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Ecological Examinations of the Radial Growth of Pine Trees (*Pinus densiflora* S. et Z.) on Mt. Namsan and the Potential Effects of Current Level of Air Pollutants to the Growth of the Trees in Central Seoul, Korea.

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Abstract

Ecological examinations of the radial growth patterns of pine trees(*Pinus densiflora* Sieb. et Zucc.) growing on Mt. Namsan in central Seoul were made to test a proposition that the pine trees decline due to the influence of air pollution and acid rain, which was proposed by some researchers in Korea, and the potential effects of current level of air pollutants to the growth of the pine trees in central Seoul have been speculated. Tree-rings of 40 trees sampled at 3 sites of Mt. Namsan were prepared and examined using a Computer-aided Tree-Ring Measuring System at Kookmin University, Korea. Air pollutant data collected by the Ministry of Environment(MOE) and the Forestry Research Institute(FRI) were used to infer the general conditions of the environment. Correlation analysis was applied to the data set of tree growth and the other environmental factors. General information derived from the close examination of the tree-rings and the data on air pollution, drought, and the other biological conditions suggested that the growth of the pine trees was severely affected by the occurrence of drought(climatic variation), the prevalence of the pine leaf gall midges(insects), and the suppression by the black locust trees(*Robinia pseudo-acacia* L.) (competition among trees). While the current condition of air pollution in Seoul cannot be categorized as good, the concentrations of air pollutants are not so high as to cause acute damages to the trees. In addition, while the data of rain acidity showed episodic low pHs of under 4.0, the average of them is far less acidic than those which were observed in either northeastern United States or central Europe, where the decline of trees were not solely attributed to any of the air pollutants. Considering the sequential facts that one of the most important environmental factors that affect the growth of trees is weather condition of the forest, that the proposition of the decline of the pine trees was made without careful examination of the growth patterns and past growth history of them as well as the complex influences of many other factors including the weather conditions to the growth of trees, and that no objective explanation has been made on the causal relationships between the current condition of air pollution and the growth of the trees, such a proposition should be evaluated as invalid for the explanation of tree growth on Mt. Namsan in central Seoul, Korea. The author evaluates the factors of air pollution (including acid rain) as the predisposing factors, which may have the potentials to chronically affect the tree growth at the forest ecosystem on Mt. Namsan for a long period of time. Ecosystem ecological studies should be further carried out to carefully explain both the functional and the structural aspects of the ecosystem

processes, which include the biogeochemistry and the long-term changes of soil conditions as well as the growth of the other tree species on the mountain.

1. INTRODUCTION

Due to rapid industrialization of our society, conditions of ambient environment of some part of Korea are getting worse in recent years than those of the past. In the 1960s and 1970s, forest ecosystems of such industrial complexes as Ulsan and Yeochon were badly destroyed by the air pollutants emitted unlimitedly from various sources of the factories in the industrial complexes. Evidences are present that the vegetation of the areas still suffers from the stresses of the present as well as the past pollutants. Despite the fact that some characteristics of ambient contaminants in Seoul are very different from those in the industrial complexes, some researchers(Lee, 1993; Lee et al., 1993) suggested that the forest ecosystems in Seoul are being destroyed in recent years. They maintained that pine trees not only on Namsan in central Seoul but also in central part of Korean peninsula suffer from the stresses of air pollutants and acid rain. After series of mass media coverage on these points were made, the public generally believe that the rain is so acidic as to force the people's hair to be fallen out when they are exposed to the rain. In addition, the public even believe that all the pine trees and the vegetation on Mt. Namsan are being destroyed by the air pollution and acid rain based on the proposition.

After the author reviewed the articles and carried out series of field surveys on the ecosystems, he found that the above proposition was inadequately made and that it misled the public without clear evidences on it, because in such studies such factors as the weather conditions, competition among trees, and insect damages were not significantly considered. He also found that the proposition was made without the close examination of the current growth patterns and the past growth history of them. No rational evaluation has been made for the current level of air pollution and the rain acidity and that no objective explanation has been made on the causal relationships between the current condition of air pollution and the growth of the trees by them. In other words, ecological considerations were not adequately given in such a proposition. Consequently, the author strongly felt that public are unduly threatened by this kind of proposition.

To clarify the confusion and to test the proposition objectively, it is necessary to evaluate the interactions between the growth of the trees and the environmental factors as well as the current growth condition of the trees and the current condition of air pollutants and the other environmental factors such as drought, competition, and the other biological factors. Through this paper, the author carried out the ecological examination of the radial growth patterns of the pine trees growing on Mt. Namsan in central Seoul to test a proposition that the pine trees decline due to the influence of air pollution and acid rain. He also extended his speculation to the potential effects of current level of air pollutants to the growth of the trees in central Seoul, Korea.

2. MATERIALS AND METHODS

To describe the current conditions of tree growth, tree cores sampled from 40 trees at 3 sites were taken using the point-sampling methods on Mt. Namsan, central Seoul, Korea(〈Figure 1〉). The sites were randomly selected considering the representativeness and the difference of the vegetation types which are closely related to the aspects (Kim, 1993). While the stands of northern and western slopes, where pine trees are growing as isolated islands on the ridges of the mountain, are mainly dominated by the deciduous tree species, southern slopes are mainly dominated by the pine trees. On the eastern slopes, pine trees are showing a generally suppressed growth by the other taller trees. Sampled tree-rings were carefully prepared and precisely examined using a Computer-aided Tree-Ring Measuring System at Kookmin University. Critical years that trees showed synchronously good or bad growth were determined.

Air pollutant data collected by the Ministry of

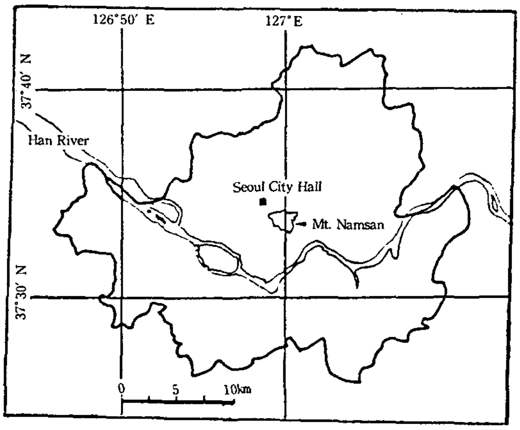

Fig. 1. Map showing the location of Mt. Namsan in central Seoul, Korea

Environment and the Forestry Research Institute were used to infer the general conditions of the environment. Data on the records of the major air pollutants, drought records simulated by using the computer model "BROOK" for the last 82 years (Federer and Lash, 1978), and the past epidemics of the pine leaf gall midges on Mt. Namsan in central Seoul were interpreted to test the proposition that the pines decline due to the influence of air pollution and acid rain. Correlation analysis was carried out to find out the relationships among the growth of tree species and the other environmental variables. Ecological interpretation was made for the factors that affect the growth of trees growing on Mt. Namsan.

3. RESULTS AND DISCUSSION

3. 1. The growth patterns of pine trees on Mt. Namsan

Examination of the tree-rings made it possible to describe the growth patterns of the individual trees as well as all the trees at the sites.(Fritts, 1976, 1987; Kim, 1988)

3. 1. 1. Tree growth patterns on the southern slope of Mt. Namsan

Sixteen trees growing on a southern slope of the mountain were sampled and the mean diameter growth patterns were presented in ⟨Fig. 2⟩. The trees are mainly composed of pine trees. Until the early 1960s pine trees grew very slowly. The reason for this slow growth of trees may include the combination of such factors as the suppression by other trees and the prevalence of the pine moths and the pine leaf gall midges in the trees(Forestry Research Institute, 1985; Kim, 1993; Park, 1994). It is worthwhile to note that the pine trees showed rapid growth from the early 1970s, which is mainly attributed to the clearing of the competing broadleaved trees in order to revive the pine trees at the site, where they were severely damaged by the pine leaf gall midges by the Namsan Park Management Office in the early 1970s(Park, 1994). From then on, the pine trees grew relatively rapidly and the majority(about 80 %) of the pine trees grew faster in the last decade than the past at the site. If the proposition that the pine trees are declining due to air pollution holds true, the radial growth of the pine trees should decrease continuously to a very low level. However, it is difficult to find out trees that showed such growth patterns. Therefore, it is unreasonable to maintain the proposition that the pine trees are declining due to air pollution at the site. In other words, the pine trees are growing well by applying the active management practices such as clearing the competing tree species and controlling the pine leaf gall midges by the pesticide injection to stems of pine trees. The growth patterns of the individual trees at the site are presented by the paper prepared by the author (Kim, 1993).

Another interesting point to be mentioned is that the trees show a wide annual fluctuation in radial growth, which indicates that there are some other factors than air pollution that cause this fluctuation. As the condition of air pollution does not fluctuate so widely by year, air pollution can not be the causal factor that induces such fluctuation in radial tree growth. As can be described later, the author considers the possible candidates for the factors are the drought occurrence and the prevalence of the pine leaf gall midges.

3. 1. 2. Tree growth patterns on the eastern slope of Mt. Namsan

Sixteen trees growing on an eastern slope of the mountain were sampled and the mean diameter

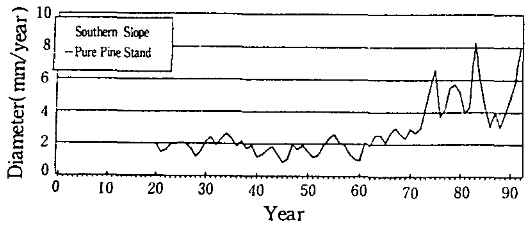

Fig. 2. Tree growth patterns on the southern slope of Mt. Namsan(mean growth of 16 trees)

growth patterns were presented in ⟨Figure 3⟩. At the site, four tree species are growing together, i.e., pine trees, black locusts, mountain cherries(*Prunus sargentii* Rehder), and Mongolian oaks(*Quercus mongolica* Fischer). At this site, the pine trees showed typical growth patterns that are suppressed by other fast growing tree species.

It is worthwhile to note that the black locusts and the Mongolian oaks are growing very fast while the pine trees are growing slowly for the last 3 decades. As a result, the pine trees showed the declining patterns in radial growth. Here, the reason why the pine trees are declining at the site is clearly attributed to the suppression of them by other fast growing trees rather than any other factors including air pollution. If the proposition that trees on Mt. Namsan are suffering from the air pollution holds true, the other tree species should at least show similar declining growth patterns. In order to evaluate the effect of air pollutants to the growth of pine trees objectively, prior evaluation of the competition effects to them should be adequately carried out.

If we really want to save the pine trees at the site, the best thing we can do is to get rid of the other competing trees. Then the pine trees will show the recent growth patterns on the southern slope discussed above. Discussion about the competition of the pine trees with the other tree species will be further carried out in this paper. The growth patterns of the individual trees at the site are also presented by the paper prepared by the author (1993).

Another interesting point to be noticed is that the fast growing trees of the black locusts and the Mongolian oaks showed a large and a similarly synchronous annual fluctuation to that of the pine trees on the southern slope in radial growth, which indicates that there are some other factors than air pollution that cause this synchronous fluctuation. As the pine trees were so much suppressed by the other trees, they could not show significantly synchronous growth with the other suppressing trees at the site. As the condition of air pollution does not fluctuate so much by year, the possible candidates for the fluctuation of them are the drought occurrence or the other climatic factors.

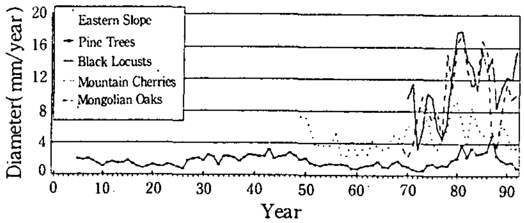

Fig. 3 .Tree growth patterns on the eastern slope of Mt. Namsan(mean growth of 16 trees)

3. 1. 3. Tree growth patterns on the northern slope of Mt. Namsan

Eight trees growing on a northern slope of the mountain were sampled and the mean diameter growth patterns were presented in ⟨Fig. 4⟩. At this slope, natural vegetation dominates the stands. On the ridges of the slope, where bed rocks are exposed, scattered pine trees are distributed with the Mongolian oaks. At this site, the pine trees are growing relatively independently without much suppression from other trees.

During the periods of the 1930s, from mid-1950s to mid-1960s, and from late-1960s to early-1980s, the pine trees showed fairly depressed radial growth compared to the growth of the Mongolian oaks.

The depression of the growth can be attributed to the factors of prevalence of such forest insects as the pine leaf gall midges and the pine moths other than the climatic factors or soil-related factors that affect the growth of the two species similarly(Forestry Research Institute, 1985; Kim, 1992; Kim, 1993; Park, 1994). Therefore, as was discussed by the author(Kim, 1993), the effects of forest insects on the growth of pine trees on the Mt. Namsan should be adequately evaluated prior to the suggestion of the proposition that air pollution is the major factor that causes the decline of pine trees on Mt. Namsan.

In recent years, it can be found that the amounts of radial growth of the pine trees and the Mongolian oaks are almost the same, which is thought to be attributed to the control of the pine leaf gall midges by the pesticide injection to stems of the pine trees. It is worthwhile to note that the pine trees and the Mongolian oaks fluctuate similarly in radial growth, which also indicates that there are some other factors than air pollution that cause this synchronous fluctuation. As the condition of air pollution does not fluctuate so much by year, the possible candidates for them are drought or the other climatic factors. The growth patterns of the individual trees at the site are also presented by the paper prepared by the author(Kim, 1993). At this site, it was difficult to find out the evidence that the trees are dying due to air pollution.

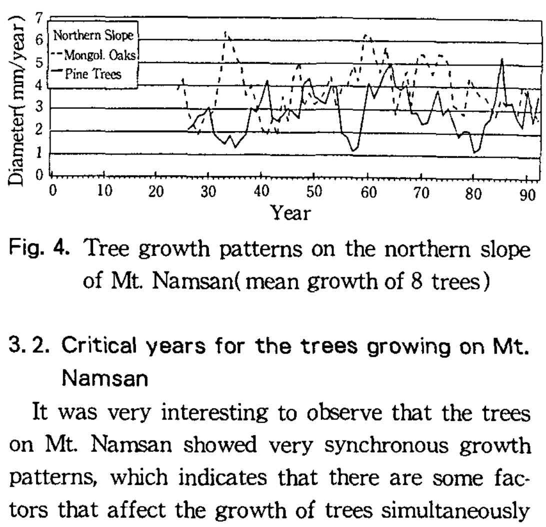

Fig. 4. Tree growth patterns on the northern slope of Mt. Namsan(mean growth of 8 trees)

3.2. Critical years for the trees growing on Mt. Namsan

It was very interesting to observe that the trees on Mt. Namsan showed very synchronous growth patterns, which indicates that there are some factors that affect the growth of trees simultaneously (Kim, 1988). Another thing to point out is that there are certain years that trees showed very good or bad growth synchronously. It is called the critical year. By examining the environmental factors in these years, we can interpret which are the major environmental factors that affect the growth of tree species significantly. Based on the records of tree growth, critical years were selected as was shown in the rightmost column of the 〈Table 1〉. The year that more number of trees are apparent in the Table indicates that the trees have shown either better or worse growth in the year. The conditions of these years are further interpreted related to the other factors on Mt. Namsan.

3.3. The condition of air pollution and rain acidity in Seoul

The discussion of the condition of air pollutants in Seoul itself can be the topics of many studies. Those studies should include such disciplines as the physics, dynamic modelling, chemistry, statistics, meteorology, biology, etc.

As of now, such pollutants as SO_X(sulfur oxides), NO_X(nitrogen oxides), O_3(ozone), CO(carbon monoxide), THC(total hydrocarbons), and TSP (total suspended particulates) are categorized as the major air pollutants in Korea. Although NOx and O_3 become more problematic in recent years than in the past due to speedy development and advancement of the industries and our life styles, SO_X and rain acidity have been the major factors that attracted the attention of the public.

Therefore, for the ease of discussion, general means and patterns on the conditions of some of the major air pollutants and rain acidity in Seoul will be presented and interpreted in relation to the growth of trees.

3.3.1. The concentration of SOx in Seoul

Although the concentrations of SO_X in Seoul were high in the past, it is doubtful to consider that they were toxic enough to cause acute injury to the trees on Mt. Namsan. Smith(1990) suggested that the impact of sulfur dioxide on forest trees may fall only in the 0.1ppm-0.15ppm chronic exposure range when he reviewed the studies on the relationships between air contaminants and the woody plants. Whether or not the trees had been suffered from the air pollutants of the past may depend on the past conditions of air pollution in Seoul. The author speculates that air pollutants of the past might have induced chronic impacts upon the growth of trees. It may be very difficult to find out the direct proofs that air pollutants in Seoul had negatively affected the trees on Mt. Namsan, however.

According to the Ministry of Environment (MOE) in Korea(1994), the concentration of SO_X in recent years is fairly low (〈Fig. 5〉). Mean annual concentrations of SO_X in 1992 and 1993 were

Table 1. Evaluation of Critical Years for the Sampled Trees Growing on Mt. Namsan.

Year	The Growth of Pine Trees		Evaluation of Critical Year for the Pine Trees[1]	The Growth of Deciduous Trees		Evaluation of Critical Year for the Deciduous Trees[1]	Remarks[2] (Comparison of Critical Years)
	No. of Trees that Showed Bad Growth	No. of Trees that Showed Good Growth		No. of Trees that Showed Bad Growth	No. of Trees that Showed Good Growth		
1961	3	5	+	2	2		
1962	6	1	−−	1			B(−)*
1963	1	2		2	3		
1964	7	6	(−+)	1			
1965	7	4	(−−+)	2		−	B(−)*
1966	1	3	+	1	2		
1967	3	6	++	1	6	++	B(++)**
1968	5	1	−−	3	1	−	B(−)*
1969	7	5	(−+)	2	4	+	
1970	4	3	(−+)		4	++	D(+)
1971	3	3		4	1	−−	D(−)
1972	3	5	+	2	2		
1973	3	8	(−++)		5	+++	B(++)**
1974	5	6	(−+)	1	5	++	D(+)
1975	4	9	(−++)	6	2	−−	P(+)D(−)
1976	11	1	−−−−	8	1	−−−	B(−−−)***
1977	4	5	(−+)	3		−	D(−−)
1978	3	6	(−++)	2	4	(−++)	B(+)*
1979	3	11	+++	2	9	+++	B(+++)***
1980	10	6	(−−+)	1	3	+	P(−)D(+)
1981	8	6	(+−)	3	3		
1982	4	4		9	1	−−−	D(−−−)
1983	3	12	+++	3	6	(−++)	B(++)**
1984	9	3	−−	6	2	(−−+)	B(−−)**
1985	8	9	(++−−)		9	+++	D(+++)
1986	11	1	−−−−	5		−−−	B(−−−)***
1987	3	10	+++	3	5	(−++)	B(+)*
1988	10	2	−−−	7		−−−	B(−−−)***
1989	4	4	(+−)		12	++++	D(++++)
1990	3	7	++	4	3	(+−)	P(+)
1991	8	4	−−	8		−−−	B(−−)**
1992	3	13	++++	1	2		P(++++)

Note : 1) Notation of the relative growth conditions using + or − sign(s)
+(−) : a few trees grew well(bad)
++(−−) : many trees grew well(bad)
+++(−−−) : majority of trees grew well(bad)
++++(−−−−) : almost all the trees grew well(bad)
the years evaluated in the ( ) represent that trees grew differently
2) Notation of the symbol using alphabets
P : Pine trees, D : Deciduous trees, and B : Both of the trees.

0.035ppm and 0.023ppm, respectively. This shows that the condition of SO_X in Seoul is so much improved that it is difficult to assume that trees on Mt. Namsan are being damaged by SOx alone. Although further studies are needed to the diurnal and/or daily variation of the concentration of this pollutant, it is premature to maintain that the growth of trees on Mt. Namsan are negatively affected by the sulfur oxides in the present.

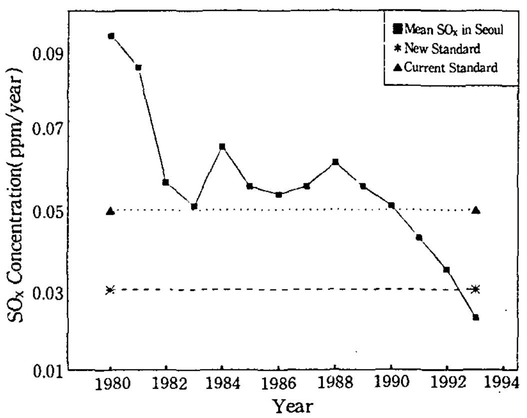

Fig. 5. Mean annual concentration of SOx in Seoul (Data Source: MOE, 1994)

3.3.2. The acidity of rain in Seoul

Monthly means of rain acidity from October 1992 to September 1993 in Seoul were reviewed and illustrated in ⟨Fig. 6⟩. Data of rain acidity were collected by both the Ministry of Environment over the Seoul area and the Forestry Research Institute(FRI) at Hongreung Arboretum in Seoul. Observation of the figure shows several points to be noticed. There are systematic discrepancies between the values of pH measured simultaneously in almost the same region. The automatic acid rain monitoring systems of the Ministry of Environment provide the systematically higher values of pH than those measured manually by the Forestry Research Institute. Here, the author can maintain that at least one set of the values of pH measurement is incorrect. If we use the values measured by the MOE for the interpretation of the effect of the acid rain on the growth of trees, it is very difficult to find the ground that rain acidity directly influences the forest negatively. If we use the values measured by the FRI, the acidity of rain may or may not influence the forest negatively. While the data of rain acidity showed episodic low pHs below 4.0, experimental studies of simulated acid rain treated for the whole growing season did not report significant alterations of metabolism in plants(Kim, 1986; Huh, et al., 1992; Matsumoto, et al., 1992).

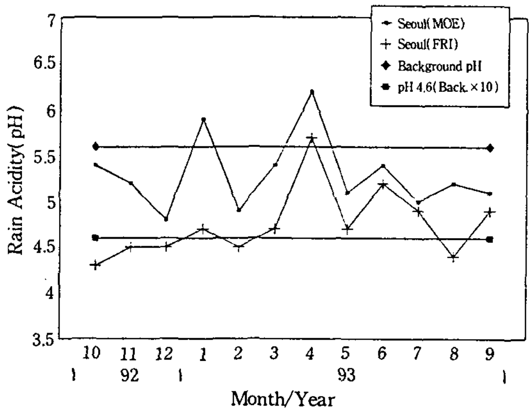

Fig. 6. Mean monthly pH in the bulk precipitation in Seoul(Data Source: FRI, 1993; MOE, 1994)

Although it is premature to provide definite evidences that the rain acidity in Seoul affects the growth of trees negatively, it is worthwhile to mention that the rain acidity is definitely lower than those of some forests in Germany or northeastern U.S.A. where forest declines have been reported. ⟨Fig. 7⟩ presents the rain acidity at the Hubbard Brook Experimental Forest in New Hampshire, U.S.A., where classic "Acid Rain" hypothesis was proposed in the world(Likens, 1976) without any industrial complex present in the region.

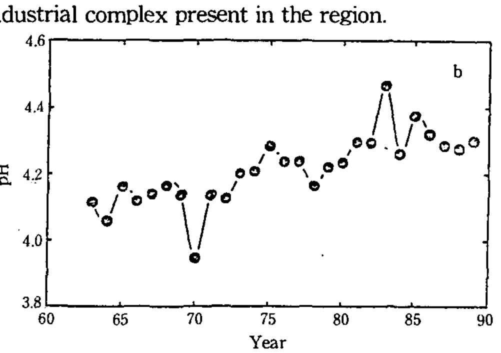

Fig. 7. Mean annual pH in bulk precipitation at the Hubbard Brook Experimental Forest in New Hampshire, U.S.A.(HBEP, 1991)

Here, the author supposes that no adequately designed researches have been carried out to address this "acid rain issue" in Korea. Rather than accepting the groundless proposition that "Pine trees on Mt. Namsan are dying due to acid rain," the author suggests that the rain acidity may have serious potentials to directly or indirectly affect various pathways of forest processes on Mt. Namsan. At this point, the author wants to point out that further studies are needed on the interaction between acid rain and forest ecosystems as well as the monitoring of rain acidity to clarify this confusion.

3. 3. 3. The concentrations of the other air pollutants in Seoul

In terms of the interaction between air pollutants and forest trees, there are other air contaminants to be considered, *i.e.*, nitrogen oxides, ozone, photochemical oxidants, etc (Smith, 1990). As the concentrations of these air pollutants are increasing and they are becoming more problematic in recent days, emphases should be placed upon the interpretation of the ecological processes between the components of ecosystems and air pollutants.

Annual mean concentrations of NO_x, O_3, CO, THC, and TSP in recent years in Seoul are summarized in ⟨Table 2⟩ with the additional data of SOx and rain pH. While the concentration of O_3 showed a slightly increasing trend in recent years, those of the other pollutants showed either unchanging or decreasing trends in recent years. All the concentrations of the pollutants are under those of the mean annual standards.

3. 3. 4. Correlation between the growth of trees and the concentration of air pollutants

The most important thing to carry out in this study is to address such question as "Are the concentrations of air pollutants negatively correlated to the growth of trees on Mt. Namsan?" Although it is very difficult to answer this question definitely, statistical analysis provides a tool to review the probability of the causal relationships numerically. As the environmental data are available only for less than 14 years, it is not good enough to apply the data for the statistical analysis. However, to get ideas about the relationships, correlation analysis has been applied to the data set and the results of the analysis is summarized in ⟨Table 3⟩.

Table 2. Mean Annual Concentrations of the Major Air Pollutants Measured in Seoul(Date Source : MOE, 1994)

Year	NO_x (ppm)	O_3 (ppm)	CO (ppm)	THC (ppm)	TSP ($\mu g/m^3$)	SO_x (ppm)	Rain pH
1980						0.094	
1981	0.056					0.086	
1982	0.056					0.057	
1983	0.057					0.051	6.0
1984	0.029	0.008	3.2	2.8	210	0.066	5.7
1985	0.034	0.019	2.7	4.3	216	0.056	5.5
1986	0.033	0.011	3.0	2.7	183	0.054	5.3
1987	0.033	0.010	3.2	2.7	175	0.056	5.1
1988	0.033	0.009	2.8	2.6	179	0.062	5.7
1989	0.027	0.008	3.2	2.7	149	0.056	5.6
1990	0.030	0.009	2.6	2.9	150	0.051	5.0
1991	0.033	0.012	2.2	2.8	121	0.043	5.4
1992	0.031	0.014	1.9	2.8	97	0.035	5.3
1993	0.032	0.013	1.5	2.8	88	0.023	5.4
Mean Annual Standard	0.050	0.020	8.0	3.0	150	0.050	

Table 3. Correlation Coefficients Among the Variables and the Tree Species.(Number in the parenthesis indicates the number of years calculated)

Tree Species	SO_X(14)	NO_X(13)	O_3(10)	CO(10)	THC(10)	TSP(10)	Rain pH (11)
Pines of Site 1	−0.19	+0.19	+0.18	−0.37	+0.01	−0.35	+0.33
Pines of Site 2	+0.50*	+0.39	−0.14	+0.77***	+0.08	+0.72**	+0.10
Oaks of Site 2	+0.50*	+0.40	+0.49	+0.07	+0.63**	+0.38	−0.04
Black Locust of Site 2	+0.55**	+0.51*	+0.54*	+0.12	+0.50	+0.18	−0.27
Cherries of Site 2	+0.63**	+0.38	−0.29	+0.64**	+0.16	+0.49	+0.42
Means of Site 2	+0.67***	+0.54*	+0.42	+0.35	+0.61*	+0.51	+0.00
Pines of Site 3	+0.61**	+0.27	−0.10	+0.60*	+0.27	+0.37	−0.12
M. Oaks of Site 3	−0.44	−0.47*	+0.63**	+0.11	+0.83***	+0.51	−0.30
Mean of Site 3	−0.12	−0.29	+0.44	+0.38	+0.78***	+0.57*	−0.30

Statistical Significance :

- * : $0.05 < p \leq 0.10$
- ** : $0.01 < p \leq 0.05$
- *** : $p \leq 0.01$

If the proposition that air pollutants affect the tree growth negatively in Seoul area holds true, the correlation coefficients between the growth of trees and the concentrations of air pollutants should at least be negative and those between the growth of trees and pH values should be positive. The results showed generally reverse relationships, *i.e.*, the concentration of air pollutants showed positive and pH values did not show any significant correlations to the growth of trees. This indicates that the trees grow better in the year when the concentrations of the air pollutants are higher and that trees grow independently regardless of the condition of rain acidity of Seoul. Care should be given to this kind of interpretation, because this statistical analysis has been carried out with data set of relatively small number of years(10 to 14 years period) and because more objective quantification of the tree growth other than the radial growth values should be performed before the analysis(Kim, 1988). In addition, causality between the variables should be provided ecologically and/or physiologically prior to the application of the statistical analysis. Otherwise, high correlation coefficients do not mean anything for the interpretation of natural phenomena, i.e., they can only be artefacts.

In terms of the interpretation of the correlation analysis between the growth of trees and the concentration of air pollutants, it is premature to infer any of the specifics of the interrelationships between the air pollutants and the growth of tree species despite the reverse high correlation coefficients. However, it can be concluded that the concentrations of them is not so high as to induce acute injury to the trees on Mt. Namsan. Here, the author strongly suggests that further studies should be carried out on the dynamics of each of the pollutants mentioned above and the other potential pollutants including the other photochemical oxidants, acid fogs, and acid cloud, which can address the specifics of current question(Lovett, *et al.*, 1982; McLaughlin, 1985; Kim and Aneja, 1992; Aneja and Kim, 1993).

Overall, the author does not maintain that the conditions of air pollution are good in Seoul, but points out that negative aspects of air pollution were over-exaggerated intentionally or unintentionally by some researchers and mass media. Frequently, public recognition based on the biased information or inadequately formulated hypotheses on the ecosystem processes prevents the needed researches from being initiated or carried out by the other researchers. The author maintains that our current recognition of the interaction between air contaminants and forest ecosystems should be systematically tested based upon studies on ecosystem processes instead.

3. 4. Drought conditions and their effects

When it is difficult to conclude that the conditions of air pollutants are bad enough to induce any acute damage to the growth of trees on Mt. Namsan, additional attention should be given to the other major factors that affect tree growth. In 1994, the people as well as the organisms(plants, animals, and microbes) in this region experienced severe drought(moisture stress) ever, which has made the public to be convinced that the moisture deficit to organisms is one of the most limiting factors in nature. The author simulated daily soil moisture contents using daily inputs of temperature and precipitation data for the last 82 years(Kim, 1992). Computer simulation model, BROOK, developed by Federer and Lash(1978), made it possible to simulate the daily soil moisture deficit in this region.

Based on the results of the simulation of the BROOK model, summary table for the occurrence and the period of drought in each year since 1961 is presented in 〈Table 4〉. When the occurrences of the drought and the critical year were compared with each other, there were several years that tree growth was negatively related. For example, the years of 1988, 1982, 1979, 1965, and 1977 can be categorized as very dry years. Except in the year of 1979, trees showed negative growth in those years when droughts occurred. It is also worthwhile to note that the trees grew well in the years of 1970, 1967, 1974, and 1992, when no drought occurred. Ten years among the 32 year period have shown either positive or negative growth synchrony with the fluctuation of soil moisture conditions. These conclusively indicate that tree growth is strongly affected by the occurrence of drought. In other words, drought is the major factor that gives a strong and negative impact upon the growth of trees on Mt. Namsan.

When the relationships between the drought and tree growth were examined statistically, there were strong correlations between them by species (〈Table 5〉). Generally, trees showed negative correlations to the length of drought of the current year and the previous year. However, the mountain cherries on Mt. Namsan showed a positive correlation to the length of drought of the previous year. In addition, trees showed high correlations to the lowest moisture condition of the current year and the previous year. Although the absolute values of the correlation coefficients are generally smaller than those observed in the 〈Table 3〉, this values are more meaningful because more number of years(more than 30 years) have been included in the statistical analysis and because there are close cause-effect relationships between the variables ecologically and physiologically.

Table 4. The Concurrence of the Critical Year and the Drought Records Simulated by the BROOK Model since 1961.

Year	Number of Days for Severe Drought	The Lowest Moisture Condition of the Year (mm)	Critical Year Suggested in 〈Table 1〉[1)]	Year That Tree Growth May Have Been Negatively Affected
1961	0	119		
1962	4	95	B(−)*	○
1963	5	95		
1964	9	123		
1965	35	82	B(—)*	○
1966	0	112		
1967	0	112	B(+ +)**	no drought
1968	1	99	B(—)*	
1969	9	94		
1970	0	127	D(+)	no drought
1971	0	112	D(—)	
1972	3	96		
1973	0	107	B(+ +)**	
1974	0	105	D(+)	no drought
1975	0	100	P(+)D(−)	
1976	0	101	B(———)***	
1977	27	94	D(——)	○
1978	10	98	B(+)*	
1979	68	84	B(+++)***	
1980	1	99	P(−)D(+)	
1981	0	106		
1982	56	77	D(————)	○
1983	2	97	B(+ +)**	
1984	0	107	B(——)**	
1985	0	110	D(+ + +)	no drought
1986	0	118	B(———)***	
1987	8	98	B(+)*	
1988	107	84	B(———)***	○
1989	0	92	D(++++)	
1990	0	104	P(+)	
1991	0	102	B(——)**	
1992	0	109	P(++++)***	no drought

Note : 1) Notation of the tree symbol using an alphabet
P : Pine trees; D : Deciduous trees; and B : Both of the trees.

Here, it is worthwhile to note that the correlation coefficients between the growth of trees and the drought vary by species. While some of these differences can be explained by the difference of the growth strategy of the tree species, some of them can be attributed to the mere chance. These should be explained by the ecophysiological studies on the growth of tree species. In this paper, it is suffice to point out that soil moisture stress is the major factor that should be explained prior to describe any effect that is caused by the air pollutants in natural conditions.

Table 5. Correlation Coefficients between the Drought-related Variables and the Growth of Tree Species. (Number of years considered in the statistic analysis is 32 years)

TREE SPECIES	Number of Days for the Severe Drought of the Current Year	Number of Days for the Severe Drought of the Previous Year	Lowest Moisture Condition of the Current Year	Lowest Moisture Condition of the Previous Year
Pines of Site 1	−0.054	0.213	−0.102	−0.390**
Pines of Site 2	0.130	0.134	−0.099	−0.097
Oaks of Site 2	−0.189	0.136	0.056	−0.246
Black Locust of Site 2	−0.064	0.176	0.070	−0.088
Cherries of Site 2	−0.131	0.462***	0.018	−0.383**
Mean of Site 2	−0.029	0.258	−0.040	−0.263
Pines of Site 3	−0.231	−0.047	0.281	0.005
M. Oaks of Site 3	−0.213	−0.322**	0.297*	0.191
Mean of Site 3	−0.287	−0.234	0.376**	0.124

Statistical Significance :
- * : $0.05 < p \leq 0.10$
- ** : $0.01 < p \leq 0.05$
- *** : $p \leq 0.01$

3. 5. Pine Leaf Gall Midges and their effects

Whenever the growth of pines is described in relation to some environmental factors in Korea, there is one important biological factor to be considered that has been affecting the pine trees continuously and seriously, which is the effect of pine leaf gall midges(*Thecodiplosis japonensis* Uchida et Inouye). They were firstly discovered in a palace (Changdokgung) in Seoul and in Mokpo city(Southwestern tip of the Korean peninsula) in 1929. They spread rapidly and injured the pine trees severely. They are distributed to almost all the part of this country except small part of Kangwondo Province at present (⟨Figure 8⟩) and they were categorized as the most damaging forest insect in Korea. As can be seen from the map, pine trees were affected from the attacks of the pine leaf gall midges. At present, pine trees on Mt. Namsan are severely affected by them and curing measures including pesticide injection to stem are being taken.

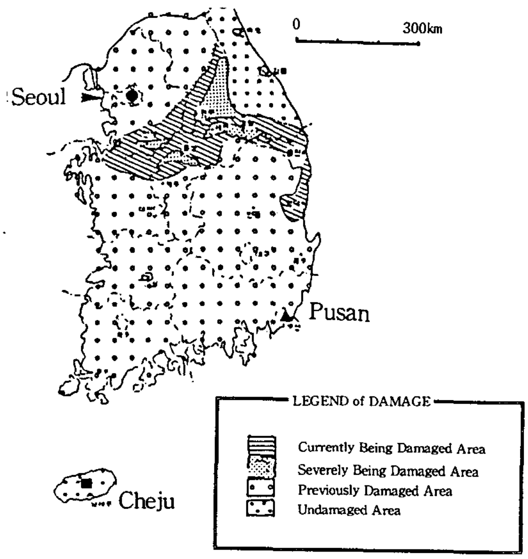

Fig. 8. Damage distribution map of pine leaf gall midges in south Korea(FRI, 1992)

Here, the author wants to point out that it is inappropriate to mention any damage of pine trees affected by the air pollutants at almost all part of our country including Mt. Namsan without prior evaluation of the effects of the pine leaf gall midges. The author(1993) described some of the specifics of the growth patterns of pine trees on Mt. Namsan affected by the pine leaf gall midges. When the tree-rings were examined and measured by using microscopes, there were periods of very suppressed growth of the pines in the past. That can be the direct evidence that the pine trees are severely affected by the forest insects including the pine leaf gall midges. Readers are referred to the Forestry Research Institute(1985).

3. 6. Black locusts, the major suppressing tree species, and their effects

Another important biological factor that affects the growth of pine trees is the competition among the trees, especially with rapidly growing trees. The author (1993) described this with a diagram (〈Figure 9〉). In sites where pine trees are growing naturally with other trees, pine trees are suppressed by the other trees. It is ascribed to the differences of the growth characteristics. Pine trees are slow growing trees both in height and in diameter, whereas some trees such as the black locusts grow very fast both in height and in diameter and soon occupy the upper space of the forest crown. As a consequence, the pine trees which favor light and space for survival are naturally suppressed and, ultimately, declined. These sequential changes of trees in forest are referred to as the forest succession.

〈Figure 9〉 shows the typical competition phenomenon occurred on Mt. Namsan. The old but small pine trees are suppressed by the young but tall black locusts or mountain cherries. Pine trees severely weakened by the pine leaf gall midges are more vulnerable to the suppression of the other trees. When the tree-rings were examined and measured by using microscopes, the pine trees suppressed by the black locusts showed very slow growth both in diameter and in height while the black locusts showed very fast growth(Kim, 1993). Here, again, the author wants to point out that it is inappropriate to mention any damage of pine trees affected by the air pollutants on Mt. Namsan without prior evaluation of the effects of suppression of the pine trees by the other fast growing trees including the black locusts and the other broadleaved trees.

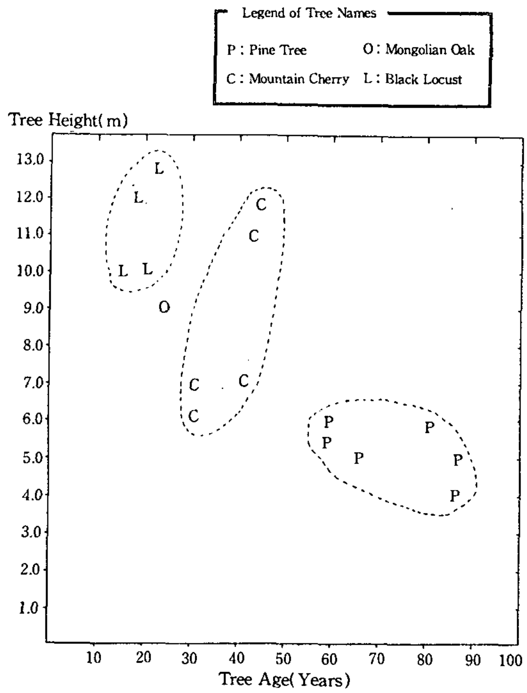

Fig. 9. The age and the height of trees growing at a site where pine trees are growing under severe suppression from the other fast growing trees on Mt. Namsan(Kim, 1993)

3. 7. General Discussion

As was described in the introduction, the public generally believe that the pine trees on Mt. Namsan are dying due to the air pollution. Through this study, the author found that the majority of the pine trees are not dying as the public believe and that the major factor that causes slow growth for some pine trees can be attributed to the complex of the factors such as the prevalence of the pine leaf gall midges, the drought stress, and the suppression by the black locusts rather than the effect of air pollutants. For those factors, the author provided the evidences that the public are misinformed about the real factors that affect the growth of trees on Mt. Namsan in central Seoul.

Manion(1981) grouped the factors that affect the decline of tree growth into 3 categories, i.e., predisposing factors, inciting factors, and contributing factors. These categories provide a good tool for evaluating the relative importance of the environmental factors that are thought to contribute to the decline of tree growth in forest ecosystems.

The predisposing factors are those that make the trees susceptible to be affected by such long term factors as chronic air pollution, soil stresses, climatic stresses, etc. The inciting factors are those that make the trees to be severely affected by such short-term and strong factors as acute air pollution, drought, forest insects, climatic abnormalities, etc. Trees that have been weakened by the long-term predisposing factors are strongly affected by the occurrence of these inciting factors. In case these inciting factors are severe enough or sustain long enough to bring about irreversible conditions to the growth of trees, the trees are directly affected by such contributing factors as the disease, forest insects, etc.〈Figure 10〉 is a diagrammatic presentation of the Manion's decline spiral diagram.

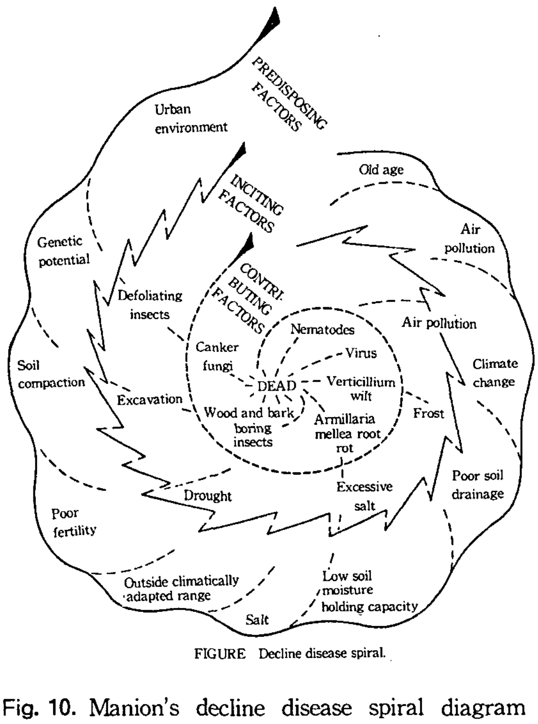

FIGURE Decline disease spiral.

Fig. 10. Manion's decline disease spiral diagram (Manion, 1981)

When the author evaluates the current environmental condition on Mt. Namsan in central Seoul, the factors of air pollution(including acid rain) as well as the suppression of pine trees by the black locusts, the distribution of the pine leaf gall midges and the soil acidity can be grouped into the predisposing factors. They may chronically affect the tree growth for long period of time. The outbreak of pine leaf gall midges and the occurrence of severe drought can be grouped into the inciting factors. They strongly and adversely affect the tree growth in a short period of time. If these stresses continues for a long period of time, the trees are eventually to be declined affected by the contributing factors. It is important for the readers to regard this grouping relatively. According to the condition of the environmental factors, certain predisposing factors can be evaluated as the inciting factors. This interpretation was made possible through the careful examination of tree-rings of the tree species and the ecological interpretation of the environmental factors.

It is worthwhile to mention that researchers who participated in the subsection of "Global Change and Terrestrial Ecosystems" under the section of " Ecology and Environmental Biology" of the 15th International Botanical Congress showed very similar views to that of the author. Kandler and Innes of Germany(1993) maintained that the term "Waldsterben(forest death)" should be dropped because they have failed to confirm that the forests are dying or are even damaged over large areas of central Europe and because the damage of the forests are apparent only on a local scale where it is attributed to high concentrations of SO_2 in combination with other stresses, which they explain it as a not new phenomenon. Tesche et al.(1993) also maintained that the forests of Norway spruce (*Picea abies*) and Scots pine(*Pinus sylvestris*) have been locally damaged due to high doses of industrial emissions in the region of eastern Europe and that they have been further stressed by the combined factors of the other abiotic environmental factors as well as biotic damaging agents. They emphasized the relevance of the Manion's decline disease spiral for the interpretation of the deaths of the trees. Hakamata and Shindo(1993) also maintained that no apparent effects of acidic precipitation on the ecosystem have been reported in Japan. Although there are many documents that address these issues(Mahony, 1991; Matsumoto, et al., 1992; Kandler, 1993), it is very difficult to find documents that showed the causal relationships between the decline of tree growth and current level of rain acidity.

Ecosystem studies on Mt. Namsan should be further carried out to clarify the confusions pointed out in this paper and to carefully explain both the functional and the structural aspects of the ecosystem, which includes the soil conditions as well as the other tree species on the mountain.

4. CONCLUSIONS

This study was carried out to test a proposition that the pine trees decline due to the influence of air pollution and acid rain, which was proposed by some researchers in Korea. Through this study, it was found that the majority of the pine trees are not dying as the public believe and that the major factor that causes slow growth for some pine trees can be attributed to the complex of the factors such as the prevalence of the pine leaf gall midges, the drought stress, and the suppression by the black locusts rather than the effect of air pollutants. For those factors, the author provided the evidences that the public are misinformed about the real factors that affect the growth of trees on Mt. Namsan in central Seoul.

While the current condition of air pollution in Seoul cannot be categorized as good, the concentrations of air pollutants are not so high as to cause acute damages to the trees. While data of rain acidity showed episodic low pH of under 4.0, the average of them is far less acidic than those that were observed in either northeastern United States or central Europe, where the decline of trees were not solely attributed to any of the air pollutants. Considering the sequential facts that one of the most important environmental factors that affect the growth of trees is weather condition of the forest, that the proposition of the decline of the pine trees was made without careful examination of the growth patterns and past growth history of them as well as the complex influences of many other factors including the weather conditions to the growth of trees, and that no objective explanation has been made on the causal relationships between the current condition of air pollution and the growth of the trees, such a proposition should be evaluated as invalid for the explanation of tree growth on Mt. Namsan in central Seoul, Korea. Instead, there are some potentials that air pollutants including acid rain are chronically affecting the forest ecosystem on Mt. Namsan.

This interpretation was made possible through the careful examination of tree-rings of the tree species and the ecological interpretation of the environmental factors. Ecosystem studies on Mt. Namsan should be further carried out to clarify the confusions pointed out in this paper and to carefully explain both the functional and the structural aspects of the ecosystem processes, which include the biogeochemistry and the long-term changes of soil conditions as well as the other tree species on the mountain.

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南山소나무의 直徑生長과 現在 水準의 서울地域 大氣汚染物質이 樹木生長에 미칠 潛在的 影響의 生態學的 考察

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抄　錄

本 研究는 최근 大氣汚染과 酸性비때문에 南山의 소나무가 죽어간다는 一部 學者들의 主張의 眞僞를 實證的으로 檢定하기 위하여 南山에 生育하는 소나무의 生長變化를 精密分析하고 그것에 대한 生態學的인 解析을 試圖함과 아울러, 現在 狀態의 大氣汚染이 소나무의 생육에 미칠 수 있는 影響을 推論하고자 試圖되었다. 南山의 3個 地點에서 40그루 나무의 나이테를 調査한 바, 大多數의 南山소나무들은 最近 10年동안에 지금까지 자라온 平均生長量에 比하여 더욱 빠른 生長을 보여주었고 그동안 솔잎혹파리나 아까시나무 등과 같은 生物的인 要因에 依하여 生長의 障害를 받아온 記錄을 많이 볼 수 있었다. 더욱이 나무가 生長하는데 가장 重要한 因子의 하나인 土壤水分要因이 樹木의 生長에 미치는 影響을 調査해 보았을 때, 南山위에 分布하는 나무들은 가뭄(旱魃)現象에 대하여 매우 敏感하게 그 生育이 調節되는 生長類型을 보여 주었다. 多樣한 環境汚染 要因들에 대하여 綿密한 檢討없이 提起된 一部 學者들의 上記 主張은 說得力을 갖지 못할 뿐만 아니라 매우 性急한 것인 바, 本 研究를 통하여 필자는 南山에 있는 소나무를 對象으로 大氣汚染의 被害를 論하는 것은 適切하지 못하다는 것을 밝혔다. 특히 現在段階에 있어서 서울 中心地域인 南山에 있어서 大氣汚染物質과 降雨 酸度와 같은 環境要因은 長期的으로 慢性的인 被害를 줄 수도 있는 素因(predisposing factor)의 次元에서 影響을 주는 것으로 推定할 수 있다. 이러한 結果는 수목의 나이테에 대한 集中的 調査와 多樣한 環境要因의 變化樣相에 관한 研究를 통하여 提示할 수 있었던 바, 追後 南山內 다른 地點의 소나무 뿐 만 아니라 신갈나무와 아까시나무와 같은 다른 樹種의 生長 및 環境汚染物質의 負荷와 生態系內에서 그들이 變化하는 動態를 포함한 더욱 廣範圍한 生態系 生態學的 次元에서의 研究가 施行되어야 할 必要가 있다.