Modeling the Effect of Surface Crop Residue on Sugarcane Soil Moisture

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Motivation

Brazilian sugarcane is traditionally rainfed, but the expansion of sugarcane cultivation to hotter and drier regions in addition to the aridification due to climate change of wet regions in which the crop has been grown for centuries has put the crop's water supply into jeopardy.

There is a growing need to optimize management strategies in order to minimize water use, maximize sugar yields, and maximize biofuel production from excess crop biomass. One potential solution to these challenges is green cane management, a harvesting strategy which employs the deposition on the soil of crop residue, a form of excess crop biomass.

Thus, this study aims to observe how the use of crop residue as mulch might impact the local water balance, exploring a way to maintain sugarcane as a rainfed crop by optimizing the management of precipitation in the hydrological system.

Figure 1: Sugarcane green cane harvesting (left) and sugarcane crop residue (right)

Materials and Methods

This project uses CropSyst, a field-scale, multi-year, multi-crop model composed of a complex web of subprograms and equations which simulate the behavior of agricultural systems given location- and farm-specific conditions.

In this study, CropSyst was used to simulate the effect of surface crop residue on local water balance using four treatments: allocating 0%, 10%, 20%, and 30% of harvested biomass to be crop residue used as mulch.

Water Balance Components

The change in soil water storage can be loosely described by the following equation:

$$\Delta H_2O_{storage} = P - I - ET - R \qquad (1)$$

where P represents precipitation (mm), I infiltration (mm), ET evapotranspiration (mm), and R surface runoff (mm).

Study Area (i.e., sites)

Two commercial sites in Central-Southern Brazil with similar soil and climate conditions were selected:

- Jaboticabal site (21°20'20''S, 48°18'35''W) with sandy-clay-loam soil
  - 14 sets of soil water content measurements (SWC, m^3 m^{-3}) for 10 different depths were collected during the first harvest cycle, and 11 aboveground biomass (AGBM, kg ha^{-1}) points over four cycles were used for calibrations, in addition to two leaf area index (LAI, m^2 m^{-2}) measurements.
- Pirassununga site (21°55'54''S, 47°10'54''W) with sandy-clay-loam soil
  - 11 sets of SWC measurements for 10 different depths were collected during the first harvest cycle, and 11 AGBM points over four harvest cycles were used for calibrations, in addition to two LAI measurements. However, data from the second ratoon was lost due to a fire.

CropSyst calibration approach

CropSyst performance was assessed with root mean square errors (RMSE) between the model's output and field data such as AGBM, LAI, and SWC under rainfed conditions.

- Base and cutoff temperatures adjustments for calibrations: CropSyst development stages are based on crop-specific thermal time accumulation (growing degree-days, GDD), where each crop has a base and cutoff temperature below and above which thermal accumulation does not take place.
- Canopy development: LAI (m^2 m^{-2}) and AGBM (kg ha^{-1}) simulations were compared against field data. The length of phenological stages (GDD) was adjusted.
- SWC (m^3 m^{-3}): Canopy cover parameters were adjusted to calibrate SWC using observed soil moisture from 10 depths along soil profile.

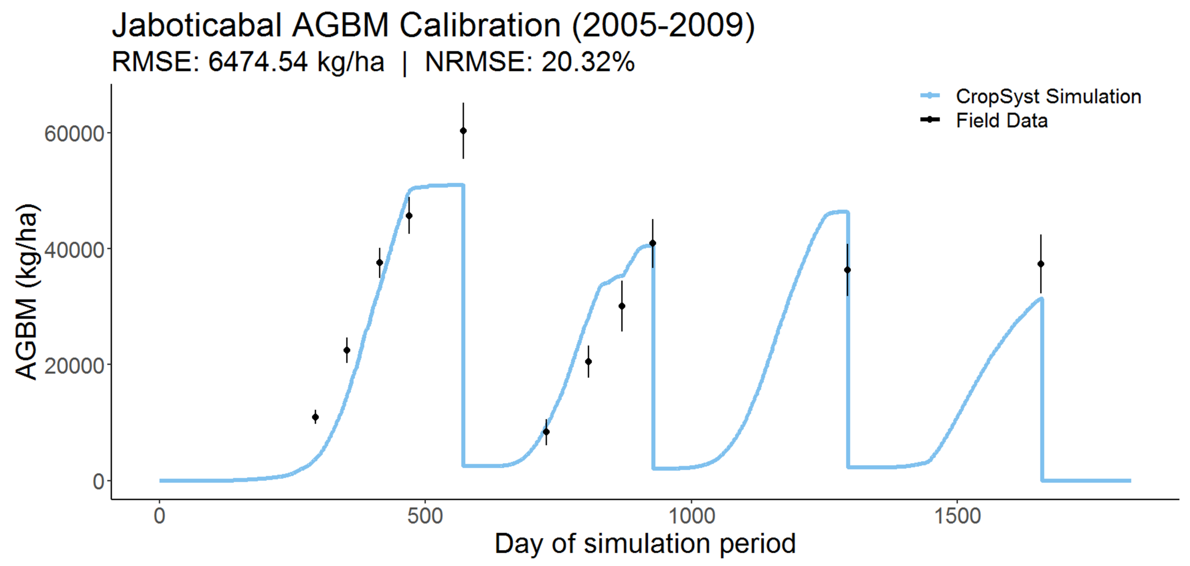


Figure 3: Jaboticabal AGBM calibration

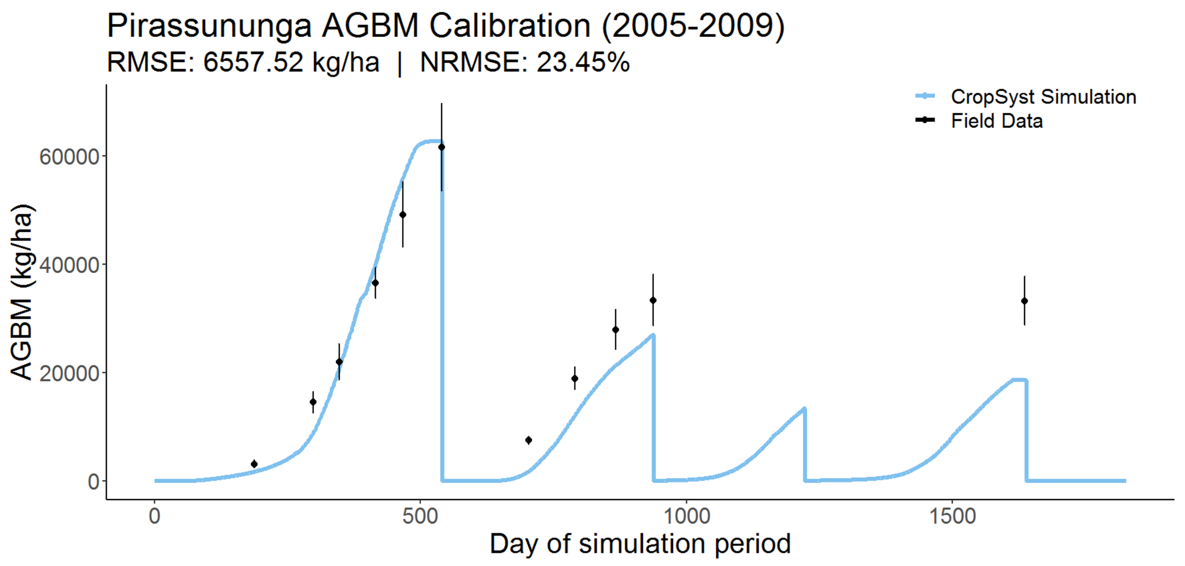


Figure 4: Pirassununga AGBM calibration

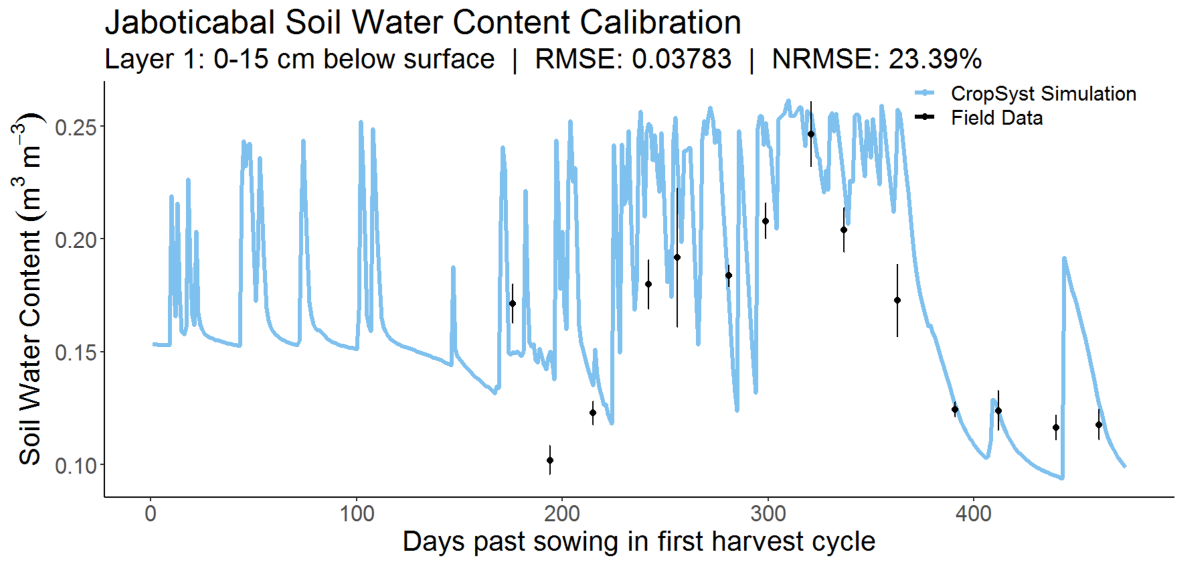


Figure 5: Jaboticabal first layer SWC calibration

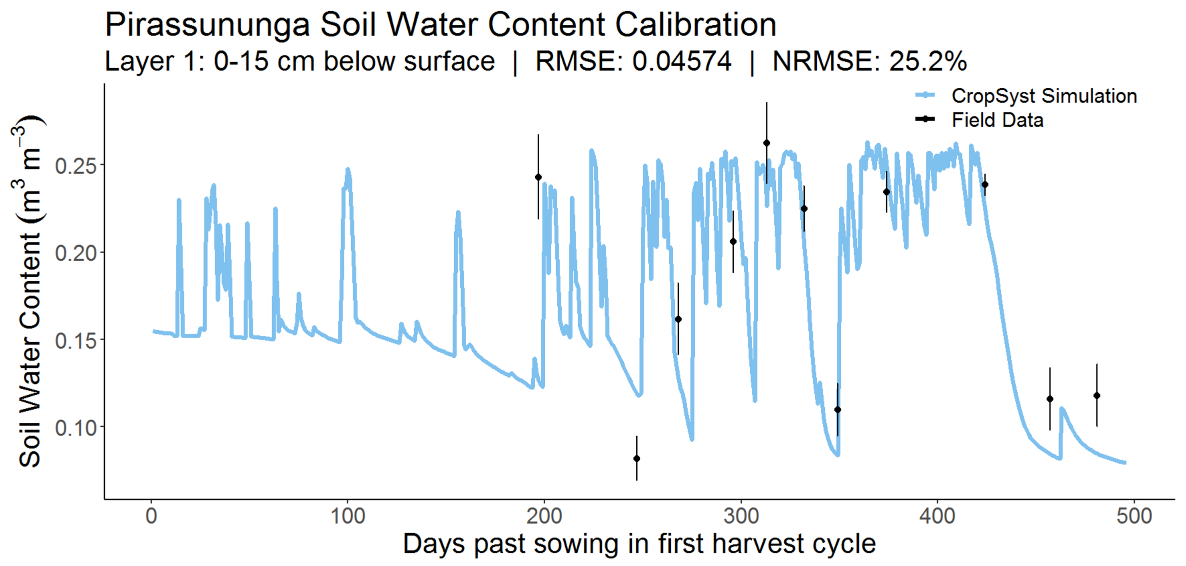
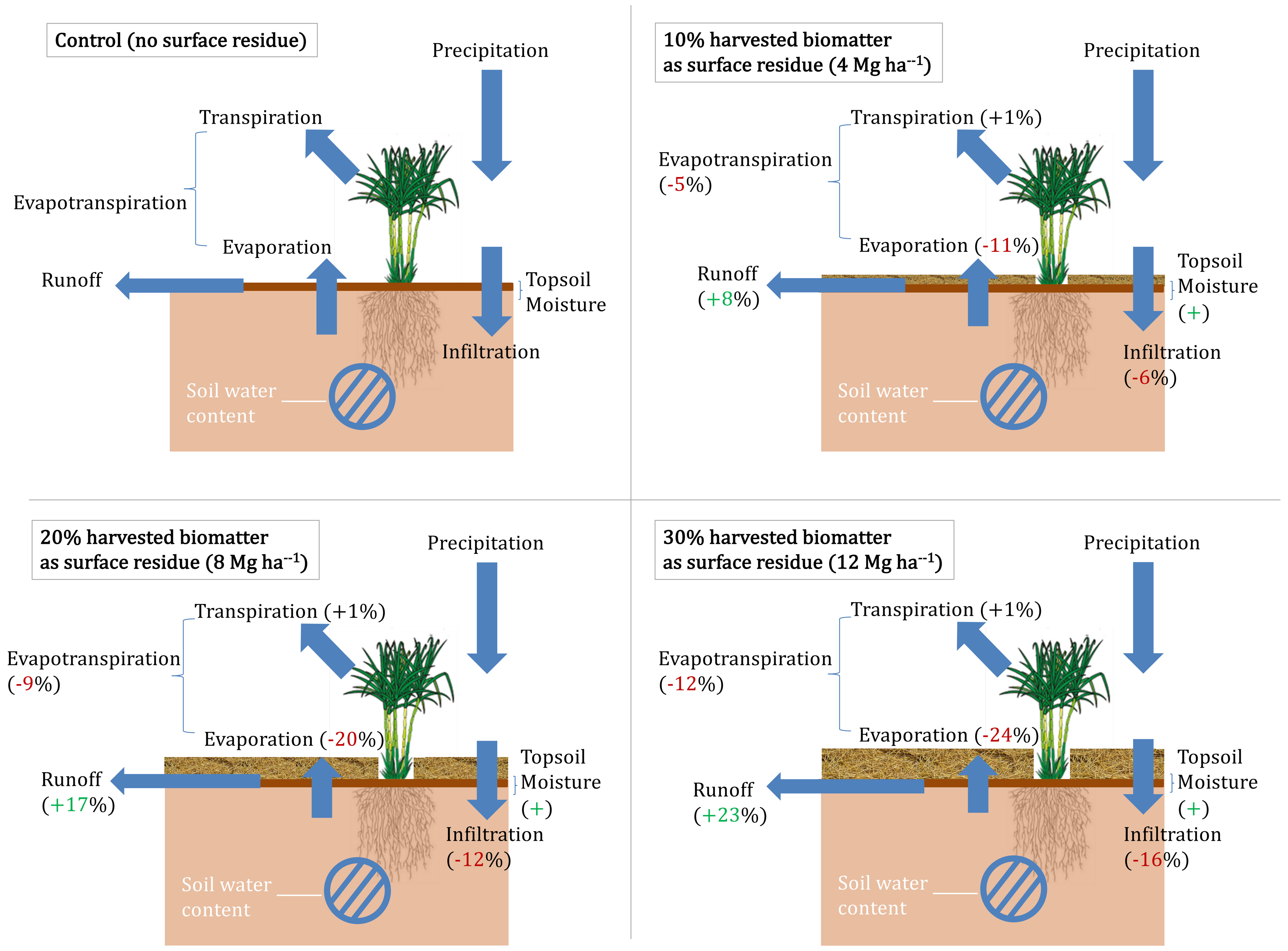


Figure 6: Pirassununga first layer SWC calibration

Figure 7: Illustrations of percent changes in water balance components for different amounts of crop residue as mulch: Percent changes from the 0% "no residue treatment" condition and amounts of mulch applied after each harvest listed (Mg ha^{-1}) are averages across the two simulated sites, Jaboticabal and Pirassununga.



Discussion

- The amount of surface crop residue applied increased soil moisture of only the topsoil layer, while the moisture of other layers was unchanged. Although contrary to tentative expectation, this can be explained:
  1) by the high level of water retention of the sandy clay loam soil at the sites and
  2) by the fact that the amounts of residue applied as mulch are, on average, still below those which typically increase SWC deeper in the soil [1,2].
- For the two sites used in this study, CropSyst predicts that crop residue use does not significantly affect yield; this could be attributed to the soil at the two sites being clay-heavy rather than being sandier[2].

Acknowledgments

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More information

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