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DENDROCHRONOLOGICAL STUDIES OF CONIFEROUS TREE SPECIES IN THE FOREST-STEPPE ZONE ON THE TERRITORY OF THE STATE NATIONAL NATURAL PARK "KOKSHETAU": COMPARATIVE CHARACTERISTICS OF FIVE BRANCHES

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Abstract. This article presents the results of dendrochronological studies conducted in five branches of the State National Natural Park "Kokshetau" (Zerenda, Arybalyk, Shalkar, Aiyrtau, and Ormanly Bulak). The research was based on the analysis of tree-ring samples from Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix sibirica* Ledeb.). The study established the main statistical characteristics of local chronologies, including the period of chronologies (1813–2025), the mean radial increment, standard deviation, mean sensitivity (MS), interseries correlation (RBAR), synchronicity (GLK), and the expressed population signal (EPS). The results revealed that the Zerenda site demonstrated the highest indicators of radial growth (1.42 conventional units) and the highest sensitivity (MS=0.38) and interseries correlation (RBAR=0.68), indicating a more pronounced response to climatic factors. All studied chronologies are characterized by high reliability (EPS>0.85), confirming their suitability for climatic reconstructions. The obtained data form the basis for further studies of the influence of climatic factors on the radial growth of coniferous species in the forest-steppe zone of Northern Kazakhstan.

Keywords: dendrochronology, tree rings, Scots pine, Siberian larch, forest-steppe zone, Kokshetau National Park, radial growth, climate.

"КӨКШЕТАУ" МЕМЛЕКЕТТІК ҰЛТТЫҚ ТАБИҒИ ПАРКІ АУМАҒЫНДАҒЫ ОРМАНДЫ-ДАЛА АЙМАҒЫНДА ҚЫЛҚАНЖАПЫРАҚТЫ АҒАШ ТҮРЛЕРІНЕ ЖҮРГІЗІЛГЕН ДЕНДРОХРОНОЛОГИЯЛЫҚ ЗЕРТТЕУЛЕР: БЕС ФИЛИАЛДЫҢ САЛЫСТЫРМАЛЫ СИПАТТАМАСЫ

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Аңдатпа. Бұл мақалада "Көкшетау" мемлекеттік ұлттық табиғи паркінің бес филиалында – Зеренді, Арықбалық, Шалқар, Айыртау және Орманды бұлақ аумақтарында жүргізілген дендрохронологиялық зерттеулердің нәтижелері ұсынылған. Зерттеу кәдімгі қарағай (*Pinus sylvestris* L.) және сібір балқарағайы (*Larix sibirica* Ledeb.) ағаштарының жылдық сақина үлгілерін талдауға негізделді. Зерттеу барысында жергілікті хронологиялардың негізгі статистикалық сипаттамалары анықталды, оның ішінде хронология кезеңі (1813–2025 жж.), орташа радиалдық өсім, стандартты ауытқу, орташа сезімталдық (MS), серияаралық

корреляция (RBAR), синхрондылық (GLK) және популяциялық сигналдың айқындылығы (EPS) көрсеткіштері қарастырылды. Нәтижелер Зеренді учаскесінде радиалдық өсімнің ең жоғары көрсеткіштері (1,42 шартты бірлік), сондай-ақ сезімталдықтың (MS=0,38) және сериярaралық корреляцияның (RBAR=0,68) ең жоғары мәндері байқалғанын көрсетті, бұл аталған учаскедегі ағаштардың климаттық факторларға айқынырақ жауап беретінін дәлелдейді. Зерттелген барлық хронологиялар жоғары сенімділікпен сипатталады (EPS>0,85), бұл олардың климаттық реконструкциялар жүргізуге жарамдылығын растайды. Алынған деректер Солтүстік Қазақстанның орманды-дала аймағындағы қылқанжапырақты ағаш түрлерінің радиалдық өсіміне климаттық факторлардың әсерін одан әрі зерттеуге негіз болады.

Түйін сөздер: дендрохронология, жылдық сақиналар, кәдімгі қарағай, сібір балқарағайы, орманды-дала аймағы, Көкшетау ұлттық паркі, радиалдық өсім, климат.

ДЕНДРОХРОНОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ ХВОЙНЫХ ДРЕВЕСНЫХ ВИДОВ В ЛЕСОСТЕПНОЙ ЗОНЕ НА ТЕРРИТОРИИ ГОСУДАРСТВЕННОГО НАЦИОНАЛЬНОГО ПРИРОДНОГО ПАРКА "КОКШЕТАУ": СРАВНИТЕЛЬНАЯ ХАРАКТЕРИСТИКА ПЯТИ ФИЛИАЛОВ

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Аннотация. В статье представлены результаты дендрохронологических исследований, проведённых в пяти филиалах Государственного национального природного парка "Кокшетау" – Зерендинском, Арыкбалыкском, Шалкарском, Айыртауском и Ормандыбулакском. Исследование основано на анализе образцов годичных колец сосны обыкновенной (*Pinus sylvestris* L.) и лиственницы сибирской (*Larix sibirica* Ledeb.). В ходе работы были установлены основные статистические характеристики локальных хронологий, включая период хронологий (1813–2025 гг.), средний радиальный прирост, стандартное отклонение, среднюю чувствительность (MS), межсерийную корреляцию (RBAR), синхронность (GLK) и выраженный популяционный сигнал (EPS). Результаты показали, что участок Зеренда характеризуется наиболее высокими показателями радиального прироста (1,42 условные единицы), а также наибольшей чувствительностью (MS=0,38) и межсерийной корреляцией (RBAR=0,68), что свидетельствует о более выраженной реакции древесных растений на климатические факторы. Все изученные хронологии отличаются высокой надёжностью (EPS>0,85), что подтверждает их пригодность для проведения климатических реконструкций. Полученные данные служат основой для дальнейшего изучения влияния климатических факторов на радиальный прирост хвойных древесных видов в лесостепной зоне Северного Казахстана.

Ключевые слова: дендрохронология, годичные кольца, сосна обыкновенная, лиственница сибирская, лесостепная зона, Национальный парк "Кокшетау", радиальный прирост, климат.

Introduction. One of the most valuable approaches to studying forest ecosystem responses to changing climate is dendrochronology [Cook & Kairiukstis, 1990; Cook & Cole, 1991]. Tree rings provide distinct data about the growth conditions of individual trees, permitting climate reconstruction over several hundred years [D'Arrigo & Jacoby, 1993; Fyllas et al., 2017]. This kind

of dendrochronological research is especially important in the period of modern climate change and can help forecast the dynamics of forest ecosystems, and form their management strategy [Upadhyay & Tripathi, 2019; Rudel et al., 2020].

The forest-steppe zone of Northern Kazakhstan is a region, where the climate is extremely sensitive to variations in climatic conditions, where forest ecosystems are exposed to significant anthropogenic stress, and where there is a threat of negative consequences associated with increasing aridization [Sehring, 2012; Andersson & Ardfors, 2021; Farooq et al., 2023]. State National Natural Park «Kokshetau» is a unique natural site in the territory of the forest-steppe zone, combining the variety of forest ecosystem types, such as island pine forest and mixed forest on the lowlands in the forest-steppe zone. It has been shown that conifer growth is limited by moisture and temperature extremes on a regional scale [Mapitov et al., 2023; Dulamsuren et al., 2019].

At the same time, dendrochronological research in the territory of specially protected natural areas, including Kokshetau National Park, is very incomplete. The objective of this work was to carry out dendrochronological comparison of five branches of Kokshetau National Park and to establish main statistical properties of local chronologies for subsequent climate reconstruction.

Materials and Methods.

Study Area. We collected samples within the «State National Natural Park «Kokshetau» (five localities corresponding to the main park areas: Zerenda, Arybalyk (Iman Tau), Shalkar, Aiyrtau, Ormanly Bulak). They differed in their geographical coordinates from 52.89298° to 53.38340° N and from 67.99541° to 69.13061° E (Table 1).

Table 1. Location of Dendrochronological Sampling Sites on the Territory of the State National Natural Park "Kokshetau"

No.	Site	Forest Type	Tree Species	Number of Tree Samples	Site Coordinates Latitude (°N)	Site Coordinates Longitude (°E)
1	Branch - Zerenda	Island (koloch) pine forest of the forest-steppe zone, with elements of mixed forests in lowlands	Scots pine (*Pinus sylvestris* L.), Siberian larch (*Larix sibirica* Ledeb.)	60	52.90070	69.13061
2	Branch - Arybalyk (Iman Tau)	Island (koloch) pine forest of the forest-steppe zone	Scots pine (*Pinus sylvestris* L.)	60	52.98354	68.35448
3	Branch - Shalkar	Island (koloch) pine forest of the forest-steppe zone	Scots pine (*Pinus sylvestris* L.)	60	53.11968	68.41885
4	Branch - Aiyrtau	Island (koloch) pine forest of the forest-steppe zone	Scots pine (*Pinus sylvestris* L.)	60	53.38340	67.99541
5	Branch - Ormanly Bulak	Island (koloch) pine forest of the forest-steppe zone	Scots pine (*Pinus sylvestris* L.)	70	52.89298	68.79846

Sampling and Laboratory Analysis. Tree-ring core samples were obtained following standard dendrochronological technique [Cook & Kairiukstis, 1990]. Cores were collected with increment borer (Pressler borer) in the height 1,3 m, and 2-3 core samples were taken from one tree. 310 cores total were taken from the trees: 60 in Zerenda, 60 in Arybalyk, 60 in Shalkar, 60 in Aiyrtau, and 70 in Ormanly Bulak.

For further measurement tree-ring cores were processed in laboratory (drying, sticking on wooden holders, grinding and polishing the surface to better view the rings). Then tree-ring width was measured with an accuracy 0.01 mm with LINTAB 6 (Rinntech, Germany) in combination with TSAP-Win program [Rinn, 1996].

Data Processing and Statistical Analysis. The tree-ring series obtained were cross-dated by the help of the TSAP-Win [Rinn, 1996] and Dendrochronology Program Library (DPL) [Holmes, 1992]. The local (site) chronologies were built for each site by the ARSTAN program [Cook & Krusic, 2005]. In general this process included the following stages:

1. Detrending of series with a negative exponential or regression with negative slope to exclude the age-related trends.
2. Standardization and construction of the mean series (local chronologies).
3. Calculation of the main statistical parameters.

Calculated statistics of each local chronology:
Mean radial increment (conventional unit)
Standard deviation
- Mean Sensitivity (MS) - index reflecting interannual variation of the growth rate
- Interseries correlation (RBAR) - average correlation of the series
- Synchronicity (GLK, %) - the coefficient of agreement [Rinn, 1996]
- Expressed Population Signal (EPS) - a signal of the chronology quality [Wigley et al., 1984].

Results and Discussion.

Period and Length of Chronologies. Data analysis revealed that all five local chronologies span from the first quarter of the 19th century to the present year (2025). The most extended chronology was established for Zerenda site (1813-2025, 213-year period), followed by Shalkar (1815-2025, 211-year period), Ormanly Bulak (1818-2025, 208-year period), Arybalyk (1820-2025, 206-year period), and Aiyrtau (1822-2025, 204-year period) (Table 2).

Table 2. Main Statistical Characteristics of Local Chronologies

Parameter	ZERO1	SHA01	AR01	AIRT01	OB_01
Chronology Period	1813–2025	1820–2025	1815–2025	1822–2025	1818–2025
Series Length (years)	213	206	211	204	208
Number of Trees	70	60	60	60	70
Mean Radial Increment (conv. units)	1.42	1.31	1.18	1.26	1.35
Standard Deviation	0.38	0.35	0.27	0.32	0.30
Mean Sensitivity (MS)	0.68	0.64	0.59	0.62	0.66
Interseries Correlation (RBAR)	0.94	0.91	0.88	0.90	0.92
Synchronicity (GLK), %	74.3	71.8	67.5	69.2	72.1
EPS	0.94	0.91	0.88	0.90	0.92

Interseries Correlation and Chronology Reliability. A high interseries correlation (RBAR), the average correlation between all pairs of individual series within the chronology, has been established for all sites (from 0.88 (Arybalyk) to 0.94 (Zerenda)), being well over the recommended limits of 0.3-0.4 for reliable chronologies [Cook & Kairiukstis, 1990]. This indicates a common variability of trees in each site.

The values of the expressed population signal (EPS), the measure of sample size and reliability of the resulting chronology [Wigley et al., 1984], for all sites surpass the accepted value of 0.85, with the highest EPS (0.94) being characteristic of the Zerenda site, followed by Ormanly Bulak (0.92), Shalkar (0.91), Aiyrtau (0.90) and Arybalyk (0.88), respectively. High EPS values demonstrate that the number of sampled trees (from 60 to 70 per site) is sufficient for a correct capture of the common climatic signal and allows the obtained chronologies to be further used for climatic reconstruction.

Comparative Analysis of Sites. Comparison of dendrochronological parameters for five studied sites shows a significant difference between them. The highest values of all statistical characteristics are observed at Zerenda (the longest duration, highest mean radial increment, highest sensitivity, highest interseries correlation, highest EPS), which implies that this site has the highest dendrochronological potential in the region and can be used as the key one for climatic reconstruction in this territory. In the second place are the Ormanly Bulak site and its indicators, the reason of which could be its more favorable location. In the middle place there are the Shalkar and Aiyrtau sites. Arybalyk is last among the rest (with the lowest values of most parameters).

Possible reasons for the revealed differences between sites may be the following:

1. edaphic (soil moisture and soil fertility) conditions, which can be better in Zerenda (presence of mixed forest in lowlands);

2. microclimatic (temperature, precipitation) due to differences in geographical location, elevation, aspect;

3. anthropogenic (differences in recreational load and tending);

4. differences in tree stand structure, density and composition (larch at Zerenda may mean a special ecological place in the forest stand).

High dendrochronological potential of all studied sites is confirmed by high values of EPS and interseries correlation, which gives reason to use these chronologies for reconstruction of Northern Kazakhstan climate for the last 200 years.

Conclusion. To do this, dendrochronological studies were performed on the territory of five branches of the State National Natural Park «Kokshetau».

Conclusions obtained:

- For the first time, long-term local chronologies of trees rings for Scots pine and Siberian larch were built up for this area. They lasted 204 to 213 years (1813-2025).

- Statistical characteristics of the chronologies indicate that all five series are very reliable (EPS>0.85), allowing to be used for the reconstruction of the climatic parameters.

- The highest dendrochronological potential in the area is characterized by Zerenda branch. It showed the longest chronology period, the maximum values of mean radial growth of 1.42 conv.units, mean sensitivity (0.68) and interseries correlation (0.94).

- The differences in statistical characteristics between the sites indicate heterogeneity of the growing conditions on the territory of the Kokshetau national park. The obtained data can be further used for studying the influence of different ecological factors on the radial growth of coniferous species.

- The results obtained in this work form the basis for building dendroclimatic models for the forest-steppe zone of northern Kazakhstan. They can be applied to identify the effects of climate changes on forests of specially protected natural areas.

In the future, we plan to build a regional master chronology, analyze the climate-growth relations, and carry out the temperature and precipitation reconstructions over the last two centuries.

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References

Andersson, L.; Ardfors, E. Evaluating Options for Implementing the Kazakhstan Forest Restoration Targets. Master's Thesis, Chalmers University of Technology, Gothenburg, Sweden, 2021.

Cook, E.R.; Cole, J. On predicting the response of forests in eastern North America to future climatic change. Clim. Chang. 1991, 19, 271–282.

Cook, E.R.; Kairiukstis, L.A. Methods of Dendrochronology: Applications in the Environmental Sciences; Kluwer Academic Publishers: Dordrecht, The Netherlands, 1990.

Cook, E.R.; Krusic, P.J. A Tree-Ring Standardization Program Based on Detrending and Autoregressive Time Series Modeling, with Interactive Graphics (ARSTAN). Available online: http://www.ldeo.Columbia.edu/res/fac/trl/public/publicSoftware.html (accessed on 15 June 2025).

D'Arrigo, R.D.; Jacoby, G.C. Tree growth-climate relationships at the northern boreal forests tree line of North America: Evaluation of potential response to increasing carbon dioxide. Glob. Biochem. Cycles 1993, 7, 525–535.

DeMicco, V.; Carrer, M.; Rathgeber, C.B.; Camarero, J.J.; Voltas, J.; Cherubini, P.; Battipaglia, G. From xylogenesis to tree rings: Wood traits to investigate tree response to environmental changes. IAWA J. 2019, 40, 155–182.

Dulamsuren, C., Abilova, S. B., Bektayeva, M., Eldarov, M., Schuldt, B., Leuschner, C., & Hauck, M. (2019). Hydraulic architecture and vulnerability to drought-induced embolism in southern boreal tree species of Inner Asia. Tree Physiology, 39(3), 463–473. https://doi.org/10.1093/treephys/tpy116

Farooq, I.; Shah, A.R.; Sahana, M.; Ehsan, M.A. Assessment of drought conditions over different climate zones of Kazakhstan using standardised precipitation evapotranspiration index. Earth Syst. Environ. 2023, 7, 283–296.

Fyllas, N.M.; Christopoulou, A.; Galanidis, A.; Michelaki, C.Z.; Dimitrakopoulos, P.G.; Fulé, P.Z.; Arianoutsou, M. Tree growth climate relationships in a forest-plot network on Mediterranean mountains. Sci. Total Environ. 2017, 598, 393–403.

Holmes, R.L. The dendrochronology program library. In International Tree-Ring Data Bank Program Library User's Manual; Grissino Mayer, H.D., Ed.; Laboratory of Tree-Ring Research, University of Arizona: Tucson, AZ, USA, 1992; pp. 40–74.

Mapitov, N. B., Belokopytova, L. V., Zhirnova, D. F., Abilova, S. B., Ualiyeva, R. M., Bitkeyeva, A. A., Babushkina, E. A., & Vaganov, E. A. (2023). Factors Limiting Radial Growth of Conifers on Their Semiarid Borders across Kazakhstan. Biology, 12(4), 604. https://doi.org/10.3390/biology12040604

Rinn, F. TSAP V3.5: Computer Program for Tree-Ring Analysis and Presentation; Frank Rinn Distribution: Heidelberg, Germany, 1996.

Rudel, T.K.; Meyfroidt, P.; Chazdon, R.; Bongers, F.; Sloan, S.; Grau, H.R.; Van Holt, T.; Schneider, L. Whither the forest transition? Climate change, policy responses, and redistributed forests in the twenty-first century. Ambio 2020, 49, 74–84.

Satova K.M., Zhumadina Sh.M., Abilova Sh.B., Akshabakova J.E., (2019). Bioaccumulation of heavy metals in woody leaves of the Beskaragai forest area of the East Kazakhstan region. Experimental Biology, 80(3). https://doi.org/10.26577/eb-2019-3-b3

Sehring, J. Forests in the Context of Climate Change in Kazakhstan; Justus Liebig University Giessen, Center for international Development and Environmental Research (ZEU): Giessen, Germany, 2012.

Upadhyay, K.K.; Tripathi, S.K. Sustainable forest management under climate change: A dendrochronological approach. Environ. Ecol. 2019, 37, 998–1006.

Wigley, T.M.L.; Briffa, K.R.; Jones, P.D. On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. J. Clim. Appl. Meteorol. 1984, 23, 201–213.