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Letters to the Editor

551.573

BALANCING PENMAN'S FORMULA ON POTENTIAL EVAPORATION AT A SEMI-ARID TROPICAL LOCATION

1. The original equation suggested by Penman (1948) to estimate evaporation from open water surface was verified in comparison with actual measurements by several workers (Tanner and Pelton 1960, Abdel Azeez *et al.* 1964, Thompson and Boyce 1967 & Krishnan and Kushwaha 1971) and it was found that the equation under estimates evaporation from open water surface. The under estimation of evaporation by Penman's equation was mainly due to less weightage given to the aerodynamic term in his formula (Baier 1967, Krishnan and Kushwaha 1971). Penman himself was aware of the above mentioned limitations and has stated that he had only suggested a practical and useful method and not one of greater accuracy. Therefore, he suggested the need for verification and calibration of his formula (Penman 1956).

Though the daily evaporation measurements are carried out using standard US open pan evaporimeter, there is a possibility of gaps in these measurements mostly due to inadequate safety to the pan evaporimeter exposed in open area. In order to fill such gaps in open pan evaporation measurements, we have attempted to modify the weightage of aerodynamic component in relation to the energy balance using the multiple correlation methodology suggested by Krishnan and Kushwaha (1971).

2. Daily weather data of Hayathnagar Research Farm, Hyderabad (17° 20′ N, 78° 35′ E, 515.5 m amsl) on all the meteorological parameters required in Penman's equation are available for the years 1976-80, 1984-86, 1988-89 and 1992, a total of eleven years. Weekly averages were worked out for the different parameters. Available weather data during the years 1976-80 and 1984-86 were used to determine the weightage of aerodynamic *vis-a-vis* energy term in the Penman's equation. Data for three years, *viz.*, 1988, 1989 and 1992 were used for testing. Solution of Penman's formula was carried out in a quattro spread sheet. Global radiation (*Ra*) in equivalent evaporable water was interpolated from the values given by Doorenbos and Pruitt (1975). Albedo (r) for the water surface was taken to be 0.06 as used by Michael *et al.* (1977). To estimate solar radiation from sunshine hours the constants a and b were taken to be 0.14 and 0.55 as published by Gangopadhyay *et al.* (1970). Possible sunshine hours (N) was interpolated from values published in Smithsonian tables. Stefan-Boltzmann's constant σ in equivalent evaporable water was calculated as 1.998467×10^{-9} mm $°K^{-4}$ day^{-1} Saturation vapour pressure was calculated by Tetens (1930) equation. Actual vapour pressure was worked out using dry and wet bulb temperature and the atmospheric pressure. The rate of change of saturation vapour pressure with temperature (Δ) was worked out by differentiating Tetens (1930) equation. Wind speed at 2 m height was obtained by multiplying wind speed recorded at 3 m height by a factor of 0.933 as used by Rao *et al.* (1971). Psychrometric constant (γ) was worked out to be 0.472 mm of Hg/°C.

3. To determine mean relative weightage between energy and aerodynamic term in Penman's formula all the 416 (8 years × 52 weeks) values of Δ were tabulated and it was found that it ranged between 2.338 and 0.953 mm of Hg/°C during the eight years period. The average was worked out to be 1.515 mm of Hg/°C. Therefore, the existing mean weightage between energy *Rn* and the aerodynamic term *Ea* is as follows :

$$Rn : Ea = \Delta : \gamma = 1.515 : 0.472 = 3.210 : 1 \qquad (1)$$

Krishnan and Kushwaha (1971) also observed that the weightage to energy balance term, was 3 or 4 times more than the aerodynamic term under arid conditions of Jodhpur. Thus, the pan evaporation is underestimated using the above relation which gives more weightage to energy than aerodynamic term. Therefore, multiple regression analysis was carried out between observed pan evaporation and radiation and

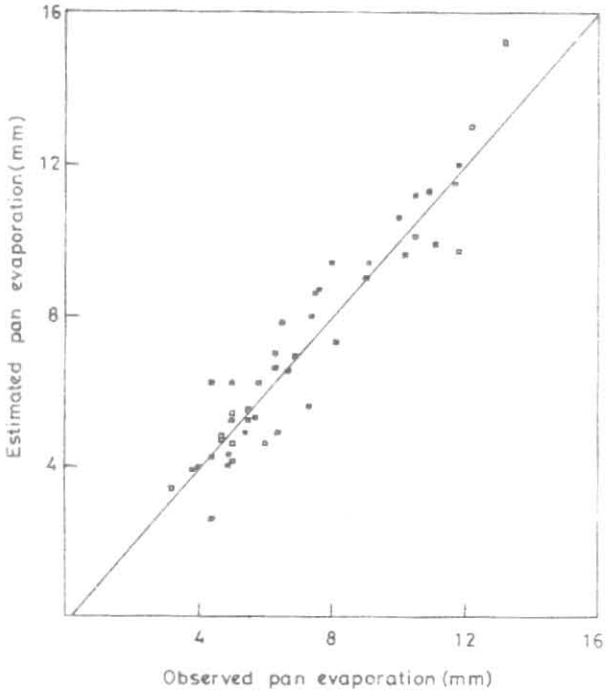

Fig. 1. Observed *Vs* estimated weekly evaporation at Hyderabad (1992)

aerodynamic terms of Penman's equation. The following equation was obtained :

$$Y = 1.733 + 0.165 X_1 + 0.572 X_2 \qquad (2)$$

$$R^2 = 0.872$$

where,

Y — evaporation (mm day^{-1})

X_1 — energy balance component (mm day^{-1})

X_2 — is aerodynamic term (mm day^{-1})

Therefore, weightage between aerodynamic term and energy term should be

$$Rn : Ea = 0.165 : 0.572 = 1 : 3.467 \qquad (3)$$

To get the above weightage we should have the following ratio between energy and the aerodynamic components :

$$Rn : Ea = \Delta : 11.129\ \gamma \qquad (4)$$

The factor 11.129 was obtained by multiplying 3.210 and 3.467.

Thus, the Penman's equation for estimating evaporation under Hyderabad conditions with revised weightage for energy vis-a-vis aerodynamic term could be written as

$$Eo = \frac{\Delta\, Rn + 11.129\, \gamma\, Ea}{\Delta + 11.129\ \gamma} \qquad (5)$$

With above modification the correlation between observed and estimated open pan evaporation has significantly increased from 0.38, 0.37 and 0.41 to 0.93, 0.92 and 0.94 during three test years of 1988, 1989 and 1992 respectively. Fig. 1 shows scatter diagram of observed *versus* estimated pan evaporation during the year 1992. Most of the points are seen to cluster around 1 : 1 line validating the approach quite satisfactorily. Similar patterns were also obtained during the years 1988 and 1989 also.

4. Student's 't' statistics was worked out for all the 52 weeks using 3 years namely 1988, 1989 and 1992 data on observed and estimated pan evaporation. The observed 't' varies between 0.06 and 2.36 while theoretical value is 2.78 at 5 per cent level of significance and 4 degrees of freedom. This shows that the mean differences for the two series are not significant. Thus, the approach is validated statistically too.

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