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Energy-mediated trade-offs in canopy structure contribute to productivity in alpine plant communities

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Understanding links between growing season length, plant canopy structure and primary productivity is critical to assess ecosystem functioning and diversity patterns in alpine environments. In a high-elevation watershed located in the southwestern French Alps, we sought to quantify primary productivity at high spatial resolution (2 m) and to identify trade-offs in functional strategies contributing to carbon uptake across plant community types. Our approach consisted of applying Monteith logic to estimate primary productivity. We relied on hyperspectral imagery, obtained in late-July, to estimate light use efficiency (LUE) as well as the fraction of photosynthetically active radiation (fPAR). Available photosynthetically active radiation (PAR) was estimated by combining Landsat imagery from five surrounding years to estimate the average snow-free period, and next by summing snow-free received solar radiation for growing degree days > 0°C. We then combined maps of primary productivity and its components with presence/absence grid sampling of forty-four dominant plant species (N=221 sample points), and differentiated community-types based on total productivity as well as the relative contributions of growing season length, chlorophyll content and the quantity of leaf tissue. In addition to an overall decrease in productivity along an elevation gradient, we found pronounced differences in productivity among plant communities distributed along mesotopographic gradients. Communities exhibiting similar levels of productivity were nonetheless contrasted by consistent variations in the relative contributions of LUE, fPAR and PAR, which indicated different functional strategies with respect to energy availability. This work establishes a protocol for using remote-sensing to estimate primary productivity in topographically complex study areas, and lays the groundwork for improved understanding of responses of alpine plant systems, in terms of both diversity patterns and productivity, to climate-change induced shifts in growing season length and energy availability.