

Large-scale mapping of leaf area index using remote sensing data

TAKASHI ISHII, MAKOTO NASHIMOTO &
HISASHI SHIMOGAKI

Central Research Institute of Electric Power Industry, 1646 Abiko, Abiko-shi,
Chiba-ken 270-1194, Japan

e-mail: tk-ishii@criepi.denken.or.jp

Abstract The estimation of forest leaf area index (*LAI*) based on satellite data was evaluated. We compared direct and indirect *LAI* measurements for two softwood plantations to examine the applicability of the indirect method. Comparison of the normalized difference vegetation index (*NDVI*) based on satellite data with the *LAI* based on the indirect method shows a good relationship for a broad range of *LAI* values. An *LAI* map of Japan estimated from NOAA data largely coincides with published data for all of Japan.

Key words remote sensing; leaf area index; vegetation index; phenology

INTRODUCTION

Recently developed forest assessment techniques using satellite remote sensing data to evaluate the environmental preservation abilities of a forest have not considered leaf area index. Leaf area index (*LAI*) is defined as the total leaf area on a unit ground surface area. It is an important factor in evapotranspiration from the crown and in losses of rainfall due to foliar interception. The *LAI* is applicable to various numerical models of weather prediction and hydrological simulation. Thus, it is important to develop a method of estimating *LAI*.

EVALUATION OF THE INDIRECT MEASURING METHOD

In the past, most leaf area measurements were made directly by clipping foliage. However, in recent years, indirect measuring equipment, such as the LAI-2000 (Plant Canopy Analyzer, Licor Inc.), has come to be used. The LAI-2000, which is designed to make rapid, non-destructive *LAI* determinations, calculates leaf area from incident optical quantity in the forest (for a detailed description, see Welles & Norman, 1991). We compared directly measured *LAI* to indirectly estimated *LAI* in young plantations of Japanese cypress (*Chamaecyparis obtusa* Endl) and Japanese cedar (*Cryptomeria japonica* D. Don). Study plots were located at the field science centre of Tokyo University of Agriculture and Technology and at Mount Fuji National Forest in Shizuoka prefecture. Slopes in these areas are relatively flat. Each *LAI* value was measured by a stratified clip technique and by using the LAI-2000. We observed that predicted *LAI* values using the LAI-2000 were 37% below the direct *LAI* values for Japanese cypress and 22% below the direct *LAI* values for Japanese cedar. There was a

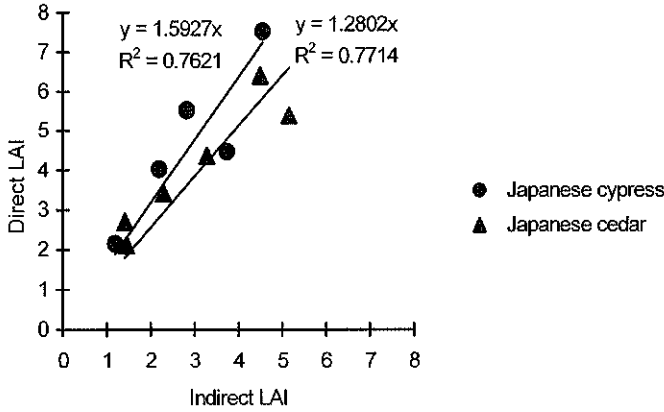


Fig. 1 A comparison of direct and indirect measurements of LAI for two softwood plantations.

strong positive correlation (Fig. 1). These results indicate that the indirect method tends to underestimate LAI as compared with the direct method. The results agreed with those obtained by Gower & Norman (1991) for white pine and Norway spruce. We suggest that the indirect method can be applied practically by using coefficients for each stand.

ESTIMATION OF LAI USING REMOTE SENSING DATA

We compared indirectly measured LAI to the normalized difference vegetation index (NDVI) at the same forest sites where the indirect measuring method was evaluated. Here, NDVI was calculated from visible bands and near infrared bands of SPOT (Satellite Probatoire d’Observation de la Terre) satellite data. The SPOT data used in this investigation consisted of two scenes (row 279, path 329; row 277, path 330), taken on 21 and 22 October 1997. Field measurements in this area were carried out

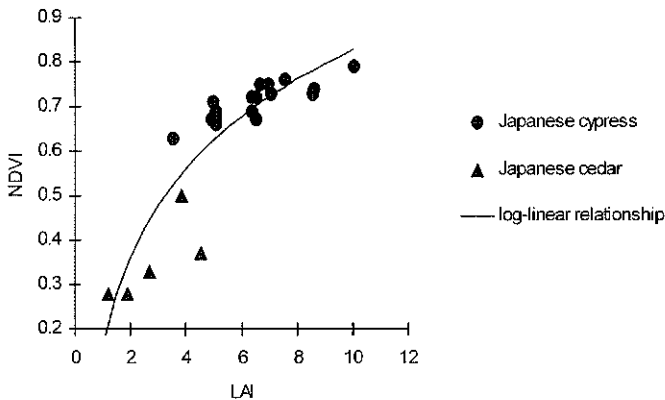


Fig. 2 Relationship between NDVI and LAI values converted from LAI-2000 output into direct LAI. ($NDVI = 0.29 * \ln(LAI/0.577)$ $r^2 = 0.89$.)

during the same month. The comparison showed a good relationship for a broad range of *LAI* values (Fig. 2). A log-linear relationship emerged between the two variables. The relationship seemed to be linear up to an *LAI* of 3–4 and approached an asymptote around an *LAI* of 6–7. These results agreed with those obtained by Nemani & Running (1989) in western Montana, USA.

LARGE-SCALE MAPPING OF *LAI*

In order to apply this method to all areas of Japan, the maximum *LAI* value estimated from NOAA satellite data using this method was compared to literature values found in Shidei & Kira (1977). Figure 3 shows the essential details of the *LAI* mapping procedure. Estimation of *LAI* is according to the following procedure:

- estimation of *LAI* by using the *NDVI*–*LAI* relationship,
- comparison of estimated *LAI* and literature values for each forest type, and
- correction of estimation errors by linear regression.

This method is derived from maximum *LAI* because most of literature values record only maximum *LAI* values. We obtained NOAA satellite-derived *NDVI* data from April 1992 to November 1995 prepared by the EROS Data Center (Townshend *et al.*, 1994). In addition, we collected the *Vegetation Survey File* (Environmental Agency of Japan, 1993), and land-use data of the *Digital National Land Information* (Geographical Survey Institute, 1998). The *LAI* product is an *LAI* value from zero to nine for each 1×1 km pixel (see Fig. 4). The comparison shows almost complete agreement for all areas of Japan. This *LAI* map has a high resolution (1 km), 100 times higher than that of the conventional *LAI* map of Japan.

This approach to estimating *LAI* involves many simplifications and approximations. Therefore, this method of measuring *LAI* using remote sensing data will need to

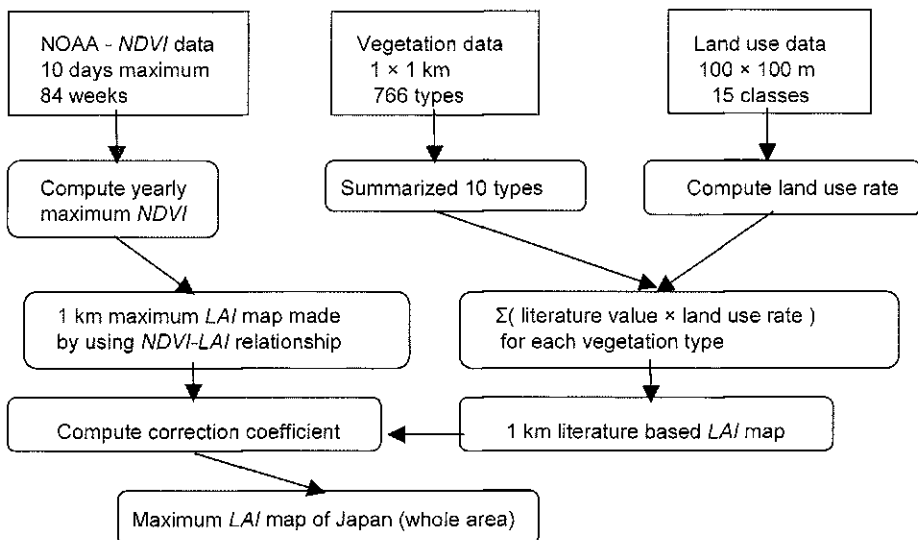


Fig. 3 Details of the *LAI* mapping algorithm.

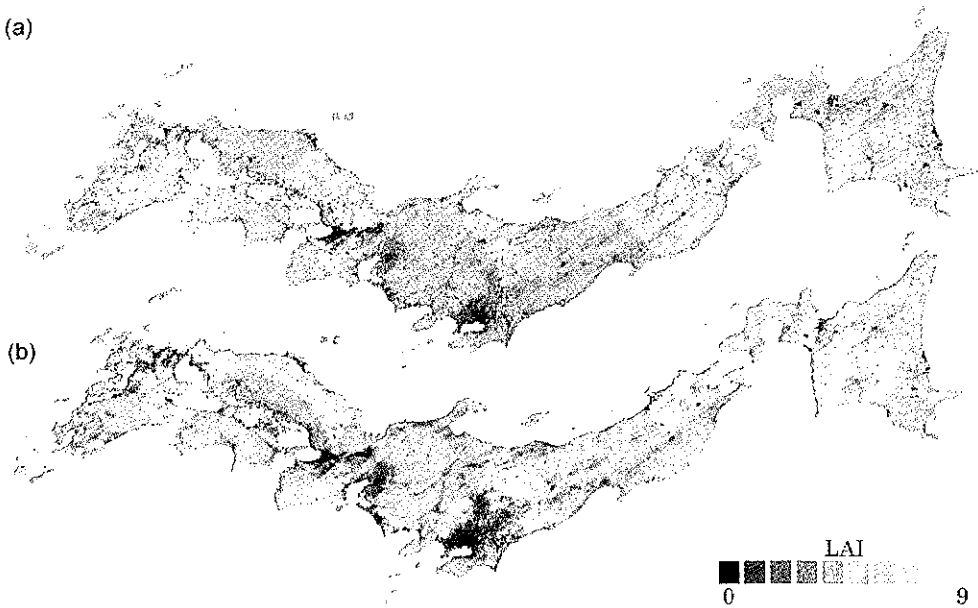


Fig. 4 Maximum value maps of leaf area index in Japan: (a) created from vegetation and land use maps, and published values; and (b) created using satellite data and coefficient values.

be corrected by the verification of evapotranspiration and water balance over a large area.

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