

Growth conditions at the upper and lower forest limits in the mountain-forest steppe of Northwest Mongolia

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Introduction

The mountains surrounding the Uvs Nuur basin in northwest Mongolia are characterised by larch woodland, which exists within the altitudinal range of the mountain-woodland steppe. This woodland area constitutes the most southerly extension of the Light Siberian Taiga. Within the zonal semiarid steppe climate, these larch forests are exclusively found on north-facing slopes, while the remaining areas are occupied by mountain steppe vegetation. This distribution is mainly due to differences in exposure to solar radiation. On north-facing slopes, the reduced radiation input results in thermal, hygric and edaphic site conditions that favour forest growth. In areas sloping towards the Uvs Nuur basin, the forests are limited to the zone between 1700m (lower limit) and 2400m (upper limit) a.s.l.

Material and methods

Observations focused on six main study areas comprising a total of 25 sites in the Turgen-Kharkhira and Khan Khökhiiyn mountains that encompass the Uvs Nuur Basin in the Northwest of Mongolia (Fig. 1). A total of 1200 samples (stem cores and cross-sections) were collected. Dendrochronological and dendroecological methods were used to record the tree ring width, age structure, and growing behaviour, and to assess the role of climatic influences, as described comprehensively by Fritts (1976) and Schweingruber (1983). Tree-ring curves were determined for each stand on the basis of 30 selected tree cores or cross-sections. Monthly air temperature and precipitation data for correlation with tree-ring curves are available from the meteorological stations of Ulaangom at 939m a.s.l. and Baruunturuum at 1232m a.s.l., with records beginning in 1952 and 1961, respectively. Their distance from the study sites is 20 and 40 km, respectively.

In addition, temperature and precipitation were recorded at eight data-logger locations in June to September 1997-1999 along a transect that extended from the basin to the watershed (Krüger *et al.* 2001) (fig.1). By using regression equations determined from the continuous data-logger records, it was possible to extrapolate the temperature and precipitation data of the meteorological stations for the lower and upper forest limit. Soil temperatures were recorded at 5 - 30cm depths at several sites between the lower and upper forest limit for the period of one year (1997).

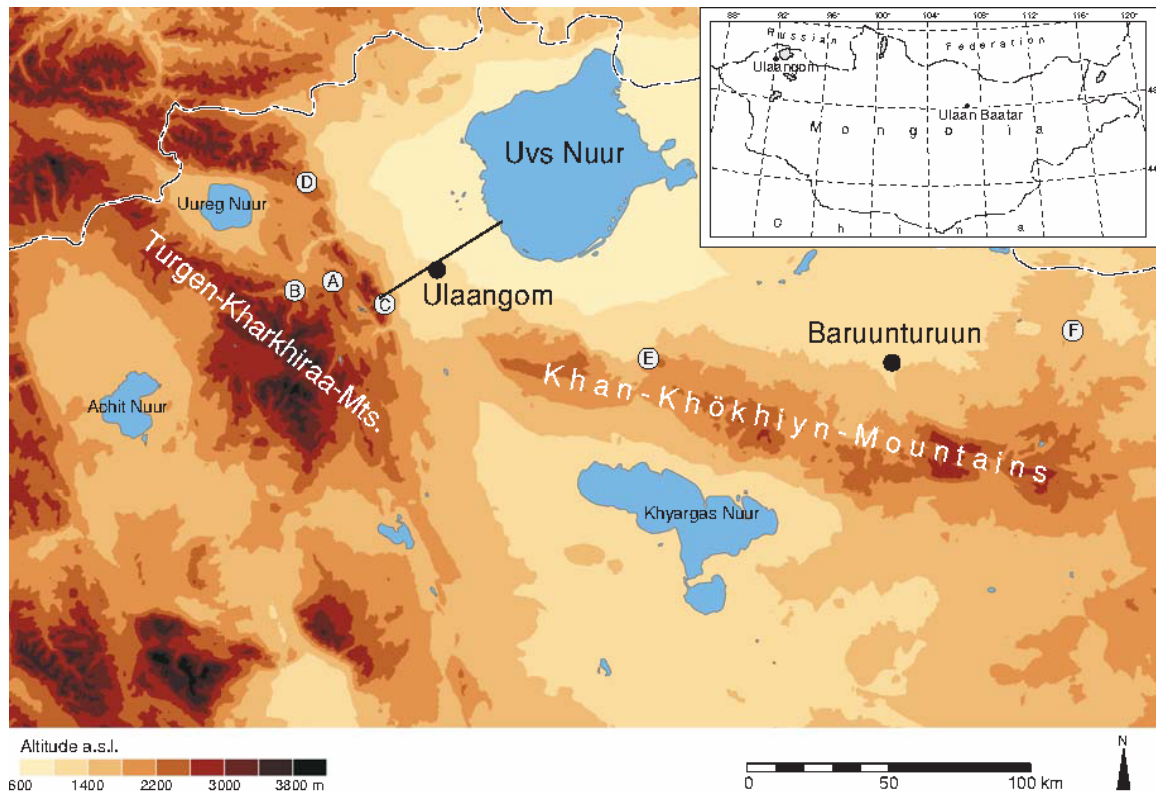


Figure 1: Map of the study area showing the location of the six areas (A-F) that provide the focus for this study and the transect of data-logger measurements.

Results

According to the climatic data measured in the years 1998 and 1999, the average temperature for the months of June - August is 15°C at the lower forest limit (1700m a.s.l.) and decreases to 11°C at the upper forest limit. Summer precipitation (June - September), however, increases from 105mm to 145mm from lower to upper forest limit. Precipitation measurements carried out in the interior mountain region in 1997/98 confirm this trend.

The tree-ring curves of sites near and at the upper forest limit are significantly and positively correlated with temperature and precipitation, although the correlation between tree-ring width and temperature is higher than between tree-ring width and precipitation (fig. 2). It could thus be deduced that low air temperatures thermally control the upper forest limit. Mid June to mid August soil temperatures at 10 cm depth, however, are 1 - 2 K higher at the upper forest limit than at the lower forest limit.

This suggests that average air and soil temperatures play a less important role as limiting factors than extreme events, such as late frosts, that prevent a further expansion of larch to higher altitudes. Such late frosts are proved by soil temperature records and the existence of frost rings that occur in the same years throughout the study area (fig. 3). These frost rings are predominantly present in the first 20 growth rings of the trees. It can thus be inferred that only young trees are susceptible to frost damage. Trees that have survived these late frosts presently form the stands at the upper tree limit. It is conceivable that, favourable temperature and moisture conditions presumed (in particular rising temperatures), the

absence of late frosts for long periods could lead to a shift of the tree line to higher elevations.

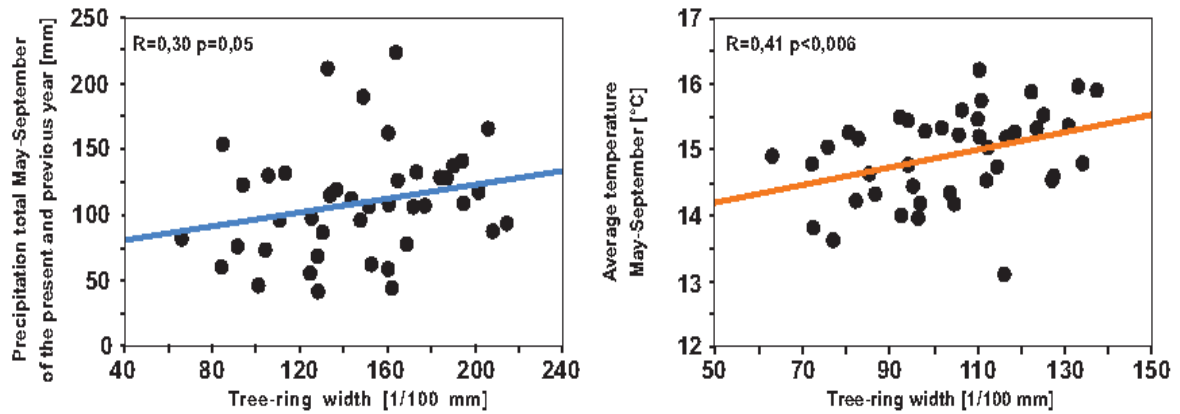


Figure 2: Correlation diagrams for locations near the upper forest limit (2300-2400m a.s.l.) for the time period 1950-1995: (left) correlation between tree ring width and total precipitation for the months May-September of the present and previous year, (right) correlation between tree ring width and average temperature of the months May-September. R = Spearmann's Rank Correlation, p = significance level

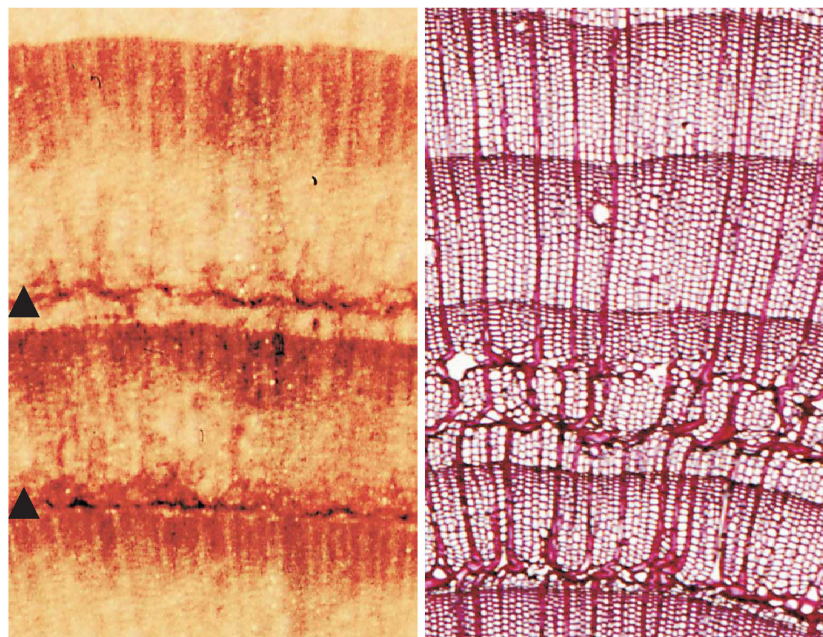


Figure 3: Frost rings of the years 1966, 1967 and 1968 at a site at the upper forest limit in the Turgen-Kharkhiraa-mountains: left) stem cross-section, right) microsection.

At the lower forest limit on the slopes facing the Uvs Nuur Basin, the lack of moisture is the key limiting factor. Low precipitation combined with relatively high temperatures result in narrow tree rings. Total precipitation for the months of June to August and tree ring width is highly positively correlated. Average June - August temperatures and tree-ring width, however, are negatively correlated (fig. 4).

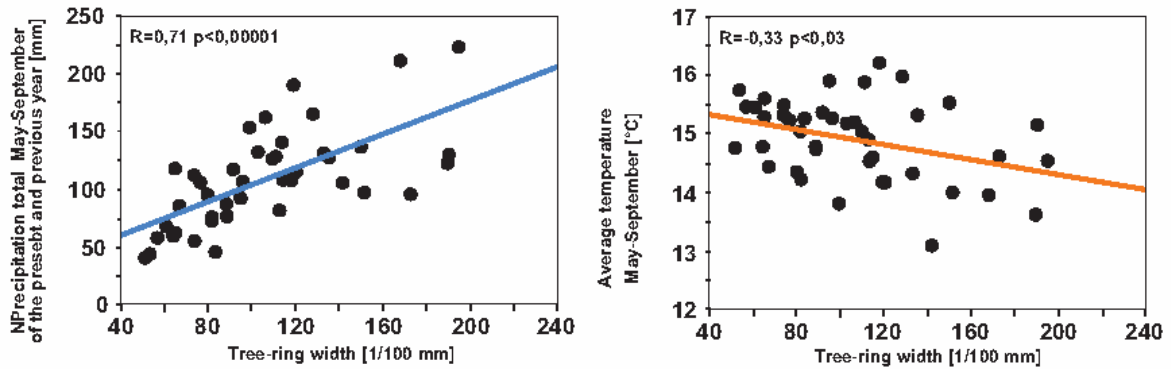


Figure 4: Correlation diagrams for locations near the lower forest limit (1700-1900m a.s.l.) for the time period 1950-1995: (left) correlation between tree-ring width and total precipitation for the months May-September of the present and previous year, (right) correlation between tree-ring width and average temperature of the months May-September. R = Spearman's Rank Correlation, p = significance level.

The frequent occurrence of double rings (pseudo-rings or false rings) resulting from dry periods during the growing season is a further proof for frequently occurring drought-induced stress (fig. 5).



Figure 5: False rings at a site at the lower forest limit in the Turgen-Kharkhira mountains: (left) stem cross-section, (right) microsection.

At 1700m a.s.l., the lower forest limit is currently located on slopes with an angle of approximately 25°. Immediately below this elevation, the slopes grade into the gently sloping pediments that lead towards the Uvs Nuur. Gentle slopes receive more radiation, resulting in generally less favourable site conditions and restricting or preventing a forest expansion further down slope into an even dryer and more drought-prone environment.

In the eastern part of the Khan Khökhyn mountain range, the lower forest limit is also found on steep slopes at about 1400m. According to the data of the Baruunturuun meteorological station these eastern areas receive higher precipitation and experience a different distribution of precipitation. Temperatures, however, differ solely due to the 300m elevation difference (fig. 6a and 6b). Due to the more favourable moisture conditions, these areas do not experience well developed drought periods so that double tree rings are quiet rare.

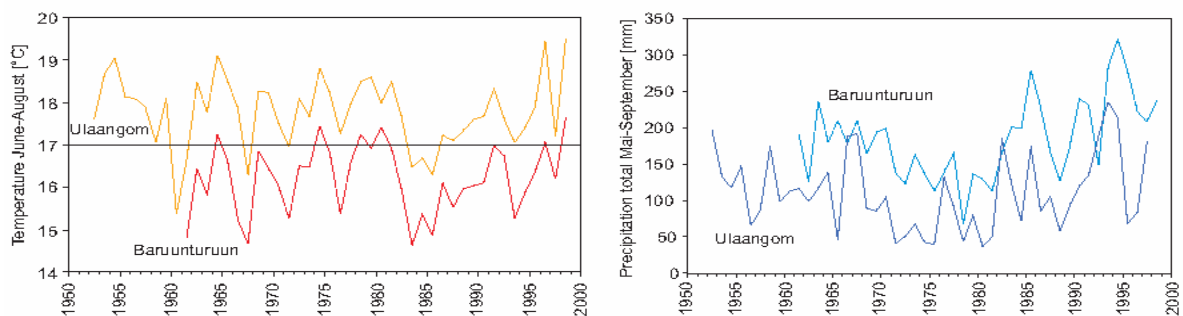


Figure 6: Selected climatological data for the stations Ulaangom (939 m a.s.l.) and Baruunturuun (1232 m a.s.l.): left) average temperature for the months June-August, right) total precipitation for the months May-September.

In conclusion, the comparison of the tree-ring curves shows that, in areas showing the same regional climate, growth conditions at the lower forest limit differ to such an extent from those at the upper forest limit that only minor similarities exist between the respective tree-ring curves (fig. 7).

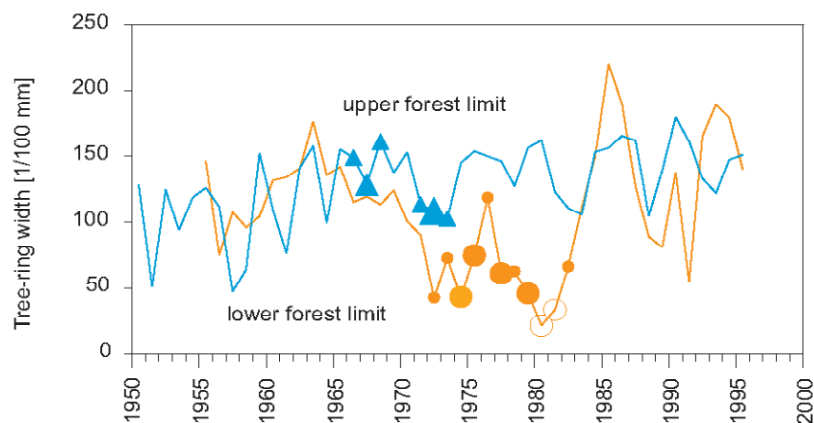


Figure 7: Tree-ring curves (raw data of tree ring width) for a site at the upper and lower forest limit showing the location of the frost rings (triangles), false rings (dots) and light rings (circles). The size of the symbols indicates their relative occurrence frequency within the stand.

The original assumption of decreasing tree-ring widths with increasing elevation and corresponding decrease of temperatures can not be confirmed. The measured increase in precipitation obviously compensates the effect of decreasing temperatures. With respect to basal area increments as calculated from tree-ring widths for the same time periods, very little difference exists between the upper and lower forest limit. The shape of the curve at sites at the lower forest limit, however, is characterized by significant drought induced interferences. At the upper forest limit, the shape of the curve is largely smooth. Both growth curves show a rising growth trend (fig. 8).

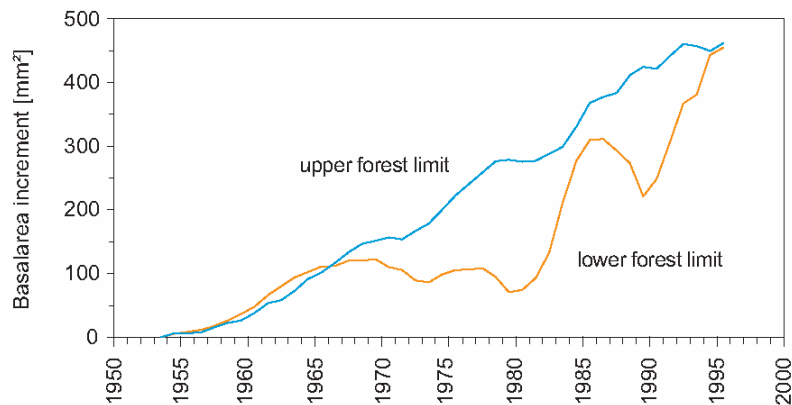


Figure 8: Growth curves (5-year moving average) of the same sites as in Fig. 7. The dips in the curve for the lower forest limit mark periods of low precipitation and thus corresponding narrow tree rings.

Conclusion

Precipitation or more generally climatic conditions and soil moisture constitute a key factor for the existence and dynamics of the larch forests in the mountain forest steppe of Northwest Mongolia. At the upper forest limit the findings suggest that average air and soil temperatures play a less important role as limiting factors than extreme events, such as late frosts. The latter prevent a further expansion of larch to higher altitudes. Only the young trees are susceptible to lethal frost damage. Trees that have survived these late frosts presently form the stands at the upper tree limit. It is conceivable that, given favourable climatic conditions (in particular rising temperatures), the absence of late frosts for long periods could lead to a shift of the tree line to higher elevations. The lower forest limit is mainly controlled by low precipitation. Given the present moisture conditions, a continued expansion downwards onto the gently sloping pediments and thus into a drier and more drought prone environment, can not be expected.

References

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