STRATEGIES FOR DETERMINING THE LEAF AREA INDEX AND ITS VARIATION ON FORESTED CATCHMENTS

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1.0 Introduction

Through transpiration and interception, leaves are active agents of the major water vapour losses on forest catchments. These exchanges of water are not only related to the amount of rainfall, solar radiation and wind, but also primarily affected by the amount of leaf surface area involved. This leaf surface area is usually expressed as a leaf area index (LAI), a dimensionless ratio of the leaf surface area, to the ground surface area (Watson 1947).

Though easy to see, the leaf area of trees is difficult to measure, and in spite of its fundamental importance to studies of catchment hydrology, LAI has never been thoroughly studied on a catchment scale. Consequently, no established methodologies exist for determining this quantity on catchments.

The intention of this paper is to review the status of the techniques available for measuring LAI and to discuss how these individual techniques may be combined and applied to estimate catchment LAI.

2.0 Individual techniques

2.1 Remote sensing

Remotely sensed measurements of spectral reflectivity have been used to determine LAI (Pollock and Kanemasu 1979; Curran and Williamson 1987; Peterson et al. 1987; Whitford 1988). Satellite or aircraft based scanners are used. The major attraction of this technique is the potential for complete catchment measurement at a single point in time. No other technique offers such an appropriate scale of measurement.

Remote sensing of LAI has been applied in the jarrah forest (Whitford 1988). This work found that major theoretical and technical developments are required before remote sensing technology may be **routinely** applied to monitor catchment LAI.

To determine LAI from remotely sensed reflectivity, the variation in spectral reflectivity or combinations of spectral bands must be primarily related to variations in LAI. Variations in reflectivity caused by factors other than LAI must be small, random or both, in order for the data to effectively yield values of LAI. Several confounding factors affect the relationship of LAI to remotely sensed data.

There are 4 major factors which impede the routine use of remote sensing to measure LAI.

2.1.1 Sun, scene and sensor geometry effects.

A forest scene is not a simple flat reflecting surface (Breece and Holmes 1971; Suits 1972). The tree canopies in the scene are made up of a complex structure of reflecting elements which are **not** randomly oriented. Because of this structured orientation of reflecting elements, the reflectivity of a scene is affected by the position of the light source, (the sun) and the light sensor, relative to each other and to the scene (Suits 1972; Kanemasu 1974; Ranson et al. 1986).

If forest scans do not share the same sun, scene and sensor geometry, relationships established between LAI and reflectivity in one scan cannot be applied to another scan, ie. when this scan geometry changes, relationships between reflectivity and LAI must be re-established for each scan (Whitford 1988; Leprier et al. 1988).

2.12 Vegetation effects

Increasing the LAI increase the amount of leafy material that reflects solar radiation. Increases in LAI also affect the orientation and layering of the leaves in the tree canopy. Consequently, changes in LAI affect reflectivity both by changing the amount of reflecting material, and by changing the orientation and layering of the reflecting surfaces (Suits 1972).

The spectral response of vegetation is also affected by the stand under-storey and over-storey species composition (Kenneson et al. 1986; Badwar et al 1984), the leaf age, flowering and fruiting of the under-storey and over-storey, and the plant moisture status (Hoffler and Johannsen 1969; Everitt and Nixon 1986; Ripple 1986).

2.1.3 Soil effects

The remote sensing trial conducted in the jarrah forest showed a strong inverse relationship between soil reflectivity and LAI. With increases in LAI, the crown cover increased, and the amount of radiation reflected by the soil decreased (Whitford 1988). Soil reflectivity is affected by the soil type (Colwell 1974; Bunnik 1978) and soil moisture content (Bunnik 1978). If changes in catchment LAI were monitored using remote sensing, then relationships for LAI would need to be re-established to account for the seasonal changes in soil moisture content. Across catchments, the effect of spatial variations in soil type may also need to be considered. Major substrate changes, eg. granite, would effect the assessed LAI (Elvidge and Lyon 1985).

2.1.4 Reflectance and atmospheric effects

Theoretically, relationships exist between bidirectional reflectivity, ie. the percentage of reflected energy under a specific geometry, and LAI. In practice, multispectral scanners measure the reflected radiation as a count, which can be related to the amount of reflected energy detected at the sensor. These scanners are rarely designed to measure both incoming and reflected radiation. (This would enable computation of the reflectance at the sensor altitude.) Consequently, the conversion of the count to actual reflectance, measured at the sensor, involves complex secondary measurements (Gross et al 1987; Chavez 1989). Additionally, if data from separate scans is to be treated similarly, atmospheric effects must be considered to enable the reflectivity measured at the scanner to be converted to reflectivity at ground level (Robinove 1982; Nelson 1985).

Because of these four confounding effects,

2.1.1 sun, scene and sensor geometry,
2.1.2 vegetation effects,
2.1.4 soil effects and
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it is extremely difficult to use the data from one calibration scan to produce a relationship between reflectance and LAI that can be applied to other scans. The published methodologies that use remote sensing (Curran and Williamson 1987; Peterson et al. 1987) involve the development and application of a relationship within a single scan. Although remote sensing provides a complete catchment data set, the high cost of establishing a relationship for LAI on each scan reduces its effectiveness.

Future developments in this technology may improve understanding and enable the use of the complete catchment measurement provided by remote sensing. At present this technology is oriented toward qualitative rather than quantitative description. It is in determining the qualitative variations in LAI about a catchment that this technology would be of most use.

2.2 Gap probability/light interception techniques

Gap proportions, or probabilities, can be measured as the fraction of light that is transmitted through the canopy. Three techniques for determining LAI from gap probabilities have been developed. These are the Li-Cor LAI-2000, the Lang 'Demon' light meter and hemispherical photography. All use slight variations of a common theory and each application has its benefits and shortcomings.

Additionally, the relatively simple design of this sampling strategy allows a straight forward statistical analysis of confidence intervals for the calculated LAI.

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5.0 Conclusion

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