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Retrieving Leaf Area Index of Boreal Conifer Forests Using Landsat TM Images

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Vegetation indices, including the simple ratio (SR) and the normalized difference vegetation index (NDVI), from Landsat TM data were correlated to ground-based measurements of LAI, effective LAI, and the crown closure in boreal conifer forests located near Candle Lake and Prince Albert, Saskatchewan and near Thompson, Manitoba, as part of the Boreal Ecosystem–Atmosphere Study (BOREAS). The measurements were made using two optical instruments: the Plant Canopy Analyzer (LAI-2000, LI-COR) and the TRAC (Tracing Radiation and Architecture of Canopies). The TRAC was recently developed to quantify the effect of canopy architecture on optical measurements of leaf area index. The stands were located on georeferenced Landsat TM images using global positioning system (GPS) measurements. It is found that late spring Landsat images are superior to summer images for determining overstory LAI in boreal conifer stands because the effect of the understory is minimized in the spring before the full growth of the understory and moss cover. The effective LAI, obtained from gap fraction measurements assuming a random distribution of foliage spatial positions, was found to be better correlated to SR and NDVI than LAI. The effective LAI is less variable and easier to measure than LAI, and is also an intrinsic attribute of plant canopies. It is therefore suggested to use effective LAI as the most important parameter for radiation interception considerations.

INTRODUCTION

Leaf area index (LAI) quantifies the amount of foliage area per unit ground surface area. It is therefore an important parameter controlling many biological and physical processes associated with vegetation on the Earth's surface, such as photosynthesis, respiration, transpiration, carbon and nutrient cycle, and rainfall interception. LAI is a required input to many climate and ecological models (Sellers et al., 1986; Dickinson et al., 1993; Running and Coughlan, 1988; Bonan, 1993).

Satellite remote sensing provides a unique way to obtain the distributions of LAI over large areas. Green leaves are selective absorbers of solar radiation. Compared with nonvegetative surfaces, green leaves absorb more visible radiation for photosynthesis and less near infrared radiation. Reflectance in red and near-infrared wavebands, denoted by ρ_n and ρ_r, have therefore been used to formulate various vegetation indices as indicators of the conditions of vegetated surfaces (Jordan, 1969; Deering, 1978; Huete, 1988; Baret et al., 1989; Kaufman and Tanré, 1992; Qi et al., 1994; Liu and Huete, 1995; and Roujean and Bréon, 1995). Among the various vegetation indices, the normalized difference vegetation index (NDVI) (Deering, 1978), $(\rho_n - \rho_r)/(\rho_n + \rho_r)$, and the simple ratio (SR) (Jordan, 1969), ρ_n/ρ_r, are most frequently used to derive LAI and other surface parameters from spaceborne and airborne remote sensing data (Sellers et al., 1994; Running et al., 1994), in spite of their limitations in removing the effects of background. Numerous studies have been done to relate vegetation indices to LAI of agricultural crops (e.g., Asrar et al., 1985; Best and Harlan, 1985; Curran and Williamson, 1987; Shibayama and Akiyama, 1989; Wiegand et al., 1988). There have also been several investigations on this relationship between satellite-derived vegetation indices and LAI in conifer stands (Badhwar et al., 1986; Spanner et al., 1990a,b; 1994). The uncertainties in the relationship were found to be large due to the complexity of the radiation environment in forest stands and errors in ground-based measurements. The data for boreal forests appear to be lacking, and much work needs to be done to understand remotely measured spectral signals from forested surfaces.

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