BOREAL FOREST LEAF AREA INDEX (LAI) ESTIMATION USING WIDE OPTICS AIRBORNE WINTER PHOTOS

Terhikki Manninen [1],*, Lauri Korhonen [2], Pekka Voipio [3], Panu Lahtinen [1] and Pauline Stenberg [4]

[1]Finnish Meteorological Institute, [2]University of Joensuu, [3]Finnish Forest Research Institute (Metla),
[4]University of Helsinki

1. INTRODUCTION

The boreal zone land cover has a very significant influence on the northern hemisphere albedo and is an important component of the northern hemisphere carbon budget [1, 2] and is sensitive to changes in local and global climate [3]. Forest transition zones react to changes in mean temperature and moisture conditions in the long term [4] whereas changes in, for example, forest leaf area index (LAI) through defoliation indicate stress factors in shorter time scale [5]. Also the timing of the phenological phase transitions is an important indicator of global climatological processes [6]. LAI is one of the Essential Climate Variables (ECV) defined in the Implementation Plan for the Global Observing System for Climate in Support of the United Nations Framework Convention on Climate Change (UNFCCC) [7]. The development and validation of satellite based LAI estimation methods require reliable *in situ* measurements of LAI. For large areas of tall vegetation it is difficult to get aerially representative ground truth using direct or indirect methods [8, 9], especially in regions of difficult accessibility.

2. MATERIALS AND METHODS

A new airborne method is presented here for leaf area index estimation. The basic technique is the same as used in hemispherical photo analysis [10, 8]. The difference is just that the background is the snow covered terrain instead of the sky. This naturally limits the use of the technique to the areas with annual snow cover. In addition, the method is not directly suited for broadleaved canopies, which are usually without leaves at the time of the snow cover. Boreal forests are typically dominated by coniferous species and the snow covered season is mostly long. Therefore the method is well suited for LAI estimation of boreal forest in larger areas and especially useful in the northernmost regions, where the roads are sparse and it is difficult to access the forests scattered between wetlands.

Figure 1. An example of the wide optics airborne photos taken from a helicopter.

The photos are taken automatically and stored to a laptop during the flights [Figure 1]. The hemispherical analysis is carried out later using the Nobis-Hunziker [11] or Ridler-Calvard [12] thresholding algorithms to separate the vegetation pixels from the background. Possible shadows of trees can be removed using the 2nd principal component of the blue channel of the RGB images.

3. RESULTS

The R^2 value of the linear regression of the airborne and ground based LAI measurements was 0.89 for the whole test data set and better, when the amount of deciduous species was reduced [Figure 2]. The reason for this is that the ground truth was measured in the autumn, when the leaves were still present, but the airborne data was gathered in winter, when the deciduous trees were without leaves.

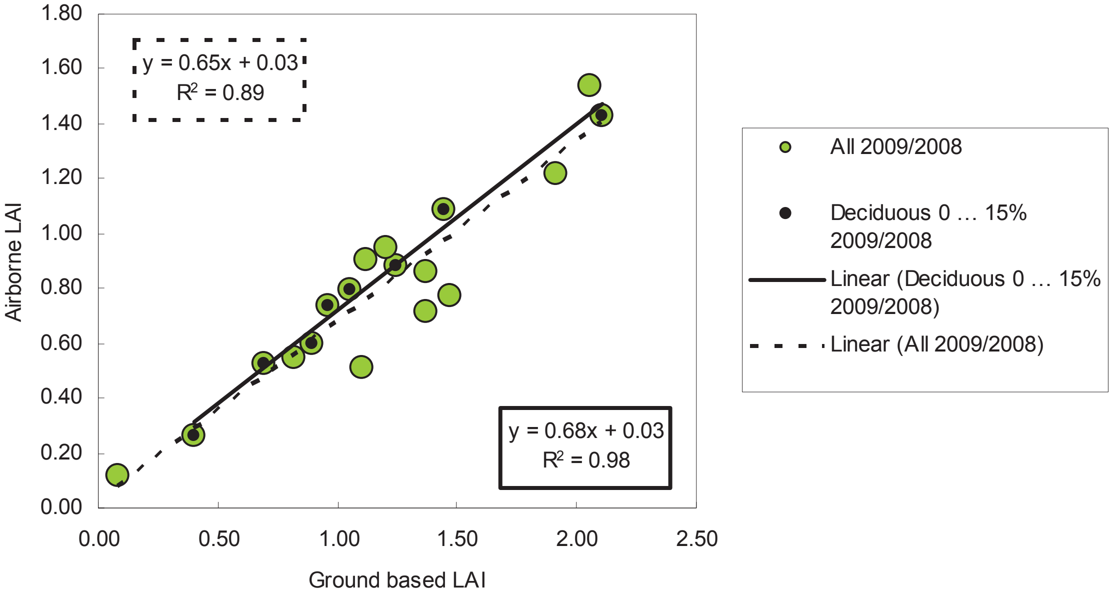

Figure 2. Relationship of the ground based and airborne LAI values. The airborne values were measured in March 13, 2009 and corresponding ground measurements were carried out during August 26 - September 5, 2008.

The angle from the image centre for the airborne camera was about 41° at the corners of the rectangular images and 35° and 28° at the middle of the image edges. The ground based images were taken using a full hemispherical view angle, but only zenith angles 0–75° were utilized in the analysis so as to correspond to measurements by the LAI-2000. This explains why the slope of the ground vs. airborne LAI estimates deviates from unity.

4. REFERENCES

[1] Bonan, G.B.; Pollard, D.; Thompson, S.L. Effects of boreal forest vegetation on global climate. *Nature* **1992**, *359*, 716-718.

[2] Randerson, J. T.; Liu, H.; Flanner, M. G.; Chambers, S. D.; Jin, Y.; Hess, P. G.; Pfister, G.; Mack, M. C.; Treseder, K. K.; Welp, L. R.; Chapin, F. S.; Harden, J. W.; Goulden, M. L.; Lyons, E.; Neff, J. C.; Schuur, E. A. G.; Zender, C. S. The Impact of Boreal Forest Fire on Climate Warming, *Science* **2006**, *314(5802)*, 1130 – 1132.

[3] IPCC: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, **2007**, 976pp

[4] Solantie, R. Productivity of boreal forests in relation to climate and vegetation zones. *Boreal Environment Research* **2005***, 10*, 275-297.

[5] ICP Forests: *The Condition of Forests in Europe, 2007 Executive Report*, Federal Research Centre for Forestry and Forest Products (BFH), Hamburg and Brussels **2007**, 33 p.

[6] Menzel, A. Sparks, T.H. Estrella, N., Koch, E., Aasa, A., Ahas, R., Alm-Kübler, K., Bissolli, P., Braslavská, O., Briede, A. Chmielewski, F.M., Crepinsek, Z., Curnel, Y., Dahl, Å, Defila, C., Donnelly, A., Filella, Y., Jatczak, K., Måge, F., Mestre, A., Nordli, Ø., Peñuelas, J., Pirinen, P., Remiřová, V., Scheifinger, H., Striz, M., Susnik, A., Van Vliet, A.J.H., Wielgolaski, F.-E., Zach, S., Zust, A. European phenological response to climate change matches the warming pattern, *Global Change Biology* **2006**, *12 (10)* , 1969–1976.

[7] (http://unfccc.int/2860.php).

[8] Jonckheere, I.; Fleck, S.; Nackaerts, K.; Muysa, B.; Coppin, P.; Weiss, M.; Baret, F. Review of methods for in situ leaf area index determination Part I. Theories, sensors and hemispherical photography. *Agricultural and Forest Meteorology* **2004**, *121*, 19–35.

[9] Breda, N.J. Ground-based measurements of leaf area index: a review of methods, instruments and current controversies. *Journal of Experimental Botany* **2003**, *54*, 2403-2417.

[10] Miller, J. B. A formula for average foliage density, *Aust. J. Bot.* **1967,** *15*, 141-144.

[11] Nobis, M., Hunziker, U. Automatic thresholding for hemispherical canopy-photographs based on edge detection, *Agricultural and Forest Meteorology* **2005**, *128* (2), 243-250.

[12] Ridler, T.W. and Calvard, S. Picture thresholding using an iterative selection method, *IEEE Transac-ons on Systems, Man, and Cybernetics* **1978,** *8*, 630-632.