# Improval of radiative transfer model-based LAI retrieval from Sentinel-2 data through machine learning and phenological constraints

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**Abstract**

In land surface monitoring, parameters such as the Leaf Area Index (LAI) have been widely studied to describe the canopy structure, foliage cover, crop yield and growth. Accurate and up to date mapping of such biophysical variables at global scale is thus essential for decision makers and agricultural management [1], as it can help monitor growth conditions and adapt practices. The retrieval of LAI from remotely sensed data is commonly done through the inversion of a combined leaf and canopy radiative transfer model (RTM) [2]. These models relate leaf biochemistry and canopy structure to spectral variation [3]. However, the inversion process is computationally expensive and the ill-posed nature of the problem does not ensure a unique LAI retrieval solution [4].

The aim of this research is to accelerate LAI retrieval by exploiting machine learning regression algorithms and thus allow more widespread crop monitoring from remote sensing data. We propose a more operational method for large-scale retrieval by emulating the inversion problem with a machine learning algorithm. These models effectively capture non-linearities, proving particularly pertinent in the context of land surface modeling. Our work focuses on the agricultural land in Switzerland, monitored through Sentinel-2 imagery between 2017 and 2023. We use the PROSAIL RTM [3] to simulate the spectral response of Sentinel-2 to various combinations of biophysical and canopy variables, including LAI. A look-up table (LUT) relating leaf and canopy parameters to reflectance spectra is thus generated and used to train the machine learning algorithm. Methods among Random Forest, Neural Network and Gaussian Process Regression are tested and the best model is selected according to the root mean squared error (RMSE) on in-situ validation measurements of LAI of several fields in Switzerland.

To further improve LAI retrieval, we include phenological *a priori* knowledge to constrain the underdetermined problem. Specifically, we limit LAI values knowing the general relation of crop development with temperature. Accumulated Growing Degree Days (GDD) represent the cumulative temperature above the base temperature of a plant, where no growth occurs. We thus use GDDs to determine phenological macro-stages and constrain LAI values using physically sound assumptions. With the incorporation of phenological constraints, we additionally enable the customization of the model to suit specific crops or seasons, offering a simple solution to increase model performance according to stakeholder needs.

# References


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