2.5 Contribution of Dew to the Water Budget and Ecology of a Grassland Area in The Netherlands

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INTRODUCTION

Dew is a meteorological phenomenon that can provide moisture to a given surface. Although such phenomenon contribute free water to the earth's surface, in meteorology dew is not considered as real precipitation. Dew is formed through condensation, and has roughly a theoretical maximum of 0.8 mm night^{-1} (Monteith, 1957). Such dew quantities are small and as a consequence are difficult to measure.

Nevertheless, dew may provide free liquid water to living organisms (Evenari et al., 1982; Jacobs et al., 2000), and can also contribute to the water budget (Baier, 1966; Beysens, 1995).

Dew can form drops or water films on plant leaves causing so-called leaf wetness. Leaf wetness affects plant growth (Wallin, 1967) and favors the development of plant diseases (Aylor, 1986). When water is deposited on leaves for critical periods and when temperatures are suitable, fungal spores and other pathogens may develop that can be extremely harmful to plant canopies and natural vagetations.

EXPERIMENTAL SET-UP

As the Netherlands has a very high frequency of dew events, a grassland area was selected to determine whether dew input could be significant. The study site is situated within the Wageningen University meteorological observatory.

Direct dew measurement experiments were carried out in 2004. Data were used to verify a surface energy dew model, which was then applied to an 12-year data set.

During the 2004 direct experiments, simple manual lysimeter containers were used to measure dew. The containers were weighed every 30 minutes during special periods. For each night, new samples were taken in order to avoid a deviation between the moisture balance of the container and its direct environment. Although this approach is very accurate, it is very laborious and time-consuming.

THEORY

Dew can occur when evening radiative cooling allows water vapor from the atmospheric water reservoir to condense on a given surface (Garratt and Segal, 1988; Jacobs and Nieveen, 1995). In addition, dew can form when soil water evaporates during the night and is intercepted by a canopy (Monteith, 1957; Garratt, 1992), and through an internal plant water excretion process known as guttation. Guttation amounts, however, are small (Long, 1955) and will be neglected in the present study.

We start from the earth's surface energy budget (Garratt and Segal, 1988):

$$Q^* - G = \lambda_v E + H \qquad (1)$$

where Q^* (W m^{-2}) is net radiation, G (W m^{-2}) is soil heat flux, $\lambda_v E$ (W m^{-2}) is evapotranspiration and H (W m^{-2}) is sensible heat, and combine this result with the free water evaporation/dew formation (Garratt and Segal, 1988):

$$\lambda_v E = \rho \lambda_v \frac{q^*(T_o) - q}{r_{av}} \qquad (2)$$

where $q^*(T_o)$ (kg kg^{-1}) is saturated specific humidity at surface temperature T_o (^{o}C), q (kg kg^{-1}) is specific humidity at a reference level, z_r, in our case z_r = 1.5 m above the grass cover, and r_{av} (s m^{-1}) is the aerodynamic resistance to vapor transport. Then the evaporation or dew formation of free liquid water is reached after using Penman's substitution (Garratt, 1992):

$$\lambda_v E = \frac{s}{s+\gamma}(Q^* - G) + \frac{\gamma}{s+\gamma}\frac{\rho \lambda_v \delta q}{r_{av}} \qquad (3)$$

where $s = \dfrac{dq^*}{dT}$ (K^{-1}) is the slope of the saturation specific humidity curve, $\gamma = \dfrac{c_p}{\lambda_v}$ (K^{-1}) is the psychrometric constant, $\delta q = q^*(T_a) - q$ (kg kg^{-1}) is the deficit specific humidity at reference level, T_a is the air temperature and the aerodynamic resistance to vapor transport is r_{av} (s m^{-1}).

The accumulated amount of dew within the grass cover is calculated by summing the negative evaporation according to:

$$\begin{aligned} D_{i+1} &= D_i + E_i \Delta t \;\; if \;\; D_{i+1} \geq 0 \\ D_{i+1} &= 0 \;\; if \;\; D_i + E_i \Delta t < 0 \end{aligned} \qquad (4)$$

where D_{i+1} is the new accumulated dew amount, D_i is the former dew amount, E_i is the dew flux density calculated using Eq. 3, and Δt (= 600 s) is the time step. If $D_i + E_i\Delta t < 0$, D_{i+1} is set to zero since this means that all free water on the leaves has evaporated. In addition, it must be noted that after D_{i+1} has been set to 0, the evaporation equation (3) cannot be applied anymore, since the crop resistance, r_c, must be taken into account.

RESULTS AND DISCUSSIONS

Microlysimeter measurements were made over 20 nights in April and May, 2004. Due to rain and fog events, however, only 8 nights could be used in this study. Figure 1 displays the course of the dew amounts gathered with the lysimeters along with the simulated amounts according to the surface energy budget model, for 1 selected night (29-30 May 2004).

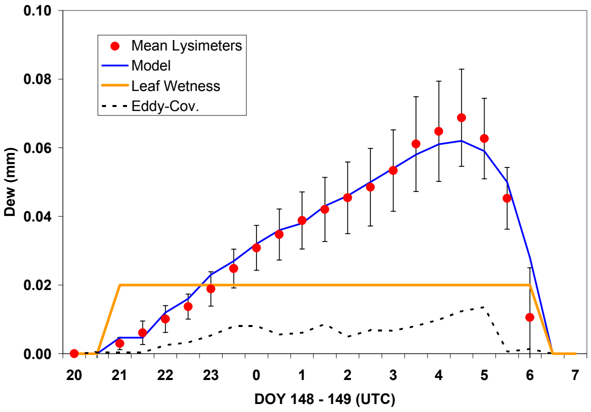

Figure 1: *Example of the course of accumulated dew during the night 29-30 May 2004.*

Figure 2 displays the course of the annual dew and precipitation amounts based on the 12-year data record period. The averaged dew and precipitation during this period were 37 mm and 830 mm, respectively, with standard deviations of 8 mm and 200 mm, respectively. On average, dew contributes only about 4.5 % of the mean annual precipitation. The mean annual dew amount is small in comparison to the mean precipitation and to the standard deviation of the precipitation.

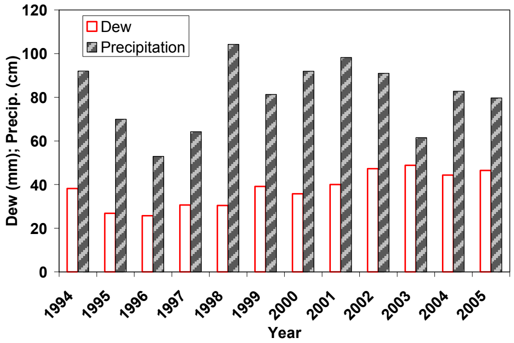

***Figure 2**: Course of the annual dew and precipitation amounts during the 12-year data period.*

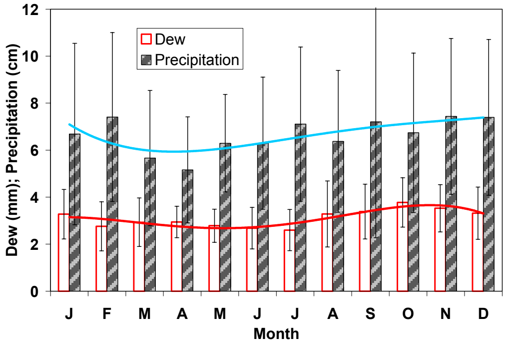

***Figure 3**. Course of the mean monthly dew and precipitation amounts (and standard deviations) during the 12-year data period.*

Figure 3 compares the mean monthly dew and precipitation amounts calculated for the selected 12-year data period, along with the trend functions (4th order polynomial). In order to correct for different days per month, the data in figure 3 have been normalized for 30 days. The dew and precipitation amounts are more or less evenly distributed over the year. There appears to be a slight tendency for lower dew amounts during the longest daylight period (May to July), and vice versa during fall. The standard deviation of the mean monthly dew is about 1 mm while the standard deviation of the mean precipitation is about 30 mm. Again, the contribution of dew to the mean monthly water balance is of minor importance.

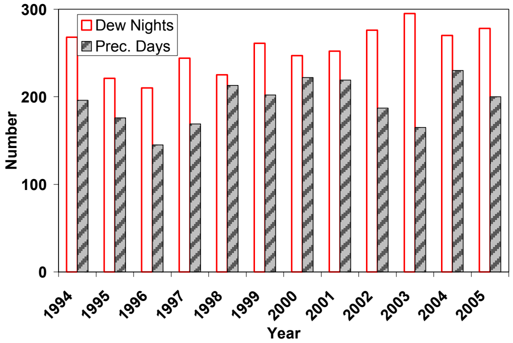

***Figure 4**. Number of annual dew nights and precipitation days during the 12-year data period.*

Figure 4 displays the number of annual dew nights and precipitation days for the 12-year data period. Here a dew night is defined as a night with more than 0.05 mm dew and a precipitation day as a day with more than 0.1 mm rain. On average the number of dew nights is 250 with a standard deviation of 25 nights and the number of precipitation days is 190 with a standard deviation of 26 days. Dew occurs on nearly 70 % of all nights, which is a very high frequency of dew events.

In the study region, precipitation occurs about 50% of the year. Figure 5 compares the distribution of the mean number of monthly dew nights and precipitation days. Moreover, the trend functions (4th order polynomial) have been plotted in figure 5. The results are given in percentages in order to compensate for the different number of days per month. For the mean number of monthly averaged dew nights, a trend in the yearly cycle can be recognized. During the summer period (July to

September) a maximum number of dew nights occur (about 25), while during the winter period (January until March) there is a minimum of about 17. The number of precipitation days tends to have an opposite pattern.

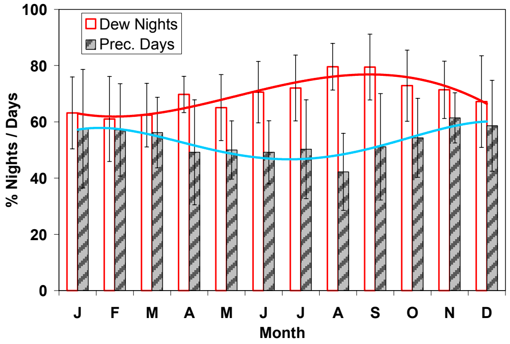

***Figure** 5. Percentage of monthly dew nights and precipitation days, and standard deviations and trend lines.*

In spite of the meager contribution to the water budget, dew plays an important role in agriculture and ecology in the Netherlands. Leaf wetness and temperature combine to present conditions for pathogens, and fungal and other foliar diseases can endanger crop yield. Such diseases are often controlled by fungicide sprays. With increasing environmental awareness and the high cost of fungicides, there is a pressing need to curb excessive use of chemical control measures.

CONCLUSIONS

On the basis of the results and discussion we conclude:

1. Nighttime dew amounts can be correctly simulated by the surface energy budget dew model during spring, summer and fall.
2. The averaged annual dew amount is 37 ± 8 mm, which is about 4.5 % of the mean annual precipitation (820 ± 200 mm). Dew is thus of minor importance in this region in terms of the total water budget.
3. The dew amounts are evenly distributed throughout the year with a monthly average of 3.1 ± 1.0 mm. Thus dew does not affect the monthly water budget in this region.
4. The annual averaged number of dew nights is 250 ± 25, which is a high frequency of occurrence.

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