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I. M. KOVAL1,3, assist. prof., PhD, A. BRÄUNING2, prof., Dr., E. E. MELNIK3, V. O. VORONIN1
1V. N. Karazin Kharkiv National University,
Svobody Sq. 6, 61077, Ukraine,
Koval Iryna@ukr.net
2Institute of Geography, Friedrich-Alexander-Universität Erlangen-Nürnberg
Wetterkreuz 15, 91058 Erlangen, Germany
3Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky
Pushkinska st. 86, Kharkiv, 61024, Ukraine

DENDROCLIMATOLOGICAL RESEARCH OF SCOTS PINE IN STAND OF THE LEFT-BANK FOREST-STEPPE OF UKRAINE

Purpose of this research was to detect influence of climatic change on pine radial increment in stand in the Left-bank Forest-steppe of Ukraine as example 100-years-old stand at State Enterprise 'Kharkiv forest scientific research station'. Methods. Dendrochronological. Method of correlation function and multiple regressions (response function) were used to analyze the influence of climatic factors on tree radial increment. For this purpose computer program RESPO was used. Results. Tree ring series were built and were used for correlation analysis between climatic factors and pine radial increment for two periods: 1960-1988 and 1988-2016. Years of minimum (1933, 1942, 1956, 1972, 1976, 1976, 1987, 1992, 2002, 2006 and 2012) and maximum (1933, 1942, 1956, 1972, 1975, 1976, 1979, 1979, 1987, 1992, 2002 and 2012) of radial increment were detected. Depressions of pine radial increment were as a result of negative weather conditions: low and high winter and early-spring temperature, droughts during vegetation period. Maximums of radial increments were dependent on favorable weather conditions for pine radial growth. Correlation and Response analysis for two periods showed that increase of temperature and precipitation, excluding winter precipitation, changed response of forest ecosystems to climatic change: if in first period (1960-1988) radial increment limited by April temperature and together July temperature positively influenced on radial growth, in second period (1988-2016) June temperature negatively influenced on radial increment. Slight increase precipitation during vegetation period could not soften impact if high temperature during vegetation period on tree radial increment. Conclusions. At comparison 1960-1988 and 1988-2016 it was detected that during first period positive influence of summer temperature on radial growth was distinctive and for second period one started to limit increment (negative influence) were detected. Slight increase of precipitation for vegetation period in second period significantly didn’t influence on pine radial growth. In second period increase of winter temperature and number of thaws negatively influenced on soil moisture, decreased of tree ring widths.

Key words: radial increment, pine, climatic change

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DENDOCLIMATICKIE ISSLEDOVANIIA SOSNY OBYKNOVENNOY V NASASHDENII LIVOBERZHENNOY LESOSTEPI UKRAINY

Цель. Выявление влияния изменений климата на радиальный прирост сосны в Левобережной степи Украины на примере 100-летнего соснового насаждения ГП «Харьковская лесная научно-исследовательская станция». Методы. Дендрохронологические. Результаты. Созданы древесно-кольцевые хронологии для установления связей между климатическими показателями и радиальным приростом сосны за два периода: 1960-1988 та 1988-2016 гг. Корреляционный анализ и функция отклика за два периода показали, что при увеличении температур и количества осадков (исключением стали зимние осадки) изменилась реакция лесных экосистем на вариации условий природной среды. Так, если в первом периоде (1960-1988 гг.) радиальный прирост ограничивали апрельские температуры, в то же время на прирост положительно влияли летние (июльские) температуры, то во втором периоде летние температуры (июньские) стали негативно влиять на прирост деревьев. Незначительное увеличение количества осадков за вегетационный период не смогло смягчить влияние высоких температур вегетационного периода на радиальный прирост. Выводы. При сравнении 1960-1988 и 1988-2016 гг. выявлено, что для первого периода характерно положительное влияние летних температур на радиальный прирост, однако для второго периода они начинают ограничивать прирост деревьев. Незначительное увеличение количества осадков за вегетационный период не смогло смягчить влияние высоких температур вегетационного периода на радиальный прирост.

Ключевые слова: радиальный прирост, сосна обыкновенная, изменения климата

**Introduction**

For the past 100 years temperature increases by 0.4-0.6°C in Ukraine [1]. This climatic change will be able to move natural habitats and borders of forest areas, changes of dominant tree species and level of resistance of forest ecosystems [3]. As result of growing of stands in relatively favourable climatic and soil conditions, to reveal complex of factors limited tree growth sometimes enough difficult because it changes during calendar year.

In previous studies it was elicited tree ring formation in stands growing in conditions of temperate climate are limited by temperatures of the growing period, early spring and winter, as well precipitation for the growing period [4, 5, 6, 8, 9].

Dendrochronological methods were used [2, 10, 11, 12]. Pine cores were collected in 100 years old pine stand growing at the State Enterprise ‘Kharkiv forest scientific research station’ (quarter №159, board №2, latitude 50°03’27”N, longitude 36°21’08”E). Main taxation indices of planting: average height of trees is 24 m, average diameter trees is 42cm, estimated productivity II, type of forest B2-dC (fresh pine-oak subor), degree of density 0.6, tree volume for 1 ha / 310 m³.

Cores were taken by Pressler borer at 1.3 m of trunk of dominant and undamaged trees. The widths of early and late wood were measured using LINTAB (measuring system is widely used in dendrochronology) and the TSAP software in dendrochronological laboratory at Institute of Geography, Friedrich-Alexander-Universität Erlangen-Nürnberg. Dating of tree rings was carried out to determine calendar date of formation for each tree ring. Quality of tree ring dating was checked using the program COFECHA [9, 10]. Common tree ring chronology was built on the base of tree ring chronologies for tree ring width for each tree by averaging ones.
Indexing of tree-ring chronologies was realized using the program ARSTAN to move away age trend. This makes it possible to analyze response of pine radial growth to climatic factors using the program RESP from the program set DPL [10]. We used index tree ring STANDART to analyze influence of climate on pine radial growth because the best results were gotten with this tree ring index chronology.

Correlation analysis and multiple regressions were used for revelation of influence of climate on radial growth by the program RESPO. Values of STANDART chronology were used as independent variables while the average monthly air temperature values and the average monthly precipitation values for 1959-2016 for the period from June to September of the current year, have been applied as variables. The data of the Kharkiv meteorological station at the airport (49° 55′N, 36° 17′E, 152 m altitude) for the period 1959-2016 was used. The average monthly temperature and monthly precipitation values for the Kharkiv meteorological station are presented on fig. 1. The most warm (21.9 °C) and humid (70 mm) month was July, and the coldest month – January (-4.6 °C). The minimum precipitation was noted in March.

Results and discussion

The dynamics of the pine radial growth for all types of wood is presented in Fig. 1. The years of minimum and maximum growth, which are called the pointer years, in which about 90% of trees have the same growth trend are revealed. Years of minimal growth: 1933, 1942, 1956, 1972, 1976, 1976, 1987, 1992, 2002, 2006, and 2012; years of maximum growth: 1933, 1942, 1956, 1972, 1975, 1976, 1979, 1979, 1979, 1987, 1992, 2002, and 2012 (Fig. 2).

Depression of the pine radial growth was due to negative weather conditions (low and high winter and early spring temperature; droughts during the growing season). Maximum radial growth was as result favorable weather conditions (Fig. 2, 3, 4).

Climatic indicators during two periods (1960-1988 and 1988-2016) were compared. In the last years of 1988-2016, compared with 1960-1988, the average annual temperature increased by 1.2 °C, during the growing season – by 0.9 °C, during the winter – by 1.7 °C and in March – at 2.1 °C. Low increase in precipitation for growing period (by 19 mm), and at the same time, the winter precipitation decreased by 15 mm were noted (Table 1). The biggest changes occurred for winter and early autumn temperatures.

For 2009-2016 a significant increase in temperatures during the growing season was noted, which negatively affected the radial increment (Fig. 1, 2.). Deviation from the norm of this temperature was 9% (1.7 °C), while the indices of radial growth decreased by 4% during this period.
Fig. 2 – Dynamics of the tree ring chronology and the index tree ring STANDART chronology

Fig. 3 – Dynamics of temperature (data of the Kharkiv meteorological station)

Fig. 4 – Dynamics of precipitation (data of the Kharkiv meteorological station)
Table 1

| Periods, years | Difference in % between first and second periods |
|---------------|-----------------------------------------------|
| 1960-1988     | 1988-2016                                    |
| Average temperature (°C) |                                     |
| Year          |                                               |
| 7.5           | 8.7                                           |
| IV-VIII months | 16.8                                          |
| winter        | -5.3                                          |
| III month     | -0.67                                         |
| Precipitation (mm) |                                               |
| Year          |                                               |
| 542           | 579                                           |
| IV-VIII months | 258                                          |
| winter        | 134                                           |
| Index tree ring chronology STANDART |               |
| 0.98          | 0.95                                          |

The correlation coefficient (0.44) between tree ring chronologies for all trees allows realization of correlation analysis between radial growth and climatic factors (Table 2).

The coefficient of autocorrelation of the first order, which characterizes how closely tree ring width of the annual ring of this year is related to the tree ring width of the previous year [11], was high (Table 2). This indicates the favorable forest and climatic conditions for growing pine stands.

Table 2

| Interval, years | Average, mm/relative units | Average sensitivity | Standard deviation | Autocorrelation 1st order | Number of tree rings, pieces | Internal correlation coefficient |
|----------------|----------------------------|---------------------|--------------------|---------------------------|-----------------------------|---------------------------------|
| Radial growth  | 0.21                       | 1.62                | 0.88               | 810                       | 0.44                        |
| S*             | 0.133                      | 0.179               | 0.57               | 809                       |                             |

*STANDART index-tree chronology

The correlation analysis and the response function for two periods showed that with the increase of temperatures and precipitation (the exception is winter precipitation), the reaction of forest ecosystems to the influence of climate changes, as in 1960-1988, the radial growth was limited the low April and high July temperatures, then later, in 1988-2016 negatively affected the radial increase of September temperatures of the previous year which are influence on winter wet accumulation, and the negative influence of June temperatures. There was a slight increase in precipitation, but on the background of high temperatures negative correlations between the indices of radial growth and precipitation became more in the second period than in the first one (Fig. 5).
In the first period of 1960-1988, there was a positive effect of precipitation on radial growth in the 1960-1988 because on the background of low winter temperatures there was moisture accumulation in the soil, but in the next years 1988-2016 this influence became opposite - negative, which is probably due to an increase in winter and early spring temperatures, which did not contribute to the formation of a constant snow cover. As a result of thawing during the winter there was no moisture accumulation at the level of the past 1960-1988, which negatively affected the formation of tree ring widths.

D.V. Tishin [7] also showed an increase in the negative effects of winter precipitation on radial growth, due to the increase in winter temperatures and flooding over the past years. Such a reaction of radial growth to the influence of winter precipitation can be due not only to climate fluctuations, but also to changes in groundwater levels.

**Conclusions**

At comparison 1960-1988 and 1988-2016, it was revealed that for the first period, the positive influence of summer temperatures on the radial growth is characteristic, while for the second period they begin to limit the radial growth. A slight increase in precipitation for growing period could not mitigate the negative influence of high temperatures on the formation of tree rings. In the second period, the increase of the negative influence of winter precipitation on growth, which was caused by an increase in winter temperatures and thaw, was found to have a negative effect on the wet accumulation of soil and the formation of annual pine rings.

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Література

1. Дідух Я. Екологічні аспекти глобальних змін клімата. Причини, наслідки, дії. Вісн. НАН України. 2009, № 2, С. 34-44.
2. Битвінскас Т.Т. Дендрокліматичні ісследовани. Л.: Гидрометеоиздат. 1974. 170 с.
3. Букша І. Ф., Іогин І. І., Ємельянова Ж. Л., Трофимова І. В., Шершевський А. І.; ред.: В. В. Васильченко, М. В. Раппун. Україна та глобальний парниковий ефект. Ч. 2. Врахування і адаптація екологічних та економічних систем до змін клімату. К.: Агентство з раціон. використ. енергії та екол., 1997. 206 с.
4. Коваль І.М. Вплив клімату та забруднення на динаміку радіального приросту сосни звичайної в лісотеповій зоні. Вісник Харківського Національного Аграрного Університету імені В.В. Докучаєва. Серія "Географія". 2013. Вип. 1. С. 209-212.
5. Коваль І.М., Бологов О.В., Нюсьчук С.А., Юзинський Г.А. Радіальний приріст дуба звичайного та ясена звичайного як індикатор стану лісових екосистем в умовах Новоград-Волинського фізико-географічного району. Лісництво і агроселізоляція : зб. наук. праць. Харків: Вид-во УкрНДІЛ-ГА. 2015. Вип. 126. С. 202-211.
6. Коваль І.М., Токерева Н.А., Невмивка М.В., Воронін В.О. Динаміка радіального приросту дерев, пошкождених пожежею, в соснових насадженнях Лісостепової зони Волинської області. Ж. Л., Трофимова І. В., Шершевський А. І.; ред.: В. В. Васильченко, М. В. Раппун. Україна та глобальний парниковий ефект. Ч. 2. Врахування і адаптація екологічних та економічних систем до змін клімату. К.: Агентство з раціон. використ. енергії та екол., 1997. 206 с.
7. Інтернет-ресурс: http://www.climate-data.org (дата використання: 01.01.2021).
8. Bräuning H. Dendrochronology Program Library Users Manuals; University of Arizona: Tucson, AZ, USA. 2001. Vol. 57(2), 205-221.
9. Holmes, R.J. Dendrochronology Program Library-Users Manual; University of Arizona: Tucson, AZ, USA. 1994, 51.
10. Holmes, R.L., Adams R.K., Fritts H.C. Tree ring chronologies of western North America: California, eastern Oregon and northern Great Basin, with procedures used in the chronology development work, including users manuals for computer programs COFECHA and ARSTAN. Chronology Series VI Laboratory of Tree Ring Research. Tucson: University of Arizona. 1986
11. Methods of Dendrochronology. Applications in the Environmental Sciences. Edward R. Cook and Leonardas A. Kairiukstis (editors). Dordrecht, the Netherlands: Kluwer Academic Publishers and International Institute for Applied Systems Analysis, 1990. 394.
12. Koval Iryna. Climatic signal in earlywood, latewood and total ring width of Crimean pine (Pinus nigra subsp. Pallasiana) from Crimean Mountains, Ukraine. Baltic Forestry. 2013.Vol 19(2), 245-251.
13. Maxime, C. & Hendrik, D. Effects of climate on diameter growth of cooccurring Fagus sylvatica and Abies alba along an altitudinal gradient. Trees. 2011. 25:2, 265-276.
14. Orwig, D.A. & Abrams, M.D. ‘Variation in radial growth responses to drought among species, site, and canopy strata. Trees. 1997. 11:4, 474-484.
15. Pilcher, J.R. & Gray, B. The relationships between oak tree growth and climate in Britain. Journal of Ecology. 1982. 70:1, 297-304.

References

1. Didukh. Ya. (2009) Ekologichni aspekty hloabal'nykh zmian klimatu. Prychyny, naslidky, diiy [Ecological aspects of global climatic changes].// Herald of the NAS of Ukraine. 2. 34-44 [In Ukrainian].
2. Bitvynskas T.T. (1974). Dendroklimaticheskie issledovaniya [Dendroclimatological research]. L.: Gidrometeoizdat. 170 p. [In Russian].
3. Buksha I. F., Hozhyk P. F., Yemel'yanova Zh. L., Trofymova I. V., Shershevskyy A. I. (1997). Ukrayyna ta hlobalnyi parnkyovyi efekt [Ukraine and Global greenhouse effect]. Ch. 2. Vrazlyvist' i adaptatsiya ekologichnykh system do zminy klimatu [Sensitivity and adaptation of ecological and economic systems to climatic changes]. K.: Ahent stvo z ratsion. vykoryst. enerhii ta ekol. 206 p. [In Ukrainian].
4. Koval I.M. (2013). Vplyv klimatu ta zabrudnennya na dynamiku radial'noho prirostu sosny zvychaynoyi v lisostepovyh zoniy [Influence of climate and pollution on dynamics of radial growth of Scots pine in Forest Steppe zone. Bulletin of Khariv National Agrarian University after V.V. Dokuchayev. 1, 209-212 [In Ukrainian].
5. Koval I.M., Bolohov O.V., Nusbaum S.A., Yuzvynskyy H.A. (2015). Radialnyy pryrist duba zvychaynoho ta yasena zvychaynoho yak indyktor stanu lisovykh ekosystem v umovakh Novohrad-Volynskoho fizykheohrafichnoho rayonu // Forestry and Forest Melioration: Kharkiv: UkrNDILHA. – 2015. №. 126б 202-211 [In Ukrainian].

6. Koval I.M., Tokareva N.A., Nevmyvka M.V., Voronin V.O. (2016). Dynamika radialnoho pryrostu derev, poskodzhenykh pozhezheyu, v sosnovykh nasadzhennyah Lisostepovoyz Kharkivs'koyz // Visnyk of V.N. Karazin Kharkiv National University. Series Ecology. 15, 81-88. [In Ukrainian].

7. Tyshyn D.V., Chyzhykova N.A., Chuhunov R.H. (2014). Radialnyy pryrost sosny (Pinus Sylvestris L.) verkhovykh bolot kak yndykator lokal'nykh yzmenenyy klymata // Forestry Bulletin. № 5, 177-182. [In Russian].

8. Bräuning Achim, Maaike De Ridder, Nikolay Zafirov, Ignacio García-González; Dimitar Petrov Dimitrov and Holger Gärtner (2016) Tree-ring features: sndicators of extreme event impacts . IAWA Journal. 37 (2), 206.

9. Grissino Mayer Henri D. (2001) Evaluating accuracy: a manual and tutorial for the computer program COFECHA . Tree-ring researchVol. 57(2), 205-221. [in English].

10. Holmes, R.J. (1994) Dendrochronology Program Library-Users Manual; University of Arizona: Tucson, AZ, USA. 1994, 51. [in English].

11. Holmes, R.L., R.K Adams, H.C. Fritts (1986) Tree ring chronologies of western North America: California, eastern Oregon and northern Great Basin, with procedures used in the chronology development work, including users manuals for computer programs COFECHA and ARSTAN. Chronology Series VI Laboratory of Tree-Ring Research. Tucson : University of Arizona. [in English].

12. Methods of Dendrochronology (1990). Applications in the Environmental Sciences / Edward R. Cook and Leonardas A. Kairiukstis (editors). Doredrecht, the Netherlands: Kluwer Academic Publishers and International Institute for Applied Systems Analysis, 394. [in English].

13. Koval Iryna (2013). Climatic signal in earlywood, latewood and total ring width of Crimean pine (Pinus nigra subsp. Pallasiana) from Crimean Mountains, Ukraine . Baltic Forestry. 19(2), 245-251. [in English].

14. Maxime, C. & Hendrik, D. (2011). ‘Effects of climate on diameter growth of cooccurring Fagus sylvatica and Abies alba along an altitudinal gradient’ // Trees 25:2, 265-276. [in English].

15. Orwig, D.A. & Abrams, M.D. (1997). ‘Variation in radial growth responses to drought among species, site, and canopy strata’. Trees 11:8, 474-484. [in English].

16. Pilcher, J.R. & Gray, B. (1982). The relationships between oak tree growth and climate in Britain. Journal of Ecology 70:1, 297-304. [in English].

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