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Spatial differences and temporal patterns of ring-width and density chronologies of the mountain forests of northern Central Asia

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Introduction

During the last ten years a dens network of tree-ring sites was established in northern Central Asia. Sample plots were preferably selected at the local lower and upper tree line respectively.

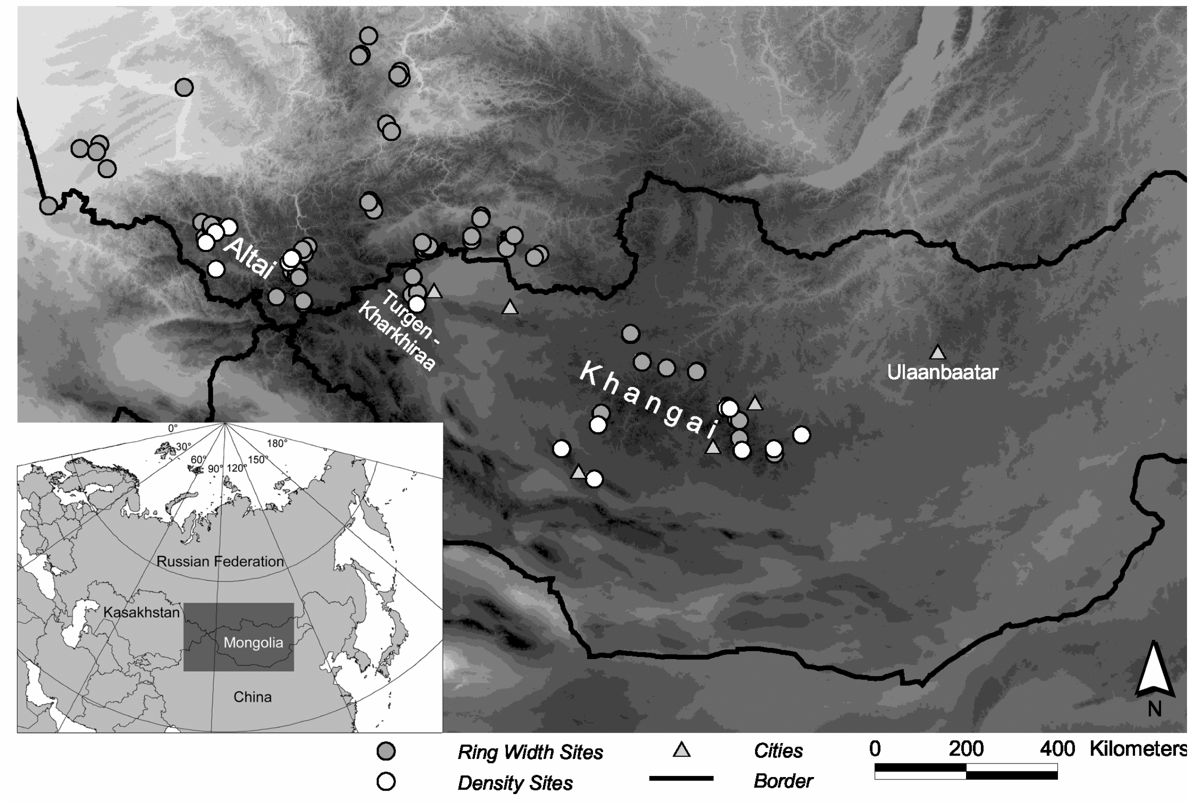

Figure 1: The research area with tree-ring width and density sites

Most parts of Mongolia, as well as several parts of Southern Siberia belong to the arid and semiarid regions of mid-latitude Eurasia. In this region the latitudinal vegetation belts from the boreal forest in the north to the steppe- and semi desert ecosystems in the south are broken by the vertical distribution of the vegetation in various mountain ranges (Sommer 2000). This leads to a mosaic of different forest types close to each other (Block et al. 2004).

Semi arid regions are generally fragile ecosystems (Yatagai 2003) and climate change may cause changes in the extend and composition of forest easily (Treter and Block 2003).
Most of the sites were located in the mountain ranges of the Republics of Altai, Tuva and Mongolia. Few sites are situated in the forest steppe in Southern Siberia. Besides the measurement and analysis of tree-ring width, a network of tree-ring density sites was established (Fig. 1).

Material and Method

Increment cores and stem disks were taken at preferably selected sample plots at the local lower and upper tree line. Most samples were taken from Siberian Larch (*Larix sibirica* Ledeb.). In addition at a couple of sites at the upper tree line samples from Siberian Pine (*Pinus sibirica* Du Tour) were collected. Only in the forest steppe areas in the mountain forelands larch is absent and samples were taken from Scots Pine (*Pinus sylvestris* L.). For the comparison of ring-width and density chronologies only larch sites are included.
Dendrochronological methods, as described by Fritts (1976), Cook and Kairiukstis (1990) and Schweingruber (1996) were used to prepare and measure samples and crossdate ring width data using TSAP and COFECHA. After separate crossdating in Erlangen and Krasnoyarsk the data was joined and crossdated again. Then the ring width data was processed with ARSTAN to site chronologies.
The samples for the measurement of wood density were prepared and measured as described by Schweingruber (1983, 1996). The measured data of maximum latewood density was crossdated and the first 50 years of every tree-ring density series were removed to reduce the influence of age trend. Then the data was processed with ARSTAN to site chronologies.
For the analyses of the spatial and temporal patterns of tree-ring width and density Pearson's correlation coefficients and cluster analyses were used (Block et al. 2004, Magda et al. 2004).

Results

Cluster analyses and analyses of correlations between tree ring width chronologies of the whole region for longer time periods (100 to 300 years) show well defined groups. All sites from upper tree line, as well as the sites from lower tree line form one separated group with high cluster distance between each other (Block et al. 2004). In these groups of upper and lower tree line sites different regions are represented as subgroups. For shorter periods, which were investigated with stepwise clusters with a 25 years window, changes in these groups were found (Magda et al. 2004). Moving correlations, which were calculated between sites from upper and lower tree line show periods with positive, negative and without correlations. This explains the switch of some sites to different groups in several periods. The moving correlations between sites are correlated with summer temperatures (Block et al. 2004).
This paper is focused to the 14 sites for which ring width and maximum density chronologies are processed (see Fig. 1).

Spatial differences

The results of cluster analysis for the common period from 1811 – 1994 of the 14 sites for which ring width and maximum density chronologies are available, show different results for ring width and density data (Fig. 2). The highest cluster distance for ring width chronologies was found between a group of lower tree line sites of Mongolia including one intermediate site from Altai (Fig. 2a, 1-2) and a group of upper tree line sites from Mongolia and Altai and lower tree line sites from Altai (Fig. 2a, 3-5). In this second group the lower tree line sites are clearly separated from the upper tree line sites.

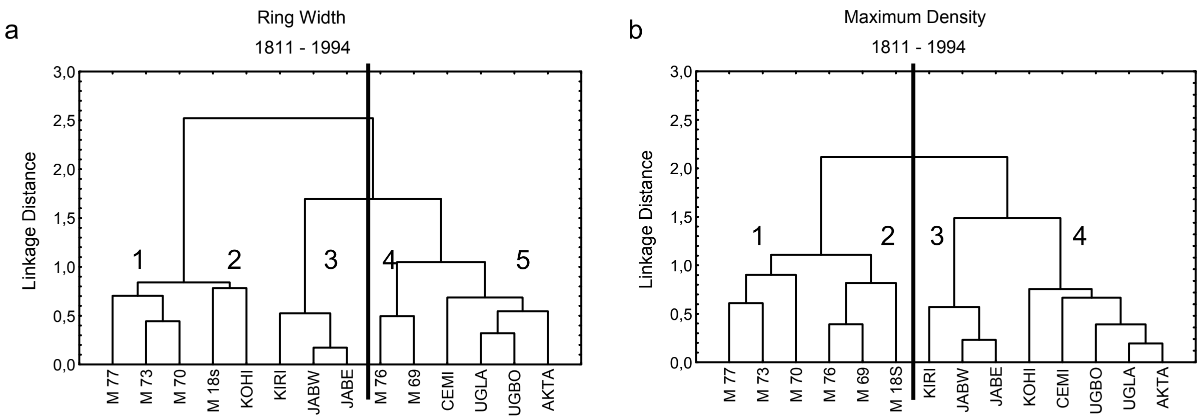

Figure 2: Tree Diagrams (Ward's method, 1-Pearson r) for ring width (a) and maximum density (b) for the 14 selected sites for the common period. Black line in a) divides upper and lower timberline sites, black line in b) divides sites from Mongolia and Altai. Numbers mark groups from upper (a4, a5, b2, b4) and lower timberline sites (a1, a2, a3, b1, b3).

The tree diagram for density chronologies (Fig. 2b) shows the highest cluster distance between the two investigated areas of Mongolia and Altai. In the two main groups the sites from lower and upper tree line of each region form well divided subgroups (Fig 2b, 1-4).

Temporal patterns

For the analysis of the temporal patterns only the six sites in Mongolia were selected. The results of cluster analysis for the common period from 1811 – 1994 are nearly equal, except the intermediate site M 18s, which belongs in the tree diagram of ring width chronologies to the group of lower tree line and in the tree diagram of maximum density chronologies to the group of upper tree line (Fig. 3a and b).

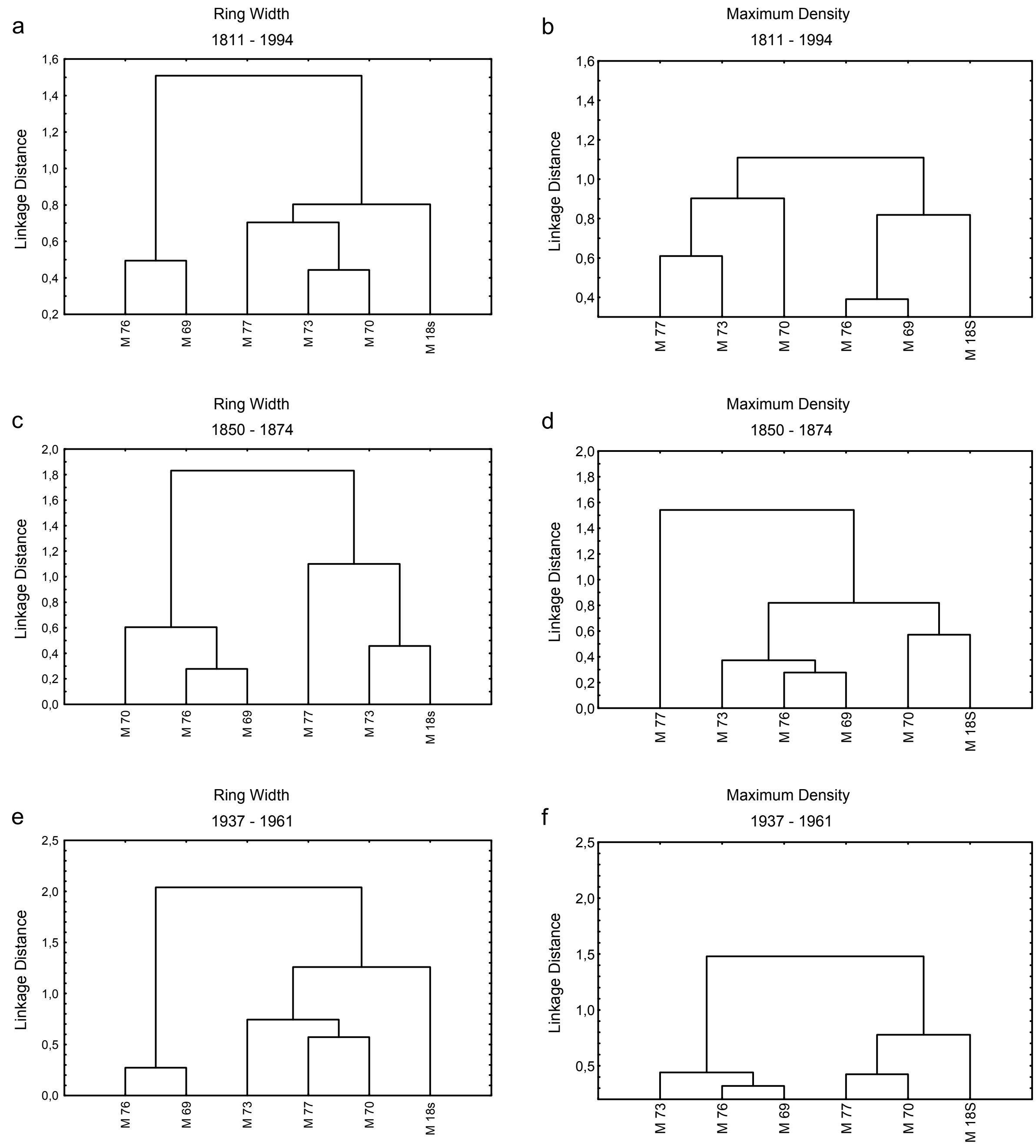

Figure 3: Tree Diagrams (Ward's method, 1-Pearson r) for ring width (a, c, e) and maximum density (b, d, f) for the 6 selected sites in Mongolia for the common period (a, b), a period with lower differences between upper and lower timberline sites (c, d) and a period with higher differences between upper and lower timberline sites (e, f).

The stepwise cluster analysis with 12 years steps and a window of 25 years have shown several periods with different distribution of sites in the tree diagrams. The two periods 1850 – 1874 and 1937 – 1961 shown in Fig. 3 represent extreme differences between a known cold period in the 19th century and a warm period in the 20th century (Ovtchinnikov 2002).

The tree diagrams for the warmer period in the middle of the 20th century show the same clear groups for upper and lower tree line sites then the tree diagrams of the common period, but the differences in the groups are much smaller, especially in the diagram for the maximum density chronologies (Fig. 3f). For the cooler period in the middle of the 19th century the clear groups of upper and lower tree line sites disappear and some sites from lower tree line switch to group of upper tree line sites (Fig. 3c) or be separated (Fig 3d). The cluster distances show that the differences between regions become stronger then the local differences between upper and lower timberline sites of one region.

Conclusion

The analyses of ring width and density chronologies show clear spatial differences and temporal patterns. The comparison of the results from cluster analysis for the whole region and the common period show, that ring width data has bigger differences between upper and lower tree line sites and the data of maximum density has bigger differences between the regions (Fig. 2). Considering the dependence of density values from summer temperature (Schweingruber 1996), the sites in Mongolia belong to different temperature regimes then the sites in Altai, or trees show different reaction to temperature due to other factors. In the ring width data also the moisture signal is included, but decreasing moisture influence with increasing elevation of the sites can lead to more or less common reaction of trees at upper tree line sites in both regions (Fig 2a, 4-5).

The results of stepwise cluster analysis show clear temporal patterns. In the cooler period of the 19th century the moisture stress of some lower tree line sites decreased and the temperature signal in these sites became stronger. The result is that some sites start to become closer to upper tree line sites. In addition it seems that in this period the differences of the temperature signal are higher then the signal of moisture, which increases the cluster distances between regions, see for example the separated site M 77 in Fig. 3d, which is the most eastern site in the Khangai Mountains. In the warmer period in the middle of the 20th century, the moisture stress in this semiarid region increased. The sites are divided in the two groups of upper and lower tree line sites. The trees at the upper tree line are able to react more or less to the influence of temperature because they have enough moisture. At the lower tree line during this period the reaction of trees to the influence of temperature is decreasing due to the lack of moisture. This fact could explain the high cluster distance between upper and lower tree line sites for this period (Fig 3e-f).

Analysis of ring width and maximum density chronologies gave similar but not always equal results. The analyses of temporal patterns in one region gave nearly equal results for ring width and maximum density chronologies but the analysis between Mongolia and Altai show different results. It is concluded, that the analyses of maximum density chronologies can give more detailed results for the interregional comparison of tree ring sites then the ring width chronologies.

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Sources for map in Figure 1 were obtained from GTOPO30, US Geological Survey (USGS) and the Digital Chart of the World.