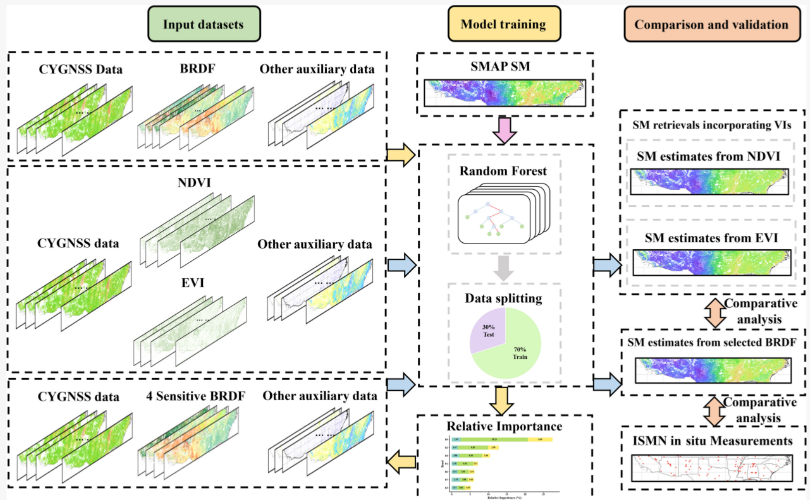
Improving Soil Moisture Retrieval by Combining MODIS BRDF and CYGNSS Data

GA, UNITED STATES, March 25, 2026 /EINPresswire.com/ -- A new soil-moisture retrieval strategy has improved the accuracy of satellite-based moisture mapping by combining microwave reflection signals with vegetation-structure information that conventional indices often miss. Instead of relying mainly on Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI), the method adds Bidirectional Reflectance Distribution Function (BRDF) parameters and uses machine learning to identify the most informative features. The result is a more accurate and more efficient way to estimate soil moisture, especially in densely vegetated regions where existing approaches often struggle.



Basic framework of the research.

Soil moisture is a key variable linking the water, energy, climate, and agricultural systems of the Earth. It influences heat exchange, hydrological processes, ecosystem dynamics, and crop conditions, making accurate monitoring essential for weather forecasting, drought assessment, and land management. Microwave remote sensing has become an important tool for soil-moisture retrieval because it can work in nearly all weather conditions. However, in areas with dense vegetation, commonly used vegetation indicators such as Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) do not fully capture canopy structure or directional reflectance effects, which can reduce retrieval accuracy. Based on these challenges, deeper research is needed into improved soil-moisture retrieval methods that better represent vegetation complexity.

Researchers from Beijing Normal University and related research centers reported the study in the Journal of Remote Sensing, published on January 26, 2026. The team addressed a practical remote-sensing problem: how to retrieve soil moisture more accurately in regions where vegetation interferes with microwave signals. Their solution combines Moderate Resolution Imaging Spectroradiometer (MODIS) Bidirectional Reflectance Distribution Function (BRDF) information with Global Navigation Satellite System (CYGNSS) observations in a Random Forest model, aiming to reduce the limitations of conventional vegetation-index-based methods and improve soil-moisture estimates across complex landscapes.

The study's core advance is the integration of BRDF-derived anisotropic reflectance and vegetation-structure information into CYGNSS-based soil-moisture retrieval. The optimized model, called Scheme A+, selected only four highly sensitive BRDF parameters rather than using the full set, allowing the method to remain computationally efficient while improving accuracy. Across the study area, Scheme A+ achieved the highest consistency with SMAP reference data, reaching a correlation coefficient of 0.94 and an root-mean-square error (RMSE) of 0.024 cm^3/cm^3. Its RMSE was 4.32% lower than the NDVI-based scheme and 6.59% lower than the EVI-based scheme, with the largest gains appearing in forested areas.

The team focused on 23 states in the continental United States and evaluated the method across forest, shrubland, grassland, and cropland. They found that BRDF-based retrieval consistently outperformed conventional vegetation-index-based methods across all major land-cover types. The strongest improvement appeared in forests, where dense canopies weaken CYGNSS coherent signals and make moisture retrieval especially difficult. Feature-importance analysis showed that the most influential variables in forest regions were not the classic NDVI/EVI bands, but specific BRDF parameters, particularly b5 fiso (18.32%), DEM (13.68%), b2 fiso (8.32%), b5 fvol (6.8%), and b4 fiso (6.32%). The results suggest that shortwave-infrared isotropic and volumetric scattering carry critical information for handling vegetation effects. The study also showed that using just 19% of the BRDF variables preserved much of the full model's value, confirming that careful feature selection can deliver a strong balance between accuracy and efficiency.

The researchers argue that the value of BRDF does not simply come from adding more spectral bands. Instead, it comes from capturing directional and structural information that better represents vegetation complexity and canopy interactions. Their findings suggest that this optical–microwave combination offers a meaningful new route for soil-moisture retrieval, particularly in densely vegetated environments where traditional index-based approaches tend to underestimate moisture conditions.

The team used CYGNSS L1 V3 data from 2020, monthly aggregated to match SMAP Level 3 soil-moisture data. Input variables included CYGNSS surface reflectivity, surface roughness, elevation, slope, land-cover type, tree height, and BRDF parameters from the MODIS MCD43A1 product. A Random Forest model was trained with 70% of the data and tested on the remaining 30%. The model used 500 trees and a minimum leaf size of 25, while feature importance and SHAP analysis were applied to identify the most influential variables and optimize the final input set. Validation also involved ISMN in situ measurements.

References
DOI
10.34133/remotesensing.0981

Original Source URL
https://doi.org/10.34133/remotesensing.0981

Funding information
This work was funded by the Major Program of the Natural Science Foundation of China (42090013) and the General Programs of the Natural Science Foundation of China (42471352).

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