

Radial growth and climate signals of *Picea schrenkiana* at different elevations in the Sary-Chelek Biosphere Reserve, Kyrgyzstan

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Introduction

Kyrgyzstan is a Central Asian Republic located in the north of the Tian Shan mountains massif. Most of these territories (93%) is located between the altitudes of 800 to 3000 m a.s.l. The territory of Kyrgyzstan was divided into eight different climate regions. Spruce occupies almost all of the regions. In the Fergana-Chatkal region (third Kyrgyz Forest Region), Schrenk spruce reaches its south range (Gan 1970, Grisa et al. 2008). Most of the forests here are situated in the Sary-Chelek Biosphere Reserve. This Reserve is one of the most interesting and unique places in the Fergano–Chatkal forest region, recognizes a UNESCO Biosphere Reserve (Grisa et al. 2008). Except spruce forest, in the Sary-Chelek there are also walnut-fruit forests and juniper forests, which are included in the Red Book of Kyrgyzstan (Antonia et al. 2009).

In the Sary-Chelek Reserve Schrenk spruce found good growing conditions, but spruce stands are very fragmented and grow at different elevations, where climate factors create diversified growing conditions. The altitude of spruce stands in Sary-Chelek varies from 1300 to 2500 m a.s.l. (Grisa et al. 2008).

The objective of this study was to answer the question about climatic factors influencing radial growth of spruce trees at different elevations: 1350-1400, 1500-1600 and 1900-2000 m a.s.l. in the Sary-Chelek Biosphere Reserve.

Material and methods

The study was conducted in the Sary-Chelek Biosphere Reserve (Fig. 1), which is situated on the southern slopes of Chatkal massif in the western mountain ranges of the Tian Shan. The climate at Sary-Chelek station, located at 1100 m asl., is classified as dry continental, with hot summers (type DS according to Köppen 19xx; Grisa et al. 2008). The average annual temperature is 7.9°C. The hottest month is August, with a mean temperature of 19°C. The coldest month is January, with the average temperature of -5.3°C. The average annual rainfall is 993 mm. Most of the rain falls in spring (March-May), when monthly precipitation reaches 120-150 mm. The least rainfall occurs in August and September (average 37 mm per month).

Increment cores were collected in 2010 during field campaign organized within the Erasmus-Mundus External Cooperation Window Asia programme. The study plots were located at various altitudes: 1350-1400, 1500-1600, and 1900-2000- m a.s.l., with north slope ranging from 35 to 50 degrees. The lowest study plots were established near the Sary-Chelek village, while the most upper site was located next to the Sary-Chelek lake, which is located about five kilometres from the village. Increment cores (one per tree) were sampled from dominant and co-dominant trees perpendicularly to the slope to minimize the effects of slope on the tree ring width. There were 15-20 trees sampled in each plot, depending on the number of trees located in the area.

Tree-ring widths were measured using the CooRecorder 7.3 software, and verified using CDdendro 7.3 (www.cybis.se). After COFECH analyses samples with low cross-correlation results were eliminated based on results (Holmes 1983). After COFECH analyses were eliminated samples with low cross-correlation. To build residual chronology all samples from the lower site were used, 17 samples from the middle one and only 13 samples from the upper. The ARSTAN

software was used (Cook and Holmes 1986; Cook and Kairiukstis 1990) to develop residual chronologies by detrending method (negative exponential curve with straight line). The residual chronology was used for comparison of the radial increment of spruce in the analysed area. The following basic statistical measures of ring widths were calculated: arithmetic mean, maximum, minimum and median values, standard deviation, coefficient of variation, and mean sensitivity (Tab. 1).

In addition, pointer years were identified for years where $\geq 80\%$ of all trees indicated synchronous growth intervals (Tab. 2). A minimum replication criterion of 10 trees was used in this procedure (Elling 1966, Huber 1970). The residual chronologies were employed to assess growth-climate relationships using the response function model described in details by Fritts (1976) with the monthly temperature and precipitation data from the Sary-Chelek meteorological station over the 1966-2009 period.



Figure. 1. Map of Kyrgyzstan with Sary-Chelek Biosphere Reserve (large black point) (source: https://www.cia.gov/library/publications/the-world-factbook/maps/maptemplate_kg.html)

Results

The longest chronology, reaching back to 1773 AD, was created from the spruce site located at 1900-2000 m asl. (236 years). The chronologies from 1350-1400 and 1500-1600 m a.s.l are shorter, spanning 105 and 188 years, respectively (Tab. 1).

The mean tree ring width is similar among the spruce sampling sites, reaching from 0,97 mm (low), to 0,97 mm (middle) and 0,99 mm (upper site). However, differences in other statistical parameters were observed, such as maximum, minimum, and median tree ring width, as well as standard deviation and variability. At the lower and middle elevations a very high diversity exists between the minimal and maximal tree ring widths (Tab.1). The highest variability was observed in the middle elevation, with a coefficient of variation reaching about 23% (Tab.1). The pointer years were similar between low and high elevation sites (Tab.2).

Influence of weather conditions on the creation of Schrenk spruce growth were different at three elevations (Fig.1 and 2). Significant and positive correlations between tree ring width and monthly temperatures were observed at the upper elevation site for January, February and November in the year of ring formation. Significantly negative correlations were observed at the lowest elevation site for June and July in the year preceding tree ring formation, and at the middle elevation site for March, April, May, July, June, September in the year of ring formation and for August, September, November prior to the year of tree-rings formation (Fig. 1).

The monthly precipitation data shows mostly positive association with the tree ring growth on all the sites. Positive correlations were found with winter, spring and summer precipitation prior to the

year of ring formation at the lower (January, February, March, April, Mai, June, July) and upper (January, February, April, June, July, August) elevation (Fig. 2). The middle elevation site showed significantly positive correlations between winter, spring and summer (January, March, April, Mai, June July, August) precipitation in annual year of ring formation. In the upper site has founded positive correlation between tree rings growth and spring (March) of current year.

Table 1: Characteristic of residual chronology from the study plots in Sary-Chelek Biosphere Reserve.

	Site 1	Site 2	Site 3
Elevation m a.s.l	1350-1400	1500-1600	1900-2000
Chronology length	1904-2009	1821-2009	1773-2009
Mean tree ring width	0.97	0.97	0.99
Max. tree ring width	1.51	2,05	1.94
Min. tree ring width	0.55	0.22	0.06
Median tree ring width	0.96	0.96	0.98
Standard deviation	0.18	0.22	0.19
Variability	19%	23%	19%

Table 2: Pointer years.

<u>1350-1400m a.s.l</u>	<u>1500-1600m a.s.l</u>	<u>1900-2000m a.s.l</u>
<u>Positive pointer years</u>		
1999		1999
1997		1997
1987	1987	
1980		1980
1973		1973
		1958
	1958	
<u>Negative pointer years</u>		
2008	2008	2008
2001		2001
	2000	2000
1998		1998
1995	1995	1995
	1994	1994
1989		1989
1979		1979
1976		1976
1974		1974
1971		1971

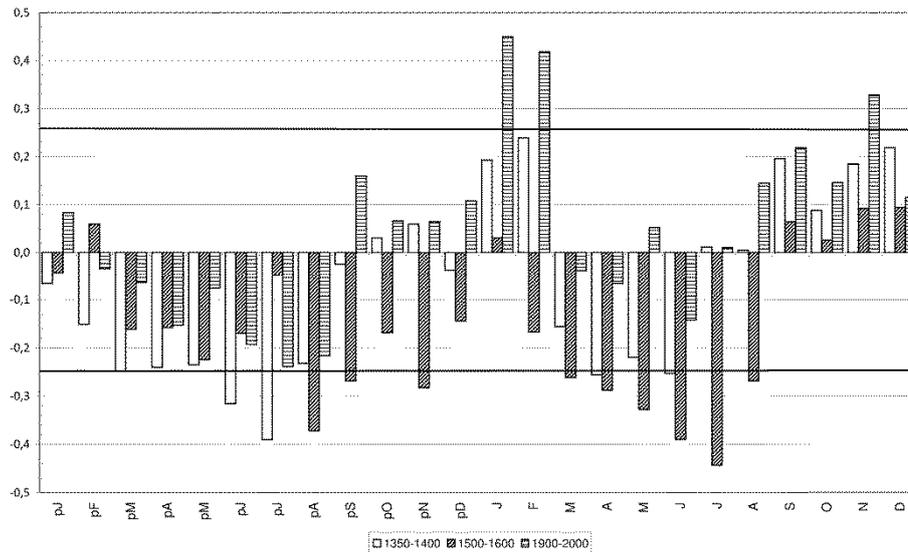


Figure 1: Correlation between *Picea Schrenkiana* residual chronologies from different elevations and monthly temperatures in the Sary-Chelek Biosphere Reserve. Horizontal lines indicate correlations at $p < 0.05$.

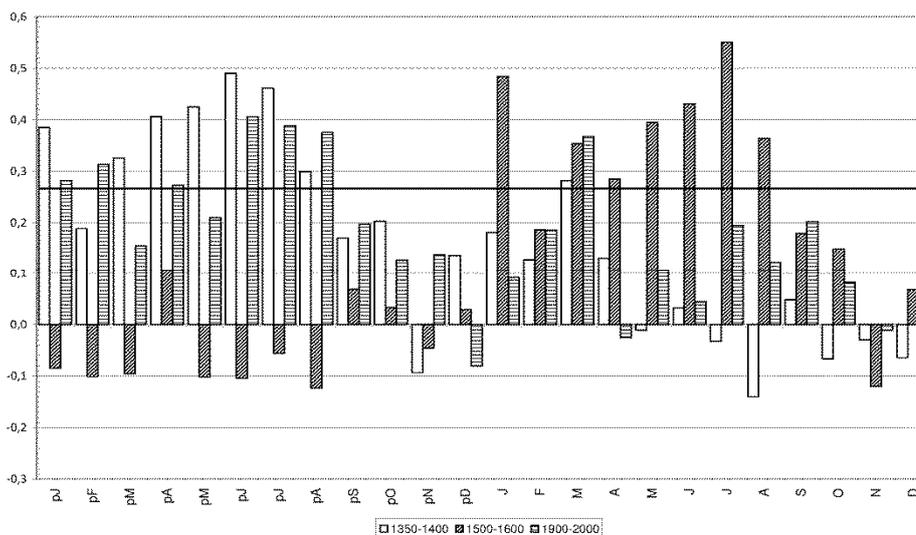


Figure 2: Correlation between tree rings width of *Picea Schrenkiana* trees and mean monthly precipitation in Sary-Chelek Biosphere Reserve. Horizontal lines indicate correlations at $p < 0.05$.

Discussion

The growth of Schrenk spruce from the Sary-Chelek Reserve is more dependent on rainfalls than temperature in all analysed plots (Fig. 1 and 2). Vertical distribution of spruce forests depends on the availability of moisture and the temperature conditions (Grisa et al. 2008). Thus in the Kyrgyz Tian-Shan the lower border of spruce forests depends on limited availability of moisture, and the upper border on the availability of the heat (Orlow 1989).

In the Sary-Chelek Biosphere Reserve on three studied sites at different altitudes, the relationship between climate and tree ring growth was totally different. The limiting factor in the upper site should be limitation of temperature, but in this investigation it isn't. Positive correlation between tree rings growth and the coldest months (January, February) on the upper sites (1900-2000) could be caused by local conditions which are created by the Sary-Chelek lake. On the other

hand, in the lower sites the limiting factor is stock of water, what was confirmed by positive correlation between precipitation in the prior year and tree ring width (winter, spring is the season when precipitation in Sary- Chelek is the highest). If the previous season is filled with moisture, trees can use it in the next growing season. However if the temperature is high during the rainfall season, it can result in reducing water in the soil and therefore hence the stress. This occurs particularly in the continental climate at the lower altitudes. The same strategy was observed by Wang et al. (2005) during investigation of Schrenk spruce located in the Xinjiang reserve in Uygur, an autonomous region of China. A positive correlation between the tree ring width in the annual rainfall and also in August of the year preceding the altitude gradient in the central part of the Tian Shan mountains in China was a common feature connecting all tree areas.

One of the most important sources of water in a continental climate could be melting of the snow, which can be a moisture stock in the high mountains during spring and summer. That can explain the positive correlation between the precipitation in winter and tree rings width (Fig. 1 and 2).

Conclusions

- The researched stands are characterized by similar tree-ring width values, but different variability of tree rings width through the entire altitude gradient.
- For all plots a positive correlation between precipitation and tree-ring widths was observed:
 - On the lower one positive influence of precipitation were in winter, spring and summer prior year of tree rings formation,
 - On the middle one, it was observed with positive influence on precipitation in winter, spring and summer of current year of the tree ring growth.
 - On the upper plots positive influence of precipitation was observed? in winter, spring and summer prior to the year of tree rings formation and also in March of current year of tree rings formation
- The influence of temperature at all elevations is negative. The only exception is plot from the upper elevation, where temperature in winter and spring months of the current year is positively correlated with the tree ring widths.
- The number of pointer years was a similarity between the lower plot (1350 – 1400 m a. s. l.) and the upper plot (1900–2000 m a. s. l.).

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References

- Antonia, E., Lazkov, G., Newton, A. (2009): The Red List of Trees of Central Asia. Fauna & Flora International, Cambridge . United Kingdom
- Cook, E.R., Holmes, R.L. (1986): User manual for program ARSTAN. In: Holmes RL, Adams RK, Fritts HC (eds) Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin. Chronology Series VI: S. University of Arizona, Tucson, pp 50–56
- Cook, E.R., Kairiukstis, L.A. (1990): Methods of dendrochronology: applications in the environmental sciences. Kluwer Academic Publishers, Dordrecht, Netherlands
- Elling, W. (1966): Untersuchungen über das Jahrringverhalten der Schwarzerle. *Flora* 156B:155-201
- Fritts, H.C. (1976): Tree rings and climate. Academic Press, New York

- Gan, P.A. (1970): Lesa SSSR v pyati tomakh. Tom 5: Lesa Kazakhstana, sredneaziatskykh respublik i yugo vostoka evropeyskoy chasti SSR (in Russian) [The forests of the SSSR in Wve volumes, vol 5:
- Grisa, E., Venglovsky, B., Sarymsakov, Z., Carraro, G. (2008): Forest typology in the Kyrgyz Republic. Practice oriented document for field assessment and sustainable management of forest stands. Bishkek
- Holmes, R. (1983): Computer-assisted quality control in tree-ring dating and mearesurement. Tree-Ring Bull 43:69–78
- Huber, B. (1970): Dendrochronologie. [in:] Handbuch der Mikroskopie in der Technik 5, B.1. Umschau Verlag, Frankfurt, S.171-211
- Orlow, W.P. (1989): Kultury eli Tian-Szanskoj. Akademia Nauk Kirgijskoj CCP, Instytut Biologii, Otdel Lesa. Frunze
- Wang, T., Ren, H., Ma, K. (2005): Climatic signals in tree ring of *Picea schrenkiana* along an altitudinal gradient in the central Tianshan Mountains, northwestern China. Springer-Verlag 19: 735-741