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A Study on Soil Particle Size in Mountains of Seoul Vicinity for Forest Restoration*

Kim, Jae Geun[1)]

[1)] Department of Biology and The Korea Institute of Ornithology, Kyung Hee University

생태 복원을 위한 서울근교의 삼림 토양 입자 크기에 관한 연구*

김 재 근[1)]

[1)] 경희대학교 생물학과 · 한국조류연구소

ABSTRACT

서울근교에 존재하는 소나무림은 낙엽활엽수림으로 바뀌고 있다. 그러므로 서울근교의 산림에 대한 조사는 자연 식생형 산림 특히 소나무 복원에 그 시사점을 줄 수 있다. 본 연구에서는 서울근교에 존재하는 8개 산의 15개 지소를 선정하여 그곳에 존재하는 식생형을 파악하고, 토양의 물리적 특성을 조사하여 산림 복원 시 고려할 토양 특성을 확인하고자 하였다. 8개 산에서 선정된 15개 조사지소는 소나무군락, 소나무-낙엽활엽수군락, 낙엽활엽수군락으로 나누어 물리적 토양 특성을 조사하였다. 소나무의 평균 중요치는 소나무군락에서 137이었으며 소나무-낙엽활엽수군락에서는 8이었다. 평균 바위분포 면적-토양 깊이-경사는 소나무군락에서 26-22-31, 소나무-낙엽활엽수군락에서 7-53-32, 낙엽활엽수군락에서 14%-34cm-28°로 나타났다. 소나무군락, 소나무-낙엽활엽수군락, 낙엽활엽수군락의 임상 및 토양에 존재하는 총 유기물량은 각각 2490, 1757, and 2107g/m^{2}로 조사되었다. L층에서의 유기물량은 모든 군락 유형에서 비슷하였으나, F층과 H층에서는 매우 다르게 나타났다 : F층은 소나무군락에서 가장 발달하였고 H층은 낙엽활엽수군락에서 가장 발달하였다. 통계처리 결과는 바위분포 면적, 고도, 경사, 사면은 군락의 유형과 유의한 관련성을 보여주지 않았으나, 토양의 깊이, 자갈의 함량, 세사와 미사의 함량은 군락의 유형에 따라 다름을 보여주었다. 본 연구는 소나무군락의 토양이 자갈과 세사의 높은 함량과 관련이 있으며, 이에 따라 H층의 발달이 미약하게 나타남을 보여 주었다. 그러므로 2-10mm의 자갈이 40% 이상되는 장소에는 분해가 덜된 유기물과 소나무를 사용할 때 복원의 성공가능성이 높으며, 자갈의 함량이 30% 이하이며 모래의 함량이 50% 이상인 장소에는 분해된 유기물의 함량을 높이고 낙엽활엽수를 이용하는 것이 복원 성공 가능성이 높음을 시사한다.

Key Words : *pine forest, tree restoration, soil particle size, habitat characteristics, organic contents*

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Ⅰ. INTRODUCTION

Montane forests of Korea and adjacent areas of Manchuria have *Pinus densiflora* as a dominant pine at low to moderate elevations with *P. koraiensis* increasing abundance at higher elevations in some areas. Coastal parts of southern Korea are dominated by *P. thunbergii* (Richardson and Rundel, 1998; Lee, 1986). A particularly prominent aspect of pine biogeography is the common association between pines and acidic nutrient-poor soils (Scholes and Nowicki, 1998).

P. rigida is a native pine in north America and imported into Korea in 1906. Pine trees dominate 1.3% of forested area in Korea and half of them has been planted since 1953 because *P. rigida* is a recommended tree species to be planted (Korea Forest Service, 1973). On the other hand, natural pine forests in the Seoul vicinity are changed into deciduous forests. Insects might be responsible for the degeneration of pine trees (Park and Hyun, 1983) or forest fire might lead uneven pine dominated regions to oak dominated regions because of differences in regeneration capability from burnt stamps (Choung, 2000). The disappearance of human disturbance due to the change of energy source from woods to fossil fuel might lead the natural succession of pine forests.

To restore pine and other forests successfully in destroyed forests by anthropogenic activities, such as mining and road construction, it is necessary to know which factors are influencing tree establishment and growth. It is reported that the factors contributing largely to the growth of red pine seemed to be tree form-locality, soil type, humus content, position on slope and type of slope (Oh, 1972; Ma, 1974; Kim and Han, 1997; Lee and Cho, 1999; Yun and Hong, 2000). There has been no consideration on distribution of soil particle size. Therefore, the purpose of this study is to find any significant difference in soil particle size distribution and habitat characteristics including organic contents, position on slope, type of slope, and soil depth among pine forest and others in the Seoul vicinity area. This result will contribute to the restoration projects of tree species.

Ⅱ. METHODS

1. Study Sites

Study sites were selected at 8 mountains in the Seoul Vicinity where is pine forest (Figure 1) and have closed canopy. Pine forests were first selected at each mountains and tried to find other forests near pine forests, which minimize climatic and soil type differences. Dominant species in pine forests were *P. densiflora* or *P. rigida*. Forest type was categorized as pine forest, mixed forest, and deciduous forest according to succession stage of Nelson (1979).

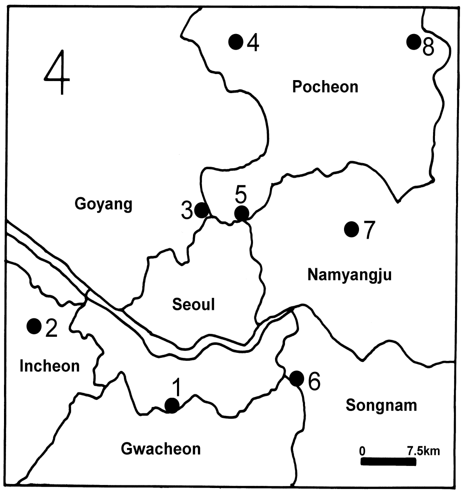

Figure 1. Location of the study sites (•).
1. Mt. Gwan-ak (GA), 2. Mt. Gye-yang (GY), 3. Mt. Do-bong (DB), 4. Mt. So-yo (SY), 5. Mt. Su-rak (SR), 6. Mt. Cheong-nyang (CN), 7. Mt. Chun-ma (CM), 8. Mt. Chung-gye (CG)

2. Methods

A 10m×10m quadrat was set in a study site in

2001. Rock coverage, altitude, slope, and slope aspect were determined in the quadrats. Diameter at Breast Height (DBH) of trees larger than 1.6 cm DBH was measured and number of trees smaller than that was counted. DBH of small trees was considered as 1cm and relative coverage was calculated based on basal area. Importance value was calculated as the sum of relative coverage and density.

At each study sites, litter and soil were collected at one or two quardrats (30cm×30cm) and litter layer was divided into 3 horizons : Litter horizon (L), Fermentation horizon (F), and Humified horizon (H). Collected samples were air-dried in a laboratory. Soil depths were measured at each corner and the center of 10m×10m quadrats and averaged.

Dry weight was determined after 24 hrs in a 105℃ dry oven. Organic content was determined as loss on ignition in 450℃ furnace for 4 hrs. For soil texture analysis, standard sieves (size 2mm, 0.5mm, 0.355mm, 0.2mm, 0.1mm. 0.053mm) and sieve shaker (CSC Scientific Company Inc. Catalog No. 18480, strength 6 for 3 minutes) were used. Silt and clay content were summed as soil less than 0.053mm grain size. StatView for windows (Abacus Concepts, Inc. Version 4.57) was used for statistical analysis.

Ⅲ. RESULTS AND DISCUSSION

1. Habitat Characteristics at Sampling Sites

Forests were categorized based on importance value of pine trees. Average importance values of pine trees in pine forests and mixed forests were 137 and 8.2 (Figure 2). Pine trees include *P. densiflora, P. koraiensis* and *P. rigida* and most of *P. rigida* had been planted and well established.

Table 1 shows the species composition and habitat characteristics of pine forests. *Quercus momgolica* consists of 23.4% relative coverage at Mt. Do-bong 1 and there is no other deciduous species that has more than 10% relative coverage. Average rock coverage of pine forest was about 26.3±15.4% and average soil depth was 21.7±3.9cm. Average slope was 31.3±1.7° and aspects of two, three, and one site were NE, SE, and SW, respectively.

Table 2 shows the species composition and habitat characteristics of mixed forests. Dominant tree species were *Q. mongolica, Styrax japonica, P. rigida, Castanea crenata* and dominant shrub

Table1. Species composition of pine forests in the Seoul vicinity.

Site Name	Mt. Gwan-ak 1		Mt. Gwan-ak 2		Mt. So-yo 1		Mt. Gye-yang		MT. Do-bong 1		Mt. Su-rak 1	
Rock coverage (%)	25		<5		100		<5		25		<5	
Soil depth (cm)	26		22		5		17.6		32.7		26.8	
Altittude (m)	200		160		458		207		195		172	
Average slpoe	30		37		35		29.3		25.2		31.25	
Exposure	N20E		S35E		N15E		S45W		S10E		S30E	
Species	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)
Pinus densiflora					**78.4**	**78.3**	**90.4**	**41.8**	**47.1**	**30.0**	**1.3**	**1.1**
Pinus rigida	**100**	**100**	**92.1**	**44.2**					**13.7**	**8.3**	**75.9**	**21.2**
Quercus mongolica			2.3	16.3	14.5	14.5	3.9	37.3	23.4	18.3	5.1	42.1
Quercus accutissima			1.6	11.6								
Euonymus alatus for. Ciliato-dentatus			0.7	4.7								
Robinia pseudo-acasia			3.3	23.3							6.4	5.6
Rhodendron mucronulatum					7.2	7.2			5.0	20.0	0.7	2.2
Lespedeza maximowiczii									4.0	6.7	0.3	1.1
Prunus serrulata											2.2	1.1
Weigela subsessilis											4.2	13.3
Lindera obtusiloba											1.0	3.3
Juniperus rigida							0.8	3.0	1.7	6.7	2.5	7.8
Castanea crenata							4.9	17.9			0.3	1.1
Alnus japonica									0.4	1.7		
Zanthoxylum schinifolium									0.4	1.7		
Sorbus alnifolia									4.3	6.7		

species were *Robinia pseudo-acasia, Rhododendron schlippenbachii*, and *Cornus controversa*. Average rock coverage of pine forest was about 7.0±4.5% and average soil depth was 52.7±5.3cm. Average slope was 32.1±1.7° and aspects of three and two sites were NE and SE, respectively.

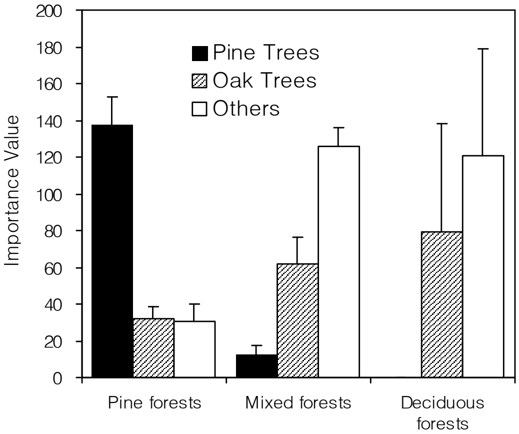

Figure 2. Average importance value of pine, oak, and other deciduous trees at three forest types. Bar means one standard deviation.

Table 3 shows the species composition and habitat characteristics of deciduous forests. Dominant species were Q. mongolica, R. pseudo-acasia, and Sorbus alnifolia. Average rock coverage of pine forest was about 13.8±9.2% and average soil depth was 34.4±10.5cm. Average slope was 28.0±4.4° and aspects of one, two, and one site were NE, SE, and SW, respectively.

Lee and Cho (1999) reported that pine trees prefer south or east aspect because they grow well under strong sunshine. However, this study show no statistically significant difference in rock coverage, altitude, slope, and aspect among three forest types in study sites.

2. Soil Characteristics

Organic matter in litter layer was the highest in So-yo 1 as about 5kg/m^2 and the lowest in Gye-yang and Cheong-nyang as about 0.2kg/m^2 (Figure 3). Gye-yang was dominated by *P. densiflora* and Cheong-nyang was dominated by *Q. mongolica*

Table2. Species composition of mixed forests of pine and deciduous trees in the Seoul vicinity.

Site Name	Mt. Chun-ma 1		Mt. Chun-ma 2		Mt. Cheong-nyang		Mt. Su-rak 3		MT. Do-bong 2	
Rock coverage (%)	<5		<5		<5		<5		25	
Soil depth (cm)	53.8		47.9		54.6		>60		37.2	
Altittude (m)	185		196		397		182		207	
Average slpoe	35		31		33.5		25.8		35	
Exposure	N20E		N5E		N20E		S21E		S60E	
Species	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)
Pinus densiflora					**13.5**	**1.4**			**2.8**	**0.8**
Pinus rigida	**28.9**	**2.4**					**5.0**	**1.3**		
Pinus koraiensis			0.4	2.4						
Larix leptolepis	26.4	1.6								
Quercus mongolica	4.5	9.6	25.2	14.3	32.6	20.3	72.0	17.3	73.7	18.9
Quercus accutissima			4.8	4.8						
Styrax japonica			25.3	26.2	21.7	11.6				
Alnus japonica					13.8	5.8				
Rhodendron mucronulatum					3.0	11.6	11.9	36.0	12.9	43.3
Sorbus alnifolia									7.3	30.7
Prunus serrulata									0.2	0.8
Alnus hirsuta							3.7	8.0	1.6	0.8
Juniperus rigida									1.4	4.7
Rhus trichocarpa	0.4	0.8								
Robinia pseudo-acasia	10.8	23.2								
Morus alba	6.3	13.6	0.9	2.4						
Lindera obtusiloba	1.3	6.7	2.0	2.4			4.0	12.0		
Rhododendron schlippenbachii	13.4	28.8	0.4	2.4						
Acer palmatum					7.3	17.4				
Cornus controversa			1.3	2.4	8.1	31.9				
Castanea crenata	6.0	12.8	20.4	19.0						
Corylus heterophylla var. thunbergii	3.4	7.2					1.7	20.0		
Weigela subsessilis			2.3	2.4			1.8	5.3		
Quercus variabilis			6.1	2.4						
Styrax obassia			10.8	19.0						

Table 3. Species composition of deciduous forests in the Seoul vicinity.

Site Name	Mt. Su-rak 2		Mt. Su-rak 4		Mt. Chung-gye		Mt. So-yo 2	
Rock coverage (%)	<5		<5		25		25	
Soil depth (cm)	55		20.2		34.3		28.2	
Altittude (m)	160		175		157		461	
Average slpoe	29.5		27.4		35		20	
Exposure	S30E		S38W		S60E		N20E	
Species	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)	R.C. (%)	R.D. (%)
Robinia pseudo-acasia	85.5	28.3	12.5	62.5				
Juniperus rigida	3.4	16.7	0.4	0.8				
Quercus mongolica	0.7	3.3	9.0	5.0	87.9	63.2	82.9	68.2
Rhodendron mucronulatum	5.7	28.3	0.4	0.8				
Cornus controversa	3	15					2.3	4.5
Stephanandra incisa	1.7	8.3						
Sorbus alnifolia			61.2	10.8				
Alnus japonica					8.8	10.5	3.8	9.1
Weigela subsessilis			10.9	7.5	2.0	15.8		
Lindera obtusiloba			5.7	12.5	1.3	10.5		
Morus alba							11.0	18.2

and *S. japonica*. It is not reasonable to consider fast decomposition rate at these sites because species composition is different between Gye-yang and Cheong-nyang. This result might come from human disturbance or microenvironment such as air flow. Most of organic matter in pine forest is in F horizon and this reflect low decomposition rate. However, big portion of organic content in other forest types is in H horizon and H horizon increases with decrease of pine trees.

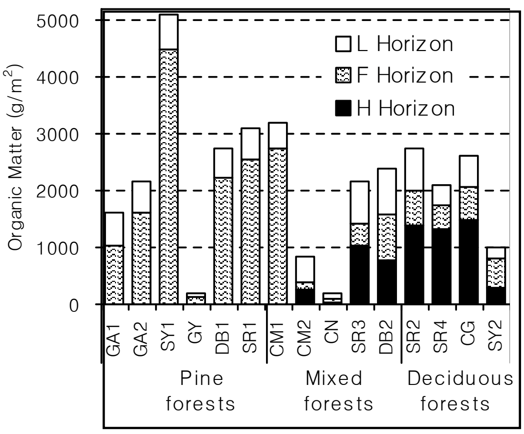

Figure 3. Organic matter in litter layer at study sites.

In general, decomposition rate in pine forests is low and there is enhanced generation of humic and fulvic acids in thick (Scholes and Nowicki, 1998). Total organic content was high in pine forests at study sites but pine forests did not show any development of H horizon. There should be some mechanism to remove H horizon and I hypothesize that small organic matter in pine forests was leached with rain through big soil particles such as gravel. Figure 4 shows that pine forests have high percentage of gravel (particles between 10 and 2mm size) than others. Statistical analysis shows that there are significance differences in organic matter in H horizon and soil particle size distribution among forest types (Table 4). Coarse

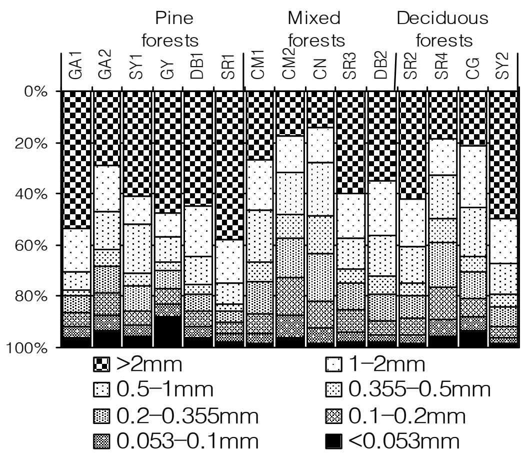

Figure 4. Particle size distribution of soil within 15cm depth at study sites.

sand of size 0.2mm-2mm among soil particle size is the most significant contributor in these differences. Figure 4 and Table 4 indicate that high gravel and low coarse sand contents are related with the development of H horizon. Kim *et al.* (1966) reported that decomposition rate of litter was highest in the H horizon in the pine stand and the F horizon of the oak stand. Rapidly decomposed organic matter in H horizon of pine stand could be leached with rain.

Table 4. ANOVA analyses of soil characteristics among pine, mixed, and deciduous forests. Values are average±standard error.

	Pine forest	Mixed forest	Deciduous forest
Sample number (n)	6	5	4
L layer organic matter (g/m^2)	483±85	515±27	447±117
F layer organic matter (g/m^2)	2007±606	825±499	540±39
H layer organic matter (g/m^2)	0**	416±204	1120±280**
Gravel % (2mm - 10mm)	46±4*	30±7	29±6*
Sand % (0.355mm - 0.5mm)	$3.9 \pm 0.6^{1*,2*}$	$8.5 \pm 1.8^{1*}$	$6.8 \pm 0.8^{2*}$
Sand % (0.355mm - 2mm)	$31.0 \pm 2.6^{1*,2*}$	$41.2 \pm 3.2^{1*}$	$42.7 \pm 2.5^{2*}$
Sand % (0.2mm - 2mm)	$38.4 \pm 3.3^{1*,2**}$	$54.2 \pm 4.7^{1*}$	$54.5 \pm 2.8^{2**}$
Sand % (0.053mm - 2mm)	$48.9 \pm 4.0^{1*,2*}$	$68.3 \pm 6.6^{1*}$	$67.0 \pm 4.7^{2*}$
Soil depth (cm)	21.7±3.9*	52.7±5.3*	34.4±7.4

** significance level of $p < 0.01$
* significance level of $p < 0.05$

Table 4 also shows the significant difference in soil depth among forest types. Soil depth increase with successional stage (Barbour *et al.,* 1999) and pine tree has a capability to grow in wide range of soil moisture (Lee and Cho, 1999). Thus, deep soil layer was expected in late successional stage but mixed forests have deepest soil depth. Deciduous forests have medium soil depth. This may be a result of microenvironmental difference among sites or site selection bias. Also, there is a possibility to consider human disturbance; plantation or removal of specific species. This can be explained after consideration of local human history.

3. Synthesis

Most of the natural pine stands were destroyed under the Japanese ruling period (190-1945) and during Korean war (1950-1953) (Kim and Zsuffa, 1994). An additional problem to this pine was damage from pine gall midge (Park and Hyun, 1983). Pine trees are not climax species in Korea and would be substituted by oak and *Carpinus laxiflora* except the ridge of mountains and rocky area, where soil depth is shallow and infertile. Pine forests in Korea may be in secondary succession process or plantation (Kim and Song, 1995).

Soil type of pine forests is Entisol which was generated from granite (Korean Society of Earth Science, 1998). Pine trees distribute in all aspect but growth rate is high in east and south aspect (Lee and Cho, 1999). Pine trees adjust well on the ridge of mountains, where is infertile and dry (Lee and Cho, 1999).

It is known that soil factors related with the growth of *P. densiflora* are topography, altitude, available P, Mg, K, Ca, pH, and loss on ignition of soil (Oh, 1972; Kim and Han, 1997; Yun and Hong, 2000). Ma (1974) analysed the environmental factors for the growth of pine trees and concluded that soil type, soil color, soil depth, aspect, slope, and altitude, in the sequence of strength, are related factors. Also, Growth of *P. thunbergii* was related with soil depth, slope, organic matter, total N, soil pH, and base saturation (Chung *et al.* 1993).

As above, many soil and environmental factors were known to be related with the growth of pine trees. However, there is no amiable explanation about the mechanism through which pine trees were growing well. In general, above factors are related to the growth of any trees in pure stands. If there is a competition of pine tree with others, above factors might work for others than pine trees. This study was done in natural or naturalized forests where trees have been compete with each others for more than 30 years and shows that soil particle size and organic content of H horizon or F horizon are related to the distribution of plant communities in Seoul vicinity.

The difference of organic content of H horizon among forest types can be explained as follows. Decomposition rate in F horizon of pine stands was low and that in H horizon was high (Kim *et al.,* 1966) and decomposed small particles in H horizon can be leached through pores among gravels. Pine forests have high content of gravel and H horizon has been under-developed in pine forest. However, this hypothesis should be further tested in the lab with the soil and humus.

Ⅳ. CONCLUSION

It is necessary to know the characteristics of habitats and to consider these factors in restoration projects for successful restoration of trees. This study tried to reveal physical soil characteristics of plant communities in Seoul vicinity. Plant communities were in natural or stabilized condition and study results expected to give some crucial information for tree restoration, especially pine trees.

As physical factors, rock coverage, soil depth, altitude, slope exposure, organic contents of L, F, H horizon, and contents of different soil particle size were analyzed. Statistical analysis showed that there were significant differences in soil depth, gravel content, coarse sand content, organic content of F and H horizons among forest types. This study showed the change of soil texture might be accompanied with succession : gravel is decreasing and 0.2 - 2mm coarse sand is increasing with succession from pine forests to deciduous forests.

Pine forests have very little organic material in H horizon and high content of gravel. This can be explained by the decomposition rate in F and H horizon and leaching through gravel : low decomposition in F horizon and high decomposition in H horizon. The results of Kim et al. (1966) support this explanation.

This study suggests that pine tree restoration is good for where gravel content is high (larger than about 40% of 2 - 10mm gravel) and decomposed organic nutrients are little (no humus) in Seoul vicinity. In other hand, deciduous tree restoration, especially oak trees, is good for where coarse sand content high (higher than 50% of 0.35 - 2mm sand) and humus content high is high.

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