10.1 COMPARISON BETWEEN FOUR METHODS TO ESTIMATE LEAF WETNESS DURATION CAUSED BY DEW ON GRASSLAND

Roy J. Wichink Kruit[1*], W. Addo J. van Pul[2], Adrie F.G. Jacobs[1] and Bert G. Heusinkveld[1]

[1] *Wageningen University, Wageningen, The Netherlands*
[2] *National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands*

1. INTRODUCTION.

Leaf Wetness Duration (LWD) is very important factor in the spreading of diseases in plant canopies and dry deposition of air pollution to plants. The objective of the present paper is to evaluate four methods to estimate leaf wetness duration. Two of them are parameterisations that predict dew amounts as well as dew duration and two of them only predict dew duration.

2. MODEL DESCRIPTIONS

The first method to predict LWD is the dew parameterisation by Garratt and Segal (1988) based on earlier work by Penman and Monteith:

$$L_v E = \frac{s}{s+\gamma}\left(Q_* - G\right) + \frac{\gamma}{s+\gamma}\frac{L_v\,\rho_a\,\delta q}{R_a} \quad (1)$$

where s is the slope of the curve of the partial pressure of the saturated water vapour for actual air temperature, γ is the psychrometric constant ($\gamma = c_p p / L_v \varepsilon$; c_p being the specific heat of air, p being the air pressure, L_v being the latent heat of vaporization and ε being the ratio (0.622) between dry air and water vapour gas constants), Q_* is the net radiation, G is the soil heat flux at the surface, ρ_a is the air density, δq is the difference between saturated humidity and actual humidity in the air and R_a is the aerodynamical resistance to heat or water vapour transfer.

The second method is the dew parameterisation by Pedro and Gillespie (1982):

$$L_v E = -\left(\frac{\varepsilon}{p}\right) 2\,hw\,\left(e_s - e\right) \quad (2)$$

where $hw = 1.07 \frac{L_v}{c_p} hc$

and $hc = \frac{Nu\ \lambda}{D}$

with hw is the water vapour transfer coefficient, e_s is the saturated vapour pressure, e is the actual vapour pressure, hc is the heat transfer coefficient, Nu is the Nusselt number, λ is the thermal conductivity of still air and D is the effective leaf diameter (in cm).

The third method is a constant threshold value for the relative humidity (RH) of 87%, which is used in the atmospheric transport model (OPS) of RIVM (Van Jaarsveld, 1995).

The fourth method is also a constant RH threshold value of 87%, but this threshold value is extended with an arbitrary threshold value for the change in RH in time. For RH between 70% and 87% leaves are assumed to be wet if RH increases more than 3% in 30 minutes. Leaves are assumed to be dry if RH decreases with more than 2% in 30 minutes. For RH below 70% leaves are assumed to be dry and for RH above 87% leaves are assumed to be wet.

Corresponding author address:
R.J. Wichink Kruit, Wageningen University, Dept. of Meteorology and Air Quality, Duivendaal 2, NL-6701 AP Wageningen, The Netherlands, +31-317-482109,
E-mail: Roy.Wichinkkruit@wur.nl

3. EXPERIMENTAL SETUP

Observations from a leaf wetness (grid) sensor are used for the comparison between the different methods. Half-hourly observations are available for a period of more than 200 days (more than 10000 data points) in 2003. Net radiation, Q_*, is calculated from the net incoming shortwave radiation ($Q_s^{\downarrow}$ - $Q_s^{\uparrow}$) and the net incoming long wave radiation ($Q_l^{\downarrow}$ - $Q_l^{\uparrow}$). Soil heat flux, G, is measured with a heat plate buried at 7.5 cm depth and is scaled up to the surface with the soil temperature profile. Relative humidity is measured with a (hair-)hygrometer at two metres height. All these variables are available at a half-hourly base.

To compare the four methods, 3 statistical scores are used. To calculate these scores, we use contingency tables (see Table 1).

TABLE 1. Contingency table.

observations \ model	yes	no
yes	A	B
no	C	D

If a method correctly predicts wetness, it is put in box A. If a method does not predict wetness, while it does occur, it is put in box B (misses). If a method predicts wetness, while it does not occur, it is put in box C (false predictions). And if a method correctly not predicts wetness, it is put in box D.

Statistical scores are obtained by putting each prediction in one of the four boxes and dividing by the total number of predictions. The first score, we use in this study, is the Fraction of Correct forecasts (FC). The FC is the sum of correct predictions (box A) and correct rejections (box D). This score should be as high as possible, but it has a maximum value of 1.

The second score is the False Alarm Ratio (FAR). This is the wrongly predicted wetness (box C) divided by the total predicted wetness (box A + box C). So, it is the fraction of the predicted wetness that was wrong. Of course, this score should be as small as possible.

The third score we use is the bias. The bias is the total number of predicted wetness occurrence (box A + box C) divided by the actual wetness occurrence (box A + box B). If the bias is greater than 1, the number of events is overestimated. A bias smaller than 1 means that the model underpredicts the events. So, a good method should have a bias close to 1.

4. RESULTS AND DISCUSSION

Figure 1 shows the results of the four different methods for a short period of 8 days within the total data set. This figure illustrates the daily course of the RH and its effect on method 3 and 4 (RH threshold and extended RH threshold method).

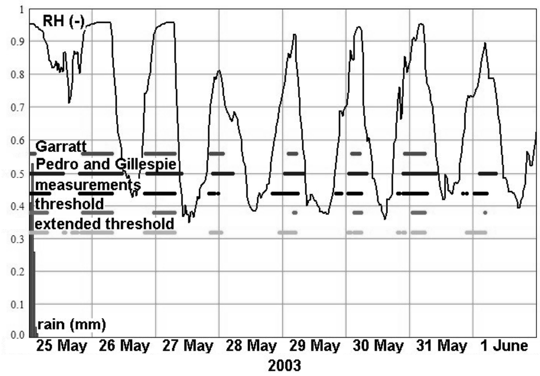

FIGURE 1. Comparison between four methods to estimate LWD on grassland. The thin line is the relative humidity (-). The vertical bars are rain amounts (mm). The thick horizontal lines represent the LWD calculated with the different methods and the LWD measured with the wetness sensor.

This figure clearly shows that there are differences in starting and ending time for leaf wetness. None of the methods is perfectly predicting the LWD. However, it's obvious that the LWD predicted by the extended threshold method is closest to the observed LWD.

Furthermore, it's clear that in relatively dry nights (from the 27th of May until the 1st of June), the threshold method 'misses' a lot of wetness events, while the extended version of this method does predict this wetness rather well.

The dew parameterisations by Garratt and Segal (1988) and Pedro and Gillespie (1982), method 1 and 2, also predict LWD rather well. However, they both seem to be too late in generating dew. In general, the dew parameterisation by Pedro and Gillespie predicts longer LWD's than the dew parameterization by Garratt and Segal, which underestimates LWD for this period.

In the following analysis, we investigate if the results for this short 8-day period are also valid for the total data set (of more than 10000 points/5000 hours).

The individual contingency tables of the different methods are given below (Table 2 till Table 5).

TABLE 2. Contingency table Garratt and Segal (1988)

observations \ Garratt and Segal (1988)	yes	no
yes	0.30	0.20
no	0.01	0.49

TABLE 3. Contingency table Pedro and Gillespie (1982)

observations \ Pedro and Gillespie	yes	no
yes	0.45	0.05
no	0.13	0.37

TABLE 4. Contingency table RH threshold

observations \ RH threshold	yes	no
yes	0.33	0.17
no	0.02	0.48

TABLE 5. Contingency table extended RH threshold

observations \ extended RH threshold	yes	no
yes	0.42	0.08
no	0.05	0.45

On basis of these four contingency tables, the three statistical scores for each method are calculated in Table 6.

TABLE 6. Statistical scores for the four methods to estimate leaf wetness.

	FC	FAR	bias
1st Garratt and Segal	0.80	0.02	0.62
2nd Pedro and Gillespie	0.82	0.22	1.15
3rd "threshold"	0.82	0.04	0.70
4th "extended threshold"	0.87	0.10	0.94

We see that also for the whole data set the extended threshold method gives best results. This method gives the highest FC score; 87% of all the predictions (wet as well as dry) are correct. The bias is also close to 1, so there is balance between the over- and underestimates. Furthermore, only 10% of the forecasted wetness is wrong.

The threshold method gives a lower FC, but also a lower FAR. Furthermore, the bias is far below 1, which means that this method under predicts LWD. The same reasoning is valid for the Garratt and Segal method.

The Pedro and Gillespie method gives comparable results. The FC score is

also slightly lower (82%), while the bias is just above 1. This means that the Pedro and Gillespie method overpredicts the leaf wetness, which is an important difference with the other methods. This overprediction results in a larger FAR; 22% of the predicted wetness is wrong.
The method to use depends strongly on the purpose of the prediction of LWD. To prevent against plant diseases it might be important not to underpredict LWD. So, in that case the Pedro and Gillespie method might be favourable to use, despite of its large FAR. However, especially in atmospheric transport models that are often limited in calculation time, we recommend to use the extended RH threshold method.

5. CONCLUSION

Leaf wetness duration on grassland can best be predicted with the extended threshold method. The use of other methods may be favourable in certain situations.

6. LITERATURE

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