Wood tomography assessment of internal stem wood decay and growth dynamics of pinus forests in the green zone of Ulaanbaatar city

Ganbaatar Batsaikhan[1], Bayarsaikhan Udval[2], Erdenechuluun Naranbayar[2], Battulga Ganbold[2], Choimaa Dulamsuren[2]

[1] Institute of Geography and Geoecology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia

*Corresponding author. Email: batsaikhang@mas.ac.mn, batsaikhan.ganbaatar@ecology.uni-freiburg.de

INTRODUCTION

Assessing the internal decay of tree stems in forests is essential for estimating forest productivity and greenhouse gas absorption, as well as for developing forest conservation management plans. Therefore, it is necessary to detect the regularity of growth of cedar forests in the green zone affected by recreational use, to make a detailed assessment of stem rot, and to improve the management of cedar forests in the future. Internationally, Sonic tomography (SoT) has been widely used to study stem rot in urban and peri-urban forest trees (Gilbert et al. 2016). It was necessary to observe in detail the process of internal decomposition the stems of cedar forest trees in the green zone of the capital using this tool. The purpose of this study is to evaluate a) growth dynamics, b) climate effect on growth and c) internal decomposition of the stem of the green zone cedar forest and to provide information necessary for forest carbon accounting and modelling.

METHODS

Study location

The study was carried out in the cedar forest, which is affected by the recreational use of the green zone of Ulaanbaatar city (Figure 1). The research area is the southernmost border forest of the Khentii mountain forest distribution in the forest vegetation region of Mongolia, and it belongs to the East Khentii Cape of the Uvur-Baigali forest vegetation region (Tsedendash, 1996).

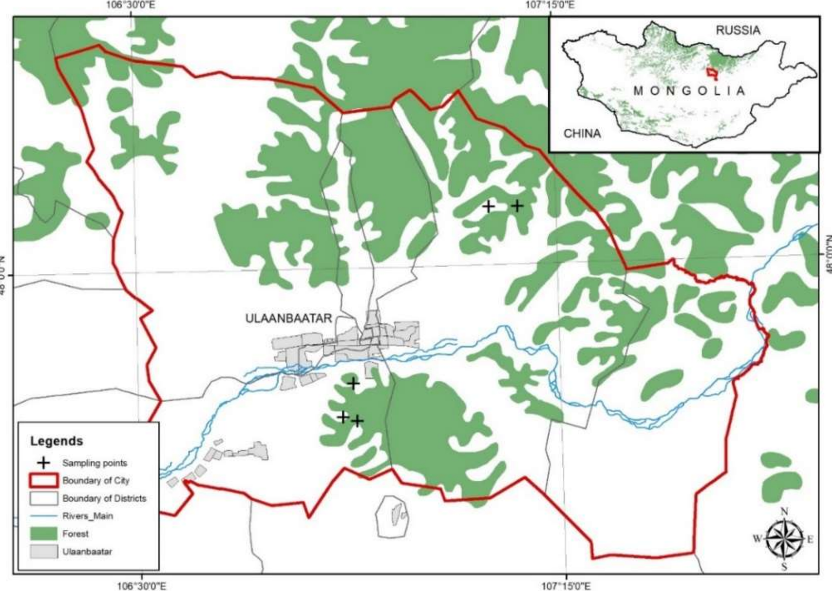

Figure 1. The location of the study area

Field research methodology

The survey was carried out at the end of the vegetative period of the cedar forest and a sample plot of 20 x 20 m (400 m^2) was established and measured and counted. The diameter of the trees in the sample area was measured in tape metres and the height in Vertex, and samples were taken from these trees using a growth drill. In addition, the shape of the trunks of trees over 30 cm in diameter counted in the sample area was measured using a calliper, and decay was measured using an ultrasound tomography device (PiCUS Sonic tomograph) at 50 cm and 150 cm up the trunk. Climate data were downloaded from the International Climate Database (CRU TS version 4.06 - open source).

Statistical processing

The total cedar biomass was calculated using the equation (Equ 1) developed by Altanazakas (Altanzagas et al. 2019).

$$\ln^{*}Y = \ln a + b \_ \ln(D2 \_ H) \qquad (1)$$

here: Ina=-2.736, b=0.889

In addition, the samples drilled to determine diameter increment were measured in the laboratory using the tool "Lintab 6", and the measurement results were processed using the program "TsapWin-4.64". The relationship between tree diameter growth and climate and seed year was determined using the "R 4.2.2" programme.

Materials

The research was carried out in the forest of Nukht pass (NP), Turgen pass (TP) in the Bogd Khan mountain region, Khandgait pass (KP) in Sukhbaatar district, Uliastai pass (UP) in Bayanzurkh district, Sanzai pass (SP) of Chingeltei district, Jigjid pass (JP), Gachuurt's Shar khooloi Shivert pass (GP) and 1 each as well as a total of 7 sample plots were separated and the taxa parameters of 198 trees were measured and growth samples were taken. In addition, tomographic analysis was carried out on a total of 36 trees with a diameter of more than 30 cm (Table 1). The data of the study plots are presented in the following table (Table 1).

Table 1. Collected data

№	Plot	Coordinates	Compocition, age	Altitude, m	Slope, °	Aspect	Density, tree/ha^{-1}	DBH, cm	H, m	BA, m^2/ha	Stock, m^3/ha^{-1}
1	NP	N47°49′22.6″ E106°51′47.5″	5Ps(170)2Ps(130)2Py(230)1Py(125)	1572	12	N	675	18.4	16.4	16.1	134.4
2	KP	N 47°51′45.4″ E106°52′57.2″	4PS(179)2PO(201)2LS(143)2Ps(100)	1533	4	N	950	20.6	13.7	24.3	186.2
3	SP	N 48°08′25.9″ E106°55′5.5″	4Ps(155)3Ls(128)2B(110)1Py(100)	1626	6	N	475	24.4	14.0	27.0	207.3
4	JP	N 47°49′22.7″ E106°51′47.7″	5Ls(103)3Po(98)1Py(100)1Ps(93)+Py(75)	1615	6	EN	800	29.1	15.6	40.3	327.6
5	GP	N 48°04′07.4″ E107°10′55.6″	8Ps(129)2Ls(237)+B(79)	1916	3	N	775	24.0	12.8	36.7	254.1
6	TP	N 47°49′04.7″ E106°53′16.7″	8Ps(135)1Py(144)1Po(148)	1833	4	EN	700	27.2	18.5	59.5	583.6
7	UP	N 48°04′09.0″ E107°07′50.3″	9Ps(124)1Ls(109)	1838	6	N	1025	21.3	14.6	45.7	352.6

Note: DBH-Diameter at breast teight, H-Tree height; BA-basal area; N-north, NE-north-east; PS – Pinus sibirica; PSY – Pinus sylvistris; LS – Larix sibirica; BP – Betula platyphylla; PO – Picea obovata;

RESULTS

State of cedar forest

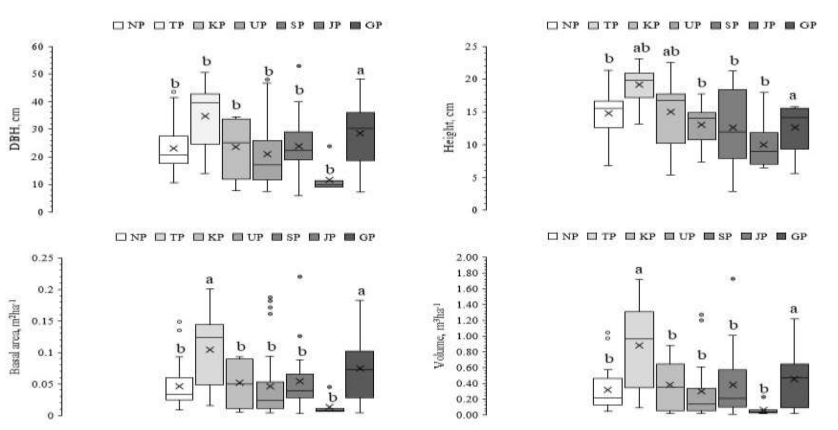

Figure 2. DBH, Height, Basal area and volume indicators of cedar forests and their comparison

According to the results of the research, mature and old cedar forests dominate in the green zone of Ulaanbaatar city. There was a statistically insignificant difference (F=3.01, P<0.014) in the height of the cedar forest in each experimental plot. Tree stem diameter (F=5.21, P<0.000), basal area (F=5.79, P<0.0001), and stock (F=5.87, P<0.0001) were statistically significantly different (Figure 2, Table 1). According to the height growth index, cedar trees in the GP plot ranked first in height, trees in the TP and KP plots ranked second, and trees in other plots ranked third. In terms of diameter, the trees in the GP plot ranked 1st, while the trees in the other areas were all ranked 2nd. However, the basal area of the trees and resources is the same. The trees in the TP1 and GP plots are of first order growth, while the trees in the other plots are of second order growth (Figure 2).

Stem decay of cedar forest trees

14.6% of the trees were big (DBH>30 cm) and the remaining 85.4% were other (DBH<30 cm) trees (Figure 7). Trees less than 30 cm in diameter averaged 704 trees per hectare, accounting for 56% (97.5 t/ha) of the aboveground biomass, while trees larger than 30 cm in diameter averaged 125 trees per hectare, accounting for 56% (97.5 t/ha) of the aboveground biomass. 44% (76.7 tons/ha) respectively (Figure 7). Solid wood percentage of measured by tomography were 94.7%, and the remaining 5.3% were decayed and the percentage of decay was different (Figure 4). Decay is greater in the lower part (up to 1 m) of the tree stem (Markus et al. 2023), this pattern was the same in our study.

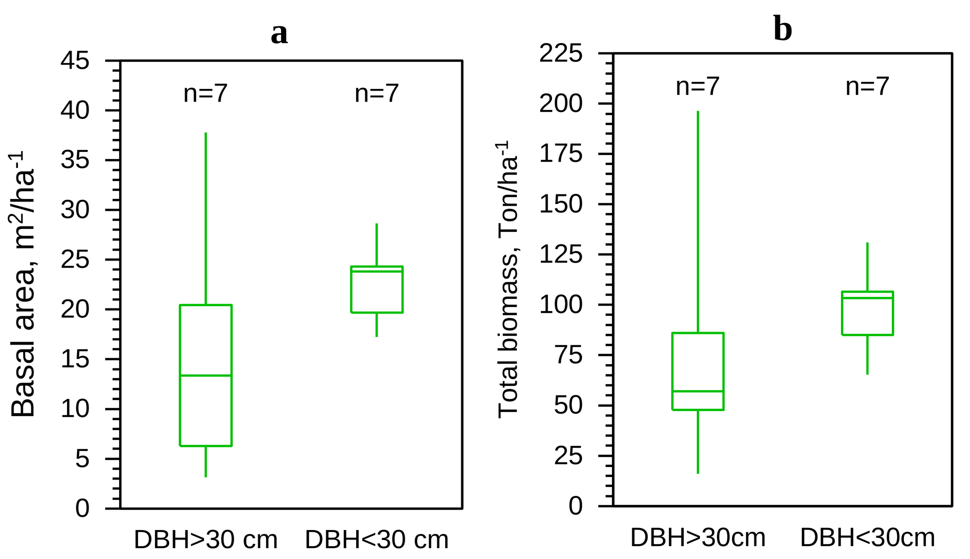

Figure 3. a) Totall basal area, b) total biomass of tree

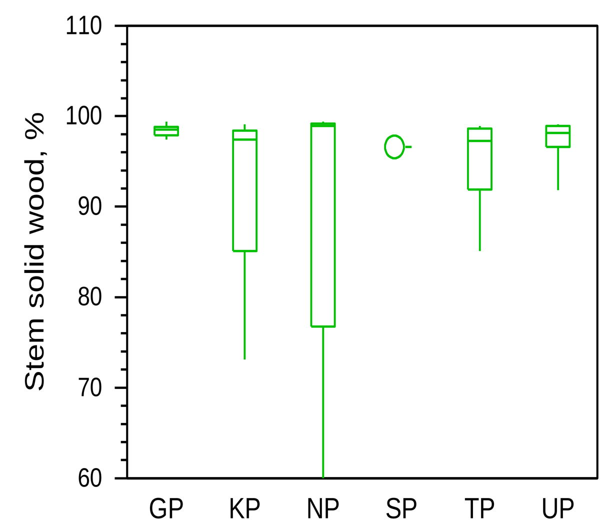

Figure 4. Solid wood percentage of thick (DBH>30 cm) trees in the study area.

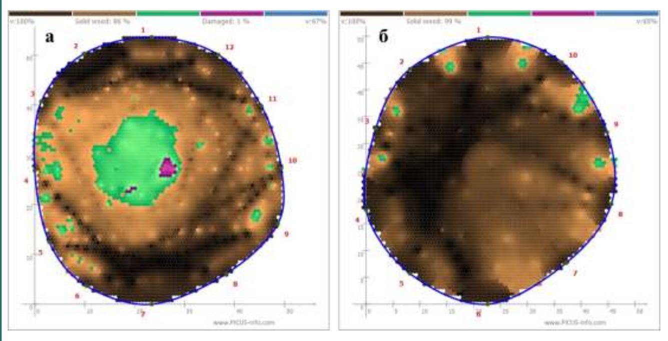

Figure 5. Examples of sonic tomograms of living *Pinus* stems at 50 cm and 150 cm height, where brown color represents solid wood, purple color represents rotten wood, and blue color represents cavities.

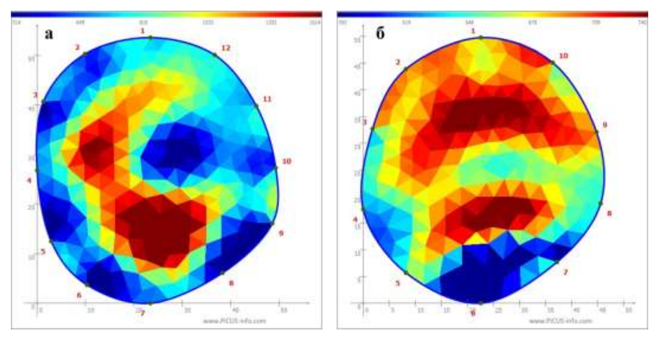

Figure 6. Examples of electric tomograms of living *Pinus* stems at a) 50 cm and b) 150 cm height, where black brown color represents solid wood, blue color represents rotten wood

Figure 7. PiCUS Sonic tomograph.

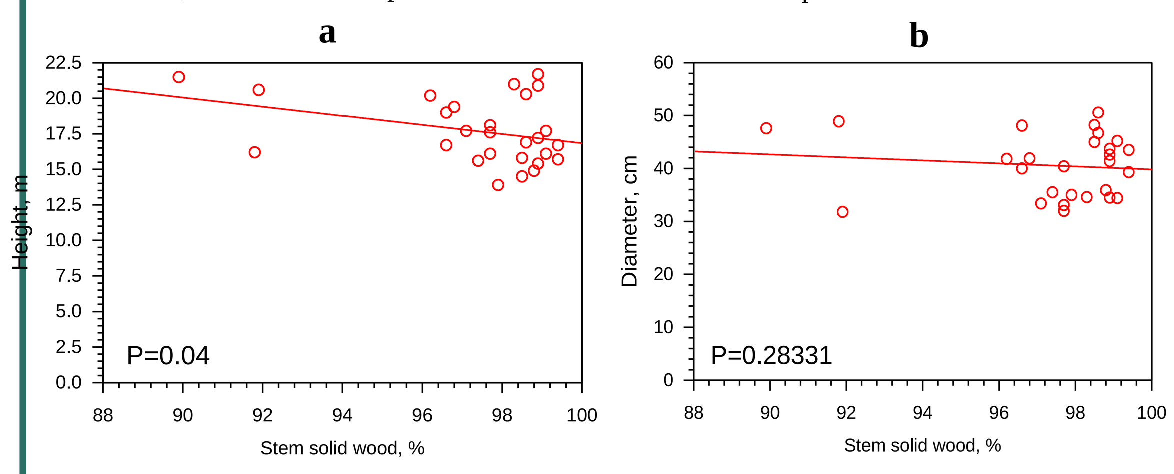

Figure 8. Correlation between a) Height VS Solid wood and b) DBH vs Solid wood. Sampling trees DBH more than 30 cm

Researchers found that studies that assumed all trees in a forest were healthy and unrotted overestimated aboveground biomass by 7% (Heineman et al. 2015). According to our study, 94.7% of the tree stem biomass was not rotted and 5.3% was rotted, with an average of 2.8 tons of rot per 1 ha (Figure 9).

Older trees in a forest store more biomass and carbon than younger trees (Luyssaert et al 2008). But there is decay to some extent, so it is necessary to calculate the absorption taking into account the decay.

Decay of tree depends on nature, weather and external mechanical action (Hietala et al 2015). Decay of stem is dependent on diameter (Figure 8). Decayed trees are at risk of main stems being blown over by strong winds and rain (Putz et al., 1983; Worrall and Harrington, 1988; Shaw et al. 2004).

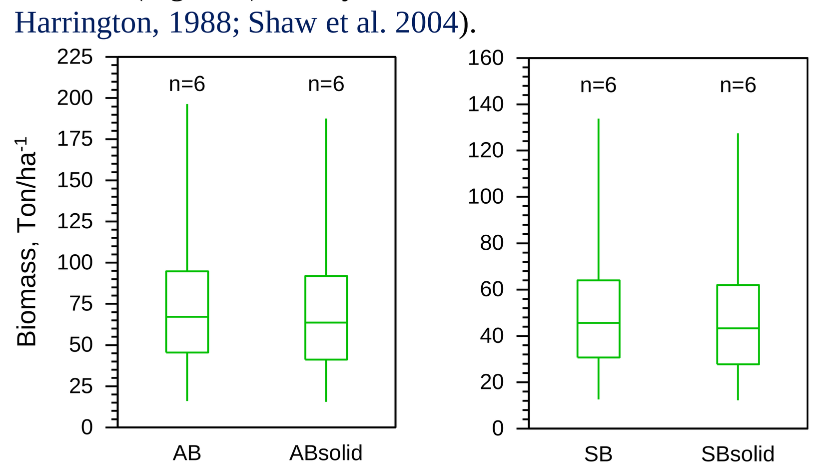

Figure 9. Solid and wood decay biomass of a) total b) stem of large trees in 1 ha area

Figure 10. a) wooden for "muna" hitting and shaking, b, c) fault caused by muna

Radial growth of cedar forest

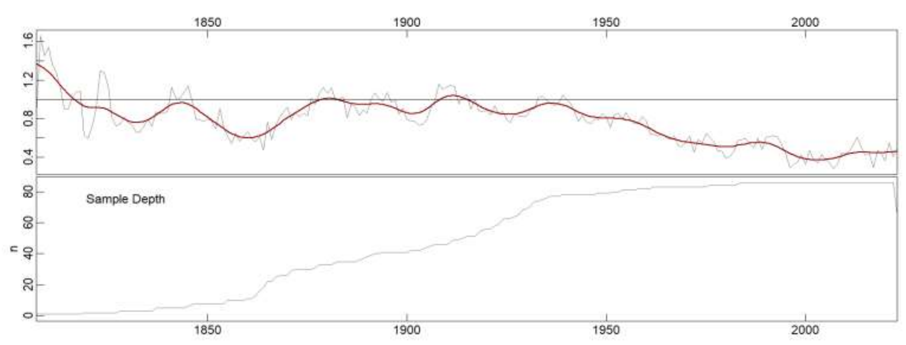

Figure 11. Interannual variation of tree ring widht of *Pinus sibirica*

According to the growth process of the diameter of the cedar forest trees in the green zone, the growth was regular until 1950, then it decreased intensively from 1950, and the growth process increased from 2000 (Figure 11).

The climate data of the study area were compared and analysed with the radial diameter growth of the cedar trees (Figure 12). According to the results of the research, July air temperature and June precipitation in 1900-1950, June rainfall in 1940-1995, September precipitation in 1961-2010, 2014 - 2018 precipitation in April had a positive effect on the growth of the trees. However, air temperature in April 1950-1960, precipitation in May 1960-1980 and winter air temperature in recent years had a negative effect (Figure 12).

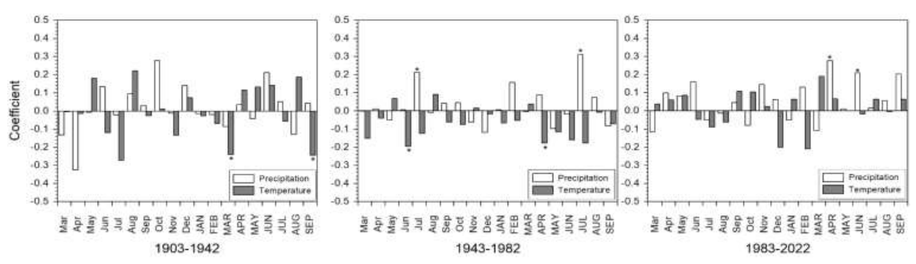

Figure 12. Correlation of tree growth (Ring-width-index) with monthly-resolution climate data (monthly total precipitation and monthly mean temperature). The correlations were calculated for three observation period (1903–1942, 1943-1982, 1983-2022). Uppercase (lowercase) letters represent current- (previous)-year climate variables. * Indicates a significant correlation at the 0.05 level.

In particular, the air temperature at the beginning of the vegetative period (r = -0.76) strongly affects the growth of the diameter, and the amount of rainfall in the IV and V months and the duration of extremely dry days are the main factors determining the growth of the diameter (Figure 12).

Instead, data on cedar seed exports over the last decade were plotted against diameter growth. From this, it is apparent that a trend exists whereby diameter growth slackens during years of abundant cedar nut ripening (r=-0.2) and the subsequent year (r=-0.18). This proves that the time and technique employed for collecting cedar nuts can impede the growth of tree diameter (refer to Figure 13).

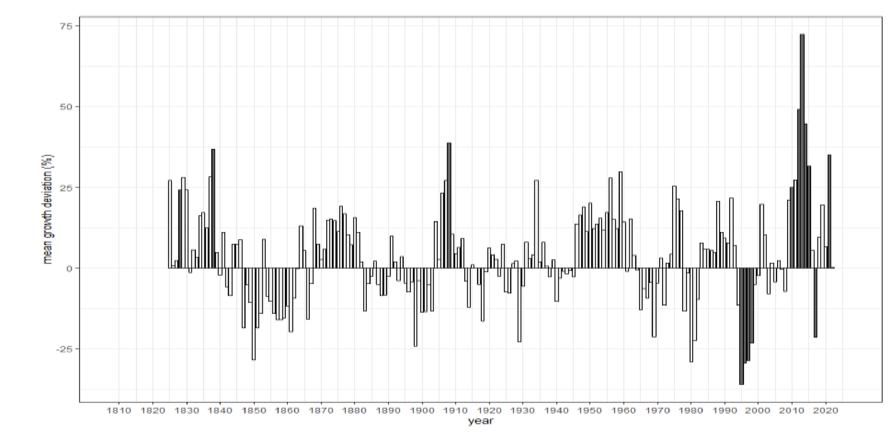

Figure 13. Cedar diameter growth in the green zone. In black, years identified as positive or negative pointer years are highlighted.

Figure 14. a) Taking core, b) measuring the core on the lintab instrument.

CONCLUSIONS

The field has fewer trees (DBH>30cm), but they account for half of the total biomass aboveground. All of these thick trees had decayed to varying degrees. Large, older trees contribute significantly to global forest biomass and consequently organic carbon reserves, and they play a unique role in biodiversity conservation and climate change mitigation. As a result, it is critical to maintain and accelerate the growth and development of normal and dominating dominant trees, and it is recommended that their protective management be prioritized. The use of sound tomography (SoT) and electrical resistant tomography (ERT) to the study of stem rot in forest trees has proven to be extremely useful in estimating forest production and sequestration, as well as developing forest conservation management.

Acknowledgement: I would like to thank the whole team of the project headed by Professor Markus Hauck for giving me the opportunity to conduct the research. Also, thank you for researchers division of forest resources and forest protection of the Institute of Geography and Geoecology of MAS, who provided human resources and management for the field work.

IASFRMCA

2 October 2024 Ulaanbaatar Mongolia