ESTIMATION OF EVAPORATION FROM RELATED METEOROLOGICAL DATA

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THE surface of the earth receives water from precipitation and loses the same to the atmosphere through the process of evaporation. The chief parameters which affect evaporation are temperature (both of the evaporating surface and the atmosphere), relative humidity of the atmosphere, wind velocity and the amount of radiation falling on the evaporating surface. Direct measurement of evaporation is done by the use of atmometers like Piche or water pans (sunken, surface or floating). Observations demonstrate that evaporation from atmometers or pans is not representative of natural evaporation. The emphasis has therefore been to compute evaporation, the need for which is being felt in many diverse fields of science such as Climatology, Agriculture, Hydrology, Biology and Micrometeorology. The importance is further demonstrated by the efforts that are being made by the World Meteorological Organisation to reduce evaporation values that are being recorded to a standard data.

The relation between "evaporating power" of air and the meteorological factors in general may be represented by:

$$E = (e_0 - e_a)\ f(u)$$

where E = evaporation in unit time.
e_0 = saturation vapour pressure at the water surface temperature.
e_a = vapour pressure of air.
$f(u)$ = function of horizontal wind at pan level.

Formula of the above type was used by Rohwer (1931) and Raman and Satakopan (1934) and by many other investigators. In this equation the most important factor affecting evaporation namely radiation is not taken into consideration. A number of formulæ have been presented later to arrive at reasonable estimates of evaporation. Among them are those of Penman (1948), Thornthwaite (1948), Blaney (1952) and Kohler (1957).

In the present study values of the weekly evaporation at Poona are calculated using Penman's formula. This has not been done so far. For a more detailed description of the evolution of the method reference may be made to "Evaporation in Nature" by H. L. Penman in *Reports on the Progress in Physics*, Vol. XI, 1948. The necessary meteorological data were taken from the records of the Central Agricultural Meteorological Observatory, Poona, for 18 years. Penman's equation for daily evaporation from an extended sheet of open water is:

$$E = \frac{H + \frac{\gamma}{\Delta} E_0}{\left(1 + \frac{\gamma}{\Delta}\right)}$$

where H = net radiant energy available at the surface
$= R_c\ (1 - r) - R_B$
where R_c = measured incoming short wave radiation.
r = reflectivity.
R_B = net outgoing long wave radiation.
γ = psychrometric constant.
Δ = slope of the saturation vapour pressure *versus* temperature.
E_0 = aerodynamic evaporation term $= f(U)\,(e_a - e_d)$.
e_a = saturation vapour pressure at mean temperature of air.
e_d = vapour pressure.
U = wind velocity.

This equation has been used for computing evaporation from observed meteorological parameters as follows: The evaporation E is in inches of water per day, temperatures in degrees absolute, wind in miles per day at 10 ft. which is the height taken for wind measurements at all Agri-meteorological and Crop-weather stations, temperature of air T_a is taken as the mean of the temperature at 0700 hr. and 1400 hr. Local Mean Time of the place (this is not very different from the mean of maximum and minimum temperature), vapour pressure in millibars, and energies in equivalent amounts of water evaporated in inches (with latent heat of vapourisation 590 cals./sq. cm. appropriate to our temperatures) and e_a is the saturation vapour pressure at temperature T_a and e_d the mean vapour pressure expressed in millibars. The formula for evaporation then becomes

$$E = [0{\cdot}93\ R_A\ (0{\cdot}20 + {\cdot}48\ n/N) - 0{\cdot}97 - T_a^4\ (0{\cdot}47 - {\cdot}067 \sqrt{\ }\ )(0{\cdot}20 + {\cdot}80\ n/N) + \gamma/\Delta\{{\cdot}0105\ (e_a - e_d)(0{\cdot}50 + {\cdot}01\ U)\}]\ (1 + \gamma/\Delta)^{-1}$$

R_A = net incoming short wave radiation at the outer limit of the atmosphere.

n = actual hours of sunshine per day.

N = maximum possible hours of sunshine per day.

The relation between R_C and R_A is given by the empirical equation

$$R_C = R_A\ (0{\cdot}20 + {\cdot}48\ n/N).$$

For computational purposes the above equation was simplified by writing

$a = 0{\cdot}93\ R_A$ (function of latitude and time of year).

$b = 0{\cdot}97 - T_a^4 (0{\cdot}47 - 0{\cdot}067 - e_d)$ (function of air temperature and vapour pressure).

$c = {\cdot}0105\ \gamma/\Delta$ (function of air temperature).

$d = (1 + \gamma/\Delta)^{-1}$ (function of air temperature).

$f_1(n) = 0{\cdot}20 + 0{\cdot}48\ n/N$ (function of sunshine and time of year).

$f_2(n) = 0{\cdot}20 + 0{\cdot}80\ n/N$ (function of sunshine and time of year).

Equation for evaporation reduces to:

$$E = [a f_1(n) - b f_2(n) + c\ \{(e_a - e_d)(0{\cdot}50 + {\cdot}01\ U)\}\ d.$$

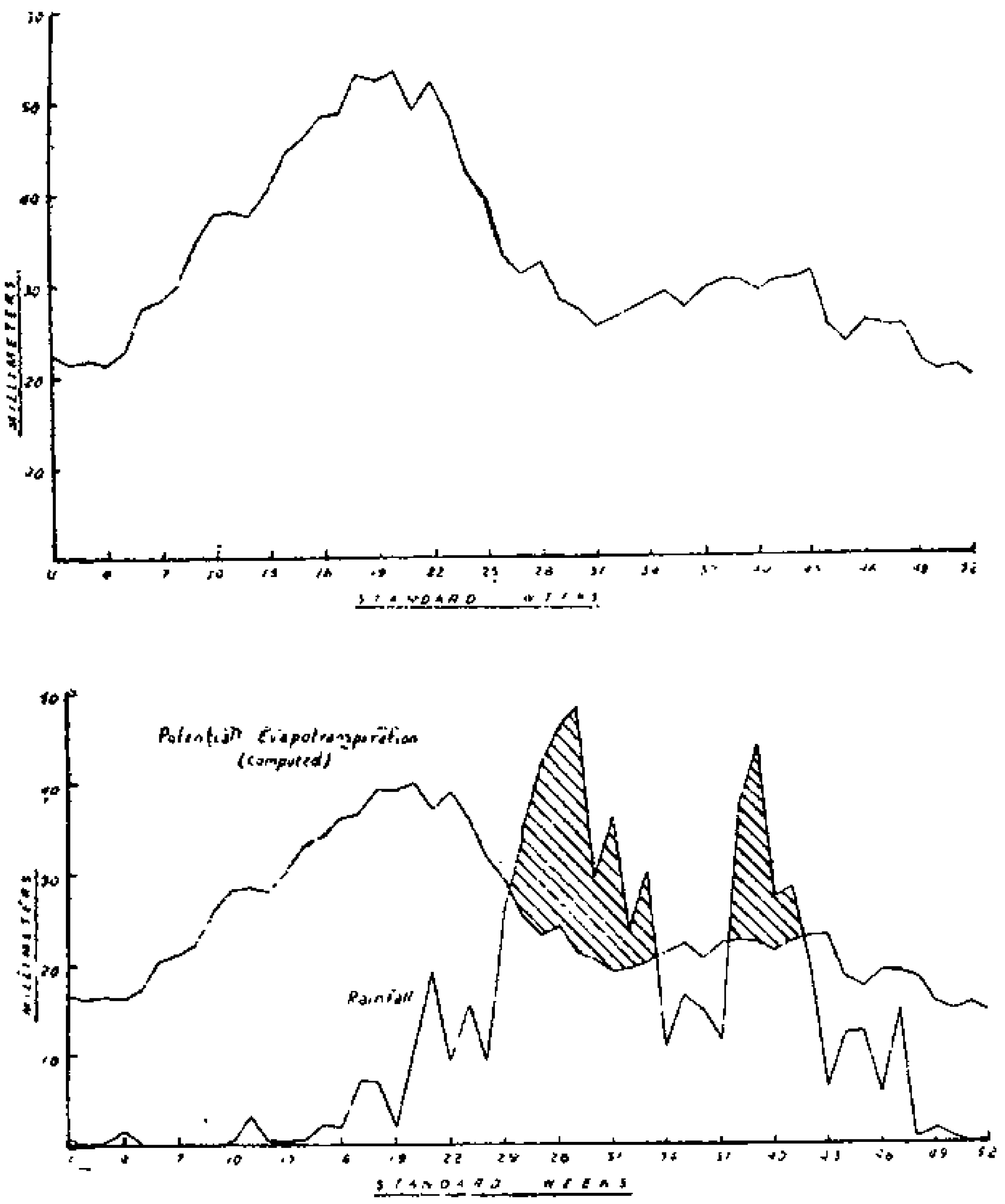
Tables were drawn up for $f_1(n)$, $f_2(n)$, a, b, c and d, and computations made.

Table I gives the mean daily values of evaporation computed by the Penman's formula using meteorological data of 18 years by the present authors and those actually observed from open pan (screened) for a period of 3 years for the different months of the year and those computed earlier using Rohwer's formula by Raman and Satakopan (1934) and also by using Thornthwaite's formula by Subramanyam (1956). A comparison of the values is not called for but the table gives general features and essential soundness of Penman's equation. Values of evaporation at Poona for each week obtained by using the above formula are plotted in Fig. 1. It may be seen that highest values are obtained in May in association with higher wind speeds and sunny climate. The lower values in rainy season are associated with humid conditions while the lowest values in winter are associated with low air temperatures and low wind speeds. It was also noticed during the analysis that during winter the values of long wave radiation from the earth are such that they not only retard evaporation but favour condensation. It may be seen from Fig. 1 that about 46% of the annual evaporation occurs during the summer months (March-June).

TABLE I

Month	Mean daily evaporation (mm.)		Mean daily potential evapotranspiration (mm.)	
	Observed class A pan (screened)	Computed from Rohwer's formula	Computed from Thornthwaite's formula	Computed from Penman's formula
January	3·8	7·0	2·0	2·3
February	5·6	7·5	2·8	2·9
March	8·4	10·4	4·6	4·1
April	10·4	15·0	5·5	5·0
May	8·6	11·8	5·9	5·6
June	7·9	7·5	5·3	4·4
July	3·3	4·4	4·2	3·2
August	3·6	3·7	3·7	2·9
September	3·8	3·8	3·7	3·1
October	4·1	4·7	3·8	3·2
November	3·8	6·2	2·6	2·7
December	4·1	5·6	1·9	2·2

excess is assumed to replenish soil moisture. The shaded area in Fig. 2 represents the weeks



FIGS. 1–2

with water surplus. A knowledge of evapotranspiration is important in irrigation agriculture. In raising crops with the help of irrigation, the amount of water lost by evapotranspiration constitutes the minimum demand that has to be met with. Similar studies to determine potential evapotranspiration according to Penman using the valuable data collected at Crop-weather and Agrometeorological stations in India are in progress and it is proposed to publish potential evapotranspiration maps of India for each of the 52 weeks of the year which are so essential for finding out the water requirement of crops.

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ROTATION OF PLANET MERCURY FROM RADIO-ASTRONOMY OBSERVATIONS

MEASUREMENT of Doppler shifts in radio-echoes from Mercury seems to have yielded results contrary to what has been the general belief so long regarding the period of rotation of the planet. In the case of the two inner planets of the solar system, Mercury and Venus, it has always been thought that the planet's period of axial rotation is the same as its period of revolution around the Sun. For Mercury it is about 88 days each, and for Venus it is about 225 days each. Thus they are supposed to be presenting the same side to the Sun—as in the case of Moon around the Earth.

G. H. Pettingill and R. H. Dyce of Cornell University, reporting their measurements of radio-echoes from Mercury, studied with the 1000 ft. fixed radio-telescope in Puerto Rico, find that the rotation period of the planet is 59 ± 5 days. The direction of this rotation, like that of most planets, is counterclockwise with respect to a view from above its north pole. The exception, as other radio-astronomical studies have shown, is Venus which rotates slowly in a clockwise direction.—(*Scientific American*, June 1965).