Net radiation

Definition

Net radiation is an input variable of the potential evapotranspiration equation formulated by Penman (1948).

"Net radiation is the difference between incoming and outgoing radiation of both short and long wavelengths. It is the balance between the energy absorbed, reflected and emitted by the earth's surface or the difference between the incoming net shortwave and the net outgoing longwave radiation. Net radiation is normally positive during the daytime and negative during the nighttime. The total daily value for net radiation is almost always positive over a period of 24 hours, except in extreme conditions at high latitudes" (Allen et al. 1998).

Formula

The calculation of the net radiation requires the following steps (cf. Allen et al. 1998).

Extraterrestrial radiation

The daily extraterrestrial radiation $R_a =$ [MJ·m^{-2}·d^{-1}] has to be calculated as follows (Allen et al. 1998):

$$R_a = \frac{24 \cdot 60}{\pi} \cdot G_{sc} \cdot d_r \cdot [\omega_s \cdot \sin\varphi \cdot \sin\delta + cos\varphi \cdot \cos\delta \cdot \sin\omega_s]$$

where G_{sc} is the solar constant, which is equal to 0.082 [MJ·m^{-2}·min^{-1}], d_r the inverse relative distance Earth-Sun, ω_s the sunset hour angle [rad], φ the latitude [rad] , and δ the solar declination [rad].

The inverse relative distance Earth-Sun d_r is calculated as follows:

$$d_r = 1 + 0.033 \cdot \cos\left(\frac{2\pi}{365} \cdot J\right)$$

where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).

The sunset hour angle ω_s [rad] is calculated as follows:

$$\omega_s = \arccos[-\tan\varphi \cdot \tan\delta]$$

and the solar declination [rad] δ as follows:

$$\delta = 0.409 \cdot \sin\left(\frac{2\pi}{365} \cdot J - 1.39\right)$$

The conversion from decimal degrees to radians is obtained as follows:

$$[\text{Radians}] = \frac{\pi}{180}\,[\text{decimal degrees}]$$

Solar radiation

The solar radiation R_s [MJ·m^{-2}·d^{-1}] can be calculated based on the Angstrom formula (Allen et al. 1998):

$$R_s = \left(a_s + b_s \cdot \frac{n}{N}\right) \cdot R_a$$

where n is the actual duration of sunshine [hours], N the daylight hours [hours], and R_a the extraterrestrial radiation [MJ·m^{-2}·d^{-1}]. a_s is a regression constant expressing the fraction of extraterrestrial radiation reaching the earth on an overcast day $(n = 0)$. $a_s + b_s$ is the fraction of extraterrestrial radiation reaching the earth on a clear day $(n = N)$. When no actual solar radiation data are available, the values $a_s = 0.25$ and $b_s = 0.50$ are recommended (Allen et al. 1998).

Solar radiation R_s can also be derived from air temperature differences as follows (Allen et al. 1998):

$$R_s = R_a \cdot k_{Rs} \cdot \sqrt{T_{max} - T_{min}}$$

where R_a is the extraterrestrial radiation [MJ·m^{-2}·d^{-1}], $k_R s$ an adjustment coefficient [°C^-0.5] which is usually comprised between 0.16 ("interior" locations) and 0.19 ("coastal" locations), T_{max} maximum air temperature [°C] and T_{min} minimum air temperature [°C].

Clear-sky solar radiation

The clear-sky solar radiation R_{so} [MJ·m^{-2}·d^{-1}] can be calculated as follows when a_s and b_s values (cf.solar radiation?) are not available (Allen et al. 1998):

$$R_{so} = (0.75 + 2 \cdot 10^{-5} \cdot z) \cdot R_a$$

where z is elevation above sea level [m].

Net shortwave radiation

The net shortwave radiation R_{ns} [MJ·m^{-2}·d^{-1}] is calculated as follows (Allen et al. 1998):

$$R_{ns} = (1 - \alpha) \cdot R_s$$

where α is the albedo or canopoy reflection coefficient, which is usally between 0.20 and 0.25 for green vegetation covers, and R_s the incoming solar radiation? [MJ·m^{-2}·d^{-1}].

Net longwave radiation

The net longwave radiation R_{nl} [MJ·m^{-2}·d^{-1}] is calculated as follows (Allen et al. 1998):

$$R_{nl} = \sigma \cdot \left(\frac{T_{max}^4 + T_{min}^4}{2} \right) \cdot \left(0.34 - 0.14 \cdot \sqrt{e_a} \right) \cdot \left(1.35 \cdot \frac{R_s}{R_{so}} - 0.35 \right)$$

where σ is the Stefan-Bolzmann constant, which is equal to $4.903 \cdot 10^{-9}$ [MJ·K^{-4}·m^{-2}·d^{-1}], T_{max} and T_{min} maximal and minimal temperature [K] during the 24-hr period, e_a actual vapor pressure [kPA], R_s solar radiation? [MJ·m^{-2}·d^{-1}], and R_{so} clear-sky solar radiation? [MJ·m^{-2}·d^{-1}].

$\frac{R_s}{R_{so}}$ is limited to 1.

Net radiation

Finally, the net radiation R_n [MJ·m^{-2}·d^{-1}] can be calculated as follows (Allen et al. 1998):

$$R_n = R_{ns} - R_{nl}$$

where R_{ns} [MJ·m^{-2}·d^{-1}] is net shortwave radiation? and R_{nl} [MJ·m^{-2}·d^{-1}] net longwave radiation.

Reference

Allen et al. (1998)
