, east, south and west), and π is pi (the ratio of the circumference of a circle to its diameter).

Based on the specific gravity of trees (Kijima *et al.* 1962, Nakai and Yamai 1982, Wood Tec. and Wood Utilization Div. 1982; Table 2), we also estimated the CO_2 storage of a stand using the following procedure (Koike 1993);

1) Chemical reaction of photosynthetic rate in green plants is as follows;

$$CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

molecular weight of CO_2 is 44 and $C_6H_{12}O_6$ is assumed to be 180 because it stands for glucose. Therefore, $C_6H_{12}O_6$ is assumed to be produced by 6 CO_2 molecules (molecular weight; MW = 44 × 6 = 264). In general, the final products of photosynthesis are a mixture of glucose and starch $(C_6H_{10}O_5)_n$ = 162, but we employed them as glucose (MW=180).

2) CO_2 content (kg) of wood of one cubic meter ($1m^3$) is strongly affected by the specific gravity. We can estimate CO_2 (kg) in $1m^3$ "wood" as follows;

$$CO_2 = 264/180 \times \text{"wood"}$$

where the unit of "wood" is ($m^3 \times kg \cdot m^{-3}$).

3) However, specific gravity of the wood is usually expressed as oven dry mass, which means ca. 85% of the air-dry mass (Kijima *et al.* 1962). Value of "wood" was expressed as the dry mass.

Results

1. Temperature

The first year results are shown in Figure 2. Mean annual temperature was 5.9°C and maximum value was 31.6°C on August 8, 1999, and minimum value was -31.0 °C on January 27, 2000. As compared with

Photo. 1. Overview of the study site in late-April.

Photo. 2. Deep and tall Sasa bamboo in the study site.

Photo. 3. A dam for measuring water flow.

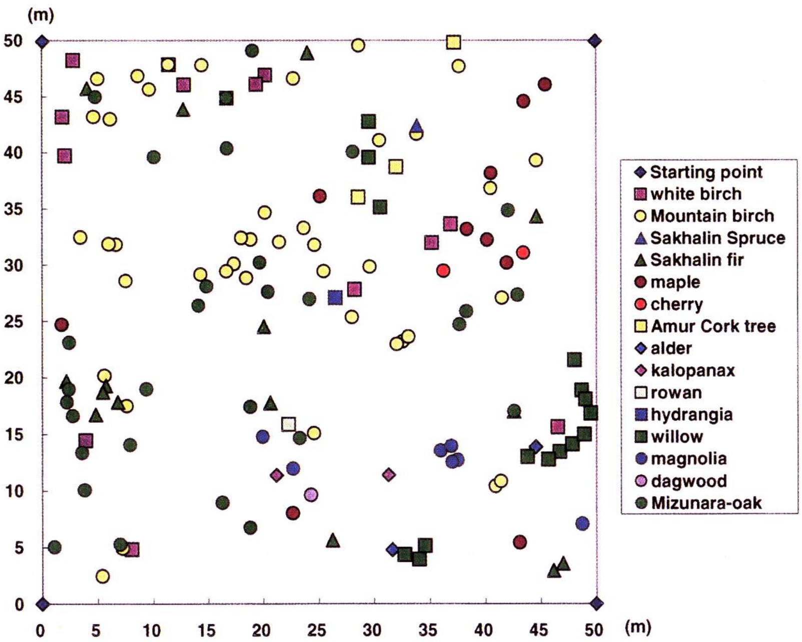

Fig. 7. Distribution map of standing trees in the selected study site.

Table 1. Yield table of Nakajima for Compartment of No. 149·150 and the rest stands

DBH	Conifer Type1		Conifer Type 2		Broadleaf Type 1		Broadleaf Type 2	
(cm)	Height(m)	Volume(m3)	Height(m)	Volume(m3)	Height(m)	Volume(m3)	Height(m)	Volume(m3)
10	9	0.04	9	0.04	10	0.04	11	0.04
12	10	0.07	10	0.07	11	0.06	12	0.07
14	11	0.09	11	0.09	12	0.09	13	0.10
16	12	0.13	12	0.13	13	0.12	14	0.13
18	13	0.18	13	0.18	14	0.17	15	0.18
20	14	0.23	14	0.23	15	0.22	16	0.24
22	15	0.30	15	0.30	16	0.28	17	0.30
24	16	0.37	16	0.37	16	0.34	18	0.38
26	17	0.46	17	0.46	17	0.42	19	0.46
28	18	0.56	17	0.53	18	0.51	20	0.57
30	19	0.67	18	0.64	18	0.59	21	0.68
32	20	0.79	19	0.76	19	0.70	21	0.77
34	21	0.93	20	0.89	19	0.79	22	0.91
36	21	1.04	20	0.99	20	0.93	22	1.01
38	22	1.20	21	1.15	20	1.03	22	1.13
40	23	1.38	22	1.33	21	1.12	23	1.30
42	23	1.52	23	1.52	21	1.32	23	1.43
44	24	1.73	23	1.67	22	1.51	23	1.57
46	24	1.88	24	1.88	22	1.64	23	1.71
48	25	2.12	25	2.12	22	1.79	24	1.94
50	25	2.29	25	2.29	23	2.02	24	2.10
52	26	2.56	26	2.56	23	2.18	24	2.27
54	26	2.75	26	2.75	23	2.34	24	2.44
56	26	2.96	27	3.05	24	2.62	24	2.62
58	26	3.16	28	3.37	24	2.81	24	2.81
60	27	3.49	28	3.59	24	3.00	25	3.11
62	27	3.72	29	3.94	24	3.20	25	2.32
64	27	3.96	29	4.20	25	3.53	25	3.53
66	27	4.20	30	4.58	25	3.76	25	3.76
68	27	4.45	30	4.85	25	3.97	25	3.97
70	28	4.85	31	5.27	25	4.20	25	4.20
72	28	5.12	31	5.57	25	4.44	25	4.44
74	28	5.40	32	6.02	25	4.68	25	4.68
76	28	5.68	32	6.34	26	5.11	25	4.93

*1 Tree height was estimated by the growth function calculated by Hokkaido University Fororest (Rule 24th Chapter 3).
*2 Volume of trees was calculated by the Nakajima's equation (1958).
*3 Classification of tree types is as follows; Conifers type 1; fir, type 2; spruce,
Brodleaf type 1; Oak, kalopanax, ash, Kastura (*Cercidiphyllum japonicum*), Monarch birch, basswood
Broadleaf type2; the rest hardwood species including *Taxus cuspidata*

the temperature in large cities in Hokkaido, namely Sapporo, Asahikawa and Wakkanai (Table 3), Teshio Experimental Forest (Toikanbestu Town) has greater temperature differences because Toikanbetsu is located inland. The range between maximum and minimum daily temperature of Toikanbestu was 10.2°C and the maximum temperature was 26.5 °C

2. Wind

Mean wind speed of Toikanbetsu was 2.0 $m \cdot sec^{-1}$ during April 1999 to March 2000 (Fig. 3). The strongest winds were recorded during winter (late-January and early-February). However, this value was smaller when compared with Wakkainai and Sapporo (Table 3). The frequency distribution of wind direction showed that the dominant wind direction was from the northeast through all seasons (Fig. 4).

3. Precipitation

There were heavy rains in late-July, 1999 in the Toikanbetsu region. The total amount of precipitation was 1010.5mm. A large amount of precipitation was also recorded during May and from late-September to mid-November (Fig. 5). As shown in Table 3, precipitation in northern Hokkaido was relatively larger that in inland of Hokkaido. Snowfall at

Table 2. Specific gravity of various tree species as oven dry mass.
(after Kijima *et al.* 1962, Nakai and Yamai 1982, Wood Tech. & Wood Utilization Div. 1982)

Species	common name	(SS)	mean	(min-max) ($g \cdot cm^{-3}$)
Taxus cuspidata	Japanese yew	L	0.54	
Abies sachalinensis	Sakhalin fir	M	0.40	0.39-0.41
Picea glehnii	Sakhalin-spruce	M-L	0.43	0.41-0.46
Picea jezoensis	Ezo-spruce	L	0.41	0.40-0.43
Larix kaempferi	Japanese larch	E	0.50	0.53-0.59
Larix gmelinii	Kurile larch	E	0.55	
Salix bakko	willow	E	0.45	0.49-0.59
Alnus hirsuta	alder	E	0.50	0.40-0.60
Betula ermanii	mountain birch	E	0.68	
Betula maximowicziana	Monarch birch	E-G	0.67	0.50-0.78
Betula platyphylla var. *japonica*	white birch	E	0.64	
Quercus mongolica var. *grosserrata*	Mizunara-oak	M	0.68	0.45-0.90
Ulmus davidiana var. *japonica*	elm	M	0.63	0.42-0.71
Magnolica obovata[1)]	magnolia	G	0.49	0.40-0.61
Hydrangea paniculata	---	E		
Prunus sargentii	cherry	L	0.62	
Prunus ssiori	Shiuri-cherry	G-L	0.67	
Sorbus alnifolia	---	L	0.68	0.65-0.80
Sorbus commixta	Japanese rowan	E	0.68	0.65-0.85
Pherodendron amurense	Amur cork-tree	G	0.49	0.38-0.57
Acer mono	maple	L	0.60	0.58-0.77
Tilia japonica	basswood	L	0.50	0.37-0.61
Acanthopanax sciadophylloides	---	G	0.48	
Kalopanax pictus[2)]	kalopanax	G	0.52	0.40-0.69
Cornus contravasa	dogwood	G	0.64	
Fraxinus mandshurica var. *japonica*	ash	G	0.55	0.43-0.74

Note; SS means the successional status in a forest
Current Latin name; 1) *Magnolia hyporeuca* and 2) *Kalopanax septemlobus*
Common name is followed by Sato (2000)

Toikanbetsu started in late-November and ceased in late-April. Maximum snow depth reached 118cm similar to Asahikawa City (Table 3).

4. Water balance

The value of water depth shown is from just after the weir for gauging water flow (Photo. 3) was established (Fig. 6). Water flow ceased from December to March because the streams water were frozen. The snow started to melt around mid April. Data is not complete enough to for make a hydrograph, however, the pattern of water runoff was similar to the previous data obtained in Teshio Experimental Forest.

5. Stand structure

One population of fir was found, however, other conifer individuals were scattered throughout the selected 0.25ha study site (Fig. 7). Both types of birch were distributed uniformly in the study site while willow and alder were found along the streams. The oak trees were distributed uniformly while magnolias

Table 3. Climatic condition of Toikanbestu and representative cities in Hokkaido, northern Japan.

Climate factors	City and town name in Hokkaido Sapporo	Asahikawa	Wakkanai	Toikanbetsu
Location	43°N, 141°E	44°N, 142°E	45°N, 142°E	45°N, 142°E
Altitude (m a.s.l.)	17m	112m	3m	40m
Temperature (°C)				
Mean	9.4	7.1	7.1	5.9
Max. temp.	35.2	34.3	28.7	31.6
Min. temp.	-14.7	-24.9	-14.3	-31.0
Dif. in mean	7.7	10.0	5.2	10.2
Dif. in max.	18.5	20.0	18.5	26.5
Wind speed ($m \cdot sec^{-1}$)	2.6	1.8	4.5	2.0
Precipitation (mm)	679.5	689.0	1079.0	1010.5
Max. snow depth (cm)	142	112	75	118

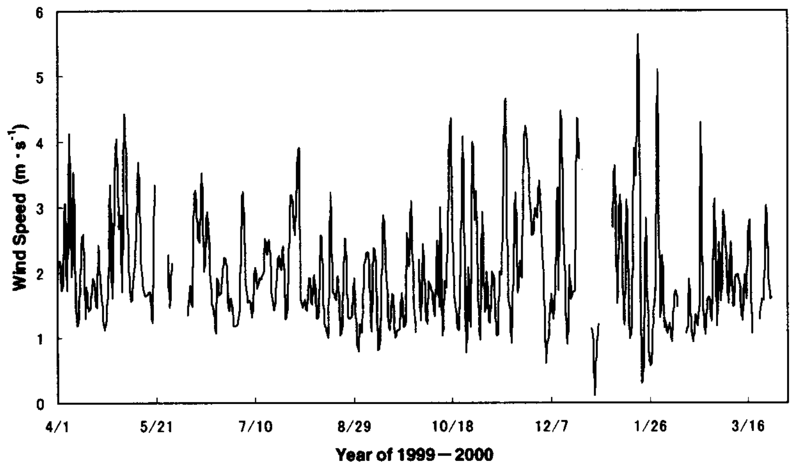

Fig. 3. Wind speed at Toikanbetsu during 1999 and 2000

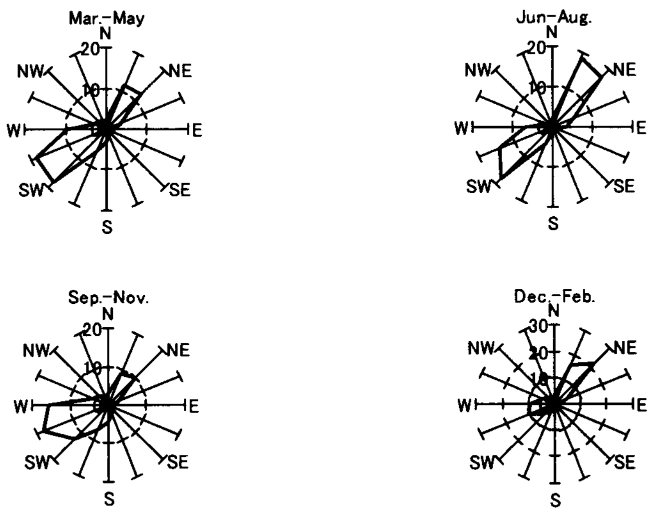

Fig. 4. Frequency distribution of wind direction around Toikanbetsu.

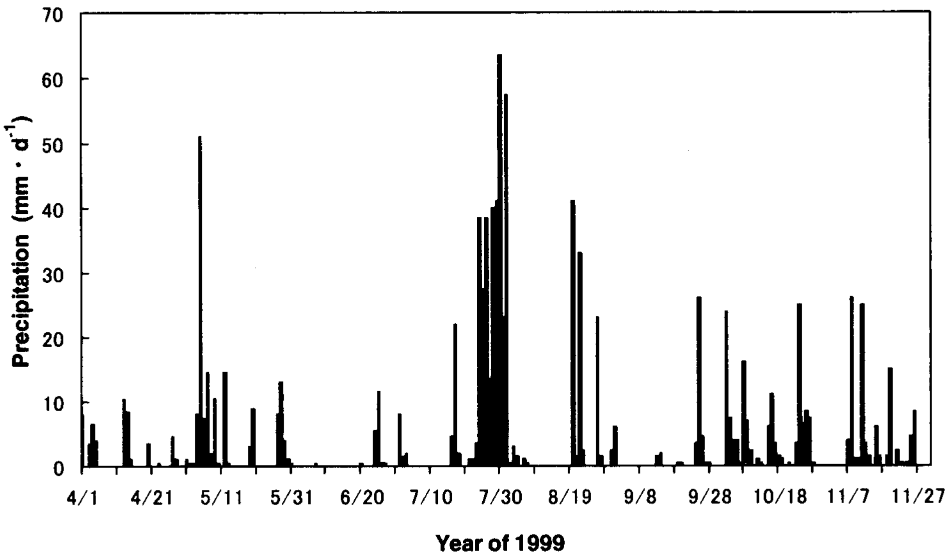

Fig. 5. Seasonal change in the precipitation from 1999

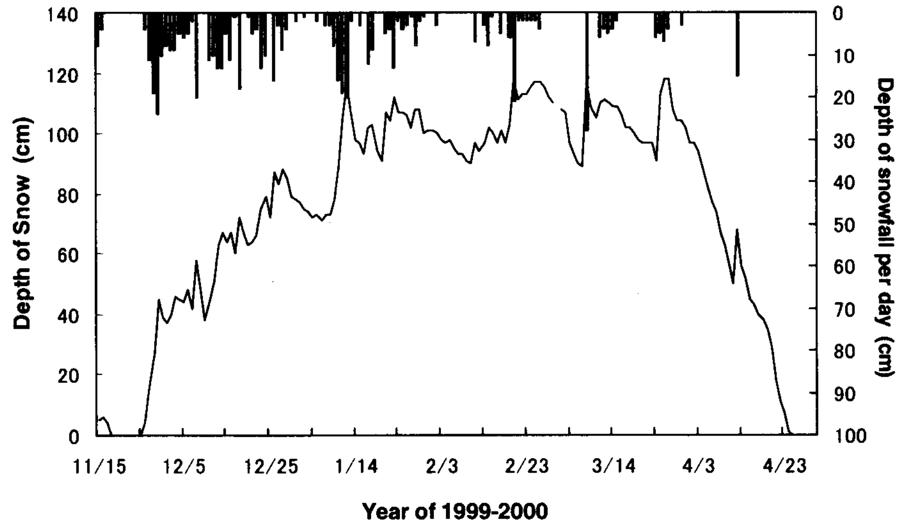

Fig. 6. Seasonal change in the depth of snowfall.

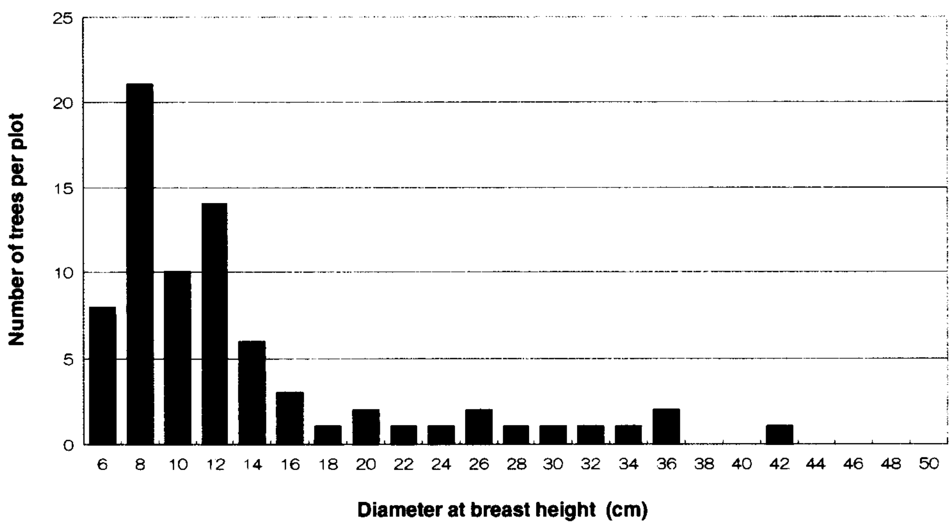

Fig. 8. Frequency distribution of diameter at breast heught.

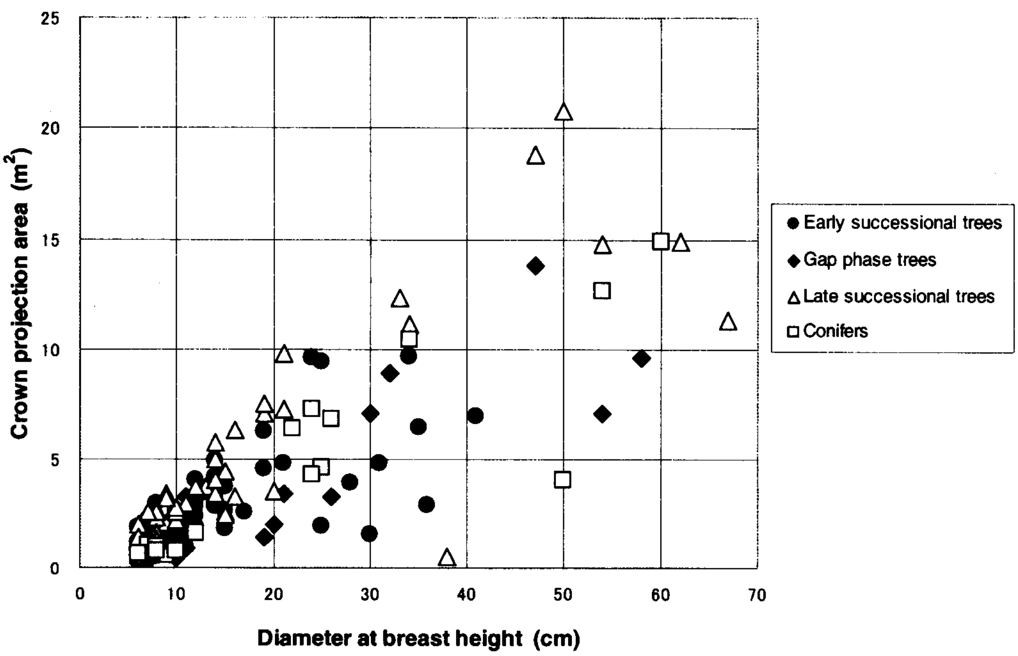

Fig. 9. Relationship between DBH and CPA (crown projection area).

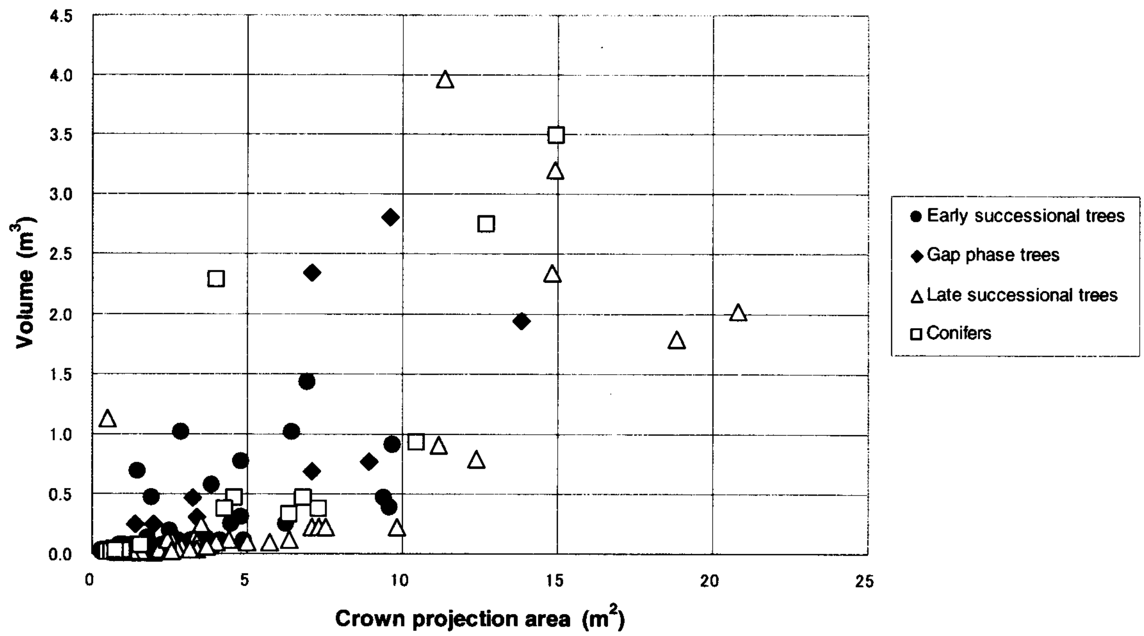

Fig. 10. Relationship between CPA and biomass of volume.

grew in clumps. The frequency distribution of DBH of early successional trees showed a typical L-shaped distribution and the maximum DBH reached 42cm, however, most of them were less than 16cm (Fig. 8). Gap-phase trees and late successional trees were distributed uniformly, and the maximum DBHs were 58cm and 68cm, respectively. Conifers except for fir also were uniformly distributed and the maximum DBH was 60cm.

There was a positive relationship between DBH and CPA (Fig. 9). The regression line between conifers and gap-phase species was steeper than that of early- and late-successional trees. Conifers and gap-phase trees had smaller CPA than early- and late-successional trees. Except for a few individual trees, there was a positive relationship between CPA and stem biomass volume(Fig. 10). Only gap-phase trees showed a positive correlation between CPA and biomass volume, however, these tendencies were not clear.

6. CO_2 storage capacity of Teshio Experimental Forest

The biomass volume of each species was estimated by using Nakajima's harvesting table (Table 1). The number of species and the biomass volume are shown in Table 4. The number of conifers and hardwood trees was 1,449 and 3,543 and total biomass volume was 950,96m^3 and 2192,32m^3, respectively. The proportion of dead stems to the total number of trees was 2.0% for the number of trees and 1.2% for biomass volume.

The total amount of CO_2 stored was estimated to be 1,702.9ton (124.2 ton$CO_2 \cdot ha^{-1}$; 84.5 ton $\cdot ha^{-1}$ for aboveground biomass). For conifers, it was about 532.1 tonCO_2 (38.8 ton$CO_2 \cdot ha^{-1}$), while hardwoods reserved 1,170.9tonCO_2 (85.4ton$CO_2 \cdot ha^{-1}$).

Discussion

1. Environmental condition

The climate of Teshio Experimental Forest is classified as continental, as compared with the city of Wakkainai City or Sapporo City because of its large temperature differences and higher maximum

Table 4. Number of species and biomass volume of dominant (D) and suppressed trees (S) in the whole study site

Species	Tree Number;			Volume (m^3)		
	D	S	Total	D	S	Total
Taxus cuspidata	8	1	9	1.6	0.9	2.5
Abies sachalinensis	886	9	895	647.4	3.7	651.1
Picea glehnii	134	0	134	59.5	0	59.5
Picea jezoensis	411	0	411	237.9	0	237.9
Conifers	1439	10	1439	946.3	4.6	951.0
Salix bakko	166	13	179	22.2	2.0	24.2
Alnus hirsuta	222	34	256	29.1	5.6	34.7
Betula ermanii	500	6	506	246.7	1.5	248.2
Betula maximowicziana	29	0	29	24.2	0	24.2
Betula platyphylla var. *japonica*	1441	22	1463	303.2	2.3	305.5
Quercus mongolica var. *grosserrata*	383	2	385	347.3	5.3	352.6
Ulmus davidiana var. *japonica*	18	0	18	2.34	0	2.4
Magnolica obovata[1)]	71	2	73	12.9	0.4	13.4
Hydrangea paniculata	1	0	1	0.8	0	0.8
Prunus sargentii	7	0	7	6.1	0	6.1
Prunus siorii	10	0	10	2.2	0	2.2
Sorbus sargenti	11	0	11	3.2	0	3.2
Sorbus commixta	155	3	158	34.8	0.4	35.3
Pherodendron amurense	117	4	121	16.3	0.3	16.6
Acer mono	163	1	164	72.5	0.9	73.4
Tilia japonica	12	0	12	3.8	0	3.8
Acansanopax sciadophylloides	52	0	52	11.6	0	11.6
Kalopanax pictus[2)]	87	2	89	79.4	3.0	82.4
Cornus contravasa	7	0	7	0.7	0	0.7
Fraxinus mandshurica var. *Japonica*	2	0	2	0.3	0	0.3
Broadleaf trees	3454	89	3543	1219.6	21.7	1241.6
Total	4893	99	4992	2165.9	26.3	2192.6

Notes: D; dominant trees, S; suppress trees or dead trees
Current Latin name; 1) *Magnolia hyporeuca* and 2) *Kalopanax septemlobus*

temperatures in summer. As shown in Figure 2, the minimum temperature of -31°C, which makes the Toikanbetsu region one of the coldest areas in Japan. Snow is one of the most important sources of water. As compared with the city of Wakkanai located along the Okhotsk Sea and Asahikawa City located inland of Hokkaido, Toikanbestu region had similar pattern of temperature, wind and snowfall and its amount in the city of Asahikawa. Other environmental features were similar to those of Asahikawa City located inland of Hokkaido.

2. Vegetation characteristics

Stand structure of the selected 0.25ha site has a similar co-existence pattern as a northern mixed forest, especially for fir and oak (Yajima 1982, Hiura *et al.* 1995, Hiura and Fujiwara 1999). Fir and oak have quite different capacities of longevity and shade tolerance; with fir having a high shade tolerance and oak With a rather broad range of shade tolerance. These growth pattern of each species seem to provide the two species for coexisting in the same stand (Yajima 1982). The relative growth rate of the two species was similar but mortality of size class in oak was lower than in fir (Hiura and Fujiwara 1999). This difference may account for the duration of co-existence of the two species. This stand had a similar co-existence pattern to other oak-fir forests.

Alder and willow were mainly distributed along the streams because both species prefer mesic conditions (Sakagami 1985). Magnolia usually appeared in clumps because of its tendency to grow from one central trunk with many suckers. According to the distribution pattern, the 0.25ha stand showed bimodal pattern of DBH class, which may be attributed to the effects of harvesting because early successional trees, such as mountain birch and white birch, invaded the gap created by timber harvests. Large trees may act as mother trees in the stand. Of course, a thick, tall layer of Sasa bamboo inhibits the regeneration of trees, however, the Sasa community's photosynthetic production, which seems to be larger during the leafless period of the top layer, may also act as a CO_2 sink (Lei and Koike 1998). It is important to evaluate the photosynthetic production of these undergrowth plants.

Increased atmospheric CO_2 usually reduces stomatal conductance (Koike *et al.* 1996, 2000), which may decrease the size of the vessels of ring porous wood. Recently, it has been found that the wet deposition of nitrogen oxide in forest ecosystems acts as a kind of nitrogen fertilizer. Enhanced nitrogen fertilizer increased ring width and seedling growth of Norway spruce (*Picea abies*) which doubled CO_2 storage capacity (Hattenschwiler *et al.* 1996). Therefore, we should not only monitor CO_2 flux but also the input and output of nitrogen compounds supplied by wet or dry deposition. Moreover, we should check the specific gravity of stem (dry mass per volume) because it increases with atmospheric CO_2 concentration (Telewski *et al.* 1999). The value of specific gravity of stems should be re-evaluated using a current materials of "wood". Based on the revised data, we will re-calculate the CO_2 storage capacity of trees and the 0.25ha stand. The net ecosystem production (NEP) estimate should also be accompanied by a soil respiration measurement.

The biomass of the 0.25ha stand was estimated to be 84.5 ton·ha^{-1}. This value is one fourth of the mean biomass of cool temperate deciduous forests (mean value =200ton·ha^{-1}; Satoo 1973). However, we could not take into account the biomass production of Sasa bamboo. The thick layer of Sasa may be important for forests. Further studies will be needed to evaluate photosynthetic production of Sasa biomass (Oshima 1961, Lei and Koike 1998) and its potential as a large CO_2 sink.

3. Growth characteristics of larch

Japanese larch (*Larix kaempferi*) is not native to Hokkaido, but was transplanted from the central part of Japan nearly 50 years ago because of its higher growth rate (Hokkaido Regional Government 1987, Koike *et al.* 2000). In the beginning of larch plantations, the seedlings suffered from shoot blight and damage by red-back voles (Koike *et al.* 2000). Therefore, the F1 hybrid larch (*Larix gmelinii* from Sakhalin x *Larix kaempferi*) was introduced. Heterosis of this F1 is highly resistant to several biological stresses, moreover, this species has a relatively high stem bulk density (Kijima *et al.* 1962; 0.55 for *L. gmelinii*, 0.50 for *L. kaempferi*). In addition, a hybrid larch acclimates more easily to low photon flux density (Kitaoka *et al.* 2000) and it has a slender crown shape in *L. gmelinii* (Gower and Richards 1990). Plantation of hybrid larch will allow for a higher stand density which increases higher CO_2 storage capacity. Further monitoring study will be needed to evaluate CO_2 fixation and the storage capacity of areas planted with hybrid larch.

Acknowledgements

We thank Environment Agency of Japan, National Institute of Resources and Environment (by Dr. S. Yamamoto) and the Japanese MESSC for partly supporting this survey. Prof. F. Shi is acknowledged to Eco-Frontier Fellowship of NIES.

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Appendix

Table 1. Specific gravity of species in the selected study site

Species	Number of individual	Volume (m^3)
Abies sachalinensis	17	11.21
Picea jezoensis	2	0.48
Conifers	19	11.69
Salix bakko	16	2.65
Alnus hirsuta	2	0.11
Betula ermanii	42	5.21
Betula platyphylla var. *japonica*	16	3.54
Quercus mongolica var. *grosserata*	31	16.36
Magnolica obovata[1)]	7	1.10
Hydrangea paniculata	1	0.02
Prunus sargentii	3	2.05
Sorbus commixta	1	0.02
Pherodendraon amurense	4	1.77
Acer mono	10	2.54
Kalopanax pictus[2)]	2	5.15
Cornus contravasa	1	0.02
Hardwood	136	40.54
Total	155	52.23

Current Latin name; 1) *Magnolia hyporeuca* and 2) *Kalopanax septemlobus*

Table 2. Diameter at breast height, volume, crown size and position of the study site

Tree species	DBH (cm)	D 2cm rounding	Volume	Crown 1 (m)	Crown 2 (m)	Crown 3 (m)	Crown 4 (m)	X axis	Y axis	Z axis	Note
Mountain birch	31	32	0.77	2.6	1.1	3.1	3.2	5.387	2.437	-0.026	
Mountain birch	25	26	0.46	2.5	2.0	0.8	1.0	7.220	4.917	0.240	
Mizunara-oak	10	10	0.04	1.9	1.8	2.2	0.9	6.992	5.241	0.459	
white birch	8	8	0.02	0.5	0.3	1.3	1.1	8.007	4.810	0.055	
Mizunara-oak	14	14	0.09	2.4	2.6	2.6	2.5	3.822	10.053	0.433	
Mizunara-oak	67	68	3.97	4.8	3.8	2.8	3.8	1.071	5.013	0.325	
Mizunara-oak	11	12	0.06	1.9	1.8	2.1	1.9	3.586	13.338	0.258	
white birch	41	42	1.43	1.4	3.2	5.4	2.0	3.891	14.442	0.098	
Sakhalin fir	6	6	0.01	1.0	0.9	1.0	0.8				
Mizunara-oak	9	10	0.04	0.5	0.4	1.1	1.6	2.747	16.612	0.392	
Sakhalin fir	10	10	0.04	1.1	0.9	0.8	1.2	4.819	16.718	-0.134	
Mizunara-oak	10	10	0.04	1.0	1.3	2.4	2.5	2.233	17.819	0.013	
Mizunara-oak	8	8	0.02	1.5	1.8	1.3	1.1	2.406	18.953	-0.019	
Sakhalin fir	7	8	0.02	1.4	0.8	1.4	1.1	2.188	19.683	-0.102	
Mountain birch	35	36	1.01	2.3	5.2	1.8	2.8	5.615	20.155	0.370	
Sakhalin fir	6	6	0.01	0.9	0.6	0.9	0.8	5.725	19.277	-0.164	
Sakhalin fir	7	8	0.02	1.0	0.9	0.7	1.1	5.459	18.717	0.075	
Sakhalin fir	8	8	0.02	1.3	0.8	1.2	1.2	6.797	17.831	0.078	
Mountain birch	34	34	0.91	3.4	3.8	3.0	3.9	7.577	17.485	0.184	
Mizunara-oak	33	34	0.79	4.6	3.3	2.5	5.6	9.380	18.976	0.194	
Mizunara-oak	50	50	2.02	4.0	4.8	6.1	5.7	2.426	23.081	-0.131	
maple	6	6	0.01	1.9	1.7	1.5	1.3	1.782	24.703	0.079	
Mountain birch	6	6	0.01	1.9	1.4	0.2	0.8	7.480	28.572	0.449	
Mountain birch	10	10	0.04	2.8	0.5	0.6	3.0	6.635	31.773	0.294	
Mountain birch	14	14	0.10	2.6	2.6	2.4	2.4	6.020	31.821	0.334	
Mountain birch	6	6	0.01	0.3	1.9	0.8	0.5	3.476	32.435	0.216	
white birch	17	18	0.18	2.1	1.4	1.2	2.5	2.040	39.707	-0.045	

white birch	11	12	0.07	1.7	1.0	0.5	2.2	1.822	43.181	-0.182
Mountain birch	12	12	0.07	2.0	0.4	1.0	2.8	4.655	43.181	-0.371
Mountain birch	11	12	0.07	1.7	0.5	0.2	2.3	6.159	42.964	0.050
Sakhalin fir	26	26	0.46	3.1	2.6	2.5	3.6			
Mizunara-oak	15	16	0.12	2.2	0.9	1.9	2.3	10.102	39.587	-0.068
Sakhalin fir	22	22	0.33	3.2	2.5	2.7	3.0	12.736	43.872	-0.051
white birch	21	22	0.30	3.8	3.6	1.3	1.2	12.779	46.053	-0.004
white birch	6	6	0.01	1.6	0.6	0.3	1.4	11.431	47.843	0.320
Mountain birch	15	16	0.13	1.1	2.0	2.2	0.8	11.431	47.843	0.320
Mountain birch	6	6	0.01	0.7	0.7	0.2	1.1	9.660	45.635	0.230
Mountain birch	8	8	0.02	2.1	3.0	1.9	0.7	8.613	46.819	0.356
Mizunara-oak	47	48	1.79	5.9	5.1	4.3	4.3	4.791	44.931	-0.154
Mountain birch	6	6	0.01	1.5	1.4	0.8	0.5	5.036	46.565	0.019
Sakhalin fir	6	6	0.01	1.2	0.8	0.9	0.7	4.060	45.712	-0.205
white birch	25	26	0.46	3.2	3.2	2.8	4.8	2.797	48.228	-0.013
white birch	11	12	0.07	2.8	1.9	-0.1	-0.2	2.797	48.228	-0.013
Mountain birch	12	12	0.07	3.2	3.6	0.8	0.3	14.449	47.797	0.281
Mizunara-oak	8	8	0.02	0.8	1.2	2.8	2.4	19.050	49.068	0.026
white birch	12	12	0.07	1.8	3.0	1.0	1.3	20.171	46.920	-0.112
white birch	7	8	0.02	0.7	0.1	0.9	1.5	19.354	46.078	-0.242
white birch	19	20	0.24	3.2	3.7	1.5	3.1	19.354	46.078	-0.242
white birch	24	24	0.38	3.2	3.8	4.0	3.0	16.683	44.859	0.196
Mizunara-oak	19	20	0.22	3.7	2.5	2.1	3.7	16.683	44.859	0.196
Mizunara-oak	21	22	0.22	4.3	2.4	3.4	4.1	16.705	40.352	0.014
Sakhalin fir	24	24	0.37	3.2	1.6	2.1	2.5	24.015	48.877	-0.314
Mountain birch	10	10	0.04	2.6	1.0	0.9	1.3	22.744	46.577	-0.189
Mountain birch	10	10	0.04	0.2	0.5	2.1	2.1	28.625	49.524	-0.372
Mizunara-oak	21	22	0.22	3.1	2.2	2.2	4.8	29.939	50.039	-0.329
Amur Cork tree	32	32	0.77	2.6	4.4	2.8	4.0	37.191	49.815	0.000
Mountain birch	12	12	0.07	2.0	1.5	2.1	3.5	37.616	47.676	0.058
maple	6	6	0.01	0.8	1.6	1.0	0.8	45.424	46.041	0.281
maple	6	6	0.01	1.0	-1.0	2.4	3.1	43.500	44.525	0.311
Mountain birch	8	8	0.02	0.9	1.4	1.8	0.5	44.633	39.280	0.243
maple	9	10	0.04	-0.4	0.8	2.8	-1.0	40.494	38.132	0.496
Mountain birch	7	8	0.02	1.1	1.2	1.3	0.9	40.474	36.800	0.313
Mountain birch	7	8	0.02	2.2	0.8	-1.2	0.9	33.830	41.626	0.135
Sakhalin Spruce	25	26	0.46	2.8	2.8	2.0	2.1	33.832	42.382	0.345
willow	28	28	0.57	1.8	3.0	2.8	1.3	29.523	42.753	0.067
Mizunara-oak	15	16	0.12	1.9	2.2	2.5	2.9	16.281	8.927	0.269
Mizunara-oak	13	14	0.09	2.6	2.2	1.7	2.2	18.793	6.731	0.093
maple	34	34	0.91	3.7	3.8	3.0	4.7	22.678	7.996	-0.013
Sakhalin fir	50	50	2.29	2.4	3.9	1.3	1.6	26.226	5.624	-0.036
dagwood	8	8	0.02	2.2	1.3	1.2	1.7	24.323	9.601	0.079
magnolia	6	6	0.01	0.9	1.3	0.7	0.5	22.659	11.923	0.212
kalopanax	58	58	2.81	4.7	2.6	2.2	4.5	21.191	11.352	0.096
magnolia	11	12	0.07	0.6	0.7	0.7	2.7	19.929	14.748	0.254
rowan	7	8	0.02	1.2	0.8	1.1	1.0	22.259	15.866	0.132
Mizunara-oak	8	8	0.02	1.4	0.8	1.4	1.5	23.274	14.641	0.234
Mountain birch	8	8	0.02	3.0	1.7	0.4	1.8	24.560	15.060	0.093
Sakhalin fir	34	34	0.93	3.6	4.0	3.8	3.2	20.637	17.749	0.275
Mizunara-oak	62	62	3.20	7.0	3.7	2.5	4.3	18.822	17.402	-0.034
Sakhalin fir	54	54	2.75	5.0	5.1	3.2	2.8	20.058	24.523	0.110
Mizunara-oak	14	14	0.09	2.3	2.2	2.2	1.6	14.082	26.374	-0.083
Mizunara-oak	10	10	0.04	0.8	2.0	3.1	1.6	14.851	28.082	0.055
Mountain birch	10	10	0.04	1.2	2.5	1.8	1.2	14.282	29.128	0.164
Mountain birch	10	10	0.04	0.9	2.4	1.6	1.5	16.665	29.429	0.263
Mountain birch	8	8	0.02	0.8	1.8	1.3	0.2	17.332	30.059	0.322
Mountain birch	6	6	0.01	1.2	1.4	0.7	1.7	18.478	28.816	0.268
Mizunara-oak	15	16	0.12	1.6	1.2	1.6	2.7	19.663	30.189	0.225
Mizunara-oak	7	8	0.02	1.2	1.2	1.9	3.0	20.407	27.585	0.275
Mountain birch	9	10	0.04	0.4	2.0	1.7	1.0	17.992	32.366	0.229
Mountain birch	8	8	0.02	0.9	1.6	1.0	0.9	18.860	32.221	0.283
Mountain birch	14	14	0.10	2.2	2.7	2.4	1.9	20.170	34.628	0.216
Mountain birch	11	12	0.07	1.3	1.6	1.0	1.3	21.448	32.005	0.345
Mountain birch	6	6	0.01	1.0	2.6	1.9	0.7	23.682	33.252	0.319
Mountain birch	14	14	0.10	1.7	2.2	1.6	2.1	24.621	31.751	0.276
Mountain birch	13	14	0.10	2.2	3.4	1.2	1.8	25.459	29.422	0.466
Mizunara-oak	9	10	0.04	2.2	1.8	2.1	2.2	24.166	26.923	0.344

hydrangia	8	8	0.02	1.9	1.2	0.4	0.5	26.472	27.064	0.346	
Mountain birch	7	8	0.02	1.5	0.9	0.2	0.9	27.982	25.343	0.403	
white birch	15	16	0.13	2.1	2.6	1.8	2.2	28.210	27.817	0.419	
Mountain birch	14	14	0.10	2.6	2.2	1.0	2.3	29.604	29.829	0.342	
maple	9	10	0.04	2.0	0.9	1.5	2.1	25.132	36.070	0.279	
Mountain birch	15	16	0.13	2.6	2.6	1.2	0.9	32.059	22.945	0.128	
Mountain birch	11	12	0.07	1.1	2.4	1.3	1.1	32.554	23.173	0.012	
Mountain birch	19	20	0.24	2.6	2.8	1.9	2.3	33.084	23.604	-0.067	
kalopanax	54	54	2.34	5.6	1.2	0.6	4.6	31.296	11.391	-0.178	Dead tree
magnolia	10	10	0.04	-0.2	0.8	1.7	0.7	35.937	13.530	-0.008	
magnolia	30	30	0.68	4.6	2.6	1.5	3.3	36.873	13.929	-0.314	
magnolia	10	10	0.04	2.8	-0.4	-0.5	1.5	37.461	12.688	-0.316	
magnolia	20	20	0.24	0.6	1.4	2.1	2.3	36.971	12.536	-0.307	
Mountain birch	8	8	0.02	0.9	0.4	1.0	1.3	40.904	10.376	-0.442	
Mountain birch	8	8	0.02	1.2	1.2	1.3	0.9	41.397	10.822	-0.418	
maple	20	20	0.24	2.2	2.5	1.7	2.1	43.085	5.392	-0.242	
willow	8	8	0.02	2.4	0.8	0.5	0.8	34.516	5.123	-0.199	
willow	7	8	0.02	1.8	0.8	0.6	1.6	33.990	3.938	-0.095	
willow	6	6	0.01	1.2	1.8	0.6	0.8	32.706	4.341	-0.036	
alder	9	10	0.04	1.0	2.0	2.1	1.3	31.621	4.773	0.026	
Sakhalin fir	12	12	0.07	1.2	1.4	1.7	1.4	46.136	2.934	-0.086	
Sakhalin fir	8	8	0.02	1.2	0.8	0.8	1.2	46.987	3.563	-0.489	
Sakhalin Spruce	7	8	0.02	1.2	0.7	0.7	0.9	46.987	3.563	-0.489	
magnolia	7	8	0.02	1.4	2.0	2.9	0.8	48.754	7.052	0.118	
willow	7	8	0.02	1.4	1.4	1.6	2.1	43.802	13.007	-0.376	
alder	11	12	0.07	1.8	1.4	1.3	2.6	44.547	13.858	-0.485	
willow	12	12	0.07	1.1	1.8	2.3	3.0	45.673	12.757	-0.456	
willow	7	8	0.02	2.2	0.3	-0.2	2.3	46.696	13.441	-0.446	
willow	10	10	0.04	1.0	1.0	2.2	1.7	47.826	14.121	-0.420	
willow	7	8	0.02	0.4	1.3	1.1	2.2	48.929	14.983	-0.447	
willow	10	10	0.04	1.8	1.2	1.4	2.2	48.929	14.983	-0.447	
white birch	8	8	0.02	1.3	1.2	0.7	0.8	46.508	15.624	-0.531	
willow	7	8	0.02	1.6	1.6	0.5	0.9	49.502	16.839	-0.427	
willow	11	12	0.07	1.6	1.2	2.6	1.6	49.017	18.085	-0.205	
willow	7	8	0.02	1.4	1.0	1.1	0.7	48.679	18.891	-0.192	
willow	7	8	0.02	1.1	1.4	1.8	1.4	48.034	21.551	-0.337	
Mizunara-oak	54	54	2.34	3.4	4.8	4.3	5.0	42.573	17.004	-0.310	
Sakhalin fir	24	24	0.37	3.6	3.2	2.3	3.1	42.573	17.004	-0.310	
Mizunara-oak	14	14	0.09	3.2	1.2	2.2	2.6	37.626	24.695	-0.073	
Mizunara-oak	14	14	0.09	2.2	2.6	2.5	3.6	38.271	25.860	-0.189	
Mountain birch	12	12	0.07	1.9	1.8	1.2	2.8	41.534	27.055	0.096	
Mizunara-oak	12	12	0.06	2.5	1.8	1.6	2.8	42.905	27.302	-0.038	
cherry	47	48	1.94	5.0	3.0	3.8	5.0	43.444	31.036	-0.610	
cherry	11	12	0.07	2.2	1.8	1.6	2.6	43.444	31.036	-0.610	
Sakhalin fir	60	60	3.49	5.2	5.0	4.2	3.1	44.617	34.302	-0.198	
Mizunara-oak	16	16	0.12	1.2	4.2	3.1	3.3	42.075	34.809	-0.092	
maple	38	38	1.13	2.2	1.8	-0.4	-0.4	40.169	32.199	0.038	dead tree
maple	16	16	0.13	1.9	1.8	2.6	1.9	41.956	30.165	-0.116	
cherry	10	10	0.04	2.0	1.2	1.4	2.8	36.207	29.437	0.117	
white birch	14	14	0.10	1.9	2.0	2.2	2.3	35.156	31.951	0.343	
white birch	10	10	0.04	1.6	1.6	1.9	1.9	36.854	33.618	0.236	
Amur Cork tree	19	20	0.24	2.7	1.1	0.9	0.9	31.995	38.714	0.463	
Mountain birch	11	12	0.07	1.9	2.0	1.6	0.4	30.498	41.071	0.228	
willow	30	30	0.68	1.5	1.9	0.9	1.3	29.507	39.550	0.216	
Mizunara-oak	19	20	0.22	2.4	2.5	3.8	3.7	28.066	40.050	0.236	
Amur Cork tree	26	26	0.46	0.8	1.5	4.4	1.7	28.568	36.011	0.370	
Amur Cork tree	21	22	0.30	0.4	0.2	3.9	3.8	28.568	36.011	0.370	
willow	36	36	1.01	2.4	1.7	1.8	1.8	30.551	35.121	0.423	
maple	8	8	0.02	1.8	1.8	1.3	2.0	38.311	33.149	0.240	
Mizunara-oak	9	10	0.04	3.0	1.6	1.6	1.9	7.876	14.036	0.544	
								50.000	0.000	0.000	
								49.956	49.917	-0.236	
								0.000	0.000	0.000	
								0.056	49.905	0.146	
155本			52.23								

Volume was estimated based on DBH of 2cm rounding

Volume table was applied with the data of compartment of 149 and 150