Wavelets: a useful tool to derive vegetation properties from hyperspectral data

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Introduction

Objective:

To evaluate continuous wavelet analysis (CWA) as a tool to determine leaf gravimetric water content (GWC, %) from hyperspectral reflectance data for a wide range of water content values and species from different ecosystems. CWA enables the multi-scale analysis of absorption features in reflectance spectra and provides the potential to capture shape information over spectral regions of various widths.

Data sets:

- PANAMA: collected for liana and tree species from tropical forests in Panama.
- PROSPECT: simulated using the radiative transfer model PROSPECT-4.
- LOPEX: collected for trees, crops and plant species around JRC in Italy.

Estimation of *leaf gravimetric water content (%)* for measured samples:

$$LWC_D = \frac{FW - DW}{DW} \times 100\% \qquad LWC_F = \frac{FW - DW}{FW} \times 100\%$$

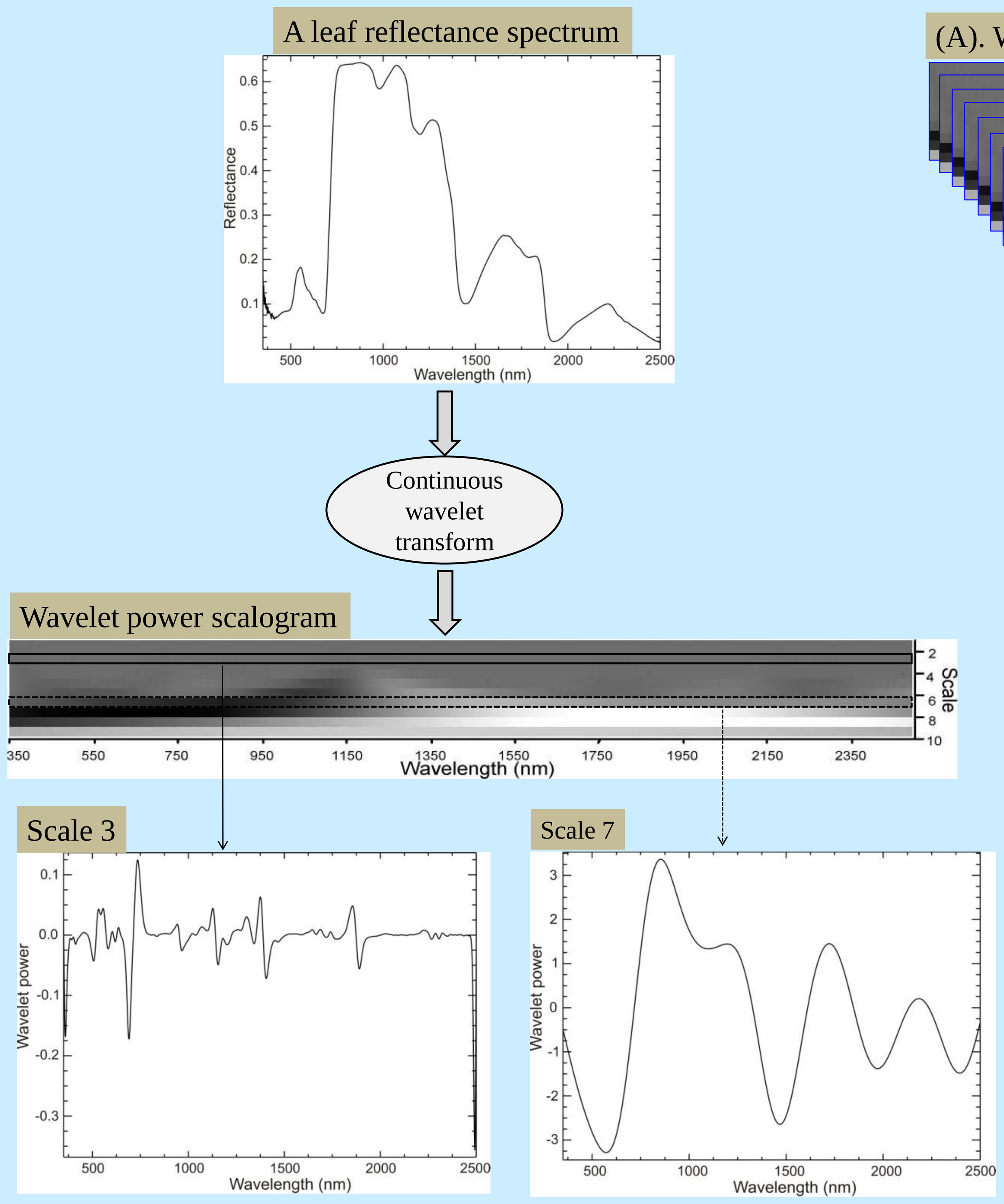
For PROSPECT simulated samples:

$$LWC_D = \frac{C_w}{C_m} \times 100\% \qquad LWC_F = \frac{LWC_D}{100\% + LWC_D} \times 100\%$$

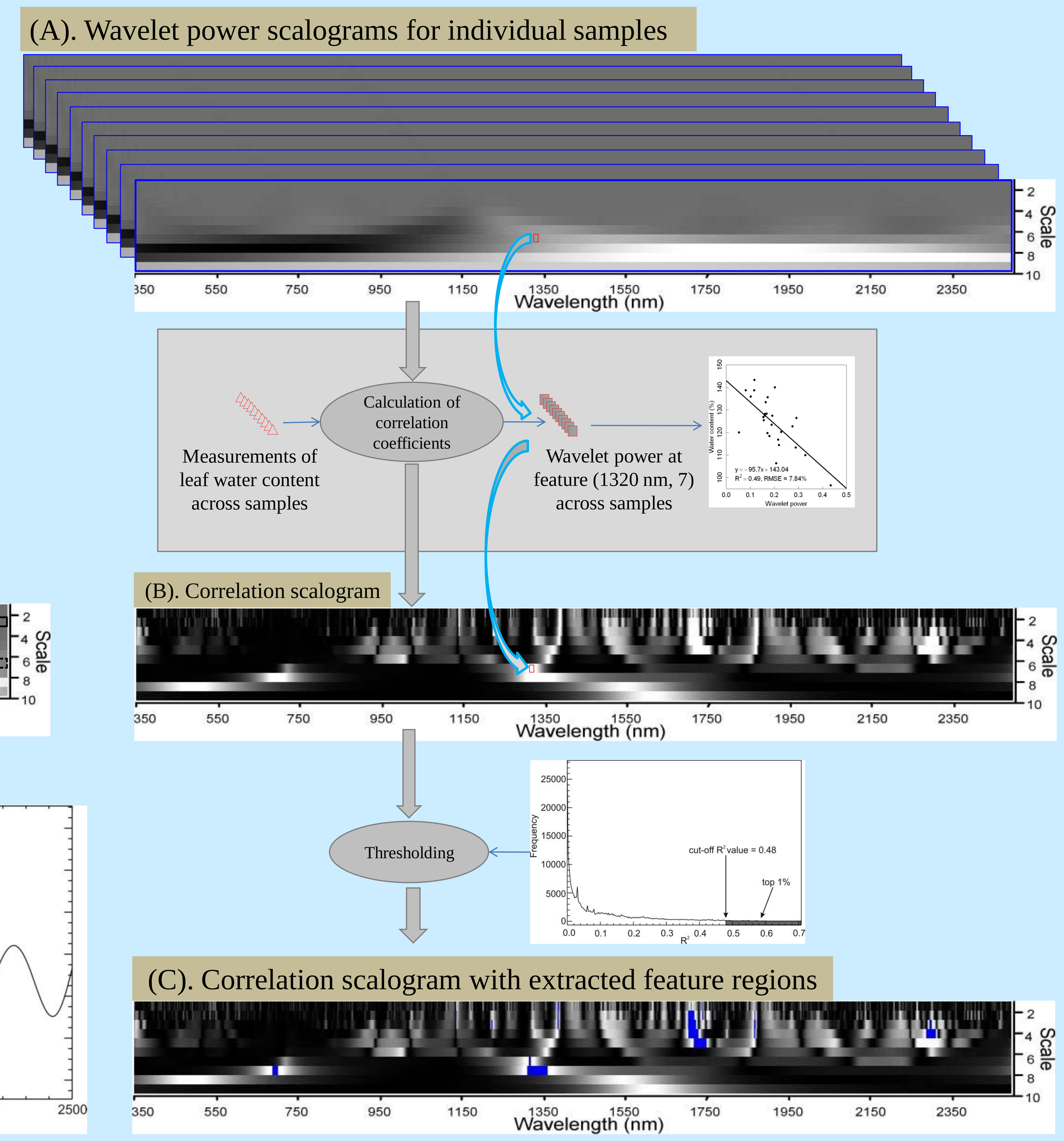
Table 1. summary of statistics for the three data sets

			LWC_D (%)			LWC_F (%)		
	# spectra	# species	Mean±s.d.	Min.	Max.	Mean±s.d.	Min.	Max.
PANAMA	265	47	143.60 ± 52.44	32.31	418.20	57.23± 8.62	24.42	80.70
PROSPECT	530	-	149.13 ± 95.94	20.20	592.89	54.71±14.79	16.80	85.57
LOPEX	325	44	240.47±193.18	9.43	1258.57	64.87±13.60	8.62	92.64

Methods



1. Continuous wavelet transform of leaf reflectance spectra



2. Selection of wavelet features as a function of wavelength and scale

Results

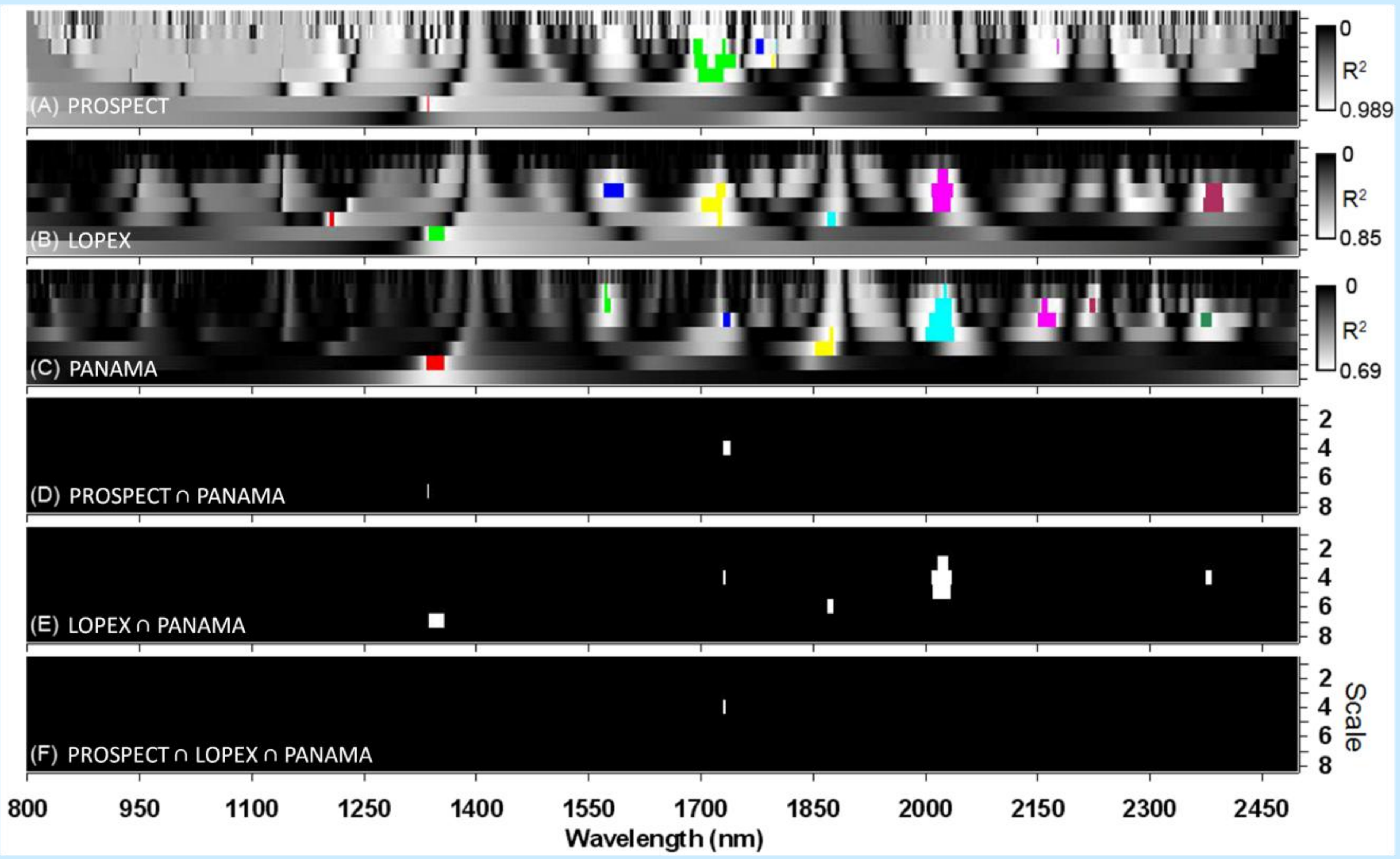


Fig. 2. Features regions overlaid on correlation scalograms relating wavelet power and leaf water content (LWC_F) for (A) the PROSPECT data set, (B) the LOPEX data set, and (C) the PANAMA data set adapted from Cheng et al. (2011). Feature regions shown in (D), (E), and (F) are the intersection of regions in (A) and (C), (B) and (C), and (A), (B), and (C), respectively. The brighter a pixel on correlation scalograms A, B, and C, the stronger the correlation.

Almost all feature regions, representing strong wavelet features for the estimation of leaf GWC, were located in the SWIR region (1300-2500 nm). Five overlapping feature regions were found for the measured LOPEX and PANAMA data sets, with wavelet features spanning from scales 3 to 7. One of them overlaps the feature regions derived from the PROSPECT data set. The spectral information indicative of leaf GWC was captured by both high-scale and low-scale wavelet features.

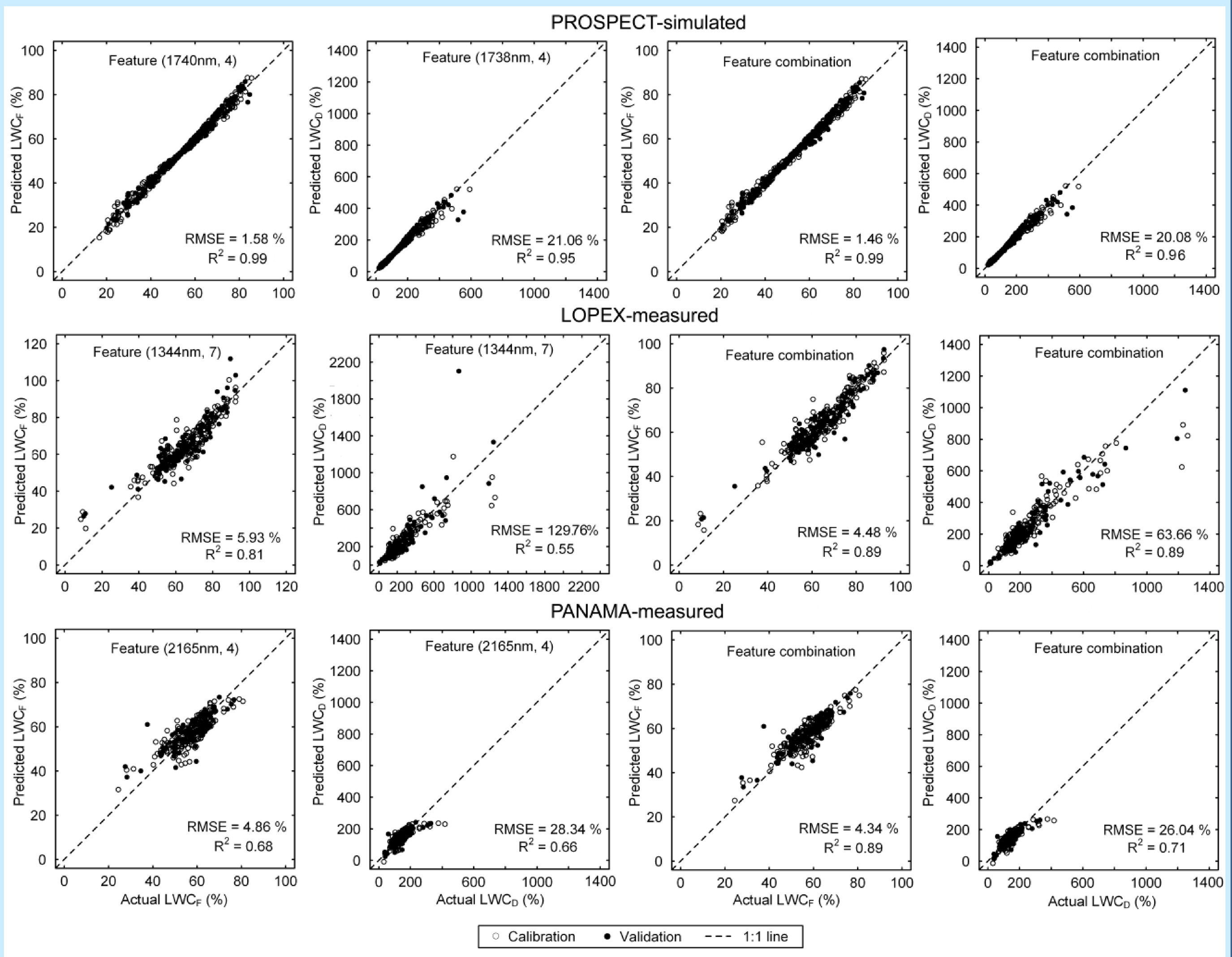


Fig. 5. Plots of actual versus predicted LWC_F (*left*) or LWC_D (*right*) derived using best-performing single wavelet features and the combination of all wavelet features. RMSE and R^2 values represent validation samples in the three data sets. Plots for the PANAMA data set are adapted from Cheng et al. (2011).

For each data set, best accuracies for the prediction of LWC_F and LWC_D were obtained using combinations of wavelet features. The predictions of LWC_F followed closely to the 1:1 lines but underestimation of LWC_D occurred at high LWC_D values. These accuracies obtained using the wavelet approach are higher than those reported in relevant studies using spectral indices and partial linear squares regression.

Conclusion

The findings from the three data sets confirmed the effectiveness of continuous wavelet analysis for estimating leaf GWC for a wide range of GWC values and species from different ecosystems.

Particularly, the recurrent wavelet features between the two measured data sets may serve as reliable and efficient predictors of leaf GWC in relevant studies.

Using high-scale and low-scale wavelet features, spectral variations caused by changes in leaf GWC were separately observed over the overall amplitude and dry matter absorption regions.

The wavelet-based spectral analysis tool adds a new dimension to modeling vegetation biophysical properties with hyperspectral measurements.

Acknowledgements

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Key references

[1] Cheng, T., Rivard, B., Sánchez-Azofeifa, G.A., Feng, J. & Calvo-Polanco, M. (2010). Continuous wavelet analysis for the detection of green attack damage due to mountain pine beetle infestation," *Remote Sensing of Environment*, *114*, 899-910.
[2] Cheng, T., Rivard, B., Sánchez-Azofeifa, G. A. (2011). Spectroscopic determination of leaf water content using continuous wavelet analysis. *Remote Sensing of Environment*, *115*, 659-670.