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# Geomorphological factors and human impacts influences on treeline altitude in the Italian Alps: regional and site-scale approaches for predicting future responses to climate change

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Altitudinal treelines (defined by the upper limit of 2 m tree growth forms), are a fundamental component of high-mountain landscapes that are strictly linked to past and present climate regimes. Both forest expansion towards higher altitudes and forest ingrowth have been reported for many mountain sites, as a consequence both of a warming climate and of other factors, like in the European Alps, the alpine-farming decline. Since the expansion of a forest cover may directly influence soil properties and also geomorphological processes like surface movements and erosion, it is important to detect climatic treelines at the regional scale and to assess the treeline responses to climate in the recent past in natural sites.

At the regional scale, we analyzed about 300 km of treelines fixing the coordinates of trees growing at the highest altitudes in inner and peripheral regions of the Italian Alpine chain (Western and Central Alps). The analysis was performed detecting what main factor could have constrained the tree altitude, distinguishing between orographic-geomorphologic, anthropogenic and climatic factors in order to select sites appropriate for the study of climatic treeline dynamics. The results showed that present-days treeline altitudes mostly depends on anthropogenic and orographic-geomorphologic factors. Climatic treelines were limited to steep and inaccessible slopes and they resulted at higher altitudes and much further away from mountain peaks in the inner regions of the mountain range than in the peripheral regions. Climatic treelines in the inner regions were found in the Valpelline-Etroubles valley (maximum altitude: 2525m a.s.l., Western Alps) and in the Valfurva valley (2480m, Central Alps), whereas in the peripheral regions they were found in the Brembana-Gemelli valley (2260m, Central Alps). In the inner regions of the Alpine range treelines were further away from human disturbances and from geomorphologic constraints than in the peripheral regions, resulting potentially more free to shift upwards under the recent more favorable temperature conditions. Inner regions of the Alps are those that will likely experience greater forest expansion at the treeline, with trees advancing in the alpine grasslands. We also found that, in the valleys selected, human disturbance is mainly concentrated about 165 m below non-climatic treelines, suggesting a homogeneous influence on treelines, regardless of geographic position.

At the site scale, by means of a tree-ring based approach, we reconstructed the treeline positions for the last three centuries. The site is characterized by the presence of extensive talus cones above the forest line and by unfavorable substrates that strongly prevented an intensive exploitation of the area also in the past centuries. However, up to high altitudes there are sparsely several wide portions of grassland where trees may easily establish and growth. The reconstruction of past treeline positions revealed an acceleration of tree colonization rates into the alpine domain, averaging 10m and 13m per decades in the periods 1901-1950 and 1951-2000 respectively. We have found that the treeline has shifted upwards up to 115m over the period 1901-2000, reaching the altitude of 2505m in 2000 and 2515m in 2008. Present colonization patterns towards unvegetated areas and mountain peaks at higher altitudes reveal an increasing importance of geomorphological factors in controlling future treeline position and colonization patterns, regardless of the constant increase in air temperature. On the other hand, while treeline is reaching higher altitudes, it is also getting more strictly related to the recent climatic trends, getting farther away from the areas impacted by past human activities.

Our approach at two spatial scales was developed for providing accurate information on climate change impacts on high-altitude forests and to detect areas potentially more impacted by future changes in alpine landscapes.