LEAF-Toolbox Monthly Leaf Area Index for Canada at 20m Resolution using the Simplified Level 2 Prototype Processor - CCRS v1 Product User Guide

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Definitions

Leaf area index (LAI) is defined as half the total green foliage per unit horizontal ground area [1].

Summary of Changes in v1

V1 implements the SL2P-CCRS algorithm [2] for Sentinel 2 Multispectral Instrument Imagery produced by the European Space Agency [3] and archived in Google Earth Engine [4].

V1 differs from the original implementation of the SL2P algorithm [5] within the implementation of SL2P in the S2Toolbox [6] as follows:

1. SL2P samples canopy parameters used for calibration and validation simulations using truncated distributions. S2Toolbox incorrectly specifies the truncation by "reflecting" the truncated probability density functions about their boundary.. This tends to increase the likelihood of retrievals of very low and high (in the reflected regions) LAI [7].
2. SL2P defines a retrieval as out of bounds of the input range of the calibration dataset if measured input reflectance does not sufficiently match values in the calibration database. To do this, SL2P partitions the input reflectance space into regular hypercubes with a length of 0.1. The input domain is then approximated as those hypercubes containing a calibration sample and retrievals are flagged as out of domain if the measured inputs do not fall in any such hypercube. S2Toolbox implements an approximate solution that results in significantly more retrievals flagged as out of domain (the approximation defines a convex hull of input reflectances , dilates the hull to a certain extent and checks if retrievals are within the convex hull [7].
3. SL2P uses only one regression estimator irrespective of land cover. This estimator is suitable for non-woody vegetation[8,9] but underestimates LAI for forests and other woody vegetation [7]. The SL2P-CCRS algorithm applies separate estimates for broadleaf woody vegetation (DBF), evergreen woody vegetation (ENF) calibrated using measurements from forests and shrubs in addition to the SL2P estimator that is applied for other vegetated land cover. No estimate is produced over non-vegetated land cover (snow, ice, water) and urban land cover.

Algorithm Description

The SL2P-CCRS algorithm is defined in [2]. For each cover class, the algorithm calibrates a per-measurement (pixel) non-linear regression estimator for LAI as a function of inputs from the Sentinel 2A or 2B Level 2A Surface Reflectance Products [10] and land cover [11] (Table 1). Version 1 does not make a distinction in spectral response between S2A and S2B instruments as the calibration difference is currently larger [10].

Table 1. SL2P inputs for S2A MSI. Noise for angles corresponds to half of their quantization range.

Input	Centre Wavelength	Bandwidth	Multiplicative Noise	Additive Noise
MSI Band or Angle	nm	nm	% relative	%reflectance of degrees
Band 3 – Green	559.8	36	4	2
Band 4 – Red	664.6	31	4	2
Band 5 – Vegetation red edge	704.1	15	4	2
Band 6 – Vegetation red edge	740.5	15	4	2
Band 7 – Vegetation red edge	782.8	20	4	2

Band 8A – Narrow NIR	864.7	21	4	2
Band 11 – SWIR	1613.7	91	4	2
Band 12 – SWIR	2202.4	175	4	2
Solar Zenith Angle				0.5
View Zenith Angle				2.5
Relative Azimuth Angle				2.5

The estimators are derived from samples drawn from a population of simulations of S2A MSI top-of-canopy directional (under typical clear sky conditions) reflectance representative of global acquisitions over vegetation for the cover class. Directional reflectance is simulated using the PROSPECTD leaf optical model [12] coupled with 4SAIL2 canopy radiative transfer model [13] modified to include shoot clumping effects. Vegetation conditions are sampled using Sobol sampling from the 13 dimensional probability distributions of parameters used by model calibrated using available in-situ data. Marginal distributions of the bivariate distribution of LAI and each parameter are further constrained using in-situ data. As such these distributions are realistic but could be locally unbiased. Acquisition geometry is random sampled using a Sentinel 2A orbital model (identical for S2B) for each simulation independent of vegetation parameters. Measurement error corresponding to the same uncertainties used in SL2P for S2A measurements over flat terrain (Table 2) are added to each sample. A total of 41782 (for non woody) and 228,000 (for woody vegetation) samples are used for calibration and an independent set samples of the same size are used for validation.

LEAF-Toolbox-Canada Products

The standard LEAF-Toolbox-Canada v1 products are at 20m spatial resolution in Lambert Equal Area Conformal Conic projection defined using parallels specific to Government of Canada national products (Table 2) and subsetted using a tiling grid defined for National Scale Land Surface Characterization (Figure 3). Data for tiles indicated outside of Canada are available on request. Users are encouraged to use the LEAF-Toolbox (https://github.com/rfernand387/LEAF-Toolbox) to produce local higher resolution products for custom temporal intervals.

Table 2. Projection parameters and ellipsoidal earth model for products.

Parameter	Value
Projection LCC	Lambert Confromal Conic
1st parallel	49º
2nd parallel	77 º
Central meridian	95º
Upper left corner	2,600,000m E , 10,500,000m N
Lower right corner	3,100,000m E, 5,700,000m N
Easting	0m E
Northing	0m N
Major semi-axis	6,378,137m
First eccentricity	0.00669438002290
Ellipsoidal flattening	0.00335281068118

Table 3. Product Definition LEAF_LAI_Canada_Monthly_V1. Size corresponds to one product tile.

Layer Name	Definition	Min	Max	Scale	Type	Size
LAI	Leaf area index monthly composite.	0	12	20	8U	2.5Gb
Datem	Date of sample pixel.	0	65535	Days since January 1, 1970	16U	5.0Gb
QC	Quality of LAI retrieval.	0	127	N/A	8U	2.5Gb

Table 4. QCm

Bit	**Value**	**Description**
Bit 0: Input within domain bit		
	0	Input data within domain
	1	Input data out of domain
Bit 1: FCOVER within range bit		
	0	LAI within range
	1	LAI out of range range
Bit 2: Valid input bit.	0	Input valid.
	1	Input invalid, snow covered, cloudy.
Bits 4-7	40, 56, 64, 72, and 168	Input Sensor. 168 corresponds to Sentinel 2A or 2B

The SL2P-CCRS algorithm is applied to S2A and S2B products using Google Earth Engine based on python code [13].The monthly compositing algorithm is performed on a per-pixel basis as 20m resolution. All valid retrievals within domain and range for a given pixel are composited by maximizing Equation 1:

pix_score = spec_score x time_score (1)

Where spec_score is a score proportional to the likelihood a pixel is clear sky [2] and time_score is inversely proportional to the difference, in days, between a considered retrieval and the mid-date of the composite interval. The calculation of the spec_score is only based on blue and infrared bands, so is applicable for most multispectral satellite images. There are two reasons to include the time_score in the scoring system: (1) ensuring the selected clear-sky pixels were measured within a short period of time; (2) increasing the spatial smoothness of a composited image.

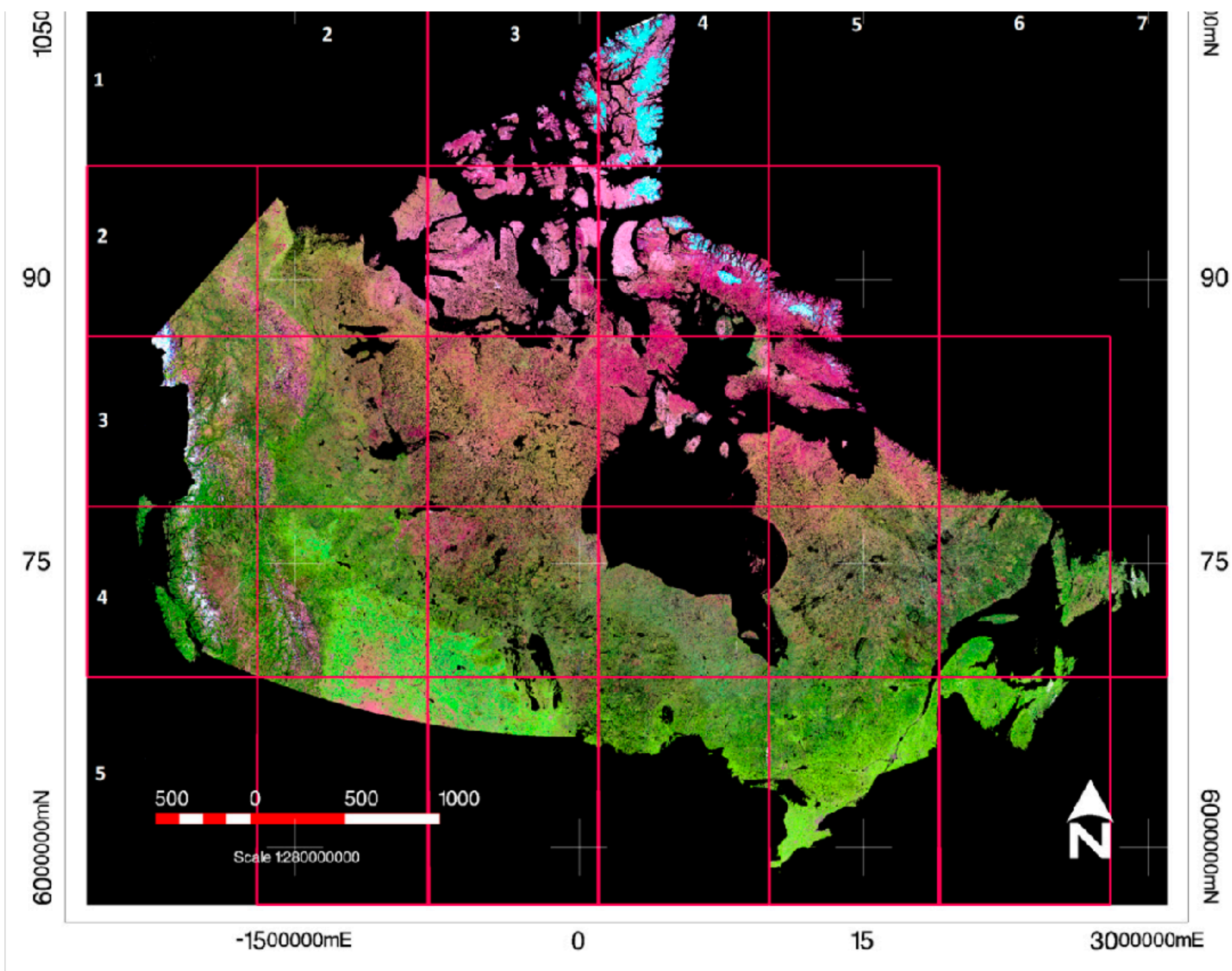

Figure 3. Tiling system used for product physical formatting of National Land Surface Characterization products for Canada [11].

Product Uncertainty

Product uncertainty is quantified according to Committee of Earth Observing Systems (CEOS) Good Practices [15] at CEOS Level 3 (representative of Canada). Uncertainty is given in [16] for North American woodlands, forests and treed wetlands and [7,8] for croplands, grasslands, and vegetation in built up areas. Uncertainty has not been quantified over tundra and non-treed wetlands. Uncertainty of retrievals with invalid or out of range QC flags is not quantified. These flags may have errors so users are recommended to additionally screen products based on conditions listed in Table 5. Expected values for the root mean square uncertainty based on cross-validation can be modelled using functions given in Table 6. Actual uncertainty may vary in space and time but current validation indicates these models are representative of typical retrievals on average [7,8,9]. Users should refer to the SL2P-CCRS ATBD [2] for detailed uncertainty estimates at other percentiles of cross-validation residuals.

Table 5. Guidance for uncertainty modelling.

Condition	Value
Out of domain.	Table 6 as minimum bound.
Out of range.	Invalid if negative retrieval. Table 6 at maximum valid retrieval minimum bound.
Invalid pixel QC.	Discard retrieval.
Complex terrain (not flat)	Table 6 as minimum bound if terrain slope >5degrees.
Complex terrain (differences in canopy heights >20m between pixels).	Table 6 as minimum bound.
Mixed pixels, flooded pixels, snow or ice pixels, senescent vegetation >10%.	Discard retrieval

Table 6. Expected value of 1 standard deviation uncertainty for LAI (U) as a function estimated LAI.

Land Cover	Model	range	outside range
Non woody vegetation or barren land.	U=max(0.25,-0.1406+0.6045LAI-0.05145LAI^2)	[0,6]	2
Broadleaf woody vegetation	U=max(0.25,-0.00215+0.5156LAI-0.04387LAI^2)	[0,7]	1.5
Needleaf woody vegetation	U=max(0.25,0.2567+0.4722LAI-0.04338LAI^2)	[0,7]	1.5

How to Obtain the Data

Products can be visualized via Government of Canada Open Science and Data Platform (https://datacube.services.geo.ca/en/viewer/eo4ce/vegetation/monthly-vegetation.html).

Products can be downloaded from STAC Catalogue links replacing YYYY with the year and MM with the month:

https://datacube-prod-data-public.s3.amazonaws.com/store/land/vegetation/biosphysical-vegetation-parameters/medium-resolution/monthly-vegetation-parameters-20m-v1/monthly-vegetation-parameters-v1-YYYYMM-LAI.tif

Note that ancillary 'Retrieval Date' layers will be available for products December 2024 with STAC Catalogue links replacing YYYY with the year and MM with the month:

https://datacube-prod-data-public.s3.amazonaws.com/store/land/vegetation/biosphysical-vegetation-parameters/medium-resolution/monthly-vegetation-parameters-20m-v1/monthly-vegetation-parameters-v1-YYYYMM-date.tif

We recommend using either the STAC API in Python or QGIS for free and open subsetting and access. In QGIS you can view and subset data from the 'LAYER->Add Layer->Raster' menu by selecting the 'Protocol' button as the data source and pasting the desired STAC catalogue link.

If you require other dates consider using the LEAF Production tool GitHub - fqqlsun/LEAF_production.

Policies

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