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A DENDROCHRONOLOGICAL STUDY OF DECLINE OF PINE STANDS IN SOUTH ESTONIA

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Abstract. Yearly radial increment of Scots pines (*Pinus sylvestris* L.) was studied in seven sample plots in damaged pine stands of *Vaccinium uliginosum—Calluna* and *Calluna* site types in South Estonia. As chronical damage of trees has a complex character, often pest insects give the *coup de grâce*. This study shows the different course of multi-year increment in both damaged and undamaged trees. The residual growth after temperature and precipitation effects removed by subtracting a multiple regression curve reveals a continuous decline of annual ring widths of damaged trees during the last decades.

Key words: forest decline, Scots pine, dendroclimatology, tree rings.

INTRODUCTION

One of the most widely spread agents of forest damage in Estonia are the root rots (Karoles, 1990). In 1987 there was nearly 1500 ha of forests in Estonia damaged by root rots and there were even more of infected stands (Karoles, Mihkelson, 1988). As a matter of fact, the causes of forest decline are rather complex: they involve other agents as well, such as air pollution, weather conditions, pests, etc. (Etverk, 1988; Heikkinen, 1988; Kairiukstis, Stravinskiene, 1992; Kairiukstis et al., 1992). Usually pollution-caused changes weaken the resistance of trees and they become susceptible to diseases and phytophagous insects. The physiological mechanisms of the effects of pollutants are complicated (Laisk et al., 1990).

The course of decline of a tree can be imagined as follows. Root rots are more often than not initiating the process. For some reason or other, a fungal disease, root rot (*Fomitopsis annosa* (Fr.) Karst.), activates in some pine trees, and so the decline process starts. The crown grows thinner, and the tree looks suppressed. Typically, crown damages lead to a decreased radial growth, i. e. to narrow tree-rings (Banks, 1992).

Usually the tree takes many years to die. There are two ecological forms of *F. annosa* distinguished in conifer species. Damage in the pine form of *F. annosa* culminates in forests of the age of 30—60 years (Karoles, Mihkelson, 1988).

At a certain stage of damage the trees are attacked by insects. When the tree is weakened over a critical threshold, it dies. Probably there are also other factors involved in the process of decline, e. g. the chemical characteristics of the soil, increased air pollution and weather conditions.

The involvment of the fungus can often be detected by the bluish colour of pine wood; then there are their characteristic prints in tree trunks left by insects. Establishing the role of various other agents causing the death of a tree is still more complicated.

In this study, an attempt is made to describe the growth pattern of damaged pines so that possible features in the radial growth-rates referring to dieout of trees might be established.

SAMPLE SITES AND MATERIAL

The sample areas, representing *Vaccinium uliginosum—Calluna* and *Calluna* site types, were chosen in damaged pine-forests in Southern Estonia. As to tree growth these site types belong to IV . . V classes.

The sample areas were as follows:

1 — Kiidjärve I, dead pines with brown crowns, with the age of trees about 60 years (counted by growth-rings on cores at breast height). 10 trees sampled by corer from two opposite radii (N and S side) from each trunk. Sampled on Sept. 24, 1992.

2 — Kiidjärve II, living, healthy pines at the same stand, of the age of about 60 years (by growth-rings); their height about 20 m. 10 trees sampled from two radii each. Sampled on Sept. 24, 1992.

3 — Kiidjärve III, living pines, their age about 50 years. 9 trees sampled. The sample trees were banded by insect traps in 1992. Sampled on Sept. 24, 1992.

4 — Kiidjärve IV, 4 pines infested by weevil (*Pissodes piniphilus* Hrbst.), were cut on July 27, 1992. Age about 40 years. Sampled by borer, one core from each tree, on Sept. 24, 1992.

5 — Kiidjärve V, dead pines with brown crowns; infested by weevil (*P. piniphilus*) one year ago. Age about 40 years. 6 trees sampled by corer, two cores from each tree, on Sept. 24, 1992.

6 — Kikka, living pines, damaged by weevil (*P. piniphilus*) and pine-looper (*Bupalus piniarius* L.), age about 60 years. 10 trees sampled by taking cross-sections at 3 m height; one radius measured per tree. Sampled in autumn 1990.

7 — Orava, living pines, damaged by weevil (*P. piniphilus*), age about 50 years. 10 trees sampled by taking cross-sections at the height of 3 m; one radius measured per tree. Sampled on Nov. 20, 1990.

Altogether ring widths in 94 radii were measured from 59 sample trees. For various reasons (broken cores, low correlation with other tree-ring sequences) some cores were omitted from the analysis, so the actual number of analysed sequences was somewhat smaller. The widths of growth-rings were measured by a binocular microscope, and averaged by the sample areas. All ring sequences were presented graphically for synchronisation.

GROWTH CURVES

The 9 pines from sample area 7, at Orava, reveal continuous smooth decrease of yearly radial increment during tens of years (Fig. 1, *A*). The average annual increment of wood in the last five years of their life is 0.24 mm; the thickness of the last growth-ring under bark is 0.17 mm on an average. The life of these 9 pine-trees was finished by a saw.

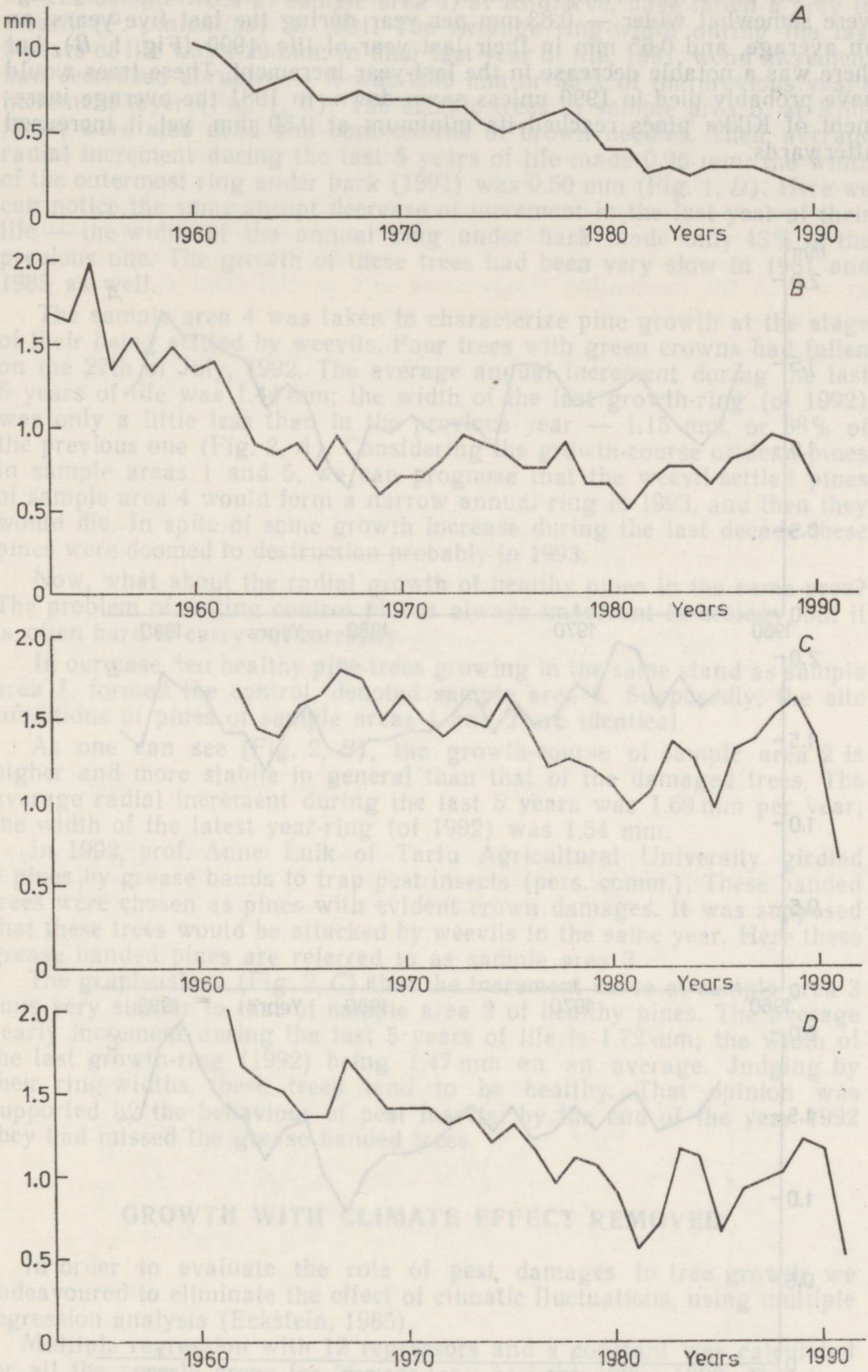

Fig. 1. Growth curves of damaged pines in sample areas: *A* — Orava; *B* — Kikka; *C* — Kiidjärve I; *D* — Kiidjärve V.

In the pines from sample area 6, at Kikka, the outermost growth-rings were somewhat wider — 0.83 mm per year during the last five years, on an average, and 0.65 mm in their last year of life, 1990 (Fig. 1, *B*), but there was a notable decrease in the last-year increment. These trees would have probably died in 1990 unless sawn down. In 1981 the average increment of Kikka pines reached its minimum at 0.50 mm, yet it increased afterwards.

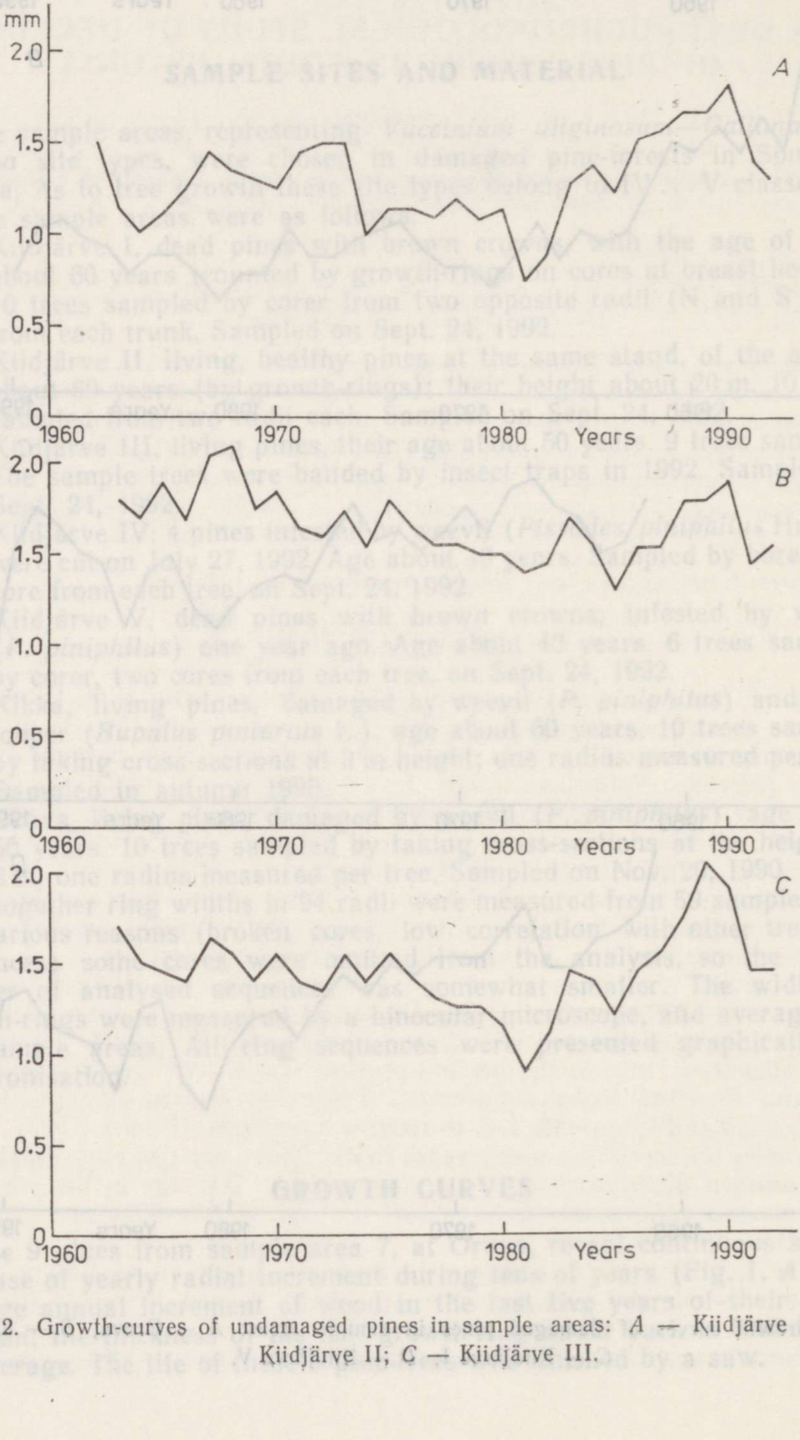

Fig. 2. Growth-curves of undamaged pines in sample areas: *A* — Kiidjärve IV; *B* — Kiidjärve II; *C* — Kiidjärve III.

The sample trees at sample area 1, at Kiidjärve, have fallen a prey to weevil (*P. piniphilus*) in 1991. The average ring-width during the last 5 years of life was 1.29 mm; in their last year of life, 1991, wood increment had decreased abruptly — it was 0.66 mm or 50% of the previous year's increment layer (Fig. 1, *C*). The sample trees in sample area 5, at Kiidjärve, were also dead and bore crowns of brown needles. Their average radial increment during the last 5 years of life made 0.96 mm; the width of the outermost ring under bark (1991) was 0.50 mm (Fig. 1, *D*). Here we can notice the same abrupt decrease of increment in the last year of their life — the width of the annual ring under bark made only 43% of the previous one. The growth of these trees had been very slow in 1981 and 1985 as well.

The sample area 4 was taken to characterize pine growth at the stage of their being settled by weevils. Four trees with green crowns had fallen on the 27th of July, 1992. The average annual increment during the last 5 years of life was 1.44 mm; the width of the last growth-ring (of 1992) was only a little less than in the previous year — 1.15 mm, or 88% of the previous one (Fig. 2, *A*). Considering the growth-course of dead pines in sample areas 1 and 5, we can prognose that the weevil-settled pines of sample area 4 would form a narrow annual ring in 1993, and then they would die. In spite of some growth increase during the last decade these pines were doomed to destruction probably in 1993.

Now, what about the radial growth of healthy pines in the same area? The problem of setting control plot is always important in ecology, but it is often hard to carry out correctly.

In our case, ten healthy pine-trees growing in the same stand as sample area 1, formed the control, denoted sample area 2. Supposedly, the site conditions of pines of sample areas 1 and 2 are identical.

As one can see (Fig. 2, *B*), the growth-course of sample area 2 is higher and more stabile in general than that of the damaged trees. The average radial increment during the last 5 years was 1.69 mm per year; the width of the latest year-ring (of 1992) was 1.54 mm.

In 1992, prof. Anne Luik of Tartu Agricultural University girdled 9 pines by grease bands to trap pest insects (pers. comm.). These banded trees were chosen as pines with evident crown damages. It was supposed that these trees would be attacked by weevils in the same year. Here these grease banded pines are referred to as sample area 3.

The graphs show (Fig. 2, *C*) that the increment curve at sample area 3 runs very similar to that of sample area 2 of healthy pines. The average yearly increment during the last 5 years of life is 1.72 mm; the width of the last growth-ring (1992) being 1.47 mm on an average. Judging by their ring-widths, these trees tend to be healthy. That opinion was supported by the behaviour of pest insects: by the end of the year 1992 they had missed the grease banded trees.

GROWTH WITH CLIMATE EFFECT REMOVED

In order to evaluate the role of pest damages to tree growth, we endeavoured to eliminate the effect of climatic fluctuations, using multiple regression analysis (Eckstein, 1985).

Multiple regression with 12 regressors and a constant was calculated for all the sample areas for 25-year-long periods, 1966—1990. This is a period where age-effect of the trees is not significant any more.

In one version, average monthly temperatures from September of the year prior to growth to August of the growth year were taken as regressors; in the second version the regressors were the monthly sums of atmospheric precipitation from September prior to growth to August of the growth season. All temperature and precipitation records are from Tartu meteorological station, which is situated about 40 km from the sample areas. The regression curves are shown in Figs. 3 and 4.

In these Figures we can see that the growth curves, due to monthly temperatures, fluctuate quite similarly, except for the regression for Orava sample area. The same can be said about the regression curves due to monthly precipitation (Figs. 3 and 4).

In general, the regression curves are in good accordance with the actual growth-curves of trees. Deviations appear mainly due to different increment levels in the sample areas. We can conclude that the reaction of tree growth to the fluctuating temperature and precipitation curves is principally the same in different sample areas.

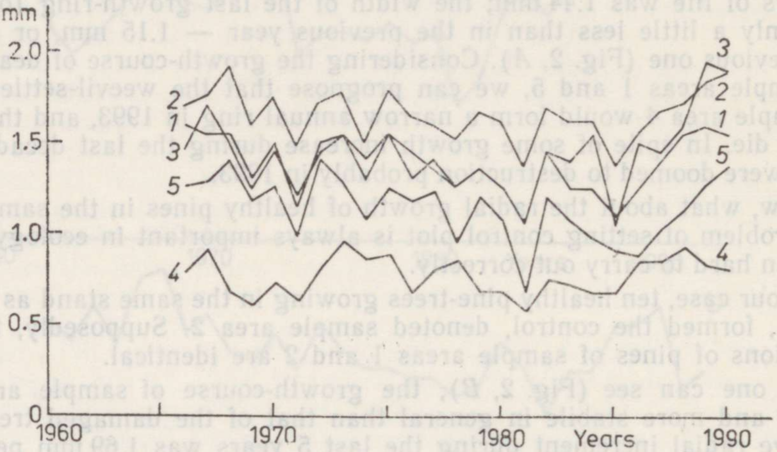

Fig. 3. Regression curves of radial increment of pines in the sample areas, calculated from multiple regressions of 12 monthly temperatures of the hydrological year. *1* — Kiidjärve I; *2* — Kiidjärve II; *3* — Kiidjärve III; *4* — Orava; *5* — Kiidjärve V.

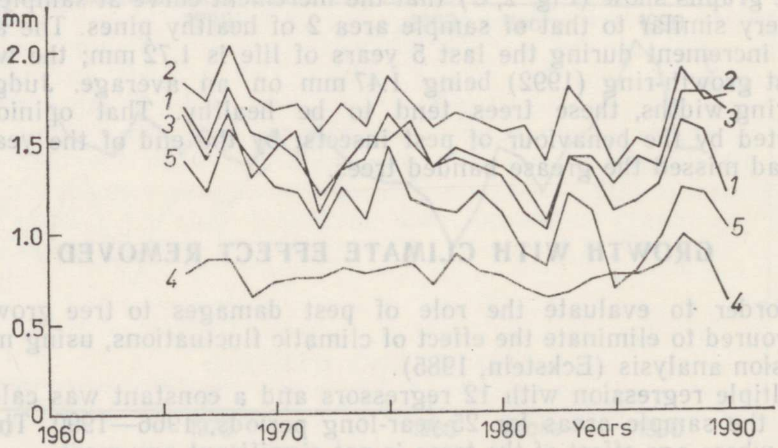

Fig. 4. Regression curves of radial increment of pines in the sample areas, calculated from multiple regressions of 12 monthly precipitation of the hydrological year.

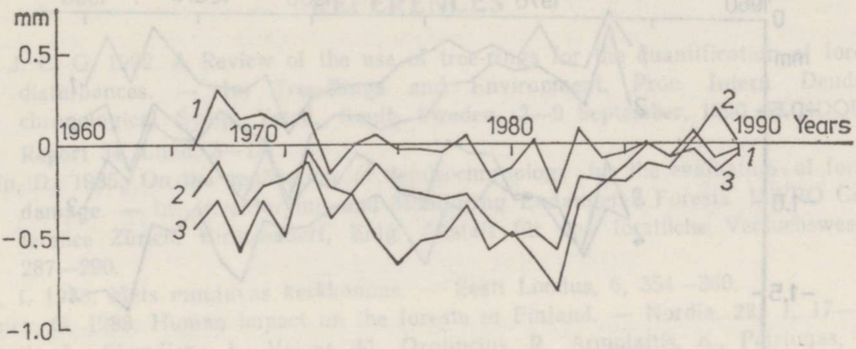

Fig. 5. Residual growth-curves of pines in the undamaged sample areas, with 12 monthly temperature-caused fluctuations removed. *1* — Kiidjärve II; *2* — Kiidjärve III; *3* — Kiidjärve IV.

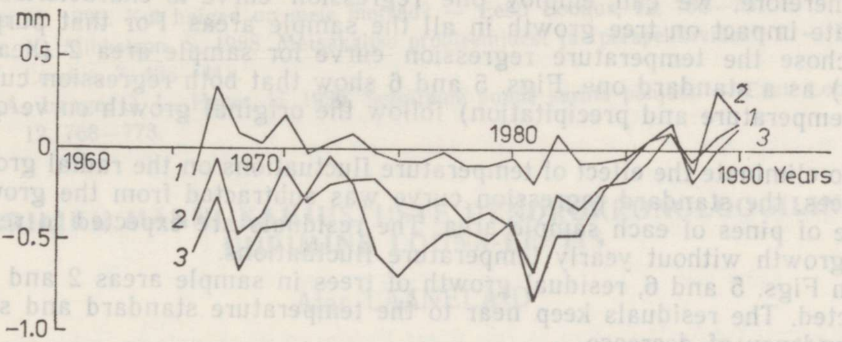

Fig. 6. Residual growth-curves of pines in the undamaged sample areas, with 12 monthly precipitation effects removed. *1* — Kiidjärve II; *2* — Kiidjärve III; *3* — Kiidjärve IV.

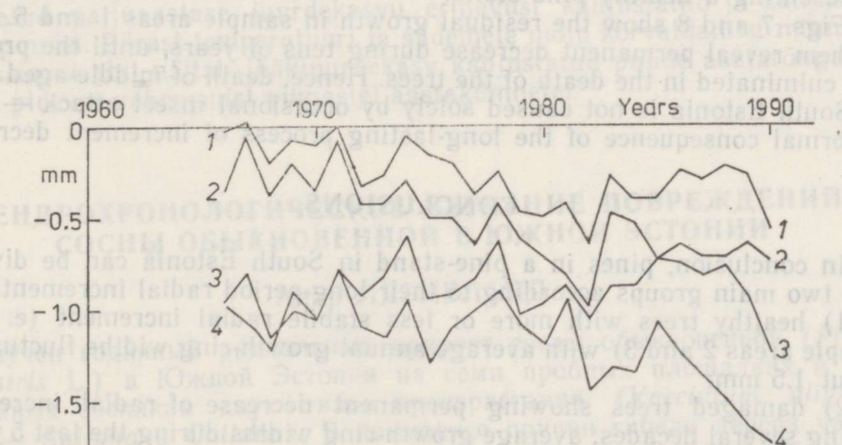

Fig. 7. Residual growth-curves of pines in the damaged sample areas, with 12 monthly temperature effects removed. *1* — Kiidjärve I; *2* — Kiidjärve V; *3* — Kikka; *4* — Orava.

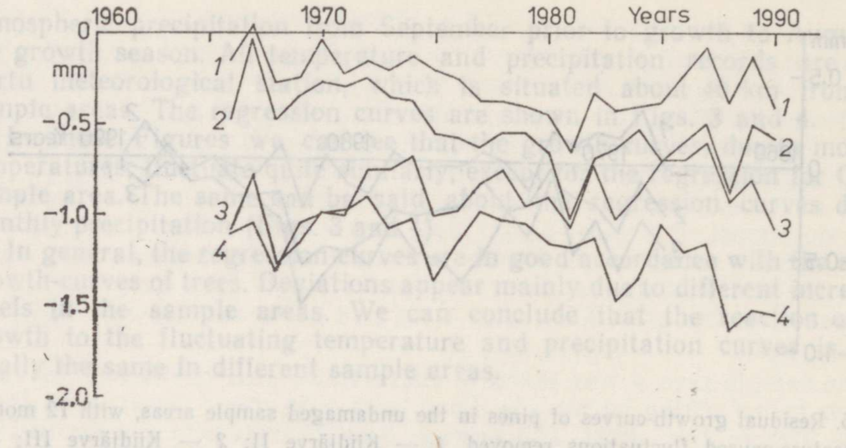

Fig. 8. Residual growth-curves of pines in the damaged sample areas, with 12 monthly precipitation effects removed. *1* — Kiidjärve I; *2* — Kiidjärve V; *3* — Kikka; *4* — Orava.

Therefore, we can employ one regression curve to characterize the climate impact on tree growth in all the sample areas. For that purpose we chose the temperature regression curve for sample area 2 (healthy trees) as a standard one. Figs. 5 and 6 show that both regression curves (of temperature and precipitation) follow the original growth curve quite well.

To eliminate the effect of temperature fluctuations on the radial growth of trees, the standard regression curve was subtracted from the growth-curve of pines of each sample area. The residuals are expected to reveal tree-growth without yearly temperature fluctuations.

In Figs. 5 and 6, residual growth of trees in sample areas 2 and 3 is depicted. The residuals keep near to the temperature standard and show no tendency of decrease.

In Fig. 5, residual growth of trees in sample area 4 is depicted. In the period 1971—1985 annual growth has stayed below the standard curve and then released. Thus sample area Kiidjärve IV can be conceived as representing a healthy pine stand.

Figs. 7 and 8 show the residual growth in sample areas 1 and 5. Both of them reveal permanent decrease during tens of years, until the process had culminated in the death of the trees. Hence, death of middle-aged trees in South Estonia is not caused solely by occasional insect attack — it is a normal consequence of the long-lasting process of increment decrease.

CONCLUSIONS

In conclusion, pines in a pine-stand in South Estonia can be divided into two main groups according to their long-period radial increment:

1) healthy trees with more or less stabile radial increment (e. g. in sample areas 2 and 3) with average annual growth-ring widths fluctuating about 1.5 mm;

2) damaged trees showing permanent decrease of radial increment during several decades; average growth-ring widths during the last 5 years of their life approximately 1 mm; a sub-group can be extracted in this group, consisting of trees at a weakness stage when weevils attack the trees. As a consequence, radial increment decreases to about 50%, after which trees usually die.

The situation of pine-stands in South Estonia is dangerous due to extensive areas of severely damaged trees dying out every year.

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HARILIKU MÄNNI KAHJUSTUSTE DENDROKRONOLOOGILINE UURIMINE LÕUNA-EESTIS

Alar LÄÄNELAID

On uuritud hariliku männi (*Pinus sylvestris* L.) radiaalset juurdekasvu seitsmel proovialal *Vaccinium uliginosum—Calluna* ja *Calluna* kasvukohatüübi kahjustatud männikutes Lõuna-Eestis. Puude kompleksse iseloomuga krooniliste kahjustuste korral saavad sageli määravaks putukkahjurid. On selgitatud paljuaastase juurdekasvu erinevust kahjustatud ja kahjustamata puudel. Pärast temperatuuri ja sademete mõju kõrvaldamist mitmese regressiooni abil näitab jääkjuurdekasv kahjustatud puude aastarõngaste laiuse pidevat vähenemist viimastel aastakümnetel.

ДЕНДРОХРОНОЛОГИЧЕСКОЕ ИЗУЧЕНИЕ ПОВРЕЖДЕНИЙ СОСНЫ ОБЫКНОВЕННОЙ В ЮЖНОЙ ЭСТОНИИ

Алар ЛЯЭНЕЛАЙД

Изучен годичный радиальный прирост сосны обыкновенной (*Pinus sylvestris* L.) в Южной Эстонии на семи пробных площадках в пораженных сосняках двух типов произрастания (*Vaccinium uliginosum — Calluna* и *Calluna*). В комплексе причин гибели дерева часто решающими являются вредители-насекомые. Настоящим исследованием выявлена разница в приросте у поврежденных и здоровых деревьев. Элиминацией влияния температуры и атмосферных осадков на прирост древесины с помощью множественной регрессии показано непрерывное уменьшение ширины годичных колец поврежденных деревьев в течение последних десятилетий.