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Modeling Water Flux through Crops based on the Optimum Water Use Hypothesis

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Vegetation models can be used to predict plants response to altering climate conditions. Stomatal conductance (g_s) controls diffusion of CO_2 from the atmosphere to the leaf and water loss through transpiration and allows plants to adjust themselves to fluctuating environmental conditions. The hypothesis that stomata adapt optimally to its environment to maximize assimilation (A) for a given amount of water loss through transpiration (E) was introduced by Cowan and Farquhar (1977). This theory provides a framework for modeling the interactions between vegetation dynamics and soil moisture that does not rely on empirical calibration as long as photosynthetic canopy properties and total amount of water available for transpiration are known. The current study introduces a new approach to implement optimization theory of stomatal conductance into a canopy gas exchange model. The adequacy of the new approach was tested in a real case study by comparing predicted diurnal cycles of assimilation and transpiration rates as well as variability of soil moisture with observations at a winter wheat (*Triticum aestivum cv.Cubus*) field in southwest Germany. For analyzing the impact of soil texture on stomata regulation, three soil types were compared in a drying soil simulation scenario. Soil water balance was calculated from measured precipitation and simulated transpiration using a single bucket model, where the soil within the root zone was assumed to be homogeneous. Since the model focused on fully developed vegetation canopies, soil evaporation is considered negligible. Marginal water use efficiency can be expressed as partial derivative of assimilation with respect to transpiration ($\partial A/\partial E = \lambda$). Daily values of λ were determined using the formalism of Lagrangian multipliers. Potential evapotranspiration (Penman-Monteith) and effective reduction factor of root water uptake under unfavorable soil moisture conditions were used to estimate amounts of plant available water per day. The present study shows that the model based on the optimal water-use hypothesis produced reasonable results for different soil textures under drying conditions. When water becomes less available, the gradual increase of λ reflects the differences in soil water retention properties. Moreover, the model could delineate the diurnal cycle of transpiration and assimilation of winter wheat during the development stages with higher discrepancies over leaf senescence period.