Spatial Downscaling of Sentinel 2 Leaf Area Index (LAI) Using Active Learning Regularization

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Spatial krigging (AATPRK) outperforms spectral recalibration (ALR) for downscaling Sentinel 2 LAI maps.

Background: **High resolution LAI maps are required environmental monitoring. The SL2P processor maps LAI @20m using from Sentinel 2 (S2) 10m and 20m . Three approaches for producing 10m maps from S2 tested.**

Downscaling Approaches:

Method	Inputs	Algorithm
REF	1m HS imagery, S2 Bands upscaled to 10m x 10m	SL2P applied to upscaled 10m bands (used for validation)
SL2P[1]	1m HS imagery, S2 1Bands, upscaled to 20m using S2 PSF	SL2P, + nearest-neighbour resampling to 10m
ALR[2]	SL2P20 inputs and outputs + 10m vegetation indices (Vis)	Random Forest approximating SL2P20 using only 10m VIs
AATPRK[3]	SL2P20 inputs downscaled to 10m using AATPRK	SL2P applied to downscaled 10m bands

Results:

Validation at 10 US NEON sites (blue panel, bottom left) spanning range of surface conditions using three metrics (blue panel, bottom right) shows:

A. **Qualitative: ALR and AATPRK preserve texture, SL2P visibly blurry. ALR misses extreme values.**

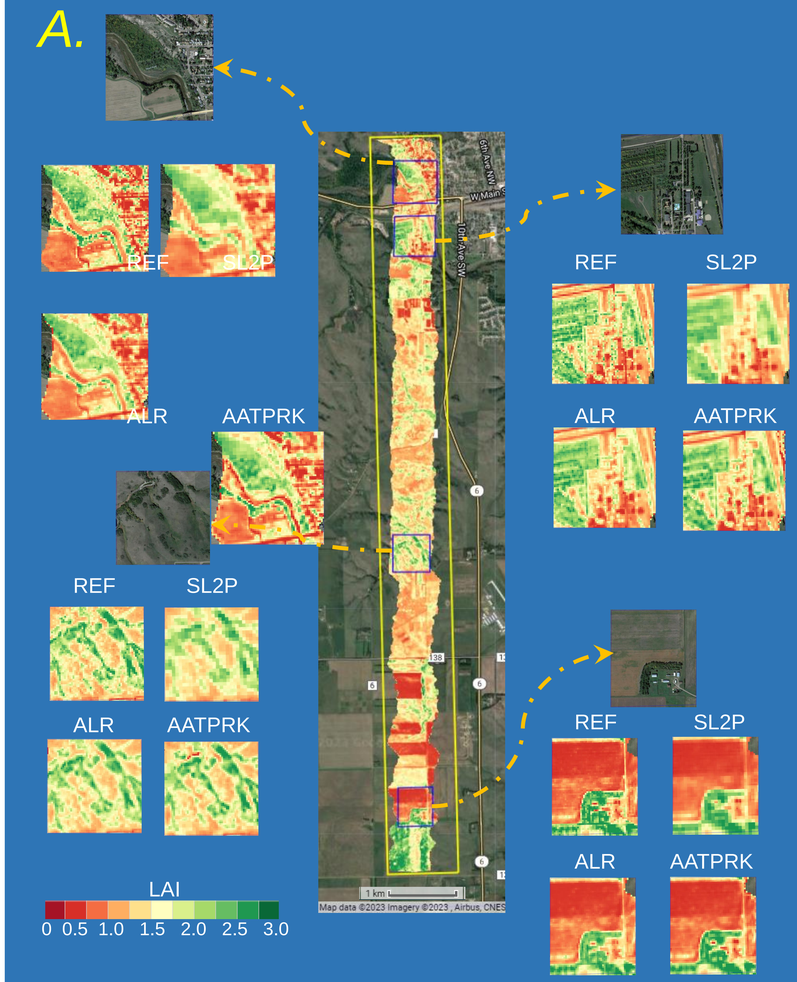
B. **Local r2: AATPRK highest local correlation with REF; ALR slightly better than SL2P**

C. **Abs. residual: AATPRK consistently lowest residuals; ALR and SL2P residuals comparable**

Conclusions:

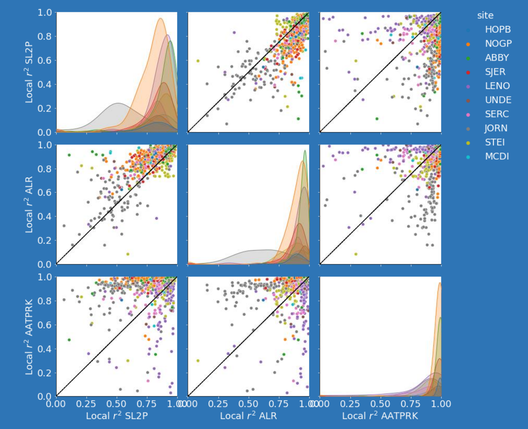
- **AATPRK suitable for 10m LAI mapping using S2 (requires low and high resolution bands). Absolute downscaling error <0.25 LAI.**
- **ALR may be useful for high res LAI mappnig given only high resolution bands. Absolute downscaling error <0.5 LAI.**
- **SL2P with nearest neighbour interpolation not recommended due to blurring and low local correlation with reference. . Absolute downscaling error <1 LAI.**

A.



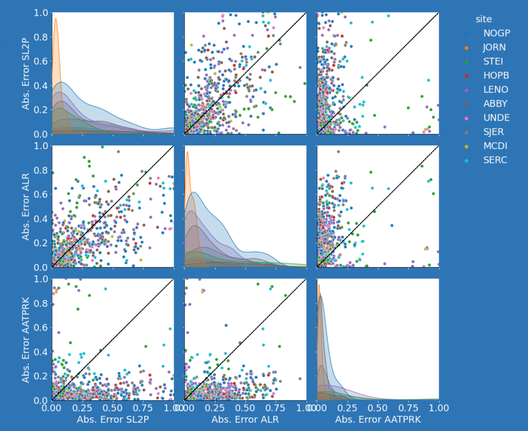
Comparison of LAI maps over a mixed land use site (UNDE).

B.



Comparison of local (150m x 150m) r^2 between LAI estimates from each method and reference LAI.

C.



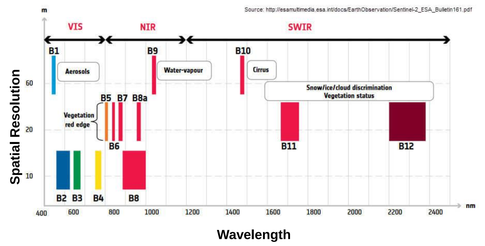
Comparison of absolute residuals between LAI estimates from each method and reference LAI .

NEON study sites with 1m hyperspectral imagery.

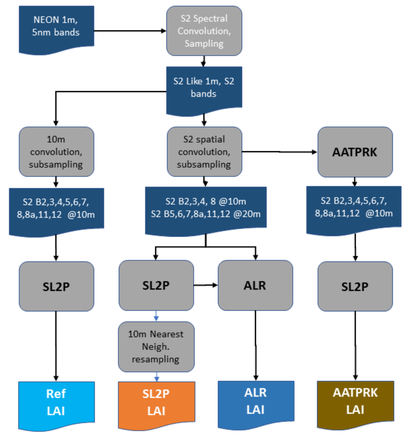
Metric	Description
Qualitative	Visual comparison over differing land cover and local LAI variability.
Abs. Error	Absolute difference between method and REF 10m LAI. Uniform sampled from REF LAI.
Local r^2	Local (150m x 150m) coefficient of determination between method and REF 10m LAI. Uniform sampled from REF LAI.

Evaluation metrics.

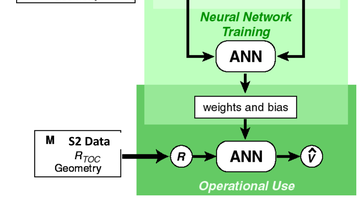
Methods:



S2 Multispectral Instrument bands.



Data processing flowchart.



SL2P algorithm schematic.

References:

1 Weiss, M., Baret, F., 2016. S2ToolBox Level 2 Products: LAI, FAPAR, FCOVER, 1.1. https://step.esa.int/docs/extra/ATBD_S2ToolBox_L2B_V1.1.pdf.

2 Wang, Q. Shi, W., Atkinson, P.M.., Zhao, Y., 2015. Downscaling modis images with area-to-point regression kriging Remote Sens. Environ., 166, 10.1016/j.rse.2015.06.003

3 Djamai, D., Fernandes, R. 2021. Active learning regularization increases clear sky retrieval rates for vegetation biophysical variables using Sentinel-2 data Remote Sens. Environ., 254, 10.1016/j.rse.2020.112241

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