REGENERATION OF SCOTS PINE TREES DAMAGED BY PESTS ACCORDING TO THE RETROSPECTIVE ANALYSIS OF TREE RING TIME SERIES

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Abstract

The main aim of forest monitoring in protected areas is to determine and predict the condition of forest ecosystems and their changes with respect to the regional variation and impact of air pollutants. Scots pine (*Pinus sylvestris L.*) is one of the most sensitive species for pollution in Lithuania and therefore it was chosen to be the main research object. In Dzūkija National park the investigations of forest condition have been carried out since 1992. Since 1993 pine stands have experienced intensive damage by insects *Lymantria monacha* and *Dendrolimus pini*. Only after application of biologic insecticide FORAY - 48B against Nun Month and Pine Caterpillar. In 1995 and 1996 the defoliation of Pine trees started to decrease and regeneration process has been registered. Data on long-term changes in defoliation and tree increment as well as estimated regularities and peculiarities of pest impact on tree condition and increment are presented in the article in question. Impact of biotic and abiotic factors on tree condition regeneration process are investigated. It is estimated that regeneration process of the tree condition as well as annual tree increment of dominant trees occurs most intensive. Suppressed tree foliage losses were least, but their energetic losses due to concurent fight were big and therefore the regeneration potential was very low. The main factor which affected tree condition in Dzūkija National park was the unfavourable climatic factor - drought. As the result of such a situation outbreaks of forest pests were registered.

Keywords: forest pest, climatic factor, tree ring time series, status group, condition class, defoliation

INTRODUCTION

After the decrease of production and modernisation of industry in Eastern Europe reduction of pollution load has been registered. Thus the investigations of the impact of unfavourable natural biotic and abiotic factors on forest, where pollution load does not reach regional level are very important. Therefore the investigations of forest condition have been carried out in National Park since 1992.

The main aim of our investigation is to determine and predict the condition of Scots pine trees and its changes with respect to the regional variation and impact of biotic and abiotic factors. The main tasks are:

- to monitor year-to-year long-term changes in defoliation and tree increment;
- to estimate factors and their impact on condition and productivity of trees;
- to assess impact of forest pests on tree condition;
- to estimate interdependence of defoliation and increment losses of a tree.

MATERIALS AND METHODS

As the main research object was chosen semimature Scots pine stand in Dzūkija NP, which was severely damaged by pests: Nun moth and Pine Caterpillar (*Lymantria monacha* and *Dendrolimus pini.*). The defoliation of sample trees has been assessed according to ICP(6). For the investigation of tree ring time series 60 different relative diameter (Dr) sample trees were selected, which were distributed in tree status groups. The simulation of ring time series were completed by Statistica.

RESULTS

Long-term changes in defoliation of investigated trees

According to the theory which was presented in XV Pacific Ocean Congress in New Zeland forest damages due to biotic factors are results of chronic stresses of abiotic factors. The main abiotic stress factors having impact on forest condition are unfavourable climatic factors and pollution (Mueeller-Dombois, 1988).

Very hot summer and drought in 1992 resulted in outbreak of forest pests in Southern part of Lithuania, in Dzûkija NP. The situation grew even worse after 1994 drought. In 1992 the investigated Pine stand was not damaged and was assessed as healthy. In 1993 after the huge outbreaks of forest pests sanitary condition of the stand worsened significantly. In 1994 the greatest number of trees was defoliated by 65-70%. In 1995 after the application of insecticide - a little less - 45-50%, next year - 35-40% and last year the greatest number of trees was defoliated only by 25-30%.

After the distribution of sample trees in 4 different tree status groups (suppressed, intermediate, codominant and dominant tree groups) the influence of tree status on tree defoliation dynamics was analysed (Fig. 1). It was estimated that dominant trees (Dr=1,4-1,5) were most damaged. During 1992-1994 year period mean defoliation of such trees increased from 10% to 72% - more than 7 times.

The negative change of intermediate and codominant (Dr=0,9-1,2) trees was less their mean defoliation increased from 14-15 to 62-63% - more than 4 times. The least negative change was observed in suppressed tree group where the mean defoliation increased from 30 to 71% - only more than 2 times.

Mortality of trees is one of the main indicators of stand health. The significant number of dead trees was registered in suppressed tree group and made about 7-8% in 1994 and 1996. In intermediate and codominant tree groups dead trees made only 1-3% and in dominant tree group dead trees were not registered. Last year mortality of tree decreased significantly and made at an average 1.5%.

During 1994-1997 year period the most positive condition improvement of the dominant trees was registered. Defoliation of these trees decreased from 72 to 45%, what makes 27 %. Codominant tree defoliation decreased from 62 to 40%, what makes about 22%. During this period the improvement of tree condition was evident, but none healthy tree has been registered so far.

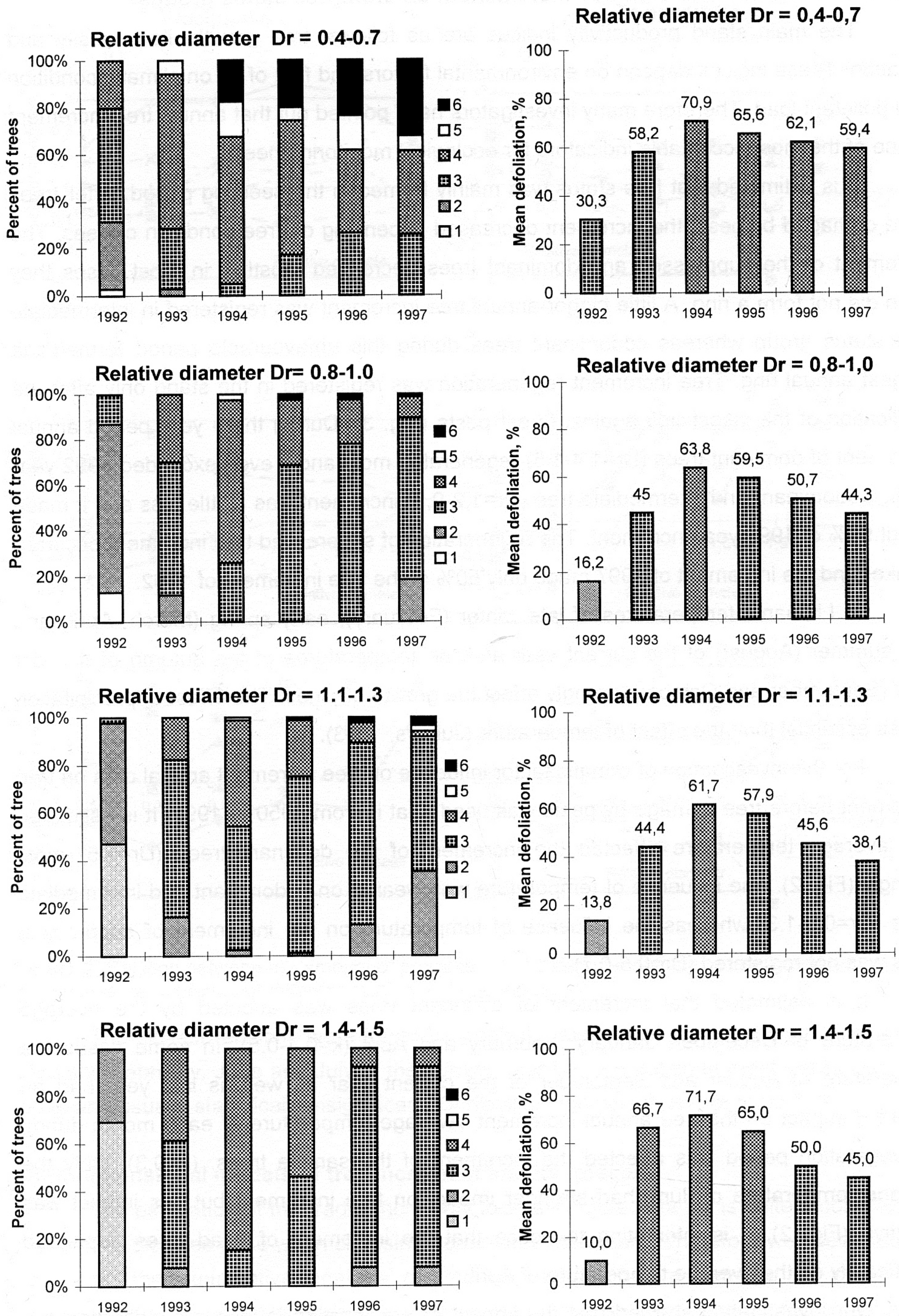

Figure 1. Defoliation of Scots pine trees in different diameter groups, 1992-97.
(Defoliation degrees: 1. 0-10%; 2. 11-25%; 3. 26-60%; 4. 61-99%; 5. 100%; 6. dead tree)

Impact of climatic factors on tree increment in different tree status groups

The main stand productivity indices are as follows: tree growth, its intensity and duration. These indices depend on environmental factors and first of all on climatic condition and pollutant load. Therefore many investigators have pointed out that annual tree increment is one of the most acceptable indicators for ecological monitoring needs.

It is estimated that tree status was mainly formed in the seedling period. After trees were damaged by pests the increment decreased depending on tree condition classes. The increment of the suppressed and dominant trees decreased mostly - in most cases they even did not form a ring. A little bigger annual tree increment was registered in intermediate tree status group whereas codominant trees during this unfavourable period formed the biggest annual ring. Tree increment regeneration was registered in the stand only after the application of the insecticide against forest pests (Fig. 3). During three year period annual increment of dominant trees (Dr=1,4-1,5) regenerated most and it even exceeded 1992 year level. Codominant and intermediate tree (Dr=1,2-0,8) increment was a little less and it made about 95% of 1992 year increment. The regeneration of suppressed tree increment occurred weaker and the increment of 1997 made only 50% of the tree increment of 1992.

In Lithuania temperatures of late winter (February), early spring (March, April) and late summer (August) of the current year and the temperatures of the autumn of the last year (September and October) strongly affect the growth of pines. The effect of precipitation is less essential than the effect of temperature (Juknys, 1993).

For the investigation of climatic factor influence on tree increment annual data on tree increment before tree damage by pests was used, that is from 1950 to 1992. It is estimated that average temperature affected the increment of the dominant trees (Dr=1.5) most strongly (Fig. 2). The influence of temperature was weaker on codominant and intermediate trees (Dr=0.9-1.3) whereas the influence of temperature on the increment of suppressed trees was not registered (Dr=0.5-0.7).

It is estimated that increment of dominant trees was affected by the average temperature of December, January, February and April (k=0.4-0.5). In some cases the temperature of August and September of the current year as well as last year had an essential impact on the tree annual increment. Average temperature of each month during the vegetation period less affected the increment of the sample trees. ($k<0.3$). Only the average temperature of June had stronger impact on tree increment but this impact was negative (Fig. 2). It is interesting to notice that the increment of dead trees depended significantly on the average temperature of April.

Our investigation showed that the impact of precipitation is less essential than the impact of temperature and it affected the increment of trees independently of their status.

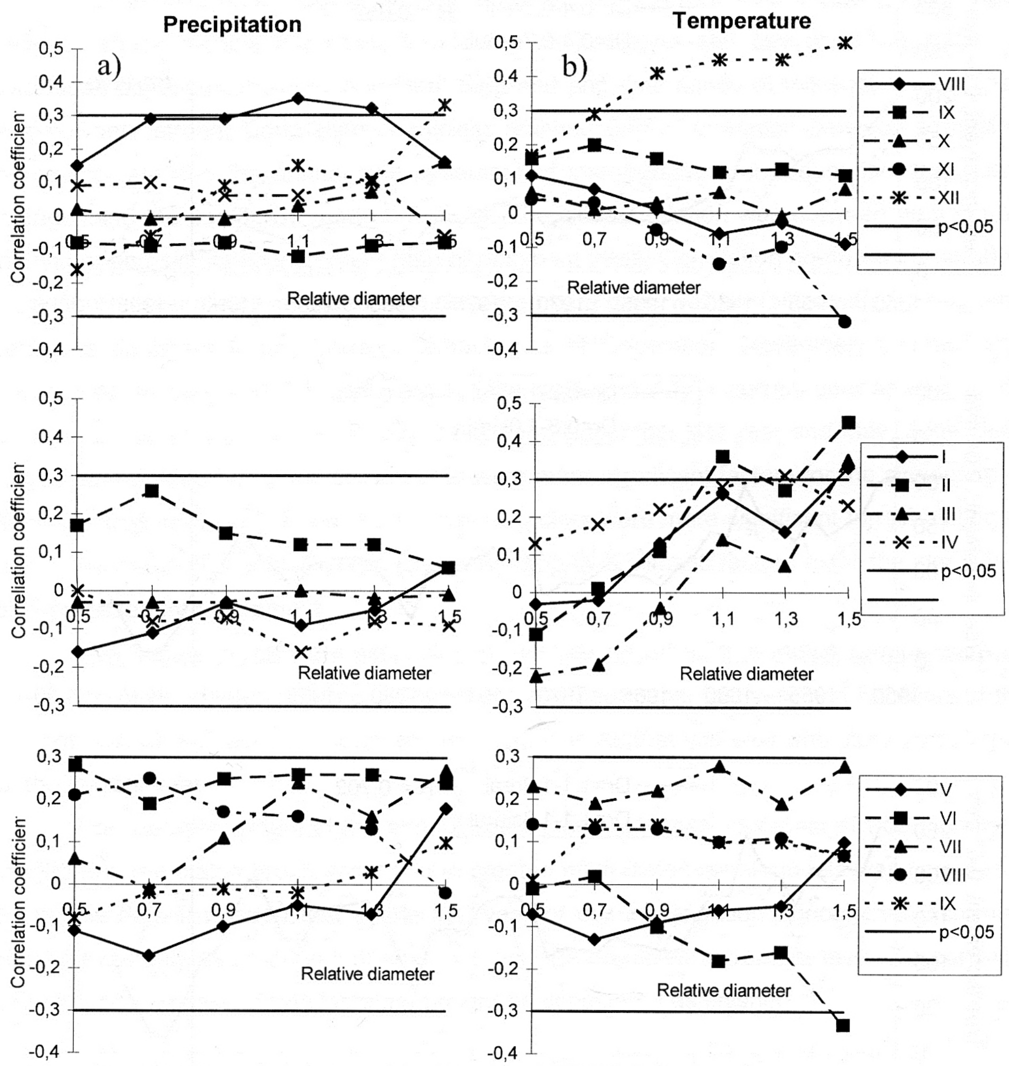

Figure 2. Relation between a) - amount of precipitation of different months and tree increment; b) - average temperature of different months and tree increment

The closest relations were found between the amount of precipitation in August last year and February, June and July of the current year but correlation in most cases was very weak and usually statistically insignificant. Correlation coefficient did not reach 0.3.

Multi-dimensional models of tree increment and its forecast

The estimation of tree radial increment losses in injured stands is quite a complicated problem. Difficulties arise when choosing normal tree increment. Therefore we used method, based on the quantitative analysis of tree ring series before damage by pests and dependence of the width of annual rings from exogenous and endogenous factors which is most promising. The value of this method depends on the level of our knowledge in the scope of causes of natural ring-series fluctuations (Juknys, 1993).

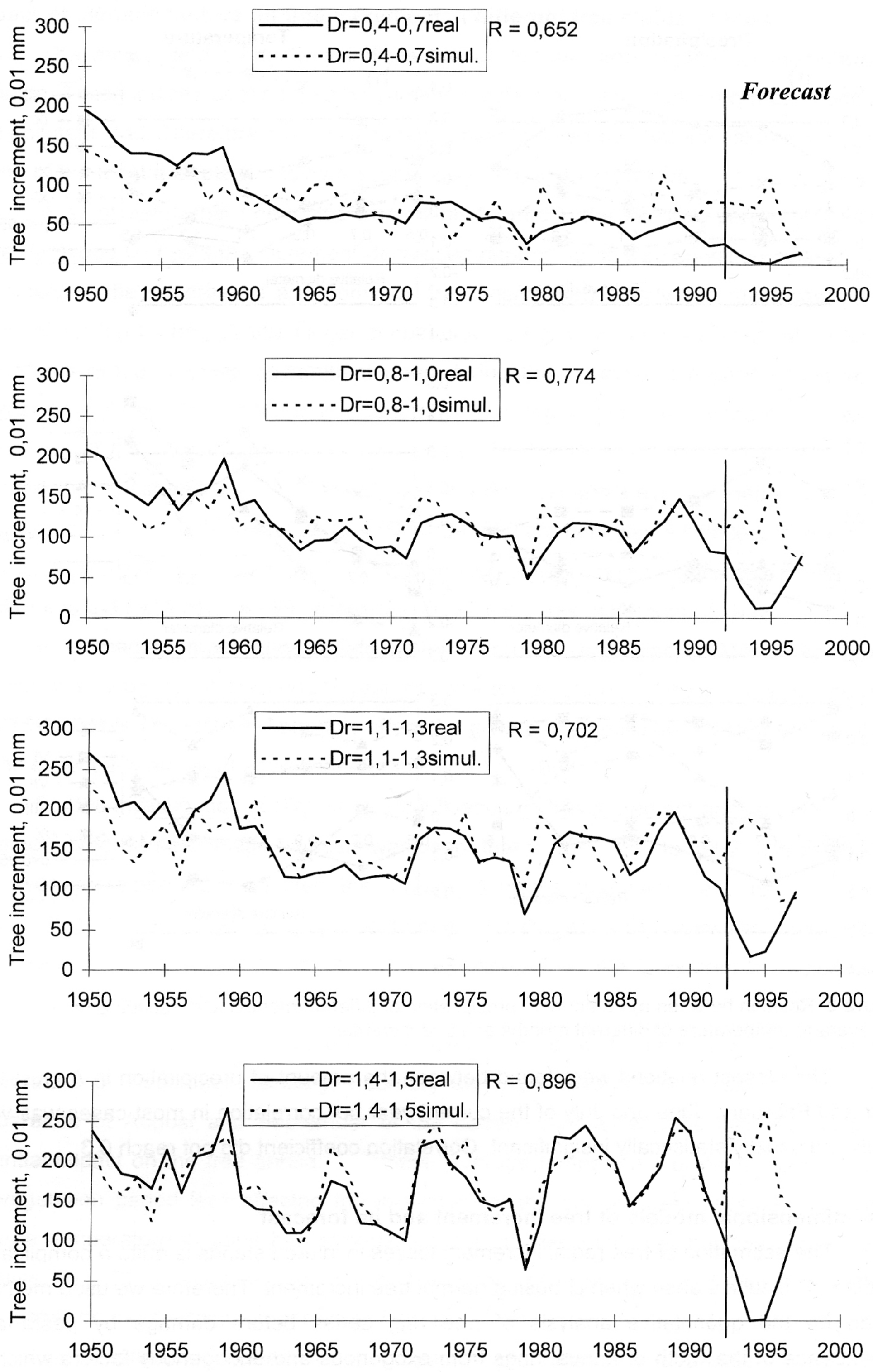

Figure 3. Multi-dimensional models of tree increment in different tree diameter groups (Dr - relative diameter if to compare with mean diameter of all tree)

Multi-dimensional models of tree increment in different tree status groups were created. These models are presented in Figure 3. As we can see from this data the correlation between simulated increment data and ring time series of the suppressed trees was not very strong. Correlation coefficient reached 0.66. Correlation between simulated increment data and the annual tree increment of intermediate and codominant trees was stronger and the coefficient made 0.70-0.74. The closest relation was between annual tree increment and simulated increment data of dominant trees. Correlation coefficient made 0.9. From figure presented it is evident that simulated data quite well conforms with the ring time series of dominant trees. Average temperature of December, November, October and September last year and February, March, May, June and July of current year as well as the amount of precipitation in August, September and December last year and May, June, July, August and September of the current year were more significant factors for the simulation of dominant tree increment. About 10-12 climatic factors were more significant for simulation of codominant and intermediate tree increment and only 8 climatic factors - for the simulation of suppressed tree increment.

The factors which were significant in most cases for all tree status groups were as follows: the average temperature of December and September last year and February of the current year as well as the amount of precipitation in August last year and June and August of the current year

For the assessment of the annual tree increment losses - forecast of tree increment in different tree status group according to created multi-dimensional models was completed. From this data it is seen that in the last year of our investigation annual tree increment reached not only 1992 increment level but also the predicted increment level. To our mind regeneration process of tree increment might be considered as finished.

The impact of crown defoliation on tree radial increment

The final task of our investigation was the analysis of the impact of crown defoliation on tree increment and increment losses in four different tree status groups. The impact of crown defoliation on the radial tree increment has been investigated for already twenty and more years. The investigators have no unanimous opinion what concerns this problem. The data presented is different and very often contradictory. Many investigators pointed out that increment losses of only severely damaged trees, crown defoliation of which exceed 40-50% can be estimated (Franz e.d., 1986). To the mind of others losses can be estimated when defoliation reaches 10-20% (Schweingruber, 1985) or when there are no crown damage symptoms (Wenk, 1977). At last it is affirmed that there is no relation between the degree of defoliation and increment losses.

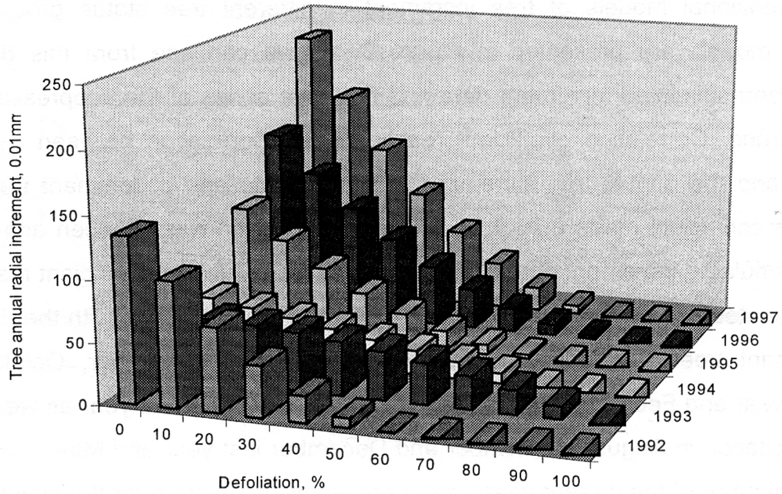

Figure 4. Influence of tree defoliation on tree increment from 1992-1997

Results of our investigation are presented in Figure 4. As we can see from the data presented, the impact of defoliation on annual radial increment during 5 year period depends on climatic factors. "Normal" increment in these years differs too. Therefore average defoliation degree and increment losses in 4 tree status groups during 5 year period were estimated first of all. Only after that the impact of defoliation on radial increment losses was analysed.

There were no significant differences in relation between defoliation and increment losses in suppressed, intermediate, codominant and dominant tree status groups. Therefore the common analysis of correlation between tree defoliation degree in all tree status groups and tree increment losses was completed.

The correlation coefficient (k=0.8) proves the direct impact of defoliation on tree increment losses (Fig. 5). It is interesting to notice that the tree the crown of which was defoliated by more than 70% in most cases did not form a tree ring.

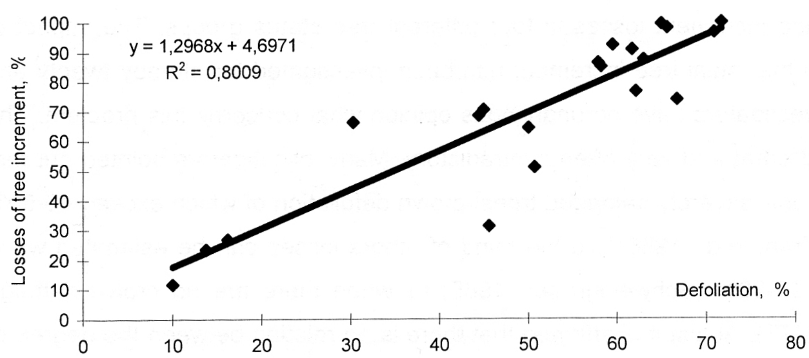

Figure 5. Influence of tree defoliation on tree increment losses according to the average data in 4 tree status groups during 5 year period

In conclusion it should be remarked that stress factor which occurs singly, only under exceptional cases is a limiting factor for tree growth and condition. In most cases trees are exposed to a number of environmental stress factors simultaneously and only then their impact is very significant. In our case stress factors were drought and outbreaks of forest pests. Our results show that only under simultaneous impact trees were damaged very severely but due to very high Scots pine tree resistance the stand was not destroyed.

Under such a condition after a few years the stand should be dead but unfavourable climatic factors do not continue for several years and therefore the regeneration process starts to occur even under one stress factor - forest pest. According to the data presented we expect even further improvement of condition of such damaged Scots pine tree stands in southern part of Lithuania, in Dzūkija National Park.

CONCLUSIONS

1. According to our data dominant trees in the stand are most sensitive for unfavourable biotic (impact of forest pests) and abiotic (climatic) factors. Their losses in foliage as well as increment if to compare with the trees from the other tree status groups are biggest. But the potential possibilities of these trees are very high because they do not experience energetic losses due to concurrent fight with other neighbouring trees. Therefore the condition regeneration process of these trees as well as annual tree increment occurs most intensive.

2. Suppressed tree foliage losses due to pests were least, but their energetic losses due to concurent fight were big and therefore the regeneration potential was very low.

3. The main factors which affected tree defoliation and productivity in Dzūkija National Park were unfavourable climatic factors - droughts in 1992 and 1994. As a result of such a situation outbreaks of forest pests were registered. Therefore today it is quite difficult to estimate the anthropogenic impact and first of all the impact of long-range transbondary air pollution, which could have had an essential affect on Scots Pine stand dynamics.

References

1. **Antanaitis V., Zgreev V.** 1981. Forest increment. Moskow, 200 p. (in Russian)
2. **Franz F., Preuhler T., Rohle H.** 1986. Vitalitatsmerkmale und Zuwachsreaktionen erkrankter Bergwaldbestande in Bayerischen Alpenraum. Allgemeine Forstzeitschrift, V. 41, N 39, S.962-964.
3. **Juknys R.** 1993. Dendrochronological Data Applications at Forest Monitoring System. Climate and Atmospheric Deposition Studies in Forests. Conference Papers, Warszawa, pp. 245-254.
4. **Mueeller-Dombois D.** 1988. Towards a unifying theory for stand-level dieback. Geo Jurnal, N 2, pp. 249-251.
5. **Schweingruber F.H.** 1985. Abrupt changes in growth reflected in tree ring sequences as an expression of biotic and abiotic influences. Inventory and monitoring endangered Forests. Zurich, pp. 291-295.
6. **UN-ECE Manual** on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. 1994. ICP, 178 pp.
7. **Wenk G., Fiedler F.** 1977. Forstliche Ertragskunde. Grundlagen, Tharandt, N 1-2