



Using long-term remote sensing series to upscale the vegetation shifts along elevation in the GLORIA network Italian peaks

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Plant species and communities' distribution are remarkably affected by the climate change, particularly in arctic and alpine biomes. In alpine ecosystems, species and communities are shifting upwards due to the temperature increase, seeking for the optimum growth conditions. As a prominent effect, a progressive increase of vegetation cover is leading an alpine greening, with important consequences for the overall plant diversity. Nonetheless, little is known about how this trend may produce different effects along elevation gradients. Innovative upscaling approaches able to link field monitoring evidence to remote sensing data represent a promising tool to get new insights into the ecological mechanisms involved in these changes, and to produce reliable projections over time. This study aimed at parsing the long-term trends of remote sensing-derived vegetation indices in five GLORIA (Global Observation Research Initiative in Alpine Environments) network target regions, located across the Italian Alps and Apennines. Normalized Difference Vegetation Index (NDVI) was calculated for each growing season (June-September) in the period 1985-2022, using Landsat 5 and 8 multispectral satellite images of each mountain summit. Linear mixed-effects models were used to analyze the relationships between NDVI, time and climate variables, in different elevation belts. NDVI linearly increased over the last 37 years, but with significant higher increase rates and values at the treeline, lower alpine and alpine zones, compared to the upper alpine, subnival and nival belts. Moreover, NDVI was significantly affected by temperature at lower altitudes, with a significant interaction with rain precipitations, while climate variables were not determinant at high elevations. These results provided further evidence of the ongoing alpine greening and showed that vegetation at the treeline is responding faster than the other communities to a warmer and drier climate. Therefore, future scenarios depicting the fate of alpine plant community communities should not neglect for the interplay of temperature and precipitation regimes. Our finding opens future perspectives on the interpretation of GLORIA field evidence, in a continental upscaling perspective.

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