VYTAUTAS MAGNUS UNIVERSITY

Adomas Vitas

IMPACT OF CLIMATE FACTORS ON THE RADIAL INCREMENT OF NORWAY SPRUCE (*PICEA ABIES* (L.) KARSTEN)

Summary of Doctoral dissertation
Biomedical Sciences, Ecology and Environmental Sciences (03B)

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Adomas Vitas

KLIMATO VEIKSNIŲ ĮTAKA PAPRASTOSIOS EGLĖS (*PICEA ABIES* (L.) KARSTEN) RADIALIAJAM PRIEAUGIUI

Daktaro disertacijos santrauka
Biomedicinos mokslai, ekologija ir aplinkotyra (03B)

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INTRODUCTION

Actuality. The climate of the Earth is under increasing pressure of anthropogenic activities and likely to provoke the climate warming and forest decline (Lamb, 1995; Мазепа, 1998). Stability and resistance of the ecosystem is decreasing. Research of the impact of changing climate on forest ecosystems has acquired importance (Yoo, Wright, 2000). For the analysis of climate changes, a dendrochronological research could be used (Cherubini, 2000; Roig et al., 2001). Forest decline in industrial and urbanised regions is also connected to Human's activity – air pollution. Research of the impact of environmental changes on plants became important (Banks, 1992; Lovelius, 1997; Yoo, Wright, 2000; Ловелиус, 1980). Tree rings during the growing season accumulates the information about the state of the environment and are excellent indicators of environmental conditions and changes. The obtained information could also be used for environmental prognosis (Bräker, 1992; Eckstein, 1989; Schweingruber, 1993; Stravinskienė, 1997, 2000; Yoo, Wright, 2000; Битвинскас, 1974, 1984а, 1984б; Битвинскас и др., 1975; Колчин, Черных, 1977 etc.).

According to the data of the National forest inventory of the 1st January 2001, the stands of Norway spruce (*Picea abies* (L.) Karsten) occupy 23.1% of the forest area in Lithuania (Kuliešis, Rutkauskas, Butkus, 2001). The main part of the dendrochronological research carried out in Lithuania was concentrated on Scots pine (Битвинскас, 1974 etc.), although the radial increment of spruce is more sensitive to the changes of environment than Scots pine is (Stravinskienė, 2002).

Due to a surface root system of the Norway spruce, windfalls are frequent in wet soils. Spruce prefers stable moisture of the soil and is an excellent indicator of droughts. Hurricane winds in the last decade of the XX century and more often unusual droughts in Lithuania, according to the opinion of scientists could attribute to climate change. Therefore, the significance of an ecological research on Norway spruce increases even more (Ozolinčius, 1998).

Trees, growing on dry forest sites are more sensitive to climate factors and more valuable in dendroclimatological research (Fritts, 1987; Stokes, Smiley, 1968 etc.). The results of the Forest monitoring of Lithuania shows, that the biggest probability of the invasion of pests is also on dry stands of spruce, especially after droughty periods (Karazija, 1997), e.g., due to a catastrophic manifestation of bark beetle (*Ips typographus* L.) 3.3% of spruce stands (18.3-18.6% of mature stands) were cut during 1993-1996 (Ozolinčius, 1998). Therefore, the biggest part of research plots on dry forest sites of Norway spruce during this work were selected.

Hypothesis. Using the network from fifty-four research plots of Norway spruce, applying multivariate regression and pointer years analysis is possible to evaluate exhaustively the impact of climate factors on the radial increment of spruce.

Aim of the work. The aim of the work is a dendroclimatological research of Norway spruce, growing on dry forest sites in Lithuania and the construction of masterchronologies on radial increment.

Goals of the work. For the purpose of research, goals were solved: 1) Selection of the research plots in Lithuania and collecting of samples during the field work; 2) To measure tree ring widths by using a LINTAB measuring table and TSAP program installed on PC; 3) To construct local chronologies for each research plot and masterchronologies for dry sites of Norway spruce in Lithuania; 4) Using data of precipitation and air temperature of meteorological stations in Lithuania to carry out the dendroclimatological analysis of spruce radial increment series: to calculate the coefficients of multivariate regression – a response function and to detect the pointer years of the radial increment of Norway spruce.

Novelty and originality. A network of 54 research plots (1598 trees) of Norway spruce covering the all territory of Lithuania was compiled for the first time. Modern computer programs, corresponding to the international dendrochronology research standards, were used during the data's analysis. Using modern methods, series of the radial increment from individual tree were indexed separately and local chronologies were constructed as biweight robust means (Cook, Shiyatov, Mazepa, 1990; Riiters, 1990).

Only the annual radial increment was used during the dendroclimatological research until now. Latewood and earlywood widths of the radial increment also were used during this research.

Results of dendroclimatological research, carried out in Europe and Lithuania shows that the link coefficients between the radial increment and climate factors are weak and often insignificant (Schweingruber, 1983). Therefore, not only the coefficients of the multivariate regression between the radial increment and climate factors were calculated, but also the pointer years of the radial increment were detected.

During the statistical treatment – a calculation of the impact of climate factors on the radial increment, a recent method of multivariate regression techniques was adapted. Response function better expresses the nonlinear interactions among climate factors and radial increment than simple correlation coefficients and eliminates autocorrelation between the series of climate factors (Briffa, Cook, 1990).

Masterchronologies of the annual radial increment (including latewood and earlywood) for Norway spruce growing on dry forest types (*Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*) were constructed. They could be used in dendrochronology, forestry, ecology, environmental sciences and other studies in Lithuania and abroad.

During the dendrochronological research, a GPS technique was used for the first time in Lithuania. Precise geographical coordinates for each research plot were established.

Structure and extent. The work consists of preface, review of literature, research objects and methods, results, conclusions, literature of 214 titles, publications, acknowledgements and appendices. The work is illustrated with 20 tables and 74 figures.

CONTENTS OF THE WORK

CHAPTER 1. REVIEW OF LITERATURE.

1.1. Review of Lithuanian climate. Climate conditions in Lithuania are surveyed.

1.2. Climatic regions of Lithuania. History of the division of climate into regions in Lithuania during the XX century is shortly described. Climate regions distinguished by K. Kaušyla in 1981 are presented.

1.3. Extreme climatic conditions. Extreme climatic conditions limiting the radial increment of trees are surveyed.

1.3.1. Droughts. The formation and impact of spring and summer droughts is discussed.

1.3.2. Cold winters. The formation and impact of winter colds is discussed.

1.3.3. Hurricane winds. The formation and impact of hurricane winds is discussed.

1.4. Climatic changes: reasons and "greenhouse effect". The climatic changes in Lithuania from the end of the 'Little' ice age until the XX century is presented. The frequency and recurrence of extreme climatic conditions in respect to climatic changes is analysed. Factors influencing long-term climatic changes and causes of the greenhouse effect are presented.

1.5. Lithuanian spruce forests.

1.5.1. Review of spruce forests in Lithuania. The review of Norway spruce (*Picea abies* (L.) Karsten) stands in Lithuania is presented. According to scientist's opinions, spruce stands in Lithuania correspond to the general climatic conditions of our country and in the physically-geographically are the most important (Basalykas, 1958).

1.5.2. Historical dynamic of spruce forests area. Distribution of spruce in forests of Lithuania during the Holocene is shortly presented.

1.5.3. Geographical distribution of spruce forests. The geographical distribution of the forests with predominant Norway spruce in regions of Lithuania is shortly surveyed.

1.5.4. Forest types of spruce forests in Lithuania. Forest types of stands of Norway spruce are referred too.

1.6. Historical review of the dendrochronological research.

1.6.1. Development of dendrochronological research. History of dendrochronology all over the world from the first observations in the XV-XVI centuries and the formation of dendrochronology in the XX century are reviewed.

1.6.2. Dendrochronological and dendroclimatological research in Europe. Results of a dendrochronological and dendroclimatological research carried out in Europe are presented.

1.6.3. Dendrochronological and dendroclimatological research in Lithuania. The main research conducted on tree rings in Lithuania is presented here.

1.6.4. Dendroclimatological research of Norway spruce in Lithuania. Dendroclimatological research carried out on Norway spruce in Lithuania is presented. The main results of the previous research on the link between tree ring widths of spruce and climate conditions are briefly discussed.

CHAPTER 2. RESEARCH OBJECTS AND METHODS.

2.1. Research objects, methods of field and cameral research. Fifty-four research plots were selected in mature stands of Norway spruce in Lithuania. The main part of research plots (34) represents dry forest types. By using 'Suunto' increment borer, samples were taken at breast height, one sample from one tree. In each research plot 20-30 trees were bored. By using a GPS device MAGELLAN 315, geographical coordinates for each research plot were established. Tree ring widths (earlywood and latewood separately) were measured by using a LINTAB tree-ring measuring table with a TSAP 3.14 computer program within the accuracy of 0.01mm.

2.2. Dating quality control, indexation of radial increment series and constructing of chronologies. Dating quality control was performed by using the COFECHA 3.00P program. Tree ring series of asynchronous growth or with possible dating problems were eliminated from the next stages of the research. Each tree ring series obtained from an individual tree was indexed separately. Indexing was carried out in two stages (Holmes, 1994). By using a negative exponential curve and linear regression and after applying the spline function the age curve was removed. The program CHRONOL from the ITRDB Program Library compiled in the University of Arizona by R.L. Holmes was used. Local chronologies for each research plot were constructed as biweight robust means (Cook, Shiyatov, Mazepa, 1990; Riitters, 1990). The nine longest local chronologies were submitted to the International Tree Ring Data Bank.

2.3. Principles of constructing master chronologies. During the research, two master chronologies for spruce of dry forest types (*Piceetum vaccinio-myrtillosum* and *Piceetum hepatico-oxalidosum)* for the first time in Lithuania were constructed (forest types were established using the typology of prof. S. Karazija). During the construction of masterchronologies, local chronologies were dated using the COFECHA program and masterchronologies that were constructed as robust means. The latewood, earlywood and annual radial increment are presented in masterchronologies.

2.4. Research methods of response function – the impact of climatic factors (air temperature and precipitation) on the radial increment of Norway spruce. For the modelling of tree growth and climatic factors (air temperature and precipitation) the modern method – multivariate regression techniques – response function was used (Cook, Jacoby, 1977; Fritts, 1987, 1991; Serre-Bachet, Tessier, 1990). Calculations using data of the average month air temperatures and the monthly amount of precipitation from the October of the previous year to the current September in the period of 1930-1994 were carried out. Calculations were carried out using the PRECON 5.17B computer program that was developed in the University of Arizona by H.C. Fritts in 1999. Local chronologies of thirty-one research plots of dry sites and fourteen of wet were used in the analysis. Climatic data for each research plot from the nearest meteorological station was selected. Discussing geographical peculiarities of the impact of climate in chapters 3.2, 3.3 and 3.6 eight regions were distinguished: Seaside, Hills of Žemaitija, Central, Southwest, South, East, North and Northeast.

2.5 Research methods of the radial increment of pointer years. Pointer years of the radial increment were accepted if the increment increased or decreased by 75% or more trees. Indexed series of an individual tree were used. Pointer years were estimated also for the latewood and earlywood radial increment. For the interpretation of pointer years, monthly average air temperature and the amount of precipitation and hydrothermal indicator, proposed by T. Bitvinskas (formula 1) (Битвинскас, 1965, 1974) were used.

$$H_i = \frac{t_i}{k_i} \quad (1)$$

H_i – hydrothermal indicator, t_i – average air temperature in the respective period (month, year, hydrological year etc.) and k_i – amount of precipitation during the same period.

2.6. Research methods of Norway spruce seasonal radial increment. Research on the seasonal radial increment has been carrying out in the Aukštaitija National Park since 1976. By using, the method of steel tape (Schweingruber, 1993) the radial increment of three Norway spruce trees was investigated (Karpavičius, Vitas, 2000). The formation of the seasonal increment of Norway spruce and links with climatic factors (i.e. air temperature and precipitation) during 1995-1998 was analysed (Karpavičius, Vitas, 2000).

2.7. Research methods of links between hydrothermal indicators, Solar activity, and climatic factors with the radial increment of Norway spruce in different periods. Several hydrothermal indicators as proposed by T. Bitvinskas (Битвинскас, 1965, 1974) were used and they are as follows: the yearly average air temperature and the amount of precipitation; the hydrological year's (September-August) average temperature and precipitation; the hydrothermal indicator (Битвинскас, 1965, 1974, 1984a) of a year, the hydrological year and the vegetation season (May-August). Calculations of correlation coefficients using the longest local chronologies from eight research plots during the XX century have been performed. For this research of the link between Solar activity and the radial increment of spruce, coefficients of correlation and the similarity (gleichläufigkeit) between the masterchronologies and Solar activity (i.e. Volf values) were counted in the period between 1893-1999. For the purpose of this research of climatic factors, limiting the increment of spruce in separate periods of the XX century (1900-1920, 1921-1940, 1941-1960, 1961-1980 and 1981-1995) were used eight longest local chronologies. Correlation coefficients were counted from the October of the previous year to September of the current year.

CHAPTER 3. RESULTS.

3.1 Masterchronologies of Norway spruce. For the masterchronology of Norway spruce in *Piceetum vaccinio-myrtillosum* forest type 18 local chronologies (464 trees) and *Piceetum hepatico-oxalidosum* – 13 chronologies (354 trees) were used (Fig. 1). The time span of chronologies covered by ten or more trees is 132 years (1868-1999) and 106 years (1894-1999), respectively. A similarity between two masterchronologies is 71.3-81.4 and correlation coefficients are +0.78 - +0.89. A weak link between the masterchronologies and the Solar activity was discovered: correlation coefficients are +0.04 - +0.12 and the coefficients of similarity – 52.4-61.4.

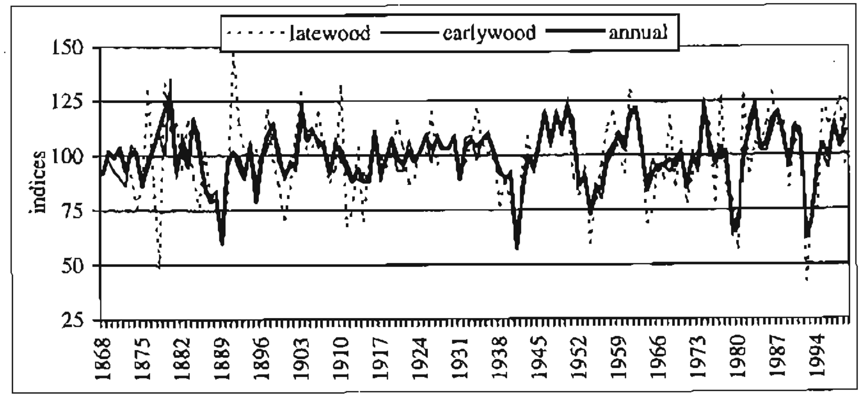

Fig.1. Masterchronology of Norway spruce in *Piceetum vaccinio-myrtillosum* forest type

3.2 Results of multivariate regression-response function between climatic factors and Norway spruce radial increment.

3.2.1. Link between the latewood radial increment, air temperature and precipitation. The latewood radial increment of spruce is weakly impacted by the air temperature during the end of the previous year and winter of the current year. The positive impact of air temperatures in spring (April and May) is significant and of summer (July and August) inverse. Impact of precipitation is different: negative link with precipitation in previous October, January was found and positive significant impact of precipitation is of May and July.

3.2.2. Link between the earlywood radial increment, air temperature and precipitation. Positive links predominate between the earlywood radial increment and air temperature. Negative link only with June temperature was established. The positive significant impact is of the air temperature in April. Direct impact of the precipitation in May and June were discovered.

3.2.3. Link between the annual radial increment, air temperature and precipitation. Links between the annual radial increment of Norway spruce and the air temperature is similar to the links with earlywood. The main differences on dry forest sites are as follows: bigger positive influence in May, negative in August and more positive in September. Links between the annual radial increment of spruce and the precipitation is similar to the links with earlywood.

3.3. Pointer years of the radial increment.

3.3.1. Pointer years of the radial increment of Norway spruce on dry forest sites. Negative and positive pointer years of the radial increment of spruce are presented in this chapter. The main negative pointer years were established in 1941, 1954, 1979, 1980, 1992 and 1993 and the positive in 1946, 1962 and 1974. Using the climatic data from the Vilnius Meteorological Station was established that the negative pointer years were provoked by dry or cool springs and by dry and hot summers. Positive pointer years were induced by humid summers and warm springs. By using the number of trees with increased or decreased increments and histograms of the radial increment, the negative pointer years of latewood increment could be placed in significant decreasing order: 1992, 1980, 1941 and 1954. The order of pointer years of the earlywood increment is different: 1941, 1992, 1979, 1980, 1954 and 1993. The order of pointers years of the annual radial increment is similar to that of the earlywood: 1941, 1992, 1979, 1980, 1993, 1954, 1971 and 1955. Positive pointer years of the latewood radial increment were not detected. The decreasing order of the significance of pointer years in earlywood and the annual radial increment are: 1974, 1962 and 1946.

3.3.2. Pointer years of the radial increment of Norway spruce on wet forest sites. The main negative pointer years were in 1941, 1954, 1979, 1980, 1992 and 1993, and the positive in 1905, 1950, 1962, 1983 and 1997. Negative pointer years were caused by dry and cold springs and by dry and hot summers. Positive pointer years of the annual radial increment on wet forest sites were provoked not by humid summers as in dry forest sites, but by warmer than normal winters and springs. The negative pointer years of latewood increment in significant decreasing order are: 1992; 1980, 1941 and 1940. The number and order of pointer years of the earlywood increment is different: 1941, 1980, 1992, 1979, 1993 and 1954. The order of pointers years of the annual radial increment is similar to that of the earlywood: 1941, 1980, 1992, 1979, 1954 and 1993. The positive pointer year of the latewood radial increment was in 1997. The decreasing order of significance of the pointer years of earlywood is: 1997, 1983, 1962, 1905 and 1950 and the annual radial increment: 1997, 1983, 1950, 1962 and 1905.

3.3.3. Geographical analysis of pointer years. When performing the analysis of the geographical distribution of the pointer years, the monthly data of temperatures, precipitation and the hydrothermal indicators were used.

Negative pointer for **1941** is peculiar on dry and wet forest sites. A decrease of the latewood increment was less significant in Western and Southern Lithuania. A decrease of the earlywood was strongest and involved a larger territory. This could be connected to the rainfall differences in the mentioned regions. An assumption that the pointer year was caused by cold winter also should not be denied.

Positive pointer in **1946** was ascertained on dry and wet forest sites. The biggest increase of the increment was in the Eastern, Western and Southern regions. A positive influence on the radial increment was from a warm spring and a wet summer.

The positive pointer in **1950** was detected on wet forest sites. The largest increase was in Western and Northern Lithuania. A positive influence was from a warm May, but due to a dry summer, positive pointer year were not registered on dry forest sites.

Negative pointers in **1954** and **1955** were on dry and wet forest sites. A decrease on wet forest sites in 1954 was more significant than on the dry forest sites. A very cold winter and spring in 1954 provoked pointer year. The pointer year for 1955 on wet sites is not significant. A cool April and a dry summer induced the pointer year. The long lasting effect of a cold winter in 1954 also could have helped to interpret the pointer for 1955.

The negative pointer for **1956** was peculiar only on wet forest sites and was not significant in Eastern Lithuania. An explanation of pointer year: very cold March, cool April, cool and wet summer.

A positive pointer for **1962** was discovered on dry and wet forest sites – the most significant in Southern and Southeast regions. This pointer year is caused by a high amount of precipitation in May-June.

A negative pointer for **1971** was observed on dry forest sites. A dry spring and summer influenced negatively. Where the amount of precipitation was bigger (South and Southeast regions) the pointer year was less significant.

A positive pointer for **1974** was detected on dry forest sites. The biggest increase of the radial increment was in Southeast, South and East regions. A wet summer affected positively.

Negative pointers for **1979** and **1980** were discovered on dry and wet forest sites. The dry summers of 1979 and 1980 influenced it negatively. A slightest decrease of the increment was observed in Western Lithuania. This could be attributed to a larger amount of precipitation and milder winter conditions.

A positive pointer in **1983** was detected on wet forest sites. The radial increment was stimulated by a warm May. The summer was dry.

A negative pointer in **1992** was observed on dry and wet forest sites. A decrease of the increment was significant in all territory of Lithuania. The strongest negative influence was from an extreme summer drought.

A negative pointer for **1993** was on dry and wet forest sites. A significant decrease of the radial increment on wet forest sites is peculiar to all regions. A less significant decrease on dry forest sites was at the Baltic Seaside and in the Northeast regions. The extreme drought of 1992 and the dry spring of 1993 affected it negatively. Because of the bigger amount of precipitation in the Western regions, felt during the previous 1992 autumn, a decrease of the increment in 1993 was only slight.

A negative pointer in **1994** was registered on dry forest sites. The strongest decrease detected was from the latewood increment. A dry and extremely hot summer influenced it negatively.

3.4. Links between hydrothermal indicators, climatic factors and Norway spruce radial increment in different periods. The correlation coefficients between the radial increment of spruce and hydrothermal indicators are presented here. The essential differences between latewood, earlywood and annual increment were not established. Positive links were established with the precipitation and the air temperature of the year and the hydrological year. The links with hydrothermal indicators of the year and the hydrological year are insignificant. Correlation coefficients with hydrothermal indicator of the vegetation period (May-August) are negative and significant ($p \leq 0.05$, $p \leq 0.01$). The link with the hydrological year indicators is slighter comparing with the year indicators. During the analysis, the essential differences between dry and wet forest sites were not observed.

During the analysis of the links between the radial increment and climatic factors in separate periods, it was found that the biggest individuality distinguishes latewood increment. Correlation coefficients between the radial increment of Norway spruce and the monthly amount of precipitation and the average air temperature in separate periods during the XX century, showed the biggest differences in links with the air temperature.

The last period from 1981-1995 was distinguished by the biggest peculiarities of the links. Negative coefficients with air temperature increased, positive impact from a warm spring decreased, negative impact from high summer temperatures on wet forest sites appeared and positive influence from the summer precipitation was found.

This indicates changes of climatic conditions at the end of the XX century, which played a significant negative role to the flourishing of Norway spruce (*Picea abies* (L.) Karsten) in Lithuania.

3.5. Research of Norway spruce's seasonal radial increment. Monthly data of the climate for Vaišnoriškė and Utena meteorological stations are briefly presented and discussed in the chapter. The leading feature of the climate during 1995-1998 and the vegetation season – frequent dry and hot summers, especially in the second half. Only the summer of 1998 was wet. The radial growth of Norway spruce during the research years began on 22nd of April - 4th of May and finished at the beginning of September. By using correlation coefficients, the links between the seasonal increment and climatic factors in 1995-1998 were analysed. The air temperatures of May-June positively influenced the radial growth of spruce in 1995-1997. However, during July-August due to a high temperature negative links were found. In 1996, the precipitation played an important role in the second half of the summer, because of high summer temperatures and a lower amount of precipitation. In the beginning of the 1998 summer, positively influenced the precipitation, but in the second half of the summer (July-August) neither the impact from the precipitation nor the air temperature was detected. Trees responded positively and quickly after the longer hot period, when the small amount of precipitation was felt. A hot and dry second half of the summer reduced the biological differences of the reaction to droughts and high temperature, the main limiting factor, correlates negatively with the radial growth.

3.6. Discussion of the research's results on Norway spruce's radial increment. In this chapter, the research's results have been analysed, summarised and discussed.

Fieldwork and further analysis were performed according to international methods used in dendrochronological research. By using, 31 local chronologies (818 individual tree ring series) two masterchronologies for dry forest sites were constructed. Data from masterchronologies are presented in the dissertation and could be used for practical purposes by scientists in Lithuania and abroad. The links between masterchronologies and solar activity are insignificant.

For the purpose of the research of links between the climatic factors and the radial increment of Norway spruce, a multivariate regression analysis – response function and pointer year analysis were used. Monthly data of the air temperature and precipitation were used in the calculations.

Links with the precipitation on dry and wet forest sites is more different than of air temperatures. The main differences in the link between the latewood radial increment and climate factors on dry and wet sites are as follows: 1) the significant impact of temperature in May on dry forest sites and of April on wet; 2) More positive impact of precipitation in May-July on dry sites; 3) Stronger negative impact of precipitation on wet sites in previous November, August and September comparing with dry; 4) The more positive impact in May-July on dry sites than on wet in the links between earlywood, annual radial increment and precipitation was found (fig 2, 3).

Results of the response function are presented in respect to climatic regions.

Latewood.

- ✓ Positive significant links with the precipitation of July on dry forest sites and positive link with air temperature in April and inverse link with precipitation in August in Žemaitija on wet forest sites were detected.
- ✓ Negative links with the precipitation of previous November on dry forest sites and positive link with the air temperature in April on wet forest sites in Southwest regions were established.
- ✓ Negative links with the precipitation in January on wet forest sites in East regions were found.
- ✓ Positive link with the air temperature in May on dry forest sites in North regions exist.
- ✓ More positive links with the air temperature in May and the precipitation in June, July in Northeast regions on dry forest sites were detected.
- ✓ Statistically significant links were not established at the Seaside, South and Central areas of Lithuania.

Earlywood.

- ➢ Positive links with the precipitation in June on dry forest sites in Baltic Seaside were found.
- ➢ Positive links with the precipitation in June-July on dry forest sites in Žemaitija were established.
- ➢ Positive links with the air temperature in April and the precipitation in May-June in Southwest region on dry forest sites exist. Positive links with the precipitation in June on wet forest sites also exist.
- ➢ Positive links with the precipitation in June on dry forest sites in South and East regions were discovered.
- ➢ Positive links with the air temperature in April and the precipitation in June on dry forest sites in North regions exist. Positive links with the air temperature in April on wet forest sites also exist.
- ➢ Statistically significant links were not established in Northeast and Central Lithuania.

Annual increment (fig.2, fig. 3). Abbreviations of regions: Se – Seaside, Z – Hills of Žemaitija, C – Central Lithuania, SW – Southwest, S – South, E – East, N – North, NE – Northeast. Each value in the figures represents the arithmetic average counted from response coefficients of the research's plots in a particular region.

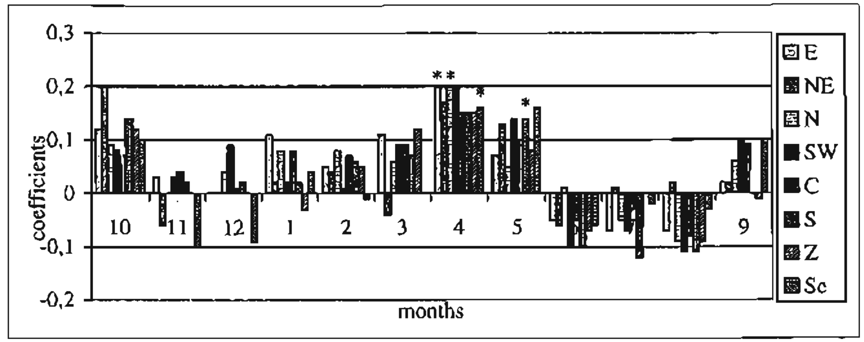

Fig. 2. Coefficients of the response function between the ring width of Norway spruce and monthly air temperature (* - significance p≤0.05)

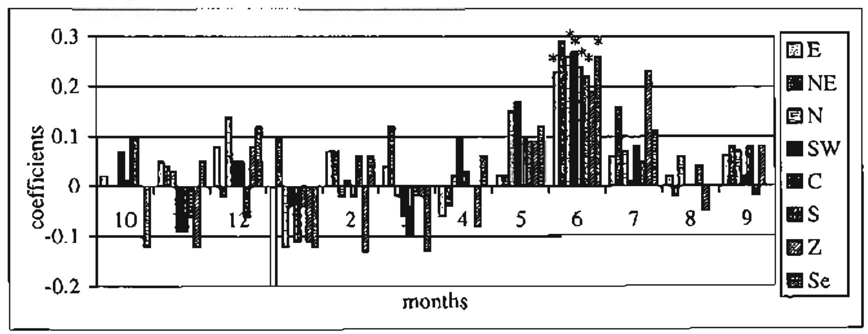

Fig. 3. Coefficients of the response function between the ring width of Norway spruce and monthly amount of precipitation (* - significance p≤0.05)

- Positive links with the precipitation in June-July on dry forest sites in Žemaitija were detected.

- Positive links with the precipitation in June on dry forest sites in Central Lithuania were discovered.
- Positive links with the precipitation in June on both forest sites exist. Positive links with air temperature in April and precipitation in May on dry forest sites in Southwest regions also exist.
- Positive links with the precipitation in June on dry forest sites in South Lithuania were established.
- Positive links with the precipitation in June on both sites in East Lithuania exist. Positive links with air temperature in April on dry forest sites also exist.
- Positive links with the air temperature in April on both sites in North Lithuania exist. Positive links with the precipitation in June on dry sites also exist.
- Positive links with the precipitation in June on dry forest sites in Northeast regions were found.
- Statistically significant links were not established at the Seaside.

The comparison of the results of multivariate regression obtained during this research with the previous results is difficult. The latewood and earlywood radial increment was not analysed during the previous research. The research encompassing the network of plots of spruce in all territory of Lithuania was carried out for the first time. The earliest dendroclimatological research, carried out by I. Čerškienė in the West Lithuania showed the weak links with the precipitation and air temperature during the vegetation season (Чершкене, 1975). However, the conclusion that the precipitation plays the greater role than air temperature for the radial increment of spruce has proved out in my research.

The research on Norway spruce carried out in two research plots near Kaunas by J. Karpavičius et al. in 1996 showed the positive influence of the temperature in spring (Karpavičius, Kairaitis, Yadav, 1996). Inverse links with the precipitation in winter and direct with precipitation in summer were ascertained. The mentioned results that the increment of spruce is under the direct influence of cool and wet summers correspond with my conclusions. The essential difference is the more negative impact of the precipitation in January during my research.

The results of the research on spruce carried out in Southern Sweden cleared the precipitation of June to be the main climatic factor influencing the radial growth of spruce. The temperature of the early spring affects the radial increment of spruce in the West and South Sweden (Linderson, 1992). The research carried out in Northern Germany showed, that the fluctuations of the radial increment of Norway spruce is under the impact of dry periods in spring and summer and longer than 15 days duration (Krause, 1992). The mentioned results carried out in the abroad (significant impact of precipitation in June, weaker influence of temperature in spring, and negative impact of droughts) correspond highly with my research.

Results of pointer years are also presented in respect to climatic regions. In this chapter, I have summarized the results discussed in the previous 3.3.1.-3.3.3. chapters.

A particularly negative influence on dry forest sites during a drought summers was observed. On the wet forest sites, a considerably bigger negative impact from the cool summer was found, e.g., in 1980. It could be stated that the radial increment of Norway spruce markedly decreases during the spring and summer droughts. Differences between the causes of positive pointer years on dry and wet forest sites are: 1) positive pointer years on dry forest sites are induced by wet summers, 2) positive pointer years on wet forest sites are caused by warm winters and springs. A considerable summer precipitation loses significance

for the increase of the radial increment of Norway spruce (*Picea abies* (L.) Karsten) on wet forest sites.

Under the impact of droughts, the latewood radial increment was not so significantly reduced in the Western regions: Seaside and Žemaitija. Under the influence of extreme droughts, the latewood increment was reduced severely in all territories of Lithuania. The most significant pointer year of latewood increment was in 1992.

Reduction of earlywood and annual radial increments also does not depend on the moisture of the forest's type. The Western region is distinguished by the slighter impact from droughts. If droughts occupy all territories of Lithuania, then the increment is most severely reduced in the Eastern region. In the case of positive pointer years, the biggest increase of earlywood was found in the East, South and Southwest regions (table 1).

Table 1. Pointer years of Norway spruce annual radial increment in Lithuania (+ positive, ++ significant positive, +++ highly significant positive, - negative, -- significant negative, --- highly significant negative)

Years	Dry forest sites								Wet forest sites			
	Pa	Ž	C	PV	P	R	Š	ŠR	Ž	PV	R	Š
1941	--	---	---	---	---	---	---	---	---	---	---	---
1946	+++	++	+++	+	+++	+++	+	++	++	++	++	++
1950									++	++	+	+++
1954	---	--	--	---	--	---	---	--	--	---	---	---
1955	---	---	---	--	---	---	-	--	---	--	---	-
1956									--	---	--	--
1962	+	++	++	++	+++	+++	++	+	+	+++	++	+
1971	--	---	---	---	--	---	--	---				
1974	++	+++	++	++	+++	+++	+	++				
1979	--	--	---	---	---	---	---	---	---	---	---	--
1980	-	--	---	---	---	---	---	---	---	---	---	---
1983									++	++	++	++
1992	---	--	---	---	---	---	---	---	---	---	---	---
1993	--	---	---	---	--	---	---	--	-	---	---	---

The comparison of the results of pointers years obtained in my research with the research results of the other authors is even more complicated, because the research of pointer years covering the all territory of Lithuania was carried for the first time. The results of I. Čerškienė (Чершкене, 1978) of the years with increasing or decreasing the radial increment of spruce correspond mainly with my results. However, the geographical interpretation of the pointer years was not performed. Several pointer years established during my research differs from these established by I. Čerškienė, e.g., in 1900-1940 years any significant negative pointer years were not detected in my research. Scientists from Poland (A. Zielski, G. Wojcik, R. Przybylak, K. Marciniak and M. Koprowski) in the International Dendrochronological Conference "Eurodendro – 2001" in Slovenia presented the pointer years of Norway spruce for the Northeast Poland. Negative pointer years were ascertained in 1917, 1934, 1944, 1954, 1978, 1979, 1992 and positive in 1913, 1916, 1919, 1926, 1928, 1933 and 1967. Some of the mentioned negative pointer years (1954, 1979 and 1992) correspond with these established in my research. It points to the climatic extreme, which determined the small radial increment of spruce in Lithuania to be present in the territory of Poland also.

Conclusions

1. The dendroclimatological research that was carried out on the network of 45 research plots of Norway spruce using more than 1500 spruce trees and 100 000 annual rings has shown that tree rings of Norway spruce (*Picea abies* (L.) Karsten) are sensitive to the climatic factors of vegetation season, very sensitive to the air temperature of spring and summer droughts, but weakly responding to climate conditions of previous autumn and winter.
2. The masterchronologies of Norway spruce for the dry forest sites (*Piceetum vaccinio-myrtillosum, Piceetum hepatico-oxalidosum*), covering 1868-1999 and 1894-1999 periods respectively, were constructed. They could be used in dendrochronology, forestry, ecology and environmental sciences in Lithuania and abroad.
3. The links between the annual radial increment of spruce and climatic factors in 1930-1994 period were established:
   a) The radial increment of spruce on dry forest sites positively responds to a high spring (April, May), negatively – high summer (June-August) air temperature. Positive influences were of a considerable amount in summer (May-July) and negatively – a lot of precipitation was felt in January.
   b) The biggest differences in the reaction to climatic factors between dry and wet forest sites with the precipitation were established: a negative impact of the precipitation in summer (August-September) to the latewood increment; a weaker positive reaction to the amounts in May-June's precipitation and a weaker negative impact of precipitation in January was found on wet forest sites.
   c) The biggest differences were established in the response of climatic factors to the radial increment at the Baltic seaside and the Hills of Žemaitija. The links between climatic factors and the radial increment in some months differ fundamentally from other regions.
4. An analysis of pointer years on the radial increment of Norway spruce during XX century demonstrated that:
   a) During extreme droughts, the latewood radial increment significantly decreased on dry and wet forest sites. The decrease of latewood radial increment on West Lithuania is weaker. From all pointer years of the latewood radial increment, the most significant was in 1992 with a very significant decrease of the increment in all regions of Lithuania.
   b) During years of extreme droughts, the earlywood and annual radial increment decreased irrespectively of forest sites. If the drought occupies all the territory of Lithuania, the radial increment of spruce mostly suffered in the East region. The biggest increase of the increment during positive pointer years was in East, South and Southwest regions of Lithuania.
5. When carrying out the research on the seasonal radial increment using method of steel tapes it was established that the radial growth of spruce in 1995-1998 began on 22nd April – 4th May and finished at the beginning of September. The significant negative impact of a hot June, July and August to the radial growth of spruce was observed. After a longer hot period, when a small amount of precipitation was felt, trees responded positively and quickly.
6. Significant negative correlation coefficients ($p \leq 0.05$, $p \leq 0.01$) were established between the radial increment of Norway spruce and the hydrothermal indicator (H) of the vegetation period (May-August).

7. The correlation coefficients between the radial increment of Norway spruce and the monthly amount of precipitation and average air temperature in separate periods during the XX century showed the biggest differences in the links with air temperature. Decrease of positive impact of warm spring, negative impact of high summer temperature on wet forest sites and increase of positive influence of summer precipitation during 1981-1995 compared to other periods indicated changes of climatic conditions at the end of XX century. These played a significant negative role in the flourishing of Norway spruce (*Picea abies* (L.) Karsten) in Lithuania.
8. Estimated changes and trends of the air temperature in 1778-2000 and precipitation in 1887-2000 of the months limiting spruce growth and established the increase of temperature in April, precipitation in January and more frequent droughts during summers – likely to influence the radial increment of spruce in the next decades.

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List of publications and presentations

Six articles were published by the author on the subject of the dissertation. Ten presentations were announced during scientific conferences held in Lithuania and abroad.

Publications:

1. **Vitas A., Bitvinskas T.** 1998. Dendroclimatological similarities of *Picea abies* (L.) Karsten and *Pinus sylvestris* L. *Baltic forestry*, **4(1)**: 24-28.
2. **Vitas A.** 1998. Dendroclimatoecological Research of Spruce Forests in Lithuania. *Proceedings of the International Conference: „Eurodendro – 98. Dendrochronology and Environmental Trends"*. Kaunas: Vytautas Magnus University. P: 132-138.
3. **Vitas A.** 1999. Įvykių ir rodiklinių metų analizė paprastosios eglės (*Picea abies* (L.) Karsten) radialinio prieaugio eilutėse. Doktorantų mokslinės konferencijos *„Jaunimas siekia pažangos '99" straipsnių rinkinys.* Kaunas: LŽŪU. P: 103-106.
4. **Karpavičius J., Vitas A.** 2000. Pastovūs medžių sezoninio radialinio prieaugio tyrimai Aukštaitijos nacionaliniame parke (Vaišnoriškėje). *Ekologija.* Vilnius: Lietuvos Mokslų Akademijos leidykla. 1: 30-39.

5. **Bitvinskas T., Vitas A.** 1999. Klimato ekstremumai ir padariniai. *VDU Botanikos sodo raštai*. Kaunas: VDU. 9: 82-98.
6. **Vitas A.** 2001. Drought of 1992 in Lithuania and consequences to Norway spruce. *Baltic Forestry*. 7(2): 25-30.

Presentations:

1. **Žmogaus ir gamtos sauga**. 1997 m. gegužės 28-30 d. Kaunas: LŽŪU. Ekstremalių klimato sąlygų poveikis eglynams.
2. **Žmogaus ir gamtos sauga**. 1998 m. gegužės 26-28 d. Kaunas: LŽŪU. Žmogaus ir aplinkos sveikatos ryšio analizė.
3. **Lietuvos meteorologijos ir hidrologijos problemos XXI a. išvakarėse**. 1998 m. kovo 23 d. Vilnius: VU. Kompleksiniai klimato rodikliai ir jų ryšys paskutiniojo šimtmečio laikotarpiu su pušies ir eglės prieaugio dėsningumais įvairiose Lietuvos miškų masyvų augimvietėse. (together with T. Bitvinskas)
4. **State and Monitoring of Forests at the beginning of XXI century**. 1998 m. balandžio 7-9 d. Minsk (Belarus): Institute of experimental Botany. Correlation between the radial growth of Scots pine and Norway spruce and climate in Kazlų Rūda forests, Lithuania. (together with T. Bitvinskas)
5. **Environmental studies in Baltic Region**. 1998 m. lapkričio 5-8 d. Kaunas: VDU. Dendrochronological Investigation of Forest Ecosystem of Lithuania.
6. **Lietuvos jaunųjų botanikų darbai**. 1999 m. balandžio 27-28 d. Vilnius: Botanikos institutas. Ekstremalių klimato sąlygų poveikio Lietuvos eglynams dendrochronologinė analizė.
7. **Gamtos mokslai ir aplinka**. 1999 m. gegužės 12 d. Kaunas: VDU. Rodiklinių metų analizė paprastosios eglės (*Picea abies* (L.) Karsten) dendroskalėse.
8. **Jaunimas siekia pažangos'99**. 1999 m. lapkričio 11 d. Kaunas: LŽŪU. Įvykių ir rodiklinių metų analizė paprastosios eglės (*Picea abies* (L.) Karsten) radialinio prieaugio eilutėse.
9. **Eurodendro-2001**. 6-10 June 2001, Gozd Martuljek (Slovenia): University of Ljubljana. Master chronologies of Norway spruce (*Picea abies* (L.) Karst.) on dry forest sites in Lithuania.
10. **Tree-Rings and People**. 22-26 September 2001, Davos (Switzerland): Federal Institute for Forests, Snow and Landscape Research (WSL). Pointer Years of Norway Spruce (*Picea abies* L. Karst.) Tree Rings on Dry Forest Sites in Lithuania.

REZIUMĖ

Aktualumas. Pastaruoju metu Žemės klimatą vis labiau įtakoja žmogaus veikla, tikriausiai sukelianti klimato šiltėjimą ir miškų nykimą (Lamb, 1995; Мазепа, 1998). Todėl silpnėja ekosistemų atsparumas nepalankiems veiksniams. Besikeičiančio klimato poveikio miškų ekosistemoms tyrimai tampa vis svarbesniais (Yoo, Wright, 2000). Klimato kaitos analizei galima naudoti ir medžių rievių – dendrochronologijos metodus (Cherubini, 2000; Roig et al., 2001). Miškų nykimas ir žuvimas pramoniniuose ir urbanizuotuose regionuose siejamas su žmogaus veikla – oro tarša. Vis svarbesne tampa būtinybė analizuoti aplinkos pokyčių įtaką augalams (Banks, 1992; Lovelius, 1997; Yoo, Wright, 2000; Ловелиус, 1980). Medžių rievės augimo metu kaupia informaciją apie aplinkos būklę ir yra geri aplinkos sąlygų ir jų pokyčių indikatoriai, kurių informacija gali būti naudojama ir aplinkos būklės prognozėms (Bräker, 1992; Eckstein, 1989; Schweingruber, 1993; Stravinskienė, 1997, 2000; Yoo, Wright, 2000; Битвинскас, 1974, 1984а, 1984б; Битвинскас и др., 1975; Колчин, Черных, 1977 ir kt.).

2001 m. sausio 1 d. Nacionalinės Lietuvos miškų inventorizacijos duomenimis paprastosios eglės (*Picea abies* (L.) Karsten) medynai užima 23,1% miško ploto (Kuliešis, Rutkauskas, Butkus, 2001). Nors daugumoje iki šiol Lietuvoje atliktų dendrochronologinių tyrimų objektu pasirinkta paprastoji pušis (Битвинскас, 1974 ir kt.), tačiau paprastosios eglės radialusis prieaugis aplinkos pokyčiams yra jautresnis nei pušies (Stravinskienė, 2002).

Paprastosios eglės šaknys paviršinės. Todėl medžius dažnai išverčia vėjas, ypač drėgnesniuose dirvožemiuose. Be to, eglei reikia nuolatinės dirvožemio drėgmės, todėl ji yra labai geras sausrų indikatorius. Uraganiniai vėjai paskutiniame XX a. dešimtmetyje ir padažnėjusios nebūdingos Lietuvai sausros, mokslininkų nuomone, sietinos su besikeičiančiu klimatu. Todėl dar labiau padidėja eglės ekologinių tyrimų vertė (Ozolinčius, 1998).

Nustatyta, kad medžiai, augdami sausose augavietėse, yra jautresni klimato veiksniams ir, tuo pačiu, vertingesni dendroklimatologiniuose tyrimuose (Fritts, 1987; Stokes, Smiley, 1968 ir kt.). Lietuvos miškų monitoringo duomenimis, didžiausia kenkėjų masinio išplitimo tikimybė taip pat yra sausose eglynų augavietėse, ypač po sausringų laikotarpių (Karazija, 1997), pvz., 1993-1996 m. dėl katastrofinės žievėgraužio tipografo (*Ips typographus* L.) invazijos buvo iškirsta 3,3% visų Lietuvos eglynų (18,3-18,6% brandžių) (Ozolinčius, 1998). Todėl dauguma šiame darbe naudotų tyrimo barelių parinkti sausose eglynų augavietėse.

Darbo hipotezė - darbe naudojant paprastosios eglės barelių tinklą apimantį 54 tyrimo barelius, vartojant daugiafaktorinę regresinę analizę ir reperinių metų išaiškinimą, galima išsamiai įvertinti klimato veiksnių įtaką paprastosios eglės radialiajam prieaugiui.

Tikslas – ištirti dendroklimatologiniu metodu Lietuvos sausų augaviečių eglynus ir sudaryti jiems radialiojo prieaugio etalonines dendroskales.

Uždaviniai. Numatytam darbo tikslui pasiekti buvo sprendžiami šie uždaviniai: 1) lauko darbų metu parinkti tyrimo barelius visoje Lietuvoje ir juose surinkti tiriamąją medžiagą, 2) medžių gręžinių rieves išmatuoti LINTAB medžių rievių matavimo aparatu sujungtu su asmeniniu kompiuteriu naudojant TSAP programą, 3) sudaryti lokalias kiekvieno tyrimo barelio dendroskales ir sausų Lietuvos eglynų augaviečių etalonines dendroskalės, 4) remiantis Lietuvos meteorologinių stočių kritulių ir oro temperatūros duomenimis, atlikti dendroklimatologinius eglynų tyrimus: apskaičiuoti daugiafaktorinės regresijos – atsako funkcijos koeficientus bei išaiškinti reperinius paprastosios eglės radialiojo prieaugio metus.

Naujumas ir originalumas. Pirmąjį kartą paprastosios eglės tyrimams sudarytas 54 tyrimo barelių (1598 medžių) tinklas, apimantis visą Lietuvą. Duomenų analizės metu vartotos šiuolaikinės kompiuterinės programos, atitinkančios pasaulinius dendrochronologinių tyrimų standartus. Naudoti šiuolaikiniai metodai: individualaus medžio radialiojo prieaugio eilutės indeksavimas prieš lokalios dendroskalės sudarymą bei dvisvoris robastinis vidurkis (Cook, Shiyatov, Mazepa, 1990; Riiters, 1990).

Iki šiol atliktuose dendroklimatologiniuose tyrimuose naudotas tik metinis radialusis prieaugis. Šiame darbe daugumoje skaičiavimų vartoti ir vėlyvosios bei ankstyvosios medienos radialiojo prieaugio pločiai.

Dendroklimatologinių tyrimų, atliktų Europoje ir Lietuvoje, rezultatai rodo, kad radialiojo prieaugio ir klimato veiksnių ryšio koeficientai retai būna patikimi ar reikšmingi (Schweingruber, 1983). Todėl šiame darbe apskaičiuoti ne tik ryšio koeficientai tarp metinio prieaugio ir klimato veiksnių, bet išaiškinti ir reperiniai radialiojo prieaugio metai.

Statistinės analizės metu klimato veiksnių įtakos radialiajam prieaugiui skaičiavimuose naudota moderni šiuolaikinė metodika – daugiafaktorinė regresinė analizė, nevartojant koreliacijos koeficientų, kurių naudojimą riboja klimato veiksnių eilučių tarpusavio koreliacija. Atsako funkcija geriau nei koreliacijos koeficientai įvertina netiesinį ryšį tarp tiriamųjų klimato veiksnių ir radialiojo prieaugio eilučių (Briffa, Cook, 1990).

Sudarytos sausų augaviečių (*Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*) eglynų metinio radialiojo prieaugio (vėlyvosios ir ankstyvosios medienos) etaloninės dendroskalės, kurias praktiškai galima vartoti dendrochronologijoje, miškininkystėje, ekologijoje, aplinkotyroje ir kituose moksluose Lietuvoje ir užsienyje.

Pirmąjį kartą Lietuvoje dendrochronologiniuose tyrimuose pavartota geografinių koordinačių nustatymo GPS technika. Naudojant GPS techniką, nustatytos tikslios kiekvieno tyrimo barelio geografinės koordinatės, kurios įgalins rasti parinktą tyrimo barelį ateityje bei bus naudojamos bendradarbiaujant su užsienio mokslininkais ir skelbiant tyrimo rezultatus užsienyje. Geografinių koordinačių nustatymo paklaida ±25 m, $p \leq 0{,}05$.

Apimtis ir struktūra. Disertaciją sudaro įžanga, literatūros apžvalga, tyrimo objektai ir metodika, rezultatai, išvados, 214 šaltinių literatūros sąrašas ir priedai. Darbas iliustruotas 20 lentelių ir 74 paveikslais.

Išvados

1. Atlikti dendroklimatologiniai tyrimai naudojat 45 paprastosios eglės tyrimo barelių tinklą Lietuvoje (daugiau kaip 1500 medžių ir 100 000 metinių rievių) parodė, kad paprastosios eglės (*Picea abies* (L.) Karsten) metinės rievės yra jautrus vegetacijos sezono klimato veiksnių indikatorius, labai jautrus pavasario oro temperatūrai ir vasaros sausroms, bet silpnai reaguojantis į praėjusio rudens bei žiemos klimato sąlygas.
2. Sudarytos sausų augaviečių (*Piceetum vaccinio-myrtillosum*, *Piceetum hepatico-oxalidosum*) eglynų metinio radialiojo prieaugio etaloninės dendroskalės, apimančios 1868-1999 ir 1894-1999 m. laikotarpius. Jas galima vartoti dendrochronologijoje, miškininkystėje, ekologijoje, aplinkotyroje ir kituose tyrimuose Lietuvoje ir užsienyje.
3. Atlikus paprastosios eglės metinio radialiojo prieaugio ryšių su klimato veiksniais analizę 1930-1994 m., nustatyta:
   a. Sausose augavietėse paprastosios eglės radialųjį prieaugį teigiamai įtakoja aukšta pavasario (balandžio, gegužės), neigiamai – aukšta vasaros (birželio-rugpjūčio) oro temperatūra. Teigiamai veikia didelis vasaros (gegužės-liepos), o neigiamai – didelis sausio kritulių kiekis.
   b. Didžiausi skirtumai tarp sausų ir drėgnų augaviečių nustatyti ryšiuose su krituliais. Drėgnose augavietėse nustatyta neigiama didelio vasaros (rugpjūčio-rugsėjo) kritulių kiekio įtaka vėlyvajai medienai, silpnesnė teigiama didelio kiekio gegužės-birželio kritulių įtaka ir silpnesnis neigiamas didelio kiekio sausio kritulių poveikis.
   c. Didžiausi tirtų klimato veiksnių įtakos radialiajam prieaugiui skirtumai nustatyti pajūryje ir Žemaitijos aukštumose. Šiuose regionuose kai kurių mėnesių klimato veiksnių ryšys su radialiuoju prieaugiu esminiai skiriasi nuo nustatyto ryšio kituose regionuose.
4. Reperinių paprastosios eglės radialiojo prieaugio metų analizė XX amžiaus laikotarpiu parodė:
   a. Ekstremalių sausrų metu vėlyvosios medienos prieaugis smarkiai sumažėdavo ir sausose, ir drėgnose augavietėse. Vakariniuose Lietuvos rajonuose vėlyvosios medienos prieaugio sumažėjimas mažesnis. Iš visų reperinių vėlyvosios medienos metų – reikšmingiausi 1992 metai, kuriais labai žymūs prieaugio sumažėjimas, būdingas visiems Lietuvos rajonams.
   b. Ankstyvosios medienos ir metinio radialiojo prieaugio sumažėjimas ekstremalių sausrų metais beveik nepriklauso nuo augaviečių sąlygų. Sausroms apėmus visą Lietuvos teritoriją – labiausiai radialusis paprastosios eglės prieaugis nukenčia rytiniuose rajonuose. Žymiausias teigiamų reperinių metų prieaugio padidėjimas aptiktas rytiniuose, pietiniuose ir pietvakariniuose Lietuvos rajonuose.
5. Atliekant sezoninio radialiojo prieaugio tyrimus juostų metodu nustatyta, kad paprastoji eglė 1995-1998 m. laikotarpiu pradėjo augti balandžio 22 d. – gegužės 4 d., o augimas baigėsi rugsėjo pradžioje. Didelę neigiamą įtaką eglės radialiajam prieaugiui daro karšti birželio, liepos ir rugpjūčio mėnesiai. Po ilgesnio karšto laikotarpio, iškritus net ir mažam kritulių kiekiui, medžiai reaguoja teigiamai ir greitai.
6. Nustatyti patikimi neigiami koreliacijos koeficientai ($p \leq 0{,}05$, $p \leq 0{,}01$) tarp paprastosios eglės radialiojo prieaugio ir vegetacijos laikotarpio (gegužės-rugpjūčio) hidroterminio t/k koeficiento.
7. Koreliacijos koeficientai, apskaičiuoti tarp paprastosios eglės radialiojo prieaugio ir mėnesių kritulių kiekio bei vidutinės oro temperatūros atskirais XX a. laikotarpiais, parodė žymesnius skirtumus ryšiuose su oro temperatūra nei krituliais. 1981-1995 m. laikotarpiu susilpnėjusi teigiama šilto pavasario įtaka, neigiama vasaros temperatūros įtaka drėgnose augavietėse bei sustiprėjęs teigiamas vasaros kritulių poveikis, lyginant su kitais laikotarpiais, rodo pasikeitusias klimato sąlygas XX a. pabaigoje, kurios turėjo žymų neigiamą poveikį paprastosios eglės (*Picea abies* (L.) Karsten) augimui Lietuvoje.
8. Įvertinus nustatytų eglės radialųjį prieaugį įtakojančių mėnesių oro temperatūros (1778-2000 m.) ir kritulių (1887-2000 m.) kaitą ir nustačius balandžio oro temperatūros kilimą, sausio kritulių gausėjimą bei vasaros sausrų dažnėjimą, tikėtina, kad minėti veiksniai įtakos paprastosios eglės radialųjį prieaugį Lietuvoje artimiausiais dešimtmečiais.

Moksliniai straipsniai ir pranešimai

Pagrindiniai darbo rezultatai skelbti šešiuose moksliniuose straipsniuose ir dešimtyje mokslinių pranešimų konferencijose.

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