Turkish Journal of Earth Sciences

http://journals.tubitak.gov.tr/earth/

Research Article

Turkish J Earth Sci
(2022) 31: 622-628
© TÜBİTAK
doi:10.55730/1300-0985.1823

A case study on geomorphology: Tree-ring-based confirmation of the formation year of Lake Kaindy after the 1911 Kemin earthquake in Almaty (Kazakhstan)

Ünal AKKEMİK[1,*], **Kuralay MAZARZHANOVA**[2], **Arailym KOPABAYEVA**[2]

[1]Department of Forest Botany, Faculty of Forestry, İstanbul University-Cerrahpasa, Bahçeköy, İstanbul, Turkey

[2]Department of Forest Resources and Forestry, Faculty of Forestry, Wildlife and Environment, S. Seifullin Kazakh Agrotechnical University, Nur-Sultan, Kazakhstan

Received: 12.08.2022 • **Accepted/Published Online:** 16.10.2022 • **Final Version:** 16.11.2022

Abstract: Lake Kaindy, which is located in the Kazakhstan side of the Tien Shan Mountains is one of the most famous places in the World due to having sunken *Picea schrenkiana* Fisch. & C.A.Mey. trees within the Lake. The purpose of the study is to find the dead years of the sunken trees in the lake and therefore to confirm the formation time of Kaindy Lake, and if there is an effect of the 1911 Kemin earthquake on the tree-ring width of *Picea schrenkiana* around the lake. Eight wood pieces and two increment cores from the sunken trees were taken to find the formation time of the lake. For building a reference chronology to date these sunken woods, a total of 43 increment cores from 25 trees of *Picea schrenkiana* were extracted by using an increment borer 50 cm long. Four sunken trees were dated to 1912, and dating statistics which are Gleichlaufigkeit value (percentage of parallel variation), t-tests (T_V, T_{VB}, T_{VBP}), and CDI (cross-dating index) were calculated as 74%(***), 3.3(**), 7.9(***), 9.7(***) and 57, respectively, and all are significant. According to the 11-year event analysis, the ratio of decrease after the earthquake is 34% in older trees, and 20% in younger ones. One of the main reasons for long-term decreasing growth may be breaking the root tips and dying the roots with the effect of the violent vibration in the earthquake. With this dendrogeomorphological study, the formation date of Lake Kaindy was determined as 1911 and the local information was confirmed with tree-ring data. After the year of the great earthquake, a long-term dry period occurred up to the years of 1930s. Tree-ring results showed that the affected trees from the earthquake produced narrower rings during this dry period.

Key words: Dendrogeomorphology, dating, tree ring, dendrochronology, lake formation

1. Introduction

Lake Kaindy is one of the most famous places in the World due to having sunken *Picea schrenkiana* trees within the Lake. It is located on the Kazakhstan side of the Tien Shan Mountains and is covered with great forests. Because the water of the Lake is cold (note more than 6 °C also in summer), the sunken trees are not still rotten and standing in good conditions, and therefore they have a wonderful appearance. In winter the lake's surface is much colder and mostly freezes.

According to the information provided by the local people, the lake was formed when the river was blocked as a result of a large landslide in the great earthquake of 1911. This earthquake was called the 1911 Kebin earthquake or the Chon-Kemin earthquake. Delvaux et al. (2001) stated that this 1911 Kemin Earthquake was observed in the field over a total of 190 km and its magnitude was Ms-8.2 (Delvaux et al., 2001; Campbell et al., 2015).

As is well known, earthquakes are great catastrophic natural events in the World. The 1911 Kemin Earthquake, which is one of the most severe earthquakes in the world, caused catastrophic events. Havenith et al. (2003) explained that two large landslides occurred after the 1911 Kemin earthquake called the Kaindy rock avalanche and the Ananevo rockslide, and "*the Kaindy landslide, with a volume of 15 × 10⁶ m³, was formed of a mass of limestone that buried a group of yurts and killed 38 people*". Delvaux et al. (2001) stated a landslide occurred in Kaindy and called it as Kaindy Landslide, and explained "*The largest, Kaindy, rockslide of about 8–10 mln m³ in volume lies immediately on the path of a seismogenic rupture related to the left-bank segment.*"

After great earthquakes, landslides, land masses (e.g., Jacoby and Ulan, 1983) and lake formations (e.g., Aytuğ and Kılıç, 1993) may occur in any part of the affected area. If the fault line passes under or close to the root system of a tree, and the roots are cracked by a major earthquake, tree may be affected by it and may respond by producing narrow or wide rings after the event (Schweingruber, 1988). Yadav and Kulieshius (1992) performed a study on

* Correspondence: uakkemik@istanbul.edu.tr

trees from three stands of *Picea schrenkiana* growing on the northern Zaileeskii Alatau mountain ranges near the epicenter of the 1887 earthquake, and they suggested that suppression on tree-ring widths of particularly two trees occurred just after the earthquake and extended up to 15 years (Yadav and Kulieshius, 1992).

Within Kaindy Lake (Saty-Almaty, Kazakhstan), there are many sunken trees of *Picea schrenkiana*. The purpose of the present dendrogeomorphology study is to find (1) the dead years of the sunken trees in the lake and therefore to confirm the formation time of Kaindy Lake, and (2) if there is an effect of the 1911 Kemin earthquake on tree-ring width of *Picea schrenkiana* around the lake.

2. Materials and methods

The study area is Lake Kaindy and its environs (Figure 1). The geographic coordinates of the lake, which is located in the Almaty region are 42°59'6.16"N and 78°27'57.19"E, respectively, and its altitude is 1897 m a.s.l. (Figure 1). Within many sunken trees in Lake Kaindy (Figure 2), eight wood pieces and two increment cores from ten sunken trees were taken to find the formation time of the lake (Figures 1 and 2).

For reference chronology 43 increment cores from 25 trees of *Picea schrenkiana* were collected from the western slope of the lake (Figures 2b–2c). Within these samples, older trees were selected, and 21 cores from 12 trees were used to build a reference chronology, which is older than the year of the 1911 Kemin earthquake. All cores from living trees were coded as KAY, and the dead (sunken) trees as KAG.

In the laboratory, all cores mounted the wooden carriers to protect against broken, and then the transversal surfaces of the cores and the woods were sanded to see clearly tree-ring borders. Before measurements, all tree rings were divided into sections ten-year by ten-year for cross-dating. LINTAP-TSAP measuring system (Rinntech) was used in all measurements and dating processes. The COFECHA program (Holmes, 1983) was used to check the quality of the reference chronology and later ARSTAN Program (Cook, 1985; Grissino-Mayer et al., 1996) was used to build three different versions of chronology, standard, residual, and arstan to remove the effect of age. The standard version of the reference chronology was used for dating. All standardized individual chronologies from dead trees were dated by using TSAP.

In dating, Gleichlaufigkeit value (percentage of parallel variation between reference chronology and floating chronology), T_V (standard t-value of correlation), T_{VBP} (t-value after detrending with moving average with bandwidth = 5 and logarithm to base *e* (Baillie and Pilcher, 1973), max = 100), T_{VH} (t-value after detrending with the Wuchswert (Hollstein, 1980), max = 100) and CDI (crossdating index-date index, combined from t-values and Gleichlaeufigkeit values, max = 1.000) were calculated by TSAP to show the quality of dating.

To find the effect of the 1911 Kemin earthquake, first, we selected 19 cores from 12 trees, which are the number of tree rings that exceed the year of the earthquake. Later, we divided these 12 trees into two groups younger than the year of 1880 and older than this year. The reason for this grouping is to find the responses of younger and older trees to the earthquake. Six trees are older than the year of 1880, and the other 6 ones are younger than this year (they were about 30 years old in the year of the earthquake and they were young). We again built two different standard chronologies for these two groups. Later 11-year moving averages of standard versions of the reference chronologies were calculated.

Furthermore, the EVENT analysis (Grissino-Mayer et al., 1996) was performed on the standard chronologies. This analysis was performed for the window of years before and after the event year (1911):±11 years.

3. Results and discussion

After all analysis, a reference chronology covering the years 1818–2022 was built for around Lake Kaindy (KAY in Figure 3). COFECHA output showed statistically significant results. The average of series intercorrelations of all cores is 0.79 (***), and their average mean sensitivity is 0.31. According to the COFECHA results, there are not any problems in the segments of the cores. The sensitivity, which is a measure of changes in tree-ring widths from one year to the next one (Fritts, 1976), is high (more than 0.20), and therefore we can discuss that trees produce sensitive rings in this area.

The individual chronologies of the dead trees were dated with the reference chronology (Table) and their mean chronology showed good correlations with the reference chronology (KAG in Figure 3). Their statistical results are generally significant and 5 of them were related to the formation of the Lake and the earthquake in 1911 (Table). The trees coded as KAG2, KAG3, and KAG9 were dated to 1912, and KAG6 was dated to 1911. Probably these three trees, which died in 1912, lived one more year after the earthquake. In some of the trees, outer rings were eroded, and the last rings were not determined. The last years of the woods without last rings range from 1862 to 1882, and they evaluated that they did not relate to the earthquake.

In the valley of Lake Kaindy, many dead trees were observed within the river, and probably they were moved with overflows. Some of the wood studies (e.g., KAG4, KAG5, KAG8) may be moved with overflows, and they did not relate to the earthquake. The in-situ samples are completely related to the earthquake (Table). The first

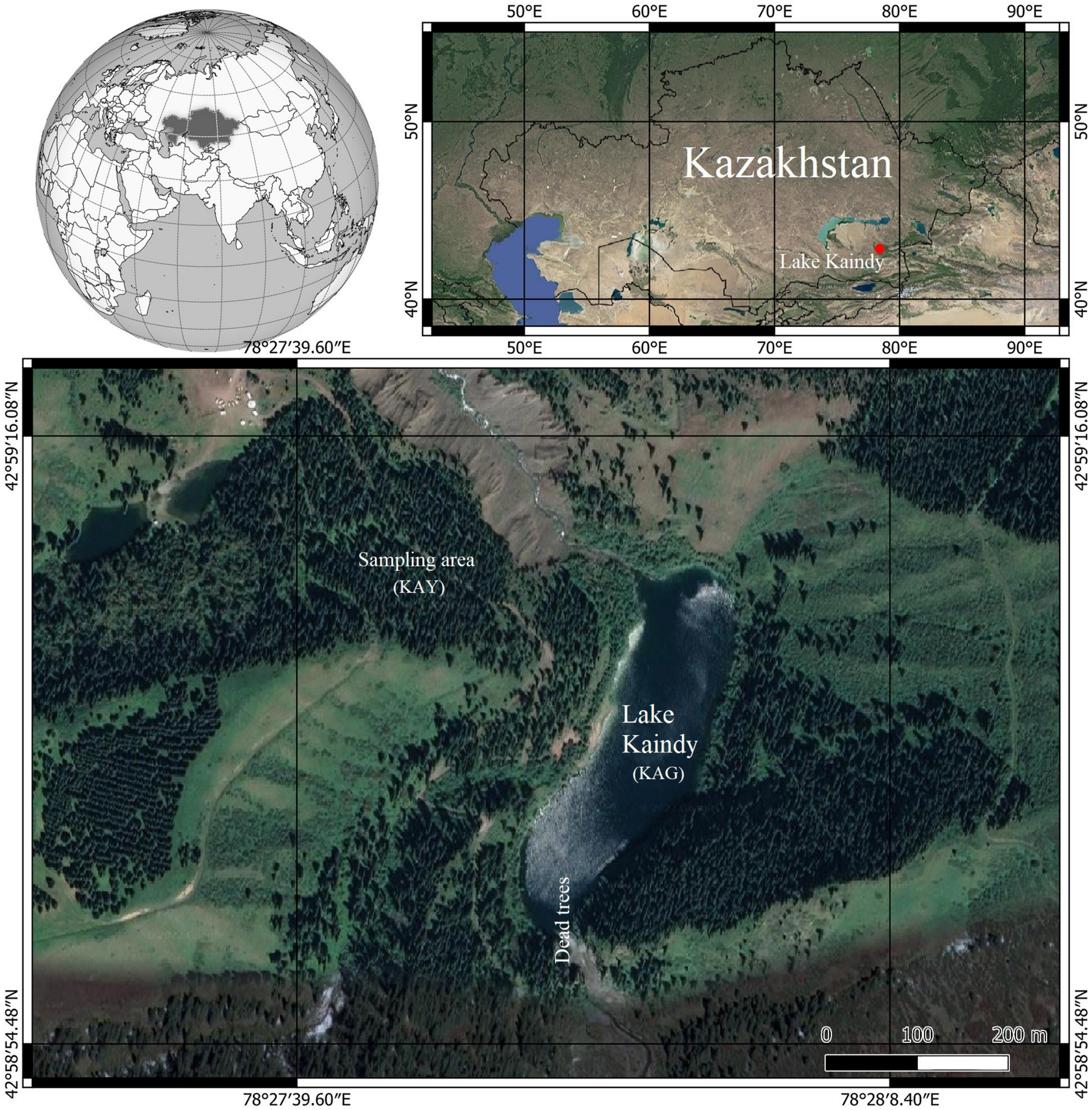

Figure 1. The location of Lake Kaindy and its environs. The cores from living trees in "Sampling area (KAY)" were collected. The sunken trees in the southern border of Lake Kaindy (KAG) were sampled.

sample KAG1, which was out of the lake and fell down to the river, dated to 2016.

Finally, the standard mean chronology built from dead trees was dated to 1912 (KAG in Figure 3). Gleichlaufigkeit value (percentage of parallel variation), T_V, T_{VB}, T_{VBP} and CDI (crossdating index) were calculated as 74%(***), 3.3(**), 7.9(***), 9.7(***) and 57, respectively. All these values are statistically significant (Table) and represent reliable dating.

To find the effect of the earthquake on tree-ring widths of *Picea schrenkiana*, the sampled living trees were divided as older, which goes back to earlier than the year of 1880, and younger, which is younger than the year of 1880 (Upper in Figure 4). Eleven-year moving average chronologies of the older and younger trees showed a clear difference in response to the earthquake (Lower in Figure 4).

A long-term decrease in tree-ring widths was seen between the years 1911–1930. Decreases in ring widths are higher in older trees and lower in younger ones. According to the 11-year event analysis, the ratio of decrease after the earthquake is 34% in older trees, and 20% in younger ones. Regarding the effect of the earthquake in 1887 in Almaty, Yadav and Kulieshius (1992) pointed out that its negative effect extended up to 15 years on tree-ring widths. The reason for these negative events on tree-ring widths may be 1) Because *Picea* trees produce surface roots and because

Figure 2. Lake Kaindy; a) General appearance of Lake Kaindy with sunken trees (KAG) inside and the valley, b) Arrows indicate the sampled trees in the southern border of the lake, c) Sampled trees with an increment borer.

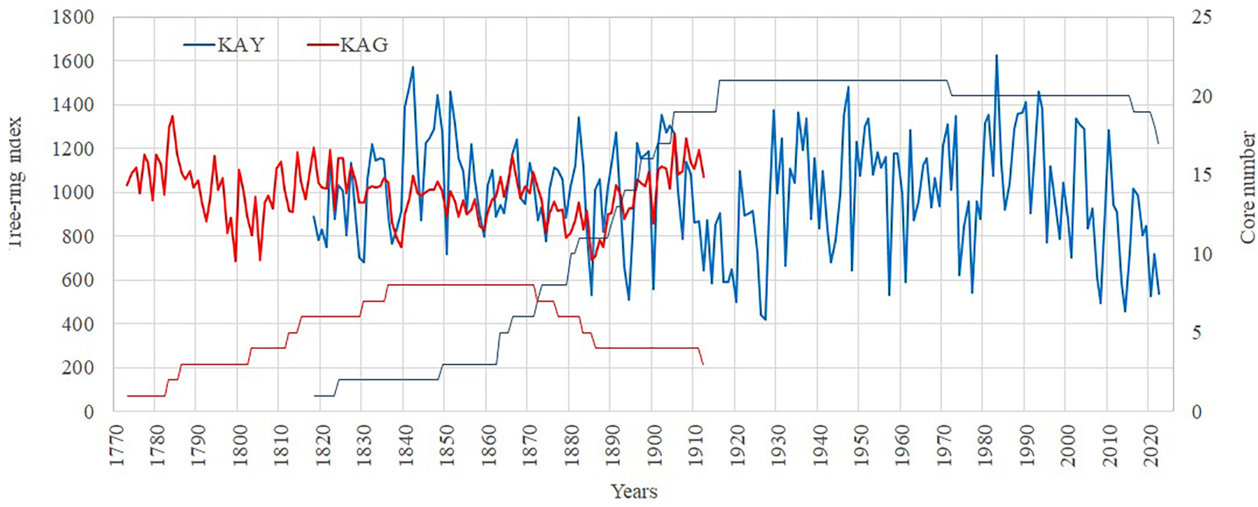

Figure 3. The reference chronology (KAY, blue one) and dating of the mean floating chronology from the lake (KAG, red one) to the year of 1912, and their core numbers.

Table. Dating results of the ten dead (sunken) trees (KAG1 to KAG10).

Individual chronology	**Cover years on the reference chronology**	**Last ring**	**Position in the area**	**GL (%)**[1]	**T_{VH}**[1]	**CDI**[2]	**Dated to the year**	**Related to the great earthquake in 1911**
KAG1	1956–2018	+	Lying	78***	5.7***	39	2016	No
KAG2	1783–1912	+	In situ-erect	62*	4.0***	22	1912	Yes
KAG3	1863–1912	+	In situ-erect	67**	5.1***	32	1912	Yes
KAG4	1815–1871	–	Lying	66**	4.7***	29	1871	No
KAG5	1803–1876	–	Lying	65*	3.3**	18	1876	No
KAG6	1836–1911	+	In-situ-erect	65**	4.6***	25	1911	Yes
KAG7	1830–1882	+	Lying	73***	3.5***	25	1882	No
KAG8	1786–1862	–	Lying	66*	3.8***	21	1862	No
KAG9	1773–1912	+	In situ-erect	68***	3.9***	26	1912	Yes
KAG10[3]	1812–1885	–	In situ-erect	61*	3.5***	21	1885	Yes
KAG	**1773–1912**	**+**		**74*****	**9.7*** **	**57**	**1912**	**Yes**[4]

[1)] *)95% confidence level, **)99% confidence level, ***)99.9% confidence level.
[2)] There was not described threshold for significance in CDI. A value more than 20 for individual chronology, and more than 30 for mean chronology may be evaluated as reliable dating in general.
[3)] Last part of the tree-rings of this sample decomposed because they were rotten, and the last tree rings could not be measured. This wood may have probably died after the earthquake, and therefore we may relate it to the earthquake.
[4)] The sample KAG1, dated to 2016, was excluded from calculating the mean chronology (KAG). Therefore, the mean chronology from the sunken trees (KAG) was related to the earthquake.

of occurring soil erosion after an earthquake, some surface roots may be destroyed. 2) Because of the vibrations that occurred during the earthquakes, many undignified roots may have been broken away.

With respect to the age of the trees, due to having a smaller crown and higher potential of growing energy, young trees may have been affected less and overcame the negative effect of the earthquake. On the contrary, because of having a bigger crown and lower potential for growing energy, older trees may have been affected much more seriously.

On the other hand, the reason for this decrease in 1911–1930 may also be drought. Several dendroclimatological studies in Kazakhstan and its environs (e.g., Chen et al.,

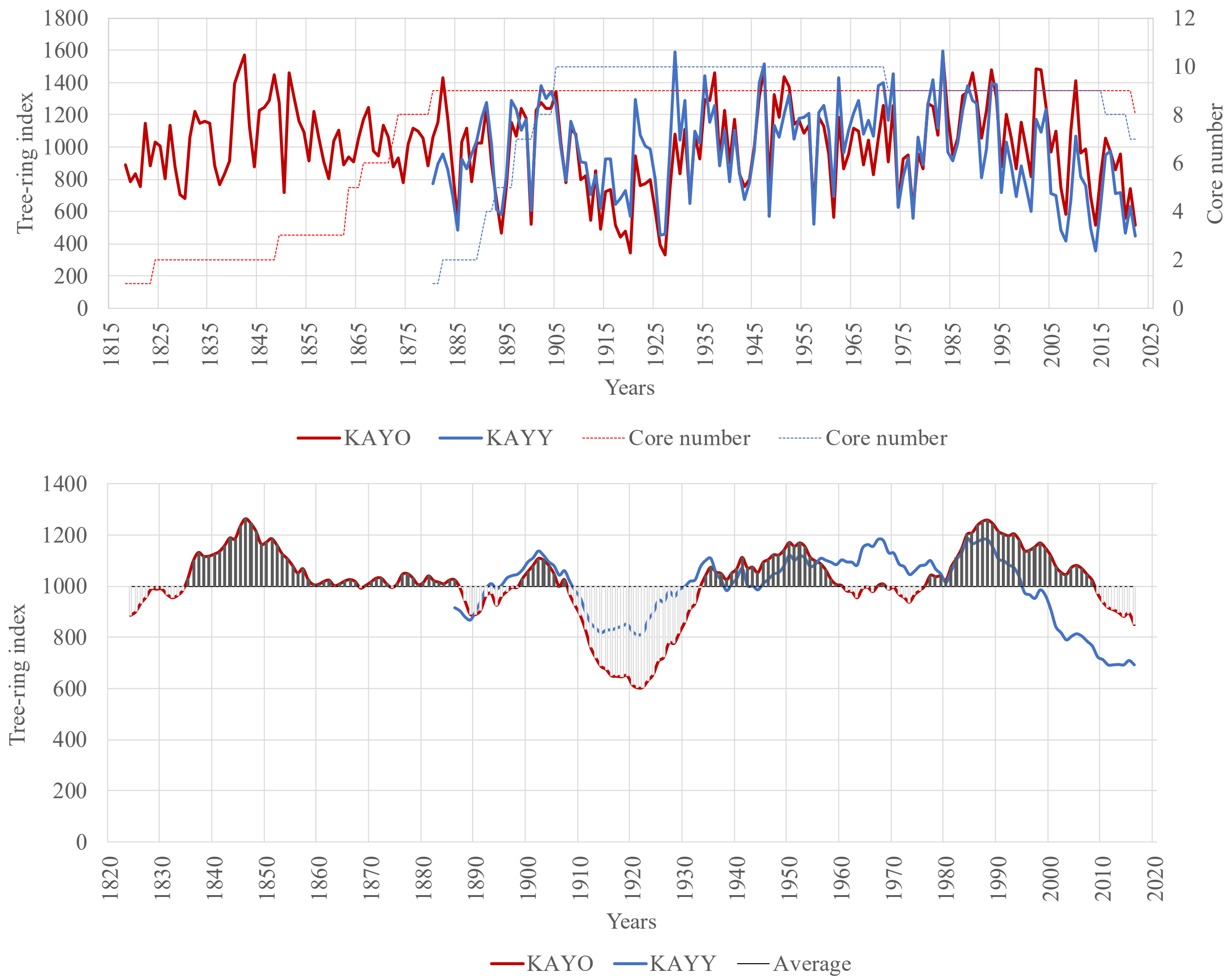

Figure 4. The chronologies of the younger and the older trees from Kaindy Lake (upper), and their 11-year moving averages (lower). KAYO represents older trees than the year of 1880, and KAYY younger trees than the year of 1880. Arrow indicates the negative effect of the 1911 Kemin earthquake.

2012, 2017; Davi et al., 2006, 2009) did not show any dramatic decrease in this time interval. Kopabayeva et al. (2017) and Mazarzhanova et al. (2017) studied the response of tree-ring widths of *Pinus sylvestris* L. in the Burabai region to climate change, which is in northern Kazakhstan, and did not show any dramatically decrease in this time span. On the contrary, Zhang et al. (2016, 2019) showed that a drought period in this time interval including the driest year 1917 in the Tien Shan mountains, which is nearer to Lake Kaindy.

Because of climate change, drought is increasing in many parts of the world (IPCC, 2015). Dendroclimatological results showed that the recent drought effect is much higher than the former ones (e.g., Zhang et al., 2016, 2019; Kopabayeva et al, 2017). For that reason, as also indicated by Yadav and Kulieshius (1992), the negative effect of the earthquake caused a dramatic decrease in tree-ring widths in particularly older trees and its negative effect extended up to the 1930s.

4. Conclusion

The trees of *Picea schrenkiana* revealed a very high correlation with each other in Lake Kaindy, and based on these good relationships, a reference chronology was built for dating and further dendroclimatological studies. With this dendrogeomorphological study, the formation date of Lake Kaindy was determined as 1911, and the local information was confirmed with this study. This Lake was formed probably just after the great earthquake occurred in 1911. Some of the sunken trees stayed within the water of the lake, living one more year, and died in 1912. Although there was a two-decade drought period just after the great earthquake, this event triggered a negative effect on tree growth, and therefore trees produced very narrow rings up to the 1930s. Finally, tree rings are good tools to understand the nature of geomorphological events whenever appropriate trees are found.

Acknowledgment and/or disclaimers, if any
We thank the staff in State National Nature Park «Kolsay Lakes» who are Ualiyeva Bagdat (Head of Science and Monitoring Department), Arinov Baurzhan (doctoral student in Kazakh National Agrar University), Nesipzhanov Marat, Nurpeisov Adlet, and Otegenov Serikbol (forest engineers in Kolsay Forestry), Amanbayev Sayat (forest engineer in Karabulak Forestry) for their kind helps in sampling. We also thank two anonymous reviewers for their valuable suggestions.

References

Aytuğ B, Kılıç A (1993). Contribution d'Une Etude Dendrochronologique il la. Constatation de i'Age du lac Sülük (Bolu), Proceeding of the 5th Optima Meeting, 8-15 September 1986, ss 219-233.

Baillie MGL, Pilcher JR (1973). A simple cross-dating program for tree-ring research. Tree-Ring Bulletin 33:7-14.

Campbell GE, Walker RT, Abdrakhmatov K, Jackson J, Elliott JR, et al. (2015). Great earthquakes in low strain rate continental interiors: An example from SE Kazakhstan, Journal of Geophysical Research: Solid Earth, 120. https://doi.org/10.1002/2015JB011925.

Chen F, Mambetov B, Maisupova B, Kelgenbayev N (2017). Drought variations in Almaty (Kazakhstan) since AD 1785 based on spruce tree rings. Stochastic Environmental Research and Risk Assessment 31: 2097-2015. https://doi.org/10.1007/s00477-016-1290-y

Chen F, Yuan Y, Wei W, Wang L, Yu S et al. (2012). Tree ring density-based summer temperature reconstruction for Zajsan Lake area. East Kazakhstan. International Journal of Climatology 32: 1089–1097. https://doi.org/10.1002/joc.2327

Cook E (1985). A time series analysis approach to tree-ring standardization. Unpublished PhD dissertation. University of Arizona. Tucson.

Davi NK, Jacoby GC, Curtis AE, Baatarbileg N (2006). Extension of drought records for Central Asia using tree rings: West-Central Mongolia. Journal of Climate 19 (1):288–299. https://doi.org/10.1175/JCLI3621.1

Davi NK, Jacoby GC, D'Arrigo RD, Baatarbileg N, Jinbao L et al. (2009). A tree-ring-based drought index reconstruction for far-western Mongolia: 1565–2004. International Journal of Climatology 29: 1508–1514. https://doi.org/10.1002/joc.1798

Delvaux D, Abdrakhmatov KE, Lemzin IN, Strom AL (2001). Landslides and surface breaks of the 1911 Ms 8.2 Kemin earthquake. Russian Geology and Geophysics 42 (10): 1583–1592.

Fritts HC (1976). Tree rings and climate. Academic Press London, New York, San Francisco.

Grissino-Mayer HD, Holmes RL, Fritts HC (1996). International Tree-Ring Data Bank Program Library Version 2.0 User's Manual. Laboratory of Tree-Ring Research, Tucson, 106 pp.

Havenith HB, Strom A, Jongmans D, Abdrakhmatov K, Delvaux D et al. (2003). Seismic triggering of landslides, Part A: Field evidence from the Northern Tien Shan. Natural Hazards and Earth System Sciences. European Geosciences Union 3: 135–149. https://doi.org/10.5194/nhess-3-135-2003

Holmes RL (1983). Computer-assisted quality control in tree-ring data and measurements. Tree-ring Bulletin 43: 69–78.

Hollstein E (1980). Mitteleuropäische Eichenchronologie. Verl. Philipp von Zabern, Mainz, 273 pp (in German).

IPCC (2015). Climate Change 2014 Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

Jacoby GC, Ulan LD (1983). Tree ring indications of uplift at Ice Cape, Alaska related to 1899 earthquakes. Journal of Geophysical Research 88: 9305-9313.

Kopabayeva A, Mazarzhanova K, Köse N, Akkemik Ü (2017). Tree-ring chronologies of *Pinus sylvestris* from Burabai Region (Kazakhstan) and their response to climate change. Dendrobiology 78: 96-110. https://doi.org/10.12657/denbio.078.010

Mazarzhanova K, Kopabeyeva A, Köse N, Akkemik Ü (2017). The first forest fire history of the Burabai Region (Kazakhstan) from tree rings of *Pinus sylvestris.* Turkish Journal of Agriculture and Forestry 41: 165-174. https://doi.org/10.3906/tar-1610-72

Schweingruber FH (1988). Tree rings, Basics and applications of dendrochronology, Kluwer Academic Publishers, The Netherlands.

Yadav RR, Kulieshius P (1992). Dating of earthquakes: tree ring responses to the catastrophic earthquake of 1887 in Alma-Ata, Kazakhstan. The Geographical Journal 158 (3): 295-299.

Zhang R, Ermenbaev B, Zhang T, Ali M, Qin L et al. (2019). The radial growth of Schrenk spruce (*Picea schrenkiana* Fisch. et Mey.) records the hydroclimatic changes in the Chu River Basin over the past 175 years. Forests 10 (3). https://doi.org/10.3390/f10030223

Zhang R, Yuan Y, Gou X, He Q, Shang Het al. (2016). Tree-ring-based moisture variability in western Tianshan Mountainssince A.D. 1882 and its possible driving mechanism. Agricultural and Forest Meteorology 218–219: 267–276. https://doi.org/10.1016/j.agrformet.2015.12.067