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Stand Structure of the Natural Broadleaved-Korean Pine Forests in Northeast China

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Abstract : Based on the data representing four typical Korean pine forest types, the age structure, DBH distribution, species composition, and forking rule were systemically analyzed for old-growth Korean pine forest in Liangshui Nature Reserve, northeast China. The age structure of Korean pine trees was strongly uneven-aged with one dominated peak following normal distribution, and age of trees varied from 100 to 180 years within a stand. The DBH and height differences in same age class (20 years) varied from 28 cm~64 cm and 5 to 20 m, respectively. Many conifer and hard wood species, such as spruce, fir, costata birch, basswood, oak, and elm, were mixed with dominated trees of Korean pine. The canopy of the old-growth Korean pine forest can be divided into two layers, and differences of mean age and height between Layer I and Layer II were ranged 80~150 years and 7~13 m, respectively. The Weibull function was used to model the diameter distribution and performed well to describe size-class distribution either with a single peak in over-story canopy and inverse J-shape in under-story canopy for old-growth Korean pine stands. The forking height of Korean pine trees ranged from 16m to 24 m (mean 19.4 m) and tree age about 120 to 160 years old. The results will provide a scientific basis to protect and recover the ecosystem of natural old-growth Korean pine and also provide the model in management of Korean pine plantation.

Key words : Pinus koraiensis, *old-growth forests, stand structure, natural broadleaved-Korean pine forests.*

Introduction

The natural broadleaved-Korean pine (*Pinus koraiensis*) forests were once the most distributed forest type in the eastern mountain area, the Lesser Xing'an Moutains and the Changbai Mountains, in northeast China (Wang, 1995; Li *et al.*, 1995; Li, 1997). The most of the broadleaved-Korean pine forests have disappeared and have been replaced by secondary forests due to extensive cutting, other human-disturbances and unbalanced growing stock between harvesting and annual increment for several decades. Now, the natural old-growth Korean pine forests are mainly limited to few natural reserves, Fenglin and Linagshui Natural Reserve in the Lesser Xingan Moutains, Heilongjiang Province and Changbai Mountains Natural Reserve in the Changbai Mountains, Jilin Province (See Table 1). It's unable to view the glorious landscape scenery of the virgin Korean pine forests again. Therefore, this kind of forest ecosystem has become endangered and attracted more concerns (Shao *et al.*, 1995; Liu and Ge, 2003).

In past several decades, many studies have carried out on the natural distribution, stand structure and dynamics, regeneration, and harvest strategies for natural broadleaved-Korean pine forests in natural reserves (Li, 1997; Wang 1995). These researches showed that: 1) the age structure was uneven-aged and trees were composed of two generations (Ge and Li, 1992, 1995; Dai *et al.*, 2002); 2) The horizontal pattern of the forest consisted of even-aged patches at different generations (Ge and Li, 1992; Li, 1997); 3) For community structure, many hard wood species mixed with the dominated species of Korean pine and the canopy layer was consisted of two or three layers (Ge and Li, 1995; Sun and Zhao, 1995); 4) Diameter structure showed the typical uneven-aged stand structure (Sun *et al.*, 1997). Otherwise, Shao *et al.* (1995) studied forest dynamics of broadleaved-Korean pine forest based on the gap model. But, few researches have been concerned on stand structure of different forest types for the natural broadleaved-Korean pine forests in detail.

The objective of this paper is to systemically investigate the age structure, DBH distribution, species composition, and forking rule by using the data of one clear cutting plot and temporary sample plots represented four typical Korean pine forest types for natural broadleaved-Korean

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Table 1. Old-growth Broadleaved-Korean pine natural reserves in northeast China.

Natural Reserve	Location	Established year	Area (ha)	Volume ($10000m^3$)
Changbai Mountains	41°41′49″~ 42°25′18″N 127° 42′55″ ~128°16′48″E	1960	196,465	4,373.5
Fenglin	48°01′~ 48°09′N 128° 59′ ~129°15′E	1963	1,8165	460.7
Liangshui	47°07′39″~ 47°14′22″N 128° 48′30″ ~128°55′50″E	1980	6,394	132.9

pine forests in Liangshui Nature Reserve. This will provide a scientific basis to protect and recover the ecosystem of natural old-growth Korean pine and also provide the model in management of Korean pine plantation.

Materials and Methods

1. Study site

Data for this study were collected from Liangshui Natural Reserve (See table 1), which is located in Yichun City of Heilongjiang province, on the mid-north of Lesser Xing'an Mountains, northeast China.

The study area is characterized as a topography with low- and medium-sized mountains, of which over 75% of total area is gentle slope within the elevation from 300 to 700 m (average 400 m). The highest peak is 707 m and relative elevation is from 80-300 m. Over 90% of the area is flat and the average gradient is 10°-15°. The annual mean temperature is -0.3°C and the mean temperature ranges from -6.6°C in January to 7.5°C in July. The annual precipitation is 600~700 mm with the evaporation of 805 mm and about 60% concentrates in June, July and August. The annual mean relative humidity is 78%. Dark brown soil is the zonal soil in this area and it accounts for about 85% of the forestry land.

The Liangshui Natural Reserve is the largest and well-protected natural distributive region of the broadleaved-Korean pine ecosystem, which is dominated by Korean pine and accompany with many warm- and cold-broad-leaved species. Overstory tree species include *Pinus koraiensis*, *Picea jezoensis*, *Picea koraiensis*, *Abies nephrolepis*, *Larix gmelini*, *Fraxinus mandshurica*, *Juglans mandshurica*, *Phellodendron amurense*, *Tilia amurensis*, *T. mandshurica*, *Quercus mongolica*, *Ulmus propinqua*, *U. laciniata*, *Acer mono*, *Betula costata*, *B. platyphylla*, *Populus davidiana*, *P. ussuriensis*, etc.. Understory tree species are *Prunus padus*, *Syringa reticulata*, *Acer ukurunduense*, *Acer tegmantosum,Alnus hirsute,Sorbus pohuashanensis*, *Padus maakii*, and etc.

Forest resource inventory in 1999 indicated that the total area was 6,394 ha. Forest coverage is up to 91.2%. The zonal climax community is the broadleaved-Korean pine forest, which was classified into 4 types: Oak-Korean pine Forest, basswood-Korean pine forest, costata birch-Korean pine forest and spruce-fir-Korean pine forest. In the valley area the boreal coniferous forest has been formed, in which spruce and fir are dominant species. It is the intra-zonal community and major types are fir forest and Spruce-Fir forest. In addition, there are some successive community types such as the poplar forest, the birch forest and hardwood forests. The areas and volumes of seven different forest types were shown in Table 2.

Table 2. Forest types in Liangshui Natural Reserve, Northeast China.

Forest types	Area (ha)	%	Volume ($10000m^3$)	%	m^3/ha
Korean pine forest	3,268	52.22	97.9	73.66	300
Birch forest	449	7.17	5.9	4.44	131
Spruce-fir forest	1,161	18.55	15.6	11.74	134
Larch forest	24	0.38	0.5	0.38	208
Poplar forest	391	6.25	3.7	2.78	95
Hardwood forest	68	1.09	1.1	0.83	162
Plantation	897	14.33	8.2	6.17	91
Total	6,258	100.00	132.9	100.00	212

From Table 2, zonal climax forest type (Korean pine Forest), intrazonal climax forest type (Spruce-fir Forest) and original Conifer-hardwood mixed forest or coniferous forest added up accounting for 70% of the total forest area and for 86% of the total growing stock. Successive forests (birch forest, poplar forest and other hardwood forests) are accounting for 30% and 14% of the total forest area and the total growing stock, respectively.

2. Data collection

The available data to study community structure for old-growth Korean pine forests were collected in Liangshui Natural Reserve from 1953 to 1956. All of the research plots were grouped into following two categories: a) 1 clear cutting plot representing the Spruce-Fir-Korean pine forest was investigated in 1956; b) 3 sample plots representing other three Korean pine forest types

Table 3. Stand attributes of 1 clear cutting plot (#216) and 3 temporary plots in the old -growth Korean pine Forests.

Plot	Forest type	Area (ha)	Stand age (years)	Mean DBH (cm)	Mean Height (m)	Trees per ha (stems)	Basal area (m^2/ha)	Stand volume (m^3/ha)
216	Spruce-Fir- Korean pine forest	1.03	210	47.5	27.65	339	50.3	686
7	Costata Birch- Korean pine Forest	0.66	203	41.1	27.10	353	37.0	473
53	Basswood-Korean pine Forest	0.9	297	48.8	27.40	358	47.5	557
113	Oak-Korean pine Forest	0.4	209	30.2	19.90	749	48.5	480

were collected from 1953 to 1956. Summary of the stand attributes were presented in Table 3.

3. Data analysis

Age of old-growth Korean pine forest was analyzed using the clear cutting plot and the normal distribution was used to model frequency distribution by age class. Tree size-class and height distribution by age class and age structure by DBH class for Korean pine trees were analyzed. The species composition and age structure by species for 4 stands represented different forest types in old-growth Korean pine forests were discussed in detail.

Through comparing the goodness-of-fit of several continuous distributions such as the Weibull, Beta, and log Normal probability density functions (pdf) that were fitted to the size-class distribution, the Weibull distribution (Bailey and Dell, 1973) was proven to be sufficiently flexible to describe a single peak of diameter distribution in over-story and to model inverse J-shape of DBH distribution in under-story canopy for old-growth Korean pine forests. Therefore, the three parameters Weibull function was applied to model the relative frequencies of trees by size-class.

$$f(x)=\frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1}\exp\left[-\left(\frac{x-a}{b}\right)^{c}\right] \quad \text{for } x>0,\ a,\ b \text{ and } c>0 \qquad (1)$$

where x =DBH; f(x) is relative frequencies of trees; a is the "location" parameter which indicates the lower end of the diameter distribution; b is the "scale" parameter of the distribution, c is the "shape" parameter of the distribution.

The maximum likelihood method implemented in STATISTICA 6.0 software (StatSoft Inc, 2001) was used to estimate the parameters of the Weibull distribution. To test the performance of the Weibull distribution, the following Chi-Square statistics was calculated for each stand.

$$X^2=\sum_{i-1}^{m}\frac{(fo_i-fp_i)^2}{fp_i}\sim X_{\alpha}^2(m-p-1) \qquad (2)$$

where m is the number of class; p is number of parameters of the weibull distribution; fo_i is observed frequency of ith class; fp_i is predicted frequency of ith class from reference distribution; α is the significance level (α=0.05).

Results and Discussion

1. Age structure

The age structure of old-growth Korean pine forest was analyzed in clear cutting plot #216. In the plot, there were 269 stems of Korean pine trees and the frequency distribution and DBH distribution by age class were listed in Table 4 and Table 5, respectively.

The age structure of Korean pine trees was strongly uneven-aged with one dominated peak, that follows normal distribution (X^2=34.03, and p=0.00 at 5% level) (see

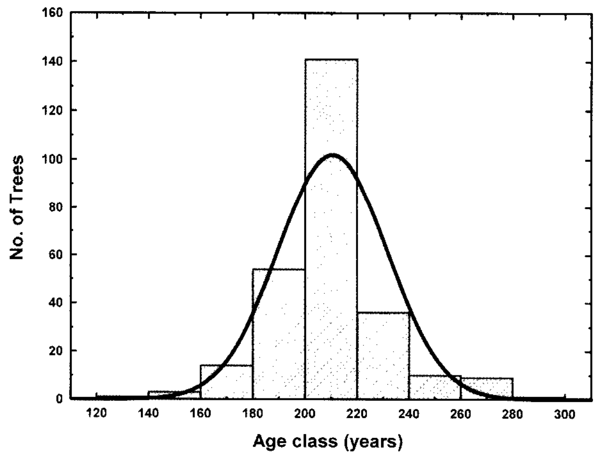


Figure 1. The age structure of Korean pine community (Plot #216).

Table 4. Frequency distribution by age class for Korean pine trees in plot 216.

Age classes (20 years)	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	Total
Frequency	1	3	14	54	141	36	10	9	1	269
Percent (%)	0.4	1.1	5.2	20.1	52.4	13.4	3.7	3.3	0.4	100.0

Table 5. DBH distribution by age class for Korean pine trees in plot 216.

DBH	Age classes (20 years)								
	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Frequency	1	3	14	54	141	36	10	9	1
Range (cm)		12.2-50.1	21.2-49.3	11.1-66.5	18.8-71.0	21.4-84.88	21-75.1	41.3-85	
Mean (cm)	23.1	25.9	36.0	36.9	44.6	53.5	56.5	65.6	70.0
S.D. (cm)		17.57	9.03	12.14	12.37	11.91	17.33	12.41	
CV%		67.84	25.08	32.90	27.74	22.26	30.67	18.92	

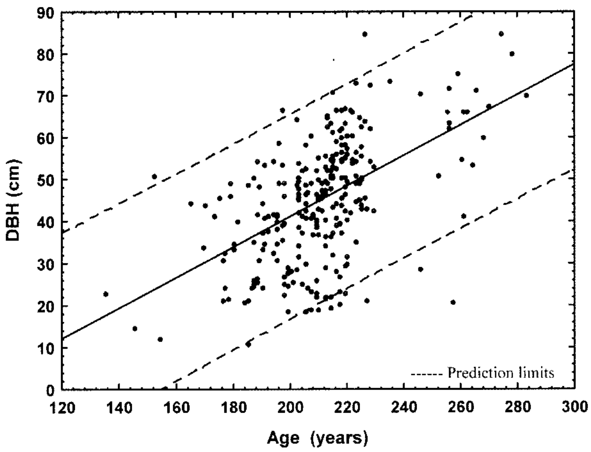


Figure 2. Relationship between age and DBH of Korean pine trees (Plot #216).

Figure 1). This indicated that regeneration of the Korean pine was continuous in old-growth forests. Within a stand, the tree age of Korean pine was different and ranged 5-9 age classes (100-180 years) and more than 87% trees were distributed in X~XII (180~240 years) (see Table 4 and Figure 1). This result is different from Ge and Li (1992), that the age structure exits two dominate peaks.

The DBH of Korean pine trees in the stand were increased with tree age. But, DBH differences in same age class (20 years) varied from 28 cm~64 cm with 50 cm of mean value (see Table 5 and Figure 2).

The age of Korean pine trees in plot 216 were also increased with tree DBH. Age of trees by same DBH class ranged from 40 to 120 years with the CV% less than 11% within the stand. For example, age varied from 152 to 264 years for the 52 cm of DBH class (see Table 6). Therefore, it is hard to estimate the tree age by using the DBH of Korean pine because the relationship between age and DBH (simple correlation coefficient is 0.54) of Korean pine trees was not significant (also see

Table 6. Age structure by DBH class for Korean pine trees in plot 216.

DBH (cm)	Age Distribution					
	Frequency	Range	No. of age classes	Mean	S.D.	CV%
12	2	154-185	2	170	15.5	9.12
16	1	145	0	145	0	0.00
20	13	176-257	5	205	21.37	10.42
24	21	135-219	5	197	17.78	9.03
28	13	187-246	4	207	14.98	7.24
32	13	176-220	3	197	14.60	7.41
36	18	169-223	4	201	14.02	6.98
40	29	173-261	5	204	15.24	7.47
44	27	165-229	4	210	16.73	7.97
48	31	179-225	3	207	11.78	5.69
52	27	152-264	6	213	19.69	9.24
56	25	188-260	5	218	12.14	5.57
60	13	196-268	4	219	16.05	7.33
64	13	202-256	4	224	15.38	6.87
68	11	197-270	4	231	25.20	10.91
72	8	215-283	4	244	21.59	8.85
76	1	259	0	259	0	0.00
80	1	278	0	278	0	0.00
84	2	226-274	3	250	24.00	9.60

Table 7. Height distribution by age class for Korean pine trees in plot 216.

Height	Age classes (20 years)							
	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Frequency	1	3	14	54	141	36	10	9	1
Range (m)		9.3-30.4	20.3-30.8	9.6-32.4	17.6-34.1	16.5-37.3	22.4-32.0	28.8-33.5	
Mean (m)	22.40	16.53	27.48	25.7	27.76	29.75	29.57	31.18	31.4
S.D. (m)		9.81	8.20	4.74	3.40	3.01	2.74	1.80	
CV%		59.35	29.84	18.44	12.25	10.12	9.27	5.77	

Table 8. Species composition for 4 stands of old-growth Korean pine forest.

Plot	Forest Type	Species Composition (by volume)*
216	Spruce-Fir-Korean pine forest	92 P.k. 4 P.j. 3T.i. 1 A.n. 1F.m. + U.I.
7	Costata Birch-Korean pine Forest	89 P.k. 9 B.c. 1P.j. 1 A.n
53	Basswood-Korean pine Forest	89 P.k. 8 T.i. 1P.j. 1 A.n. 1B.c.
113	Oak-Korean pine Forest	78 P.k. 19 Q.m. 3P.j.

**Note: P.k.—*Pinus koraiensis*, P.j.—*Picea jezoensis* and *Picea koraiensis*, T.i.—*Tilia amurensis* and *T. manshurica*, A.n.—*Abies nephrolepis*, F.m.—*Fraxinus manshurica*, U.l.—*Ulmus laciniata* and *U. propinqua*.B.c.—*Betula costata*, Q.m.—*Quercus mongolica*

Figure 2).

Height distribution by age class for Korean pine trees in plot 216 was showed in Table 7. The height of Korean pine trees with same age varied from 5 to 20 m within stand and 70% trees were varied more than 10 m.

2. Species composition

In old-growth Korean pine forest, many conifer and hard wood species were mixed with the dominated species of Korean pine. The species composition and attributes of 4 stands represented different forest type for old-growth Korean pine forest were presented in Table 8 and 9.

Mixed species in the old-growth Korean pine forests were mainly composed of spruce (*Picea jezoensis* and *Picea koraiensis*), basswood (*Tilia amurensis* and *T. manshurica*), fir (*Abies nephrolepis*), and costata birch (*Betula costata*) and also have some Manchurian ash (*Fraxinus manshurica*), Manchurian elm (*Ulmus laciniata* and *U. propinqua*) and oak (*Quercus mongolica*). In the investigated area of old-growth Korean pine forest, accompanied species for each forest type were little different. Mixed species in the spruce-fir-Korean pine forest included spruce, fir, and some hardwood species, e.g. basswood, Manchurian ash, and elm. In broad-leaved Korean pine forest, the accompanied hardwood species were mainly composed of costata birch, basswood, and oak for costata birch-Korean pine forest, basswood-Korean pine forest, and oak-Korean pine forest, where mixed with small percent of spruce and/or fir, respectively (see Table 8).

The canopy of the old-growth Korean pine forest can be divided into two layers according to the height pattern of forest canopy (see Table 9). In over-story (Layer I) canopy, the conifer species include Korean pine and spruce that average age ranged from 170 to 300 years. The hardwood species were mainly composed of basswood, Costata birch, oak, and Manchurian ash that average age ranged from 110 to 170 years. In under-story (Layer II) cannopy, the species were composed of fir, Korean pine, Manchurian elm, and birch with mean age ranged from 50 to 110 years. The Korean pine was appeared in oversorry and understory simultaneously for each forest type. This indicates that regeneration of the Korean pine keeps continuous in old-growth forests. Differences in mean age and height between Layer I and Layer II were ranged 80~150 years and 7~13 m, respectively.

Based on the data from clear cutting plot #216, the analysis of the age structure by species and layers was presented in Table 10.

In overstory canopy (Layer I), tree age of Korean pine was mainly ranged from 160 to 280 years and spruce was from 180-220 years. In this range, the hardwood species were distributed very little. The number of hardwood trees was mainly distributed in age from 60 to 180 years and the conifer trees were little distributed in this age range. The longevity of hardwood species is commonly less than 200 years old. The order of ecological longevity from long to short is *Betula costata*, basswood, oak, *Fraxinus manshurica*, and elm (Table 9 and 10). In understory canopy (Layer II), the conifer trees (fir) was mainly distributed in age from 60 to 120 year old and accompanied with elm in this age range (Table 10).

3. Diameter distribution

For old-growth Korean pine forests, diameter distribu-

Table 9. Species attributes of 4 kinds of forest type for old-growth Korean pine forest.

Plot	Forest Type	Canopy Layer	Species	Age	Mean DBH (cm)	Mean Height (m)	Trees per ha	Stand volume (m^3/ha)	Mo* (m^3/ha)
216	Spruce-Fir-Korean pine forest	I	P. k.	210	47.5	27.65	261	629	2
		I	P. j.	186	39.4	29.3	13	27	
		I	T. i.	133	29.7	20.5	21	19	
		I	F. m.	130	33.6	25.0	4	5	
		II	A. n.	94	13.4	11.4	28	5	
		II	U. l.	76	18.3	17.6	3	1	
		Total		210	47.5	27.65	339	686	2
7	Costata Birch-Korean pine Forest	I	P. k.	203	41.1	27.10	242	416	28
		I	B. c.	169	39.5	27.40	27	43	1
		I	P. j.	121	34.9	29.40	5	6	
		II	A. n.	30	14.7	15.00	32	4	
		II	P. k.	108	14.0	15.00	47	4	1
		Total		203	41.1	27.10	353	473	30
53	Basswood-Korean pine Forest	I	P. k.	297	48.8	27.40	207	476	6
		I	T. i.	124	23.4	22.50	34	43	
		II	P. k.	75	21.7	16.60	58	25	
		II	P. j.	83	20.1	15.40	12	4	
		II	A. n.	43	20.5	15.50	14	4	1
		II	B. c.	48	15.7	15.10	33	5	
		Total		297	48.8	27.40	358	557	7
113	Oak-Korean pine Forest	I	P. k.	209	30.2	19.90	483	366	18
		I	Q. m.	113	36.5	18.40	103	89	7
		II	P. k.	49	14.8	11.20	103	11	
		II	P. j.	50	17.4	13.60	60	14	
		Total		209	30.2	19.90	749	480	25

*Note: Mo is mortality volume per hectare of the stand.

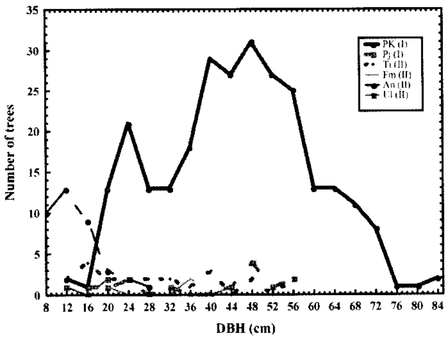
Table 10. Age distribution by species of old-grow Korean pine forest plot #216.

Age Class	Range (years)	Species (layer)						
		Pk (I)	Pj (I)	Ti (I)	Fm (I)	An (II)	Ul (II)	Total
III	40-60			1		1	2	10
IV	60-80			2		9	1	18
V	80-100			4		16		15
VI	100-120			5	2	10		22
VII	120-140	1	1	1	1			27
VIII	140-160	3	1	3	1	1		16
IX	160-180	14	1	4		1		16
X	180-200	54	6	1				21
XI	200-220	141	4					32
XII	220-240	36						29
XIII	240-260	10						37
XIV	260-280	9						28
XV	280-300	1						
Total		269	13	22	4	38	3	539

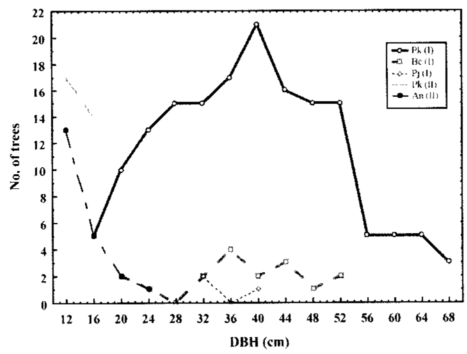
tions in different forest types have a single peak and are slightly skewed in over-story canopy. But, they are inverse J-shapes in under-story canopy except costata birch-Korean pine forest (plot #53) (see Figure 3 and Figure 4). Size-class distribution follows one dominated peak for Korean pine trees and other main accompanied species in Layer I in different forest types. But, the DBH distribution has inverse "J"-shaped for each species other than Costata birch-Korean pine forest (see Figure 3b) in under-story canopy (Layer II).

Relative frequency curve, the Weibull function, was used to model diameter distribution in old-growth Korean pine stands. Parameter estimates and Chi-square test of the Weibull function fitted to size-class distribution for four forest types in old-growth Korean pine forests were presented in Table 11.

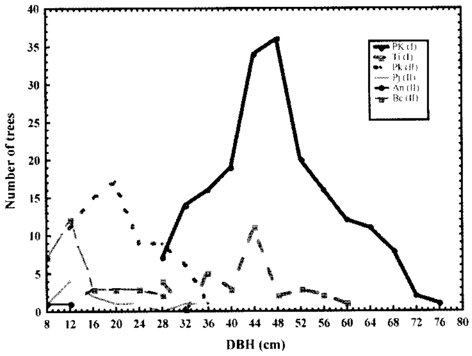
Of the 5 stands for Layer I and II, only Layer I of plot #216 rejected the null hypothesis for Chi-square test (α=0.05), and other DBH distribution of trees for four forest types accepted the null hypothesis at α=0.05 significance level. Hence, the Weibull distribution was suitable to model a single peak in over-story canopy and inverse J-shapes in under-story canopy. The observed distribution and fitted distribution from the Weibull



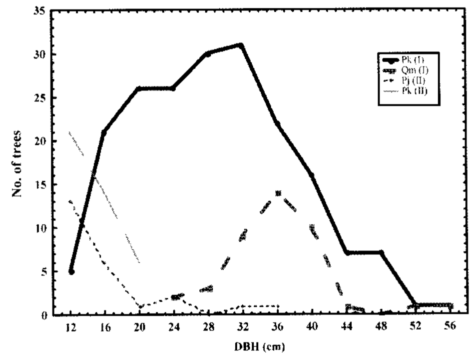
a) Spruce-fir-Korean pine forest (plot #216)



c) Basswood-Korean pine forest (plot #7)



b) Costata birch-Korean pine forest (plot #53)



d) Oak-Korean pine forest (plot #113)

Figure 3. Size-class distribution by layer and species for 4 forest types of old-growth Korean pine forest.

Table 11. Parameter estimates and Chi-square test of the Weibull function fitted to DBH distribution of trees for old-growth Korean pine forests.

Layer	Plot	Parameter a	Parameter b	Parameter c	X^2	X^2_α =0.05
I	216	10.0	37.848070	2.366970	31.9792*	26.2962
	53	26.0	23.498180	2.084423	18.1687	18.3070
	7	14.0	27.955270	2.102375	9.1847	19.6751
	113	10.0	22.591480	2.315147	11.2339	16.9190
II	216	6.0	8.798551	1.628130	0.6766	7.8147
	53	6.0	14.492440	1.923537	3.3532	11.0705
	7	10.0	4.767342	1.477013	4.5337	5.9915
	113	10.0	5.288387	1.447099	4.2546	5.9915

*Note: Significant at α=0.05 level.

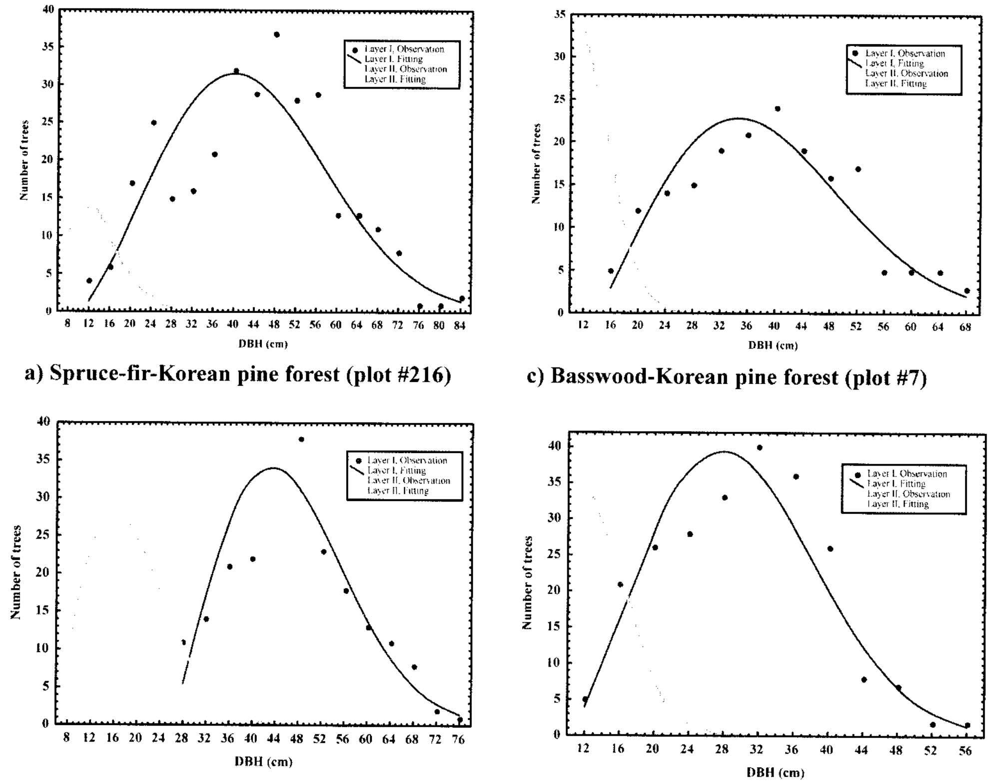
Table 12. Attribute of forking trees for Korean pine.

Variables	No. of trees	Mean	Min	Max	SD	CV%
Age (years)	180	202.0	89	325	36.12	17.88
DBH (cm)	180	47.76	14.5	87.3	11.95	25.02
Height (m)	180	28.58	15.50	34.70	2.90	10.15
Forking height (m)	180	19.40	8.00	28.50	3.99	20.57

function were showed in Figure 4 for different stands. The Weibull distribution performed fairly well to describe frequencies of trees by size-class (Table 11 and Figure 4).

4. Forking height

The forking on main stem is common phenomenon for natural Korean pine tree. In order to analyze the forking height, 180 trees were selected in over-story canopy for spruce-fir-Korean pine forest (plot #216). The forking heights of Korean pine trees were not significantly related with tree age and tree height (the simple correlation coefficients were 0.35 and 0.36, respectively). The



a) Spruce-fir-Korean pine forest (plot #216)

c) Basswood-Korean pine forest (plot #7)

b) Costata birch-Korean pine forest (plot #53)

d) Oak-Korean pine forest (plot #113)

Figure 4. The observed frequencies and predicted distribution from the Weibull function by layers for 4 forest types of old-growth Korean pine forest.

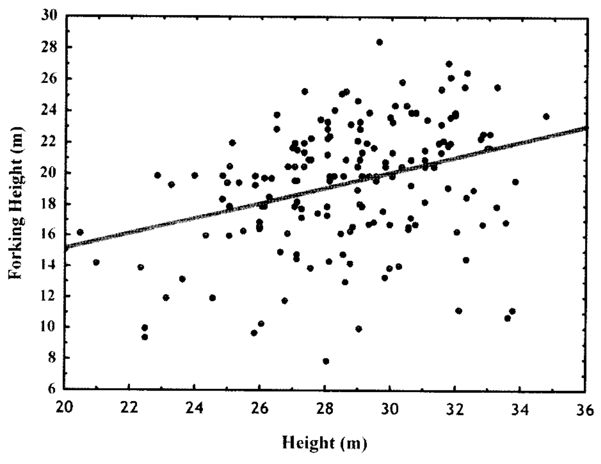


Figure 5. Relationship between forking height and total height of Korean pine trees.

forking height of 75% trees ranged from 16 m to 24 m (average forking height 19.4 m and S.D. 4 m) (see Table 12 and Figure 5) and tree age of forming forking ranged from 120 to 160 years.

Conclusion

Due to extensive cuttings and unbalanced growing stock between harvesting and stand increment for several decades, most of the old-growth Korean pine forests have been replaced by secondary forests. Now, the virgin forests of Korean pine can be found only in few natural reserves of northeast China. Therefore, this kind of forest ecosystem has become endangered and attracted more concerns. The available data to study community structure for old-growth Korean pine forests in this paper were collected from four plots in Liangshui Natural Reserve. The 4 stands represented four types of natural Korean pine forest, e.g. spruce-fir-Korean pine forest, costata birch-Korean pine forest, basswood-Korean pine forest, and oak-Korean pine forest.

The analyzing results from one clear cutting plot with area 1.03 ha (plot #216) showed that age structure of Korean pine trees was strongly uneven-aged with one dominated peak followed normal distribution (see Figure 1). Within a stand, the tree age of Korean pine was different and varied from 100 to 180 years and more than 87% trees were distributed in age ranged 180~240 year old. The DBH of Korean pine trees in the stand were increased with tree age. But, DBH differences in same age class (20 years) varied from 28 cm~64 cm with 50 cm of mean value. Alike, the age of Korean pine trees were also increased with tree DBH. Tree age in same DBH class varied from 40 to 120 years. The height of

Korean pine trees with same age varied from 5 to 20 m within the stand and 70% trees were varied more then 10 m.

In old-growth Korean pine forest, many conifer and hard wood species mixed with the dominated species of Korean pine. The structure of species composition for 4 stands represented different forest type showed that accompanied species for each forest type were little different. In the spruce-fir-Korean pine forest, mixed species included spruce, fir, and some hardwood species, e.g. basswood, Manchurian ash, and elm. In broad-leaved Korean pine forest, the accompanied hardwood species were mainly composed of costata birch, basswood, and oak, where mixed with small percent of spruce and/or fir, respectively.

The canopy of the old-growth Korean pine forest can be divided into two layers according to the height pattern of forest canopy. Differences in mean age and height between Layer I and Layer II were ranged 80~150 years and 7~13 m, respectively. For different canopy layer, the accompanied species were different. But, the Korean pine was appeared in over-sorry and under-story simultaneously for each forest type and, thus, indicates that regeneration of the Korean pine keeps continuous in old-growth forests. In over-story canopy, age was mainly ranged from 160 to 280 years for the coniferous species (Korean pine and spruce) and from 60 to 180 years for hardwood trees. In under-story canopy, the conifer trees were mainly distributed in age from 60 to 120 years.

The size-class distributions in different forest types were studied for canopy Layer I and Layer II, respectively. The results showed that the DBH distribution had a single peak in over-story canopy and inverse J-shapes in under-story canopy for old-growth Korean pine forests. As a result, the Weibull function was used to model the diameter distribution and performed well to describe frequencies of trees by size-class with a single peak in over-story canopy and inverse J-shapes in under-story canopy for old-growth Korean pine stands.

The forking heights of Korean pine trees were not significantly related with tree age and tree height. The forking height of 75% trees ranged from 16 m to 24 m with mean forking height 19.4 m that tree age of forming forking ranged about 120 to 160 year old.

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