

Elaboration of the methodology of dew measurement by means of weighing lysimeters

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Abstract: Records of the frequency of occurrence of or the total amounts of dew are scarce. The lack of such records can undoubtedly be attributed to the difficulty of making quantitative measurements of dew. Within some limitations large precision weighing lysimeters can be suitable for the accurate determination of dew amounts. The lysimeter data completed with meteorological data provide the possibility to identify such periods with positive water balance when no rainfall occurred hence dew formation is probable. Nevertheless some “data noises” (oscillations) are characteristic to weighing lysimeter data gained with a high frequency for a longer period. These oscillations can be easily mixed up with the weight increase due to dew formation, therefore filtering or smoothing functions must be used to separate them. Our research aimed to elaborate a method that is suitable to separate true dewfall periods from oscillations and to quantify the amount of dew occurred on the surface of 2 weighing lysimeters of Karcag Research Institute of RISF UD for a longer period. The method we applied for filtering was the application of weight data measured with 1 hour frequency instead of 10 minutes frequency. The investigation period lasted from 1/4/2015 to 30/9/2016. Two high precision weighing lysimeters were involved, one with bare soil surface and one with grass cover. 43.11 and 49.35 mm dew was calculated for the grass covered and the bare surface lysimeters for the total 18-month-long investigation period with the application of our method.

Keywords: dew, data filtering, weighing lysimeter

Introduction

Dew is the moisture which condenses from the atmosphere on plants, soil, or other surfaces near the ground. Due to its dependence on radiation balance, dew amounts can reach a theoretical maximum of about 0.8 mm per night; measured values, however, rarely exceed 0.5 mm. In most climates of the world, the annual average is too small to compete with rain. In regions with considerable dry seasons, adapted plants benefit from dew (Agam and Berliner, 2006). Records of the frequency of occurrence of or the total amounts of dew are scarce. The lack of such records can undoubtedly be attributed to the difficulty of making quantitative measurements of dew.

Dew can be considered from quite different points of view. For meteorologists, dew is, like rain, a natural phenomenon of condensation that proceeds from the atmosphere and starts on a substrate, submicron particles for rain, a larger surface for dew. For hydrologists, dew is a potential source of water. However, the volume of vapour that can condense at the surface of the ground is obviously much smaller than for rain, where the substrate particles are immersed in a large atmospheric volume from which they collect water (Beysens, 1995).

The amount of dew formed on plants is not well known. It would appear that during dew nights the amounts vary from very small quantities to about 0.51 mm estimated that the maximum possible amount is about 0.76 mm for a 10-hour night, but such amounts would occur only under exceptional circumstances. Total annual dew precipitation may lie between about 12.7 mm in cold climates and in nearly arid warm climates, to about 76.2 mm in semihumid warm climates (Hofmann, 1955). The actual amount of dew in a specific place is strongly dependent on surface properties. For its measurement, plants, leaves, or whole soil columns are placed on a balance with their surface at the same height

and in the same surroundings as would occur naturally (Agam and Berliner, 2006; Uclés et al., 2014). Recent advances in lysimetry allow measuring water balance components with high accuracy and high temporal resolution. Hence, precipitation as well as dewfall as a part of it can be determined directly from lysimeter data. Within some limitations large precision weighing lysimeters can thus be suitable for the accurate determination of dew amounts (Meissner et al., 2007). Furthermore, an adopted method of data interpretation is supposed to be necessary to separate dewfall from other measured water balance components (Nolz et al., 2013).

On the base of the scientific and practical experiences gained during the long-term operation of the weighing lysimeters at Karcag, Zsembeli (2005) figured out that the facilities provide very accurate data of moisture content changes of the lysimeter units. These changes caused by the different water regime of the different soil surface formations and plant covers can be compared and expressed numerically, since all the components of the water balance can be measured or calculated even for short terms.

Materials and methods

The determination of the dewfall periods was done on the base of the weight data recorded by means of a weighing lysimeter system of Karcag Research Institute RIEF University of Debrecen (KRI). There are six weighing lysimeters (the only ones in Hungary) with surface area of 1.7 m² and depth of 1 m. The sensitivity of the scales of the weighing system is 0.1 kg (0.06 mm). The basis for calculation was a water balance equation with measured quantities on the left-hand side and the (yet unknown) boundary fluxes between soil and atmosphere on the right-hand side (Eq. 1).

$$\Delta W + SW = P + I - ET \quad (1)$$

(ΔW = change of profile water content, SW = seepage water at lysimeter outlet, P = precipitation on the lysimeter, I = irrigation on the lysimeter, ET = evapotranspiration from the lysimeter; all dimensions are lengths)

The fundamental dataset contained 10-min-data of lysimeter mass (changes equaling changes of water content) and seepage water collected at the bottom outlet of the lysimeters, from which a nominal time series ($W+SW$) was calculated. The determination of the dewfall periods was done on the base of the weight data recorded by means of the weighing lysimeter system. Those periods are considered dewfall periods when positive weight changes are recorded by the lysimeters and at the same time neither natural precipitation nor irrigation occurred. The amount and duration of the natural precipitation data were determined on the base of the records with 10 minutes frequency of the meteorological station (belonging the official national network operated by the National Meteorological Service of Hungary) located in the territory of KRI at approximately 250 m distance from the lysimeter station. During the investigation period (1st April 2015 – 30th September 2016) the measurement frequency of the weight data of the lysimeters was also 10 minutes in order to harmonize them with the meteorological data. The weight changes of two weighing lysimeters – a grass covered and another with bare soil surface – were determined for each day of the investigation period and put an Excel data base.

Results and discussion

Determination of the dewfall periods: Analysing all the weighing data of our data base we signed those periods when positive weight changes were characteristic regardless their extent. All these periods were compared to the precipitation data gained by means of the meteorological station and we determined such periods when positive weight changes are recorded by the lysimeters and at the same time neither natural precipitation nor irrigation occurred. For those periods we calculated the daily water balances of the soil columns of the lysimeters taking all the relevant inputs and outputs into consideration according to Eq. 1.

Due to oscillation of the weighing system (which depends on environmental factors such as wind velocity), simple averaging methods are not sufficient to obtain an appropriate accuracy. These 'data noises' can easily be detected by the sensitive (0.1 kg) scales of the lysimeters as temporary increase of the weight. It is obvious that the higher is the measurement frequency set in the lysimeter system, the higher is the chance of the detection and store of false values. In order to distinguish the true dewfall events from the oscillations filtering of the data is necessary. There are several options to filter the data, in this paper one of them is introduced that was developed and found the easiest by our research team.

In this paper one typical day (9th September 2015) is presented when dewfall on the surface of the lysimeters was evident (visible). *Fig. 1* shows the daily weight changes (relative values, no correspondence with the real weight of the soil columns) recorded with the frequency of 10 minutes for the grass covered (left) and for the bare soil (right) lysimeters. Since no natural precipitation was detected on that day by the meteorological station, and we did not apply irrigation, theoretically the positive changes mean dewfall events, while the negative changes indicate evaporation (E) or evapotranspiration (ET). Nevertheless several oscillations also occurred during that day that cannot be explained with dewfall or evaporation/evapotranspiration as these processes are not likely to take place after each other in such a short time.

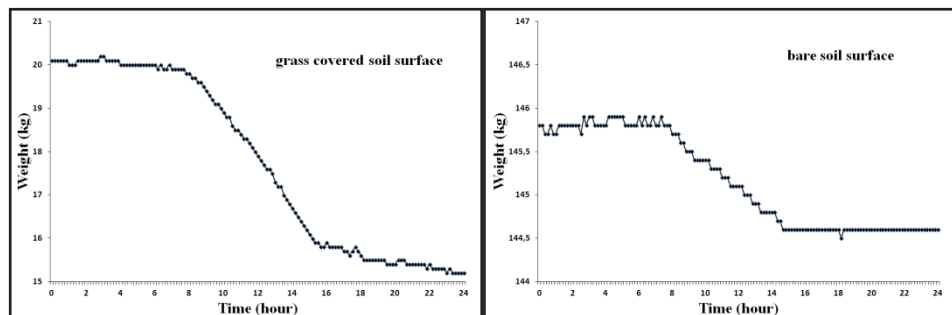


Figure 1: Daily weight changes in the lysimeters on the base of the data measured at 10 minutes frequency

As the oscillations cannot be distinguished from the true dewfall events, it was necessary to elaborate a method how the oscillations can be excluded. Our filtering method is based on the principle that dew typically forms during the evening, night and early in the morning when a surface cools through loss of infrared radiation down to a temperature which is colder than the dewpoint of the air next to that surface, hence in such periods when the chance of evaporation is practically zero. In such a case if the moisture gain of

the soil surface by dew formation does not disappear by evaporation soon, the sudden and short-term up and downwards changes in the weight of the soil column of a lysimeter are probably due to oscillations, while such increases in the weight that last longer (like an hour) are most likely due to dew formation. Therefore we changed the weight measurement frequency from 10 minutes to 1 hour (taking only every 6th data into account) in order to exclude such positive weight changes that disappear soon assuming that the longer lasting positive changes are caused by dew falling.

In Fig. 2 the daily weight changes in the lysimeters on the base of the data measured at 1 hour frequency are illustrated for the grass covered (left) and for the bare soil (right) surfaces. In the graphs shown as examples, we indicated the dewfall periods according to the principle of our estimation with black circles. In the case of the grass covered lysimeter 2x0.058 mm (0.116 mm) dew precipitated on the base of the water balance calculated from the weight changes between 2 and 3 a.m. on 9th September 2015. The first dewfall period was the same as in the case of the grass covered lysimeter with similar weight decrease after it, but then there was another weight increase lasting from 4 to 6 a.m. to resulting in 4x0.058 mm (0.232 mm) dew. The difference is primarily considered to the difference in the soil surfaces, as while in the case of the bare soil lysimeter radiational cooling of the ground surface could cause moisture to condense within the pore spaces of the surface layer of soil and that moisture condenses out of the air which is in the soil pores, in the case of the grass covered lysimeter this process is not likely to take place. Nevertheless it also must be admitted that the possible measurement error is also close to these values.

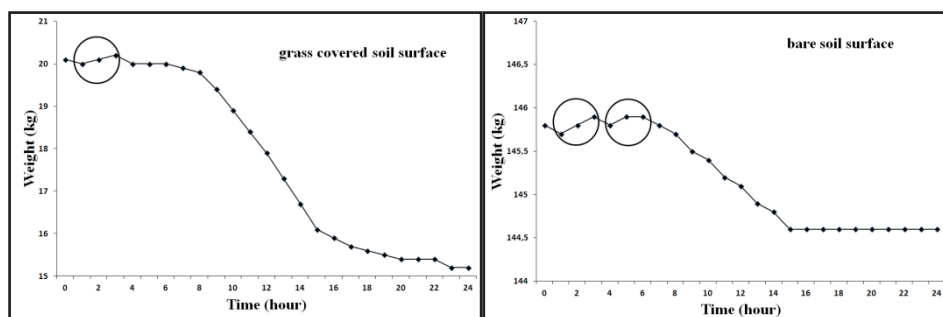


Figure 2: Daily weight changes in the lysimeters on the base of the data measured at 1 hour frequency

In harmony with the literature data our results describing that typical day with dewfall events also prove that dew is most likely to form at night, as temperatures drop and the surfaces (objects) cool. However, dew can form whenever a dew point is reached.

Determination of the amounts of dew for a longer term: By means of this dewfall identification method based on the filtering we determined the daily amounts of dew fallen on the grass covered and bare soil lysimeters during all the 549 days of the whole investigation period and calculated the total values. Altogether 43.11 mm dew was detected on the grass covered surface calculated on the base of the water balance data during the 18 months of the investigation period. In order to judge this amount being high or low, we can compare it to the literature data, but unfortunately we have no data for a complete year from January to December yet. As the annual distribution of dew is not even, we cannot compare our values directly to the literature data. Nevertheless splitting the investigation period to broken years (2x9 months) we get 20.82 mm dew between 1st of April and

31st of December 2015, while 22.29 mm between 1st of January and 30th of September 2016, respectively in the case of the grass covered soil surface. Taking these values three quarters of the total amount, the annual amount of dew would be approximately 26-28 mm, which is quite close to the value published by Szász (1992) who calculated 28.67 mm of atmospheric dew. These values are also within the range according to Hofmann (1955) who estimated the total annual dew precipitation between 12.7 mm and 76.2 mm ranging our climate closer to nearly arid warm (12.7 mm) than to the semi-humid warm climates (76.2 mm). In the case of the bare soil surface altogether 49.35 mm dew was detected during the 18 months of the investigation period, which is somewhat higher compared to the grass covered surface. Splitting the investigation period to broken years we detected 20.48 mm dew precipitated on the bare soil surface between 1st of April and 31st of December 2015, while 28.87 mm between 1st of January and 30th of September 2016, respectively. If we estimate the total annual amount taking these values three quarters, we get approximately 26-36 mm, which can be considered realistic taking the investigated conditions into consideration and are in harmony with the literature data.

Seasonality of dew: According to the relevant literature the largest chance of dew formation is during the summer months as the conditions of the condensation of water vapours. The dew formation is more when the sky is clear and less when it is cloudy. In a typical summer day, when the sky is clear and the ground and plant surfaces are cooler at nights, there is more evaporation of water and hence more dew formation. When it is cloudy, the ground and plant surfaces do not get cool in the night and hence there is less dew formation. Contrary to these, the amount of dew measured on the grass covered soil surface in the 6 summer months (June, July, August of 2015 and 2016) was only 6.58 mm giving 15% of the total 18 months (*Fig. 3*).

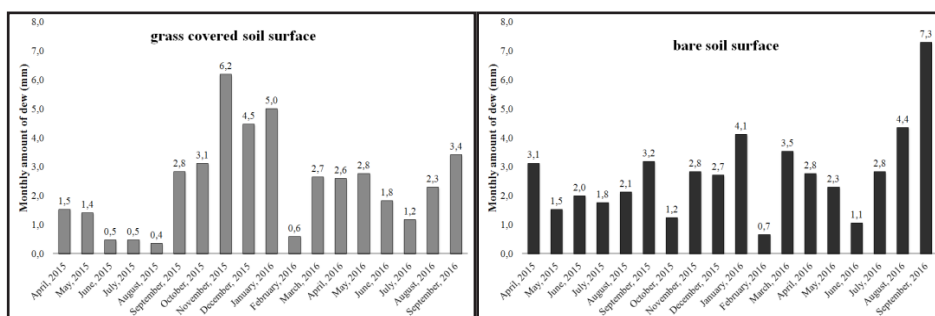


Figure 3: Monthly dew amounts measured on the lysimeters

The dewiest period was detected on the grass covered surface in the three-month-long period between November 2015 and January 2016 with its 13.77 mm (40% of the total amount). Obviously most of the dew precipitated during this period was frost. In the case of the bare soil surface a bit more even time distribution of dew formation was characteristic. The amount of dew measured on bare soil surface in the 6 summer months (June, July, August of 2015 and 2016) was 14.11 mm giving 28% of the total 18 months. The dewiest period was also during the period from November 2015 to January 2016, but with somewhat lower amount (9.65 mm) and percentage (20% of the total amount). Extreme amount of dew was detected in September 2016 with its 7.29 mm.

Conclusions

We established that the application of the weight data measured with the frequency of 1 hour seems to be more suitable to filter and exclude the oscillations and get only the weight increases that describe dewfall than the application of the weight data measured with the frequency of 10 minutes. Continuing our measurements we intend to determine the amount of dew for different soil surfaces for several years in order to have the basis for further comparisons.

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