4.3.5 Forest Protection

(1) Forest Fires

1) Current Situation of Forest Fires

The area damaged by fire throughout the country reached 4.34 million ha during the 23 year period from 1973 to 1995 with average annual damage of just over 189,000 ha, accounting for 1.4% of the forest area as shown in Table 37. The average of damaged area per fire is high at 29,000 ha, indicating that the fire becomes large in scale once it occurs. In addition, more than 200,000 ha of forests are damaged in recent years.

Table 37 Forest and Grassland Fires in Mongolia

(Unit: thousand ha)

Year	Forest Fire			Grassland Fire		Total	
	Number of Incident	Area	Area per Incident	Number of Incident	Area	Number of Incident	Area
1973	39	8	0.2	33	7	72	15
1974	48	57	1.2	50	171	98	228
1975	53	21	0.4	73	832	126	853
1976	51	174	3.4	96	573	147	747
1977	116	345	3.0	173	2,673	289	3,018
1978	193	988	5.1	92	1,648	285	2,636
1979	49	66	1.3	67	666	116	732
1980	114	107	0.9	48	289	162	396
1981	52	5	0.1	42	164	94	169
1982	62	154	2.5	47	777	109	931
1983	34	87	2.6	61	158	95	245
1984	60	156	2.6	56	358	116	514
1985	20	3	0.2	79	1,894	99	1,897
1986	58	11	0.2	146	3,151	204	3,162
1987	107	143	1.3	126	1,085	233	1,228
1988	18	0	0.0	86	219	104	219
1989	58	17	0.3	119	1,236	177	1,253
1990	74	699	9.4	55	1,871	129	2,570
1991	36	230	6.4	65	6,060	101	6,290
1992	105	253	2.4	56	4,290	161	4,543
1993	34	247	7.3	46	1,148	80	1,395
1994	50	231	4.6	60	1,783	110	2,014
1995	59	341	5.8	61	1,863	120	2,204
Total	1,490	4,343	Ave. 2.9	1,737	32,916	3,227	37,259

Source: Department of Public Safety, Ministry of Defense

Selenge Aimak is frequently hit by forest fires. A total of 88 fires that occurred in the 10 year period from 1966 to 1975 burnt 1.06 million ha, accounting for 56% of all areas damaged by fire in the country. Forest fires in Selenge Aimak tend to occur at the same stands every 60 to 70 years. As many as 20 to 40 forest fires are recorded every year. A large fire broke out in the Intensive Area and its peripheries in 1985, 1992 and 1994. Table 38 shows the cause of forest fires in the period from 1990 to 1995.

The main causes of forest fires are believed to be as follows.

- Throwing away of still burning cigarette tips or matches
- Open air fires of hunters (particularly illegal hunters), felling workers and forest visitors not properly extinguished
- Sparks from truck and tractor exhausts
- Flying sparks from burning straw, grass and refuse by farmers
- Flying sparks from house (gel) chimneys
- Lightning
- While the cause of many forest fires is unknown, it is highly likely that many are caused by open fires or the throwing away of cigarettes or matches by people entering a forest to collect antlers.

As the above shows, most forest fires are caused by human carelessness.

Table 38 Area and Cause of Damage by Forest Fires in Selenge Aimak

Year		1990	1991	1992	1993	1994	1995
Number of Forest Fires		28	42	42	8	24	35
Cause	Throwing away of burning match or cigarette	6	3	-	1	2	6
	Open air fires of hunters, etc.	-	-	-	1	-	4
	Open air fires	2	-	-	-	-	2
	Flying sparks from gel chimneys	-	-	2	3	-	-
	Burning of straw, refuse or dead grass	1	-	-	1	-	1
	Sparks from truck or tractor exhausts	3	5	3	-	2	3
	Sparks from locomotive exhausts	-	4	2	-	-	-
	Lightning	1	-	6	-	-	-
	Short-circuiting of electrical wires	-	-	-	-	1	-
	Unknown	15	30	29	2	19	19
Damaged Area (ha)	Forest	14,688	945	3,131	11,899	115,099	145,410
	Grassland	721	33,170	21,762	10,101	35,152	11,817
	Total	15,409	34,115	24,893	22,000	150,251	157,227

Source: Selenge Provincial Government

2) Statutory forest fire prevention and fire fighting measures

In the new Forest Law, it is provided that the forest fire prevention plan shall be prepared by provincial governors and district heads; that the financial resources necessary for its implementation be allocated from the local budget; that the Disaster Committee shall identify the cause of fire and assess the amount of damage and the cost of fire fighting; that individuals, enterprises and organizations are required to follow certain rules for prevention and extinguishing of fire. In the Forest and Grassland Fire Prevention Law which was promulgated in May 1996, however, the authority of local administrative body as well as responsibility of individuals, enterprises and organizations in connection with prevention and extinguishing of fire were provided in more detail as set forth below.

a. Authority of provincial governor

① Appropriate expenses required for implementation of prevention and extinguishing of forest and grassland fire every fiscal year from the local budget, make available fire fighting machinery and food and maintain them in such a condition that will enable them to be used at all times.

② Offer training related to securing of self-safety and fire fighting to individuals that are mobilized during fire fighting activities.

③ Cooperate with border army in building and maintaining firebreaks in border areas and in salvage cutting of the forest.

④ Mobilize personnel and machinery in the event of fire and carry out fire fighting activities

⑤ Determine the amount of damage caused by the fire and organize a working group for managing the damaged area.

b. Authority of district head

Has the following authority in addition to items ①, ② ④ and ⑤ in the above paragraph.

① Prepare a plan for fire prevention and fire fighting and appropriate expenses required for such purposes every fiscal year from the local budget.

② Have firebreaks built around national railroad, national highway and private stock sheds and accept them.

③ Carry out fire prevention patrol during periods when fire is likely to occur

④ Prepare personnel, machinery, vehicle, fire fighting sequence and timetable that are mobilized during fire fighting activities prior to fire risk period.

⑤ Control hiking, deer horn picking, tree cutting and byproduct collection, audit of forestry production and prohibit the aforementioned activities when necessary.

c. Authority of Bag head

① Have individuals prepare for prevention of fire.

② Mobilize personnel and machinery for prompt implementation of fire fighting activities while reporting information of fire breakout and fire status to the heads of respective administrative bodies and related bodies.

③ Assign households, individuals, enterprises and organizations to monitor fire at certain areas.

④ Cooperate with bodies that have the authority to identify the cause of fire, investigate for arson and assessment of damage.

d. Responsibility of individuals

① Households shall extinguish open fires, match fires and cigarette fires completely during the fire hazard period.

② Build firebreaks around gels, apartments, hay, wells and stock sheds.

③ Pay attention to prevent reignition of fire by requiring households to place the ember in a hole or charcoal extinguisher.

④ Protect lives and properties of individuals from fire while mastering fire extinguishing techniques and teaching them to children.

⑤ Parents and guardians shall not allow children to possess matches, lighters and other ignition devices when they enter fire hazard areas.

⑥ Each household shall prepare fire extinguishing equipment.

⑦ Start fire fighting activities immediately and report promptly to the related organizations at the responsibility of individual when fire is discovered.

e. Responsibility of enterprises and organizations

① Provide personnel and machinery for prevention and extinguishing of fires.

② Abide by the laws and ordinances of local administrative bodies related to fire prevention.

③ Obtain a permit in advance when performing research and study in a forest. In addition, permission from the district/ward head shall be obtained and a recognizance to the effect that fire will not be caused when engaging in aforementioned activities or hiking during the fire hazard period.

④ Abide by the rules for use when transporting or handling hazardous items and fuel.

⑤ Transportation and motor vehicles must be equipped with fire extinguishers that are checked before going into operation.

⑥ Engage in fire fighting activities at once and report immediately to the head of district/Bag and relevant organizations upon receipt of information about outbreak of fire.

3) Current Situation of Forest Fire Prevention Measures

Table 39 shows the forest fire prevention measures adopted by some district in Selenge Aimak. General measures are the requirements to notify of entry into a forest and to obtain a permit to enter a forest and public relations activities to prevent forest fires. In addition, the Tushig and Dzelter District Offices have established the Forest Fire Prevention Council while the Altanbulag District Office has established the Disaster Committee to implement fire prevention measures.

In Model Area 1, 50 m wide firebreaks extend over a total of some 20 km established by the Selenge Forestry Office in 1991. During the forest fire season, patrols by natural conservation officers are conducted on horseback. However, the general picture is that the Office as well as all the municipalities are finding it difficult to manage the firebreaks and measures by each city and district due to insufficient manpower and funding.

The trees damaged by forest fire are cut and hauled for timber production when such use is feasible. They are also used as firewood. There are traces of old and new forest fires throughout the Intensive Areas, indicating a great loss and deterioration of forest resources, including succeeding trees, and damage to the natural environment caused by fires.

The slow growth of trees in Mongolia due to such adverse natural conditions as the short summer, severe winter and drought makes it both essential and urgent to prevent fires which destroy not only established trees but also natural succeeding trees.

Table 39 Main Forest Fire Prevention Measures Taken by Local Districts

District/ Office	Forest Fire Prevention Measures, etc.
Selenge Forestry Office	• Designates the periods from March 20th to June 10th and from September 20th to November 10th, referred to as forest fire hazard periods by the revised Forest Law, as intensive periods for forest fire prevention. • Holds the Forest Fire Prevention Conference attended by the district nature protection officers in each of the two forest fire prevention periods. • Formerly constructed firebreaks but does not currently do so.
Uroo/ Vogant	• Issues a special appeal vis-a-vis those entering forests to take extra care for fire prevention during the forest fire hazard periods. • Often simply waits for the natural end of a fire as the lack of passable roads for vehicles in the mountain areas under its jurisdiction makes it necessary for fire-fighting teams to reach a fire site on foot (which means that early fight-fighting activities are almost impossible).
Baruunburen/ Burgaltai	• Issues a special appeal vis-a-vis those entering forests to take extra care for fire prevention. • Ensures that anyone entering a forest to collect the seeds of *Pinus sibirica* (in view of later eating them) in autumn obtains a permit from the Office. • Mobilises staff members other than nature protection officers (who are mainly responsible for the issue of forest entry permits and for calling for extra care for forest fire prevention) during the forest fire hazard periods. • Broadcasts an appeal for forest fire prevention for some 20 minutes on Mondays on the local TV (daily broadcasting of 2 hours).
Tushig/ Dzelter	• Issues a special appeal vis-a-vis those entering forests to take extra care in regard to fire prevention. • Prohibits entry into forests, in principle, during the period from April 1st to May 1st; any entry during this period approved as necessary by the Office for whatever reason must be accompanied by a nature protection officer. • Sends nature protection officers to farming households and stock farmers in forest areas to obtain a written pledge not to cause forest fires (visiting period: April 1st to June 1st). • Has established the Forest Fire Prevention Council consisting of 7 members with the district governor acting as the chairman; in addition to regular quarterly meetings, an extraordinary meeting is called when a forest fire breaks out. • Divides the district into 3 areas and appoints 3 farming enterprises to be responsible for fire-fighting in one area each.
Tsagaannuur/ Horuchi	• Issues a special appeal vis-a-vis those entering forests to take extra care in regard to fire prevention. • Sends nature protection officers to stock farmers in forest areas to obtain a written pledge not to cause forest fires. • Issues a special appeal vis-a-vis farmers to take extra care to prevent flying sparks from burning grass, etc. in autumn.
Altanbulag	• Issues a special appeal vis-a-vis those entering forests to take extra care in regard to fire prevention. • Has established the Disaster Committee. • Organizes a 40-strong fire-fighting team lead by the district mayor.
Javhlant/ Jargalant	• Issues a special note designed to protect forests from forest fires twice a year (spring and autumn) under the name of the district governor; the note describes how to react to a forest fire, the need to immediately contact the authorities and possible cooperation for fire-fighting activities, etc.
National Disaster Committee (Central Government Organization)	• Dispatches an AN-2 aircraft from Ulaanbaatar to Selenge Aimak for the periods from April 10th to June 10th and from September 20th to November 20th to ensure the early detection of forest fires and to engage in fire-fighting activities. • Some 20 people are on board the aircraft in addition to the pilot. • The fire-fighting equipment on board the aircraft includes fire pumps, buckets, spades, picks, broad axes and fire beaters, etc. • Cost sharing: - personnel cost of the pilot, fuel costs by the central government, personnel cost of the fire-fighting team by the provincial government • The aircraft lands at grassland near the fire sight (no parachuting of the team members) to commence fire-fighting activities.

(2) Biological Damage

1) Disease, insect, and mammal damage

a) Disease and insect damage

Main insects that inflict damage on pine trees in Mongolia are as shown in Table 40.

Table 40 Main Insects Damaging on Pine Trees

Specie Name	Tree Species Damaged	Parts Damaged
① Dendrolimus pini	Pinus sylvestris	Leaves
② Dendrolimus limus	Larix sibirica	Leaves
③ Bupalus pinirius	Pinus sylvestris	Leaves
④ Orgyio antiqua	Larix sibirica	Leaves
⑤ Panolis flammea	Pinus sylvestris	Leaves
⑥ Monochamus galloprovincialis	Pinus sylvestris	Cambium, xylem
⑦ Sirex juvencus	Pinus sylvestris	Cambium, xylem
⑧ Xeris gpectrum	Pinus sylvestris	Cambium, xylem
⑨ Ips typographus	Pinus sibirica	Cambium, xylem
⑩ Pityogenes chalcographus	Pinus sibirica	Cambium, xylem
⑪ Ips sexdentatus	Larix sibirica	Cambium, xylem
⑫ Ips acuminatus	Larix sibirica	Cambium, xylem
⑬ Xyleborus dispor	Larix sibirica	Cambium, xylem
⑭ Polygraphus poligrap	Larix sibirica	Cambium, xylem
⑮ Acanthocinus aedilis	Larix sibirica	Cambium, xylem
⑯ Agrilus viridis	Larix sibirica	Cambium, xylem
⑰ Urocerus gigas	Larix sibirica	Cambium, xylem
⑱ Pissodes validirotris	Pinus sylvestris	Bud, seed
⑲ Laspeyresia Zonovae	Larix sibirica	Bud, seed

Note: Tree species damaged only list the most affected trees and other pines are also affected.

The Intensive Area has a forest area of 120,149 ha including the *Pinus sylvestris* afforestation sites of 837 ha. Along with insect damage to naturally regenerated *Pinus sylvestris* trees, damage to new tree summits by shoot borers was observed. Insect damage by borers was also observed among trees damaged by forest fires and overmatured trees although the damage was rather insignificant.

The new Forest Law stipulates that the heads of provinces and districts make a forest disease and insect damage prevention plan and take annual budgetary measures. Moreover the law prohibits the use of disease and insects expellents other than that authorized by the central administration.

b) Mammal damage

Some cases of Mammal damage was observed but not so critical. The cases are:

- Peeling damage on stem bases of young trees probably by Myomorpha or Lagomorpha
- Scratching damage on stems by *Ursus arctos*
- Peeling traces by Cervidae and scratching traces by those antlers

Considerable area of *Pinus sylvestris* afforestation sites adjacent to the settlement are damaged by goats' feeding. Almost of seedling lose their leaves.

After all, appropriate measures preventing the livestock from damaging should be taken particularly at the vicinity areas of settlements. The measures will constitute control of grazing range and establishment of protective fence, etc.

2) Meteorological damage, etc.

Trees with growth inhibition caused by climatic damages such as frost and drought were seen here and there. Small-sized landslides were sometimes found along terrace scarps but were unlikely to extend the size seriously.

4.4 Volume Table Survey

4.4.1 Examination of Existing Volume Table

Through consultations with the RIFW, it was decided to examine the volume tables for the following 4 tree species which grow in the Intensive Area.

- *Larix sibirica*

- *Pinus sylvestris*
- *Pinus sibirica*
- *Populus tremula*

Some 100 cut trees with a DBH ranging from 10 cm to 80 cm were measured (by the RIFW) for each species to verify the existing volume tables.

(1) Reference Materials for Calculation of Stand Volume

1) Existing Reference Materials

The stand volume can be established using the two-way volume tables based on the DBH and tree height in the following 4 reference materials.

- On-Site Handbook for Forestry Workers
- Volume Tables of RIFW
- Volume Tables for Felled Trees of Forestry and Felling Research Institute
- Forestry Science in the Soviet Union and Mongolia (Vol. II)

The On-Site Handbook for Forestry Workers was published in 1966 in Russian by Khabarovsk Forestry, Ltd. and mainly deals with forests in Siberia. It contains tree length volume tables with bark for such species as *Pinus sylvestris, Larix sibirica, Picea obovata, Pinus sibirica* and *Abies sibirica*. The DBH range is between 8 cm and 80 cm while the tree height range is between 5 m and 40 m. The standard stump height is 30 cm.

The Volume Tables of the RIFW were prepared in 1978 for *Pinus sylvestris, Larix sibirica, Pinus sibirica* and *Betula* spp. and give the tree length volume and effective volume. The effective volume is given for timber wood, firewood and others by the stand quality class used by the former Soviet Union.

The Volume Tables for Felled Trees are tree length volume tables with bark for felled local species in Mongolia. The work to compile the tables was completed in 1992 for *Pinus sylvestris, Larix sibirica* and *Populus tremula* and work is currently in progress for *Pinus sibirica* and *Betula* spp. Some 1,000 trees of each species were sampled at Dulaankhaan, Dzuunharaa and Hond, etc. in Selenge Aimak (Study Area). The DBH range is between 11 cm and 112 cm while the tree height range is between 9 m and 32 m. The standard stump height is 30 cm.

The Forestry Science in the Soviet Union and Mongolia (Vol. II) is part of the Biological Diversity Research Project which has been jointly conducted by the Soviet Science Academy and the National Science Academy of Mongolia since 1970. Vol. II mainly features forest resources surveys and was completed in 1980 in Russian. Sample trees for the volume tables were taken near Lake Baykal. The volume formula and volume table (for tree length volume with bark) are given for the main species. The DBH range is between 4 cm and 72 cm while the tree height range is between 9 m and 32 m. The standard stump height is 30 cm.

The volume formula in use is shown below. The actual values of coefficients a, b and c and the number of samples are listed in Table 41.

The rate of error is said to be in the range of ± 9.45% - 10.2%.

$$V = a \times d^b \times h^c$$

V : volume (m^3) d : DBH (m) h : tree height (m)

Table 41 Values of Factors Used for Volume Formula and Number of Samples

Factor	*Larix sibirica*	*Pinus sylvestris*		*Pinus sibirica*	*Abies sibirica/ Picea obovata*	*Betula platyphylla*
		Mongolia	Republic of Buryat			
a	0.229067	0.356149	0.364180	0.422366	0.407192	0.121815
b	1.75631439	1.91061797	1.92649652	1.93511358	1.94199866	1.79633106
c	1.04530318	0.96807707	0.98841280	0.94402384	0.94744137	1.24762399
No. of Samples	1,067	Total: 2,130		348	1,115	349

Source: Forestry Science in the Soviet Union and Mongolia (Vol. II), 1980

The volume table availability and relevant reference materials described above are compiled into a matrix for quick reference, listed in Table 42.

Table 42 Matrix for Volume Table

Reference Material \ Species	*Larix sibirica*	*Pinus sylvestris*	*Betula* spp.	*Populus tremula*	*Pinus sibirica*	*Abies sibirica/ Picea obovata*
On-Site Handbook for Forestry Workers	○	○	---	---	○	○
Volume Tables of RIFW	○	○	○	---	---	---
Volume Tables for Felled Trees of Forestry & Felling Research Institute	○	○	?	○	?	---
Forestry Science in the Soviet Union and Mongolia (Vol. II)	●	●	●	---	---	●

Symbol	Description
---	No volume table exists
○	The volume tables are shown without any basis for estimation, such as a volume formula
●	Both the volume table and estimation basis, such as the volume formula, are shown
?	The preparation of a volume table is planned in the future

As only the Forestry Science in the Soviet Union and Mongolia provides a volume equation, number of sample trees and range of error, it was decided to use it for the volume table examination. According to the editor of the Volume Table for Felled Trees of the Forestry and Felling Research Institute, the book contains a volume table for *Populus tremula* and the volume formula is given. However, as this formula was not obtained in time for the present report, the volume formula was inferred based on the volume table figures.

2) Measurement of Sample Trees

The actual measurement conducted by the RIFW was for *Larix sibirica*, *Pinus sylvestris* and *Betula platyphylla*. Consequently, it was decided to verify the existing volume tables for these 3 species while inferring the volume formula from the existing volume table figures of *Populus tremula*.

The collection of the sample trees was made for the following species at the locations and times specified below.

Table 43 Collection of Samples

Species	Location	Time
Larix sibirica	Around Yalbuk River in Dzuunharaa	May, 1995
Pinus sylvestris	Intensive Area	September, 1994
Betula platyphylla	Around Yalbuk River in Dzuunharaa	May, 1995

The number of sample trees by DBH class is shown in Table 44. With regard to *Pinus sylvestris*, the sample trees almost evenly covered the planned DBH range (10 - 80 cm). In contrast, the initial plan to sample at least 5 trees in each diameter class was not met in the case of *Larix sibirica* and *Betula platyphylla* due to the restrictions imposed in terms of the sampling locations and times. A total of 70% of the sample trees fell in the DBH range of between 18 cm and 38 cm in the case of *Larix sibirica* and between 10 cm and 30 cm in the case of *Betula platyphylla*.

The measurement subjects were the DBH (cm), tree height (m), cutting height (cm), diameter at every 4 m intervals above the cutting height (cm) and bark thickness. The tree length volume with bark was calculated for each sample tree while Smalian's formula was used for the volume measurement of each 4 m section.

Table 44 Number of Sample Trees by DBH Class

DBH Range	Number of Samples		
	Larix sibirica	*Pinus sylvestris*	*Betula platyphylla*
<= 10			1
10 < <= 14	4	6	17
14 < <= 18	6	7	22
18 < <= 22	20	6	21
22 < <= 26	17	10	16
26 < <= 30	18	6	15
30 < <= 34	14	9	3
34 < <= 38	8	10	4
38 < <= 42	7	7	1
42 < <= 46	3	3	
46 < <= 50	3	1	
50 < <= 54		1	
54 < <= 58		6	
58 < <= 62		2	
62 < <= 66		5	
66 < <= 70		4	
70 < <= 74		1	
74 < <= 78		1	
78 < <= 82		1	
82 <			
Total	100	86	100

(2) Examination and Preparation of Volume Tables

It was decided to examine the volume tables given in the Forestry Science in the Soviet Union and Mongolia (Vol. II) for 3 species, i.e. *Larix sibirica*, *Pinus sylvestris* and *Betula platyphylla*, while inferring the volume equation for *Populus tremula* based on the volume table given in the Volume Tables for Felled Trees of the Forestry and Felling Research Institute.

1) Examination of Volume Formula of Forestry Science in Soviet Union and Mongolia (Vol. II) and Preparation of New Formula

Examination of the existing volume formula was conducted by means of identifying the difference between the actual volume (VA) of the sample trees based on sectional measurement and estimated volume (VE), to be established by applying the sample tree data to the existing volume formula. Fig. 25 gives the examination results for *Larix sibirica*, *Pinus sylvestris* and *Betula platyphylla*.

As significant differences were found in the case of *Larix sibirica* and *Betula platyphylla*, the existing volume formulas were found to be unsuitable for the volume estimation of the present sample trees. In comparison, no significant difference was found in the case of *Pinus sylvestris*, indicating the applicability of the existing volume formula for the present purposes.

Species : Larix sibirica

Compared Source : Forestry Science in the Soviet Union and Mongolia

V=a * D^b * H^c

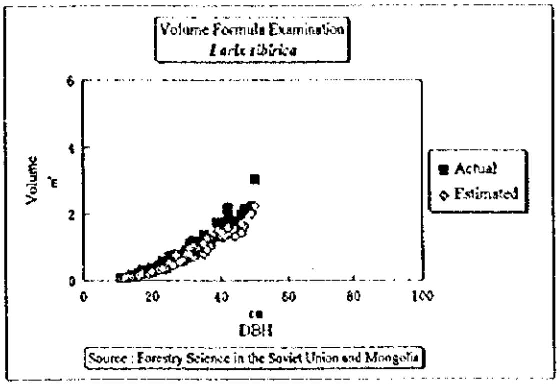
a: 0.2290670
b: 1.75631439
c: 1.04530318

Table Examination Results

	Symbol	Value
Sample No.	n	100
avg.(V(A)-V(E))	ave X	0.1123
Unbiased Average	u	0.134
Unbiased Variance	u^2	0.018
F(0)	t^2	70.063
F(f1=1,f2=99)		6.899
	F(0)>F(f1=1,f2=99)	

Significant Difference: positive

Abbreviations:
avg : average
V(A) : Actual Volume
V(E) : Estimated Volume



Species : Pinus sylvestris

Compared Source : Forestry Science in the Soviet Union and Mongolia

V=a * D^b * H^c

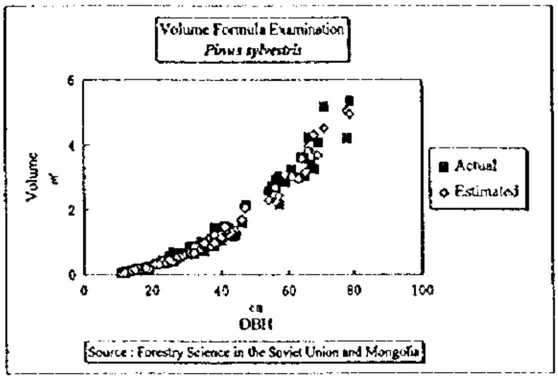
a: 0.3561490
b: 1.91061797
c: 0.96807707

Table Examination Results

	Symbol	Value
Sample No.	n	86
avg (V(A)-V(E))	ave X	0.024
Unbiased Average	u	0.229
Unbiased Variance	u^2	0.0526
F(0)	t^2	0.942
F(f1=1,f2=85)		6.943
	F(0)<=F(f1=1,f2=85)	

Significant Difference: negative

Abbreviations:
avg. : average
V(A) : Actual Volume
V(E) : Estimated Volume



Species : Betula platyphylla

Compared Source : Forestry Science in the Soviet Union and Mongolia

V=a * D^b * H^c

a: 0.1218150
b: 1.79633106
c: 1.24762399

Table Examination Results

	Symbol	Value
Sample No.	n	100
avg (V(A)-V(E))	ave X	0.078
Unbiased Average	u	0.057
Unbiased Variance	u^2	0.0033
F(0)	t^2	184.364
F(f1=1,f2=99)		6.899
	F(0)>F(f1=1,f2=99)	

Significant Difference: positive

Abbreviations:
avg. : average
V(A) : Actual Volume
V(E) : Estimated Volume

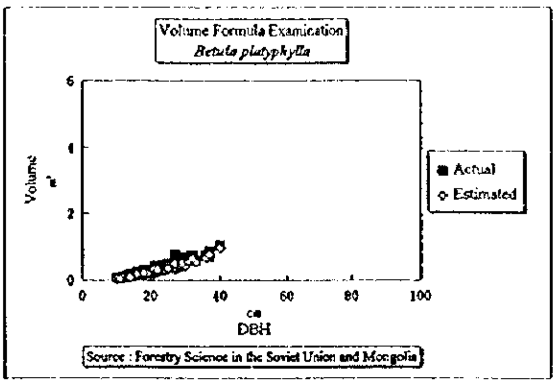


Fig. 30 Volume Formula Examination Results

Due to the inapplicability of the existing volume formulas for *Larix sibirica* and *Betula platyphylla*, it was decided to prepare new formulas while using the existing formula for *Pinus sylvestris*.

The new volume formulas for *Larix sibirica* and *Betula platyphylla* were prepared using the measured data of the sample trees with the Schumacher and Hall formula used in the Forestry Science in the Soviet Union and Mongolia (Vol. II). Here, volume means the tree length volume with bark of a felled tree. The new volume formulas are shown in Table 45.

Table 45 Volume Formulas for *Larix sibirica* and *Betula platyphylla*

Item	*Larix sibirica*	*Betula platyphylla*
Volume Formula	$V = a \times d^b \times h^c$	$V = a \times d^b \times h^c$
a	0.5640205	0.8418616
b	1.8059458	1.7245579
c	0.8242713	0.6177921
Correlation Coefficient	0.9782922	0.9649703
Standard Error (%)	15	16
Number of Sample Trees	100	100

The DBH range of the volume tables in the Forestry Science in the Soviet Union and Mongolia (Vol. II) used for the examination was 4 - 72 cm. In the case of *Pinus sylvestris*, the DBH range of the sample trees was found to be almost identical to the above range and, therefore, examination results covering the entire DBH range were obtained (See Fig. 30). In contrast, the the DBH concentration of the sample trees on the smaller side for *Larix sibirica* and *Betula platyphylla* meant that the examination was biased towards the smaller DBH range and that the entire DBH range in the given volume table was not examined.

2) Volume Formula Inference for Volume Tables of Forestry and Felling Research Institute

The latest survey failed to obtain the volume formula used for the volume tables compiled by the Forestry and Felling Research Institute. A regression analysis was conducted for the figures given by the volume tables to infer the volume formula for *Populus tremula* and the results given in the following table show a strong correlation.

Table 46 Volume Table of *Populus tremula*

Item	*Populus tremula*
Volume Formula	$V = a \times d^b \times h^c$
a	0.2082071
b	1.7954576
c	1.0807193
Correlation Coefficient	1.0000000
Standard Error (%)	0.000

The volume formula shown in Table 47 for the tree species growing in the Study Area was used to estimate the forest resources volume.

Table 47 Volume Equation Used to Estimate Forest Resources Volume

Item	*Larix sibirica*	*Pinus sylvestris*	*Betula platyphylla*	*Populus tremula*
Volume Formula	$V = a \times d^b \times h^c$			
a	0.5640205	0.356149	0.8418616	0.2082071
b	1.8059458	1.91061797	1.7245579	1.7954576
c	0.8242713	0.96807707	0.6177921	1.0807193
Source	Newly formulated	Existing formula	Newly formulated	Inferred based on existing volume table

4.5 Land Use and Vegetation Survey

Land use and vegetation survey of the Intensive Areas was conducted by means of aerial photo interpretation, field survey and field verification and land use and vegetation maps were prepared..

(1) Interpretation Items

Following preliminary interpretation of the Intensive Area by means of field verification and aerial photograph interpretation, the interpretation items shown in Table 48 were agreed upon through consultations with the Government of Mongolia for the land use and vegetation survey on the Intensive Area.

Table 48 Interpretation Items

Primary Category	Secondary Category	Tertiary Category	Symbol	Interpretation Criteria
Forest	Coniferous Forest	Pine Forest	NP	- Distributed throughout the Intensive Area. - Various tree heights with a pale black crown town.
		Larch Forest	NL	- Mainly distributed above EL 1,000 m. - Relatively high tree height with a whiter tone than *Pinus sylvestris* forests.
		Pine/Larch Forest	N	Mainly distributed above EL 800 m.
		Planted Forest	P	- The planted species is *Pinus sylvestris*. - The planting grooves after land preparation create a striped pattern.
	Broad-Leaved Forest		L	- Widely distributed. - Since the photography was conducted at the time of fresh green, young stands in particular are difficult to separate from coniferous forests.
	Mixed Forest		M	Coniferous trees often form the upper layer with broad-leaved trees forming the lower layer.
	Unstocked Land		U	Bare land which shows up white and is impossible to interprete. Some fallen trees possibly also there.
	Fire-Damaged Forest		UF	Trees damaged for forest fires are scattered and show up in white against a black background.
	Logged-Over Land		UL	Currently sparsely stocked land with some fallen trees. Likely to show up as a yarding road.
	Shrub Forest		S	- Land with shrubs where it is impossible to interprete the species. - Mainly shows up at south-facing slopes in the mountains.
Non-Forest	Grassland		G	Shows up white with large coverage.
	Farm Land		F	Farming compartments show a rectangular pattern.
	Settlement		ST	Scattered buildings (houses) are observed.
	Rocky Land		R	Shows up near mountain ridges.

(2) Interpretation Criteria

In order to interprete the current land use in the Intensive Area, primary categories of "Forest" and "Non-Forest" were introduced and the interpretation criteria were decided as described below for each interpretation item.

1) Coniferous Forest

The main species of coniferous forests in the Intensive Area are *Pinus sylvestris* (Scotch pine) and *Larix sibirica* (Siberian larch). In general, *Pinus sylvestris* mainly appears at flat land or gentle slopes while both species appear on both gentle and steep slopes in the form of pure or mixed forests.

With regard to interpretation of coniferous forests and broad-leaved forests, careful attention should be paid to young stands as such interpretation elements as the crown shape, crown edge shape, tone, shadow, pattern and texture are quite similar both types of forests. The actual interpretation for the Study used aerial photographs, field verification findings and Landsat images.

a. Pine Forest (or *Pinus sylvestris* Forest)

This type of forest predominantly consists of *Pinus sylvestris* and is found throughout the Intensive Area. In areas below EL 800 m, large, pure *Pinus sylvestris* forests tend to be formed. The typical photographic image of *Pinus sylvestris* shows a bell-shaped crown with a relatively clear and pointed crown head and a circular crown edge. The colour tone is pale black and a semi-irregular spotted pattern can be seen.

b. Larch Forest (or *Larix sibirica* Forest)

This type of forest predominantly consists of *Larix sibirica* and is generally distributed above EL 800 m. The photographic image of *Larix sibirica* shows a bell-shaped crown and a circular crown edge. Compared to *Pinus sylvestris*, the crown head is not clear. The colour tone is pale grey. A *Larix sibirica* stand shows a coarse spotted pattern with a softer texture than that of *Pinus sylvestris*.

c. Pine/Larch Forest

This type of forest is distributed above EL 800 m and shows the combined characteristics of the above *Pinus sylvestris* and *Larix sibirica* forests.

d. Planted Forest

The species used for local reforestation is *Pinus sylvestris*. As reforestation efforts only commenced in 1983, all the trees are still young and the survival rate has been low. The planting grooves after land preparation create a striped pattern.

2) Broad-Leaved Forest

This type of forest mainly consists of *Betula platyphylla* and *Populus tremula*. *Betula platyphylla* is widely found regardless of elevation in the form of a mixture with coniferous trees or in small colonies. *Populus tremula* begins to appear around EL 800 m. Both species are often mixed with coniferous trees. As it is almost impossible to distinguish between them on photographs, stands dominated by these species are all classified in the category of broad-leaved forest. The crown has an irregular shape when a forest is old while the crown of a young forest shows a slightly bulging bell shape. The crown edge is almost a true circle but is unclear. The colour tone is grey with a pale shadow. The texture is softer and finer than that of a coniferous forest.

3) Mixed Forest

This forest is a mixture of the coniferous trees and broad-leaved trees described above and the coniferous trees tend to form the upper layer and/or isolated tall trees.

4) Unstocked Land

Small areas of unstocked land are scattered in the forests and show up in greyish white.

5) Fire-Damaged Forest

The white ground is partially covered by blackish grey and the crown of the damaged trees shows up in pale white.

6) Logged-Over Land

Yarding roads run in streaks with scattered uncut trees and felled trees.

7) Shrub Forest

Shrub land is mainly found on south-facing slopes in the southern part of the Intensive Area and such shrubs as *Malus pallasiana* (Siberian apple) are scattered at 5 - 20 m intervals. In general, these shrubs show up as irregular blackish grey dots against the grey coloured grassland.

8) Grassland

Grassland shows up in white with extensive coverage. This mainly flat land is dotted with gels and such buildings as animal barns.

9) Farm Land

Farm land shows up in greyish white with a fine striped pattern in many cases. Farming compartments form a rectangular pattern divided by straight lines.

10) Settlement

Scattered buildings are found in and around Hond.

11) Rocky Land

Rocky land shows up in white or greyish white at mountain ridges with a hook-shaped shadow.

(3) Preparation of Land Use and Vegetation Map

The interpretation results were compiled in a land use and vegetation map (scale 1/50,000). The identified land area for each interpretation item is given in Table 49.

Table 49 Land Area by Land Use and Vegetation Type in Intensive Area

Primary Category	Secondary Category	Tertiary Category	Land Area (ha)	Rate (%)
Forest	- Coniferous Forest	- Pine forest	33,159	20.7
		- Larch forest	3,199	2.0
		- Pine/Larch forest	2,766	1.7
		- Planted forest	837	0.5
	- Broad-Leaved Forest		30,149	18.8
	- Mixed Forest		23,700	14.8
	- Unstocked Land		8,817	5.5
	- Fire-Damaged Forest		5,143	3.2
	- Logged-Over Land		3,588	2.2
	- Shrub Land		8,791	5.5
	Sub-total		120,149	75.0
Non-Forest	- Grassland		31,048	19.4
	- Farm Land		4,844	3.0
	- Settlement		155	0.1
	- Rocky Land		4,146	2.6
	Sub-total		40,153	25.0
Total			160,302	100

4.6 Selection of Model Areas

Two Model Areas were selected to represent typical lowland forests (Model Area 1) and mountain forests (Model Area 2) in the Intensive Area.

Model Area 1 is located in the Tojiin Nars area and Dolgontiin Nars area in the catchment area of Hodagiin River and its tributaries. The elevation ranges from 660 m to 1,070 m and the dominant species are *Pinus sylvestris* and *Betula platyphylla*. Model Area 1 stretches in the north-south direction and its northern end is some 10 km from Altanbulag. Model Area 2 is located in the Chuluutin Mountains and also in the mountains to the north of the Hangain Mountains. It stretches in the east-west direction. Its eastern part is located in the upper reaches of Bohtoon River bordered by Mt. Hoot (EL 1,342 m) while the western part is located in the upper reaches of Hangai River. The elevation ranges from 760 m to 1,340 m. The dominant species are *Pinus sylvestris* and *Betula platyphylla*. *Larix sibirica* and *Populus tremula* begin to be observed when the elevation reaches 800 m. The northern end of Model Area 2 is some 40 km from Altanbulag and the Hangai Pass, constituting the southern end of Model Area 2, is

Altanbulag and the Hangai Pass, constituting the southern end of Model Area 2, is some 20 km from Uroo Village, in turn located in the southern part of the Intensive Area. A general outline of both Model Areas is given in Table 50.

Table 50 General Outline of Model Areas

Model Area	Area (ha)	General Description
1	6,934	Lowland forest located on a gentle slope to the north side of Mt. Togos in the northwestern part of the Intensive Area. The dominant tree species is *Pinus sylvestris*.
2	22,717	Mountain forest located in the Chuluutin Mountains as well as the mountain range to the north of the Hangain Mountains in the southern part of the Intensive Area. The dominant tree species are *Pinus sylvestris*, *Larix sibirica* and *Betula platyphylla*.
Total	29,651	

The selection of these Model Areas was agreed and their locations were confirmed on the existing topographical map (scale: 1/100,000) through extensive consultations with the RIFW.

CHAPTER 5

FOREST SURVEY OF MODEL AREAS

CHAPTER 5 FOREST SURVEY OF MODEL AREAS

5.1 Soil Survey

(1) Soil Survey Method

A soil survey was conducted to examine morphological features of the forest soil profiles. The soil profiles were described in accordance with the FAO Guidelines[1] and the measurement values using Yamanaka's soil hardness meter and portable *pH* meter are attached to the above description. The soil grouping was conducted in accordance with the legend given by the FAO-UNESCO[2]. Some 200 small pits were dug to determine the soil distribution characteristics and soil maps (scale: 1/25,000) were prepared. In the case of hinterland with poor accessibility, aerial photographs were used to interprete the topographical features and plant cover and the interpretation results were used to infer the soil groups prior to mapping.

(2) Soil Groups and Characters

Of the 20 representative soil profiles described, those with typical morphological features are described in Appendix 7. The characters of each soil unit are described below.

1) Dystric Cambisols

Dystric Cambisols are dominant at steep slopes of mountains and are called Derno-Forest Soils in Mongolia. They are mainly derived from weathered materials and colluvial deposits from such base rocks as granite and diorite. Dystric Cambisols have a 3 - 5 cm O horizon (mainly FH horizon), a thin, brownish black or dark brown A horizon (8 - 10 cm) and a brown B horizon (20 - 35 cm). They are usually silty but are occasionally clayey at gentle slops of mountain tops. They can also be sandy in the case of colluvial soil. The *pH* value is generally around 5. Freezing of this type of soil can be observed from around November to May of the following year. The B horizon of some local Dystric Cambisol units show a light rust colour which is believed to be caused by weak podsolization. However, no clear podzolic soils were found.

Mixed forests of *Pinus sylvestris* accompanied by *Betula platyphylla* and *Larix sibirica* are observed at Dystric Cambisols sites. The presence of *Larix sibirica*

1) FAO, Guidelines for Soil Profile Description, Second Edition (1977)
2) FAO-UNESCO, Soil Map of the World, Vol. I, Revised Legend (1990)

can be observed from an elevation of around 850 m which become more dominant (to the extent that pure *Larix sibirica* forests can be observed) in accordance with the elevation. The forest floor has little large herbage and the main vegetation cover is provided by *Rhododendron dahuricum*, *Spiraea* spp., *Rosa* spp., *Vaccinium vitis-idaea*, *Calamagrostis* spp., *Carex* spp., *Pirola* spp. and *Majanthemum bifolium*. Many naturally generated saplings are found to be dead in localised areas covered by thick moss.

2) Humic Cambisols

In contrast to Dystric Cambisols which are dominant at convex steep slopes, Humic Cambisols were mainly found to be distributed at concave steep slopes. Humic Cambisols are also called Derno-Forest Soils in Mongolia and are characterised by a thick A horizon.

In fact, apart from the existence of an umbric A horizon (a thick, brownish black, acid horizon), Humic Cambisols have similar morphological features to Dystric Cambisols in terms of the disposition of the horizons, soil texture and soil structure, etc. and are close to Moderately Moist Brown Forest Soils in Japan. Tree growth on Humic Cambisols is better than that on Dystric Cambisols and the forest floor has much large herbage.

3) Haplic Kastanozems

The Kastanozems found in the Model Areas have a well-developed, dark brown A horizon and are called Dark Kastanozems in Mongolia. The FAO-UNESCO method, however, does not classify the A horizon of Kastanozems based on the soil colour. Haplic Kastanozems are the representative soil of pediments and alluvial cones and are also observed at mountainsides and gentle slopes next to ridgelines. Haplic Kastanozems are observed at steppes, scattered forests, young forests of *Betula* spp. and mixed forests of *Betula* spp. and *Pinus sylvestris* (where *Betula* spp. are more dominant than *Pinus sylvestris*) but are hardly observed at any climax forests of *Pinus sylvestris* or *Larix sibirica*.

The Haplic Kastanozems found at steppes or scattered forests have a little-developed O horizon. The dark brown A horizon is thick (30 - 40 cm) and has a well-developed crumb or granular structure. The brown B horizon is 20 - 30 cm thick and has a well-developed sub-angular or angular structure. In the case of alluvial cones, the B horizon is occasionally missing. Haplic Kastanozems at forest land have an O horizon of some 2 cm in thickness. Many also have a some 10 cm thick Au1 horizon which probably reflects the impact of invading trees on the top section of Kastanozems which are known as soils at arid steppe. While no sedimentation of $CaCO_3$ is observed in the lower layers, the *pH* value of 6 is high. This soil is frozen in winter.

In the case of Haplic Kastanozems found at steppes and scattered forests, the dominant species are *Stipa* spp., *Poa* spp. and *Calamagrostis* spp., etc. In the case of *Betula* spp. forests and mixed forests of *Betula* spp. and ***Pinus sylvestris***, the presence of such large herbage as *Polygonatum officinale*, *Scabiosa* spp. and *Thalictrum* spp. is observed together with such shrubs as *Spiraea* spp. and *Rosa* spp.

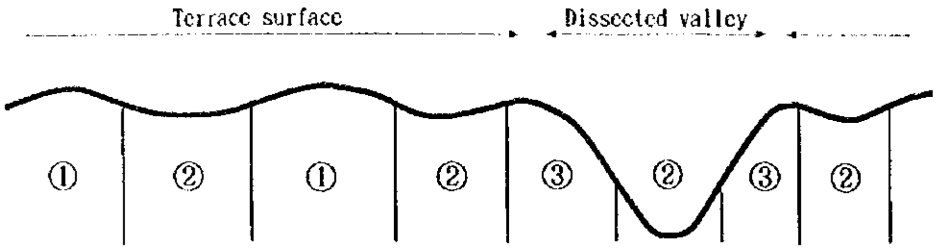
4) Haplic Arenosols

Haplic Arenosols are derived from sandy sediments and are equivalent to Derno-Forest Sandy Soils in Mongolia and Sandy Immature Soil in Japan. This soil was originally classified in the Regosols group in 1974 but has now been reclassified (in 1994) in the Arenosols group.

The sand stratum, which provides the parent materials, is extremely thick, forms the higher terraces in the Orhon watershed in areas of upto around 850 m in elevation and is widely observed around Hond. Half of the rolling land in Model Area 1 consists of this sand stratum. In Model Area 2, however, only tiny areas of the same stratum are found in the northwestern corner. The sand is mainly fine and is extremely homogeneous.

The O horizon of Haplic Arenosols is 3 - 5 cm thick and is either a F horizon or FH horizon. The mineral horizons are scarcely differentiated. A brownish black or dark brown A horizon of a few cm in thickness and the yellowish brown or brown C horizon are generally observed although the A horizon may be absent at upper parts of escarpments. The *pH* value is around 6. As the water retaining capacity is weak, the permeability is extremely good.

Haplic Arenosols are further classified into 3 types, the distribution of which corresponds to the microrelief as shown in Fig. 26.



Symbol	Soil type (tentative)	A or AC horizon	Soil moisture	Microrelief
①	Residual type	Very thin	Dry	Convex
②	Accumulected type	Thin	Weakly dry	Concave
③	Eroded type	Lacking or very thin	Dry	Cliff (upper part)

Fig. 31 Correlation Between Soil Types and Microrelief

Natural forests of *Pinus sylvestris* thrive on haplic arenosols, many of which are pure forests. The state of natural regeneration is excellent. However, the tree density at many stands is rather excessive. As a result, the trees are generally thin. The largest cause of the failure of *Betula* spp. and *Populus* spp. to invade sites of Haplic Arenosols is assumed to be the poor nutrition and water of this type of soil. The floor vegetation is poor and large herbage is seldom observed. Typical flora are *Rhododendron dahuricum*, *Vaccinum vitis-idaea* and *Cladonia* spp., all of which are known for their strong resistance to oligotrophy and drought. *Stipa* spp. and *Calamagrostis* spp., etc. are also found but are scattered and do not grow high.

5) Umbric Leptosols and Lithic Leptosols

Umbric Leptosols are very stony (a fine soil ratio of less than 20% according to the FAO-UNESCO classification criteria) and the profile appears to entirely consist of stones (gravel). Lithic leptosols are commonly called Lithosols, the solum of which is extremely thin (according to the FAO-UNESCO classification criteria, the base rock appears within a depth of 10 cm).

These 2 soil types show a mixed presence at steep mountainsides. Umbric Leptosols are mainly distributed at the lower part of steep slopes while Lithic Leptosols are mainly found at the upper part of steep slopes or at convex steep slopes.

No forest growth is observed in the case of either soil type and areas consisting of these soils are generally grassland with low *Gramineae* spp. as well as scattered *Spiraea* spp., *Rosa* spp. and *Ulmus* spp.

6) Umbric Fluvisols

Umbric Fluvisols are found at valley bottom lowland deriving from recent fluvial sediments and are equivalent to Alluvial Meadow Soils in Mongolia and are similar to Brown Lowland Soils or Gray Lowland Soils in the Classification of Cultivated Soils in Japan (1995).

Umbric Fluvisols are commonly clayey but are often sandy or silty at narrow valley bottoms in mountainous areas. In general, they consist of a 10 - 15 cm thick brownish black A horizon and a fairly thick grayish yellow brown C horizon and often have a some 30 cm thick AC horizon or CA horizon immediately below the A horizon. In some cases, several deposition layers, a 2A horizon or 3A horizon are observed. The drainage is poor and some have orange and gray mottles.

Meadows with large herbage are established on Umbric Fluvisols, preventing the invasion of trees although invasion by *Betula* spp. and/or *Populus* spp. is observed at sites along cliffs with good drainage. *Salix* spp. bushes can also be observed along streams.

(3) Mapping Units and Soil Distribution

The mapping units used to prepare the soil map are those listed under the legend in the map. A general description of each mapping unit is given below.

1) Mapping Unit "C" (Soil Complex of Dystric Cambisols and Humic Cambisols)

Due to poor access and other reasons, it was difficult to separately map Dystric Cambisols and Humic Cambisols, both of which were found to be distributed in the mountains. Consequently, mapping unit "C" was established to represent the soil complex of these 2 soil types. In terms of land area, Dystric Cambisols are believed to account for approximately 75% while Humic Cambisols account for approximately 25%. Mapping unit "C" is dominant at the steep slopes of mountainsides in Model Area 2. In Model Area 1, however, this unit is only observed in the southern-most mountains.

2) Mapping Unit "K" (Haplic Kastanozems)

Mapping unit "K" mainly represents Haplic Kastanozems containing small soil individuals of Humic Cambisols. This unit is generally observed at pediments and alluvial cones. In Model Area 2, however, its distribution is also observed spreading from mountainsides to gentle slopes on ridges in some parts of the northern mountains.

3) Mapping Unit "A" (Soil Complex of Haplic Arenosols)

As shown in Fig. 31, Haplic Arenosols are classified into 3 types. As the separate mapping of these 3 types would create a complicated soil map which would be inconvenient, it was decided to group all 3 types under the soil complex mapping unit "A". This unit is widely distributed at the surface of terraces which cover the northern half of Model Area 1. In the case of Model Area 2, tiny spots of this unit are observed at gentle slopes located in the northwestern corner.

4) Mapping Unit "L·C" (Soil Complex of Leptosols and Cambisols)

Mapping unit "L·C" represents the soil complex of Dystric Leptosols, Lithic Leptosols and Dystric Cambisols with respective composition ratios of approximately 40%, 30% and 30%. In addition, colluvial boulders of varying size and outcrops of base rock are observed on the ground surface. As in the case or rocky land described later, this soil unit is frequently observed at south-facing steep slopes in Model Area 2 but is seldom observed in Model Area 1.

5) Mapping Unit "F" (Umbric Fluvisols)

The localised presence of small soil individuals of Gleysols and minor swamps are observed in the distribution areas of Umbric Fluvisols. These mixed areas can easily be recognised by means of a field investigation or aerial photograph interpretation due to the differing vegetation compared to other areas. Small soil individuals of Mollic Fluvisols and Dystric Fluvisols are also observed. Due to the very minor coverage of each of these mixed soil individuals, they are also included in mapping unit "F".

Extensive coverage by mapping unit "F" is observed at alluvial lowland in the northwestern corner of Model Area 2. Narrow strips of mapping unit "F" can also be observed at the valley bottoms of major rivers. No site in Model Area 1 falls under mapping unit "F".

6) Mapping Unit "R" (Rocky Land)

In Model Area 2, the extensive, north-facing pediments are well developed. In contrast, the south-facing mountainsides are very steep and patches of rocky land are observed everywhere. While the land size of rocky land varies, relatively large sites based on the field survey and aerial interpretation results are shown under mapping unit "R". This unit is observed throughout Model Area 2. In Model Area 1, however, it is observed on a minor scale at ridges along the southern boundary.

(4) Soil Productivity and Forestry Practice Proposals

The present Study has so far failed to quantitatively determine the correlation between the soil conditions and tree growth. With regard to the soil conditions, although the morphological features, soil types and soil distribution have been identified, the physical, chemical and mineralogical compositions and properties have not yet been analysed. The lack of data on the soil composition and properties makes it impossible to discuss the soil productivity in detail. Consequently, the soil productivity by each mapping unit is described in this section in general terms and some general proposals are made in regard to forestry practices.

1) Forestry Practices for Mapping Soil Unit "C"

The 2 types of Cambisols comprising mapping soil unit "C" are both suitable for tree growth and their productivity is next to that of Haplic Kastanozems. However, it must be noted that Dystric Cambisols are inferior to Humic Cambisols in terms of productivity.

From the viewpoints of maintaining and improving the soil productivity and soil conservation, the ideal forest for soil unit "C" is a mixed forest of *Larix sibirica* and *Pinus sylvestris* with the inclusion of some *Betula* spp. While afforestation is fairly feasible, natural regeneration is better. In the case of the moss type floor, it is necessary to scarify the moss layer to assist natural seeding.

While most mountain roads are constructed on soil unit "C", the ongoing gully erosion is becoming deeper and wider at many sites. It is, therefore, essential to adopt measures to prevent or mitigate gully erosion throughout the location selection, design, construction and maintenance stages for soil conservation both forest roads and spur roads.

2) Forestry Practices for Mapping Soil Unit "K"

Haplic Kastanozems, the main components of mapping soil unit "K", have the best soil productivity in the Model Areas due to their weak acidity and rich nutrients and provide good growth prospects for *Pinus sylvestris* and *Larix sibirica*. Although most of the areas covered by soil unit "K" are currently steppe, afforestation efforts should be actively promoted wherever needed. In the case of gentle slopes, the conversion of steppes to cultivated land or grassland should also be considered. The soil erosion prospect is weak.

3) Forestry Practices for Mapping Soil Unit "A"

As Haplic Arenosols comprise excessively drained soil with a poor presence of organic matter and clay, they have low capacity to hold nutrients and moisture, making *Pinus sylvestris* the only suitable species for this mapping soil unit. Accordingly, the main forestry practices should be the tending, selective group cutting and clear cutting of small areas of existing *Pinus sylvestris* forests. Because of the low moisture content, planting afforestation cannot expect to achieve a high survival ratio and it appears safe to opt for natural regeneration. When planting afforestation must be conducted due to the absence of mother trees or other reasons, special care must be taken, including filling of the planting holes with soil matter of the neighbouring A horizon. However, good tree growth cannot be expected with either natural regeneration or planting afforestation. The sandy character of Haplic Arenosols means that the soil has a weak tree root holding capacity and, therefore, the trees are liable to wind damage. It is necessary to maintain the present vegetation at escarpments in dissected valleys to prevent soil erosion.

4) Forestry Practices for Mapping Soil Unit "L·C"

The land productivity is extremely low in the case of those areas classified as "L·C". While it appears possible to raise goats, the land has a small grazing capacity. The subject areas have been shaped by strong soil erosion over the years and there is no immediate danger of further soil erosion. However, the danger of landslides cannot be ignored. At present, no positive use of the subject areas is in sight apart from preservation of the status quo.

5) Forestry Practices for Mapping Soil Unit "F"

Umbric Fluvisols, the main components of mapping soil unit "F", are relatively rich in nutrients. However, their poor drainage makes them unsuitable for the growth of such useful trees as *Pinus sylvestris* and *Larix sibirica*. *Larix sibirica* in particular is liable to suffer from heart rot. The dense large herbage prevents seeding regeneration and the strong restorable ability of the herbage renders the effects of weeding minimal. It is probably more advantageous to use the subject areas as pasture or meadow. There is little danger of soil erosion but the existence of riverbank breakdown due to running water suggests the necessity to protect *Salix* spp. along streams to prevent the occurrence or further progress of such breakdowns.

5.2 Forest Physiognomy Survey

(1) Forest Type Interpretation Categories

A forest physiognomy survey was conducted in the Model Areas by means of aerial photograph interpretation and field verification on the basis of the forest type interpretation categories, involving interpretation items of land use and vegetation, and tree height and crown density given as in Table 51.

Table 51 Forest Type Interpretation Categories and Symbols

Category Type	Category	Range	Symbol
Height Class	Low	- 12 m	H3
	Medium	13 m - 20 m	H2
	High	21 m -	H1
Crown Density	Very Sparse	- 30%	D4
	Sparse	31% - 60%	D3
	Medium	61% - 90%	D2
	Dense	91% -	D1

(2) Interpretation of Aerial Photographs

Preliminary interpretation of the forest physiognomy and forest type was conducted in accordance with the respective interpretation categories/criteria. The compartments divided by this preliminary interpretation were then verified on-site and were corrected/modified with reference to the findings of the sample plot survey. The land area by each category of forest physiognomy in the Model Areas is given in Table 52.

(3) Preparation of Forest Type Map

1) Forest Division

Compartmentation was made for areas of 600 to 800 ha in the basins of Model Areas. In addition, divisions based on interpretation items for preparation of land use vegetation map and forest physiognomy interpretation categories were used as sub-compartment division. Administrative divisions were also added within each compartmentation.

2) Preparation of Forest Type Map

Forest type maps of the Model Areas (scale: 1/25,000) were prepared through interpretation of aerial photos and field inspection. The area of the Model Area by forest physiognomy category is as shown in Table 52.

Table 52 Areal Composition of Model Areas 1 and 2 by Forest Physiognomy Category

(unit: ha)

Model Area	Land Use & Vegetation Type	Total	Height Class	Crown Density Class: 1			Crown Density Class: 2			Crown Density Class: 3			Crown Density Class: 4		
				1	2	3	1	2	3	1	2	3	1	2	3
1	Pine Forest	3,965		82	366	453	89	2,026	313	124	502	10			
	Larch Forest														
	Pine/Larch Forest														
	Planted Forest	97													
	Broad-Leaved Forest	1,235			907	19		166	54		77			12	
	Mixed Forest	1,056			449	14		438		102	53				
	Unstocked Land	90													
	Fire-Damaged Forest	199													
	Logged-Over Land	42												32	10
	Shrub Land														
	Grassland	222													
	Farm Land	24													
	Rocky Land	4													
Subtotal		6,934		82	1,722	486	89	2,630	367	226	632	10		44	10
2	Pine Forest	1,571		14	417	81	257	499	5	52	114	69		32	31
	Larch Forest	1,123		449	112		440	69		34				19	
	Pine/Larch Forest	1,218		66	33		987	98		34					
	Planted Forest														
	Broad-Leaved Forest	7,376			4,084	1,277		1,481	185		258	91			
	Mixed Forest	5,755		204	823	13	1,173	2,458		573	511				
	Unstocked Land	1,579													
	Fire-Damaged Forest	18													
	Logged-Over Land	776												772	
	Shrub Land	22													
	Grassland	2,365													
	Farm Land														
	Rocky Land	914													
Subtotal		22,717		733	5,469	1,371	2,857	4,605	190	693	883	160		823	31
Grand Total		29,651		815	7,191	1,857	2,946	7,235	557	919	1,515	170		867	41

3) Legend for Forest Type Map

Legend for forest type maps is as shown in Table 53.

Table 53 Legend for Forest Type Map

Land Use & Vegetation Type

Symbol	Mapping Unit
NP	Pine Forest
NL	Larch Forest
N	Pine/Larch Forest
P	Planted Forest
L	Broad-Leaved Forest
M	Mixed Forest
U	Unstocked Land
UF	Fire-Damaged Forest
UL	Logged-Over Land
S	Shrub Land
G	Grassland
F	Farm Land
ST	Settlement
R	Rocky Land

Height Class(H)	
Class	Range
3	- 12m
2	13m - 20m
1	21m

Crown Density Class(D)	
Class	Range
4	- 30%
3	31 - 60%
2	61 - 90%
1	91% -

Delineation was made on the diagram as shown below in the order of ① Land use/vegetation category, ② Height class, and ③ Crown density.

Example: When category is pine forest and the stand is height class 1 and crown density class 2.

NPH1D2

Boundary and number between compartment and sub-compartment were also drawn on the diagram. See 7. Guildelines for Forest Management Plan for the content of categorization for compartment and sub-compartment.

5.3 Volume Survey

Volume survey was conducted through the sample plot survey in the Model Areas.

(1) Preparatory Survey

1) Survey Method

A preparatory survey was conducted to determine the sample plot size, items subject to measurement and desirable survey processes. The survey involved the establishment of sample plots for a total cruise and natural regeneration survey. In addition, the recorded items included plot access from the survey base and the time and manpower required to establish a sample plot and to complete tree measurement. A rectangular sample plot shape was decided and 2 sizes, i.e. 1.0 ha (40 m × 250 m) and 0.5 ha (40 m × 125 m), were introduced to reflect the stand conditions of boreal forests in a reasonably accurate manner. For each plot, sub-plots of 0.1 ha (20 m × 50 m) each were established to provide useful data to determine the appropriate sample plot size. A total cruise was conducted for each sample plot, following a survey on the general natural environment of the areas containing the sample plots.

It was decided that the subject trees of the total cruise would have a minimum DBH of 10 cm and the measurement items were species type, DBH, tree height and tree quality. The following 3 tree quality classes were introduced, mainly based on the trunk state.

- Class 1 : Straight, faultless healthy tree
- Class 2 : Usable to a certain extent despite some faults
- Class 3 : Unusable due to faults

In regard to the natural regeneration survey, a survey belt of 10 m × 20 m was established at the halfway point of the sample plot and the number of saplings with a DBH of less than 10 cm in the belt was counted.

The work process survey was conducted by dividing the work processes as follows.

- Survey base to dropping point (DP):
  Travelling time by vehicle

- DP to access point (AP):
  Walking time from DP to AP
- AP to starting point of sample plot (SP):
  Time required for clearing and surveying work from AP to SP
- SP to end point of sample plot (EP):
  Time required for clearing and surveying work from SP to EP
- Time required to complete the work to establish a sample plot
- Time required to measure the trees in the plot
- Time required to complete the regeneration survey

2) Preparatory Survey Findings

A preparatory survey for the sample plot survey was conducted at 7 plots. As any sample plot in a mountain forest in the southern part of the Intensive Area is located some 31 - 34 km from Hond, the access time took up approximately half of the day's working time. In the case of a sample plot in the northern part of the Intensive Area, the corresponding ratio was approximately one-quarter. It was, therefore, necessary to establish an advance base to deal with mountain forests in the south.

In principle, the sample plot survey was conducted for 8 hours day. Having taken the time required to establish an advance base and the weather conditions into consideration, the number of plots to be worked on per day was set at 0.8 - 0.9 plots.

(2) Design of Sample Plot Survey

1) Number and Size of Sample Plots

The access conditions in the Model Areas are poor, resulting in a longer access time than other sites. At these sites, the adoption of a larger sample plot size is desirable in order to reduce the number of plots. In regard to the forest physiognomy, the total cruise requires a long time in the case of a young stand where the number of trees is large. In the case of an old stand with a lower number of trees, a larger sample plot size for the total cruise is expected to decrease the variation coefficient and to improve the representative value of the sample plot. Therefore, based on the volume of the sample plot identified by the preparatory survey, the required number of plots for the inventory survey was calculated using the simple random sampling method with the following equation, assuming reliability of 95% and relative error of 15%.

$$n \gtrsim (tcs/E)^2 = (2 \times c \times 1.2/0.15)^2$$

n	:	number of samples	t	:	reliability factor
c	:	variation coefficient	s	:	safety factor
E	:	estimated relative error			

The variation coefficient was calculated by the following equation using the volume identified by the preparatory sample plot survey.

$$c = s/v$$

s : standard deviation of samples   v : sample average

The results of the trial calculations using the results of the preparatory survey are given in Table 54 for 3 different sample plot sizes, i.e. 1.0 ha, 0.5 ha and 0.2 ha.

Table 54 Relationship between Sample Plot Size and Number of Samples

Item	Unit	Sample Plot Size (ha)		
		1.0	0.5	0.2
Average Volume	m^3	214.787	98.760	40.196
Standard Deviation of Samples	m^3	78.913	43.679	21.800
Variation Coefficient		0.37	0.44	0.54
Number of Sample Plots		35	50	75

Taking the expected survey duration and survey processes for inventory survey into consideration, a sample plot size of 0.5 ha (40 m × 125 m) for some 50 sample plots is deemed appropriate.

2) Sampling Method

It appears possible to stratify both Model Areas into at least 3 forest physiognomy categories, i.e. coniferous forests (*Pinus sylvestris* forests, *Larix sibirica* forests and *Pinus sylvestris/Larix sibirica* forests), broad-leaved forests and mixed forests, as well as forest types using aerial photographs. As similar surveys in the past have proved that the stratified random sampling method provides better efficiency and better accuracy than the simple random sampling method, it appears reasonable for the stratified random sampling method to be used for the sample plot survey.

Forests in the Model Areas consist of hill forests and mountain forests. As it is judged appropriate to use vertically long sample plots for mountain forests, many of which are located on slopes, the sample plot shape is a vertically long rectangle for all plots.

(3) Inventory throughout Model Areas

1) Number and Location of Sample Plots

Having examined the design of the sample plot survey, the number of sample plots was decided to be 62. The breakdown of the sample plots by forest physiognomy category is shown in Table 55.

Table 55 Breakdown of Sample Plots by Forest Physiognomy Category

Secondary Category	Tertiary Category	Symbol	Number of Sample Plots		
			Model Area 1	Model Area 2	Total
Coniferous Forest	Pine Forest	NP	15	4	19
	Larch Forest	NL		6	6
	Pine/Larch Forest	N		6	6
Mixed Forest		M	1	17	18
Broad-Leaved Forest		L	3	10	13
All Forest Land			19	43	62

The locations of the sample plots are shown in Fig. 32 (Model Area 1) and Fig. 33 (Model Area 2).

2) List of Sample Plot Survey Results

The sample plot survey results are compiled in terms of the average DBH, average tree height, number of trees/ha and volume/ha (See Table 56).

3) Main Plants Found in Sample Plot Survey

The main plants found in the sample plot survey are compiled in terms of the degree of dominance of a certain tree species and their utilisation for each of the 4 different types of forest dominated by *Larix sibirica*, *Pinus sylvestris*, *Betula platyphylla* and *Populus tremula* respectively (see Appendix 8).

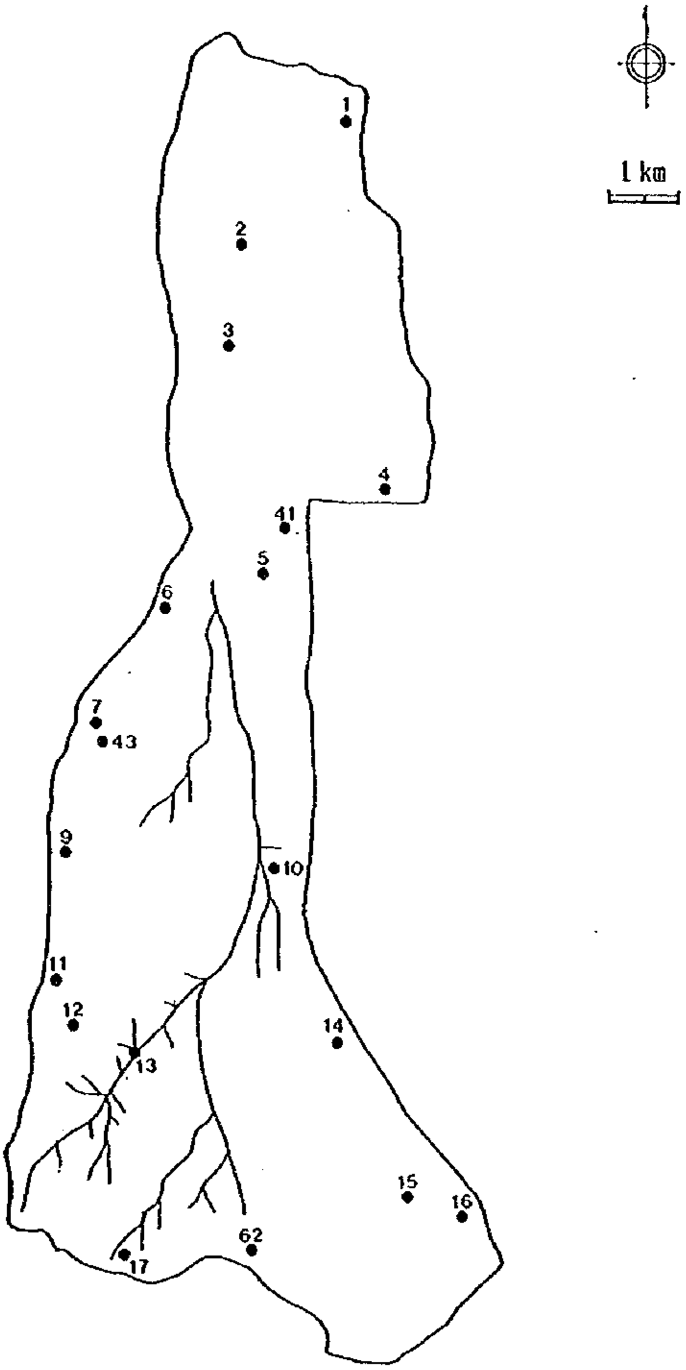


Fig. 32 Sample Plot Locations in Model Area 1

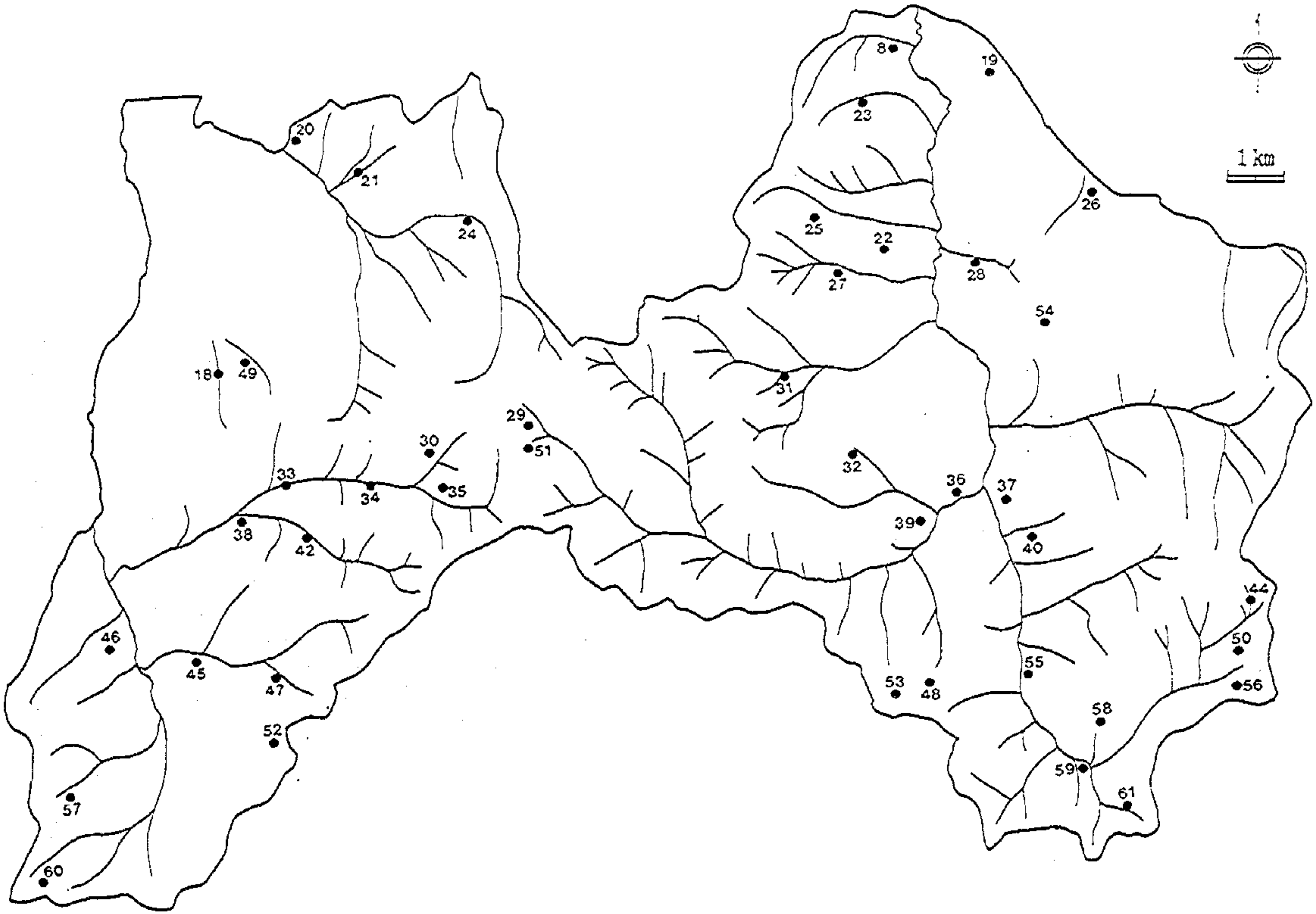


Fig. 33 Sample Plot Locations in Model Area 2

Table 56 List of Sample Plot Survey Results

Plot No.	Model Area	Forest Type			Density	DBH	Average Height	Total Volume
			H	D	(/ha)	(cm)	(m)	(m³/ha)
1	1	NP	2	3	278	25	14	106.852
2	1	NP	2	2	464	21	13	129.764
3	1	NP	2	2	730	18	13	185.904
4	1	NP	2	3	308	20	13	90.394
5	1	NP	2	1	922	18	17	266.318
6	1	M	2	2	1,008	15	12	173.188
7	1	NP	1	1	594	23	16	303.352
8	2	M	2	2	584	15	12	102.262
9	1	L	2	1	1,010	14	12	142.896
10	1	NP	2	2	606	19	15	177.364
11	1	L	2	1	682	15	11	120.514
12	1	L	2	1	438	22	13	162.408
13	1	NP	2	2	428	22	16	206.324
14	1	NP	3	2	1,008	14	10	112.210
15	1	NP	2	1	1,544	13	15	201.454
16	1	NP	2	2	1,038	14	13	140.604
17	1	NP	1	1	488	25	17	289.610
18	2	NP	2	2	346	28	16	199.244
19	2	NP	3	3	346	16	9	77.978
20	2	NP	2	2	518	19	14	141.844
21	2	M	2	1	368	22	15	150.378
22	2	L	2	1	788	15	14	144.908
23	2	NP	1	2	404	24	16	279.328
24	2	M	2	1	510	20	13	189.192
25	2	M	1	2	468	20	14	207.830
26	2	L	2	1	326	19	12	110.118
27	2	N	1	2	316	30	18	326.248
28	2	L	3	1	362	16	16	90.148
29	2	M	2	2	648	17	13	175.834
30	2	N	1	2	624	19	12	216.158
31	2	NL	1	1	404	26	18	339.188
32	2	L	2	2	324	20	12	110.270
33	2	L	2	1	888	14	10	126.858
34	2	M	1	2	640	23	16	298.584
35	2	N	2	2	486	22	13	219.712
36	2	L	2	2	394	15	12	71.096
37	2	NL	2	2	420	24	14	258.404
38	2	M	2	1	568	19	14	184.276
39	2	M	2	2	408	22	15	221.726
40	2	M	2	2	390	18	12	121.554
41	1	NP	2	1	910	18	16	237.124
42	2	M	1	1	640	20	15	273.946
43	1	NP	1	3	164	44	21	277.110
44	2	NL	1	1	578	21	15	296.598
45	2	L	2	1	696	17	13	155.752
46	2	L	2	1	996	16	13	182.188
47	2	N	1	2	422	26	15	341.914
48	2	M	2	1	586	18	14	183.548
49	2	L	2	2	450	17	11	84.274
50	2	NL	1	2	436	23	14	262.766
51	2	M	2	2	446	24	14	235.098
52	2	M	2	2	478	20	12	183.496
53	2	M	2	2	464	21	14	200.878
54	2	L	2	2	476	18	12	133.202
55	2	M	2	3	352	21	13	143.776
56	2	M	2	2	658	17	14	222.098
57	2	NL	1	1	468	23	16	281.062
58	2	N	1	2	362	28	16	279.870
59	2	M	2	2	602	19	13	226.578
60	2	NL	2	2	354	24	16	238.324
61	2	N	1	2	438	23	15	243.422
62	1	NP	2	1	278	30	14	202.360

Note: The inventory results of locations are as shown in Appendix 9.

(4) Estimation of Volume

1) Volume/ha by Forest Physiognomy

Based on the sample plot survey results, the volume/ha was calculated for each forest physiognomy category as shown in Table 57.

Table 57 Volume/Ha by Forest Physiognomy Category

(Unit: m^3)

Secondary Category	Tertiary Category	Symbol	Average	Largest	Smallest
Coniferous Forest	Pine Forest	NP	190.797	303.352	77.978
	Larch Forest	NL	279.390	339.188	238.324
	Pine/Larch Forest	N	271.221	341.914	216.158
Mixed Forest		M	194.125	298.584	102.262
Broad-Leaved Forest		L	125.741	182.188	71.096
All Forest Land			194.479	341.914	71.096

2) Estimation of Volume by Forest Physiognomy Category

By adding the volume of each forest physiognomy category based on the sample plot survey and aerial photo interpretation, the volume by each forest physiognomy category was estimated as shown in Table 58.

Table 58 Estimation of Gross Volume by Forest Physiognomy Category

(Unit: m^3)

Secondary Category	Tertiary Category	Symbol	Model Area 1	Model Area 2	Total
Coniferous Forest	Pine Forest	NP	680,140	308,170	988,310
	Larch Forest	NL		335,480	335,480
	Pine/Larch Forest	N		356,020	356,020
Mixed Forest		M	212,990	1,311,930	1,524,920
Broad-Leaved Forest		L	147,480	798,180	945,660
All Forest Land			1,040,610	3,109,780	4,150,390

3) Verification of Gross Volume

Using the simple random sampling method, the gross volume for Model Areas 1 and 2 is estimated here. Firstly, the average volume ($\bar{y}$) per ha of the sample plots is estimated to be 194.479 m^3 based on Table 57. The estimated sample variance value of this average volume is given as follows.

$$S^2 = \sum_{i=1}^{n}(y_i - \bar{y})^2/(n-1) = 5{,}013.457$$

where,

s^2	:	variance (sample variance) of average volume
y_i	:	volume per ha of sample plots
$\bar{y}$	:	average volume
n	:	number of sample plots

As the number of sample units (N) in the population is sufficiently large, the sample extraction ratio ($n/N = f$) is extremely small. Accordingly, the standard error ($s\bar{y}$) of the average volume of the sample plots can be calculated by the following equation.

$$s\bar{y}^2 = \{(N - n)/N\} \times s^2/n = (1 - f) \times s^2/n$$

$$s\bar{y} = \sqrt{1-f} \times s/\sqrt{n} = 1 \times \sqrt{5{,}013.457}/\sqrt{62} = 8.992$$

Assuming that the value of t (α, n - 1) is the value at a level of significance of $\alpha = 0.05$ with a degree of freedom of (n - 1), the confidence interval of the average volume of the sample plots ($\bar{y} \pm t(\alpha, n-1) \times s\bar{y}$) is calculated by the following equation.

$$\bar{y} \pm t(\alpha, n-1) \times s\bar{y} = 194.479 \pm 1.999 \times 8.992$$
$$= 194.479 \pm 17.975$$

In turn, the confidence interval of the gross volume (Va) is calculated as follows.

$$Va = 23{,}299 \text{ ha} \times (194.479 \pm 17.975)\ m^3$$
$$= 4{,}531{,}167\ m^3 \pm 418{,}800\ m^3$$

The relative error is calculated as follows.

$$e = (t(\alpha, n-1) \times s\bar{y}) \div \bar{y} \times 100$$
$$= 17.975/194.479 \times 100 = 9\%$$

The above relative error of 9% satisfies the relative error of 15% set at the sampling design stage.

The results of the analysis to determine whether or not the estimated volumes of Model Area 1 and Model Area 2 calculated in 2) above fall within the confidence interval of the gross volume calculated in 1) above are described below.

- Gross volume by adding the volume of each forest physiognomy category (Vb) : 4,150,390 m^3

- Gross volume by sample plot survey (Va) : 4,112,367 m^3 < Va < 4,949,967 m^3

The above 2 figures suggest that the value of Vb is within the range of target accuracy (Va) as originally planned.

(5) Preparation of Stand Volume Table

In order to prepare the forest inventory book, the volume/ha for each forest physiognomy was estimated by using the results of the sample plot survey. The estimation was conducted by regression and concluded with the provisional preparation of stand volume tables, although the number of the data for the regression was very small.

For the regression, the following formula was adopted. The dependent variable is the volume/ha for each forest physiognomy while the average tree height and crown density class are applied as independent variables.

$$Y = aX_1 + bX_2 + c$$

Y : volume/ha (m^3) a, b, c : Coefficients
X_1 : average tree height (m)
X_2 : crown density class

The data used for the regression were combined when those are too small to acquire the rational results. In that case, similar categories of forest physiognomy were put together. The data composition and the regression results are listed in Table 59.

Table 59 Regression Results for Stand Volume Table

Forest Type	Symbol	Data Composition	Correlation Coefficient	a	b	c
Pine Forest	NP	NP	0.89	16.93654	-37.35913	-36.14413
Larch Forest	NL	NL, L	0.97	25.62222	-30.38136	-212.99880
Pine/Larch Forest	N	N, NP, NL	0.92	19.20838	-36.07226	-75.12303
Broad-Leaved Forest	L	L	0.91	19.26609	-34.92365	-114.61709
Mixed Forest	M	M	0.91	22.04127	-16.26007	-184.73216

After all, the following two-way volume table for stand volume of natural forests was prepared by using the said regression results. The values given in the Table 60 was applied for the preparation of the forest inventory book as standard values.

Table 60 Stand Volume Table for Each Forest Physiognomy of Natural Forests

Forest Typo	NP				NL				N				L				M			
	Crown Density Class				Crown Density Class				Crown Density Class				Crown Density Class				Crown Density Class			
Ave.H(m)	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
5				10																
6				30																
7				40								20								
8			20	60								40								
9			40	80							20	60				20				
10		20	60	100				10			40	80				40				20
11		40	80	120				40		30	70	110			30	60			20	40
12	10	60	100	140			30	70	10	50	90	130		10	50	80	10	30	50	60
13	30	70	120	160		30	60	90	30	70	110	150		30	70	110	40	50	70	90
14	50	90	130	170	20	60	90	120	50	90	130	170	10	50	90	130	60	80	100	110
15	70	110	150	190	50	80	120	150	70	110	150	190	30	70	110	150	80	100	120	140
16	90	130	170	210	80	110	140	180	90	130	170	210	50	90	130	170	110	130	140	160
17	110	150	190	230	110	140	170	210	110	150	190	230	80	110	150	190	130	150	170	190
18	130	170	210	250	130	170	200	230	130	170	210	250	100	140	170	210	160	170	190	210
19	140	190	230	270	160	200	230	260	160	190	230	270	120	160	190	230	180	200	220	230
20	160	200	250	290	190	220	260	290	180	220	260	300	140	180	220	250	210	220	240	260
21	180	220	260	310	220	250	290	320	200	240	280	320	160	200	240	280	230	250	270	280
22	200	240	280	320	250	280	310	350	220	260	300	340	180	220	260	300	250	270	290	310
23	220	260	300	340	280	310	340	380	240	280	320	360	200	240	280	320	280	300	310	330
24	240	280	320	360	300	340	370	400	260	300	340	380	220	260	300	340	300	320	340	360
25	260	300	340	380	330	370	400	430	280	320	360	400	250	280	320	360	330	340	360	380
26	280	320	360	400	360	390	430	460	300	340	380	420	270	300	340	380	350	370	390	400

5.4 Stand Structure Survey

(1) Structure of Natural Forests

In order to understand the stand structure of natural forests, a survey was conducted together with classification based on stand similarity, in turn determined by the cumulative curve of the number of trees established for each plot using the inventory data (see Fig. 34 through Fig. 37).

The forest physiognomy categories used are coniferous forests (minimum ratio of coniferous trees: 75%), broad-leaved forests (minimum ratio of broad-leaved trees: 75%) and mixed forests (the ratio of either coniferous trees or broad-leaved trees is more than 25% but less than 75%). Moreover, categories of *Pinus sylvestris* forests and *Larix sibirica* forests are also introduced to describe coniferous forests in which the ratio of *Pinus sylvestris* or *Larix sibirica* is 60% or more.

1) Coniferous Forests

a) *Pinus sylvestris* Forests

As the *Pinus sylvestris* forests distributed in Model Area 1 and Model Area 2 have a complex structure due to repeated forest fires and cutting in the past while they show straight trunks, tree group formation and unstanding spots as well as dense growth of small and medium diameter trees. They are mainly classified into types P1 through P4 and to P5 which is exceptional (see Fig. 34).

The P1 type corresponds to forests found in both model areas. It is a multiple-layered forest in which large, medium and small diameter trees of *Pinus sylvestris* grow at the density of about 140 trees/ha and medium and small diameter trees of *Betula platyphylla* and *Populus tremula* grow in mosaic intrusion at the density of about 80 trees per hectare. While the stand volume is relatively large owing to the existence of large diameter trees, *Pinus sylvestris* trees having qualitative defects such as bark pockets and cavity account for 19% of the volume. Among broadleaved trees, trees having qualitative defects such as bend and cavity account for about 54% of the volume of broad-leaved trees.

Growth of seedlings and saplings of *Pinus sylvestris* (tree height more than 0.3 m and DBH less than 9 cm) is well in some areas and poor in other areas.

Saplings of broad-leaved species are growing in areas where the pine growth is poor.

The P2 type comprises pure forest of *Pinus sylvestris* that are disributed in Model Area 1. It has less large diameter trees and more small and medium diameter trees than the P1 type. About 380 trees are growing per hectare. The volume is small because of the limited number of large diameter trees. However, it is an excellent stand with trees having qualitative defects accounting for about 9% of the volume. Seedlings and saplings of *Pinus sylvest*ris is growing well in some areas and poor in other areas.

The P3 type is found in Model Area 1 and is a stand close to pure forest of *Pinus sylvestris* comprised mainly of small and medium diameter trees because large and medium diameter trees have been cut in the past. It has about 770 *Pinus sylvestris* trees as opposed to 20 broad-leaved trees per hectare. Seedlings and saplings of *Pinus sylvestris* often shows good growth sites in mosaic fashion. Growth of broad-leaved trees are poor. The volume ranks second after P1 type because of the large number of tree growth and trees having qualitative defects account for about 12% of the volume. In the case of stands of this type, it is necessary to conduct selective cutting, mainly of small and medium diameter trees, to encourage the thickening growth of *Pinus sylvestris*.

The P4 type is distributed in Model Area 1 and mainly consists of small diameter trees. Number of trees per hectare for *Pinus sylvestris* is 1,140, which is excessive, and about 60 for broad-leaved trees. The volume is low but trees having qualitative defects are also low at 7%. Growth of seedlings and saplings is poor because small diameter trees dominate the forest floor. In the case of stand of this type, it is important to conduct thinning as well as selective cutting of small diameter trees to encourage thickening growth. For this reason, there is a need to develop means of utilizing small to medium diameter trees.

The P5 type represents exceptional stands that appears like single layer forest because *Pinus sylvestris*, many of which are old, large diameter trees, take up the upper canopy layer while young trees that are 2 to 5 m high take up the lower canopy layer of the stands. The stands of this type appear to be hardly affected by cutting, number of small and medium diameter trees is small and the growth of seedlings and saplings is poor. However, the volume is relatively large owing to presence of large diameter trees.

b) *Larix sibirica* Forests

The *Larix sibirica* forests distributed in Model Area 2 have a stand structure of the upper canopy layer of *Larix sibirica*, the middle and lower canopy layers of *Larix sibirica* and broad-leaved trees and brushes of *Rhododendron dahuricum* growing on the forest bed. While the number of *Larix sibirica* is generally small at 180 trees per hectare as opposed to 230 trees per hectare of broad-leaved trees The volume is large in the Model Areas due to the presence of large diameter trees. However, trees having qualitative defects account for as much as 31% of conifer inventory. Seedlings and saplings of *Larix sibirica* have not only grown very little but its seedlings and saplings have not grown even in areas where they are mixed with *Pinus sylvestris*. Meanwhile, seeldings and saplings of broad-leaved trees are growing relatively well (see Fig. 35).

c) Coniferous Forests

Stands in which *Pinus sylvestris* and *Larix sibirica* are mixed with broad-leaved trees found in Model Area 2. As in a *Larix sibirica* forest, the upper canopy layer is dominated by coniferous trees while the middle and lower layers consist of both coniferous and broad-leaved trees, although mixture of broad-leaved trees is less in the lower layer compared to *Larix sibirica* forest. A larger percentage of *Pinus sylvestris* or *Larix sibirica* makes little no conspicuous difference in terms of type. The number of coniferous trees is about 210 trees per hectare in contrast to about 160 broad-leaved trees, which is generally small compared to *Larix sibirica* forest. The volume is relatively large among various stand types in the Model Area 2 due to the presence of large diameter trees, although trees having qualitative defects account for nearly 26% of coniferous tree volume. Seedlings and saplings and young trees of coniferous trees have generally not grown even though they are scattered in areas where they mix with *Pinus sylvestris*. Broad-leaved trees are growing relatively well as in the case of *Larix sibirica* forest.

2) Mixed Forests of Coniferous and Broad-leaved Trees

These are forests in which *Pinus sylvestris*, *Larix sibirica* and/or broad-leaved trees are mixed from the upper to the lower layers and are found in Model Area 2. Depending on the number of large diameter trees growing, the relevant stand is classified into either M1 or M2. M1 type accounts for the vast majority (see Fig. 37). Upper canopy layer is dominated by coniferous trees, middle canopy layer mostly consists of coniferous trees and broad-leaved trees and lower canopy layer is mostly taken up by broad-leaved trees. The number of trees per hectare is small for coniferous trees at 120 in contrast to large number of broad-leaved trees which is about 400. The volume is small owing to small number of large diameter coniferous trees and large number of small diameter broad-leaved trees. Trees having qualitative defects account for nearly 22% of inventory for coniferous trees and 26% of broad-leaved trees.

Almost of seedlings and saplings of coniferous trees do not grow, while broad-leaved trees, mainly *Betula platyphylla*, grow relatively better.

In contrast to the M1 type, the M2 type has hardly any large diameter coniferous trees and is mainly comprised of small and medium diameter broad-leaved trees. The number of trees per hectare is about 110 for coniferous trees and about 430 broad-leaved trees. The volume is small owing to small number of large diameter coniferous trees. Trees having qualitative defects account for nearly 17% of the volume for coniferous trees and 36% of that for broad-leaved trees. The growth of seedlings and saplings is same as that in the M1 type. There are also exceptional stands in which coniferous trees are scattered in the upper canopy layer (about 40 trees per hectare) and about 850 broad-leaved trees are growing per hectare in the middle and lower layers.

3) Broad-leaved Forests

These forests consist of *Betula platyphylla* and *Populus tremula* together with a small number of scattered coniferous trees and are found in both Model Areas. Many stands of this type have a canopy consisting of small to medium diameter trees, reflecting the damage caused by forest fires in the past, and some scattered medium to large diameter trees with qualitative defects that have survived forest fires and are seen above the said canopy. Depending on the stands containing large diameter trees and the number of small and medium diameter trees, there are 4 main types from B1 to B4, indicating the complexity of the stand as in the case of *Pinus sylvestris* forest. The B1 type and the B2 type are common (see

Fig. 38). As many broad-leaved species do not grow large and the number of growing trees is relatively small, the volume is extremely low.

The B1 type is found in the Model Area 2 and has scattered large diameter trees. The number of small diameter trees is relatively small with about 370 trees per hectare. Trees having qualitative defects account for nearly 54% of the volume. In particular, *Betula* spp. have many trees with qualitative defects including forked stems as well as bark pockets and cavity caused by forest fire.

The B2 type has less medium diameter trees but more small diameter trees compared to the B1 type. Stands of this type are found in both Model Areas. The number of trees per hectare is about 720 and trees having qualitative defects account for about 36% of the inventory.

The B3 type is found in both Model Areas. Stands of this type are quasi single-layered forest mostly comprised of small diameter trees with some scattered medium diameter trees. The number of trees per hectare is large at 1,000 while trees having qualitative defects goes down to about 23% of the volume.

The B4 type refers to stands with limited small diameter trees that are found in both Model Areas. The number of trees per hectare is 420. The percentage of trees having qualitative defects is 58%, which is high considering the limited number of large diameter trees.

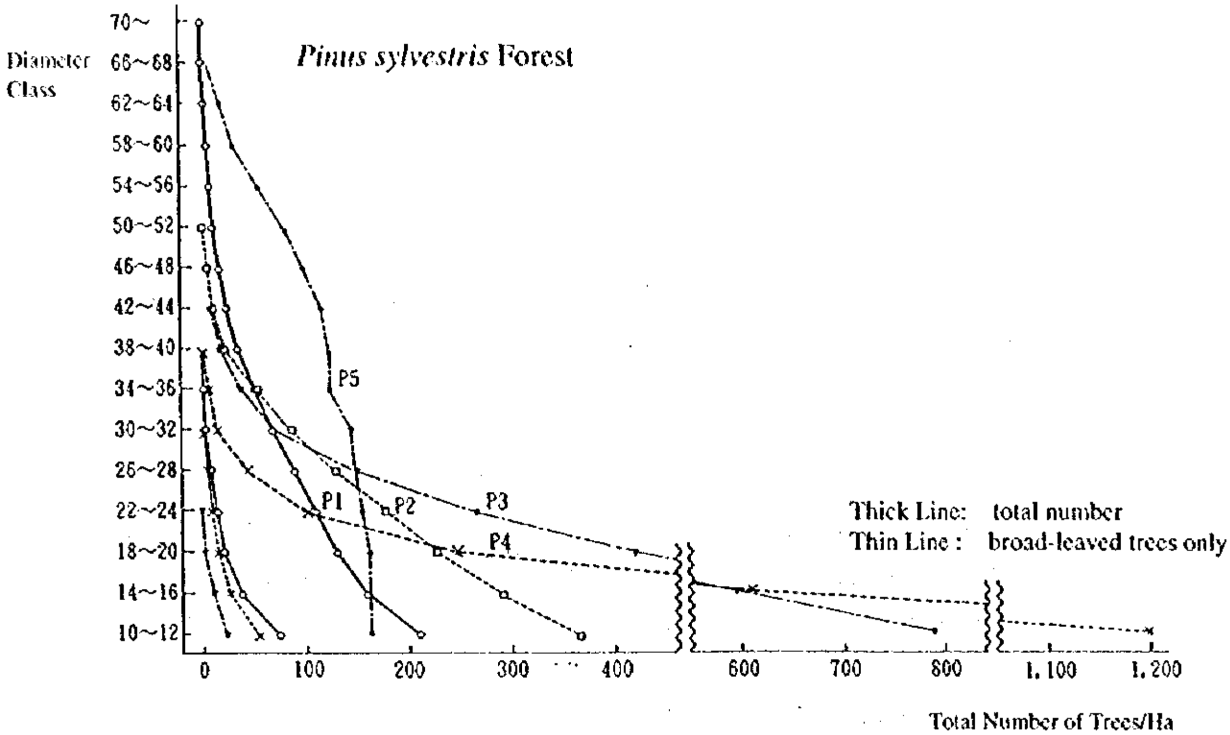


Fig. 34 Forest Type (*Pinus sylvestris* Forest)

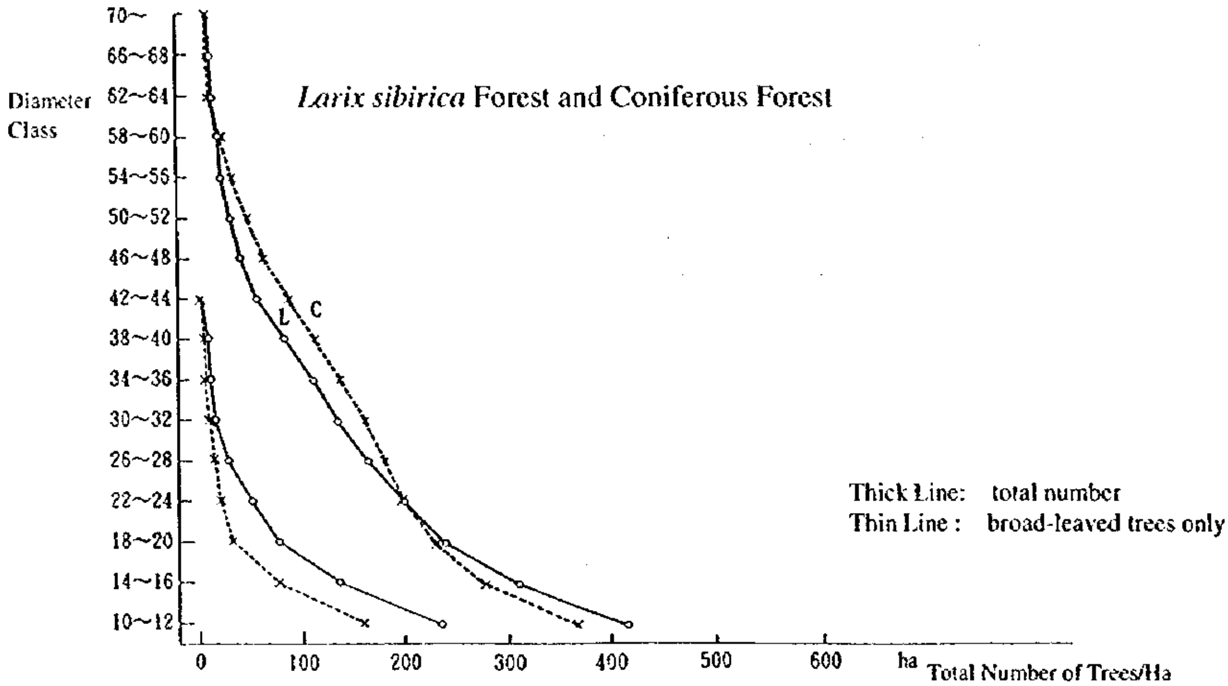


Fig. 35 Forest Type (*Larix sibirica* Forest and Coniferous Forest)

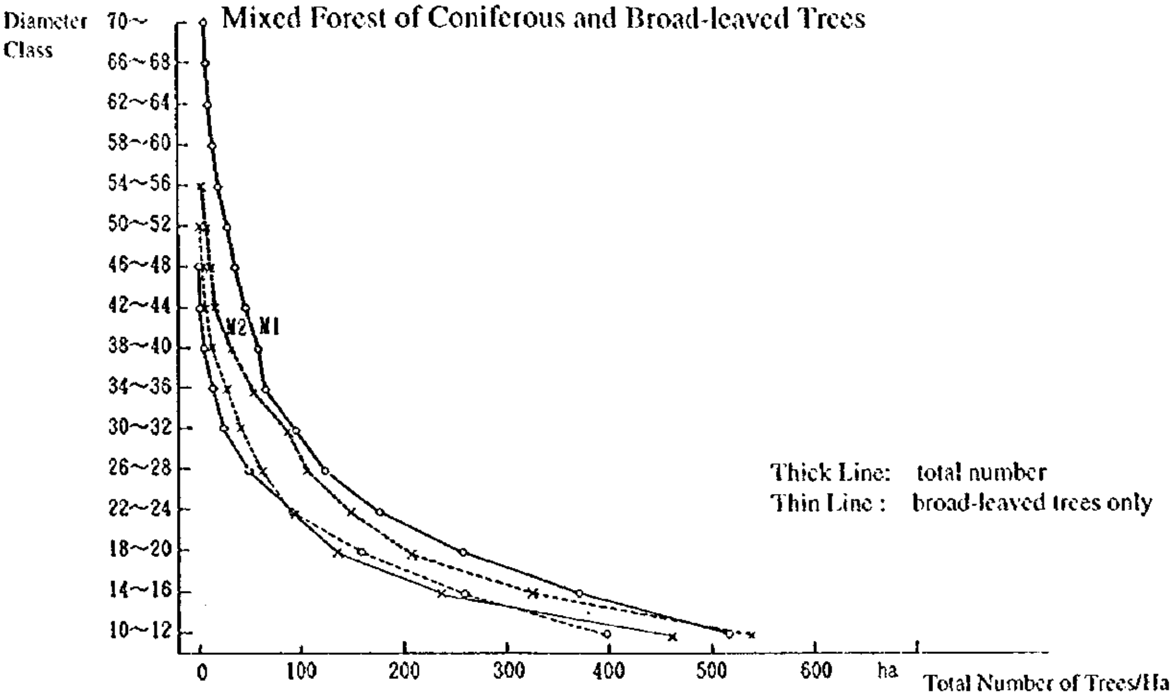


Fig. 36 Forest Type (Mixed Forest of Coniferous and Broad-leaved Trees)

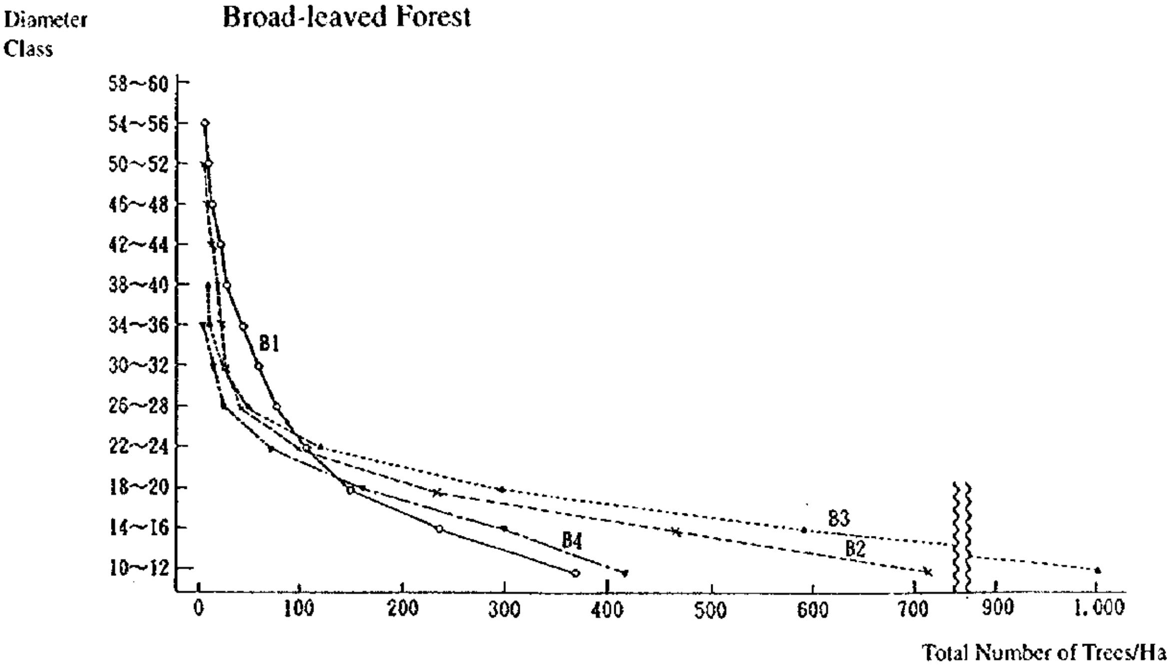


Fig. 37 Forest Type (Broad-leaved Forest)

(2) Growth of *Pinus sylvestris*

1) Growth State of Natural Trees

A general picture of the growth of a tree can be reasonably inferred by surveying the annual ring structure of the stump. The growth of the annual ring is generally determined by such environmental factors as the climate and distance between trees and the growth characteristics specific to the age of the particular tree. A survey was conducted on the correlation between the growth of the annual ring and age by examining 57 stumps of *Pinus sylvestris* just after selective cutting in a hill *Pinus sylvestris* forest growing in the sandy soil in and around Model Area 1. All of these trees once formed the upper crown of natural forests.

The ring growth by decade is shown in Fig. 38 while the correlation between ring growth and tree age observed from the stumps is shown in Fig. 39. The survey results suggest specific growth relationship between the annual ring growth by decade and tree age. The growth is slow upto the age of around 20. In the next period between 20 and 50 years of age, the growth is the fastest, followed by a period of gradual decline and further slow growth after 120 years of age. The correlation between the age of individual trees and the growth of the annual ring is weak. This is explained by the facts that a natural forest tends to consist of densely populated areas and virtually tree-less spots and that the relative location of the trees which is often altered due to gaps created by windfalls affects individual trees in either an advantageous or disadvantageous manner. Moreover, the increased competition between trees due to trend toward a decline of tree growth at a certain age also contributes to the weak correlation mentioned above.

While data on the tree age and DBH are unavailable, the inferred tree growth in the period between 70 and 120 years of age based on the survey results is an increase of 10 cm (DBH) in 28 years. (The growth of the radius in a decade is found to be approximately 1.8 cm.)

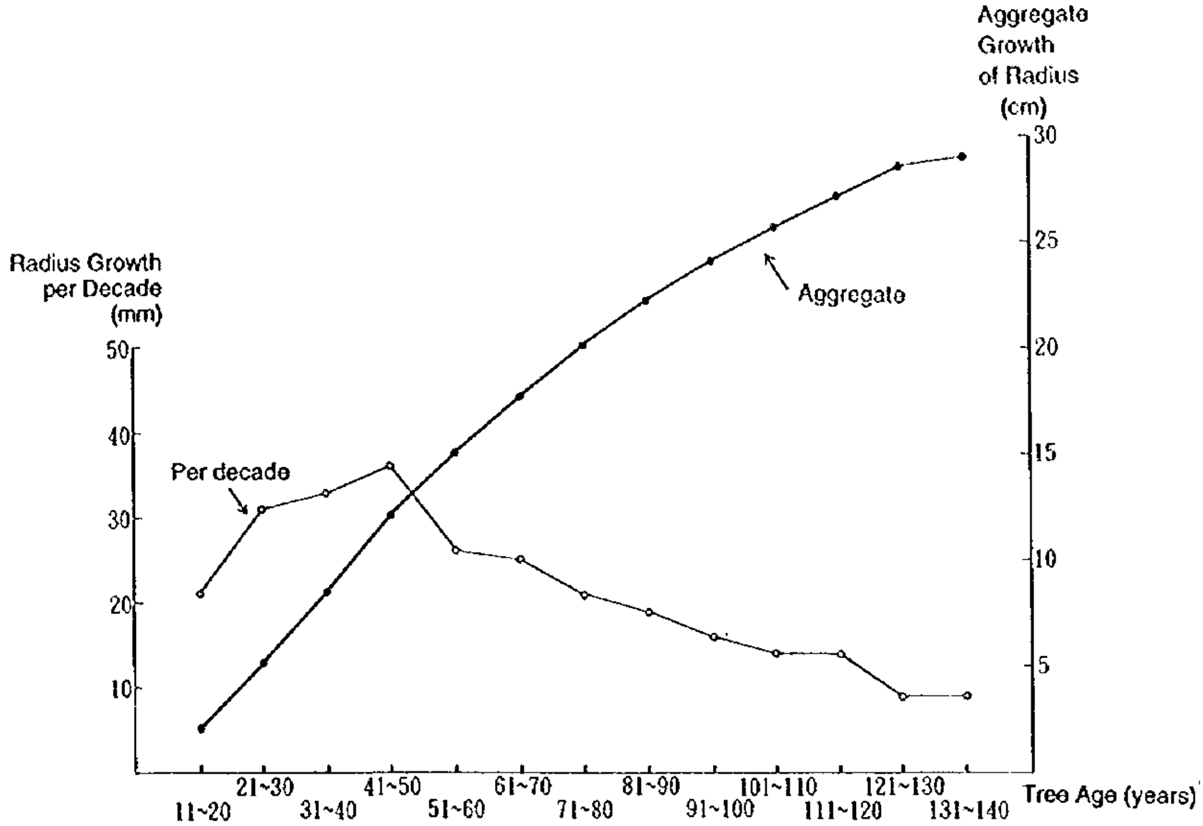


Fig. 38 Growth of Annual Ring by Decade of Stumps of *Pinus sylvestris*

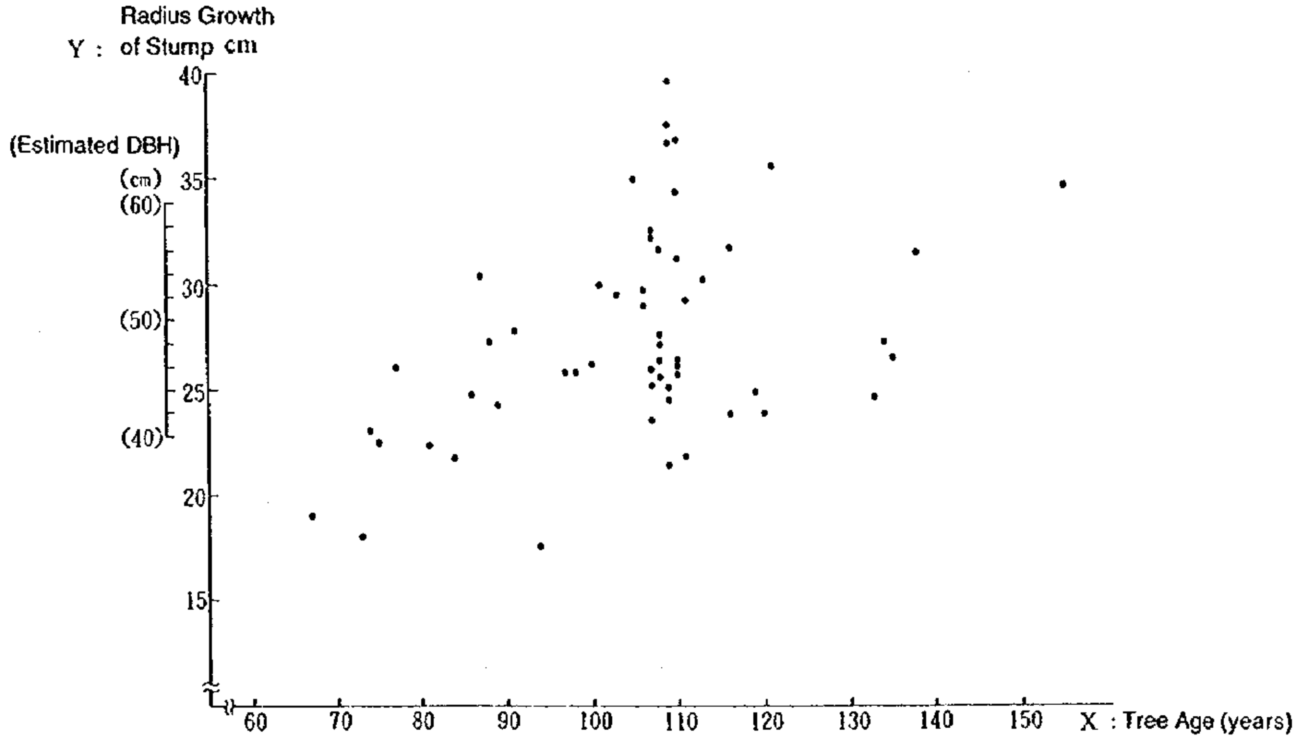


Fig. 39 Growth of Annual Ring of Stumps of *Pinus sylvestris*

2) Growth Status of Planted Trees

Pinus sylvestris afforestation sites cover seriously damaged areas by forest fire and logged-over areas. Survey plots were established at Model Area 1 and the vicinities in order to investigate the growth condition of planted trees of *Pinus sylvestris*.

In general, the number of growing planted trees is less than 1,000 trees/ha as shown in Table 61 and assessed to be very small in terms of the stand age assuming that the standard *planting* density was some 3,000 trees/ha. With the limited prospect, it is unlikely that these sites will become productive forests in the near future. Some sites could be expected to have good prospects, however, with naturally regenerated *Pinus sylvestris* trees being added to the grown trees.

The planting is mainly conducted during the beginning and middle of May. According to the survey results on survival rate of afforested sites by *Pinus sylvestris* planted a year and a half ago, the planting density at the time of planting was estimated as 2,137 trees/ha amounting to 71% of the standard planting density (3,000 trees/ha).

Those trees consist of; 550 trees/ha (26%) that are surviving, 313 trees/ha (15%) that have yellow leaves and are not sure to survive, and 1,273 trees/ha (59%) that are dead. The survival condition is extremely low and could not form productive forests presumably. The fact that the planting density at the time of planting is lower than the standard one would be due to the difficulty of land preparation inside strips of 3 - 5m width caused by obstacles such as stumps against tractors' working.

The tree heights of planted trees are lower than the ones of naturally regenerated trees among grooves on the whole. The latter ones have wider range of tree heights.

Some of the planted trees are damaged by frost and their growth is stagnant as the terminal buds are killed by frost. Others have double summits. Furthermore, trees with bent trunks due to heavy snow in June, 1990 are observed here and there.

Table 61 State of Tree Growth at Afforestation Sites

Plot No.	Defunct Compartment	Year of Planting	Planted *Pinus sylvestris* trees			Naturally Regenerated Trees				Total of *Pinus sylvestris*		Remarks
						Pinus sylvestris		*Betula platyphylla*				
			No./ha	%	Height (cm)	No./ha	Height (cm)	No./ha	Height (cm)	No. of Trees	%	
9-1	1	1983	180	6	44/5~200	85	32/10~90	–	–	265	9	
9-2	1	1983	145	5	92/10~200	60	41/10~200	–	–	205	7	
1-1	5	1990	1,280	43	33/10~70	2,505	71/10~180	–	–	3,785	126	
1-2	5	1990	960	32	32/10~80	3,450	75/10~195	–	–	4,410	147	
2-1	5	1990	305	10	31/10~55	775	54/5~140	–	–	1,080	36	
2-2	5	1990	510	17	33/10~80	2,065	71/10~180	–	–	2,575	86	
6-1	18	1986	1,150	39	93/10~200	500	92/10~190	35	161/30~200	1,650	55	
6-2	18	1986	1,620	54	83/10~180	330	83/10~195	5	195/195	1,950	65	
3-1	31	1990	860	29	27/5~75	3,115	88/15~185	95	93/50~150	3,975	133	
3-2	31	1990	945	32	26/5~55	3,845	97/20~190	70	89/50~140	4,790	160	
4-1	31	1989	70	2	16/10~20	1,035	76/10~175	-	–	1,105	37	
4-2	31	1989	110	4	20/10~50	2,225	100/20~190	-	–	2,335	78	
5-1	32	1991	2,210	74	27/5~80	270	84/5~190	50	100/30~190	2,480	83	
5-2	32	1991	2,070	69	25/5~65	400	87/30~190	55	117/20~195	2,470	82	
7-1	128	1988	1,150	38	98/20~320	–	–	5	320/320	1,155	39	replanted site in 1985
7-2	128	1988	730	24	65/20~310	–	–	–	–	730	24	replanted site in 1985
8	127	1976	103	3	–	5	–	–	–	(412) 108	}17	number of trees in brackets was cut down due to forest fire damage

Note: ①Each plot (40m × 100m) is divided into 2 plots of 0.2ha each (40m along the planting grooves × 50m) except Plot No. 8. The survey was conducted in August of 1994.
②The percentage is the ratio to 3,000 planting density per ha.

The poor survival and growth of the planted *Pinus sylvestris* trees are presumably caused by ① land preparation method removing the surface soil by a plow, ② poor root growth of the seedlings and inappropriate handling, such as deep planting, at the time of planting, and ③ climatic damage by low temperature and snow. Against the climatic damage, it would be essential that the trees planted in the sandy soil of poor water holding capacity must be protected from the conditions comprising little rainfall, dry weather and strong wind and increased in survival.

5.5 Natural Regeneration Survey

(1) State of Regeneration of Natural Forests

The state of natural regeneration of natural forests was surveyed. As the species most commonly used to produce timber in Mongolia are *Pinus sylvestris* and *Larix sibirica*, the subject stands of the survey were decided to be coniferous stands and mixed stands of coniferous and broad-leaved trees. The survey method used was the establishment of a survey plot of 10 m by 40 m in each sample plot used for the volume survey and the division of this survey plot into 4 sub-plots (10 m by 10 m each) to count the number of seedlings (tree height of 30 cm or more but less than 1.3 m) and saplings (tree height of 1.3 m or more but a DBH of less than 9 cm). Seedlings (tree height of less than 30 cm) were ignored.

In compiling the survey findings, a distinction was made between those stands with *Larix sibirica* and those stands without *Larix sibirica*. The former were further divided into stands with a mixed ratio of *Pinus sylvestris* of at least 25% and stands with a mixed ratio of *Pinus sylvestris* of less than 25%, including 0%. (The classification results were not identical to the forest physiognomy categories established in the volume survey as these percentages only relate to the natural regeneration survey plots.) It was decided to describe the state of natural regeneration by indexing the number of saplings and young trees. The standard number of trees/ha corresponding to a regeneration index of 1.0 was then decided to be 3,000 for seedlings and 2,000 for saplings. (When the number of trees/ha exceeds the standard number, the regeneration index stays at 1.0. If the number of trees/ha is below the standard number, the index varies from 0.1 to 0.9 depending on the proportion of actual trees vis-a-vis the standard number.) (see Table 62 and 63)

1) *Pinus sylvestris* Stands

Pinus sylvestris stands and those with a small number of broad-leaved trees are found in both Model Areas. As the average regeneration index for *Pinus sylvestris* is 0.4. Those sub-plots with a regeneration index of 1.0 account for 21% of all sub-plots. The corresponding figure for plots is as low as 5%, indicating that natural regeneration is uneven. The natural regeneration of broad-leaved trees in timber utilizing stands cannot be said to be important at present as these trees are seldom utilised. Both the regeneration index and ratio of plots showing good natural regeneration of broad-leaved trees in *Pinus sylvestris* stand are low. On the other hand, at broad-leaved tree stands of which the regeneration index is 1.0, hardly any saplings or young trees of *Pinus sylvestris* are growing. In contrast, neither growth of broad-leaved trees nor natural regeneration of their seedlings and saplings is observed in *Pinus sylvestris* stand extending 2 - 3 km from the edge of grassland or farmland situated in the immediate north of Model Area 1.

2) *Larix sibirica* Stands

Larix sibirica grows in Model Area 2. At mixed stands of coniferous and broad-leaved trees where *Pinus sylvestris* account for 25% or more, the regeneration indices for *Larix sibirica* and *Pinus sylvestris* are 0.1 and 0.2 respectively (0.2 for combined species and a low regeneration level mainly at coniferous stands). The ratio of sub-plots of which the regeneration index for *Pinus sylvestris* stand is 1.0 is only 11% which is reduced to zero in terms of plots, indicating the extremely poor regeneration of coniferous trees. The regeneration of broad-leaved trees is relatively good as suggested by the relevant regeneration index of 0.6.

Table 62 State of Natural Regeneration

Stand Physiognomy Category	Item	*Larix sibirica*		*Pinus sylvestris*		*Coniferous* Trees			Broad-leaved Trees			Total
		Seedlings	Saplings	Seedlings	Saplings	*Larix sibirica*	*Pinus sylvestris*	Sub-Total	*Betula platyphylla*	*Populus tremula*	Sub-Total	
A (19 Plots)	Regeneration Plot Ratio (%)	-	-	(7) 0	(16) 5	-	(21) 5	(21) 5	(0) 0	(3) 0	(5) 0	(29) 5
	Regeneration Index	-	-	0.2	0.3	-	0.4	0.4	0.1	0.1	0.2	0.6
B (11 Plots)	Regeneration Plot Ratio (%)	0	0	(0) 0	(11) 0	(0) 0	(11) 0	(14) 0	(27) 0	(9) 0	(45) 18	(55) 27
	Regeneration Index	0.0	0.1	0	0.2	0.1	0.2	0.2	0.5	0.3	0.6	0.7
C (18 Plots)	Regeneration Plot Ratio (%)	0	0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(17) 6	(0) 0	(21) 6	(21) 6
	Regeneration Index	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.6	0.6

Notes
1) Stand Physiognomy Type
A : *Pinus sylvestris* forest or coniferous forest
B : Mixed stand of coniferous and broad-leaved trees (mixed ratio of *Pinus sylvestris*: 25% or more)
C : *Larix sibirica* stand or mixed stand of coniferous and broad-leaved trees (mixed ratio of *Pinus sylvestris*: less than 25)
2) Regeneration Plot Ratio: The ratio of plots with a regeneration index of 1.0 to all plots. Figures in brackets show the similar ratio for sub-plots to all sub-plots. The regeneration index remains 1.0 even if the combined index for seedlings and saplings exceeds 1.0.

Table 63 Regeneration Index for Natural Forests

Regeneration Index	Seedlings (Tree Height: 0.3 - 1.3 m)	Saplings (Tree Height: 1.3 m or more) (DBH: less than 9 cm)
1.0	3,000 or more/ha	2,000 or more/ha
0.9	2,700 - 3,000	1,800 - 2,000
0.8	2,400 - 2,700	1,600 - 1,800
0.7	2,100 - 2,400	1,400 - 1,600
0.6	1,800 - 2,100	1,200 - 1,400
0.5	1,500 - 1,800	1,000 - 1,200
0.4	1,200 - 1,500	800 - 1,000
0.3	900 - 1,200	600 - 800
0.2	600 - 900	400 - 600
0.1	300 - 600	200 - 400

Notes
1) The subject species are *Larix sibirica*, *Pinus sylvestris*, *Betula platyphylla* and *Populus tremula*.
2) Seedlings of which the height is less than 0.3 m are ignored.

Table 64 State of Growth of Naturally Regenerated *Pinus sylvestris* Seedlings and Saplings

Plot No.	Compartment No.	Location	Stand Age	No. of Trees/ ha (1,000)	Tree Height (cm)	Standard Deviation	DBH (cm)	Remarks
21	32	In *Pinus sylvestris* forest	7 / 6 ~ 8	51.6	60 / 10 ~ 120	19		*Pinus sylvestris* stand (Ave.D: 24cm, Ave.H: 18m)
22	32	Belt-shaped cut-over area	8 / 6 ~ 9	(0.6) 20.0	124 / 40 ~ 220	14		
23	7	Belt-shaped cut-over area	9 / 8 ~ 10	(0.3) 8.1	184 / 90 ~ 300	42		
24	1	Open stand by forest fire	15 / 13 ~ 17	42.4	194 / 100 ~ 410	62	1-5	
25	1	Open stand by forest fire	15 / 14 ~ 16	33.2	163 / 50 ~ 400	47	1-4	

Note: The compartment number refers to the old compartment.

In the case of *Larix sibirica* stands or mixed stands where the mixed ratio of *Pinus sylvestris* is less than 25%, the regeneration index is zero (0.0) with no sub-plot or plot with a regeneration index of 1.0. In contrast, the regeneration index of broad-leaved trees of 0.6 is relatively good. In regard to broad-leaved trees in coniferous stand and mixed stand of coniferous and broad-leaved trees, natural regeneration mainly takes place with *Betula platyphylla* and the regeneration performance of *Populus tremula* is poor.

The relatively poor natural regeneration of coniferous trees and relatively good regeneration of broad-leaved trees of *Larix sibirica* stands or mixed stands with *Larix sibirica* are assumed to be caused by repeated forest fires or cutting in the past. When exposed to a ground fire, coniferous trees fail to sprout once the terrestrial part is burnt or dead while *Betula platyphylla* and *Populus tremula* begin spouting and regenerating immediately. Therefore, forest fires tend to stimulate the regeneration of broad-leaved trees, deeming it likely that the lower layer is dominated by broad-leaved trees. This means that the cutting of *Larix sibirica* and/or *Pinus sylvestris* which form the upper canopy layer of a natural forest will lead to the creation of broad-leaved stands in cut-over and left areas, remaining as it is for some period.

(2) Growth Condition of Seedlings and Saplings of *Pinus sylvestris*

The seeds of *Pinus sylvestris* sprout in large numbers (in some hundreds of thousands size per ha) even after a forest fire if the fire is only as minor as a ground fire which burns the forest floor vegetation. The sprouted seedlings can continue to achieve height growth if the environmental conditions are suitable in terms of sunlight, soil moisture and rehabilitating forest floor vegetation. According to the findings of the survey in which sample plots of 0.01 ha each (10 m by 10 m) were established to examine the state of growth of naturally regenerated seedlings and saplings in Model Area 1, the number of seedlings and saplings at an open site (approximately 10 m by 20 m) of a hill forest of *Pinus sylvestris* is some 50,000/ha (average 8 years old with a tree height of 10 - 120 cm). In contrast, the figure of seedlings and saplings is 8,000 - 20,000/ha (average 10 years old with a tree height of 40 - 300 cm) for an open site situated between the remaining *Pinus sylvestris* belts (some 90 - 120 cm wide) after clear cutting. The number of densely grown young trees at an open site damaged by violent forest fire is 33,000 - 42,000/ha (16 - 17 years old with a tree height of 1 - 4 m and a DBH of 1 - 5 cm) (See Table 64). Many branches are dead and the H/D ratio of most trees is more than 100. The shape of naturally regenerated *Pinus sylvestris* growing between planted lines at reforestation sites is normal and the state of growth is better than that of planted trees. In comparison, naturally regenerated seedlings and saplings in natural forests tend to have their abnormal trunk shape or spreading branches even in places where the upper canopy layer is relatively open and the height growth is rather poor.

5.6 Increment Survey

In order to establish basic data to calculate an allowable cut volume vis-a-vis the growing stock of a forest (stand), the increment was surveyed for each forest physiognomy category involving *Larix sibirica, Pinus sylvestris, Betula platyphylla* and *Populus tremula.*

(1) Rate of Volume Increment by Single Tree

1) Survey Method

An increment borer was used to sample the core at the DBH height (1.3m) for all the subject species in order to check the annual ring width for the last 5 years. Based on the measurement results of the annual ring width, the rate of volume increment was calculated for each species using the volume increment rate table prepared by Prodan (a German) and the rate of stand increment for each forest physiognomy category was estimated.

2) Volume Increment Rate

The number of sampled trees of each of the subject species is given in Table 65.

Table 65 Number of Sampled Trees for Increment Analysis

Species	Diameter Class of Sampled Trees	No. of Sampled Trees
Larix sibirica	10 cm - 92 cm	89
Pinus sylvestris	10 cm - 94 cm	92
Betula platyphylla	10 cm - 56 cm	54
Populus tremula	10 cm - 52 cm	54

Note: The measurement results of the sampled cores of all the species are given in Appendix 10.

Based on the regression calculation of the correlation between the DBH of the sampled trees and the average annual ring width at the DBH height, the following regression lines were established.

Larix sibirica	:	Y = 6.86 - 0.05 X	n = 37,	r = 0.48,	t = 3.200
Pinus sylvestris	:	Y = 6.64 - 0.02 X	n = 44,	r = 0.26,	t = 1.722
Betula platyphylla	:	Y = 7.33 - 0.01 X	n = 21,	r = 0.04,	t = 0.188
Populus tremula	:	Y = 6.71 - 0.02 X	n = 20,	r = 0.16,	t = 0.694

Y : Annual ring width of last 5 years (cm)

X : DBH (cm)

n : Number of sampled trees

r : Correlation coefficient

t : $\frac{r\,(n-2)^{1/2}}{(1-r^2)^{1/2}}$

The non-correlation verification of the subject species suggest that non-correlation becomes valid at a level of significance of 5% for all species except *Larix sibirica*. Accordingly, the formulas to express the correlation between the DBH and annual ring width for the subject species are as follows.

Larix sibirica	:	Y = 6.86 - 0.05 X
Pinus sylvestris	:	Y = 6.64
Betula platyphylla	:	Y = 7.33
Populus tremula	:	Y = 6.71

Based on the annual ring widths (revised n) achieved by substituting the DBH values (adding 2 cm each time) in the above formulas, the diameter width of each annual ring was calculated and the volume increment rate was then determined for each DBH class using Table 66. The calculation results so far are given in Table 67.

Table 66 Volume Increment Table of Prodan (Excerpt)

	Broad-leaved Species					*Picea* spp. and *Pinus* spp.				
d \ Zd	1	2	3	4	5	1	2	3	4	5
10	2.9	5.7	8.6	11.4	14.3	3.0	6.1	9.1	12.1	15.2
15	1.9	3.7	5.6	7.4	9.3	1.9	3.8	5.7	7.6	9.6
20	1.3	2.6	3.9	5.2	6.6	1.3	2.7	4.0	5.3	6.7
25	1.0	2.0	3.0	4.0	5.0	1.0	2.0	3.1	4.1	5.1
30	0.8	1.6	2.4	3.2	4.0	0.8	1.6	2.4	3.2	4.0
35	0.7	1.4	2.1	2.8	3.4	0.7	1.4	2.1	2.8	3.4
40	0.6	1.2	1.8	2.4	3.0	0.6	1.2	1.8	2.4	2.9
45	0.5	1.0	1.6	2.1	2.6	0.5	1.0	1.5	2.0	2.5
50	0.5	0.8	1.4	1.9	2.4	0.4	0.9	1.3	1.7	2.2
55	0.4	0.8	1.2	1.6	2.1	0.4	0.8	1.2	1.5	1.9
60	0.4	0.7	1.2	1.5	1.9	0.3	0.7	1.1	1.4	1.7
65	0.4	0.6	1.1	1.4	1.7	0.3	0.6	1.0	1.3	1.6
70	0.3	0.6	0.9	1.2	1.6	0.3	0.6	0.9	1.2	1.6
75	0.3	0.6	0.9	1.2	1.5	0.3	0.6	0.8	1.1	1.4
80	0.3	0.6	0.8	1.1	1.4	0.2	0.5	0.7	1.0	1.3

Notes

1) The value of Zd indicates the diameter width (mm/year) of each annual ring while the value of d indicates the DBH (cm).
2) The rates for *Picea* spp. and *Pinus* spp. are used for *Larix sibirica* and *Pinus sylvestris* while the rates for broad-leaved species are used for *Betula platyphylla* and *Populus tremula*.
3) The rates missing in the original table are estimated based on proportional distribution.

Table 67 Calculation of Volume Increment Rate by Each Species for Each DBH Class

	Volume Increment Rate (%)			
DBH (cm)	*Larix sibirica*	*Pinus sylvestris*	*Betula platyphylla*	*Populus tremula*
8		9.28		
10	7.73	8.07	8.41	7.69
12	6.47	6.86	7.23	6.61
14	5.24	5.65	6.06	5.54
16	4.33	4.75	5.14	4.70
18	3.73	4.15	4.48	4.10
20	3.15	3.56	3.81	3.49
22	2.79	3.22	3.46	3.17
24	2.44	2.89	3.11	2.85
26	2.15	2.60	2.82	2.58
28	1.93	2.37	2.58	2.36
30	1.72	2.13	2.35	2.15
32	1.60	2.02	2.23	2.04
34	1.49	1.91	2.11	1.93
36	1.38	1.81	2.00	1.83
38	1.27	1.70	1.88	1.72
40	1.17	1.59	1.76	1.61
42	1.07	1.49	1.68	1.53
44	0.97	1.38	1.60	1.45
46	0.89	1.30	1.52	1.38
48	0.83	1.23	1.52	1.38
50	0.77	1.16	1.37	1.27
52	0.72	1.12	1.33	1.23
54	0.67	1.08	1.29	1.19
56	0.61	1.04	1.25	1.15
58	0.57	1.00	1.21	1.11
60	0.52	0.96	1.17	1.07
62	0.49	0.93	1.11	1.02
64	0.47	0.90	1.06	0.97
66	0.44	0.86	1.00	0.91
68	0.42	0.83	0.94	0.86
70	0.40	0.80	0.88	0.81
72	0.37	0.76		
74	0.34	0.73		
76	0.31	0.70		
78	0.28	0.66		
80	0.24	0.63		

Note: Basic data are shown in Appendix 11.

(2) Estimation of Stand Increment Rate

Using the volume increment rate calculated for each subject species, the stand increment rate was estimated and a stand increment rate table for each forest physiognomy category was prepared. The stand increment rate factors are the crown density, tree height and mortality rate. The estimation method used is described in Table 61.

1) Stand Gross Increment Rate of Sample Plots

Using the sample plot survey results, the diameter of trees with an average volume was calculated based on the volume and average tree height for each of the 4 subject species. The stand increment rate of each sample plot was then estimated by applying the volume increment rate shown in Table 67 to the said diameter (see Appendix). The stand gross increment rate, crown density and tree height of each sample plot are given in Appendix 12.

2) Estimation of Stand Increment Rate

Regression calculations using logarithmic equations were conducted to estimate the stand gross increment rate for each forest physiognomy category by identifying the correlation between the stand gross increment rate of the sample plots and the crown density/tree height. The regression calculations used are as follows.

NP : $\log z = -0.341 \log x - 1.396 \log y + 5.172$, $r = 0.68$, $n = 19$

N : $\log z = -0.265 \log x - 1.576 \log y + 5.606$, $r = 0.74$, $n = 31$

L : $\log z = -0.103 \log x - 0.158 \log y + 0.958$, $r = 0.18$, $n = 13$

M : $\log z = -0.030 \log x - 1.649 \log y + 5.788$, $r = 0.73$, $n = 18$

- z : stand gross increment rate
- x : crown density class (four in all)
- y : tree height (m)
- r : correlation coefficient
- n : number of samples

Note:

Data on the following sample plots were used to calculate the stand gross increment rate for each forest physiognomy category.

NP : Sample plots of NP

N : Due to the small number of sample plots of N, sample plots of N, NL and NP, all of which include coniferous trees

L : Sample plots of L

M : Sample plots of M

The crown density and tree height values were then inserted in the regression equations. By subtracting the mortality rate (see Appendix 13 for mortality rate examples), the stand increment rate table was compiled (see Table 69).

NP : $M = 0.804$	N : $M = 0.804$
L : $M = 0.947$	M : $M = 0.883$

As shown above, stand increment rate is calculated by subtracting the mortality rate of the stand from the sum of single tree volume growth rate. In the event the forest physiognomy in question is in climax, stand increment rate is regarded as "0" because increment and mortality generally coincide and applied to the forest physiognomy category in Table 68.

Table 68 Stand Increment Rate Estimation Method

Forest Physiognomy Category	Estimation Method
NL, N, L	The net increment rate is a uniform 0% as NL and N of over 21m average tree height and L of over 15m average tree height are a climax forest.
NP, M Forests other than above	The rate is estimated using the crown density, tree height and mortality as the factors.

Table 69 Stand Increment Rate Table by Forest Physiognomy Category

L

y \ x	1	2	3	4
6	2.51	2.27	2.14	2.05
7	2.60	2.35	2.22	2.13
8	2.67	2.42	2.29	2.19
9	2.74	2.49	2.35	2.25
10	2.80	2.54	2.40	2.30
11	2.86	2.60	2.45	2.35
12	2.91	2.65	2.50	2.40
13	2.96	2.69	2.54	2.44
14	3.01	2.74	2.58	2.48
15	3.05	2.78	2.62	2.52
16	3.09	2.81	2.66	2.55
17	3.13	2.85	2.69	2.59
18	3.17	2.88	2.73	2.62
19	3.20	2.92	2.76	2.65
20	3.24	2.95	2.79	2.68
21	3.27	2.98	2.82	2.71
22	3.30	3.01	2.85	2.74
23	3.33	3.04	2.87	2.76
24	3.36	3.06	2.90	2.79
25	3.39	3.09	2.92	2.81

N

y \ x	1	2	3	4
6	15.35	12.64	11.27	10.38
7	11.87	9.74	8.67	7.97
8	9.46	7.74	6.87	6.31
9	7.72	6.29	5.57	5.10
10	6.42	5.21	4.59	4.20
11	5.41	4.37	3.84	3.50
12	4.61	3.71	3.25	2.95
13	3.97	3.17	2.77	2.50
14	3.45	2.73	2.37	2.14
15	3.01	2.37	2.05	1.84
16	2.64	2.06	1.77	1.58
17	2.33	1.80	1.54	1.36
18	2.06	1.58	1.33	1.18
19	1.82	1.38	1.16	1.01
20	1.62	1.21	1.01	0.87
21	1.44	1.06	0.87	0.75
22	1.28	0.93	0.75	0.64
23	1.14	0.81	0.65	0.54
24	1.01	0.71	0.55	0.45
25	0.90	0.61	0.47	0.38

M

y \ x	1	2	3	4
6	16.12	16.48	16.69	16.84
7	12.30	12.58	12.75	12.86
8	9.70	9.92	10.05	10.15
9	7.83	8.01	8.12	8.20
10	6.44	6.59	6.69	6.75
11	5.38	5.51	5.58	5.64
12	4.54	4.65	4.72	4.77
13	3.87	3.97	4.03	4.07
14	3.32	3.41	3.46	3.50
15	2.87	2.95	3.00	3.03
16	2.49	2.56	2.60	2.63
17	2.17	2.23	2.27	2.30
18	1.90	1.95	1.99	2.01
19	1.66	1.71	1.74	1.77
20	1.45	1.50	1.53	1.55
21	1.27	1.32	1.34	1.36
22	1.11	1.15	1.18	1.20
23	0.97	1.01	1.03	1.05
24	0.85	0.88	0.90	0.92
25	0.73	0.77	0.79	0.80

NP

y \ x	1	2	3	4
6	13.65	10.60	9.13	8.20
7	10.85	8.40	7.21	6.46
8	8.87	6.83	5.85	5.22
9	7.40	5.67	4.84	4.31
10	6.28	4.79	4.07	3.61
11	5.40	4.09	3.46	3.06
12	4.69	3.53	2.97	2.62
13	4.11	3.07	2.57	2.26
14	3.62	2.69	2.24	1.96
15	3.22	2.37	1.96	1.70
16	2.87	2.10	1.72	1.49
17	2.57	1.86	1.52	1.30
18	2.31	1.66	1.34	1.14
19	2.09	1.48	1.18	1.00
20	1.89	1.32	1.05	0.87
21	1.71	1.18	0.92	0.76
22	1.55	1.06	0.82	0.66
23	1.41	0.94	0.72	0.58
24	1.28	0.84	0.63	0.50
25	1.17	0.75	0.55	0.42

Note: x = crown density class, y = tree height

(3) Estimation of Stand Increment

Using the foregoing method, the volume by forest physiognomy category obtained from the inventory study was multiplied by stand increment rate to obtain the stand increment. Then the stand increment rate was extracted by Model Area and by forest physiognomy category as shown in Table 70.

Table 70 Estimation of Stand Increment

Forest Physiognomy Category	Increment (m^3)		
	Model Area 1	Model Area 2	Total
NP	13,561	4,971	18,532
NL		234	234
N		474	474
L	1,280	13,442	14,722
M	3,596	10,410	14,006
Total	18,437	29,531	47,968

5.7 Preparation of Forest Inventory Book

Forest inventory book was prepared on the following items based on the content of study.

(1) Description Concerning the Plan and Law

"Compartment Number" and "Sub-Compartment Number" are planning units of forest management plan prepared by this study.

The smallest category in this forest inventory book is "Sub-Compartment" and the attributes are described in this unit. "Compartment Number" and "Sub-Compartment Number" correspond to the forest management plan map and are all written in numbers.

The area of each sub-compartment is measured on the map and are listed by being divided into "Forest Area" and "Non-Forest Area."

Description of "Administrative Location," "Model Area," "Legal Designation" and "Management Category" is as shown below. Refer to 7. Forest Management Plan Guidelines for details on legal designation and management category.

Table 71 Forest Inventory Book Items

No.	Item	Unit	No.	Item	Unit
1	Administrative Location		14	Height Class	
2	Model Area		15	Crown Density Class	
3	Compartment Number		16	Stand Density Ratio	%
4	Sub-Compartment Number		17	Stand Age	yr
5	Forest Area	ha	18	Mean Tree Height	m
6	Non-Forest Area	ha	19	Mean DBH	cm
7	Legal Designation		20	Species	
8	Management Category		21	Composition by Species	%
9	Stand Quality		22	Volume	m^3
10	Slope Class		23	Volume per hactare	m^3/ha
11	Soils		24	Annual Increment	m^3/yr
12	Forest Management Type		25	Forest Floor Vegetation	
13	Land Use & Vegetation Type		26	Remarks	

Table 72 Description Concerning Positions and Lows

Col. No.	Item	Symbol	Contents
1	Administrative Location		
		1	Altanbulag Sum
		2	Uroo Sum
2	Model Area		
		1	Model Area 1
		2	Model Area 2
	Legal Designation		
		GZ	Green Zone
		HF	Headwater Forest
		WI	Woods Isolated
		S	Shrub
		WF	Woods on Slope Facing South
		WS	Woods on Steep Slope
8	Management Category		
		P	Nature Preservation Forest
		S	Soil & Water Conservation Forest
		H	Public Health & Culture Promotion Forest
		T	Timer Production Forest

(2) Description of the Results of the Forest Survey

The results of the Forest Survey in this Study are set forth as follows.

Table 73 Description Concerning the Results of the Forest Survey

Col. No.	Item	Symbol	Contents
10	Slope Class		
		1	<15°
		2	15° ≤ <30°
		3	30° ≤
11	Soils		
		C	Soil Complex of Dystric Cambisols & Humic Cambisols
		K	Haplic Kastanozems
		A	Soil Complex of Haplic Arenosols
		L•C	Soil Complex of Leptosols & Cambisols
		F	Umbric Fluvisols
		R	Rocky Land
13	Land Use & Vegetation Type		
		NP	Pine Forest
		NL	Larch Forest
		N	Pine/Larch Forest
		P	Planted Forest
		L	Broad-leaved Forest
		M	Mixed Forest
		U	Unstocked Land
		UF	Fire-Damaged Forest
		UL	Logged-Over Land
		S	Shrub Land
		G	Grassland
		F	Farm Land
		ST	Settlement
		R	Rocky Land
14	Height Class		
		3	-12m
		2	13m - 20m
		1	21m -
15	Crown Density Class		
		4	-30%
		3	31% -60%
		2	61% -90%
		1	91% -
18	Mean Tree Height (m)		
19	Mean DBH (cm)		
20	Species		
21	Volume Composition by Species (%)		
22	Volume (m^3)		
23	Volume per ha (m^3/ha)		
24	Annual Increment (m^3/yr)		

As shown in the Forest Management Plan Guidelines, "Forest Management Type" is comprised of the following 3 items.

Table 74 Content of Description for Forest Management Type

Col. No.	Item	Symbol	Contents
12	Forest Management Type		
		NF	Natural Forest
		MF	Manmade Forest
		U	Unstocked Land

The combination of "Forest Management Type," "Forest" and "Non-Forest" are described as follows with regard to the aforementioned land use and vegetation types.

Table 75 Forest Management Type and Forest/Non-Forest by Land Use and Vegetation Type

Land Use & Vegetation Type		Forest Management Type	Forest/Non-Forest
NP	Pine Forest	NF	Forest
NL	Larch Forest	NF	Forest
N	Pine/Larch forest	NF	Forest
P	Planted Forest	MF	Forest
L	Broad-leaved Forest	NF	Forest
M	Mixed Forest	NF	Forest
U	Unstocked Land	U	Forest
UF	Fire-Damaged Forest	U	Forest
UL	Logged-Over Land	U	Forest
S	Shrub Land	NF	Forest
G	Grassland		Non-Forest
F	Farm Land		Non-Forest
ST	Settlement		Non-Forest
R	Rocky Land		Non-Forest

Among these categories of land use and vegetation type, unstocked land (U) was further divided into "inhospitable site" and "hospitable site" during the preparation process of the forest management planning.

"Inhospitable site" corresponds to areas that were interpreted as unstocked land by aerial photos. However, their areas were included in non-forest because they are located on south-facing slopes of a mountain where existence of forest is difficult owing to its natural condition.

On the other hand, "hospitable site" corresponds to unstocked land excluding the aforementioned "inhospitable site" as areas where existence of forest is possible.

Table 76 Content of Unstocked Land Division

Land Use & Vegetation Type		Forest Management Type	Forest/Non-Forest
I	Inhospitable Site	U	Non-Forest
H	Hospitable Site	U	Forest

(3) Others

"Stand quality class," "stand density ratio" and "stand age" were quoted from the existing Forest Inventory Book of Mongolia to facilitate the comparison with this book.

"Stand quality class" refers to "tree height class" obtained by dividing stand according to its average diameter and tree height and is expressed by numbers. Smaller numbers indicated higher "tree height" and high quality of the stand as timber resource. In the case of the Model Area, stand quality class is given in the range of 3 to 5.

"Stand density ratio" refers to the percentage of the actual count among the count according to angle count sampling method under stand status in which stand density ratio of the crown density is saturated. It is recorded in 10% units in the Forest Inventory Book, with numbers closer to 10 indicating a status closer saturation.

"Stand age" was described in units of decade such as "15" standing for "150 years."