**Validation of vegetation biophysical variables retrievals from The Simplified Level 2 Product Prototype Processor (SL2P) and Landsat-8 data**

1. Introduction

Global and long-term records of vegetation variables is a fundamental requirement for effectively monitoring and managing landscapes and forest environments facing accelerated natural and anthropic changes (Venterm et al. 2020, Camarretta et al. 2020, Brovelli et al. 2020). Remotely sensed optical images have been identified as principal source for mapping vegetation variables at global scale (GCOS, 2022).

Several operational models have been developed to retrieve vegetation biophysical variables from remotely sensed optical images, including radiative transfer model (RTM) inversion, statistical approaches, and hybrid techniques (Ganguly et al., 2012; Li et al., 2015; Verrelst et al., 2015, Fang et al. 2019). For instance, about 1-decade of ~4-days leaf area index (LAI) global products are made available using multispectral data from Moderate Resolution Imaging Spectrometer (MODIS). However, although MODIS vegetation products sufficiently met the GCOS temporal requirements of ~10-days, they do not satisfy the spatial resolution requirement (<100m).

Landsat series satellites represent an essential source for temporal monitoring land conditions and dynamics at local scale. They offer an unprecedented 4-decade records of 30m spatial resolution ~biweekly multispectral data extensively used for mapping and temporal monitoring of vegetation variables (Lopes et al., 2019, Ganguly et al. 2012, Jackson et al. 2004). More recently, the European Space Agency launched the Copernicus Sentinel-2 (S2) mission with an unprecedented combination of systematic global coverage of land surfaces a high revisit (5-days in the equator) and high spatial resolution (from 10m to 60m) designed to provide satellite data that can be used to map widely used land surface variables (Drusch et al. 2012). ESA sponsored the Simplified Level 2 Prototype Processor (SL2P, Weiss and Baret, 2016) as a baseline mapping solution to estimate five vegetation biophysical variables given the surface reflectance and the acquisition geometry: the leaf area index (LAI), the fraction of canopy cover (fCOVER), the fraction of absorbed photosynthetically active radiation (fAPAR), canopy water content (CWC) and canopy chlorophyll content (CCC). SL2P is a collection of back-propagation artificial neural networks calibrated using a globally representative canopy parameters and the corresponding surface reflectance simulates from SAILH (Verhoef, 1985) radiative transfer model. Previous validation studies indicates that SL2P generally satisfies GCOS uncertainty requirements for crops (Djamai et al., 2019; Hu et al., 2020) but underestimates LAI (by up to 50%) and fAPAR (by up to 20%) in comparison to in-situ reference measurements (RMs) over dense forests (Putzenlechner et al., 2019; Brown et al., 2019, Brown et al., 2021, Fernandes et al., 2023). Similar results are generally obtained for a stage-3 validation study over 281 forested sites across North America (Fernandes et al. 2023). Fernandes et al. (2024) hypotheses that this underestimation is due to the homogeneity of the used RTM based previous research studies of Brown et al. (2019) and Shabanov et al. (2005), and they proposed an up-graded version of SL2P (SL2P-CCRS) witch consider (i) replacing the spatially homogenous SAILH canopy radiative transfer model with the heterogenous 4SAIL2 model to account for the impact of crown clumping on canopy bi-directional reflectance, (2) replacing orthogonal sampling by Sobol sampling, and (iii) using land cover specific regressions (ANNs) instead of a single regression irrespective of land cover. SL2P-CCRS is implemented in Google Earth Engine within the Landscape Evolution And Forecasting (LEAF) Toolbox (Fernandes et al. 2021), and it allows mapping the above mentioned vegetation biophysical variables from both S2 and Landsat (Landsat-8 (L8), Landsat-9 and The Harmonized Landsat Sentinel-2) data. Fernandes et al. (2024) demonstrated that, compared to SL2P, SL2P-CCRS reduced LAI bias by 65% (~0.5 at LAI~3 and by ~1 at LAI~6), fAPAR bias by 31% but <0.05 on an absolute basis.

The first objective of this study is to validate SL2P-CCRS estimates of LAI, fAPAR and fCOVER obtained from L8 data (SL2P-CCRS/L8) and from S2 data (SL2P-CCRS/S2) using extensive validation dataset with wide range of vegetation types across North America, by quantifying their accuracy, precision, uncertainty and uncertainty agreement ratio. Additionally, we aim to compare SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR to the corresponding SL2P-CCRS/S2 estimates. Our hypothesis is that vegetation variables estimates from SL2P-CCRS/L8 and SL2P-CCRS/S2 could be combined to build denser vegetation variables time-series. The temporal stability of estimates defined as “The change in bias over time” (WMO, 2022) is a factor of uncertainties to demonstrate that the estimation error remains constant over the period, typically a decade or more. In this study, we also aimed to investigate the temporal stability of SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates. We hypothesis that …..

Our study provides new validation results for SL2P-CCRS applied on different widely used medium resolution multi-spectral satellite data (L8 and S2) with an extensive validation dataset. Although, SL2P-CCRS/S2 is previously validated using similar dataset (Fernandes et al. 2024), it is important, for comparison purpose, to validate products with the same dataset. Our study is novel in that (i) it directly compares vegetation variables retrievals from L8 and S2 data using the same model (SL2P-CCRS), and (ii) it quantifies the temporal stability of vegetation variables estimates from medium resolution multispectral satellite data.

1. Study sites and materials.
   1. In-situ reference measurements

In-situ reference measurements acquired within the National Ecological Observatory Network (NEON) across North America and Canada Centre for Remote Sensing (CCRS) - Natural Resources Canada’s Cumulative Effects study sites across Canada are used.

NEON sites included a wide range of vegetation types as defined by the National Land Cover Database (NLCD, [National Land Cover Database | U.S. Geological Survey (usgs.gov)](https://www.usgs.gov/centers/eros/science/national-land-cover-database)) classification: evergreen forest (EF), deciduous forest (DF), mixed forest (DF), cultivated crops (CC), emergent herbaceous wetlands (EHW), grassland herbaceous (GH), pasture hay (PH), sedge herbaceous (SH), shrub scrub (SS), woody wetlands (WW), and dwarf scrub (DS). While CCRS sites included EF, DF and MF classes.

Figure 1 shows the location of NEON and CCRS sites, as well as the dominant NLCD class for each site. More details are provided in Table 1 of Appendix A.

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Figure 1: NEON and CCRS study sites.

For NEON sites, fraction of intercepted PAR (fIPAR), fCOVER, and LAI reference measures were derived from estimates of gap fraction obtained using digital hemispherical photography (DHP) 634 ESUs in 47 sites across North America (NEON, 2019). For each site, at least three 20 m by 20 m square ESUs were sampled bi-weekly from leaf-out to senescence for periods ranging from 3 to 6 years (Table 1 in Appendix A). In each ESU, 12 co-located upward and downward looking DHP images were acquired with 4 m spacing in North-South and East-West transects through the plot centre using 36.3MPixel Nikon D810 or D800 cameras with a Nikon 16 mm Fisheye lens giving a 180◦ diagonal field of view (Meier et al. 2018, Brown et al. 2020).

PAI was determined from upwards and downward images separately according to Miller (1967) approach as the average of effective PAI estimates for 10 azimuthal intervals within zenith angle. The effective PAI for each azimuth angle was estimated as twice the negative logarithm of the gap fraction multiplied by the cosine of the zenith angle. fIPAR (fCOVER) was determined, from upwards and downward images, as one minus the mean gap fraction within ±5◦ of the solar zenith angle at 10:00 local solar time (±5◦ of nadir).

CCRS data are acquired for 133 ESUs in 11 forested sites. ESUs were located within the dominant land cover types at each site with replication where logistics permitted. For each ESU, seven co-located upward and downward DHP images were acquired every 5 m along two parallel transects spaced 15 m apart using 45.7 Mpixel Nikon D850 cameras with a Nikon 8 mm Fisheye lens giving a 180◦ FOV in all directions. DHPs for each ESU sampling date were visually quality controlled, contrast enhanced using ViewNXi software and masked to remove the field operator. CANEYE V6.45, using the same approach as GBOV, was used to derive PAI, fCOVER and fAPAR as well as the associated 1σ uncertainties for each upward or downward DHP image.

* 1. Satellite data

L8 and S2 surface reflectance data are extracted from Google Earth Engine (GEE) collections LANDSAT/LC08/C02/T1\_L2 and COPERNICUS/S2\_SR\_HARMONIZED respectively. More details about data extraction are presented in section 3.2.

L8 is part of the Landsat Data Continuity Mission (Irons et al., 2012) launched by National Aeronautics and Space Administration in cooperation with United States Geological Survey on February 11, 2013. It has a sun-synchronous orbit at an altitude of ~705 km, with approximately 16-day revisit of the Earth and an equatorial overpass time of approximately 10:15 a.m. (descending node). It carries the Operational Land Imager (OLI) that has eight spectral bands at 30m spatial resolution covering the visible, the near infrared (NIR) and the shortwave-infrared (SWIR) spectral regions, and one 15m spatial resolution panchromatic band (Table 1). L8 surface reflectance data are estimated (atmospheric effects correction) using Landsat Surface Reflectance Code (LaSRC, Vermote et al., 2018).

S2 is a constellation of satellites, S2-A and S2-B, launched by the European Space Agency (ESA) on 23 June 2015 and 7 March 2017, respectively. They occupy the same sun-synchronous orbit at an altitude ~786 km but separated by 180°. Together, they provide better than 5-day revisit of the Earth's land surfaces with an equatorial overpass time at approximately 10:30 a.m. (descending node). S2-A and S2-B carry a virtually identical decametric resolution Multi-Spectral Imager (MSI) covering the visible, the near infrared (NIR) and the shortwave-infrared (SWIR) spectral regions (Table 2). SR data are obtained by correcting atmospheric effects on to-of-atmosphere reflectance using the Sen2Cor processor (Version 2.4.0, Müller-Wilm et al., 2017).

Table 1: L8-OLI bands (SL2P-CCRS input bands are in bold)

|  |  |  |  |
| --- | --- | --- | --- |
| Band | Resolution | Central Wavelength (nm) | Description |
| B1 | 30 | 443 | Coastal / Aerosol |
| B2 | 30 | 482 | Blue |
| **B3** | **30** | **562** | **Green** |
| **B4** | **30** | **655** | **Red** |
| **B5** | **30** | **865** | **NIR** |
| **B6** | **30** | **1610** | **SWIR 1** |
| **B7** | **30** | **2200** | **SWIR 2** |
| B8 | 15 | 590 | Panchromatic |
| B9 | 30 | 1375 | Cirrus |

Table 2: S2-MSI bands (SL2P-CCRS input bands are in bold)

|  |  |  |  |
| --- | --- | --- | --- |
| Band | Resolution | Central Wavelength (nm) | Description |
| B1 | 60 m | 443 | Ultra Blue (Coastal and Aerosol) |
| B2 | 10 m | 490 | Blue |
| **B3** | **10 m** | **560** | **Green** |
| **B4** | **10 m** | **665** | **Red** |
| **B5** | **20 m** | **705** | **Visible and Near Infrared (VNIR)** |
| **B6** | **20 m** | **740** | **Visible and Near Infrared (VNIR)** |
| **B7** | **20 m** | **783** | **Visible and Near Infrared (VNIR)** |
| B8 | 10 m | 842 | Visible and Near Infrared (VNIR) |
| **B8a** | **20 m** | **865** | **Visible and Near Infrared (VNIR)** |
| B9 | 60 m | 940 | Water vapour |
| B10 | 60 m | 1375 | Cirrus |
| **B11** | **20 m** | **1610** | **Short Wave Infrared (SWIR)** |
| **B12** | **20 m** | **2190** | **Short Wave Infrared (SWIR)** |

1. Methodology
   1. Reference measures determination and filtering

Total LAI, fCOVER and fAPAR reference measures (RM) are determined by summing PAI, fCOVER and fIPAR quantities determined from downward and upward DHPs scaled by one minus the corresponding woody-to-total area ratios given in Table 3. The understory woody-to-total area ratio is considered assuming herbaceous and shrub understory cover have non-zero woody to total area ratio that is typically less than trees due to absence of trunks (Fernades et al. 2023).

The uncertainty of RMs is determined as indicated in Fernandes et al. 2023.

~~The uncertainty of a RM value was estimated as the Euclidean sum of the understory and overstory 1σ uncertainties weighted by their proportion of the total RM. The 1σ uncertainty of overstory or understory components was estimated as the Euclidean sum of the 1σ uncertainties due to levelling error, sampling variability, the applied woody to total area ratio, ratio, and for LAI, a 0.025 1σ uncertainty due to clumping.~~

Table 3: woody-to-total area ratios for different NLCD classes

|  |  |  |
| --- | --- | --- |
| NLCD class | Overstory | Understory |
| EF | 0.16 | 0.05 |
| DF | 0.24 | 0.05 |
| MF | 0.18 | 0.05 |
| Others | 0.10 | 0.05 |

RMs from NEON sites are filtered to reduce outliers (Figure 1, Appendix B). A moving window filtering approach was used. Considering RMs time-series for a given variable acquired on a specific ESU, each observation (with an uncertainty ) is compared to the 2 enveloping quantities and acquired within +/- 15-days (when they exists). Outlier flag is raised when three conditions are simultaneously satisfied:

With is an empirical threshold fixed for each vegetation variable.

In total, less than 1% of RMs are detected as outliers (0.31% for LAI, 0.97% for fCOVER and 0.93% and fAPAR). More details are provided in Table 1 in Appendix B).

* 1. Satellite-based vegetation variables estimates.

SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR associated with their quality control flags are retrieved for the different RMs. Inputted bands are indicated in Table 1 (L8) and Table 2 (S2). Valid estimates for clear sky land pixels whose centroid fell within 30 m (20 m) radius for L8 (S2) (i.e. 3x3 pixels window) from the centre of each ESU and ± 7 days interval from the DHP acquisition date are extracted. Only satellite images with cloud cover less than 90% are considered. LaSRC and Sen2Cor cloud products are used for masking cloud from L8 and S2 images respectively. S2 cloud probability product (S2cloudless, GEE collection 'COPERNICUS/S2\_CLOUD\_PROBABILITY’) is also considered to improve the cloud mask for S2 data. Extracted SL2P-CCRS estimates from L8 and S2 are aggregated, using the median statistics, and associated as estimates for the different RMs.

* 1. Cross-validation

SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR are compared to RMs for ten different NLCD classes: EF, DF, MF, CC, EHW, GH, PH, SH, SS and WW (DS class was excluded from our analysis since ….). RMs for BARR and TOOL sites, showing a class underestimation compared to estimates (Figure 1 and Figure 2, Appendix C), are adjusted by adding the bias.

The accuracy (A), the uncertainty (U), the precision (P), the coefficient of determination (R2), and the uncertainty agreement ratio (UAR) of SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates were computed for the entire population (RMs) as:

where, , (, ) are, respectively, the SL2P-CCRS estimate and RM for the ith of N comparisons (their corresponding average values), and , are, respectively, the relative and maximum target uncertainty requirement and I is the indicator function.

Additionally, as suggested by Global Leaf Area Index Product Validation Good Practices (Fernandes et al., 2014), thematic error metrics (A, P, U) are plotted as a function of the RM value by considering a third order polynomial weighted least squares regressions fitted to quantities based on residuals between the mean of matching RM values and the corresponding SL2P-CCRS estimates as detailed in Fernandes et al. (2024).

* 1. Cross-comparison

SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR and the corresponding SL2P-CCRS/S2 estimates acquired within +/-1 day during the entire overlapping period (from 2018 to 2023) are extracted, for all NEON and CCRS sites, and processed as described in section 4.2. Multi-source estimates are directly compared using density contour plots and R2, A, P and U statistics for the different NLCD classes.

* 1. Temporal stability.

Word Meteorological Organization defined the stability as “The change in bias over time” (WMO, 2022). It is a factor of uncertainties to demonstrate that the estimation error remains constant over the period, typically a decade or more.

In this study, the slope of annual estimates bias (annual bias slope, ABS) was computed as a proxy of the stability. Annual bias (AB) values are computed for years with at least 5 RMs/estimates matchups. Then, linear fit regressor is considered to estimate the slope (S) when at least 5 (4 for L8) estimates of AB are a4vailable. The mean and the standard deviation of AB values (AB-AVG and AB-STD, respectively), as well as the 95% Confidence Interval of the slope (CI) are computed to assess the robustness and for the analysis of the stability proxy.

ABS values are computed for SL2P-CCRS estimates of LAI, fCOVER and fAPAR obtained from both L8 and S2 data, considering (i) all sites merged together, and (ii) at site basis (e.i. for each single site); for sites with more than one NLCD class (e.g. ABBY site, Table ##), each class is considered separately.

1. Results
   1. Cross-validation

Figure 2.1 (Figure 2.2) present scatter plots of SL2P-CCRS/L8 (SL2P-CCRS/S2) estimates of LAI, fCOVER and fAPAR against RMs together with population validation metrics. Figure 3 presents validation metrics for each NLCD class as well as the sample size and the variation range of RMs.

A total of 6313 matchups was found between SL2P-CCRS/L8 estimates and RMs (Figure 2.1) compared to 4935 matchups SL2P-CCRS/S2 estimates (Figure 2.2). RMs of LAI, fCOVER and fAPAR range, respectively, from 0.01 to 5.96, from 0 to 0.96, and from 0 to 0.93 for SL2P-CCRS/L8 (Figure 3 and Table 1 in Appendix 3), and from 0 to 6.87, from 0 to 0.99, and from 0 to 0.95 for SL2P-CCRS/S2 (Figure 3 and Table 2 in Appendix C).

Figures 2.1 and 2.2 indicates that despite a relatively linear relationships between estimates and RMs (R2 ~0.75), both SL2P-CCRS/L8 LAI and SL2P-CCRS/S2 (A~-0.50) LAI underestimate RMs. This explains the high uncertainty () and the low UAR (~0.10) of estimates. This is an expected result since SL2P-CCRS is not properly accounting for clumping. Conversely, both SL2P-CCRS/L8 and SL2P-CCRS/L8 fCOVER estimates are ~unbiased, and with ~equal uncertainty (~0.15), R2 (0.75) and UAR (~0.37). SL2P-CCRS/L8 and SL2P-CCRS/S2 fAPAR estimates are slightly underestimated (A=-0.05), but, as for fCOVER, with ~equal uncertainty (0.16), R2 (~0.73) and UAR (~0.34).

Figure 3 indicates that comparable class specific statistics are generally obtained for SL2P-CCRS/L8 and SL2P-CCRS/S2, mainly for A (differences from 0 to 0.39 for LAI, from 0 to 0.04 for fCOVER and fAPAR) and U (differences from 0 to 0.32 for LAI, from 0 to 0.03 for COVER and fAPAR) statistics.

SL2P-CCRS estimates are underestimated irrespective to the sensor (L8 or S2) and the vegetation variable for woody wetlands, evergreen forest, deciduous forest, and mixed forest: from-1.87 to -0.78 for LAI, from -0.12 to -0.01 for fCOVER, and from -0.19 to -0.08 for fAPAR. The underestimation is always higher for woody wetlands. While estimates are overestimated for the other classes: from 0 to 0.46 for LAI, from 0.01 to 0.12 for fCOVER, and from 0.01 to 0.08 for fAPAR.

The uncertainty of LAI estimates ranges between 1 and ~2 for forested sites (woody wetland, mixed, evergreen, and deciduous forests) and lower than 1 unit other unforested sites. For fCOVER and fAPAR no clear trend could be noted, but it ranges between 0 and 0.20.

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Description automatically generated with medium confidenceFigure 2.1: Scatter plots of SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR versus matching RMs together with population validation metrics. Dashed lines bound target user requirement around solid 1:1 line.

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Figure 2.2: Scatter plots of SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR versus matching RMs together with population validation metrics. Dashed lines bound target user requirement around solid 1:1 line.

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Figure 3: Class specific validation metrics for SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR against RMs together with used samples size (histograms) and RMs variation range (bars, intermediate point corresponds to the median value).

Figure 4 shows APU curves for SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR, as well as the partition (histogram) of samples used to fit APU curves. The increased samples density for the different variable’s levels explains the narrow confidence interval of APU models. Wider confidence intervals are for the highest variables’ levels (i.e. LAI>6, fCOVER>0.9, and fAPAR>0.9) due to the lower sample density (i.e. ~200 for LAI, ~100 for fCOVER and ~180 samples for fAPAR, regardless the sensor).

APU curves associated to SL2P-CCRS/L8 estimates compares well with the corresponding curves associated to SL2P-CCRS/L8 estimates, regardless the vegetation variable. In fact, LAI estimates uncertainty ~linearly increases from ~0 for LAI ~0 to ~3 for LAI~7; it satisfies GCOS requirements only for LAI<3. In contrast, the accuracy ~linearly decreases from ~0 for LAI~0 to ~-3 for LAI~7. Whereas the precision remains ~stable and lower than 1 for all ranges. The accuracy and the precision of estimates from L8 are found slightly lower than the corresponding quantities from S2, in contrast to the uncertainty which is slightly higher for L8.

For fCOVER, the accuracy and the uncertainty simultaneously increase from ~0.1 to ~0.15 for the range 0 - 0.2, then decrease to ~-0.1 (accuracy) and ~0.1 (uncertainty) for the range 0.2-0.8, and finally increase to ~-0.5 (accuracy) and 0.2 (uncertainty) for the range 0.8-1. The precision remains ~ stable (~0.1) for the entire range. Target uncertainty requirements are only satisfied for fCOVER levels from 0.5 to 0.9.

For fAPAR, the accuracy decreases from ~ 0.2 for fAPAR~0 to ~-0.2 for fAPAR~1. While the uncertainty decreases from ~0.2 to ~0.1 for the range 0 - 0.5, then it increases back from ~0.1 to ~0.2 for the range 0.5 - 1. Whoever, the precision, as for LAI and fAPAR, remains ~stable for the entire range.

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Figure 4: APU curves and the corresponding 95% confidence intervals (dashed contours) for SL2P-CCRS/L8 and SL2P-CCRS/S2 estimates of LAI, fCOVER and fAPAR. Dashed grey lines bound target user requirements. (add APU for intercomparison, S2 is the ref)

* 1. Cross-comparison

Figure 7 shows density contour plots of SL2P-CCRS/S2 LAI, fCOVER and fAPAR estimates versus the corresponding estimates from SL2P-CCRS/L8. Estimates for unforested classes are merged for three raisons: the small sample size for some classes, the similarity of contours behaviour (not shown), and the simplicity of figures. Figure 8 shows class specific thematic statistics.

About 32000 samples of SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR (each) are compared to the corresponding SL2P-CCRS/S2 estimates acquired within +/-1 day (Table 1, Appendix D). Biggest samples sizes are for evergreen forest, grassland herbaceous, deciduous forest, and shrub scrub with more than 5000 samples. While, the smallest samples sizes are for sedge herbaceous, pasture hay, emergent herbaceous wetlands and cultivate crops (between 280 and 1000 samples).

SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR generally compares well to the corresponding SL2P-CCRS/S2 estimates: R2>0.85 for the different variables, A~0.04 (~0.01) for LAI (fCOVER and fAPAR) and U ~0.54 (~0.09) for fCOVER and fAPAR (Table 1, Appendix D).

Figure 7 indicates that, SL2P-CCRS/L8 underestimate LAI in comparison to SL2P-CCRS/S2 estimates for deciduous and mixed forests (more pronounced underestimation ~-1.5 for high LAI values ~5) in contrast to the other classes, with LAI estimates not exceeding 4 units in general, which fit well with 1:1. For too low LAI values (<1) SL2P-CCRS/L8 generally overestimate LAI from SL2P-CCRS/L8 for the different classes. For fCOVER and fAPAR, density contours plots fit well with 1:1 line with a slight underestimation (~-0.05) for high values. Similarly, for short vegetation (fCOVER or fAPAR<0.2) SL2P-CCRS/L8 fCOVER and fAPAR generally overestimate the corresponding estimates from SL2P-CCRS/S2 for different classes.

Except for sedge herbaceous, pasture hay and emergent herbaceous wetlands which have the smallest samples sizes ~~and the narrowest variation ranges~~ (Figure 8), R2 ranges between 0.72 (mixed forest) and 0.90 (cultivated crops) for LAI, between 0.77 (mixed forest and grassland herbaceous) and 0.93 (cultivated crops) for fCOVER, and between 0.76 (mixed forest) and 0.94 (cultivated crops) for fAPAR.

The accuracy ranges between -0.33 (deciduous forest) and 0.16 (shrub scrub) for LAI, between -0.03 (deciduous forest and mixed forest) and 0.06 (sedge herbaceous) for fCOVER, and between -0.04 (evergreen forest) and 0.06 (sedge herbaceous) for fAPAR.

The uncertainty ranges between 0.30 (shrub scrub) and 0.83 (deciduous forest) for LAI, between 0.06 (shrub scrub) and 0.10 (deciduous forest, mixed forest, grassland herbaceous and pasture hay), and between 0.06 (shrub scrub) and 0.10 (deciduous forest, mixed forest and pasture hay) for fAPAR.

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Figure 7: Density contour plots of SL2P-CCRS/S2 estimates of (a) LAI, (b) fCOVER and (c) fAPAR (x-axis) versus the corresponding SL2P-CCRS/L8 estimates (y-axis): continuous and dashed lines are the 0.5 and 0.1 quantiles respectively.

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Figure 8: Class specific thematic statistics between SL2P-CCRS/S2 LAI, fCOVER and fAPAR estimates (reference) compared to the corresponding estimates from SL2P-CCRS/L8 together with the samples size (histogram) and the variation range of estimates from SL2P-CCRS/S2 (orange bars).

* 1. Temporal stability of SL2P-CCRS vegetation variable estimates

Figure ## shows the variation of AB between LAI estimates from L8 (S2) and RMs between 2014 (2019) and 2022. AB values are computed with at least ~200 samples/year for L8 and at least 700 samples/year for S2.

Results indicates that LAI estimates from L8 are quite stable during about one decade of estimates (9-years, ABS ~-0.03 units/year). AB values range between ~-1 and -0.40 units with an average of -0.60 and a standard deviation of 0.17. Results for LAI estimates from S2 are not concussive since covers a shorter period of time (4-years). Nerveless, AB values for LAI estimates from S2 data fit well with corresponding values obtained for estimates from L8 data during the overlapping period (from 2019 to 2022).

Similar results are obtained for fCOVER and fAPAR estimates (not shown to avoid complexity). Notably, the stability of estimates obtained from L8 (ABS (CI) ~0 (<0.01)) for both, and the unconclusive of ABS values obtained for estimates from S2.

The stability of SL2PCCRS estimates from L8 and S2 data is further investigated at sites basis. However, only ABS values and the associated confidence intervals are reported to avoid complexity. Figure ## shows scatter plots of ABS values compared to AB-AVG for LAI, fCOVER and fAPAR over 42 NEON sites with NLCD classes, the size of circles is proportional to the site mean RM for a given variable. The obtained ABS values range from ~0.17 to 0.08 (average -0.01 and std ~0.06) for LAI [CI mean ~0.13 and std ~0.11], and from -0.02 to 0.02 (average 0 and std 0.01) for fCOVER and fAPAR [CI mean ~0.02 and std ~0.01].

Despite the shorter covered period (unconclusive results), comparable ABS values are generally observed for estimates from S2 data (Figure ##), but with larger CIs. In fact, ABS values ranges between -0.18 and 0.25 (average 0.02 and standard deviation 0.09) for LAI [CI mean ~0.26 and std ~0.13], and from -0.03 to 0.03 (average ~0 and standard deviation ~0.01) for fCOVER and fAPAR [CI mean ~0.05 and std ~0.03].

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Figure 6.a: Scatter plots of ABS vs. AB-AVG for SL2PCCRS estimates of LAI, fCOVER and fAPAR obtained from L8 data. x/y error bars: CI / AB-STD, size: RM-AVG, color: NLCD class.

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Figure 6.b: Scatter plots of ABS vs. AB-AVG for SL2PCCRS estimates of LAI, fCOVER and fAPAR obtained from S2 data. x/y error bars: CI / AB-STD, size: RM-AVG, color: NLCD class.

1. Discussions
2. Data limitation

* Huge validation dataset with multiple land covers
* Outliers
* Unbalanced sample size
* Difference in S2 and L8 footprints

1. Important results

* compared to RMs, comparable results could be obtained using SL2P-CCRS from L8 and S2
* SL2P-CCRS underestimate LAI (U~1.30) for both sensors
* Unbaised fCOVER and fAPAR (uncertainty of ~0.15) for both sensors
* Low UAR (~0.10 for LAI, 0.35 for fCOVER and fAPAR)
* SL2P-CCRS underestimate vegetation variables for forested sites (WW, DF, EF and MF).
* SL2P-CCRS overestimate vegetation variables for unforested sites.
* The uncertainty (and the absolute value of the accuracy) generally increases with the absolute value of vegetation variable.
* The precision is stable.
* Cross-indicates that:
* R2 ranges between 0.72 and 0.94 for the different variables, except classes with low sample size
* L8 underestimate vegetation variables retrievals from S2 for forested sites (WW, DF, EF and MF), mainly for DF LAI.
* L8 generally overestimate vegetation variables retrievals from S2 for unforested sites.
* The uncertainty ranges from 0.30 to 0.83 for LAI and from 0.06 to 0.10 for fCOVER and fAPAR.

1. Conclusions
2. References

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Appendix A

Table 1: Number of ESUs, sampling period, number of acquired samples, and NLCD classes for CCRS and NEON sites.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Site** | **Network** | **#ESUs** | **Start Date** | **End Date** | **#sample** | **NLCD (#sample)** |
| Peace River | CCRS | 3 | 2019-08-12 | 2019-08-12 | 3 | DF (3) |
| YellowKnife | 3 | 2019-08-11 | 2019-08-12 | 3 | EF (3) |
| Merbleue | 3 | 2019-09-18 | 2019-09-18 | 3 | EF (2), DF (1) |
| Hay River | 28 | 2019-09-05 | 2019-09-07 | 28 | EF (27), MF (1) |
| Geraldton | 3 | 2020-07-21 | 2020-07-21 | 3 | EF (2), DF (1) |
| NovaScotia | 3 | 2021-08-26 | 2021-08-27 | 3 | EF (2), DF (1) |
| Turkey Point | 3 | 2019-06-27 | 2019-06-27 | 3 | EF (2), DF (1) |
| Vancouver Island | 3 | 2019-08-09 | 2019-08-10 | 3 | EF (3) |
| MtPolley | 3 | 2019-08-14 | 2019-08-15 | 3 | MF (2), EF (1) |
| Labrador | 12 | 2019-07-24 | 2019-07-31 | 12 | MF (6), EF (6) |
| STER | NEON | 19 | 2014-04-01 | 2022-09-08 | 357 | CC (357) |
| KONA | 24 | 2017-06-22 | 2022-10-27 | 221 | CC (221) |
| TREE | 23 | 2015-07-08 | 2022-06-21 | 238 | DF (145), MF (79), WW (11), EF (3) |
| UKFS | 24 | 2016-04-06 | 2022-10-25 | 326 | DF (268), EF (55), GH (3) |
| BART | 27 | 2016-04-14 | 2022-11-17 | 373 | DF (234), MF (128), EF (11) |
| SERC | 25 | 2017-06-16 | 2022-09-12 | 362 | DF (356), CC (6) |
| SCBI | 27 | 2015-04-29 | 2022-09-26 | 410 | DF (402), PH (8) |
| STEI | 23 | 2014-05-08 | 2022-10-18 | 265 | DF (259), MF (3), WW (3) |
| BLAN | 22 | 2015-09-12 | 2022-06-21 | 369 | DF (126), SS (118), CC (115), PH (10) |
| CLBJ | 25 | 2016-03-23 | 2022-11-01 | 348 | DF (328), GH (20) |
| ORNL | 31 | 2016-03-09 | 2022-11-27 | 437 | DF (416), EF (12), PH (9) |
| LENO | 23 | 2014-06-06 | 2022-09-26 | 307 | DF (193), WW (114) |
| GRSM | 23 | 2017-08-14 | 2022-10-04 | 323 | DF (319), EF (4) |
| MLBS | 23 | 2016-06-08 | 2022-12-03 | 214 | DF (214) |
| BONA | 25 | 2014-06-04 | 2022-10-25 | 181 | DF (93), EF (77), SS (6), MF (3), WW (2) |
| DELA | 26 | 2015-04-19 | 2022-10-03 | 332 | DF (294), WW (34), EF (4) |
| HEAL | 23 | 2017-07-17 | 2022-08-22 | 176 | DS (160), SS (15), EF (1) |
| BARR | 23 | 2018-04-26 | 2022-08-23 | 79 | EHW (64), SH (15) |
| TEAK | 20 | 2013-04-17 | 2022-08-10 | 92 | EF (91), SS (1) |
| JERC | 26 | 2015-07-28 | 2022-12-29 | 378 | EF (364), DF (7), MF (4), CC (3) |
| SOAP | 23 | 2018-07-30 | 2021-09-22 | 152 | EF (150), SS (2) |
| ABBY | 18 | 2016-11-01 | 2022-11-24 | 211 | EF (139), GH (68), SS (3), MF (1) |
| YELL | 17 | 2018-06-12 | 2022-11-01 | 83 | EF (72), SS (10), GH (1) |
| GUAN | 24 | 2019-06-13 | 2022-09-27 | 518 | EF (518) |
| SJER | 23 | 2014-05-16 | 2022-10-12 | 342 | EF (207), DF (101), GH (30), SS (4) |
| RMNP | 25 | 2016-07-06 | 2022-09-12 | 197 | EF (82), DF (58), MF (57) |
| PUUM | 23 | 2013-06-11 | 2022-08-04 | 320 | EF (320) |
| OSBS | 34 | 2017-08-04 | 2022-10-25 | 474 | EF (435), WW (22), DF (7), MF (6), EHW (4) |
| WREF | 27 | 2018-04-10 | 2022-11-01 | 176 | EF (176) |
| DEJU | 23 | 2016-08-25 | 2022-07-05 | 170 | EF (160), SS (8), WW (2) |
| TALL | 23 | 2016-03-16 | 2022-10-27 | 411 | EF (390), DF (12), MF (9) |
| KONZ | 24 | 2016-05-10 | 2022-10-17 | 352 | GH (348), DF (4) |
| NOGP | 23 | 2015-07-14 | 2022-09-19 | 274 | GH (274) |
| NIWO | 24 | 2017-06-19 | 2022-10-19 | 201 | GH (188), EF (13) |
| DCFS | 23 | 2014-03-26 | 2022-10-26 | 247 | GH (247) |
| CPER | 23 | 2014-05-08 | 2022-10-19 | 451 | GH (451) |
| WOOD | 27 | 2014-05-01 | 2022-10-24 | 372 | GH (361), EHW (11) |
| HARV | 21 | 2014-05-20 | 2022-07-12 | 378 | MF (244), EF (126), DF (6), WW (2) |
| UNDE | 27 | 2016-04-15 | 2022-12-29 | 286 | MF (105), WW (100), DF (81) |
| LAJA | 4 | 2013-02-11 | 2022-09-21 | 456 | PH (455), EF (1) |
| DSNY | 24 | 2017-07-10 | 2022-08-15 | 488 | PH (452), WW (36) |
| TOOL | 22 | 2021-07-15 | 2021-07-22 | 133 | SH (111), DS (20), SS (2) |
| SRER | 23 | 2016-04-27 | 2022-10-24 | 339 | SS (339) |
| JORN | 23 | 2015-06-10 | 2022-11-01 | 335 | SS (335) |
| OAES | 20 | 2016-03-21 | 2022-11-15 | 323 | SS (213), GH (110) |
| ONAQ | 23 | 2014-05-22 | 2022-09-13 | 350 | SS (337), EF (13) |
| MOAB | 23 | 2015-05-13 | 2022-11-01 | 314 | SS (311), EF (3) |
| **Total** |  |  |  |  | **14205** |  |

Appendix B

A graph of data showing the number of data

Description automatically generated with medium confidence

Figure 1: Example of outliers detected on RM time series acquired on site GUAN\_054

Table 1: Number and percentage (compared to the sample size) of outliers detected for each variable and NLCD class.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | LAI | | | fCOVER | | | fAPAR | | |
| NLCD | #N | #Outliers | % | #N | #Outliers | % | #N | #Outliers | % |
| EF | 3427 | 3 | 0.09 | 3427 | 30 | 0.88 | 3427 | 16 | 0.47 |
| GH | 2101 | 1 | 0.05 | 2101 | 4 | 0.19 | 2101 | 3 | 0.14 |
| SS | 1704 | 0 | 0 | 1704 | 1 | 0.06 | 1704 | 1 | 0.06 |
| MF | 639 | 1 | 0.16 | 639 | 1 | 0.16 | 639 | 1 | 0.16 |
| SH | 126 | 0 | 0 | 126 | 0 | 0 | 126 | 0 | 0 |
| EHW | 79 | 0 | 0 | 79 | 0 | 0 | 79 | 0 | 0 |
| DF | 3923 | 19 | 0.48 | 3923 | 28 | 0.71 | 3923 | 31 | 0.79 |
| PH | 934 | 16 | 1.71 | 934 | 55 | 5.89 | 934 | 48 | 5.14 |
| CC | 702 | 2 | 0.28 | 702 | 16 | 2.28 | 702 | 16 | 2.28 |
| WW | 326 | 2 | 0.61 | 326 | 2 | 0.61 | 326 | 2 | 0.61 |
| ~~DS~~ | ~~180~~ | ~~0~~ | ~~0~~ | ~~180~~ | ~~0~~ | ~~0~~ | ~~180~~ | ~~0~~ | ~~0~~ |
| **Total** | **14141** | **44** | **0.31** | **14141** | **137** | **0.97** | **14141** | **118** | **0.83** |

Appendix C

A diagram of a triangle

Description automatically generated

Figure 1: Scatter plots of SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR versus matching RMs, for BARR site, together with population validation metrics. Dashed lines bound target user requirement around solid 1:1 line.

A diagram of a function

Description automatically generated

Figure 2: Scatter plots of SL2P-CCRS/L8 estimates of LAI, fCOVER and fAPAR versus matching RMs, for TOOL site, together with population validation metrics. Dashed lines bound target user requirement around solid 1:1 line.

Table 1: R2, A, P and U statistics for SL2P-CCRS/L8 LAI, fCOVER and fAPAR estimates compared to RMs, as well as the samples size (N) and the variation range (min max) of RMs.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | LAI | | | | | | fCOVER | | | | | | fAPAR | | | | | |
| NLCD | N | R2 | A | U | min | max | N | R2 | A | U | min | max | N | R2 | A | U | min | max |
| EHW | 35 | 0.57 | 0.13 | 0.32 | 0.58 | 2.02 | 35 | 0.61 | 0.05 | 0.09 | 0.13 | 0.58 | 35 | 0.79 | 0.03 | 0.07 | 0.16 | 0.60 |
| SH | 67 | 0.47 | -0.01 | 0.20 | 0.71 | 1.88 | 67 | 0.57 | 0.01 | 0.06 | 0.24 | 0.61 | 67 | 0.52 | 0.01 | 0.07 | 0.22 | 0.60 |
| CC | 226 | 0.80 | 0.31 | 0.51 | 0.11 | 4.13 | 226 | 0.77 | 0.12 | 0.16 | 0.00 | 0.84 | 226 | 0.83 | 0.07 | 0.12 | 0.03 | 0.84 |
| PH | 374 | 0.69 | 0.37 | 0.58 | 0.57 | 3.81 | 374 | 0.68 | 0.11 | 0.17 | 0.04 | 0.84 | 374 | 0.68 | 0.06 | 0.13 | 0.03 | 0.83 |
| SS | 570 | 0.91 | 0.28 | 0.65 | 0.20 | 5.96 | 570 | 0.88 | 0.06 | 0.10 | 0.00 | 0.96 | 570 | 0.88 | 0.06 | 0.10 | 0.00 | 0.93 |
| GH | 1095 | 0.69 | 0.39 | 0.60 | 0.10 | 5.71 | 1095 | 0.75 | 0.11 | 0.15 | 0.00 | 0.94 | 1095 | 0.76 | 0.08 | 0.13 | 0.01 | 0.91 |
| WW | 137 | 0.67 | -1.55 | 1.92 | 0.57 | 5.43 | 137 | 0.55 | -0.10 | 0.17 | 0.19 | 0.88 | 137 | 0.43 | -0.18 | 0.23 | 0.18 | 0.85 |
| MF | 305 | 0.72 | -1.31 | 1.53 | 0.51 | 4.70 | 305 | 0.83 | -0.05 | 0.10 | 0.18 | 0.89 | 305 | 0.72 | -0.12 | 0.15 | 0.17 | 0.86 |
| DF | 1716 | 0.72 | -1.26 | 1.69 | 0.04 | 5.67 | 1716 | 0.74 | -0.04 | 0.13 | 0.03 | 0.95 | 1716 | 0.71 | -0.10 | 0.15 | 0.04 | 0.92 |
| EF | 1788 | 0.52 | -0.78 | 1.44 | 0.01 | 4.48 | 1788 | 0.55 | -0.05 | 0.17 | 0.01 | 0.87 | 1788 | 0.50 | -0.13 | 0.21 | 0.02 | 0.85 |
| All | 6313 | 0.77 | -0.53 | 1.30 | 0.01 | 5.96 | 6313 | 0.77 | 0.01 | 0.15 | 0.00 | 0.96 | 6313 | 0.74 | -0.05 | 0.16 | 0.00 | 0.93 |

Table 2: R2, A, P and U statistics for SL2P-CCRS/S2 LAI, fCOVER and fAPAR estimates compared to RMs, as well as the samples size (N) and the variation range (min max) of RMs.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | LAI | | | | | | fCOVER | | | | | | fAPAR | | | | | |
| NLCD | N | R2 | A | U | min | max | N | R2 | A | U | min | max | N | R2 | A | U | min | max |
| EHW | 40 | 0.47 | 0.27 | 0.37 | 0.16 | 1.88 | 40 | 0.54 | 0.02 | 0.06 | 0.03 | 0.41 | 40 | 0.51 | 0.02 | 0.07 | 0.04 | 0.41 |
| SH | 79 | 0.23 | 0.12 | 0.33 | 0.74 | 2.37 | 79 | 0.56 | 0.01 | 0.07 | 0.21 | 0.64 | 79 | 0.52 | 0.01 | 0.07 | 0.21 | 0.62 |
| CC | 163 | 0.78 | 0.38 | 0.58 | 0.01 | 4.03 | 163 | 0.78 | 0.10 | 0.15 | 0.00 | 0.90 | 163 | 0.82 | 0.07 | 0.12 | 0.01 | 0.88 |
| PH | 319 | 0.62 | 0.46 | 0.66 | 0.15 | 4.86 | 319 | 0.63 | 0.11 | 0.17 | 0.06 | 0.88 | 319 | 0.68 | 0.06 | 0.13 | 0.08 | 0.86 |
| SS | 420 | 0.86 | 0.17 | 0.66 | 0.00 | 6.08 | 420 | 0.87 | 0.07 | 0.11 | 0.00 | 0.92 | 420 | 0.87 | 0.05 | 0.10 | 0.00 | 0.90 |
| GH | 747 | 0.74 | 0.28 | 0.61 | 0.00 | 4.95 | 747 | 0.80 | 0.10 | 0.14 | 0.00 | 0.90 | 747 | 0.82 | 0.05 | 0.12 | 0.00 | 0.85 |
| WW | 84 | 0.54 | -1.87 | 2.17 | 0.63 | 5.31 | 84 | 0.48 | -0.12 | 0.18 | 0.17 | 0.89 | 84 | 0.41 | -0.19 | 0.23 | 0.18 | 0.88 |
| MF | 195 | 0.83 | -1.01 | 1.22 | 0.29 | 5.22 | 195 | 0.85 | -0.01 | 0.09 | 0.03 | 0.92 | 195 | 0.78 | -0.10 | 0.14 | 0.01 | 0.89 |
| DF | 1330 | 0.72 | -0.87 | 1.37 | 0.08 | 6.87 | 1330 | 0.73 | -0.02 | 0.13 | 0.01 | 0.99 | 1330 | 0.72 | -0.08 | 0.15 | 0.04 | 0.95 |
| EF | 1558 | 0.49 | -0.88 | 1.53 | 0.16 | 5.00 | 1558 | 0.50 | -0.03 | 0.17 | 0.05 | 0.87 | 1558 | 0.47 | -0.12 | 0.21 | 0.06 | 0.84 |
| All | 4935 | 0.73 | -0.48 | 1.23 | 0.00 | 6.87 | 4935 | 0.75 | 0.01 | 0.15 | 0.00 | 0.99 | 4935 | 0.72 | -0.05 | 0.16 | 0.00 | 0.95 |

Appendix D

Table 1: Class specific statistics between SL2P-CCRS/S2 versus SL2P-CCRS/L8 as well as the samples size and the variation range of estimates from SL2P-CCRS/S2 (reference)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | LAI | | | | | | fCOVER | | | | | | fAPAR | | | | | |
| **NLCD** | **N** | **R2** | **A** | **U** | **min** | **max** | **N** | **R2** | **A** | **U** | **min** | **max** | **N** | **R2** | **A** | **U** | **min** | **max** |
| CC | 854 | 0.90 | 0.10 | 0.40 | 0.11 | 5.12 | 797 | 0.93 | 0.03 | 0.08 | 0.00 | 0.92 | 990 | 0.94 | 0.04 | 0.07 | 0.02 | 0.90 |
| DF | 6496 | 0.83 | -0.33 | 0.83 | 0.06 | 6.06 | 6501 | 0.89 | -0.03 | 0.10 | 0.01 | 0.97 | 6499 | 0.88 | -0.03 | 0.10 | 0.03 | 0.94 |
| EHW | 559 | 0.34 | 0.05 | 0.56 | 0.06 | 2.76 | 563 | 0.49 | 0.02 | 0.12 | 0.04 | 0.66 | 566 | 0.49 | 0.02 | 0.12 | 0.05 | 0.65 |
| EF | 7850 | 0.80 | -0.07 | 0.40 | 0.01 | 4.70 | 7853 | 0.84 | -0.03 | 0.08 | 0.00 | 0.85 | 7851 | 0.83 | -0.04 | 0.08 | 0.00 | 0.83 |
| GH | 6533 | 0.73 | 0.14 | 0.39 | 0.01 | 5.92 | 6601 | 0.77 | 0.02 | 0.10 | 0.00 | 0.95 | 7285 | 0.80 | 0.03 | 0.09 | 0.00 | 0.92 |
| MF | 1358 | 0.72 | -0.09 | 0.66 | 0.53 | 4.83 | 1357 | 0.77 | -0.03 | 0.10 | 0.06 | 0.90 | 1357 | 0.76 | -0.03 | 0.10 | 0.02 | 0.88 |
| PH | 530 | 0.63 | -0.02 | 0.65 | 0.34 | 5.54 | 533 | 0.78 | 0.01 | 0.10 | 0.07 | 0.93 | 535 | 0.78 | 0.01 | 0.10 | 0.07 | 0.91 |
| SH | 287 | 0.26 | 0.07 | 0.33 | 0.65 | 2.15 | 287 | 0.51 | 0.06 | 0.10 | 0.17 | 0.62 | 287 | 0.47 | 0.06 | 0.10 | 0.18 | 0.60 |
| SS | 5613 | 0.83 | 0.16 | 0.30 | 0.14 | 5.56 | 5055 | 0.85 | -0.01 | 0.06 | 0.00 | 0.94 | 5276 | 0.83 | 0.00 | 0.06 | 0.00 | 0.91 |
| WW | 2072 | 0.77 | -0.23 | 0.69 | 0.37 | 4.93 | 2069 | 0.83 | -0.02 | 0.09 | 0.04 | 0.90 | 2069 | 0.84 | -0.03 | 0.09 | 0.08 | 0.87 |
| **All** | **32152** | **0.85** | **-0.04** | **0.54** | **0.01** | **6.06** | **31616** | **0.88** | **-0.01** | **0.09** | **0.00** | **0.97** | **32715** | **0.88** | **-0.01** | **0.09** | **0.00** | **0.94** |