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Short communication

Continuous observation of leaf area index at Fluxnet-Canada sites

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ABSTRACT

Continuous observation of leaf area index (LAI) is needed in order to interpret and model carbon, water and energy fluxes measured at Fluxnet tower sites. Although remote sensing LAI products can be used in regional and global scale modelling with reasonable performance, the site level modelling of ecophysiological processes needs more accurate LAI time series than those provided by global LAI products. Here we present a semi-empirical approach using satellite measured modified soil-adjusted vegetation index (MSAVI) and sparsely sampled LAI time series measurements at 7 Canadian Carbon Program (CCP) flux tower sites to produce continuous observations of site level LAI. The results indicate that accurate and continuous observation of site level LAI time series is possible using a few ground measurements and remotely sensed MSAVI observations. In order for the semi-empirical model to work correctly, the ground LAI measurements should represent all seasons, preferably including extreme values in winter and the peak of growing season.

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1. Introduction

Leaf area index (LAI), defined as one half the total leaf area per unit horizontal ground surface area (Chen and Black, 1992; Gonsamo and Pellikka, 2008; Jonckheere et al., 2004), is a key parameter for interpreting carbon, water and energy fluxes. It is also of a great interest to modellers who attempt to upscale the flux tower measurements and leaf level ecophysiological processes to canopy or ecosystem levels based on unit LAI (e.g., Chen et al., 1999). The global network of Fluxnet tower sites including the Canadian Carbon Program (CCP) encourages its participants to acquire accurate and consistent seasonal in situ LAI measurements. In situ LAI measurements are usually acquired using various indirect measurement techniques such as hemispherical photography, LAI-2000 (Li-Cor, Nebraska, USA), and TRAC (Third Wave Engineering, Ottawa, Canada) which have been tested and shown to have comparable estimates to that from labour-intensive direct (destructive) measurements (Breda, 2003; Chen and Cihlar, 1995; Chen et al., 2006, 1997; Gonsamo et al., 2011b; Gower et al., 1999; Jonckheere et al., 2004; Weiss et al., 2004). However, continuous indirect measurement of LAI is challenging because it involves several field visits which are not often attainable. Therefore, researchers who conduct in situ evaluation of different ecophysiological process models for carbon, water and energy flux simulations have often relied on satellite LAI products, in place of more accurate continuous ground based LAI measurements (Gonsamo et al., 2013). A recent study by Ryu et al. (2012) has shown that continuous observations of LAI using indirect methods (digital cameras) perform comparably with the direct LAI measurement. They have also demonstrated seasonal biases involved in a standard Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product indicating the satellite-based LAI estimates cannot directly be used as a replacement of continuous in situ LAI observations. One possible solution for continuous LAI observation is to measure LAI in the growing season and develop an empirical relationship with satellite-based continuous measures of vegetation index (VI). However, this relationship is often linear since it is developed at the peak of the growing season when VIs are known to saturate to changing LAI. Therefore the summertime VI-LAI relationship cannot be used for LAI seasonal mapping. This short communication will address the use of VI-LAI semi-empirical formulations considering the non-linear VI-LAI relationships constrained with sparsely sampled in situ LAI time series at CCP Fluxnet sites.

2. Methods

We focus on 7 forest and grassland CO_2 flux tower sites from the Canadian Carbon Program (CCP) formerly known as Fluxnet-Canada Research Network (FCRN) which have in situ LAI measurements. The sites include 5 needleleaf forest, 1 deciduous

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Table 1
Site description.

Site	Code	Land cover	Overstorey	LAI measurement year (number of measurements)	Lat., Long.	Instrument	Sampling	$MSAVI_{\infty}$	k	LAI measurement reference
Alberta Grassland, Lethbridge, Alberta	AB-GRL	Grassland	Mixed Prairie Grass Spp.	2001(12), 2002(14), 2003(11), 2004(13), 2005(14), 2006(14)	49.7093, −112.940	LI-3100 Area Meter	Grid	0.332	0.435	Flanagan et al. (2002)
2000 Harvested Douglas Fir, Campbell River, B.C.	BC-DF00	Needleleaf forest	*P. menziesii*	2001(1), 2002(7), 2003(7), 2004(6), 2005(6)	49.871, −125.291	LAI-2000, Point quadrant, Hemispherical, LI-1300 C Area Meter photography	Transect, grid	0.497	2.179	Chen et al. (2006) and Humphreys et al. (2005)
1988 Harvested Douglas Fir, Campbell River, B.C.	BC-DF88	Needleleaf forest	*P. menziesii*	2002(8), 2003(11), 2004(7), 2005(5)	49.535, −124.900	LAI-2000, Hemispherical photography, LI-1300 C Area Meter	Transect	0.656	3.608	Chen et al. (2006) and Humphreys et al. (2005)
Old Mixed Wood, Timmins, Ontario	ON-OMW	Needleleaf forest	*Picea mariana*	2003(2), 2004(4)	48.217, −82.156	Hemispherical photography	Grid	0.604	1.911	Thomas et al. (2008)
Old Aspen, Prince Albert, Sask.	SK-OA	Broadleaf forest	*Populus tremuloides*	2002(5), 2003(1), 2004(2), 2005(1)	53.629, −106.1978	LAI-2000, TRAC	Transect	0.635	0.843	Chen et al. (2006)
Southern Old Black Spruce, Candle Lake, Sask.	SK-SOBS	Needleleaf forest	*P. mariana*	2001(3), 2004(3)	53.987, −105.118	LAI-2000, TRAC	Transect	0.311	1.637	Chen et al. (2006)
Southern Old Jack Pine, Candle Lake, Sask.	SK-OJP	Needleleaf forest	*P. banksiana*	2001(3), 2004 (3), 2005(1)	53.916, −104.692	LAI-2000, TRAC	Transect	0.292	1.152	Chen et al. (2006)

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