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Research Article

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Dendroclimatic analysis of common pine (*Pinus sylvestris L.*) on the SNNP "Burabay"territory

The study aims to obtain new data on the chronology of *Pinus sylvestris* L. under arid conditions in the forest-steppe zone of northern Kazakhstan, specifically in the northern part of the SNNP "Burabay" territory. Two sites were selected to compare how different factors influence wood growth. Analysis of the generalised tree-ring chronologies revealed a substantial number of trees in the study area that are between 170 and 220 years old. First-order autocorrelation values ranged from 0.68 to 0.78. The sensitivity coefficient indicated the presence of a weak climatic signal. Short-term climate projections suggest a slight increase in temperature and a decrease in warm-season precipitation over the next 10 years.

Keywords: *Pinus sylvestris* L., climate prediction, Burabay, precipitation, air temperature

Introduction

Climate change cycles and increased human activity have had a significant impact on the world's forest area. Since the conclusion of the last ice age (approximately ten thousand years ago), the area of forestry has decreased from six billion hectares to four billion hectares, which equates to 31 % of the total land surface [1]. The structure and functions of forest communities in climate-sensitive regions are subject to uncertain changes in response to global warming. In particular, the reaction of pine growth to climate change in northern Central Asia remains uncertain [2]. The long-term utilization of pine forests in Kazakhstan for recreational purposes, in conjunction with the trend of climate change towards aridification and the occurrence of catastrophic fires in this region, has resulted in substantial detrimental alterations to the condition and sustainability of these plantations [3]. In this regard, monitoring of forest ecosystems is carried out on the territory of the SNNP "Burabay".

The first dendroclimatic studies on the territory of the southern part of the SNPP were published in 2017, where the impact of climate change on the width of annual rings was observed. The variability and sensitivity of annual ring widths increased after the 1940s. The observed trend of increasing precipitation, temperature and annual ring width is of particular interest. In conclusion, it can be posited that the annual rings of common pine in Burabay exhibit heightened sensitivity to prevailing growing conditions and are susceptible to the effects of climate change [4]. A classical dendroclimatic study was conducted for six coniferous forest areas near their semi-arid borders throughout Kazakhstan, including Pinus sylvestris L., a species found in temperate forest-steppes, and Picea schrenkiana Fisch. & C.A. Mey, a species found in foothills in the south-eastern region of the Western Tien Shan; Juniperus seravschanica Kom., a species found in the mountain zone in the south-eastern region of the Western Tien Shan, in the southern subtropics. In the context of Kazakhstan, it has been determined that the primary factor impeding the growth of conifers is heat stress. To address this issue, it is recommended that experiments be conducted to develop heat-protection measures for plantations and urban trees. Additionally, it is suggested that the dendroclimatic network be expanded to encompass the influence of habitat conditions and climate-driven dynamics of perennial growth [5].

Experimental

The study area is the Burabay SNNP, located in northern Kazakhstan, specifically in the Akmola region, within the Burabay district (53°05′00″N 70°18′00″E). The topography of the Burabay tract is characterized by undulating terrain, which is part of the Kazakh Shallow Soil. In the spring of 2024, two plots were established within the SNNP to collect cores of common pine (*Pinus sylvestris* L.). One of these plots was designated as Bur, representing natural growing conditions, while the second plot was designated as BurA, representing conditions influenced by anthropogenic factors. These plots were situated in the vicinity of Zhukey village, located in the Yenbekshilder district (see Figure 1 and Table 1 for further details). The sites were selected in order to compare how different factors affect wood growth.

The vegetation of the area is closely related to the landscape features of the Kokshetau upland. The presence of a forest-steppe landscape within the steppe zone is attributable to several factors, including its elevated position and strong ruggedness. Furthermore, the forest-steppe landscape is distinguished by its slightly higher precipitation levels (300–350 mm) compared to the surrounding areas, resulting in increased water availability. The topsoil is characterized by a brown earth, loessy, sandy loam composition. Common pine (Pinus sylvestris) constitutes 65 % of the total tree vegetation of the park.

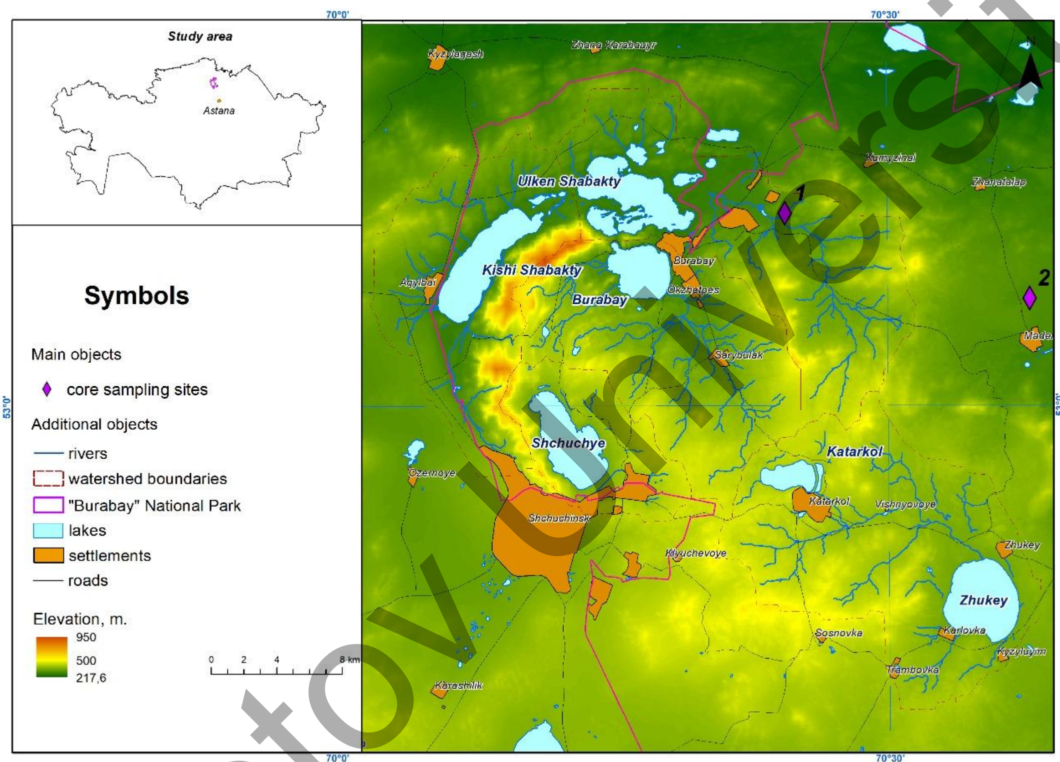


Figure 1. Sampling points in Burabay SNNP
No.1 — Bur site (natural growing conditions), No.2 — BurA site (under the influence of anthropogenic factors)

T a b l e 1

Location of sampling sites and sources of climatic data

Sampling location	Species	Geographical coordinates			Climatic grid points
Bur	PISY	53°00'38.2	70°17'44.5	388	53.25 70.25
BurA	PISY	52°54'57.1	70°36'10.6	426	52.75 70.75
*PISY — Pinus sylvestris					

The winter season is characterized by its severity and protracted nature, and is marked by a scarcity of precipitation, a consequence of the continental climate. Conditions during the winter months are considered to be within normal parameters, except on days when there is a significant increase in wind speed. However, such winds are not particularly characteristic of the northern region during the winter months. Should these occur primarily during the first two months of winter, a sharp decline in air temperature can be expected. It has been demonstrated that, on occasion, the indicators can reach a value of -45 °C. During the winter months, the presence of warm winds can result in an increase in air temperature to approximately

+5 °C. Furthermore, it has been observed that snow cover persists for duration of approximately four months. The mean annual temperature is 1.3 °C. The mean temperature in January is -16.8 °C, while the mean temperature in July is 19.1 °C. The mean duration of the frost-free period is a mere 140 days. The annual average amount of precipitation is 332.3 millimeters, with a maximum of 257.9 millimeters recorded from April to October (Fig. 2).

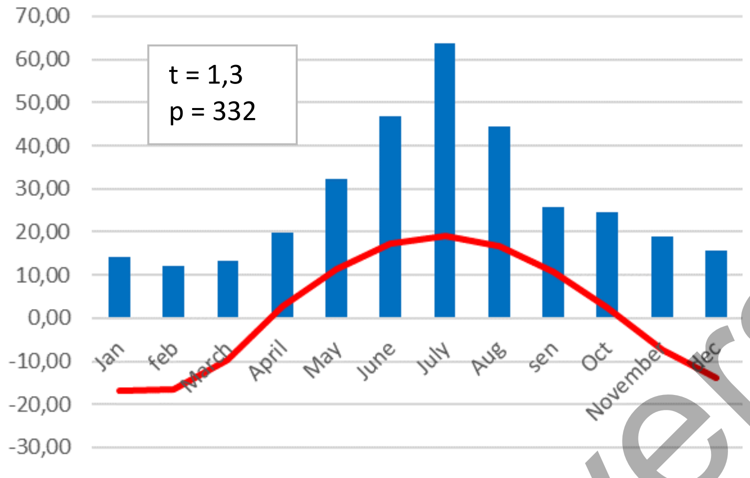


Figure 2. Average annual temperature and precipitation on the territory of SNNP “Burabay”.

A distinctive feature of closed stands is the presence of a substantial layer of forest litter. The thickness of the layer varies between 3–5 cm, with some areas reaching 10–15 cm in hollows. The litter is predominantly composed of fallen needles and small pine branches, with a paucity of grass cover in certain areas.

Samples of wood (cores) were obtained for dendrochronological analysis. These samples were taken from a variety of common pine trees of different ages. Trees for core drilling were selected in sparse forests in the areas of their most significant accumulation, in stands—within the sample areas. Cores were extracted at a height of 1.3 m from the root neck. The cores were collected and prepared for dating according to the methods adopted in dendrochronology [6–8]. The samples were meticulously cleaned using a combination of blades and a clerical knife. The presence of boundaries within annual rings was determined by applying tooth powder to the cleaned surface of the core. The width of annual rings was measured with an accuracy of 0.01 mm on a semi-automatic LINTAB VI instrument. The calendar year of each ring was determined using the CrossDating method in the TsapWin computer program [9, 10]. The accuracy of cross-dating was checked using cross-correlation analysis in the specialized computer program COFEÑHA [11-12].

The quality of the dendrochronological material was assessed using the ARSTAN program by the following indicators: Pearson correlation coefficient, standard deviation, skewness, average sensitivity coefficient, first-order autocorrelation, and total population signal of the chronology EPS (expressed population signal). A value of 0.85 is taken as the threshold value of EPS, where a total variance below this threshold indicates an unacceptable amount of noise in the chronologies [13].

Climate data (temperature and precipitation) were utilized to project climate change, which was then interpolated for the corresponding geographic coordinates of the spatially distributed CRU TS field (1901–2023). This data is publicly available in the KNMI Climate Explorer database (https://climexp.knmi.nl/start.cgi).

Results and Discussion

The indicators of the qualitative evaluation of the obtained dendrochronological material are summarized in Table 2. The obtained individual chronologies can be considered to be relatively insensitive to external environmental factors, as the sensitivity coefficient does not exceed the threshold value of 0.3. However, the site of BcrA shows a small signal, which amounts to 0.25. This phenomenon is likely attributable to anthropogenic influences, particularly the establishment of plantations in exposed locations. These plantations are susceptible to strong winds, which can result in lopsided crowns and severely bent trunks in affected trees. It is frequently observed that substantial roots, which are scarcely concealed by soil, extend across the surface of granite, particularly along crevices where diminutive branches of roots penetrate. The process of crack expansion is often accompanied by the deposition and subsequent lifting of substantial granite blocks by skeletal roots, a phenomenon that is particularly evident during the process of root growth. A high value of first-order autocorrelation (0.68-0.72) was observed, indicating that past climatic conditions are related to current annual pine growth. As demonstrated by the EPS calculations, the generalized chronology has a sufficient supply of dendrochronological data for the period from 1876–2023 (Bur) and from 1918–2023 (BurA). Generally, statistical indicators suggest the reliability of the constructed dendrochronological series and the significant impact of abiotic factors on the radial growth of common pine.

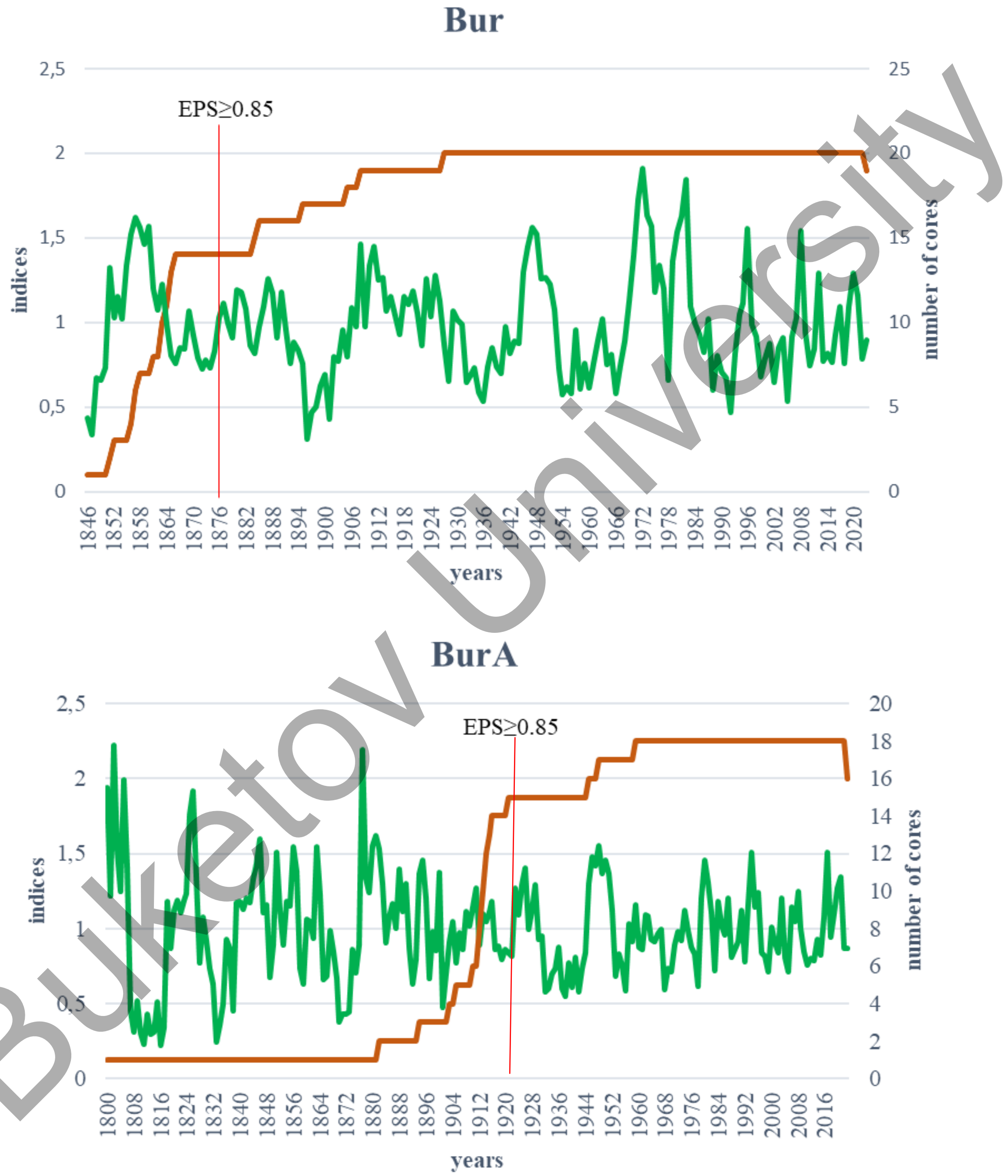


Figure 3. Tree-ring chronologies (TRC) of Bur and BurA.
The green line represents the standard chronology; the brown line represents sampling depth (number of cores for each year); the vertical red line shows the first year of EPS ≥ 0.85, i.e., the beginning of the period suitable for dendroclimatic analysis.

The total sample volume by site was 38 cores; the generalized chronologies of Burabay are shown in Figure 3, the maximum age was 223 years, and the period suitable for dendroclimatic analysis (EPS>0.85) Bur — 147 years, BurA — 105 years.

Table 2

Annual ring width chronology statistics

Plot	Number cores	Period chronologies	Maximum length (years)	Sensitivity	Autocorrelation of 1 order
Bur	20	1849-2023	178	0.20	0.68
BcrA	18	1800-2023	223	0.25	0.72

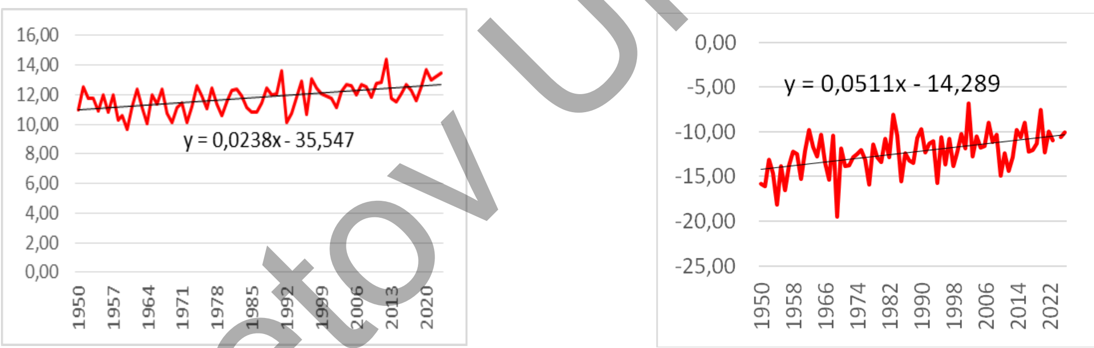
The correlation analysis demonstrated that Bur and BurA chronologies exhibited a satisfactory correlation relationship (Table 3). The correlation between the sites is (R=0.415).

Table 3

Correlation coefficients of tree-ring chronologies

Site name	BurA
Bur	0,415344

The climate was predicted using trends in air temperature and precipitation. The monthly mean climate data set utilized in this study spans from 1901 to 2023. The trends evident throughout the 20th century demonstrate that, since 1950, the region has experienced a marked increase in winter warming and precipitation. To achieve a higher degree of accuracy in the prediction, the trend calculation was utilized since 1950 (Fig. 4).



a b

Figure 4. Air temperature trends: a) temperatures of warm months (April-October); b) temperatures of cold months (November–March)

During the final decade of observation, from 2014 to 2023, the mean temperatures recorded were +12.60 °C and -10.57 °C for the respective warm and cold seasons. Projections indicate that, for the 2024–2033 period, the long-term trends observed during the 20th century are expected to continue, with an anticipated increase in average warm-season temperatures of +12.75 °C and a decrease in average cold-season temperatures of -10.31 °C.

During the final decade of observation, 2014–2023, the mean precipitation levels were recorded as 253.46 mm for the warm season and 90.46 mm for the cold season (Fig. 5).

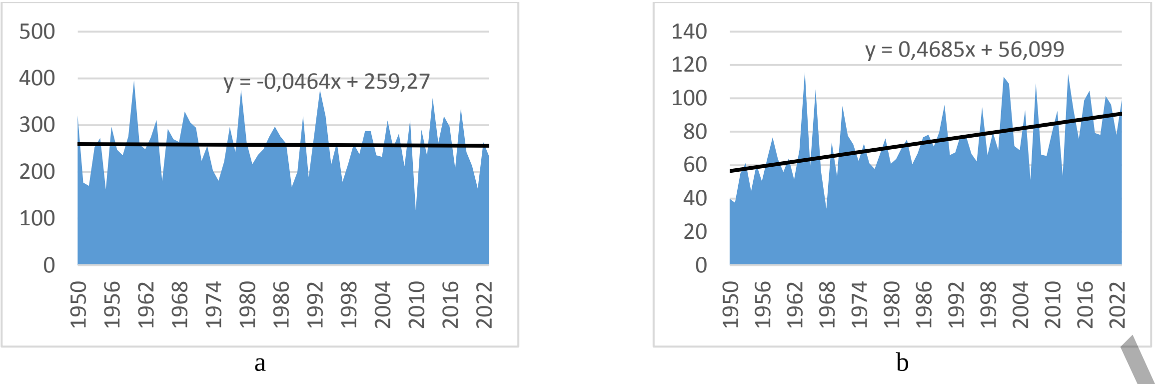


Figure 5. Precipitation trends: a) precipitation of warm months (April-October);
b) precipitation of cold months (November-March)

Projections for 2024–2033, under the assumption that long-term trends from the 20th century persist, anticipate a modest decline in warm-season precipitation, with an expected average of 253.41 mm. Conversely, there is a projected increase in cold-season rainfall, estimated at an average of 90.93 mm.

Conclusions

A comprehensive analysis of the generalized tree-ring chronologies revealed that a substantial number of trees, with an age exceeding 170–220 years, are present within the designated study area. The first-order autocorrelation values range from 0.68 to 0.78. The highest value is observed for the chronology BurA.

All chronologies exhibit a low sensitivity coefficient, indicative of an absence of a substantial climatic signal. This is further substantiated by the observation of a minimal signal (0.25) at the BurA site. This phenomenon is likely attributable to anthropogenic and biotic factors, as the trees are situated near the village and are susceptible to soil erosion and wind. This fact also confirms the EPS calculation, which indicates the amount suitable for dendrochronological work, including the construction of tree-ring chronologies and comparison with climatic parameters. The core samples obtained from this site exhibited signs of damage, indicating the onset of processes related to decomposition and the softening of plant tissues, collectively referred to as “rot”. These processes were initiated from the core of the trunk.

Statistically significant correlation values between the chronologies (0.415) indicate the presence of a standard climatic signal, as they are located in the same study area. The primary reasons for the negligible correlation between plots may be multifaceted, including the geographical separation between plots, the impact of distinct and identifiable factors, the heterogeneity of the local soil landscape, and the climatic conditions of the habitat (particularly in mountain ecosystems), which regulate the dynamics of tree growth even within the same species and climatic zone [14–16].

Short-term climate projections indicate a marginal increase in temperature and a decrease in warm-season precipitation over the ensuing decade.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Mapitov N.B.** — conceptualization, data curation, investigation, methodology, editing; **Kassanova A.Zh**. — data curation, formal analysis, supervision; **Ibraeva K.T.** — data curation, methodology; **Yestayeva M.T.** — data curation, methodology; **Daulet Z.K.** — methodology.

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Н.Б. Мапитов, А.Ж. Касанова, К.Т. Ибраева, М.Т. Естаева, З.Қ. Дәулет

«Бурабай» МҰТП аумағында кәдімгі қарағайдың (*Pinus sylvestris L.*) дендроклиматтық талдауы

Зерттеу солтүстік Қазақстанның орманды даласында, дәлірек айтқанда «Бурабай» Мемлекеттік ұлттық паркі аумағының солтүстік бөлігіндегі құрғақ жағдайда қарағайдың (Pinus sylvestris L.) хронологиясы туралы жаңа деректер алуға бағытталған. Ағаштың өсуіне әртүрлі факторлардың қалай әсер ететінін салыстыру үшін 2 учаске таңдалды. Жалпыланған ағаш-сақина хронологияларын талдау зерттеу аймағында 170-220 жастан асқан көптеген ағаштар өсетінін көрсетті. Бірінші ретті автокорреляция мәндері 0,68-ден 0,78-ге дейін ауытқиды. Сезімталдық коэффициенті шағын климаттық сигналдың болуын көрсетті. Қысқа мерзімді климаттық болжам алдағы 10 жылда температураның шамалы жоғарылауын және жылы мезгілде жауын-шашынның төмендеуі күтілетінін көрсетеді.

Кілт сөздер: Pinus sylvestris L., климаттық болжам, Бурабай, жауын-шашын, ауа температурасы

Н.Б. Мапитов, А.Ж. Касанова, К.Т. Ибраева, М.Т. Естаева, З.Қ. Дәулет

Дендроклиматический анализ сосны обыкновенной (*Pinus sylvestris L.*) на территории ГНПП «Бурабай»

Исследование направлено на получение новых данных хронологий сосны обыкновенной (*Pinus sylvestris L.*) в засушливых условиях в лесостепи северного Казахстана, а именно в северной части на территории ГНПП «Бурабай». Были выбраны 2 участка, чтобы сравнить, как влияют различные факторы на прирост древесины. Анализ обобщенных древесно-кольцевых хронологий показал, что в пределах района исследования произрастает большое количество деревьев возрастом более 170–220 лет. Значения автокорреляции 1-го порядка варьируются от 0,68 до 0,78. Коэффициент чувствительности показал присутствие небольшого климатического сигнала. Краткосрочный прогноз климата показывает, что в ближайшие 10 лет ожидается небольшое повышение температуры и понижение количества осадков теплого сезона.

Ключевые слова: Pinus sylvestris L., прогноз климата, Бурабай, осадки, температура воздуха

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