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Short communication

Estimation of leaf area index in isolated trees with digital photography and its application to urban forestry

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ABSTRACT

Accurate estimates of leaf area index (L) are strongly required for modelling ecophysiological processes within urban forests. The majority of methods available for estimating L is ideally applicable at stand scale and is therefore poorly suitable in urban settings, where trees are typically sparse and isolated. In addition, accurate measurements in urban settings are hindered by proximity of trees to infrastructure elements, which can strongly affect the accuracy of tree canopy analysis.

In this study we tested whether digital photography can be used to obtain indirect estimate of L of isolated trees. The sampled species were *Platanus orientalis*, *Liquidambar styraciflua* and *Juglans regia*. Upward-facing photography was used to estimate gap fraction and foliage clumping from images collected in unobstructed (open areas) and obstructed (nearby buildings) settings; two image classification methods provided accurate estimates of gap fraction, based on comparison with measurements obtained from a high quality quantum sensor (LAI-2000). Leveled photography was used to characterize the leaf angle distribution of the examined tree species. L estimates obtained combining the two photographic methods agreed well with direct L measurements obtained from harvesting. We conclude that digital photography is suitable for estimating leaf area in isolated urban trees, due to its simple, fast and cost-effective procedures. Use of vegetation indices allows extending significantly the applicability of the photographic method in urban settings, including green roofs and vertical greenery systems.

Introduction

Green infrastructures are key components in the planning of sustainable cities. The fields of landscape ecology and urban ecology have emerged from research to become the primary promoter of ecological design in cities (Ong, 2003; Roy et al., 2012). Determining the role urban forests have in mitigating heat island effects, removing air pollutants and cooling buildings represents a central issue (Hardin and Jensen, 2007; Nowak et al., 2006). The influence of urban forests and individual tree species on carbon cycling and greenhouse gasses reduction represent another active research topic (Manes et al., 2012). Specific surveys on urban forests have been carried out to expand the domain of multipurpose forest inventories (*e.g.*, Corona et al., 2012).

The ability to estimate leaf area index (L) is essential to accurately modelling these physiological processes. The amount of leaf area is directly related to the pollutant interception and emission rates of individual tree species (Nowak, 1994). L also influences rainfall storage and its effect on reducing water runoff (Xiao et al., 2000). L is also used as main input variable in building energy balance simulations (Sailor, 2008).

Among the various existing techniques, indirect optical methods have been widely used to indirectly estimate L from measurements of radiation transmittance through the canopy (for a review, see Jonckheere et al., 2004). The Beer–Lambert's law has often been used to model canopy transmittance (Eq. (1), based on Nilson, 1971) as

$$P\left(\theta\right) = \exp\left(\frac{-G\left(\theta\right)\,\Omega\left(\theta\right)L_t}{\cos\theta}\right) \quad (1)$$

where P is the canopy gap fraction, G is the foliage projection function, which is related to the foliage angle distribution, Ω is the foliage clumping index at zenith angle θ and L_t is the plant area

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