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Estimation of leaf area index and foliage clumping in deciduous forests using digital photography

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Rapid, reliable and meaningful estimates of leaf area index (LAI) are essential to the characterization of forest ecosystems. In this contribution the accuracy of both fisheye and non-fisheye digital photography for the estimation of forest leaf area in deciduous stands was evaluated.
We compared digital hemispherical photography (DHP), the most widely used technique that measures the gap fraction at multiple zenith angles, with methods that measure the gap fraction at a single zenith angle, namely 57.5 degree photography and cover photography (DCP).
Comparison with other different gap fraction methods used to calculate LAI such as canopy transmittance measurements from AccuPAR ceptometer and LAI- 2000 Plant Canopy Analyzer (PCA) were also performed. LAI estimated from all these indirect methods were compared with direct measurements obtained by litter traps (LAILT).
We applied these methods in 10 deciduous stands of Quercus cerris, Castanea sativa and Fagus sylvatica, the most common deciduous species in Italy, where LAILT ranged from 3.9 to 7.3.
DHP and DCP provided good indirect estimates of LAILT, and outperformed the other indirect methods. The DCP method provided estimates of crown porosity, crown cover, foliage cover and the clumping index at the zenith, but required assumptions about the light extinction coefficient at the zenith (k), to accurately estimate LAI. Cover photography provided good indirect estimates of LAI assuming a spherical leaf angle distribution, even though k appeared to decrease as LAI increased, thus affecting the accuracy of LAI estimates in DCP. In contrast, the accuracy of LAI estimates in DHP appeared insensitive to LAILT values, but the method was sensitive to photographic exposure, gamma-correction and was more time-consuming than DCP.
Foliage clumping was estimated from all the photographic methods by analyzing either gap size distribution (DCP) or gap fraction distribution (DHP). Foliage clumping was also calculated from PCA and compared with DHP. The studied stands were characterized by fairly homogeneous canopies with higher within-crown clumping than between-crowns clumping; only the segmented analysis of gap fraction for each ring of the fisheye images was found to provide useful clumping index in such homogeneous canopies. By contrast, the 1-azimuth segment method employed in PCA poorly detected clumping in dense canopies.
We conclude both fisheye and non-fisheye photographic methods are suitable for dense deciduous forests. Cover photography holds great promise as a means to quickly obtain inexpensive estimates of LAI over large areas. However, in situations where no direct reference measurements of k are available, we recommend using both DHP and DCP, in order to cross-calibrate the two methods; DCP could then be used for more routinely indirect measurement and monitoring of LAI.

Keywords: digital hemispherical photography, cover photography, litter trap, AccuPAR ceptometer, LAI-2000.