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Monitoring Large-Coverage Forest Canopy Height by Integrating LiDAR and Sentinel-2 Images

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Abstract : Continuous monitoring of forest canopy height with large coverage is essential for obtaining forest carbon stocks and emissions, quantifying biomass estimation, analyzing vegetation coverage, and determining biodiversity. LiDAR can be used to collect accurate woody vegetation structure such as canopy height. However, LiDAR's coverage is usually limited because of its high cost and limited maneuverability, which constrains its use for dynamic and large area forest canopy monitoring. On the other hand, optical satellite images, like Sentinel-2, have the ability to cover large forest areas with a high repeat rate, but they do not have height information. Hence, exploring the solution of integrating LiDAR data and Sentinel-2 images to enlarge the coverage of forest canopy height prediction and increase the prediction repeat rate has been an active research topic in the environmental remote sensing community. In this study, we explore the potential of training a Random Forest Regression (RFR) model and a Convolutional Neural Network (CNN) model, respectively, to develop two predictive models for predicting and validating the forest canopy height of the Acadia Forest in New Brunswick, Canada, with a 10m ground sampling distance (GSD), for the year 2018 and 2021. Two 10m airborne LiDAR-derived canopy height models, one for 2018 and one for 2021, are used as ground truth to train and validate the RFR and CNN predictive models. To evaluate the prediction performance of the trained RFR and CNN models, two new predicted canopy height maps (CHMs), one for 2018 and one for 2021, are generated using the trained RFR and CNN models and 10m Sentinel-2 images of 2018 and 2021, respectively. The two 10m predicted CHMs from Sentinel-2 images are then compared with the two 10m airborne LiDAR-derived canopy height models for accuracy assessment. The validation results show that the mean absolute error (MAE) for year 2018 of the RFR model is 2.93m, CNN model is 1.71m; while the MAE for year 2021 of the RFR model is 3.35m, and the CNN model is 3.78m. These demonstrate the feasibility of using the RFR and CNN models developed in this research for predicting large-coverage forest canopy height at 10m spatial resolution and a high revisit rate.

Keywords : remote sensing, forest canopy height, LiDAR, Sentinel-2, artificial intelligence, random forest regression, convolutional neural network
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