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Tree-Ring Analysis of Radial Increment of Pinus Sylvestris L. In Shalday Pine Forests in The Northeast of Kazakhstan.

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ABSTRACT

This work is aimed at obtaining new data on the impact of climate on the growth of woody species in drought conditions. Recent researches in this area were carried out in 1988. The article describes a study of Pinus sylvestris L. in forest in Northeast of Kazakhstan. It was found that in the last 50 years high air temperatures in May and June have the main limiting effect on the increment of the early wood of Pinus sylvestris L. The analysis shows that the Pinus sylvestris L. increment depends on the amount of precipitation of the current growth season.

Keywords: tree-ring chronologies, radial increment, correlation, sensitivity, Pinus sylvestris L.

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INTRODUCTION

Among the plains of central Kazakhstan steppe, there are large areas of forests of Pinus sylvestris L. and some attendant tree species scattered [1].

Woody vegetation is reliable indicator of changes in the natural environment and climate. The method of tree-ring analysis, which allows to evaluate the response of the radial increment of trees on the changes in the main climatic variables - air temperature and precipitation [2,3] is especially widely used in dendroclimatic studies. In the National Human Development Report, Kazakhstan has also been in the area of strong climate change. Predicted temperature data show that Kazakhstan will also be in the "danger zone" with a rise in temperature of 4.5 to 5.50 C [4].

RELEVANCE

Pine is the main bioindicator of the environment in our region, every, even a significant change in climatic conditions or anthropogenic load is recorded at its annual rings.

The study of the dynamics of increment of the trees on the trunk cross-sectional area in a variety of ecotopes is important to identify climate trends, the impact of anthropogenic factors on the development of tree plantations, as well as for the development of activities on protection and rational use of forest ecosystems.

Tree-ring analysis allows us to estimate the dynamics of the stand increment for the entire period of its existence, to determine climate-driven changes in the width of the annual rings and identify the impact of non-climatic (including anthropogenic) factors on the state of the stand. The increment of xylem is an integral indicator of the trees, allowing objectively assess and identify incipient changes and disturbances in the ecosystem at an early stage, when the external parameters has not yet changed significantly [5].

This work is one of the important stages of forming a methodological procedure for the use of tree-ring information in the field of Forest Science and Forestry in Kazakhstan.

Areas of forest steppe in Northeast of Kazakhstan were not sufficiently investigated in terms of studying the response of the radial increment of woody plants to climatic factors. This work is aimed at obtaining new data on the effect of climate on the growth of Pinus sylvestris L. In this regard, the aim of this work is to study the impact of climatic factors on the radial increment of Pinus sylvestris L. in the Northeast of Kazakhstan.

MAIN PART

Tree-ring study of Pinus sylvestris L. was carried out in Russia, Kazakhstan and overseas by such scholars as:

Olenin S.M., Mazepa V.S. revealed cycles in the dynamics of radial increment of Pinus sylvestris L. in the pine forests of the Pavlodar region in a dry and green forest types. They forecasted the dynamics of their increment [6].

Zhantlessova Sh., Zhumadina Sh. carried-out a study on the age-class composition of forest plantations of Betula pendula Roth. and Larix sibirica L. in the forest steppe of the Eastern Kazakhstan. The results showed that a marked deficiency of young and old trees, the principal amount of trees are at the age range from 50 to 70 years. [7,8].

Sauchyn D.J. found strong correlations of increment of Pinus contorta with precipitation in the growth season and in the period from August of the preceding to July of this year (r = 0,51 and 0,45 respectively) for the northern part of the Great Plains of the United States. Reconstruction of precipitation based on constructed chronology showed an increase in the frequency of droughts in the region in the twentieth century. [9]

Magda V.N. in the forest-steppe zone in the south of Siberia, showed that the pine increment under these conditions is limited by moisture regime during growth season. In addition, precipitation of the previous growth season affects the value of increment [10].

Pugachev P.G. conducted studies in the steppe forests of Turgai (Kustanai region, Kazakhstan). He showed that the growth of Pinus sylvestris L. in the area is defined by atmospheric moistening. In the course of increment, cycles lasting 11 and 35 years, typical for the increment of trees in drought conditions were identified [11].

Matveev S.M. showed that radial increment of trees in the central forest steppe of the European part of Russia depends on complex of hydrothermal factors and solar activity [12].

Mazepa V.S. on the basis of available tree-ring network in the subarctic zone of Eurasia, praised the role of precipitation in the formation of value of coniferous trees increment in different seasons of the year [13].

Wimmer R., Strumid G., Holawe F. studied 313 black pine trees at 29 areas in the north of the Alps, in an area with low annual precipitation, severe winters and prolonged dry seasons. Over the past 100 years, connection of “false rings” formation with the lack of precipitation fallen in May was authentically established [14].

Dulamsuren Ch., Hauck M. conducted numerous tree-ring researches on woody plants. They showed that high summer temperatures reduce the growth of Siberian larch in the south boreal forest of the Eastern Kazakhstan. Water relations of Siberian larch were studied; they showed that the trees in the forest-steppe zone of the Northern Mongolia and Saur mountains often suffer from drought. Water supply of trees growing on ridges of forest-steppe zone heavily depends on the current precipitation, since the roots do not contact groundwater [15, 16].

Touchan R., et al. using highly sensitive chronology on four types of conifers managed to build a reliable reconstruction of the amount of growth season precipitation (May-June). In a later work, the same authors reconstructed standardized moisture index (SPI) from May to July for 750 years for the majority of Turkey. Periods with the highest frequency of droughts were identified based on the reconstruction [17, 18].

Linderholm H.W. showed that the radial increment of Pinus sylvestris L. grown in dry habitats of central Sweden is mainly determined by the amount of precipitation in May-June (R^2 = 0,3). It also shows the negative impact of the growth season temperatures on the increment [19, 20].

Agafonov L.I., Kukarskikh V.V. considered the change of major climate components (air temperature and precipitation amount) and their impact on the radial increment of Pinus sylvestris L. in an island forest of the Southern Urals steppe zone for the period of 1933-2002. Significant increase in precipitation and air temperature in the second half of the period under review was established [21]

Bykov N.I., Malysheva N.V. have done a great job of creating long tree-ring chronologies for Pinus sylvestris L. in pine forests of the Altai Territory. They conducted tree-ring study of pine forests in the south of Western Siberia [22, 23].

Pinus sylvestris L. samples were selected at two areas of Shalday pine forests - in the western and eastern parts of the territory where the cores of 120 trees were taken (Figure 1). The region is within the Kulunda Plain, which is a part of the vast Western Siberian Lowland. Kulunda Plain - the Plain in the south of Western Siberia in the Altai territory of Russia and the Pavlodar region of Kazakhstan. It is located between the rivers Ob and Irtysh. In the southeast it is adjacent to the foothills of the Altai (Fig.1).

The climate is extremely continental, characterized by drought in spring and summer, high summer and low winter temperatures, sharp temperature fluctuations during the day. The average January temperature is -18º-19ºC, July temperature is + 20º + 21°C. A characteristic feature of the area climate is the lack of precipitation, especially in spring. The average annual precipitation is 250-300 mm.

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Figure 1 – Areas of research showed on the map.

MATERIALS AND METHODS

In this paper, the variability of the major climate components - precipitation and air temperature, and their effect on the radial increment of Pinus sylvestris L. in Shalday pine forests of Pavlodar region is analyzed. Few dendroclimatic researches were conducted in the northern part of Kazakhstan, and once in forest steppe of Irtysh area [6].

Field data collection. The selection of Pinus sylvestris L. samples was conducted at two areas of Shalday pine forests - in the western and eastern parts of the territory where the cores of 120 trees were taken. Cores were taken using auger at a height of about 1.3 meters from the root collar, two in each tree. The preparation of samples for further researches was carried out by common method [24].

Cameral treatment, i.e. the measurement of annual rings width was performed on LINTAB 6 measuring device. These tree-ring chronologies were visually cross-dated both in TSAP [25] and SOFECHA [26] packages.

Standardization of the individual tree-ring chronologies was performed using ARSTAN program [26]. After standardization, the index values of the radial increment of individual trees by averaging method was transformed into generalized TRC describing the basic features of the variability of increment in each of the studied areas.

Evaluation of the statistical characteristics of chronologies was carried out by the following parameters: variation and sensitivity coefficients [27].

Dendroclimatic analysis. Tree-ring chronologies were grouped according to their location in the geographic subareas: chronology 1 and 2 taken from different sites. Data of Krasnoarmeiskaya AMC (m/s) weather station were used to calculate the response functions. Series of observations from 1964 to 2012 were used. Responses were calculated separately for each variable. Statistical treatment of the studies' results was carried out using Statistica 7.0 software package.

RESULTS AND DISCUSSION

Studies' results showed that the sensitivity of tree-ring chronologies of Pinus sylvestris L., grown in Shalday pine forests in the steppe zone of Kazakhstan is characterized by high values of sensitivity coefficient (KS = 0.20-0.21).

Correlation analysis of the constructed tree-ring chronologies showed that, despite the remoteness of the various areas from each other, the radial increment of pine trees within their area of research is under the impact of a set of limiting factors. Correlation between the sites was (R = 0.78) (Figure 2).

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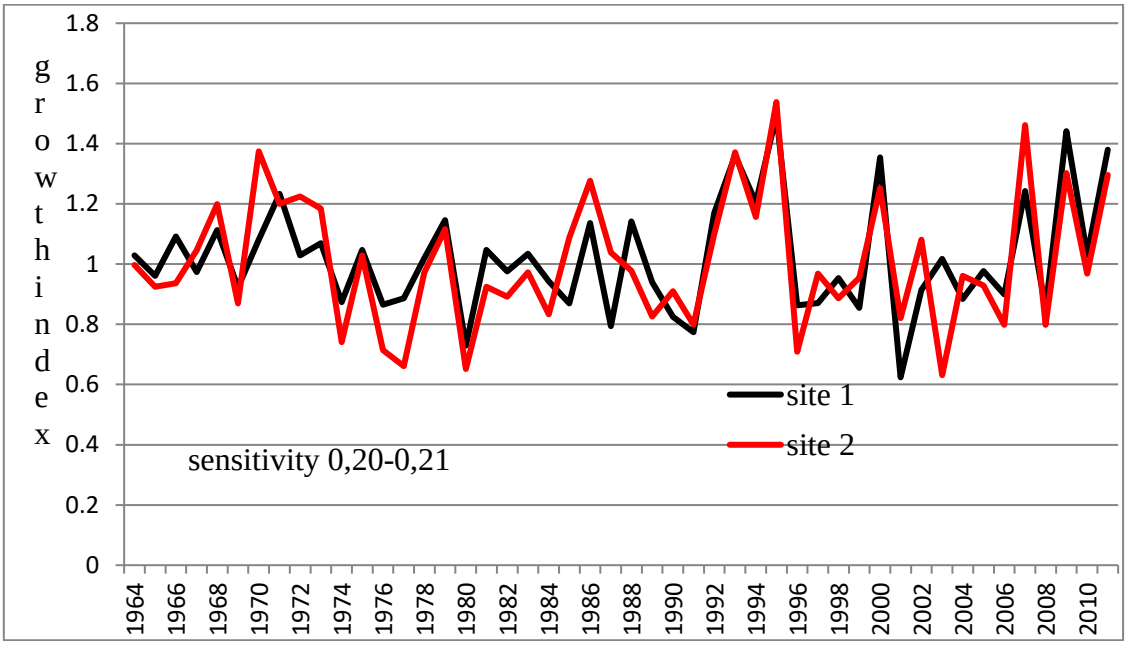

Figure 2 - Analysis of the generalized tree-ring chronologies (TRC)

Early wood increment mainly depends on the hydrothermal conditions in May and June, while there is a positive relation with an amount of precipitation and negative one with the air temperature. Conditions in September of the previous year also impact the early wood width, which may be related to the mechanism of moisture conservation in the soil (Figure 3, 4)[28].

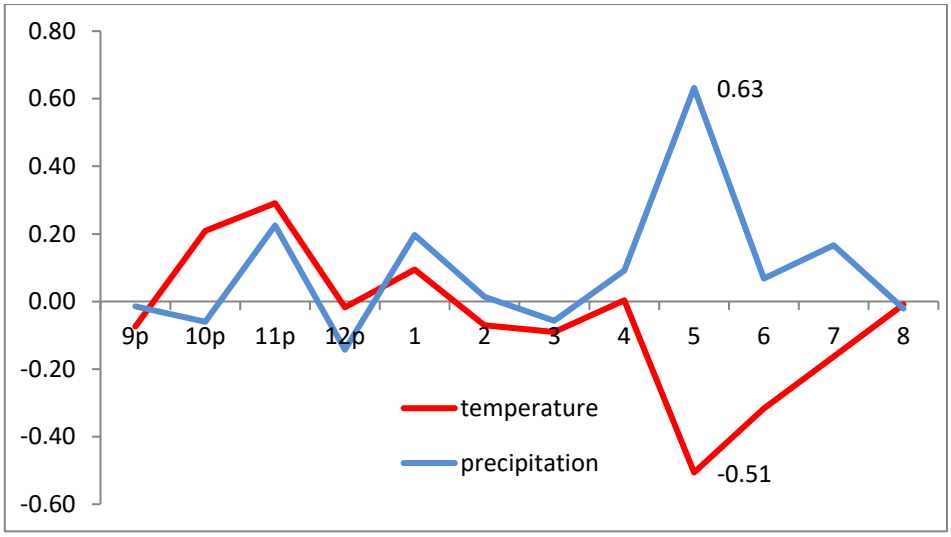

Figure 3 – Area №1. Response functions of increment indices from September of the preceding year to August of this year.

High air temperatures in May and June have the main limiting effect on early wood growth, reflecting a greater proportion of the dispersion. We compared a series of indices of Pinus sylvestris L. radial increment to each other. Both series have similar dynamics of increment. Taking into account precipitation - increment analogy in the years of 1964-2012, it is believed that late wood growth mainly depends on the number of the current growth season precipitation.

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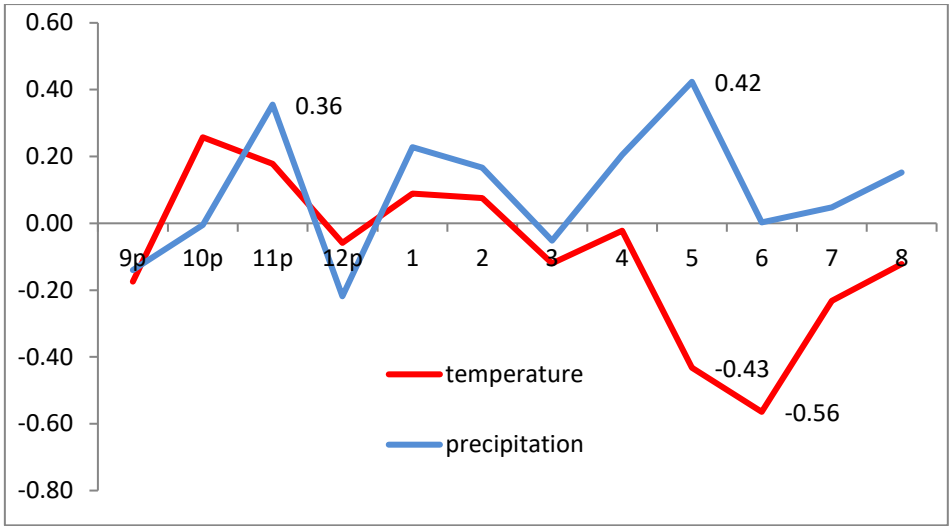

Figure 4 - Site №2. Response functions of increment indices from September of the preceding year to August of this year.

For all chronologies, located in Shalday pine forests (1, 2) there is a positive relation with an amount of precipitation and negative one with the air temperature in May and June identified. Highly significant correlation coefficients show a strong impact of both factors on early wood increment. The correlation with an amount of precipitation in individual months reaches 0.63 (May, Site 1), and air temperatures - 0.56 (June, Site 2).

From literature data, it is known, that the impact of the high positive temperatures in May and June on early wood growth is connected with increase of evapotranspiration and moisture deficit in the soil, which in turn slows down the process of xylem cells growth [29].

Currently analysis of the obtained chronology of increment in Areas 1, 2 revealed the following years with false rings (1941, 1943, 1949, 1953, 1952, 1980, 1981, 1981, 1984, 1995, 1996) and with the light rings (1958, 1956, 1966, 1965, 1963, 1974, 1998, 1999, 2003). A light ring of the year 2003, where it sometimes falls out, made a point and nothing similar is observed in other years.

To identify the reasons for the light ring formation in 2003 and its partial fall, climate data (precipitation, temperature) from 1926 to 2010 will be taken and analyzed from weather stations of the cities of Karaganda and Rubtsovsk. Reasons of false and light rings formation will be investigated and studied.

CONCLUSION

This work over again confirms an excellent opportunity to use the information of annual rings according to set goals and objectives. Conducted studies of the features of Pinus sylvestris L. radial increment in Shalday pine forests was reflected in the main conclusions:

1) Pinus sylvestris L. radial increment in Shalday pine forests is defined by hydrothermal conditions (air temperature and precipitation) of the growth season.
2) All chronology is characterized by low values of the sensitivity coefficient, especially in the late wood, indicating that they do not have the strong climate signal.
3) High values of correlation between generalized tree-ring chronologies indicate a general correlation signal, affecting the growth of the trees within the entire study area.

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