A Model To Enhance Site-Specific Estimation Of Wetness Duration Using A Wind Speed Correction

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1. INTRODUCTION

One of the most important factors influencing the outbreak and severity of foliar diseases is the duration of wetness from dew deposition, rainfall, or irrigation. Models may provide good alternatives for assessing leaf wetness duration (LWD) without the labor, cost, and inconvenience of making measurements with sensors. Another potential advantage of LWD models is that they may be operational at any desired location where either on-site weather measurements or off-site or remotely estimated data are available. The objectives of this study were 1) to estimate LWD with an empirical model using site-specific weather data and 2) to compare the accuracy of estimates to those obtained by a proprietary off-site mesoscale model.

2. MATERIALS AND METHODS

2.1 Data acquisition and wetness estimation.

Site-specific estimates of RH, air temperature, wind speed, provided by SkyBit,Inc. for 15 sites in Iowa (IA), Illinois (IL), and Nebraska (NE) were collected from May to September in 1997, 1998, and 1999. LWD, air temperature and RH were also measured at the same sites at which the SkyBit data were collected during the study period. SkyBit estimates of wind speed at 10-m height were corrected to canopy height (0.3 m) using the logarithmic wind profile equation given by Rosenberg *et al.* (1983):

$$\frac{u_1}{u_2} = \frac{\ln(z_1 - d) - \ln z_0}{\ln(z_2 - d) - \ln z_0} \qquad (1)$$

where u_1 and u_2 are the mean wind speed at the height of z_1 (10 m) and z_2 (0.3 m), respectively; d is zero plane displacement; and z_0 is roughness length.

The following models were evaluated with site-specific input data: A proprietary model whose output was provided by SkyBit, Inc. (designated the SkyBit wetness model) and two version of the CART/SLD model (Gleason *et al.*, 1994) that used SkyBit weather data without and with wind speed correction, designated as the CART/SLD/SkyBit model and the CART/SLD/Wind model, respectively (Table 1).

Table 1. Summary of LWD-estimation models evaluated in this study.

Model name	Input data source	Base model	Wind speed input
SkyBit Wetness	SkyBit	Proprietary (SkyBit, Inc.)	Wind speed estimated at 1-m height
CART/SLD/SkyBit	SkyBit	CART/SLD*	Wind speed estimated at 10-m height from SkyBit.
CART/SLD/Wind	SkyBit	CART/SLD	Wind speed estimate of SkyBit was corrected to 0.3-m height.

* Gleason *et al.* (1994)

2.2 Analysis of wetness estimation.

Measurements from wetness sensors and deviations of model simulations from those values were assumed to represent true wetness occurrence and errors, respectively. Daily data sets begin at 12:00 and ended at 11:00 in order to include entire dew periods within 24-h data records. The mean error (ME) was calculated by averaging differences between measured and model-estimated LWD for 24-h periods. Sensitivity analysis was performed in order to examine the response of each model to changes in RH and wind speed.

3. RESULTS AND DISCUSSION

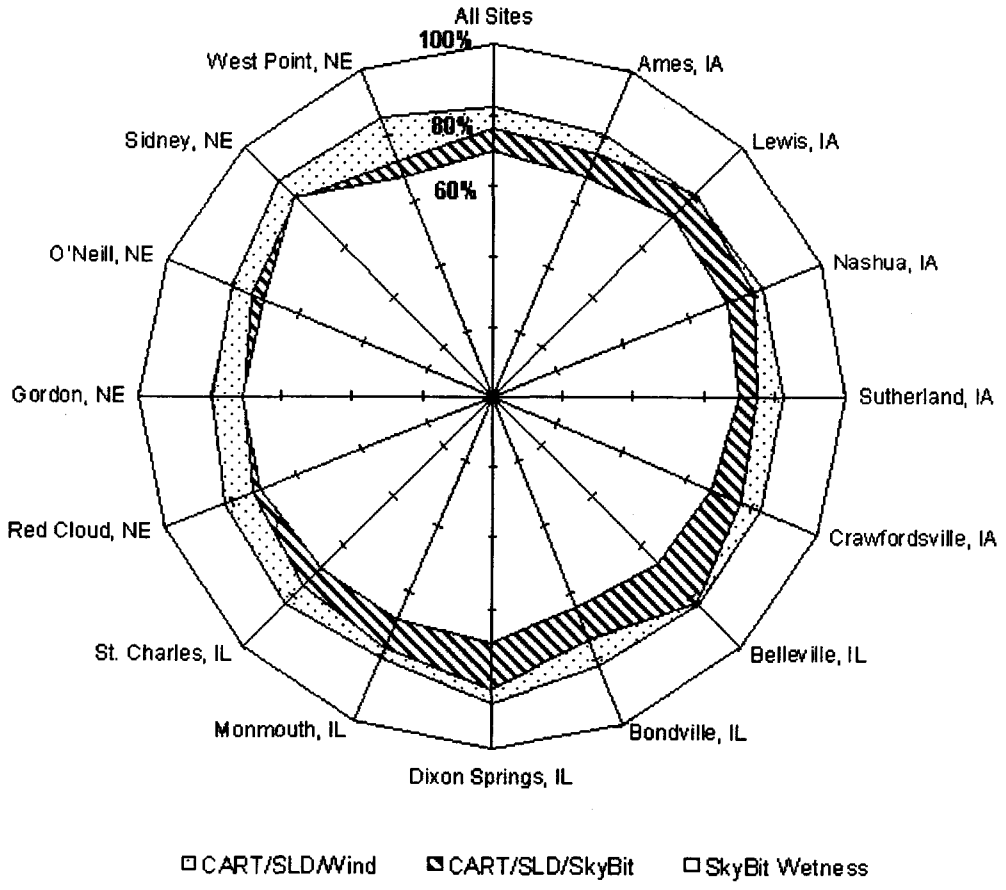

Fig. 1. Accuracy (%) of each model in identifying wet and dry hours at 15 weather stations from 1997 to 1999.

This study is the first to utilize models to enhance accuracy of commercially available, site-specific estimates of wetness duration. Because these estimates have tremendous potential for accelerating the implementation of weather-based disease-warning systems (Gleason, 2000) and have been shown to encounter considerable error in estimating wetness duration (Gleason *et al.*, 1997), the substantial improvement in accuracy should increase reliability of these technologies in disease-warning systems.

The CART/SLD/Wind model estimated LWD with higher accuracy than either the SkyBit wetness model or the CART/SLD/SkyBit model (Fig. 1). In sensitivity analysis, the amount of error by the CART/SLD/Wind model was much less than for the other models, especially for RH > 80 % (Fig. 2).

Without a wind speed correction, the CART/SLD approach using SkyBit input data substantially underestimated the duration of wet periods at all locations, which makes sense because wind speed from SkyBit was estimated at a height of 10 m rather than near the ground. The large errors incurred by this model emphasize the risk of applying commercially available input data to a LWD estimation model without recognizing the inherent limitations of the data set.

In our study, air temperature estimates of SkyBit were relatively accurate (R^2 = 0.93), whereas RH estimation errors were much larger (R^2 = 0.84). When input weather data parameters differ in degree of accuracy, the choice of algorithm for a wetness estimation model may impact accuracy. Both the hierarchical structure of the CART procedure and the wind speed correction led the CART/SLD/Wind model to estimate LWD with reasonable accuracy despite relatively inaccurate input values, especially SkyBit estimates for RH. Correlation between the magnitude of estimation error for RH and the estimation accuracy, expressed as the proportion of hours in which the CART/SLD/Wind models correctly estimated occurrence or absence of wetness, was not significant (P = 0.2043), implying that the CART/SLD approach was able to diminish the influence of erroneous RH values (Fig. 3). The CART/SLD model with wind speed correction has the potential to accurately identify periods of environmental wetness in the midwestern United States and therefore merits further attention as a tool to enhance accuracy and user acceptability of commercially available, remote estimates of weather parameters.

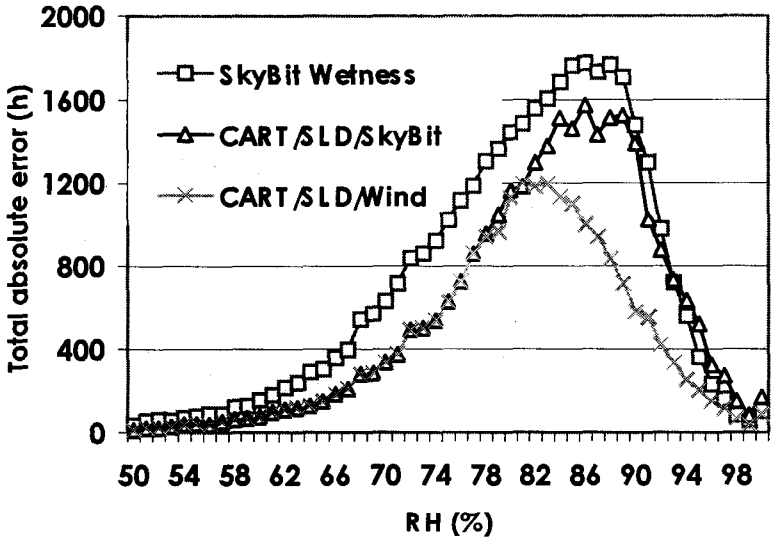

Fig. 2. Model response to RH at full ranges of wind speed ($0 \leq x \leq 13.0$ m/sec) where x is wind speed. SkyBit wetness, CART/SLD/SkyBit, and CART/SLD/Wind are total number of hours in which measured and model-estimated wetness differed at given RH.

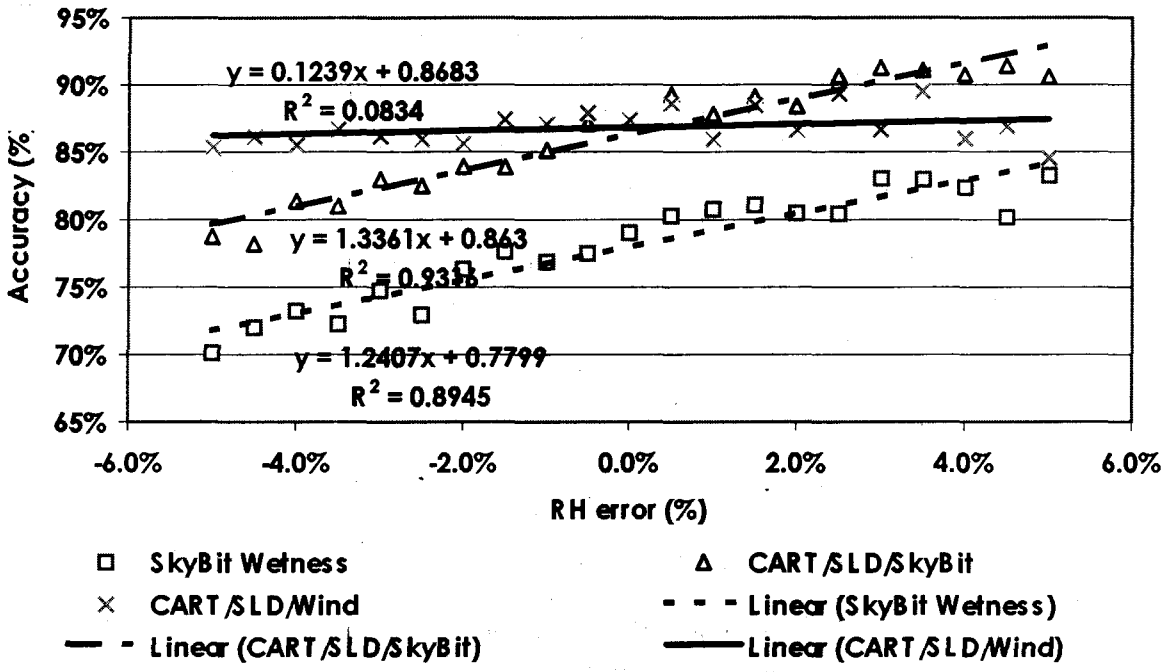

Fig. 3. Relationship between error of SkyBit RH estimate and accuracy of wetness event prediction. Accuracy is defined here as the proportion of hours in which occurrence or absence of wetness was estimated correctly. RH error and respective accuracy (%) of the SkyBit wetness model and the CART/SLD/SkyBit model were correlated significantly ($P < 0.0001$). In the CART/SLD/Wind model, the correlation between them was insignificant ($P = 0.2043$).

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