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Estimating evapotranspiration from deciduous broadleaf forests by considering the effect of foliar litter

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Abstract: Forest ecosystems play a critical role in global hydrological and energy cycles, accounting for approximately 31% of the terrestrial land area and contributing nearly 45% of global terrestrial evapotranspiration (ET). Accurate estimation of ET is essential for understanding ecohydrological processes, land–atmosphere interactions, and climate feedbacks. However, current models fail to adequately account for the complex surface characteristics of forests, particularly the role of foliar litter, which introduces significant seasonal variability in surface resistance and energy exchange. This is especially relevant in deciduous broadleaf forests (DBFs), where litter accumulation follows a pronounced seasonal cycle linked to leaf phenology. Field experiments, such as those using micro-lysimeters, have consistently shown that litter cover can reduce soil evaporation by 26% to 64% by impeding heat and water vapor exchange between the soil and atmosphere. Despite these findings, most large-scale ET models do not properly incorporate this effect, especially its seasonal dynamics, resulting in consistent overestimations during litter-covered periods.

To address this gap, this study developed a new seasonal dynamic parameterization for litter surface resistance and integrated it into the widely used Penman–Monteith (PM) framework (noted as PM-EL model). The litter surface resistance captures temporal variations in litter coverage by litter fraction (F_{lit}) and its inhibitory effect on vapor transport, using physically interpretable and generally available input variables. The PM-EL model was rigorously evaluated against eddy-covariance measurements from 18 DBF sites within the global FLUXNET2015 database. The results demonstrate that the enhanced model significantly improves ET estimates compared to the standard PM model: the coefficient of determination (R^2) increased by 8.5%, while the mean absolute error and relative root mean square error decreased by 22.1% and 20.9%, respectively. Sensitivity analysis confirmed that ground surface resistance is the most influential parameter in both models, underscoring the value of better representing this process. Moreover, the integrated litter resistance model successfully reproduced the seasonal dynamics of litter cover and its corresponding impact on surface resistance.

This study highlights the importance of incorporating dynamic litter-mediated surface resistance into ET models and provides a mechanistically grounded approach to enhance accuracy in forest ET estimation. The PM-EL model offers improved capability for representing seasonal water and energy fluxes, with valuable applications in ecohydrological modelling, land surface model development, and climate-related impact assessments. By more accurately characterizing the role of litter, this work advances our understanding of forest water cycling and supports more realistic predictions of land–atmosphere interactions under changing climatic conditions.

Keywords: *Litter surface resistance; Evapotranspiration estimation; Penman-Monteith model; Forest litter; Deciduous broadleaf forest*