

The use of dendroecological methods in a landscape-ecological approach on upper treeline fluctuations

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Introduction

Treeline fluctuations were investigated vigorously during the last decades. In this context, dendrochronological and dendroecological methods were made use of relatively early (i.e. Kullman 1979, Treter 1984). The work of Müterthies (2003) showed the potential of dendrochronological methods in a vegetation ecological approach. In this paper we present a research program based on a combination of dendroecology with remote sensing, soil science, vegetation science and human geography. We have used this set of methods to study the influence of land use change and climate change on fluctuations of the upper treeline in central Norway. Climate and land use are supposed to be the superior factors influencing the position of the upper treeline. Both parameters have changed significantly in time. In central Norway, the annual mean temperature has increased during the last century by 0.08° per decade at most (Førland et al. 2000). The change of land use led to an extensification of less productive land like mountain areas. We assume that both, climate and land use changes led to a rise of the upper treeline. However, the exact extent of the influence of each factor is unknown. The qualitative and quantitative estimation of the impact of particularly temperature and land use on the treeline is the aim of the TRELAN – project, which started in 2002.

Study region

Four study areas were chosen along a climate gradient stretching from the western, oceanic part near Bergen (Bergsdalen, 60° 30' N; 5° 50' E) across two study areas in a transition zone (Gudmedalen, 60° 45' N; 7° 5' E and Geiranger, 62° 03' N; 7° 15' E) to the most continental area in the east (Vågå, 61°53'N, 9°15'E) (Fig. 2). According to the oceanic – continental climate differentiation and a subsidiary mountain mass elevation effect *Betula pubescens* s.l. dominated treelines rise from app. 700 m at Bergsdalen to app. 1050 m a.s.l. at Vågå.

Methods

We used tree-ring widths to obtain specific information about the age structure of forests stands at the upper treeline and to indicate possible responses to changing environmental conditions during the last century. Dendroecological methods were embedded in detailed site mapping including vegetation, soil, and winter snow depth. This data set was accomplished by results from bitemporal aerial photo interpretation, meteorological measurements, and

inquiries about the history of land use. All methods were applied using a nested hierarchical design at four spatial scales along different gradients in central Norway (Fig. 1).

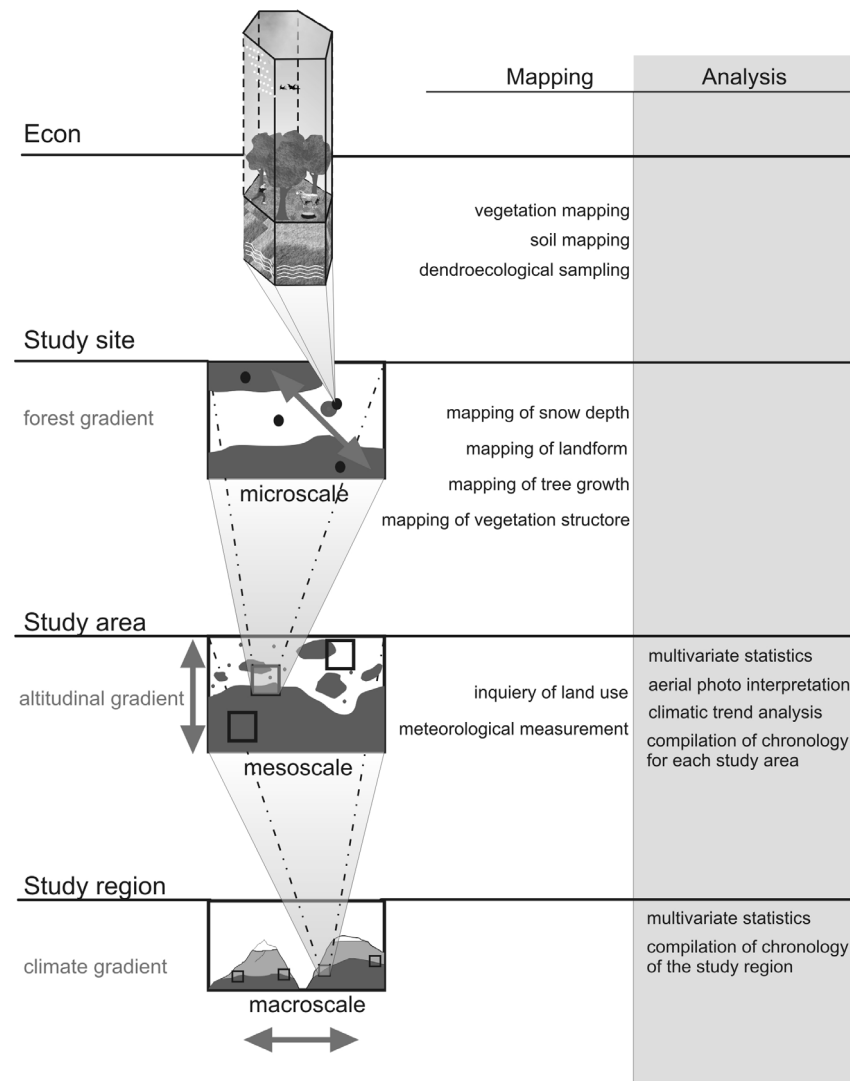


Figure 1: Mapping and analysis approach at different spatial scales.

Mapping Methods

In each study area, we investigated the upper treeline along an altitudinal gradient stretching from dense forest to the low alpine belt. Several representative study sites were selected, each comprising wooded and unwooded plots. The study sites were mapped and structured according to vegetation types, topography, and growth forms of trees. Increment cores of all present woody plants were collected.

Dendroecological Methods

Trees with a trunk diameter above 5 cm were drilled at the trunk basis, parallel and perpendicular to the slope and the length of the aslope trunk from the root to the drill-point was recorded. Cross-sections were taken from smaller trunks. Circumference and vertical height above ground were measured. Polycormic trees were sampled at different trunks.

Furthermore, we collected saplings. The cross-sections and increment cores were mounted and polished in the laboratory before tree rings were counted by using a stereomicroscope. To increase the contrast of the wood we used white chalk to fill the vessels as suggested by Iseli and Schweingruber (1989). Then, ring width was measured with a precision of 0.01 mm.

Remote Sensing

The development of the treeline was estimated by using bitemporal aerial photo interpretation. Since only limited aerial photos for the study areas were available, those of 1992 and 1993 were compared with the earliest photos existing (Vågå 1964, Geiranger 1976, Gudmedalen 1969, Bergsdalen 1972). Scales of the aerial photos differ from 1:15,000 to 1:40,000. The photos were transformed into orthophotos using a digital elevation model. Forests, solitary standing trees and woodless areas were distinguished. By comparison of the earliest and latest photos, the development of treeline was reconstructed. These results were combined with the dendroecological results of age structure.

Inquiries

We carried out inquiries about the current and the historical land use. Quantitative data about the numbers of grazing animals and the period when mountain summer farms had been utilised were obtained from official statistics (local and national scale), reports (e.g. *landbruksplan*), and archives. Inquiries of local administrative authorities (*community*) led to contact locals with relevant knowledge, e.g. farmers and landowners. The latter were interviewed by an informal and semi-structured approach about the present and former ways of land use (cp. Lundberg 2000).

Climate Analyses

Climate data derived from official meteorological stations in the valleys were analysed in terms of temperature and precipitation trend during the last decades. Moreover, these data served as a comparison with the ring width of trees.

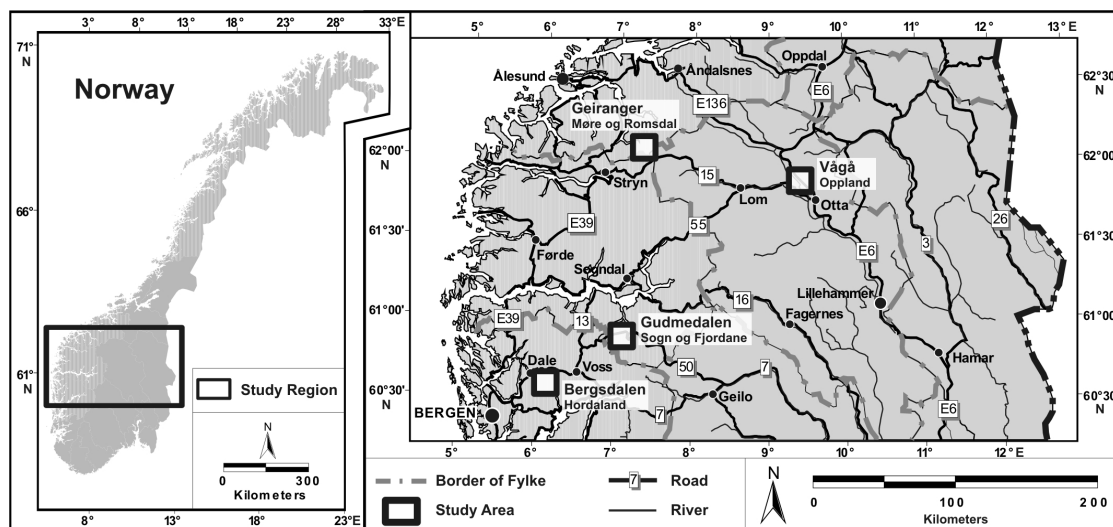


Figure 2: Map of the study region in central Norway and the location of the four study areas

Results and Discussion

We present the results by the example of the Gudmedalen area. The comparison of the aerial photo interpretation (1976 – 1992) revealed differences between the northern and the southern slope (Fig. 3). Only in the southern part of the area serious treeline changes occurred. The age determination of *Betula pubescens* trees at five study sites indicated a rising upper treeline in the southern part of the study area. Two distinct age classes were distinguished: old trees (average age 127 years) and only young trees (max. 47 years). This age structure indicated a recent rise to be interpreted as a regeneration process: old trees were found all over the treeline ecotone and form the present treeline, whereas young trees almost exclusively germinated between the older individuals (Fig. 3). Concerning the effect of changing climate on the treeline this rise might be interpreted as an effect of increasing temperature. Results of the trend analysis of climate data confirmed this hypothesis by a slightly significant increase of annual mean temperature (0.028°C/year, $p = 0.5$). But, intra-annual calculation of temperature trends showed an increase of temperature only in winter months.

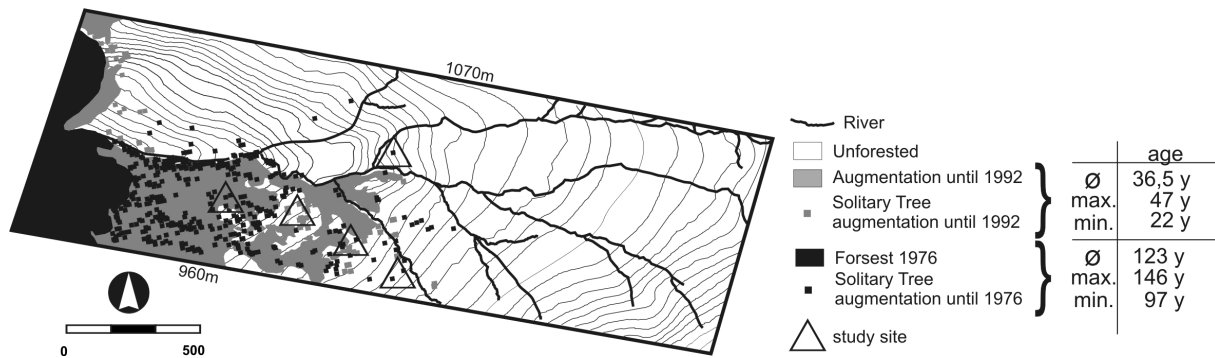


Figure 3: Comparison of bitemporal aerial photos and age structure of trees in the study area.

However, as the results of our inquiries proof, the local rise of the treeline has to be explained by changes in land use. While the northern part of the study area was continuously grazed by app. 300 goats, summer farming ceased in the southern part after 1953. Additionally, in the 1930s the former forest was rooted out apart from some solitary trees. Both incidents, abandoning and rooting could still be retraced today. As indicated by the age structure, old trees found in the area were left from the clear-cut, while young trees started to regrow in the former forest after abandonment by the summer farmers. Consequently, the recent dynamics of the treeline in this area were interpreted as a result of land use change. This finding generally holds true also for the other study regions. Moreover, similar results were published by Hofgaard (1997) and Löffler et al. (2004) for other areas in central Norway. Hofgaard (1997) even denied the sensitivity of anthropogenic treelines to recent climate changes. To test this hypothesis, we are currently working on the development of a local *Betula pubescens* tree-ring chronology covering approximately the last century.

References

- Førland, E., Roald, L. A., Tveito, O. E., Hanssen-Bauer, I. (2000): Past and future variations in climate and runoff in Norway. DNMI-Report 19/00 KLIMA. 77 p.
- Hofgaard, A. (1997): Inter-relationship between treeline position, species diversity, land use and climate change in the central Scandes Mountains of Norway. *Global Ecology and Biogeography Letters* 6, 419-429.
- Iseli, M., Schweingruber, F.H. (1989): Sichtbarmachen von Jahrringen für dendrochronologische Untersuchungen. *Dendrochronologia* 7, 145-157.
- Kullman, L. (1979): Change and Stability in the Altitude of the Birch Tree-Limit in the Southern Swedish Scandes 1915 – 1975. *Acta Phytogeographica Suecica* 65: 121.
- Löffler, J., Lundberg, A., Rößler, O., Bräuning, A., Jung, G. Pape, R., Wundram, D. (2004): The Central Norwegian Alpine Tree Line under a Changing Climate and Changing Land Use. *Norwegian Journal of Geography* 58: 183-193.
- Lundberg, A. (2002): The interpretation of culture in nature: landscape transformation and vegetation change during two centuries at Hystad, SW Norway. *Norwegian Journal of Geography* 56: 246–256.
- Müterthies, A. (2003): The potential timberline: Determination with dendrochronological methods. In: G. Schleser, M. Winiger, A. Bräuning, H. Gärtner, G. Helle, E. Jansma, B. Neuwirth, and K. Treydte, eds., *Tree Rings in Archaeology, Climatology and Ecology*, Volume 1. Proceedings of the Dendrosymposium 2002. Schriften des Forschungszentrum Jülich, Reihe Umwelt 33: 94-100.
- Treter, U. (1984): Die Baumgrenzen Skandinaviens: ökologische und dendroklimateische Untersuchungen. Franz Steiner Verlag, Weisbaden, 111p.