



Linking ecological processes and spatial patterns: the promise of remote sensing in treeline ecology

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Treelines are ecotones with a strong spatial nature. Remote sensing (RS) tools provide spatially explicit wall-to-wall maps in time. Nevertheless, despite the potential of RS to inform treeline ecologists on spatial patterns and underlying processes, its application is still scarce and heterogeneous. We performed a systematic review and meta-analysis of published literature with the aim to provide a question-oriented discussion of RS in treeline ecology. The main focus of the review was the role of RS as a tool for measuring spatial patterns and dynamics of treeline globally. We assessed the geographic distribution, scale of analysis, and relationships between RS techniques and ecological metrics through cooccurrence mapping and multivariate statistics. Only 10% of treeline studies applied RS. We observed four main types of applications; long-term aerial, long-term oblique, satellite timeseries, and high-resolution mapping. Long-term research and monitoring adopted coarser spatial resolution over long temporal extent, either with oblique or aerial photographs to measure treeline position and shift. Shorter temporal extents (i.e., up to 40 years) were investigated through satellite time-series, especially when dealing with coarse dynamics such as changes in climate. High-resolution imagery derived from UAV recently emerged as promising tools to measure tree height, canopy cover, and spatial patterns at a very fine spatial resolution (i.e., centimetres to metres). A multiscale and multi-sensor spatial approach was implemented in just 19% of papers. We advocate for an increasing interaction between classic treeline ecology based on field surveys and RS techniques. Also, the multi-dimensional structural complexity of treeline ecotones calls for a multiscale and multi-sensor approach, with high-resolution and low cost UAV acting as a powerful tool to fill the gap between local-scale ecological patterns and coarse-resolution satellite sensors.