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Ancient larch trees in the Tuva Republic, land of the oldest trees in Russia

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Keywords: sacred larch trees, natural monuments, culture, protection, tourism, preservation, Siberia, Russia, upper treeline, forest-steppe zone

Abstract

The ancient trees in the Tuva Republic have both cultural and scientific significance. Our study provides a synthesis of the results of the dendrochronological research carried out by the Siberian Dendrochronological Laboratory over the past 16 years in the Tuva Republic, Russian Federation. By applying state-of-the-art dendrochronological analysis, we identified the oldest dead larch tree (*Larix sibirica* Ldb.) in the study region, which had reached 1,307 years old. Living larch trees from the forest-steppe zone (1,000–1,500 m asl) and at the upper treeline (2,000 m asl) are known to have reached 779 and 662 years respectively. Such old trees are of great interest for the scientific community and society. Old living larch trees have witnessed the rise and fall of great nomadic civilizations and agricultural changes. Their identification and protection increase their attraction for tourists and enrich the cultural significance of the region. Until now, however, these trees have remained unprotected and are not registered in international and national registers of long-living trees. In this study, we aim to raise awareness of the need to develop forest protection policies and to preserve ancient living larch trees in the Tuva Republic.

Introduction

A tree's lifespan significantly exceeds the length of a human life, and to learn about its past we can turn to tree-ring records (Fritts 1976). The longest-living tree on Earth is the Bristlecone Pine (*Pinus longaeva* D.K. Bailey), which is known to have reached an age of 4,825 years (Currey 1965). The key to such longevity is the ability of the cambium to divide indefinitely. According to the Old List database (Brown 1996), in the state of California there are 24 trees over 500 years old, registered and protected at national level.

Many European, Baltic and Nordic countries apply comprehensive measures for the inventory and protection of ancient trees. For example, since the 1900s old living trees in Germany have been under protection, while in Poland a movement for the protection of ancient trees came into existence in the 1920s and is supported not only by the State, but also by social, environmental and religious structures (Boreyko 1996). Researchers and activists are constantly working to determine the exact age of old trees. For example, a strip-bark Heldreich's pine (*Pinus heldreichii* H. Christ), the oldest dead tree found in Europe (in Italy) reached 1,062 years (955–2016 CE) (Piovesan et al. 2018). The oldest living European larch (*Larix decidua*) is also found in Italy, aged 986 years (https://www.conifers.og/pi/Larix_decidua.php).

The Russian programme *Trees – natural monuments of nature* was initiated in 2010 (Trees – Monuments of Nature 2010). This inventory contains information about long-living trees in the Russian Federation. However, the trees included in the database are distributed unevenly geographically. In general, this is due to accessibility (proximity to settlements or tourist trails). Moreover, the age of trees is determined by indirect characteristics (for example, crown height and trunk diameter), which are not accurate indicators of their real age. The oldest trees in Siberia included in the database are a 754-year-old Siberian cedar (*Pinus sibirica* Du Tour) from the Khakassia Republic, a 604-year-old Scots Pine (*Pinus sylvestris* L.), and a 775-year-old Siberian larch (*Larix sibirica* Ldb.) from the Irkutsk region. To cross-check the age of the old Siberian larch, we conducted an independent sampling of five tree cores taken from the 775-year-old larch. Because this tree stem has rot and decay, the dendrochronological analysis of the tree rings returned an age of 351 yeas only, less than half the age declared in the database. Therefore, the content of the database must be checked for accuracy.

We also discovered a number of old trees which did not figure in this database but which we were able to cross-date using a dendrochronological approach. For example, living larch trees (*Larix cajanderi* Mayr.) in northeastern Yakutia can be up to 945 years old (Sidorova et al. 2005, 2008), while in the Polar Ural region Siberian larch trees (*L. sibirica* Ldb.) can reach 486 years old (Vaganov et al. 1996). Information about old living trees is missing for the Tuva Republic, a territory located in central Asia, but old trees can provide unique paleoclimatic information about extreme events, such as droughts, over centuries and millennia. Droughts are captured by tree rings at annual resolution and can potentially be used for the reconstruction of catastrophic drought events in the steppe basins.

Despite the longevity of some trees, the number of old trees is steadily decreasing. Recent climate change has led to the transformation of trees' growing conditions at the upper treeline and in the forest-steppe zone (Zhang et al. 2018; Cook et al. 2020; Churakova (Sidorova) et al. 2021, 2022). It is also important to

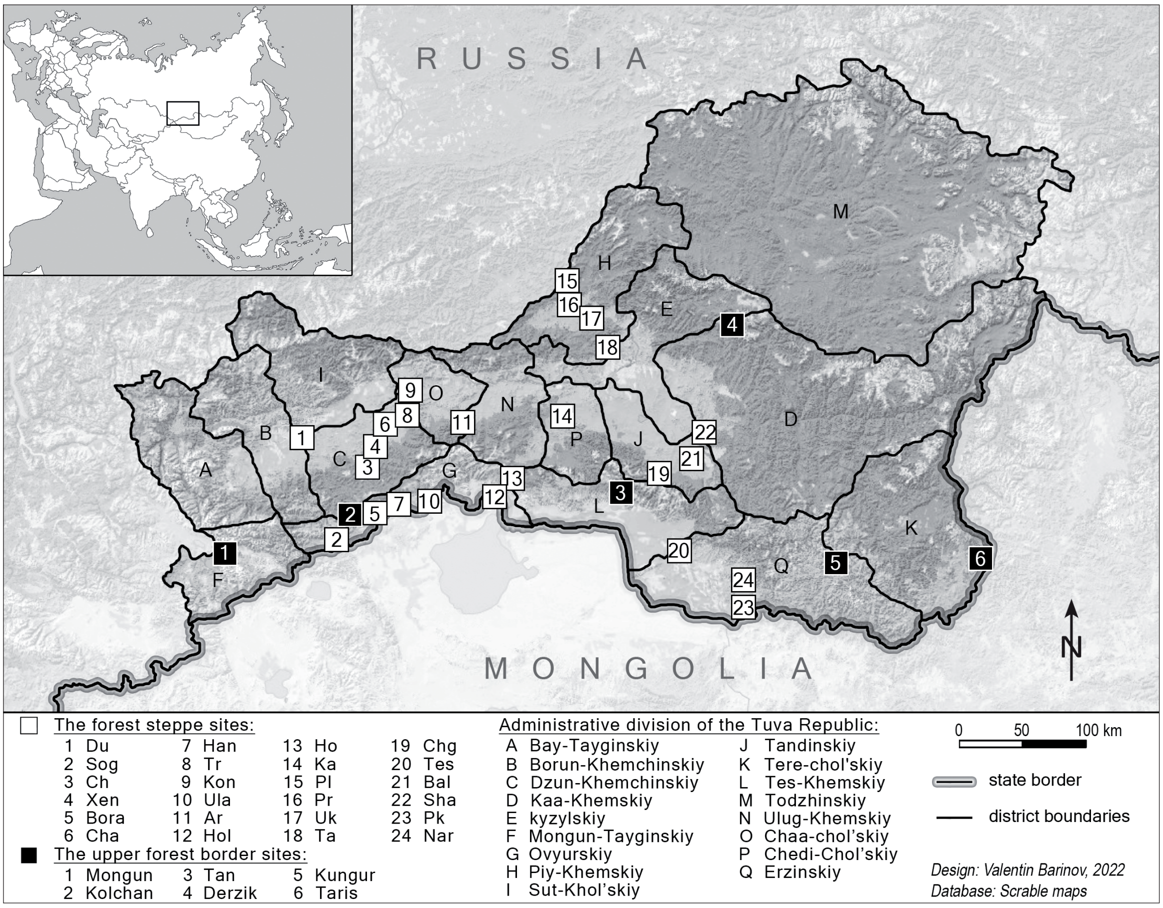

Figure 1 – Locations of dendrochronological sites in the Tuva Republic, Russian Federation. The 24 study sites located in the forest-steppe zone are Du (1), Sog (2), Ch (3), Xen (4), Bora (5), Cha (6), Han (7), Tr (8), Kon (9), Ula (10), Ar (11), Hol (12), Ho (13), Ka (14), PI (15), Pr (16), Uk (17), Ta (18), Chg (19), Tes (20), Bal (21), Sha (22), Pk (23) and Nar (24), shown in white squares. The upper tree line is represented by 6 sites in Mongun (1), Kolchan (2), Tan (3), Derzik (4), Kungur (5) and Taris (6), shown in black squares. Administrative divisions of the Republic of Tuva: A – Bay-Tayginskiy, B – Borun-Khemchinskiy, C – Dzun-Khemchinskiy, D – Kaa-Khemskiy, E – Kyzylskiy, F – Mongun-Tayginskiy, G – Ovyurskiy, H – Piy-Khemskiy, I – Sut-Khol'skiy, J – Tandinskiy, K – Tere-chol'skiy, L – Tes-Khemskiy, M – Todzhinskiy, N – Ulug-Khemskiy, O – Chaa-chol'skiy, P – Chedi-Chol'skiy, and Q – Erzinskiy.

mention trampling, root exposure (due to uncontrolled grazing), the increase in wildfires, and mechanical damage of trees, among other factors. Under such circumstances, ancient trees need careful protection. The Tuva Republic is of key importance for the preservation of the ecological state of Siberia and has been classified by UNESCO as one of 200 priority eco-regions on the planet (Kuzhuget 2001; Mongush & Mongush 2015).

In many cultures, long-living trees are not just natural objects but also cultural symbols, even objects of religious worship. The worship or reverence of trees is common among many peoples worldwide (Nam 2016). The connection between humans and nature plays an important role in traditional Tuvan culture, where people believed that by harming nature they harmed themselves. For this reason, they never cut down trees unnecessarily, did not kill animals, and did not catch more fish than they needed. Moreover, before taking something from nature, traditionally Tuvans would ask permission to do so, performing various rituals.

The worship of trees, which continues to the present day, was widespread among Tuvans, who recognize three type of sacred tree: (1) growing on mountain passes; (2) growing near mineral springs (Arzhans and Aryks); (3) Shamans' trees, which are widely distributed in the Tuva region. The third type differ from other trees by thick trunks and many branches of unusual shape. According to historical documents (Darzhaa 2007), Shaman's trees were taken care of, cherished and fed; people asked them to grant wellbeing, prosperity, health and a good life. They are divided into two groups: *tel yyash* and *ham yyash*. The first is a double-stemmed tree growing from one root, or intertwined trees of two different species. In the past, several generations of Tuvans who were blood relatives would gather together to perform rituals under the crown of the tree, which was held to be responsible for the health, wellbeing and cohesion of the family.

According to the Shamans, rheumatism in the hand or foot was caused by injuring a *tel yyash*. To treat diseases, ribbons of coloured paper or fabric were hung around the *tel yyash* and on all its branches. This allegedly calmed the angry spirit of the forests. The second type of Shaman's ritual tree, the *ham yyash*, is a larch with confused, unevenly distributed branches forming what Siberians call a *witch's broom*. Prayers to the forest spirits used to take place under these trees' branches.

The identifying feature of shamanism as practised in Tuva is its age-old coexistence with Buddhism. There is no fundamental dogmatic contradiction between the two, and thus Buddhism was able to adopt shamanic rituals. For centuries, Tuvans worshiped Shamans' trees, especially larches, of which two types served in cultural rituals.

The ritual of consecrating new shaman trees ensures continuity and succession. Each shaman has their own tree, which they visit annually to conduct a ritual. While the shaman carries out the ritual, which is performed in daylight in the presence of all the local people, the people bring boiled lamb, flatbread and *araga* (fermented soured milk) for consecration. They also ask the shaman's larch to bring rains, help for a good harvest, and prosperity for the shaman. After the shaman's death, their clothes and tambourine are hung on their tree's branches, because it is believed that the shaman's spirit has migrated and lives there. The tree is asked to ensure that the shaman's spirit is reborn in the same family (Dashkovsky 2015; Agency for Nationalities of the Republic of Tuva 2021).

Larch trees play an important role in Tuvan culture and in Siberian culture more widely. Shamans belonging to the Gas Turukhansk Selkups culture carve faces into them (Ozheredov 1995), while in Gilyak mythology the larch is the home of the ancestral mother, who owned the Sun and the Moon. The Ostyaks and Voguls (indigenous Siberian peoples) used larches during sacrifices, hanging their branches with the skins of the sacrificial animals. The tree as itself a sacred symbol is also found in Ostyak and Vogul culture (Simchenko 1965).

The oldest trees on Earth attract legends and tourists. The trees should be protected and could be used to educate people about past rituals and future protection measures. This would be in line with the socio-economic development strategy of the Tuva Republic (Brown 1996), where tourism is a priority sector. There is no doubt that long-living trees deserve protection as they serve as a natural archive of past economic, cultural and social practices, as well as of changes in climate. Without protection from unsustainable forest management and anthropogenic impacts, these old living trees and relict forest ecosystems risk disappearing.

In this study, we aim (i) to provide a summary of all the available information about old living trees in the Tuva Republic, and (ii) to raise awareness of the need to develop forest protection policies and to preserve the ancient larch trees in the Tuva Republic, at national and international levels.

Material and methods

Study region and site description

The study region is located in southern Siberia (the Asian part of Russia) in the Tuva Republic (Figure 1). The six study sites were selected at the upper treeline (2,000 m asl) in an area measuring 587 km from west to east (Figure 1, *black squares*) where tree growth is limited by summer temperatures (Taynik et al. 2016). A further 24 sites were located in the forest-steppe intermontane zone (1,000–1,500 m asl), measuring 350 km from east to west, and 240 km from north to south (Figure 1, *white squares*), where tree growth is limited by precipitation (Churakova (Sidorova) et al. 2021).

The climate throughout the study region is dry and extra-continental with severe winters and warm summers (Alisov 1956). Vegetation ranges from semi-deserts in the inter-mountain basins to mountain coniferous forests and alpine meadows, which are replaced by bare rocks and snow at higher elevations. Permafrost covers rocky screes and sandy sediments.

Sampling

Old trees were selected based on the following criteria: a disturbed crown shape, and the absence of lower branches. Tree cores were taken from long-living trees (*L. sibirica* Ldb.) using a 6 mm increment borer, according to the standard method described by Schweingruber (1996). During the fieldwork, a significant number of well-preserved dead trunks of Siberian larch trees were found on the ground's surface from which samples were taken with a chainsaw. For each tree, we noted geographical location and coordinates, and measured the diameter using a caliper (DC). 818 samples were collected from the trunks of the dead and living larch trees from the upper treeline. From the forest-steppe zone, 507 tree cores were taken from living trees. Over a period of 16 years (2006–2022) and from 30 study sites, a total of 1,325 samples were collected.

Tree-ring analysis

Resins, waxes and tannins in the wood were extracted from all the tree cores over a period of 40 hours in a Soxhlet apparatus containing 96% ethanol. At the end of the extraction procedure, wood samples were washed in boiling water (up to 120°C) for 10 hours; the water was changed every hour (Schweingruber 1996).

To perform tree-ring analysis, we glued tree cores on wooden bases and sanded them. Tree-ring widths (TRW) were measured using the CooRecorder 9.3 (Cybis, Sweden) software. The graphical cross-dating of the TRW was performed using the CDendro 9.3 program (Larsson 2013). Cross-correlation analysis using DPL (Holmes 1983) and TSAP V3.5 (Rinn 1996) specialized software packages for dendrochronological studies was applied. The quality of the cross-dating was assessed using Pearson correlation coefficients,

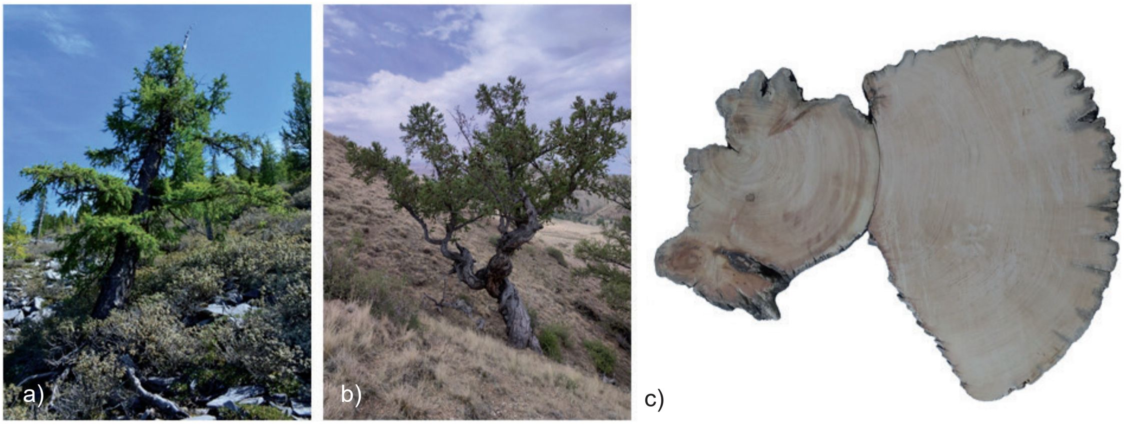

Figure 2 – (a) The 662-year-old Siberian larch (Larix sibirica Ldb.) from the upper treeline in Tere-cholskiy District, Tar site; (b) 779-year-old Siberian larch from the steppe zone, Ovyurskiy District, Ula site; (c) Siberian larch sample from a dead trunk, 1,307 years old (184–1490 CE), Mongun-Tayginsky District, Mongun site. Photos are from the Siberian Dendrochronological Laboratory archive (2019).

autocorrelation, sensitivity, and standard deviation (Wigley et al. 1984).

Results

The TRW measurements and cross-dating analysis were performed for all tree cores collected and all wood discs. The samples were checked for missing rings and frost rings using reference tree-ring chronologies developed for the study region (Myglan et al. 2008; Büntgen et al. 2017). To verify the quality of the cross-dating chronologies for the forest-steppe group, the database *Tree-ring chronologies for forensic botanical examination and dating of architectural structures in the Tuva Republic* was used (Taynik et al. 2022).

818 samples from dead and living trees at the upper treeline were collected and analysed. The oldest dead Siberian larch that we found was 662 years old (1345–2006 CE) at the Kungur site (Figure 1, site 5, black square), on southern spurs of the Ulaan Taiga

Table 1 – The oldest larch trees (Larix sibirica Ldb.) found (a) at the upper treeline in Tere-cholskiy District, Tar site, and (b) in the steppe zone, Ovyurskiy District, Ula site.

(a)

Sample ID*	Years [BCE, CE]	Sample specification	
		Age	Diameter [cm]
Living trees			
07 taris 003	1345–2006	662	32
13 kungur 021	1412–2012	601	30
13 tan 015	1413–2012	600	30
13 kungur 025	1420–2012	593	41
13 kungur 022	1425–2012	588	33
13 kungur 012	1430–2012	583	34
13 kungur 014	1441–2012	572	57
13 tan 010	1447–2006	566	28
07 mongun 018	1447–2006	560	24
08 taris 001	1458–2007	550	23
Average		588	33.2
Dead trees			
16 mongun 033	184–1490	1,307	68
08 mongun 009	960–1818	859	58
08 mongun 301	969–1784	816	48
08 mongun 136	271–1082	812	57
08 mongun 134	565–1374	810	50
07 mongun 005	88–891	804	63
07 mongun N025	861–1636	776	60
13 kol 024	561–1303	743	42
08 mongun 099	968–1707	740	21
08 mongun 086	263BCE–465CE	730	33
Average		840	50

(b)

Sample ID*	Years [CE]	Sample specification	
		Age	Diameter [cm]
18 ula 004	1240–2018	779	63
18 sog 028	1358–2018	661	36
14 han 017	1534–2013	480	22
15 tes 019	1559–2014	456	33
13 sog 014	1568–2012	445	26
18 ula 007	1583–2018	436	21
13 sog 011	1579–2012	434	25
18 sog 024	1589–2018	430	37
14 han 015	1586–2013	428	25
14 han 003	1587–2013	427	31
Average		498	31.9

Note: BCE – Before Common Era; CE – Common Era; ID – Identifier: the first two digits indicate the year of sampling after 2000; the letters indicate the site name; the final digits are the tree number.*

mountain range (Figure 2a, Table 1a). Old living trees were also found at this same site (5 out of 10 presented in Table 1a).

The analysis showed that the maximal age of trees growing in the Mongun-Taiga Massif of Mongun-Tayginsky District (Figure 1, F) is 1,307 years (184–1490 CE), which is the absolute record for conifer trees in Eurasia (Figure 2c; Table 1a).

Ten long-living trees out of 507 collected from the forest-steppe zone were analysed using dendrochronology (Table 1b). We revealed that the oldest living larch tree is 779 years old (1240–2018 CE; Table 1b and Figure 2b), in the Ovyursky District (north of the Uvs Lake Basin). At the Sog site, 80 km west of the Ula site, we selected 4 out of the 10 oldest living trees (Figure 1, sites 2 and 10, white square). The average trunk diameter of the oldest trees is just 63 cm, while younger trees may have a diameter ≥ 80 cm. Another interesting observation is related to the height of the trees, which showed no link with age, since the average height of the oldest trees in the forest-steppe zone is just 7.4 m, while the average height in the stand is about 14 m. This is because among the old trees there are individuals with a broken or withered crown.

The average age of trees at the upper treeline is 588 years; in the forest-steppe zone it is 500 years (Table 1). We did not reveal any significant link between age and DC. There are visual factors other than diameter that indicate old living trees, such as loss of the tree's crown and growth of lateral branches, the absence or traces only of branches on the lower parts of larch trunks, and the colour and shape of the bark scales.

Discussion

The application of tree-ring analysis is an important step in the accurate determination of tree age compared to simple tree-ring counting (Fritts 1976; Schweingruber 1996). For example, in the National registry of old-growth trees in Russia, 39 trees of more than 500 years were documented. However, dendrochronological analysis confirmed just five of these trees as being over 500 years old. The results of our study demonstrate the reliability of dendrochronology for identifying and creating a trustworthy register of old living trees at regional and international levels.

Our earlier tree-ring studies from Tuva Mountain region (Myglan et al. 2008; Taynik et al. 2016; Büntgen et al. 2017; Churakova (Sidorova) et al. 2021, 2022) showed that fallen tree trunks have been well preserved due to the permafrost and dry climate conditions over recent millennia. ID 08 mongun 086 for example (see Table 1) began to grow in 263 BCE and died in 465 CE. Long-living trees found during this study have not yet reached their maximum potential age as the average age for living trees is 588 years, while the average age of dead trees is 839 years, and the maximum age found to date is 1,307 years. This suggests that there are likely to be several trees in the Tuva Mountain region that have reached this record age (or older) for the Boreal zone.

The next step of our work is to formalize the status of old living trees as natural monuments of regional significance in order to protect them from being felled. The present publication could contr

ibute to their protection. In addition, the results, together with the consolidation of the legal status for long-lived trees, will become the basis for increasing their fame and attracting the attention of large public organizations, such as the Russian Geographical Society. In the future, this may stimulate regional authorities, the local population and guests of the Tuva Republic to organize searches for long-living trees and include the oldest specimens in the cultural heritage at Republic level.

Conclusion

We identified a Siberian larch specimen (*L. sibirica* Ldb.) in the forest-steppe zone in the Tuva Republic as being 779 years old. This is an absolute record for living larch trees in the steppe belt of Eurasia. Such old trees are of particular importance because they allow us to assess climate changes at the regional level over a long time period, which is not possible using other data sources (weather station data, for example, go back for no more than 60 years). Thus, the forest-steppe zone affords new opportunities for paleoclimatic reconstructions with a high temporal resolution in inner Asia over millennia.

Another important result was finding the dead larch stem of 1,307 years old, which is currently the record age for the Boreal zone of the northern hemisphere.

Linking science, state and society can help to bridge the gap between the scientific and cultural values of old trees and maximize the importance of the cultural, historical, tourist, dendroclimatic, botanical, recreational, environmental and aesthetic aspects of long-living trees. Such a multiplicity of perspectives on the importance of long-living trees at the regional level in Russia is reflected in the Baikal Rare Trees inventory, created as a part of the Baikal Tree programme (Baikal Tree 2021). Such projects not only allow the preservation of known old trees but may perhaps also lead to the discovery of new natural archives, contributing to awareness-raising of these cultural and historical objects as wonders of the world.

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tree-ring cellulose as indicator of extreme eco-hydrological changes in boreal forests (ECO-HYDROTREE).

Data availability statement

Datasets are available in Zenodo research data repository https://doi.org/10.5281/zenodo.7307751.

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