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MODELLING THE PARTITIONING OF EVAPOTRANSPIRATION IN A MAIZE-SUNFLOWER INTERCROP

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INTRODUCTION

When two or more crops are grown together in an intercropping system, the crops may succeed (*e.g.*, higher or more stable yields) or they may fail. In order to understand the outcome of such crop combinations, it is necessary to be able to quantify the processes involved in the partitioning of resources in that system. This is because these resources, such as solar radiation and water, will determine not only the growth and development of individual crop species, but also the community as a whole.

The Penman-Monteith (PM) equation (Monteith, 1965) is often used to estimate either the soil evaporation or crop transpiration. Nevertheless, its major drawback is that this equation can only be used to estimate either soil evaporation or plant transpiration, but not both simultaneously. An important extension of the PM equation is the Shuttleworth-Wallace (SW) equation (Shuttleworth and Wallace, 1985). Its improvement over the PM equation is that the SW equation specifies explicitly the energy exchanges at the soil and canopy, thereby it is possible to distinguish the fraction of water transpired and that evaporated from soil. The SW equation, however, was originally developed only for sole crops.

The objectives of this study were two-fold. Firstly, it was to model the partitioning of evapotranspiration in a maize-sunflower intercropping system in partial- and fully-grown canopies. This would be achieved by extending the original SW equation to intercropping systems. Secondly, this study was to determine the accuracy and to perform a sensitivity analysis of the extended SW equation when applied in the maize-sunflower intercrop.

MODEL DEVELOPMENT

The SW equation was extended to intercropping systems so that it included both crop transpiration and soil evaporation and allowing interaction between the two. The SW equation combined all the within-canopy resistances, and the stomatal and boundary layer resistances by assuming these resistances acted in parallel at a single level in the canopy at an effective source-sink height (mean canopy flow). The soil-plant-atmosphere system was represented as a network of resistances opposing the various fluxes of heat and water vapour. The system is such that heat and vapour fluxes can only enter or leave the bottom layer via the top one. This means any heat flux reaching the soil must traverse the entire canopy before reaching the bottom. Likewise, heat fluxes from the soil can only leave the system by traversing upward through the canopy, and their traversal are opposed by all resistances from the soil to the canopy top. The entire maize-sunflower system was described in a series of 12 independent equations with 12 unknown variables. With some algebraic manipulations and re-arrangements, the equations for the various heat and water fluxes could then be solved.

The extended SW equation required several resistance components to be determined: the aerodynamic resistance between the mean canopy flow and reference height, the bulk stomatal resistance and the bulk boundary layer resistance of every crop species, the aerodynamic resistance between soil and mean canopy flow, and the soil surface resistance.

FIELD EXPERIMENTS

To determine the accuracy of the extended SW equation, two field experiments were conducted in 1998 and 1999. Maize and sunflower were planted as intercrops, and field size was 0.13 ha. Data collection started and ended approximately 30 and 90 days after sowing, respectively. Solar radiation was measured by a ceptometer, plant transpiration by sap flow gauges, soil evaporation by lysimeters, canopy architecture by compass, protractor and measuring tape, and the standard meteorological properties by a nearby field weather station.

RESULTS AND DISCUSSION

There was an overall good agreement between the diurnal simulated and measured values of transpiration in the intercrop. The mean estimation error of transpiration was 0.00 mm h^{-1} (which indicated no overall bias in estimation errors) with 95% error band between -0.08 to 0.07 mm h^{-1}. The accuracy of transpiration modelling was not affected by the different plant growth stages or canopy cover. In addition, the simulated diurnal trends tended to follow the measured diurnal trend closely even for days when simulations were inaccurate. There was no trend that the model would under- or overestimate transpiration during low to moderate measured transpiration rates; however, the model tended to slightly underestimate transpiration when the measured transpiration rates were high. For the sunflower component in intercrop, the model tended to underestimate slightly when measured transpiration rate exceeded 0.40 mm h^{-1}. For the maize component, this occurred when the measured transpiration rate exceeded 0.15 mm h^{-1}.

There were larger errors in predictions for the daily soil evaporation than for plant transpiration. This was probably because the model did not include a soil water transport model, and that soil water content was assumed to be always at field capacity. Nevertheless, model simulations followed the daily pattern of soil evaporation closely.

Sensitivity analyses revealed that modelling plant transpiration was most sensitive to model parameters most directly related to canopy characteristics. It was most sensitive to the partitioning of captured radiation among crops, canopy resistance, and bulk boundary layer resistance. Important meteorological parameters to plant transpiration modelling were air temperature, vapour pressure and total solar radiation.

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