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Dendrochronological analysis of growth decline of Korean conifers in Urban and Rural areas

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ABSTRACT

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This study was conducted to examine the growth trends of the pines growing in three regions of Korea. Two regions, Seoul and Ulsan were selected as polluted areas, and one region, Pyungchang as unpolluted area. From each region, five sampling sites were selected. From each site, two major pine species were chosen and ten dominant or co-dominant trees of each species were sampled. Visual comparison using the pointer-year method was used to quantify abrupt growth changes. Some species indicated short-term decline but we could not find persistent growth declines in all regions. Most of short-term declines appeared to be related to either climate variation or non-anthropogenic factors such as insects. At present, it is uncertain that air pollution reduced the growths of trees.

Key-words—Forest decline, Dendroecology, Growth trend, *Pinus densiflora, Pinus thunbergii, Pinus rigida, Pinus koraiensis.*

कोरिया के शहरी एवं ग्रामीण क्षेत्रों के कोरियाई शंकुवृक्षों के वृद्धि ह्रास का वृक्षकालानुक्रमिकीय विश्लेषण

वोन-क्यू पार्क, सांग-हो चोंग, युंग-ग्यू पार्क एवं रामरतन यादव

सारांश

प्रस्तुत अध्ययन कोरिया के तीन क्षेत्रों में पाए जाने वाले चीड़ वृक्षों के वृद्धि रुझानों के प्रेक्षण हेतु किया गया है। इनमें से दो मण्डल सिओल एवं अल्सान प्रदूषित मण्डलों के रूप में चयनित किये गये तथा एक मण्डल, प्युंगचांग को प्रदूषणरहित मण्डल के रूप में चयनित किया गया। प्रत्येक मण्डल से पाँच नमूने के स्थल चयनित किए गए। प्रत्येक स्थल से दो बड़ी चीड़ प्रजातियों को चुना गया तथा प्रत्येक प्रजाति के दस प्रमुख अथवा सहप्रमुख वृक्षों के नमूने लिए गए। सूचक वर्ष प्रविधि की सहायता से चाक्षुष तुलना द्वारा खण्डित वृद्धि परिवर्तनों की मात्रा की गणना की गई। कुछ प्रजातियाँ संक्षिप्त अवधि के ह्रास संकेतित करती हैं, किन्तु सभी मण्डलों में सतत् वृद्धि ह्रास नहीं प्राप्त किए जा सके। अधिकांश संक्षिप्त अवधि के ह्रास या तो जलवायुविक परिवर्तनों से सम्बन्धित हैं अथवा अमानवोद्भवी कारकों, जैसे-कीटों से सम्बन्धित हैं। वर्तमान में यह अनिश्चित है कि वायु प्रदूषण से वृक्षों की वृद्धि में ह्रास हुआ था।

संकेत शब्द—वन ह्रास, वृक्षकालानुक्रमिकीविज्ञान, वृद्धि रुझान, *पाइनस डेन्सीफ़्लोरा, पाइनस थनबर्गाई, पाइनस रिजिडा, पाइनस कोराइएन्सिस.*

INTRODUCTION

SOME signs of forest damage caused by air pollutants have been detected in industrial regions of Korea since late 1970s. The damages observed were mainly on crown damage, while some studies detected the reduction of radial growths (Kim *et al.*, 1987; Korea FRI, 1988; Lee & Yoo, 1991; Kim, 1991; Kim *et al.*, 1991). Some studies indicated severe growth reduction of pines, just after establishing industrial complexes in Ulsan and Yeocheon (Anonymous, 1988; Kim, 1991). In Seoul, Lee and Yoo (1991) reported growth decline of *Pinus densiflora* and *Quercus* spp. growing at Namsan Mt. and attributed this decline to air-pollution damage. However, a recent study claimed that most of growth reductions of *Pinus densiflora* at Namsan resulted from insect outbreaks and droughts rather than air pollution (Kim, 1994).

Most of the trees in municipal and industrial regions in Korea are young, usually, less than 50 years old. It is difficult to determine the growth decline in the short tree-ring series of such young trees. We can hardly apply appropriate detrending procedures which can remove age-related growth trend in short series. In the present study, we applied the 'point-year' method, proposed by Schweingruber (1986), which can quantify abrupt growth changes persisting for a number of years.

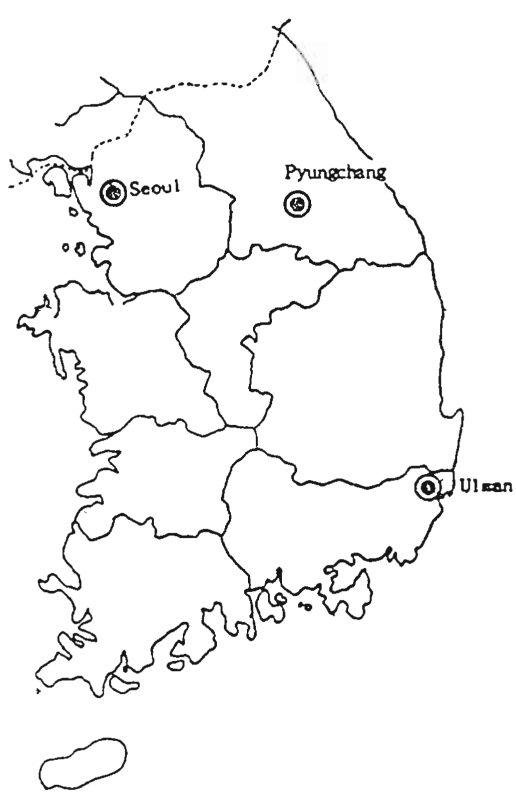

Fig. 1—Study Sites.

STUDY AREAS

Two regions, Seoul and Ulsan were selected as polluted areas, and one region, Pyungchang as un-polluted area (Fig. 1). First region, Seoul is a metropolitan region where more than 10 millions reside and hundreds of industrial factories operate. Smog is frequently observed in the city of Seoul and most concerns are given to increases of emissions from automobiles. The second region, Ulsan is a seaside city, of industrial region where heavy-chemical engineering factories have been operated since the middle 1970s. Some diebacks of pines have been reported in the areas near the factories. The third region, Pyungchang is in a mountainous area. This region is considered to be free from air pollution.

From each region, four sampling sites were selected. From each site, two major conifer species were chosen and ten dominant or co-dominant trees of each species were sampled.

The sites in Seoul located in the Bukhansan National Park, just on the northern boundary of the city of Seoul. The sites are on the exposed slope to the city. The soils of these sites are generally shallow and coarse-sandy. The species chosen in Seoul region were *Pinus densiflora* (Japanese red pine, sonamu) and *P. rigida* (pitch pine). Red pine samples were obtained from natural stands and pitch pines from planted stands. The ages of red pines (50 to 60 years) were little older than pitch pines.

The sites in Ulsan are within 2 km radius from the industrial complex. The sites are rather flat and are exposed to the emissions from the factories when the wind blows from the seaside. The soils are generally deep and fine-sandy. The species chosen in Ulsan region were *Pinus densiflora* and *Pinus thunbergii* (black pine). Both species were obtained from natural stands. The ages of both species ranged from 40 to 60. An additional site (Dudong), which located at 20 km northwest to other sites in Ulsan. This site was considered free of air pollutants from Ulsan.

The sites in Pyungchang located in the rural areas within 10 km radius. The elevations of these sites (about 300 m) are higher than in Seoul and Ulsan. Pyungchang is cold and heavy-snow area. The soils of these sites are generally deep and fine-sandy. The species sampled from Pyungchang were *Pinus*

Region	Species	Names of Site (Site identification)
Seoul	*Pinus densiflora*	Dobong, Jungneung, Sailgu, Bukak
	Pinus rigida	(DB) (JN) (SI) (BA)
Ulsan	*Pinus densiflora*	Hongyung, Dalmat, Sukyu, Yongam, Dudong
	Pinus thunbergii	(HM) (DM) (SY) (YA) (DD)
Pyung-chang	*Pinus densiflora*	Nonggong, Hangdong, Bangrim, Gupo
	Pinus koraiensis	(NG) (HD) (BR) (GP)

Fig. 2—Name of Sites and Species.

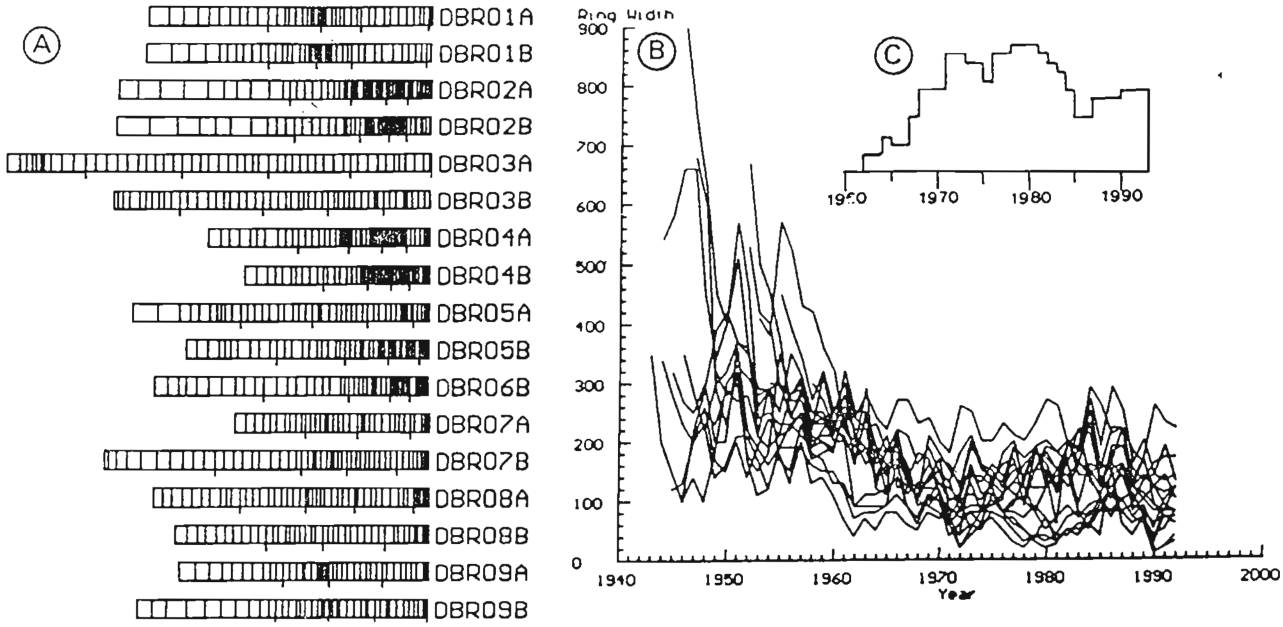

Fig. 3—Ring-width patterns of Dobong pitch pines. **A.** core-beam patterns. **B.** raw series and **C.** phase diagram (pointer-year).

densiflora and *Pinus koraiensis* (Korean pine). Red pines were obtained from natural stands but Korean pines from plantation. The ages of both species ranged from 40 to 55. Fig. 2 summarized the names of the site and species sampled.

METHODS

Two cores from each tree were collected using increment borers at 50 cm above the ground. They were crossdated using the skeleton plot method (Stokes & Smiley 1968).

To evaluate abrupt growth change, we adopt the 'pointer year' method of Schweingruber (1986). Pointer years are the years of annual rings that differ visibly and markedly from the preceding and subsequent rings. There are various kind of pointer years but we count only ones which abrupt growth reduction continues in three consequent years. Duration and intensity of growth reduction were indicated by making a bar graph. For the years when the growth reduced about 50% compared to the previous years, one bar was given, and two bars for about 70% reduction and three bars for more than 90% reduction. The final bar graph ('phase diagram') of each species was made from each site by summing all bars.

Fig. 3 demonstrates how ring-width patterns can be illustrated in different ways. Fig. 3A ('core-beam pattern') illustrates the ring-width pattern of each core. Fig. 3B is an overlaid plot of raw ring-width series. The final phase diagram obtained is given in Fig. 3C. The point-year method was originally developed to examine the growth pattern quickly without measuring ring widths. However, if we want to apply the point-year method for the ring-width data which have already been made, we can easily obtain core-beam patterns from ring-width data using computer graphics such as TSAP (Rinn, 1994). It is much easier to produce phase diagram from core-beam pattern than to re-examine the increment cores.

RESULTS AND DISCUSSION

The phase diagrams for three regions are shown in Figs. 4-6. Each diagram represents the cumulated growth reduction change of each species at one site. In Ulsan, red pines and black pines show different growth patterns (Fig. 4). The most severe reductions of red pines in Ulsan were found during 1965-1980. In most sites, the growths of red pines were recovered after 1980. The growths of black pines did not indicate any prolonged reductions during 1965-1980. Instead, ones from some sites (DMT, YAT and SYT) showed more growth reductions after 1985. It is interesting that the red pines of Dudong site, which is far from the city of Ulsan, also possessed the phase diagram similar to others for the other sites in Ulsan. We could not find any anomalies in monthly temperature and precipitation in Ulsan area during 1965-1980. Growth reductions of the red pines are unlikely attributed to air pollution damages. More likely the causes of growth reduction appear to be related with insect damages. Red pines have been periodically infected by the insects, pine-needle gall midge (*Thecodiplosis pinicola*). Nationwide survey

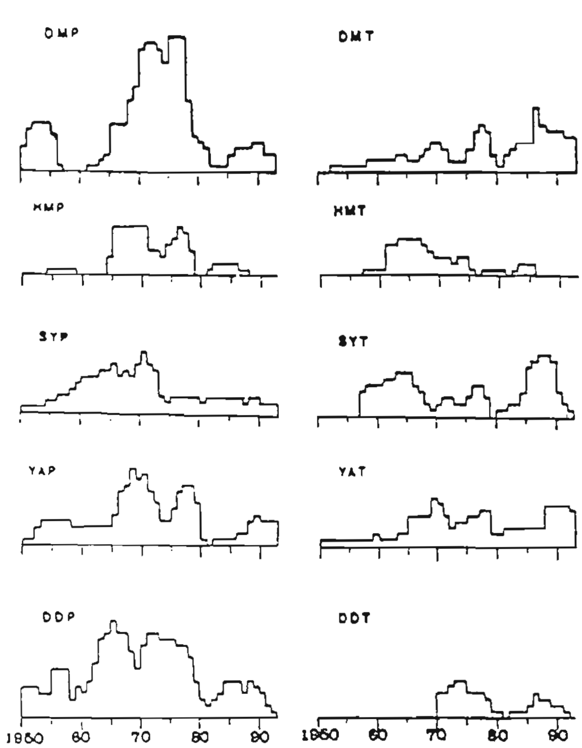

Fig. 4—Phase diagrams for Ulsan (left: red pine, right: black pine). *See Fig. 2 for site abbreviation.

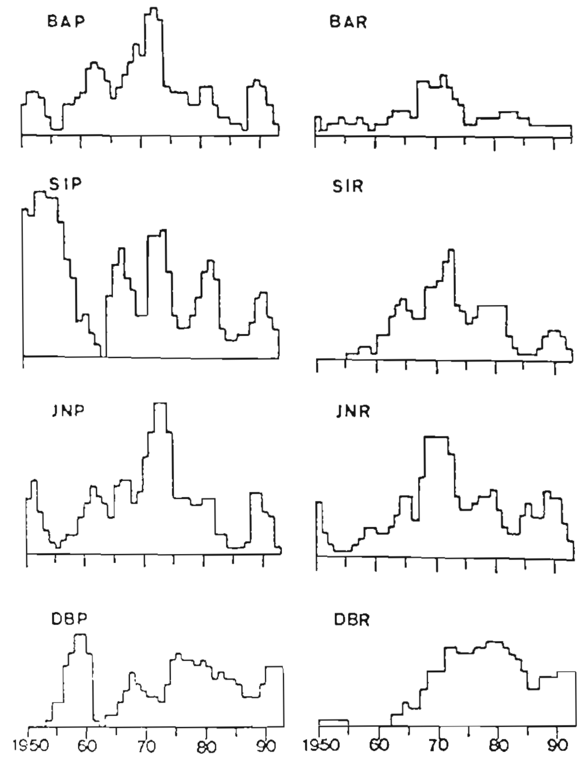

Fig. 5—Phase diagrams for Seoul (left: red pine, right: pitch pine).

indicates that the highest outbreaks of this insect occurred in 1975 and 1976 (Kim, 1994).

Growth declines of black pines in the Ulsan area have been reported in several studies (Korea FRI, 1988; Kim, 1991). They observed abrupt growth reductions around 1975, at the onset of the industrial complex. In the present study, we could not find this abrupt growth changes.

There are three plausible explanations for this discrepancy. First, the sites for the present study is little far from the factories than those for the other studies. Secondly, we might collect only living trees which had survived from the heavy dosages of pollutants and had grown under less competition. Thirdly, the analytical method was different. The previous studies did not use the dendrochronological procedures such as crossdating and detrending method.

In Seoul, the phase diagram patterns of red pines are similar to those for Ulsan's (Fig. 5). Among them, one site (SIP) indicated periodic reductions. This seems to be related with the outbreaks of the pine-needle gall midge. Highest growth reduction occurred in the early 1970s. The strong relationship between soil moisture and the growths of red pines and pitch pines growing in Seoul was found in the previous study (Vaganov & Park, 1992). The annual P-E indices of long-term effectiveness of precipitation for plant growths (Thornthwaite's) in Seoul indicates long-term moisture deficiency during 1965-1975.

Both moisture stress and insect damage seem to be responsible for the growth reductions of red pine. However, the effect of climate should be stronger because the phase diagrams for pitch pines are similar to those of red pines which are non-host trees for the gall midge insects.

The phase diagrams of Pyungchang (Fig. 6) indicate less growth reduction than the other regions but they also possess short-term variations. Both red pines and Korean pines show some growth reduction during late 1960s and late 1980s. Red pines in this regions are known to be infested by gall midge since late 1980. The causes of the reductions during late 1960 should be further studied.

CONCLUSIONS

In this study, we could not find persistent growth decline in the Ulsan, Seoul and Pyungchang regions. Most of short-term declines appears to be related to either climate variation or disturbances such as insects. At present, it is uncertain that air pollution reduced the growths of trees. In future, it is

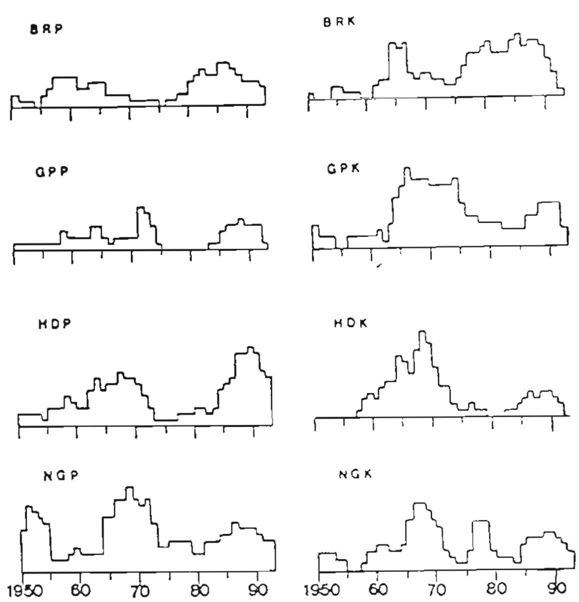

Fig. 6—Phase diagram for Pyungchang Left . red pine, right . Korean pine)

necessary to monitor environmental factors as well as tree growth in these regions.

We found that the pointer-year method was more efficient than the detrending method in determining the growth decline of young stands like most forests in Korea. Based on this finding, we adopted the former method for the 5-years forest decline monitoring project of Korea Forestry Research Institute.

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