

New PROSPECT-S model captures wheat spike growth dynamics to improve spectral simulations

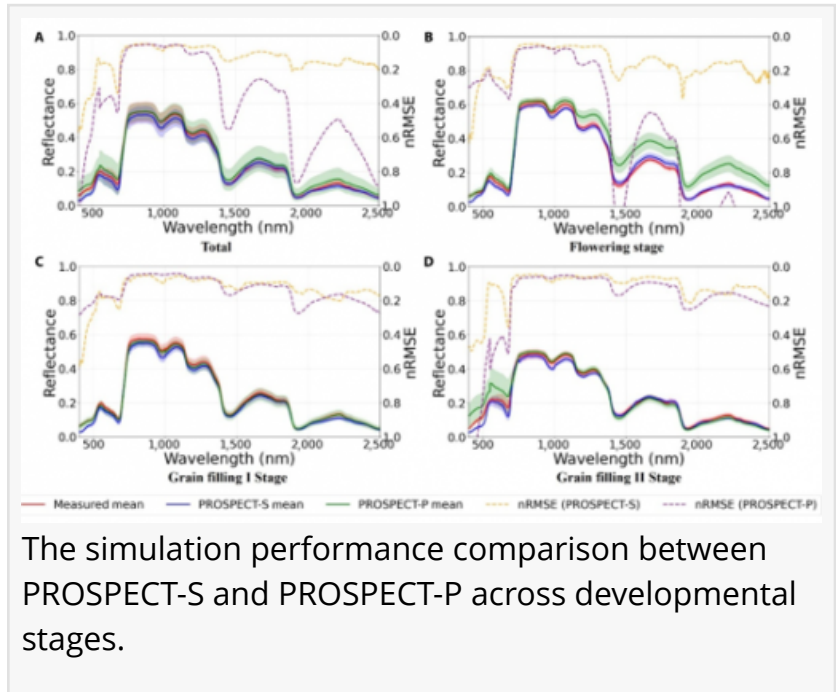
FAYETTEVILLE, GA, UNITED STATES, July 20, 2026 /EINPresswire.com/ -- Winter wheat spikes undergo substantial morphological and structural changes during grain filling, leading to corresponding variations in their optical properties. The new PROSPECT-S model simulates spike reflectance across 400–2,500 nm spectral range by incorporating dynamic growth parameters.

Wheat spikes are increasingly recognized as photosynthetically active organs that contribute substantially to grain filling, but their width and internal structure change dynamically

as grains fill, altering light absorption and reflectance. Most existing spectral models do not explicitly account for these developmental changes or rely on unmeasurable structural parameters. And most existing radiative transfer models (RTMs) were originally developed for leaves rather than reproductive organs such as spikes. These limitations highlight the need for a spectral model capable of representing spike growth dynamics throughout the crop life cycle.

On 15 May 2026, researchers from Chang'an University, Beijing Academy of Agriculture and Forestry Sciences, Beijing Normal University, Henan Polytechnic University, and Nanjing Agricultural University published (DOI: [10.34133/remotesensing.1048](https://doi.org/10.34133/remotesensing.1048)) a study in the [Journal of Remote Sensing](#). They developed [PROSPECT-S](#), a new RTM for winter wheat spikes that addresses the critical limitations of existing methods by accurately capturing the dynamic structural evolution of spikes during grain filling, which is a factor essential for calculating light interception and estimating photosynthetic capacity.

PROSPECT-S offers two key innovations over previous models (e.g., PROSPECT-4). First, it replaces the unmeasurable structural parameter *N* with measurable spike width and dry matter,



linked to accumulated growing degree days (AGDD) via logistic curves. Second, it models the refractive index using a Beer–Lambert law dependent on width. Validation with 88 spike samples from five cultivars achieved $R^2=0.92$, $RMSE=0.052$. The model was able to retrieve chlorophyll content ($RMSE=6.20\text{ }\mu\text{g}\cdot\text{cm}^{-2}$, $nRMSE=25.8\%$), equivalent water thickness ($RMSE=0.010\text{ g}\cdot\text{cm}^{-2}$, $nRMSE=16.8\%$), and dry matter content ($RMSE=0.007\text{ g}\cdot\text{cm}^{-2}$, $nRMSE=20.4\%$). PROSPECT-S demonstrated greater stability across developmental stages than models that do not account for growth dynamics.

Field experiments in Beijing and Henan, China, covered flowering and two grain-filling stages. The team measured spike length, width, fresh/dry weight, and chlorophyll content. AGDD was calculated from ERA5 reanalysis temperature data. Spike width exhibited a characteristic sigmoidal growth pattern with increasing AGDD, fitted per cultivar. The structural parameter N was estimated from reflectance at $1,131\text{ nm}$, then linked to width and dry matter via a quadratic function ($R^2=0.636$). The refractive index n_r was expressed as $n_r(\lambda, W) = n(\lambda) \times (1 - e^{-W \times k(\lambda) + d})$. Specific absorption coefficients for chlorophyll, water, and dry matter were recalibrated separately for $400\text{--}800\text{ nm}$ and $800\text{--}2,500\text{ nm}$. Global sensitivity analysis indicated that AGDD was the dominant driver of model variability in the near-infrared region, accounting for up to 90% of the variance. Cross-validation using three data partitioning methods confirmed robustness (validation $R^2=0.91\text{--}0.92$). AGDD errors ($\pm 25^\circ\text{C}$, $\pm 50^\circ\text{C}$) affected flowering-stage accuracy more than late filling stage.

“PROSPECT-S establishes a quantitative link between crop growth dynamics and optical modeling,” said Dr. Guijun Yang, corresponding author. “By linking spike width and dry matter to spectral properties, we can now track spike development non-destructively. This framework could support future applications in precision agriculture, including yield assessment, spike trait retrieval, and studies of spike photosynthesis under varying environmental conditions.”

Spike spectral reflectance was measured using an ASD FieldSpec4 spectrometer with a leaf clip providing consistent illumination. Destructive sampling gave fresh weight, dry weight, and spike surface area ($\text{length} \times \text{width} \times 3.8$). Chlorophyll content was determined via spectrophotometry at 440, 649, and 665 nm after ethanol extraction. PROSPECT-S was built by modifying PROSPECT-4: N as a function of width and dry matter, n_r as an exponential function of width. AGDD served as a temporal descriptor of spike development.

PROSPECT-S can be integrated into canopy-level RTMs to improve estimates of light interception and photosynthetic contribution of spikes—factors often neglected in crop yield models. The model may facilitate the retrieval of spike traits from UAV- and satellite-based hyperspectral observations over large agricultural regions. Future work will extend the model to rice spikes, incorporate anatomical traits (following the RSPECT leaf model), and account for the spike’s three-dimensional architecture. Such developments could improve the monitoring of cereal reproductive organs and contribute to more accurate assessments of crop performance under environmental stress.

References

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