P4.13 AN EMPIRICAL MODEL TO ESTIMATE LEAF WETNESS DURATION USING ENERGY BALANCE PRINCIPLES IN NORTHWESTERN COSTA RICA

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1. INTRODUCTION

Leaf wetness duration (LWD) is an important environmental factor in predicting the risk of crop disease epidemics. However, it is difficult to obtain LWD data since few weather stations measure this variable. An alternative way to obtain LWD data is to use models to estimate it from data for the weather parameters (e.g., temperature, relative humidity, wind speed) that influence LWD. Kim et al. (2002) reported that the CART/SLD model, a hybrid physical/empirical model, was able to estimate LWD accurately with site-specific weather estimates after a wind speed correction was applied. In this study, an empirical model was designed using the CART/SLD model and fuzzy logic with energy balance principles in order to estimate LWD from site-specific weather data in northwestern Costa Rica.

2. MATERIALS AND METHODS

2.1 *Weather data*

Hourly air temperature, RH, and wind speed measurements at 15 stations in Iowa, Illinois, and Nebraska during May through September 1997 were used as a training data set. The test data set consisted of hourly measurements from five stations in northwestern Costa Rica during the dry season (December 2000 – April 2001). Site-specific estimates of air temperature, RH, and wind speed provided by SkyBit Inc. (Boalsburg, PA) were obtained for the U.S. and Costa Rican sites during the study periods.

2.2 *Adaptation of the CART/SLD model using an energy balance equation*

Existence of wetness on a surface can be estimated in terms of either loss or gain of latent heat energy (LE), which results from condensation or evaporation of water vapor. The latent heat on the surface can be expressed using the Penman-Monteith equation:

$$LE = \frac{r C_p VPD / r_a + \Delta(R_n - G)}{\Delta + g} \quad (1)$$

where ρ is density of air, C_p is specific heat of air at constant pressure, T_a is air temperature at the height of the surface (K), VPD is vapor pressure deficit (Pa), Δ slope of the saturated vapor pressure versus temperature curve (Pa K^{-1}), R_n is net radiation (W m^{-2}), G is ground heat flux (W m^{-2}), γ sychrometric constant (Pa K^{-1}), and r_a is aerodynamic resistance for heat and water vapor (s m^{-1}).

In the CART/SLD model, dew point depression (DPD), wind speed, and relative humidity (RH) were used to construct a hierarchical decision tree to estimate LWD caused by dew. In the present study, an empirical model, which was named as the CART/SLD/VPD model, was developed by substituting VPD, which is a part of the energy balance equation to estimate LWD, for DPD in the CART/SLD model and using a fuzzy logic system. A training data set, measured weather data in the Midwestern US, was used to acquire the corresponding value of VPD to DPD thresholds in the CART/SLD and to find member functions of the fuzzy logic system to estimate LWD.

3. RESULTS

Weather estimates, especially RH, obtained from SkyBit Inc., were less accurate in northwestern Costa Rica (R^2 = 0.46) than the Midwestern US in previous study (R^2 = 0.84; Kim et. al., 2002). Weather estimates at a station in Garza, Costa Rica, were substantially different from measured weather data since geological and topological adjustment was not made to acquire site-specific weather estimates so that LWD estimation at the site was excluded from further analysis.

Overall, all models underestimated LWD during the dry season in northwestern Costa Rica (Table 1). Underestimation of LWD by the proprietary SkyBit wetness model was 1.1 h/day on average. The CART/SLD model and the CART/SLD/VPD model underestimated LWD by <1 h/day during the same period. The CART/SLD/VPD model underestimated

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LWD by 2.1 h/day, considerably less than either the SkyBit wetness model (5.9 h/day) or the CART/SLD model (4.5 h/day), during days on which measured LWD was >3 h/day. All models, however, estimated LWD within 2 h/day when measured wetness was ≤3 h/day.

4. DISCUSSION

To our knowledge, this was the first attempt to use modeling to improve accuracy of site-specific LWD estimation outside of North America. The CART/SLD/VPD model substantially improved LWD estimation accuracy compared to the SkyBit wetness and the CART/SLD model, particularly on days with prolonged LWD. Many disease-warning systems use weather data as input variables to help growers time fungicide or bactericide sprays more efficiently; for warning systems that rely on LWD input, application of the CART/SLD/VPD model, by improving accuracy of site-specific estimates of LWD during days with prolonged wet periods, could make it feasible for growers to apply this convenient source of LWD data to warning systems. The result could be more efficient use of disease-control chemicals, and potentially higher profits for growers when spray frequency is reduced. The CART/SLD/VPD model showed the possibility that an empirical model can be applied to tropical climates. This is especially promising for seasonally dry regions such as northwestern Costa Rica, in which the risk of wetness-driven crop disease epidemics is sporadic during the dry season.

5. REFERENCES

Kim, K. S., Taylor, S. E., Gleason, M. L., and Koehler, K. J., 2002: Model to enhance site-specific estimation of leaf wetness duration. *Plant Dis.*, **86**, 179-185.

TABLE 1. Mean error (ME) and mean absolute error (MAE) of LWD estimation in northwestern Costa Rica during the dry season (December-April of 2000-2001).

Location	N (days)	SkyBit[a]	DPD[a]	VPD[a]	SkyBit	DPD	VPD
		ME (SEM)[c]			MAE[c]		
All days							
CEIBA	127	-0.4 (0.44)	0.2 (0.31)	1.5 (0.39)	3.2	2.9	3.5
LIBERIA	158	-1.7 (0.47)	-1.6 (0.31)	0.1 (0.36)	4.9	3.5	3.9
MOJICA	135	-1.1 (0.49)	-0.8 (0.36)	0.7 (0.42)	4.0	3.3	3.8
SANTA CRUZ	162	-1.2 (0.43)	-1.0 (0.28)	0.6 (0.31)	3.8	2.6	2.9
All stations	582	-1.1 (0.23)	-0.9 (0.16)	0.7 (0.18)	4.0	3.1	3.5
Wet Days[b]							
CEIBA	32	-4.2 (1.19)	-2.4 (0.92)	-0.4 (1.07)	8.4	7.1	6.6
LIBERIA	66	-6.0 (0.71)	-4.8 (0.43)	-2.4 (0.59)	8.8	6.5	5.8
MOJICA	38	-5.9 (1.19)	-5.2 (0.71)	-3.1 (0.81)	10.0	7.5	6.2
SANTA CRUZ	47	-6.9 (0.80	-4.7 (0.58)	-2.2 (0.63)	9.3	6.4	5.0
All stations	183	-5.9 (0.46)	-4.5 (0.31)	-2.1 (0.37)	9.1	6.8	5.8
Dry Days[b]							
CEIBA	95	0.9 (0.34)	1.0 (0.23)	2.2 (0.35)	1.4	1.5	2.5
LIBERIA	92	1.3 (0.38)	0.7 (0.21)	1.9 (0.34)	2.0	1.3	2.5
MOJICA	97	0.9 (0.34)	1.0 (0.26)	2.2 (0.39)	1.7	1.7	2.9
SANTA CRUZ	115	1.1 (0.32)	0.6 (0.15)	1.7 (0.29)	1.6	1.1	2.1
All stations	399	1.1 (0.17)	0.8 (0.11)	2.0 (0.17)	1.7	1.4	2.5

a. Sky, DPD, and VPD indicate the SkyBit wetness model, the CART/SLD model, and the CART/SLD/VPD model, respectively.
b. Wet Days = days on which measured LWD was >3 h/day. Dry days = days with ≤ 3 h measured LWD.
c. ME, SEM, and MAE indicate mean difference, standard error of the mean, and mean absolute error, respectively.