Daily High Resolution Tracking of Crop Phenology and Productivity from Space

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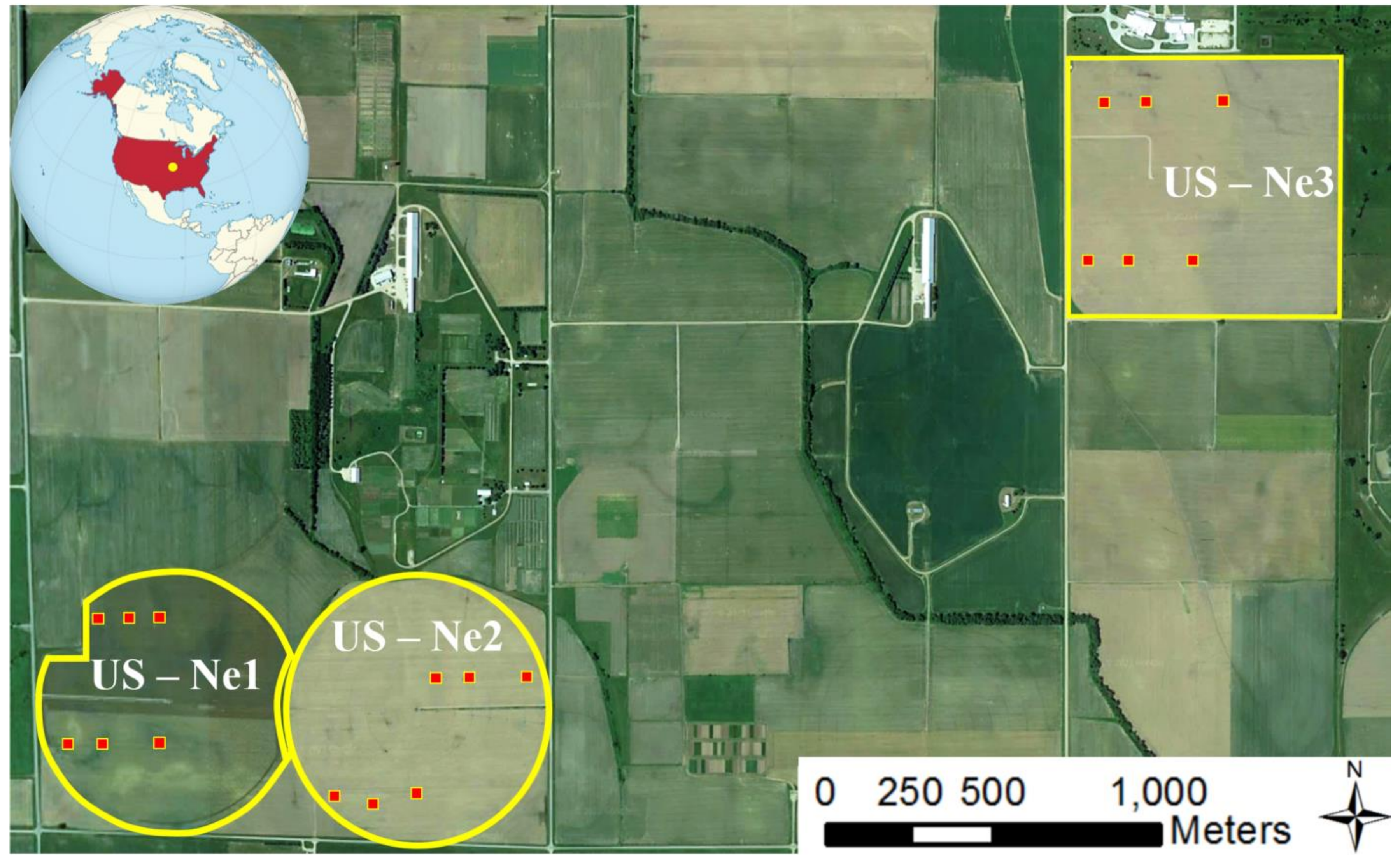
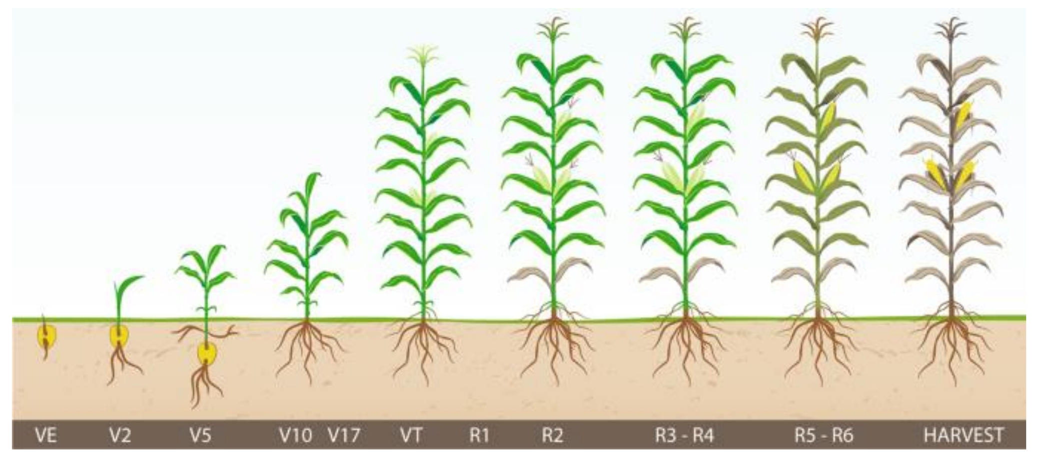
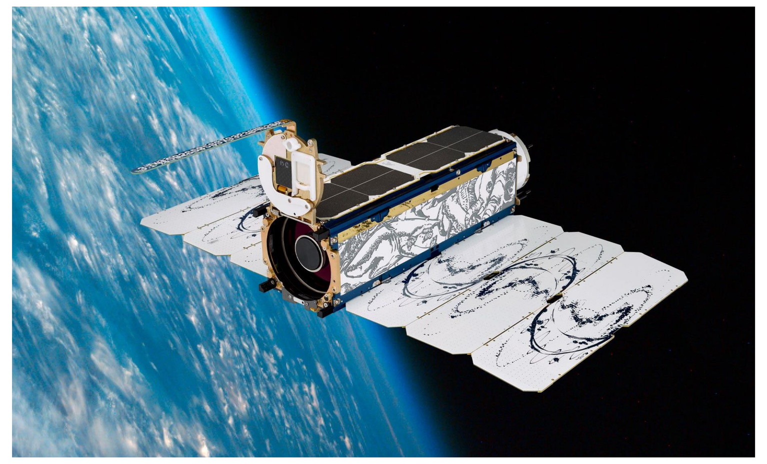
INTRODUCTION & OBJECTIVES

With the launch of CubeSat constellations consisting of 100's of satellites, it is now possible to acquire near-daily image coverage at high spatial resolution, delivering unprecedented capabilities for treatment, irrigation, and harvest scheduling of crops. Establishing a link between the image data and crop phenology is key to understanding the requirements of crops in terms of treatment amounts and timing for yield optimization. Here, we used CubeSat data harmonized based on Landsat-8 and Sentinel-2 satellite data to at surface reflectance, cloud-masked and gap-filled based on multi-sensor observation data acquired both before and after the prediction date. From this time-series of daily gap-filled and radiometrically robust CubeSat data of 3 m pixels, a machine-learning approach was employed to produce daily cloud-free leaf area index (LAI) images throughout the growing season maize fields located in Nebraska, USA. We demonstrate how daily CubeSat-derived LAI measurements and maize plant phenology are related and showcase how CubeSat-based LAI measurements can be used to detect within-field variability and facilitate treatment, irrigation and harvest scheduling based on associated crop phenological characteristics.

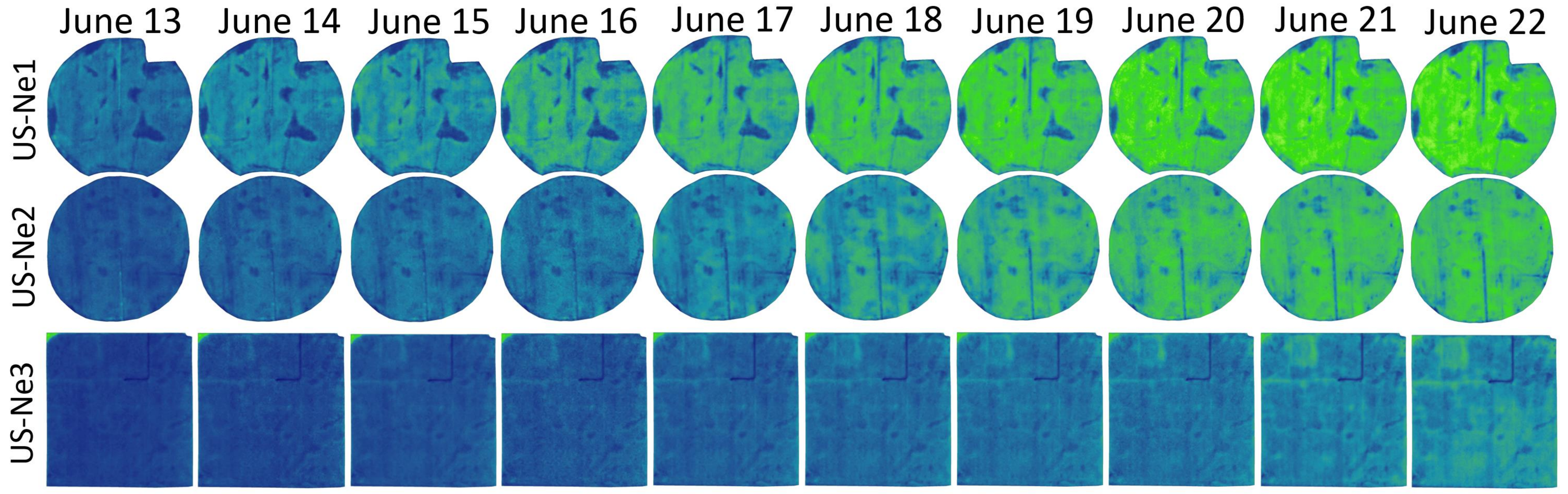
STUDY AREA & PHENOLOGY

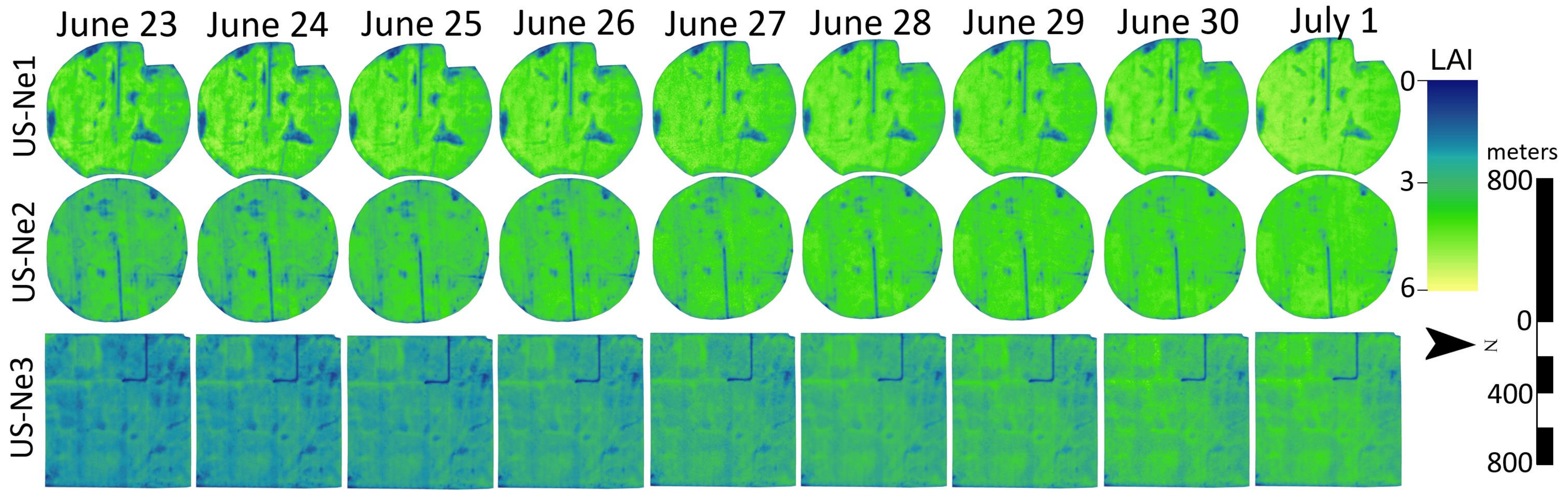


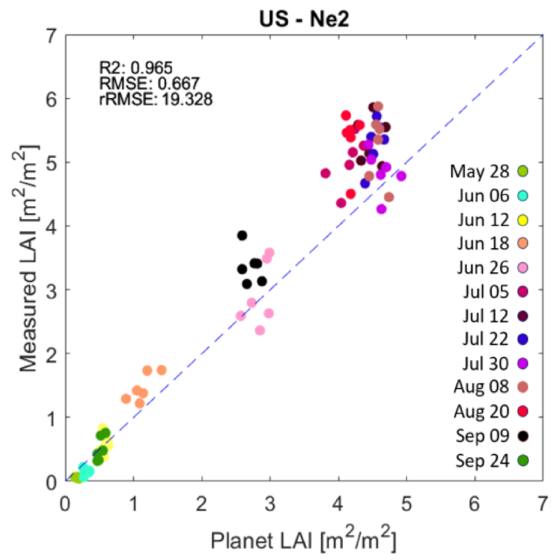


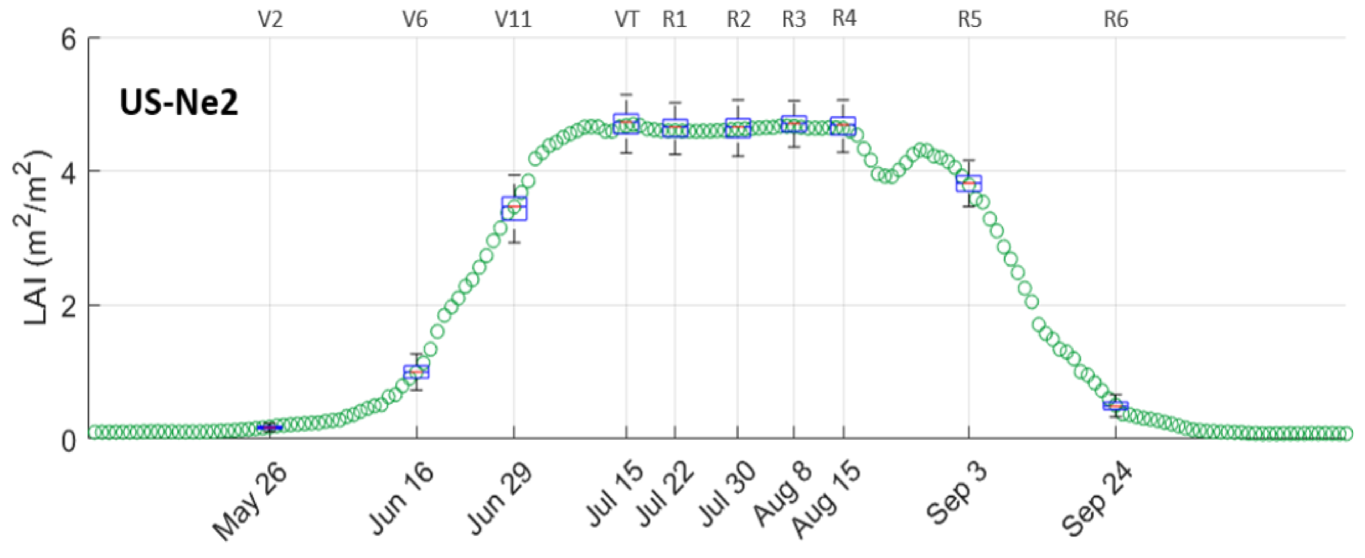


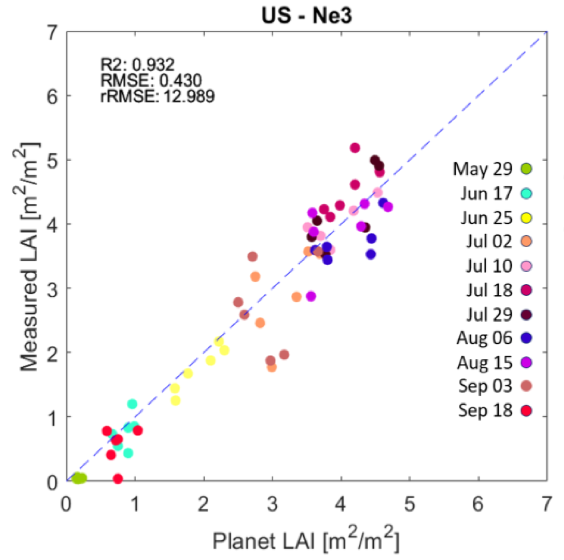
RESULTS

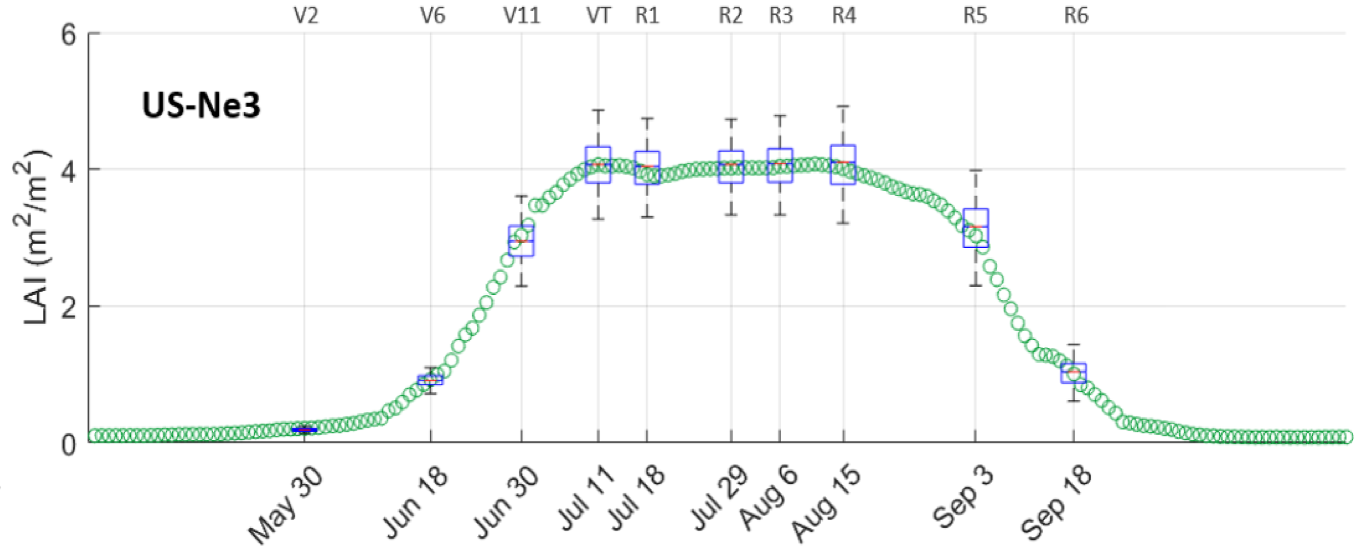












METHODS

Input parameters:

- Leaf area index (0-7)
- Leaf chlorophyll (25-75 ug cm-2)
- Carotenoids (0.25 * leaf chlorophyll)
- Leaf angles (45-65°)
- Leaf dry matter content (0.004-0.008)
- Soil brightness reflectance (0.1 – 1)
- Leaf mesophyll structure (fixed to 1.0)
- Variations in sun zenith angle considered
- Hot spot parameter (f(LAI) (min(1.0,0.5/LAI)))

→ Synthetic data set of vegetation indices and corresponding target LAI values

Sentinel-2 vegetation indices at 30 m resolution

→ Training of Sentinel-2 LAI prediction models using random forest

→ Multi-temporal Sentinel-2 based LAI at 30 m resolution

→ Sentinel-2 LAI data sampled to derive date and tile-specific LAI reference maps corrected for LAI change occurring over the given CubeSat and Sentinel-2 acquisition time spans

Input image data:
PlanetScope (CubeSat), Sentinel-2, Landsat-8, MODIS, VIIRS

→ Daily, gap-free, 3 m Planet Fusion data (Blue, Green, Red, NIR)

→ Hybrid inversion method at 30 m resolution

→ Reference CubeSat LAI at 30 m resolution

CubeSat vegetation indices at 3 m resolution

→ Cubist based regression tree approach for date and tile-specific images

→ Prediction model, relating the Planet Fusion-based predictor variables and the LAI reference data

→ Gap-free LAI at 3 m resolution

CONCLUSIONS

High resolution digital insights enable time-critical management intervention that can be used to facilitate yield optimization. Apart from offering new spatiotemporal insights into crop development and behavior, daily CubeSat-based LAI data demonstrated the capacity to capture recognized relationships between LAI and key vegetative and reproductive phenology stages. Research required to further advance the precision agricultural application of CubeSat data might include assessment of crop growth patterns, the influence of management decisions and yield prediction. Such analyses will help to determine the contribution of high spatiotemporal resolution information towards sustainable agricultural intensification and food production.