Package ‘simET’

August 19, 2023

Type Package
Title Tools for Simulation of Evapotranspiration of Field Crops and Soil Water Balance
Version 1.0.3
Date 2023-07-21
License GPL (>= 3)
Encoding UTF-8
LazyData true
Imports dplyr, ggplot2, ggpmisc, ggpubr, lubridate, magrittr, plyr, rlang, stringr, tidyr
RoxygenNote 7.1.2
NeedsCompilation no
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Depends R (>= 3.5.0)
Repository CRAN
Date/Publication 2023-08-19 14:40:02 UTC

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**cal_ActualVapourPressure_for_hourly**

*Calculating actual vapour pressure for hourly time step*

**Description**
Calculating actual vapour pressure for hourly time step

**Usage**
```
cal_ActualVapourPressure_for_hourly(Thr, RHhr)
```

**Arguments**
- `Thr` is average hourly temperature (degrees Celsius).
- `RHhr` is average hourly relative humidity [%].

**Value**
A vector for average hourly actual vapour pressure [kPa].

**References**

**cal_ActualVapourPressure_from_dewPoint**

*Actual vapour pressure derived from dewpoint temperature*

**Description**
As the dewpoint temperature is the temperature to which the air needs to be cooled to make the air saturated, the actual vapour pressure is the saturation vapour pressure at the dewpoint temperature.

**Usage**
```
cal_ActualVapourPressure_from_dewPoint(Tdew)
```

**Arguments**
- `Tdew` dew point temperature(degrees Celsius).
**Value**

A vector for actual vapour pressure

**References**


---

**Description**

The actual vapour pressure can be determined from the difference between the dry and wet bulb temperatures, the so-called wet bulb depression.

**Usage**

\[
\text{cal\_ActualVapourPressure\_from\_psychrometricData}(T_{\text{wet}}, T_{\text{dry}}, P, \text{type})
\]

**Arguments**

- \( T_{\text{wet}}, T_{\text{dry}} \): wet bulb depression, with \( T_{\text{dry}} \) the dry bulb and \( T_{\text{wet}} \) the wet bulb temperature (degrees Celsius).
- \( P \): is the atmospheric pressure (kPa).
- \( \text{type} \): psychrometer type ("Asmann type","natural ventilated","non-ventilated").

**Value**

A vector for Actual vapour pressure (ea)

**References**

**cal_ActualVapourPressure_from_RHmax**

*Calculating actual vapour pressure derived from RHmax*

**Description**

When using equipment where errors in estimating RHmin can be large, or when RH data integrity are in doubt, then one should use only RHmax.

**Usage**

```r
cal_ActualVapourPressure_from_RHmax(Tmin, RHmax)
```

**Arguments**

- `Tmin`: daily minimum temperature (degrees Celsius).
- `RHmax`: maximum relative humidity (%).

**Value**

A vector for actual vapour pressure

**References**


---

**cal_ActualVapourPressure_from_RHmaxAndRHmin**

*Actual vapour pressure derived from RHmax and RHmin*

**Description**

The actual vapour pressure can also be calculated from the relative humidity. Depending on the availability of the humidity data, different equations should be used.

**Usage**

```r
cal_ActualVapourPressure_from_RHmaxAndRHmin(Tmax, Tmin, RHmax, RHmin)
```

**Arguments**

- `Tmax`: daily maximum temperature (kPa).
- `Tmin`: daily minimum temperature (KPa).
- `RHmax`: maximum relative humidity %.
- `RHmin`: minimum relative humidity %.
Details

For periods of a week, ten days or a month, RHmax and RHmin are obtained by dividing the sum of the daily values by the number of days in that period.

Value

A vector for actual vapour pressure

References


---

cal_ActualVapourPressure_from_RHmean

Calculating actual vapour pressure derived from RHmean

Description

In the absence of RH max and RHmin, it can be used to estimate actual vapour pressure.

Usage

cal_ActualVapourPressure_from_RHmean(RHmean, Tmax, Tmin)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHmean</td>
<td>mean relative humidity(%)</td>
</tr>
<tr>
<td>Tmax</td>
<td>daily maximum temperature (degrees Celsius)</td>
</tr>
<tr>
<td>Tmin</td>
<td>daily minimum temperature (degrees Celsius)</td>
</tr>
</tbody>
</table>

Value

A vector for actual vapour pressure

References

cal_afterRedistribution

*Calculating the volumetric water content after redistribution*

**Description**

Calculating the volumetric water content after redistribution

**Usage**

\[
\text{cal_afterRedistribution(THETA\_v\_sat, alpha, Ksat, deltaT, L, THETA11\_1)}
\]

**Arguments**

- \(\text{THETA\_v\_sat}\): soil saturation water content (m³ m⁻³)
- \(\text{alpha}\): empirical coefficient. 13 for homogenous soil, 13-16 for heterogeneous soil
- \(\text{Ksat}\): saturated hydraulic conductivity
- \(\text{deltaT}\): time step difference (day)
- \(\text{L}\): the thickness(m) of soil layer i
- \(\text{THETA11\_1}\): the volumetric water content before redistribution (m³ m⁻³)

**Value**

A value for the volumetric water content after redistribution (m³ m⁻³)

---

cal_airVaporPressureDeficit_meanCanopyflow

*Calculating air vapor pressure deficit at the mean canopy*

**Description**

Calculating air vapor pressure deficit at the mean canopy

**Usage**

\[
\text{cal_airVaporPressureDeficit_meanCanopyflow(}
\text{D,}
\text{r\_a\_a,}
\text{rho\_cp = 1221.09,}
\text{DELTA,}
\text{A,}
\text{gamma = 0.658,}
\text{lambda\_ET)}
\]

Arguments

D  the vapor pressure deficit (mbar)
ra_a  the aerodynamic resistance between the mean canopy flow and reference height (s m\(^{-1}\))
rho_cp  the volumetric heat capacity for air (1221.09 J m\(^{-3}\) K\(^{-1}\))
DELTA  is the slope of the saturated vapor pressure curve (mbar K\(^{-1}\))
A  is the total energy available to the system (W m\(^{-2}\) ground)
gamma  psychometric constant (0.658 mbar K\(^{-1}\))
lambda_ET  the total latent heat flux (W m\(^{-2}\) ground)

Value

A vector for the vapor pressure deficit at the mean canopy flow (mbar)

Note

Knowing D0 is essential because this value is used to calculate the latent and sensible heat fluxes for the soil and crop components.

cal_angerFromSouth  Calculating anger from south

Description

A parameter used to determine the position of the sun relative to the observer (the other one is solar inclination).

Usage

cal_angerFromSouth(latitude, solar_altitude, solar_declination)

Arguments

latitude  is the latitude data (Radian).
solar_altitude  It can be calculated from \(\pi/2 - \text{cal\_solarinclination}\).
solar_declination  is solar declination anger. It can be calculated from \text{cal\_solardeclination}()

Details

The minus and positive signs are taken before and after solar noon, receptively. The reason for having the positive-and-negative signs is merely an artificial convention so that we are able to distinguish between the sun lying westwards (positive angles and after solar noon) and eastwards (negative angles and before solar noon).
cal_atmosphericPressure

Value
A vector for anger from south (Radian)

References

Examples
  cal_angerFromSouth(latitude=0.52, solar_altitude=-0.715, solar_declination=-0.2974005)

---

cal_atmosphericPressure

Calculating atmospheric pressure

Description
The atmospheric pressure, P, is the pressure exerted by the weight of the earth’s atmosphere.

Usage
cal_atmosphericPressure(elevation)

Arguments
elevation  elevation above sea level (m)

Details
Assuming 20°C for a standard atmosphere. Evaporation at high altitudes is promoted due to low atmospheric pressure as expressed in the psychrometric constant. The effect is, however, small and in the calculation procedures, the average value for a location is sufficient.

Value
A vector for atmospheric pressure (Kpa)

References

Examples
  cal_atmosphericPressure(100)
**cal_bulkBoundaryLayerResistance**

*Calculating bulk boundary layer resistance*

**Description**

Calculating bulk boundary layer resistance

**Usage**

\[
\text{cal_bulkBoundaryLayerResistance}(\text{nu}, \text{u}_h, \text{w}, \text{L})
\]

**Arguments**

- \(\text{nu}\) the wind speed extinction coefficient (taken as 2)
- \(\text{u}_h\) the wind speed at the canopy top (i.e., at plant height h) (m s\(^{-1}\))
- \(\text{w}\) is the mean leaf width (m)
- \(\text{L}\) leaf area index

**Value**

A vector for bulk boundary layer resistance (s/m)

---

**cal_canopyPenetrationProbabilityForNetRadiation**

*The canopy penetration probability for net radiation*

**Description**

The canopy penetration probability for net radiation

**Usage**

\[
\text{cal_canopyPenetrationProbabilityForNetRadiation}(\text{kRn}, \text{L})
\]

**Arguments**

- \(\text{kRn}\) the canopy extinction coefficient for net radiation (taken as 0.3)
- \(\text{L}\) the leaf area index (m\(^2\) leaf m\(^{-2}\) ground)

**Value**

The vector for canopy penetration probability for net radiation
cal_canopyResistance  Calculating canopy resistance

Description
Calculating canopy resistance

Usage
    cal_canopyResistance(a1, a2, It, L, Lmax)

Arguments
    a1, a2 are empirical coefficients, dependent on the crop type.
    It  the total hourly solar irradiance (W m\(^{-2}\) ground)
    L   the leaf area index (m\(^2\) leaf m\(^{-2}\) ground)
    Lmax the maximum total leaf area index (m\(^2\) leaf m\(^{-2}\) ground)

Value
    A vector for canopy resistance(s/m)

cal_canopyTem  Calculating canopy temperature

Description
Calculating canopy temperature

Usage
    cal_canopyTem(Hc, r_c_a, Hs, r_a_a, rho_cp, Tr)

Arguments
    Hc  crop sensible heat fluxes (W m\(^{-2}\))
    r_c_a the bulk boundary layer resistance (s m\(^{-1}\))
    Hs  soil sensible heat fluxes (W m\(^{-2}\))
    r_a_a the aerodynamic resistance between the mean canopy flow and reference level (s m\(^{-1}\))
    rho_cp the volumetric heat capacity for air (1221.09 J m\(^{-3}\) K\(^{-1}\))
    Tr  Tr is the air temperature at reference level (Celsius degree). weather station.

Value
    A vector for the canopy (foliage) temperature (Celsius degree)
cal_capillaryRise

Calculating capillary rise

Description
Calculating capillary rise

Usage

```r
cal_capillaryRise(
    a1,
    b1 = -0.17,
    a2,
    b2 = -0.27,
    a3 = -1.3,
    b3,
    a4,
    b4,
    Dw,
    Wa,
    LAI,
    ETm
)
```

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1</td>
<td>Soil water storage to maximum root depth at field capacity (mm).</td>
</tr>
<tr>
<td>b1</td>
<td>A parameter.</td>
</tr>
<tr>
<td>a2</td>
<td>A parameter.</td>
</tr>
<tr>
<td>b2</td>
<td>A parameter.</td>
</tr>
<tr>
<td>a3</td>
<td>A parameter.</td>
</tr>
<tr>
<td>b3</td>
<td>A parameter.</td>
</tr>
<tr>
<td>a4</td>
<td>A parameter.</td>
</tr>
<tr>
<td>b4</td>
<td>A parameter.</td>
</tr>
<tr>
<td>Dw</td>
<td>Groundwater depth below root zone (m).</td>
</tr>
<tr>
<td>Wa</td>
<td>Actual soil water storage in the root zone.</td>
</tr>
<tr>
<td>LAI</td>
<td>Leaf area index.</td>
</tr>
<tr>
<td>ETm</td>
<td>Potential crop evaporanspiration (mm/day), usually ETm=ETc(mm/d).</td>
</tr>
</tbody>
</table>

Value
The value for capillary Rise (mm/day).
References

---

cal_cropRoughnessLength

*Calculating the crop roughness length*

**Description**
Calculating the crop roughness length

**Usage**
cal_cropRoughnessLength(h)

**Arguments**
- h: the plant height (m)

**Value**
A vector for the crop roughness length (m)

---

cal_daylightHours

*Calculating Daylight hours*

**Description**
Calculating Daylight hours

**Usage**
cal_daylightHours(sunsetHourAngle)

**Arguments**
- sunsetHourAngle: is the sunset hour angle in radians from cal_sunsetHourAngle().

**Value**
A vector for day light Hours
**cal_DeepPercolation**

**References**


---

**cal_DeepPercolation Calculating Deep percolation**

**Description**

Calculating Deep percolation

**Usage**

```
cal_DeepPercolation(Wa, Wfc, a, b, t)
```

**Arguments**

- `Wa` actual soil water storage in the root zone (mm)
- `Wfc` soil water storage to maximum root depth (Zr) at field capacity (mm)
- `a` A water storage value comprised between WFc and Wa at saturation.
- `b` $b<0.0173$ for soils draining quickly. Otherwise $b>-0.0173$.
- `t` time after an irrigation or rain that produced a storage above field capacity (days)

**Value**

A vector for deep percolation(mm/day).

**References**

cal_DPe_for_DualKc  \hspace{1cm} calculating the depletion in the topsoil layer at the end of the day

Description

In fact, it performs water balance in a day

Usage

\begin{verbatim}
cal_Dei_for_DualKc(Dei_start, P, I, E, Dep, TEW)
\end{verbatim}

Arguments

\begin{verbatim}
Dei_start  \hspace{1cm} Depletion in the topsoil layer
P          \hspace{1cm} Precipitation
I          \hspace{1cm} Irrigation
E          \hspace{1cm} Evaporation on day i, mm
Dep        \hspace{1cm} Deep percolation loss from the topsoil layer on day i if soil water content exceeds field capacity, mm
TEW        \hspace{1cm} Maximum cumulative depth of evaporation (depletion) from the topsoil layer
\end{verbatim}

Value

A value for the depletion in the topsoil layer at the end of the day

---

cal_DPe_for_DualKc  \hspace{1cm} Deep percolation loss from the topsoil layer

Description

Deep percolation loss from the topsoil layer

Usage

\begin{verbatim}
cal_DPe_for_DualKc(P, I, Dei_start, fw)
\end{verbatim}

Arguments

\begin{verbatim}
P \hspace{1cm} Precipitation
I \hspace{1cm} Irrigation
Dei_start \hspace{1cm} Depletion in the topsoil layer
fw \hspace{1cm} Fraction of soil surface wetted by irrigation, 0.01-1
\end{verbatim}
**cal_DPr_for_DualKc**

**Value**

A value for deep percolation loss from the topsoil layer

**References**


---

**cal_DPr_for_DualKc**  
*Deep percolation loss from the root layer*

**Description**

Deep percolation loss from the root layer

**Usage**

```r
cal_DPr_for_DualKc(P, Irrigation, ETa, Dri_start)
```

**Arguments**

- `P` Precipitation
- `Irrigation` Irrigation
- `ETa` Actual evapotranspiration
- `Dri_start` Depletion in the root layer

**Value**

A value for deep percolation loss from the root layer

**References**

**cal_DP_for_singleKc**  
*Calculating deep percolation*

**Description**
Calculating deep percolation

**Usage**
cal_DP_for_singleKc(P, I, ETa, Dri_start)

**Arguments**
- **P**: Precipitation
- **I**: Irrigation
- **ETa**: Actual evapotranspiration
- **Dri_start**: The depletion of root layer

**Value**
A value for deep percolation

---

**cal_eddyDiffusivity_Canopytop**  
*Calculating eddy diffusivity at the canopy top*

**Description**
Calculating eddy diffusivity at the canopy top

**Usage**
cal_eddyDiffusivity_Canopytop(k = 0.4, u_, h)

**Arguments**
- **k**: the von Karman constant (0.4)
- **u_**: the friction velocity (m/s)
- **h**: the plant height (m)

**Value**
A vector for eddy diffusivity at the canopy top(m2/s)
cal_eddyDiffusivity_heightZ

*Calculating eddy diffusivity at height z*

**Description**
Calculating eddy diffusivity at height z

**Usage**
cal_eddyDiffusivity_heightZ(Kh, nK, z, h)

**Arguments**
- **Kh**: eddy diffusivity at the canopy top (m²/s)
- **nK**: the eddy diffusivity extinction coefficient (taken as 2)
- **z**: height (m)
- **h**: the plant height (m)

**Value**
A vector for eddy diffusivity at height z (m²/s)

---

cal_ET0_from_PM

*calculating reference evapotranspiration from Penman-Monteith method*

**Description**
The FAO Penman-Monteith method is maintained as the sole standard method for the computation of ETo from meteorological data.

**Usage**
cal_ET0_from_PM(delta, Rn, G, gamma, Tem, u2, es, ea)

**Arguments**
- **delta**: slope vapour pressure curve (kPa & deg;C). From cal_slopeOfSaturationVapourPressureCurve()
- **Rn**: net Radiation at the crop surface [MJ m⁻² day⁻¹]. From cal_netRadiation()
- **G**: soil heat flux density [MJ m⁻² day⁻¹].
- **gamma**: psychrometric constant (kPa & deg;C).
- **Tem**: air temperature at 2 m height [°C].
- **u2**: wind speed at 2 m height [m s⁻¹].
- **es**: saturation vapour pressure [kPa].
- **ea**: actual vapour pressure [kPa].
Value

A vector for reference evapotranspiration [mm day-1].

Note

Ten-day or monthly time step:
Notwithstanding the non-linearity in the Penman-Monteith equation and some weather parameter methods, mean ten-day or monthly weather data can be used to compute the mean ten-day or monthly values for the reference evapotranspiration. The value of the reference evapotranspiration calculated with mean monthly weather data is indeed very similar to the average of the daily ETo values calculated with daily average weather data for that month.

When the soil is warming (spring) or cooling (autumn), the soil heat flux (G) for monthly periods may become significant relative to the mean monthly Rn. In these cases G cannot be ignored and its value should be determined from the mean monthly air temperatures of the previous and next month.

Daily time step:
Calculation of ETo with the Penman-Monteith equation on 24-hour time scales will generally provide accurate results.

As the magnitude of daily soil heat flux (G) beneath the reference grass surface is relatively small, it may be ignored for 24-hour time steps.

References


cal_ET0_from_PM_for_daily

Calculating reference evapotranspiration from Penman-Monteith for daily

Description

Based on lat, z, J, Tmax, Tmin, n, RHmax, RHmin, windSpeed parameters, reference evapotranspiration was calculated by Penman-Monteith.

Usage

cal_ET0_from_PM_for_daily(Latitude, Altitude, J, Tmax, Tmin, Rs, RHmean, Wind)
Arguments

Latitude  latitude (radian), positive for the northern hemisphere and negative for the southern hemisphere.
Altitude station elevation above sea level [m].
J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).
Tmax daily maximum air temperature (degrees Celsius).
Tmin daily minimum air temperature (degrees Celsius).
Rs Solar radiation [MJ m⁻² d⁻¹].
RHmean daily mean relative humidity %.
Wind wind speed at 2 m height [m s⁻¹].

Value

A vector for reference evapotranspiration (mm/day)

References


Examples

library(simET)
data("FAlfalfa")
names(FAlfalfa)
Result_data<- dplyr::mutate(FAlfalfa, ET0=cal_ET0_from_PM_for_daily(Latitude=Latitude, Altitude=Altitude, J=Julian, Tmax=Tmax, Tmin=Tmin, Rs=Rs, RHmean=RHmean, Wind=Wind))

names(Result_data)

cal_ET0_from_PM_for_hourly

Calculating reference evapotranspiration from Penman-Monteith method for hourly time step

Description

Calculating reference evapotranspiration from Penman-Monteith method for hourly time step
Usage

```
cal_ET0_from_PM_for_hourly(
slopVapourPressureCurve,
netRadiation,
soilHeatFlux,
psychrometricConstant,
meanHourlyTem,
windSpeed,
saturationVapourPressure,
actualVapourPressure
)
```

Arguments

- `slopVapourPressureCurve` saturation slope vapour pressure curve at Thr [kPa &deg;C].
- `netRadiation` net radiation at the grass surface [MJ m-2 hour-1].
- `soilHeatFlux` soil heat flux density [MJ m-2 hour-1].
- `psychrometricConstant` psychrometric constant [kPa &deg;C].
- `meanHourlyTem` mean hourly air temperature [&deg;C].
- `windSpeed` average hourly wind speed [m s-1].
- `saturationVapourPressure` saturation vapour pressure at air temperature Thr [kPa].
- `actualVapourPressure` average hourly actual vapour pressure [kPa].

Details

In areas where substantial changes in wind speed, dewpoint or cloudiness occur during the day, calculation of the ETo equation using hourly time steps is generally better than using 24-hour calculation time steps. Such weather changes can cause 24-hour means to misrepresent evaporative power of the environment during parts of the day and may introduce error into the calculations. However, under most conditions, application of the FAO Penman-Monteith equation with 24-hour data produces accurate results.

Value

A vector for reference evapotranspiration [mm hour-1].

Note

With the advent of electronic, automated weather stations, weather data are increasingly reported for hourly or shorter periods. Therefore, in situations where calculations are computerized, the FAO Penman-Monteith equation can be applied on an hourly basis with good results. When applying the FAO Penman-Monteith equation on an hourly or shorter time scale, the equation and some of the procedures for calculating meteorological data should be adjusted for the smaller time step.

For the calculation of radiation parameters, see P74-75
References

---

**cal_extraterrestrialRadiation_for_daily**

*Calculating extraterrestrial radiation for daily periods*

**Description**

The extraterrestrial radiation, $R_a$, for each day of the year and for different latitudes can be estimated from the solar constant, the solar declination and the time of the year.

**Usage**

\[
cal_{\text{extraterrestrialRadiation}}(J, \text{lat})
\]

**Arguments**

- $J$ is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).
- lat is latitude (in Radian), positive for the northern hemisphere and negative for the southern hemisphere.

**Value**

A vector for extraterrestrial radiation for daily (MJ m$^{-2}$ day$^{-1}$)

**References**


---

**cal_extraterrestrialRadiation_for_shorter**

*Calculating extraterrestrial radiation for hourly or shorter periods*

**Description**

Calculating extraterrestrial radiation for hourly or shorter periods

**Usage**

\[
cal_{\text{extraterrestrialRadiation}}(\text{lat}, J, t, l_z, l_m, t_1)
\]
Arguments

- \( \text{lat} \) latitude (radian), positive for the northern hemisphere and negative for the southern hemisphere.
- \( J \) is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).
- \( t \) standard clock time at the midpoint of the period (hour). For example for a period between 14.00 and 15.00 hours, \( t = 14.5 \).
- \( \text{lz} \) longitude of the centre of the local time zone (degrees west of Greenwich). For example, \( \text{lz} = 75, 90, 105 \) and \( 120^\circ \) for the Eastern, Central, Rocky Mountain and Pacific time zones (United States) and \( \text{lz} = 0^\circ \) for Greenwich, \( 330^\circ \) for Cairo (Egypt) and \( 255^\circ \) for Bangkok (Thailand), radian.
- \( \text{lm} \) longitude of the measurement site (degrees west of Greenwich) radian.
- \( t1 \) length of the calculation period (hour)

Value

A vector for extraterrestrial Radiation (MJ m\(^{-2}\) hour\(^{-1}\))

References


---

**cal\_frictionVelocity**  
*Calculating friction velocity*

Description

Calculating friction velocity

Usage

```
cal_frictionVelocity(k = 0.4, zr = 2, u_zr, d, z0)
```

Arguments

- \( k \) the von Karman constant (0.4)
- \( zr \) the height of the weather station(m).
- \( u_zr \) the wind speed(m/s) at the reference height \( zr \) (m).
- \( d \) zero plane displacement height (m)
- \( z0 \) the crop roughness length(m)

Value

A vector for friction velocity(m/s)
**cal_hourAngle**

Calculating hour angle

**Usage**

`cal_hourAngle(th)`

**Arguments**

`th` is the local solar time.

**Value**

A vector for hour angle (Radian)

**References**


**Examples**

`cal_hourAngle(12)`

---

**cal_inverseRelativeDistance_Earth_sun**

Calculating inverse relative distance Earth-sun

**Description**

Calculating inverse relative distance Earth-sun

**Usage**

`cal_inverseRelativeDistance_Earth_sun(J)`

**Arguments**

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


_value_

A vector for inverse relative distance Earth-sun (Radian)

References


---

_cal_Kcend_for_singleKc_

*Crop coefficient for the end of the late season stage*

Description

Typical values for the crop coefficient at the end of the late season growth stage, Kc end, are listed in Table 12 for various agricultural crops.

Usage

```r
cal_Kcend_for_singleKc(RHmine, u2e, Ktable, he)
```

Arguments

- **RHmine**: mean value for daily minimum relative humidity during the mid-season growth stage, for 20 <= RHmine <= 80
- **u2e**: mean value for daily wind speed at 2 m height over grass during the mid-season growth stage (m/s), for 1 <= u2e <= 6
- **Ktable**: value for Kc mid taken from Table 12
- **he**: mean plant height during the mid-season stage (m) for 0.1 m < h < 10 m

Value

A value for Kcend value

Note

only applied when the tabulated values for Kc end exceed 0.45. The equation reduces the Kc end with increasing RHmin. This reduction in Kc end is characteristic of crops that are harvested ‘green’ or before becoming completely dead and dry (Kc end >= 0.45).

No adjustment is made when Kc end (Table) < 0.45 (Kc end = Kc end (Tab)). When crops are allowed to senesce and dry in the field (as evidenced by Kc end < 0.45), u2 and RHmin have less effect on Kc end and no adjustment is necessary.

References

Calculating $K_{cini}$ value

**Description**

Calculating $K_{cini}$ value

**Usage**

\[
cal\_Kcini\_for\_SingleKc(Pmean, ET0, tw, type, fw)
\]

**Arguments**

- $Pmean$ is the average depth of infiltrated water per wetting events (mm)
- $ET0$ mean $ET0$ during initial period (mm/day)
- $tw$ is the mean interval between wetting events (days)
- $type$ soil type: "coarse soil textures" and "medium and fine soil textures"
- $fw$ the fraction of surfaces wetted by irrigation or rain (0-1)

**Value**

A value for $K_{cini}$ value

**References**


---

Crop coefficient for the mid-season stage

**Description**

Typical values for the crop coefficient at the end of the late season growth stage, $K_c$ end, are listed in Table 12 for various agricultural crops. For specific adjustment in climates where RHmin differs from 45% or where $u_2$ is larger or smaller than 2.0 m/s.

**Usage**

\[
cal\_Kcmid\_for\_singleKc(RHmine, u2e, Ktable, he)
\]
Arguments

\texttt{RHmin} \quad \text{mean value for daily minimum relative humidity during the mid-season growth stage, for 20 \(\leq\) RHmin \(\leq\) 80}
\texttt{u2e} \quad \text{mean value for daily wind speed at 2 m height over grass during the mid-season growth stage (mls), for 1 \(\leq\) u2e \(\leq\) 6}
\texttt{Ktable} \quad \text{value for \(K_c\) mid taken from Table 12}
\texttt{he} \quad \text{mean plant height during the mid-season stage [m] for 0.1 m < h < 10 m}

Value

A value for \(K_{cmid}\) value

References

**Description**

It dependent on the soil water depletion (cumulative depth of evaporation) from the topsoil layer
(Kr = 1 when De,i-1 is equal or lesser than REW)

**Usage**

cal_Kr_for_DualKc(TEW, REW, De)

**Arguments**

- **TEW**: maximum cumulative depth of evaporation (depletion) from the soil surface layer when Kr = 0 (TEW = total evaporable water)
- **REW**: cumulative depth of evaporation (depletion) at the end of stage 1 (REW = readily evaporable water), mm
- **De**: cumulative depth of evaporation (depletion) from the soil surface layer at the end of day i-1 (the previous day), mm

**Value**

A value for evaporation reduction coefficient

**References**


---

**Description**

Calculating latent heat fluxes for crop

**Usage**

cal_latentHeatFluxesForCrop(DELTA, Ac, rho_cp, D0, r_c_a, gamma, r_c_s)
cal_latentHeatFluxesForSoil

Arguments

DELTA  the slope of the saturated vapor pressure curve (mbar K-1)
Ac     energy available to the crop (W m-2 ground)
rho_cp the volumetric heat capacity for air (1221.09 J m-3 K-1)
D0     the vapor pressure deficit at the mean canopy flow
r_c_a  is the bulk boundary layer resistance (s m-1)
gamma  is the psychometric constant (0.658 mbar K-1)
r_c_s  the canopy resistance (s m-1)

Value

A vector for latent heat fluxes for crop (W m-2 ground)

---

cal_latentHeatFluxesForSoil

Calculating latent heat fluxes for soil

Description

Calculating latent heat fluxes for soil

Usage

```r
cal_latentHeatFluxesForSoil(
  DELTA,
  Ac,
  rho_cp = 1221.09,
  D0,
  r_c_a,
  gamma = 0.658,
  r_c_s
)
```

Arguments

DELTA  the slope of the saturated vapor pressure curve (mbar K-1)
Ac     energy available to the soil (W m-2 ground)
rho_cp the volumetric heat capacity for air (1221.09 J m-3 K-1)
D0     the vapor pressure deficit at the mean canopy flow
r_s_a  the aerodynamic resistance between the soil and mean canopy flow (s m-1)
gamma  the psychometric constant (0.658 mbar K-1)
r_s_s  soil surface resistance, (s m-1)

Value

A vector for soil latent heat fluxes (W m-2 ground)
**cal_localDolarTime**  
*Calculating local solar time*

**Description**

Local solar time is different with local time.

**Usage**

```r
cal_localDolarTime(td, t, gamma, gamma_sm)
```

**Arguments**

- `td`: The day of year.
- `t`: is the local time.
- `gamma`: is the local longitude (Radian).
- `gamma_sm`: is the standard longitude (Radian).

**Value**

A vector for local solar time (Hour)

**References**


**Examples**

```r
cal_localDolarTime(td=1,t=12,gamma=0.52,gamma_sm=2.09)
```

---

**cal_meanCanopyFlowToReferenceLevel**  
*Calculating mean canopy flow to reference level*

**Description**

Calculating mean canopy flow to reference level

**Usage**

```r
cal_meanCanopyFlowToReferenceLevel(k = 0.4, u_, zr, d, h, nK, z0)
```
**Arguments**

- **k**: the von Karman constant (0.4)
- **u_**: the friction velocity (m s⁻¹)
- **zr**: is the reference height (m), the height of the weather station (m).
- **d**: zero plane displacement height (m)
- **h**: the plant height (m)
- **nK**: the eddy diffusivity extinction coefficient (taken as 2)
- **z0**: the crop roughness length (m)

**Value**

A vector for mean canopy flow to reference level

---

**cal_meanSaturationVapourPressure**

*Calculating mean saturation vapour pressure*

**Description**

Due to the non-linearity of the above equation, the mean saturation vapour pressure for a day, week, decade or month should be computed as the mean between the saturation vapour pressure at the mean daily maximum and minimum air temperatures for that period.

**Usage**

`cal_meanSaturationVapourPressure(Tmax, Tmin)`

**Arguments**

- **Tmax**: the daily maximum air temperature (degrees Celsius).
- **Tmin**: the daily minimum air temperature (degrees Celsius).

**Details**

Using mean air temperature instead of daily minimum and maximum temperatures results in lower estimates for the mean saturation vapour pressure. The corresponding vapour pressure deficit (a parameter expressing the evaporating power of the atmosphere) will also be smaller and the result will be some underestimation of the reference crop evapotranspiration. Therefore, the mean saturation vapour pressure should be calculated as the mean between the saturation vapour pressure at both the daily maximum and minimum air temperature.

**Value**

A vector for mean saturation vapour pressure (es)
References

Description
Calculating net longwave radiation $R_{nl}$

Usage
```
cal_netLongwaveRadiation(TKmax, TKmin, ea, Rs, Rso)
```

Arguments
- $TK_{max}$: maximum absolute temperature during the 24-hour period [K].
- $TK_{min}$: minimum absolute temperature during the 24-hour period [K].
- $ea$: actual vapour pressure [kPa].
- $Rs$: measured or calculated solar radiation [MJ m$^{-2}$ day$^{-1}$]. From `cal_solarRadiation()`.
- $Rso$: calculated clear-sky radiation [MJ m$^{-2}$ day$^{-1}$]. From `cal_skySolarRadiation_withas bs()` or `cal_skySolarRadiation_withas elevation()`.

Value
A vector for net outgoing longwave radiation [MJ m$^{-2}$ day$^{-1}$]

Note
The rate of longwave energy emission is proportional to the absolute temperature of the surface raised to the fourth power. This relation is expressed quantitatively by the Stefan-Boltzmann law. The net energy flux leaving the earth’s surface is, however, less than that emitted and given by the Stefan-Boltzmann law due to the absorption and downward radiation from the sky. Water vapour, clouds, carbon dioxide and dust are absorbers and emitters of longwave radiation. Their concentrations should be known when assessing the net outgoing flux. As humidity and cloudiness play an important role, the Stefan-Boltzmann law is corrected by these two factors when estimating the net outgoing flux of longwave radiation. It is thereby assumed that the concentrations of the other absorbers are constant. An average of the maximum air temperature to the fourth power and the minimum air temperature to the fourth power is commonly used in the Stefan-Boltzmann equation for 24-hour time steps. The term $(0.34-0.14\sqrt{ea})$ expresses the correction for air humidity, and will be smaller if the humidity increases. The effect of cloudiness is expressed by $(1.35 \frac{Rs}{Rso} - 0.35)$. The term becomes smaller if the cloudiness increases and hence $Rs$ decreases. The smaller the correction terms, the smaller the net outgoing flux of longwave radiation. Note that the $Rs/Rso$ term in Equation 39 must be limited so that $Rs/Rso \leq 1.0$. Where measurements of incoming and outgoing short and longwave radiation during bright sunny and overcast hours are available, calibration of the coefficients in Equation 39 can be carried out.


References


---

cal_netRadiation

Calculating net radiation Rn

Description

The net radiation (Rn) is the difference between the incoming net shortwave radiation (Rns) and the outgoing net longwave radiation (Rnl).

Usage

cal_netRadiation(Rns, Rnl)

Arguments

- Rns: incoming net shortwave radiation. From cal_netSolarRadiation().
- Rnl: outgoing net longwave radiation. From cal_netLongwaveRadiation().

Value

A vector for net radiation

References


---

cal_netRadiationForCrop

Calculating net radiation available to the crop

Description

Calculating net radiation available to the crop

Usage

cal_netRadiationForCrop(pRn, Rn)

Arguments

- pRn: canopy penetration probability for net radiation
- Rn: the net radiation (W/m2 ground). see cal_hourlyNetRadiation()
**cal_netRadiationForSoil**

*Calculating net radiation available to the soil*

**Value**
A vector for net radiation available to the crop (W/m2 ground)

**Description**
Calculating net radiation available to the soil

**Usage**
cal_netRadiationForSoil(pRn, Rn, G)

**Arguments**
- **pRn**: canopy penetration probability for net radiation
- **Rn**: the net radiation (W/m2 ground). See cal_hourlyNetRadiation()
- **G**: the soil heat flux (W/m2 ground)

**Value**
A vector for net radiation available to the soil (W/m2 ground)

**cal_netRadiationForSystem**

*Calculating net radiation available to the system (soil and crop)*

**Description**
Calculating net radiation available to the system (soil and crop)

**Usage**
cal_netRadiationForSystem(Ac, As)

**Arguments**
- **Ac**: net radiation available to the crop (W/m2 ground)
- **As**: net radiation available to the soil (W/m2 ground)

**Value**
A vector for net radiation available to the system (soil and crop) (W/m2 ground)
cal_netSolarRadiation  Calculating net solar (shortwave radiation) $R_{ns}$

**Description**

The net shortwave radiation resulting from the balance between incoming and reflected solar radiation.

**Usage**

```python
cal_netSolarRadiation(alpha, Rs)
```

**Arguments**

- `alpha`: albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop [dimensionless].
- `Rs`: the incoming solar radiation [MJ m\(^{-2}\) day\(^{-1}\)]. From `cal_solarRadiation()`

**Value**

A vector for net solar or shortwave radiation [MJ m\(^{-2}\) day\(^{-1}\)].

**References**


---

cal_percolationForExcessWater  Calculating percolation for excess water

**Description**

Calculating percolation for excess water

**Usage**

```python
cal_percolationForExcessWater(\text{THETA}_i_{\text{t0}}, \text{Pe}_i_{\text{t1}}, \text{THETA}_{\text{sat}_i})
```

**Arguments**

- `\text{THETA}_i_{\text{t0}}`: the water amount of the day before in soil layer $i$ (mm)
- `\text{Pe}_i_{\text{t1}}`: the percolation of previous soil layer (mm)
- `\text{THETA}_{\text{sat}_i}`: soil saturation water amount (mm)
cal_psychrometricConstant

Description
Calculating psychrometric constant

Usage
cal_psychrometricConstant(atmospheric_pressure)

Arguments
atmospheric_pressure
atmospheric pressure (kPa).

Value
A vector for Psychrometric constant (kPa/degree Celsius)

References

Examples
cal_psychrometricConstant(100.1235)

cal_reductionFactorForE

Description
Calculating reduction factor for evaporation

Usage
cal_reductionFactorForE(THETA, THETA_sat)
\section{cal_reductionFactorForT}

\textit{calculating reduction factor for transpiration}

\section{Description}

calculating reduction factor for transpiration

\section{Usage}

cal_reductionFactorForT(THETA_v_wp, p, THETA_v_sat, THETA_v)

\section{Arguments}

- THETA_v_wp: soil water content at wilting point (m$^3$ m$^{-3}$)
- p: a coefficient. 0.5 for C3 and 0.3 for C4 plant
- THETA_v_sat: soil saturation water content (m$^3$ m$^{-3}$)
- THETA_v: the water amount of the day before in root layer (m$^3$ m$^{-3}$)

\section{Value}

A value for reduction factor for transpiration

\section{cal_relativeHumidity}

\textit{Calculating relative humidity}

\section{Description}

The relative humidity (RH) expresses the degree of saturation of the air as a ratio of the actual (ea) to the saturation (e_0(T)) vapour pressure at the same temperature (T).

\section{Usage}

cal_relativeHumidity(ea, e_0)
**Arguments**

- **ea**: actual saturation vapour pressure. From `cal_ActualVapourPressure_for_*`
- **eθ**: saturation vapour pressure. From `cal_saturationVapourPressure()`

**Details**

Relative humidity is the ratio between the amount of water the ambient air actually holds and the amount it could hold at the same temperature. It is dimensionless and is commonly given as a percentage. Although the actual vapour pressure might be relatively constant throughout the day, the relative humidity fluctuates between a maximum near sunrise and a minimum around early afternoon (Figure 12). The variation of the relative humidity is the result of the fact that the saturation vapour pressure is determined by the air temperature. As the temperature changes during the day, the relative humidity also changes substantially.

**Value**

A vector for relative humidity %

**References**


---

**Description**

Calculating Solar radiation from actual duration of sunshine

**Usage**

```
cal_Rs_from_Na(as = 0.25, bs = 0.5, Na, Latitude, J)
```

**Arguments**

- **as**: regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0). Default is 0.25.
- **bs**: as+bs is fraction of extraterrestrial radiation reaching the earth on clear days (n = N). Default is 0.50.
- **Na**: actual duration of sunshine [hour].
- **Latitude**: latitude (angert).
- **J**: is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).
cal_sensibleHeatFluxesForCrop

Value
A vector for solar radiation(MJ m\(^{-2}\) d\(^{-1}\))

References

cal_saturationVapourPressure

Description
Calculating saturation vapour pressure

Usage
cal_saturationVapourPressure(Tem)

Arguments
Tem
air temperature (degrees Celsius).

Value
A vector for saturation vapour pressure at the air temperature T (kPa).

References

cal_sensibleHeatFluxesForCrop

Description
Calculating sensible heat fluxes for crop

Usage
cal_sensibleHeatFluxesForCrop(gamma, Ac, r_c_s, r_c_a, rho_cp, D0, DELTA)
cal_sensibleHeatFluxesForSoil

Arguments

- gamma: is the psychometric constant (0.658 mbar K-1)
- Ac: energy available to the crop (W m-2 ground)
- r_c_s: the canopy resistance (s m-1)
- r_c_a: is the bulk boundary layer resistance (s m-1)
- rho_cp: the volumetric heat capacity for air (1221.09 J m-3 K-1)
- D0: the vapor pressure deficit at the mean canopy flow
- DELTA: the slope of the saturated vapor pressure curve (mbar K-1)

Value

A vector for sensible heat fluxes for soil

cal_sensibleHeatFluxesForSoil

Calaulating sensible heat fluxes for soil

Description

Calaulating sensible heat fluxes for soil

Usage

```r
cal_sensibleHeatFluxesForSoil(
  gamma = 0.659,
  As,
  r_s_s,
  r_s_a,
  rho_cp,
  D0,
  DELTA
)
```

Arguments

- gamma: is the psychometric constant (0.658 mbar K-1)
- As: energy available to the soil (W m-2 ground)
- r_s_s: soil surface resistance, (s m-1)
- r_s_a: is the aerodynamic resistance between the soil and mean anopy flow (s m-1)
- rho_cp: the volumetric heat capacity for air (1221.09 J m-3 K-1)
- D0: the vapor pressure deficit at the mean canopy flow
- DELTA: the slope of the saturated vapor pressure curve (mbar K-1)

Value

A vector for soil sensible heat fluxes(W m-2 ground)
### cal_skySolarRadiation_withas_bs

*Calculating clear sky solar radiation with as and bs*

**Description**

The calculation of the clear-sky radiation, Rso, when n = N, is required for computing net longwave radiation.

**Usage**

```r
cal_skySolarRadiation_withas_bs(as, bs, Ra)
```

**Arguments**

- `as`, `bs` : as+bs fraction of extraterrestrial radiation reaching the earth on clear-sky days (n = N).
- `Ra` : extraterrestrial radiation [MJ m⁻² day⁻¹]. From `cal_extraterrestrialRadiation_for_daily()`.

**Value**

A vector for clear-sky solar radiation [MJ m⁻² day⁻¹].

**References**


---

### cal_skySolarRadiation_withas_elevation

*Calculating clear sky solar radiation with elevation*

**Description**

The calculation of the clear-sky radiation, Rso, when n = N, is required for computing net longwave radiation.

**Usage**

```r
cal_skySolarRadiation_withas_elevation(z, Ra)
```

**Arguments**

- `z` : station elevation above sea level [m].
- `Ra` : extraterrestrial radiation [MJ m⁻² day⁻¹]. From `cal_extraterrestrialRadiation_for_daily()`.
Value

A vector for clear-sky solar radiation [MJ m\(^{-2}\) day\(^{-1}\)].

References


cal_slopeOfSaturationVapourPressureCurve

*Calculating slope of saturation vapour pressure curve*

Description

Calculating slope of saturation vapour pressure curve

Usage

cal_slopeOfSaturationVapourPressureCurve(Tem)

Arguments

Tem is air temperature (degrees Celsius).

Details

In the FAO Penman-Monteith equation, where it occurs in the numerator and denominator, the slope of the vapour pressure curve is calculated using mean air temperature.

Value

A vector for slope of saturation vapour pressure curve at air temperature T

References

calc_soilHeatFlux

Description
Calculating Soil/ground heat flux

Usage
\[ \text{calc_soilHeatFlux}(pRn, Rn) \]

Arguments
- \( pRn \): the canopy penetration probability for net radiation
- \( Rn \): the net radiation (W/m² ground)

Value

A vector for the soil heat flux (W/m² ground)

\[ \text{calc_soilHeatFlux\_day} \]

Description
Calculating soil heat flux (G) for day/ten-day periods

Usage
\[ \text{calc_soilHeatFlux\_day}() \]

Value

A value for 0

References
FAO Irrigation and drainage paper 56 (P54)
Calculating soil heat flux (G) for general

Description

Complex models are available to describe soil heat flux. Because soil heat flux is small compared to \( R_n \), particularly when the surface is covered by vegetation and calculation time steps are 24 hours or longer, a simple calculation procedure is presented here for long time steps, based on the idea that the soil temperature follows air temperature.

Usage

\[
cal\_soilHeatFlux\_general(cs, T1, T0, delta\_t, delta\_z)
\]

Arguments

- \( cs \) soil heat capacity [MJ m\(^{-3}\) degrees Celsius\(^{-1}\)].
- \( T1 \) air temperature at time \( i \) [degrees Celsius].
- \( T0 \) air temperature at time \( i-1 \) [degrees Celsius].
- \( delta\_t \) length of time interval [day].
- \( delta\_z \) effective soil depth [m].

Value

A vector for soil heat flux [MJ m\(^{-2}\) day\(^{-1}\)]

Note

Complex models are available to describe soil heat flux. Because soil heat flux is small compared to \( R_n \), particularly when the surface is covered by vegetation and calculation time steps are 24 hours or longer, a simple calculation procedure is presented here for long time steps, based on the idea that the soil temperature follows air temperature.

References

cal_soilHeatFlux_hourly

*Calculating soil heat flux*(G) for hourly/shorter periods

**Description**
For hourly (or shorter) calculations, G beneath a dense cover of grass does not correlate well with air temperature.

**Usage**
cal_soilHeatFlux_hourly(Rn, periods)

**Arguments**
- *Rn* net radiation. From cal_netRadiation().
- *periods* "daylight" or "nighttime".

**Value**
A vector for soil heat flux [MJ m-2 day-1]

**Note**
Where the soil is warming, the soil heat flux G is positive. The amount of energy required for this process is subtracted from Rn when estimating evapotranspiration.

**References**

---

cal_soilHeatFlux_monthly

*Calculating soil heat flux*(G) for monthly periods

**Description**
When assuming a constant soil heat capacity of 2.1 MJ m-3 °C-1 and an appropriate soil depth, cal_soilHeatFlux_general can be used to derive G for monthly periods.

**Usage**
cal_soilHeatFlux_monthly(T1, T0, Tmonth2 = TRUE)


`cal_soilSurfaceResistance`

**Arguments**

- **T1** air temperature at time i [degrees Celsius].
- **T0** air temperature at time i-1 [degrees Celsius].
- **Tmonth2** Is the mean air temperature of next month know?

**Value**

A vector for soil heat flux [MJ m-2 day-1]

**References**


---

### `cal_soilSurfaceResistance`

*Calculating soil surface resistance*

**Description**

Calculating soil surface resistance

**Usage**

```r
cal_soilSurfaceResistance(
  tau,
  l,
  PHI_p,
  Dm_v,
  lambda_p,
  THETA_v_l,
  THETA_v_sat_l
)
```

**Arguments**

- **tau** soil tortuosity (taken as 2)
- **l** is the dry soil layer thickness (taken as the first soil layer thickness) (m)
- **PHI_p** is soil porosity
- **Dm_v** the vapor diffusion coefficient in air (24.7 10-6 m2 s-1)
- **lambda_p** the soil pore-size distribution index from the Brooks-Corey equation.
- **THETA_v_l** volumetric soil water content (m-3 m-3) of the first soil layer
- **THETA_v_sat_l** saturated soil water content (m3 m-3) of the first soil layer

**Value**

A vector for the soil surface resistance (s m-1)
cal_soilSurfaceToMeanCanopyFlow

Calculating soil surface to mean canopy flow

**Description**

the resistance between the soil surface and the mean canopy flow (s m\(^{-1}\))

**Usage**

\[
\text{cal_soilSurfaceToMeanCanopyFlow}(h, nK, Kh, zs0, z0, d)
\]

**Arguments**

- **h**: the plant height (m)
- **nK**: the eddy diffusivity extinction coefficient (taken as 2)
- **Kh**: eddy diffusivity at the canopy top (m\(^2\)/s)
- **zs0**: is the soil surface roughness length (m). Note: for flat, tilled land, zs0 can be taken as 0.004 m.
- **z0**: the crop roughness length (m)
- **d**: zero plane displacement height (m)

**Value**

A vector for aerodynamic resistance so soil surface to mean canopy flow (s m\(^{-1}\))

cal_solarDeclination

Calculating solar declination

**Description**

Calculating solar declination

**Usage**

\[
\text{cal_solarDeclination}(td)
\]

**Arguments**

- **td**: is the day of year.

**Value**

A vector for solar declination (Radian)
Note

The solar declination actually varies throughout the day too but its variation is very small; thus, it is often ignored. Negative angles occur when the angle is below the equator plane, positive for above the equator.

References


Examples

    cal_solarDeclination(34)

---

**cal_solarDeclination_in_FAO**

*Calculating solar declination with FAO56 method*

**Description**

Calculating solar declination with FAO56 method

**Usage**

    cal_solarDeclination_in_FAO(J)

**Arguments**

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

**Value**

A vector for solar declination (Radian)

**References**

**cal_solarInclination**  *Calculating solar inclination*

**Description**

A parameter used to determine the position of the sun relative to the observer (the other one is the angle from south). Conversion relationship with solar altitude angle: solar inclination = \( \pi/2 - \text{solar altitude} \).

**Usage**

`cal_solarInclination(solar_declination, latitude, hour_anger)`

**Arguments**

- `solar_declination`  
  is solar declination angle. It can be calculated from `cal_solardeclination()`.
- `latitude`  
  is the latitude data (Radian).
- `hour_anger`  
  is hour anger. It can be calculated from `cal_hourangle()`.

**Value**

A vector for solar inclination (Radian)

**References**


**Examples**

```r
  cal_solarInclination(solar_declination=-0.297, latitude=30, hour_anger=0)
```

---

**cal_solarRadiation**  *Calculating Solar radiation*

**Description**

If the solar radiation, \( R_s \), is not measured, it can be calculated with the Angstrom formula, which relates solar radiation to extraterrestrial radiation and relative sunshine duration. This is a shortwave radiation.

**Usage**

`cal_solarRadiation(as = 0.25, bs = 0.5, n, N, Ra)`
Arguments

as  regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0). Default is 0.25.
bs  as+bs is fraction of extraterrestrial radiation reaching the earth on clear days (n = N). Default is 0.50.
n  actual duration of sunshine [hour].
N  maximum possible duration of sunshine or daylight hours [hour]. From cal_daylightHours()
Ra  extraterrestrial radiation [MJ m-2 day-1]. From cal_extraterrestrialRadiation_for_daily()

Value

A vector for solar or shortwave radiation [MJ m-2 day-1]

Note

Rs is expressed in the above equation in MJ m-2 day-1. The corresponding equivalent evaporation in mm day-1 is obtained by multiplying Rs by 0.408 (Equation 20). Depending on atmospheric conditions (humidity, dust) and solar declination (latitude and month), the Angstrom values as and bs will vary. Where no actual solar radiation data are available and no calibration has been carried out for improved as and bs parameters, the values as = 0.25 and bs = 0.50 are recommended.

References

References


cal_sunsetTime	Calculating the local solar time for sunset/sunrise

Description

Calculating the local solar time for sunset/sunrise.

Usage

\[ \text{cal}_{-}\text{sunsetTime}(\text{solar}\_\text{declination}, \text{latitude}) \]

Arguments

- \text{solar}\_\text{declination}
  - can be calculated by \text{cal}_-\text{solar}\_\text{declination}().
- \text{latitude}
  - is latitude data (Radian).

Details

Knowing the time of sunrise can calculate the time of sunset. \text{sunrise}\_\text{time}=24-\text{sunset}\_\text{time}. \text{Day}\_\text{length}=2*(\text{sunset}\_\text{time}-12).

Value

A vector for the local solar time for sunset/sunrise

References

cal_TemMean

\[ \text{cal_TemMean} \]

**Description**

calculating the mean daily air temperature

**Usage**

\[ \text{cal_TemMean}(T_{\text{max}}, T_{\text{min}}) \]

**Arguments**

- \( T_{\text{max}} \) the daily maximum. The temperature is given in degree Celsius or Fahrenheit.
- \( T_{\text{min}} \) the daily minimum. The temperature is given in degree Celsius or Fahrenheit.

**Details**

It is only employed in the FAO Penman-Monteith equation to calculate the slope of the saturation vapor pressure curves and the impact of mean air density as the effect of temperature variations on the value of the climatic parameter is small in these cases. For standardization, Tmean for 24-hour periods is defined as the mean of mean of the daily maximum and minimum temperatures rather than as the average of hourly temperature measurements.

**Value**

A vector for the mean daily air temperature

**References**


---

cal_TEW_for_DualKc

\[ \text{cal_TEW_for_DualKc} \]

**Description**

maximum depth of water that can be evaporated from the soil when the topsoil has been initially completely wetted. Estimated TEW for Kr calculation

**Usage**

\[ \text{cal_TEW_for_DualKc}(\text{FC}, \text{WP}, \text{Ze}) \]
**Arguments**

- **FC** Soil water content at field capacity, m³ m⁻³
- **WP** Soil water content at wilting point, m³ m⁻³
- **Ze** Depth of the surface soil layer that is subject to drying by way of evaporation, 0.10–0.15 m.

**Value**

A value for total evaporable water

**References**


---

**Description**

Calculating total latent heat flux

**Usage**

```r
cal_totalLatentHeatFlux(
  DELTA,
  gamma,
  r_a_a,
  r_c_a,
  r_s_a,
  r_c_s,
  r_s_s,
  A,
  rho_cp = 1221.09,
  D,
  As,
  Ac
)
```

**Arguments**

- **DELTA** the slope of the saturated vapor pressure curve (mbar K⁻¹)
- **gamma** is the psychometric constant (0.658 mbar K⁻¹)
- **r_a_a** the aerodynamic resistance between the mean canopy flow and reference height (s m⁻¹)
$r_{_c,a}$ the bulk boundary layer resistance (s m-1)

$r_{_s,a}$ is the aerodynamic resistance between the soil and mean canopy flow (s m-1)

$r_{_c,s}$ the canopy resistance(s m-1)

$r_{_s,s}$ soil surface resistance (s m-1)

$A$ energy available to the system (total)(W m-2 ground)

$\rho_{cp}$ is the volumetric heat capacity for air (1221.09 J m-3 K-1)

$D$ the vapor pressure deficit (mbar)

$As$ energy available to soil (W m-2 ground)

$Ac$ energy available to crop (W m-2 ground)

**Value**

A vector for the total latent heat flux (W m-2 ground)

---

**cal_WaterStressCoef**  
*Calculating water stress coefficient*

**Description**

Calculating water stress coefficient

**Usage**

`cal_WaterStressCoef(Dr, TAW, p)`

**Arguments**

<table>
<thead>
<tr>
<th>Dr</th>
<th>root zone depletion(mm).</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAW</td>
<td>total available soil water in the root zone(mm).</td>
</tr>
<tr>
<td>p</td>
<td>fraction of TAW that a crop can extract from the root zone without suffering water stress.</td>
</tr>
</tbody>
</table>

**Value**

A value for water stress coefficient which is a dimensionless transpiration reduction factor dependent on available soil water
cal_windSpeed_Canopy  Calculating wind speed above and within the canopies.

Description

Calculating wind speed above and within the canopies.

Usage

cal_windSpeed_Canopy(z, h, u_, k = 0.4, d, z0, nu = 2)

Arguments

- z: the height (m)
- h: the plant height (m)
- u_: the friction velocity (m/s)
- k: the von Karman constant (0.4)
- d: zero plane displacement height (m)
- z0: the crop roughness length (m)
- nu: the wind speed extinction coefficient (taken as 2)

Value

A vector for the wind speed (m/s) at height z(m)

cal_zeroPlaneHeight  Calculating zero plane displacement height

Description

Calculating zero plane displacement height.

Usage

cal_zeroPlaneHeight(h)

Arguments

- h: the plant height (m)

Value

A vector for zero plane displacement height (m)
**compare_model_plot**

Show the results of different models

**Usage**

```r
compare_model_plot(model_list, names)
```

**Arguments**

- `model_list` List. Including output results of different models.
- `names` Vector. Name of models.

**Value**

A list for ggplot2 plot

---

**convert_angert_to_radian**

Converting angert to radian

**Description**

Converting the unit of angle in longitude and latitude into the unit of radian.

**Usage**

```r
convert_angert_to_radian(anger)
```

**Arguments**

- `anger` Longitude or dimension in Angle.

**Value**

A vector for longitude or dimension in radian.

**Examples**

```r
convert_angert_to_radian(98.8)
```
convert_Date_to_dayofyear

Convert date to day of year

Description
Convert date to day of year

Usage
convert_Date_to_dayofyear(Date)

Arguments
Date is a date format data.

Value
A vector for the day of year.

convert_degreesCelsius_to_Fahrenheit

Convert degrees Celsius to Fahrenheit

Description
Convert degrees Celsius to Fahrenheit

Usage
convert_degreesCelsius_to_Fahrenheit(degrees_Celsius)

Arguments
degrees_Celsius

Temperature in degrees Celsius(°C).

Value
A vector for temperature in Fahrenheit(°F).

References
**convert_Fahrenheit_to_degreesCelsius**  
*Convert Fahrenheit to degrees Celsius*

**Description**

Convert Fahrenheit to degrees Celsius

**Usage**

```r
convert_Fahrenheit_to_degreesCelsius(Fahrenheit)
```

**Arguments**

- **Fahrenheit**
  
  temperature in Fahrenheit(°F).

**Value**

A vector for temperature in degrees Celsius(°C)

**References**


---

**convert_Rad_unit**  
*Convert radiation unit*

**Description**

Type has the following types: MJ\_m2\_day\_to\_J\_cm2\_day; MJ\_m2\_day\_to\_cal\_cm2\_day; MJ\_m2\_day\_to\_W\_m2; cal\_cm2\_day\_to\_MJ\_m2\_day\_to\_J\_cm2\_day\_to\_cal\_cm2\_day\_to\_W\_m2\_day\_to\_cal\_cm2\_day\_to\_mm\_day\_to\_W\_m2\_day\_to\_MJ\_m2\_day\_to\_J\_cm2\_day\_to\_cal\_cm2\_day\_to\_W\_m2\_day\_to\_cal\_cm2\_day\_to\_mm\_day\_to\_MJ\_m2\_day\_to\_J\_cm2\_day\_to\_cal\_cm2\_day\_to\_W\_m2\_day\_to\_cal\_cm2\_day\_to\_mm\_day\_to\_MJ\_m2\_day\_to\_J\_cm2\_day\_to\_cal\_cm2\_day\_to\_W\_m2\_day

**Usage**

```r
convert_Rad_unit(rad, type)
```

**Arguments**

- **rad**
  
  Radiation data need to be converted from one unit to another unit.

- **type**
  
  Used to specify how to convert.

**Value**

A vector for radiation converted unit
convert_windSpeed_to_2m

Convert wind speed to the standard of 2m

Description

For the calculation of evapotranspiration, wind speed measured at 2 m above the surface is required. To adjust wind speed data obtained from instruments placed at elevations other than the standard height of 2 m, a logarithmic wind speed profile may be used for measurements above a short grassed surface.

Usage

convert_windSpeed_to_2m(uz, z)

Arguments

uz  measured wind speed at z m above ground surface [m s⁻¹].
z  height of measurement above ground surface [m].

Value

A vector for wind speed at 2 m above ground surface [m s⁻¹].

References


create_modelDF

Create a csv file or a dataframe in R to store the model data

Description

# @title Converting the every sheets in XLSX file to csv files
# @param xlsx_file the xlsx file path
# @export
# @importFrom utils write.csv
# @return No return value

Usage

create_modelDF(TreNum = 1, rowNum = 1)
Estimating missing humidity data

Where humidity data are lacking or are of questionable quality, an estimate of actual vapour pressure, \( e_a \), can be obtained by assuming that dewpoint temperature (\( T_{dew} \)) is near the daily minimum temperature (\( T_{min} \)). This statement implicitly assumes that at sunrise, when the air temperature is close to \( T_{min} \), that the air is nearly saturated with water vapour and the relative humidity is nearly 100%.

Usage

\[
\text{estimate_ea}(T_{min})
\]

Arguments

- \( T_{min} \) the minimum temperature daily.
Value

A vector for humidity

Note

The relationship T_dew near Tmin holds for locations where the cover crop of the station is well watered. However, particularly for arid regions, the air might not be saturated when its temperature is at its minimum. Hence, Tmin might be greater than T_dew and a further calibration may be required to estimate dewpoint temperatures. In these situations, "Tmin" in the above equation may be better approximated by subtracting 2-3 degrees Celsius from Tmin. Appropriate correction procedures are given in Annex 6. In humid and subhumid climates, Tmin and T_dew measured in early morning may be less than T_dew measured during the daytime because of condensation of dew during the night. After sunrise, evaporation of the dew will once again humidify the air and will increase the value measured for T_dew during the daytime. This phenomenon is demonstrated in Figure 5.4 of Annex 5. However, it is standard practice in 24-hour calculations of ETo to use T_dew measured or calculated during early morning. The estimate for ea from Tmin should be checked. When the prediction by Equation 48 is validated for a region, it can be used for daily estimates of ea.

References


---

**estimate_ET0_with_TmaxAndTmin**

*Estimating ETo with Tmax and Tmin*

**Description**

When solar radiation data, relative humidity data and/or wind speed data are missing, they should be estimated using the procedures presented in this section. As an alternative, ETo can be estimated using the Hargreaves ETo equation.

**Usage**

```
estimate_ET0_with_TmaxAndTmin(Tmean, Tmax, Tmin, Ra)
```

**Arguments**

- `Tmean` : mean temperature.
- `Tmax` : max temperature.
- `Tmin` : min temperature.
- `Ra` : extraterrestrial radiation [mm day^-1].

**Value**

A vector for reference evapotranspiration (mm day^-1).
Note

Units for both ETo and Ra in Equation 52 are mm day\(^{-1}\). Equation 52 should be verified in each new region by comparing with estimates by the FAO Penman-Monteith equation (Equation 6) at weather stations where solar radiation, air temperature, humidity, and wind speed are measured. If necessary, Equation 52 can be calibrated on a monthly or annual basis by determining empirical coefficients where ETo = a + b ETo Eq.52, where the Eq. 52 subscript refers to ETo predicted using Equation 52. The coefficients a and b can be determined by regression analyses or by visual fitting. In general, estimating solar radiation, vapor pressure and wind speed as described in Equations 48 to 51 and Table 4 and then utilizing these estimates in Equation 6 (the FAO Penman-Monteith equation) will provide somewhat more accurate estimates as compared to estimating ETo directly using Equation 52. This is due to the ability of the estimation equations to incorporate general climatic characteristics such as high or low wind speed or high or low relative humidity into the ETo estimate made using Equation 6. Equation 52 has a tendency to underpredict under high wind conditions (u2 > 3 m/s) and to overpredict under conditions of high relative humidity.

---

**estimate_goodnessOfFit**

*Calculating the goodness-of-fit indicators between measured and simulated values*

**Description**

Calculating the goodness-of-fit indicators between measured and simulated values

**Usage**

```r
estimate_goodnessOfFit(Sim, Obs)
```

**Arguments**

- `Sim`  
  The simulation value of model.
- `Obs`  
  The observed value.

**Value**

A vector for the goodness-of-fit indicators
estimate_LAI_for_alfalfa

*Estimate LAI for alfalfa*

**Description**

Estimate LAI for alfalfa

**Usage**

```r
estimate_LAI_for_alfalfa(hc)
```

**Arguments**

- `hc` is the vegetation height in meter. (in meter)

**Value**

A vector for leaf area index of alfalfa

**References**


---

estimate_Rs_for_islandLocations

*Estimating solar radiation for island locations*

**Description**

For island locations, where the land mass has a width perpendicular to the coastline of 20 km or less, the air masses influencing the atmospheric conditions are dominated by the adjacent water body in all directions. The temperature method is not appropriate for this situation. Where radiation data from another location on the island are not available, a first estimate of the monthly solar average can be obtained from the empirical relation.

**Usage**

```r
estimate_Rs_for_islandLocations(Ra, b = 4)
```

**Arguments**

- `Ra` extraterrestrial radiation [MJ m$^{-2}$ day$^{-1}$].
- `b` empirical constant, equal to 4 MJ m$^{-2}$ day$^{-1}$. 

**Value**

A vector for solar radiation

**Note**

This relationship is only applicable for low altitudes (from 0 to 100 m). The empirical constant represents the fact that in island locations some clouds are usually present, thus making the mean solar radiation 4 MJ m\(^{-2}\) day\(^{-1}\) below the nearly clear sky envelope (0.7 Ra). Local adjustment of the empirical constant may improve the estimation. The method is only appropriate for monthly calculations. The constant relation between Rs and Ra does not yield accurate daily estimates.

**References**


---

**Description**

The difference between the maximum and minimum air temperature is related to the degree of cloud cover in a location. Clear-sky conditions result in high temperatures during the day (\(T_{\text{max}}\)) because the atmosphere is transparent to the incoming solar radiation and in low temperatures during the night (\(T_{\text{min}}\)) because less outgoing longwave radiation is absorbed by the atmosphere. On the other hand, in overcast conditions, \(T_{\text{max}}\) is relatively smaller because a significant part of the incoming solar radiation never reaches the earth’s surface and is absorbed and reflected by the clouds. Similarly, \(T_{\text{min}}\) will be relatively higher as the cloud cover acts as a blanket and decreases the net outgoing longwave radiation. Therefore, the difference between the maximum and minimum air temperature (\(T_{\text{max}} - T_{\text{min}}\)) can be used as an indicator of the fraction of extraterrestrial radiation that reaches the earth’s surface. This principle has been utilized by Hargreaves and Samani to develop estimates of ETo using only air temperature data.

**Usage**

\[\text{estimate\_Rs\_from\_airTemDiff}(Ra, T_{\text{max}}, T_{\text{min}}, \text{locations})\]

**Arguments**

- **Ra**: extraterrestrial radiation [MJ m\(^{-2}\) d\(^{-1}\)].
- **\(T_{\text{max}}\)**: maximum air temperature.
- **\(T_{\text{min}}\)**: minimum air temperature.
- **locations**: The adjustment coefficient \(k_{Rs}\) is empirical and differs for interior’ or ‘coastal’ regions.
Value

A vector for solar radiation

Note

The temperature difference method is recommended for locations where it is not appropriate to import radiation data from a regional station, either because homogeneous climate conditions do not occur, or because data for the region are lacking. For island conditions, the methodology of Equation 50 is not appropriate due to moderating effects of the surrounding water body. Caution is required when daily computations of ETo are needed. The advice given for Equation 49 fully applies. It is recommended that daily estimates of ETo that are based on estimated Rs be summed or averaged over a several-day period, such as a week, decade or month to reduce prediction error.

References


FIalfalfa

A example dataset of alfalfa under flood irrigation

Description

A example dataset of alfalfa under flood irrigation

Usage

FIalfalfa

Format

A data frame with 161 rows and 22 variables

Kcb_adj_for_DualKc

Adjust the recommended Kc values at the middle and late stages

Description

Adjust the recommended Kc values at the middle and late stages

Usage

Kcb_adj_for_DualKc(Kcb_table, u2, RHmin, h)
**linear_interpolation**

**Arguments**

- **Kcb_table**: Recommended value of KC in FAO 56 at the middle and late stages
- **u2**: Wind speed at 2 m
- **RHmin**: Minimum relative humidity
- **h**: Plant height

**Value**

A value for adjust Kc at middle and late stages

**References**


---

**linear_interpolation**  *linear interpolation for vector*

**Description**

Linear interpolation is performed by using the values on both sides of the missing values.

**Usage**

```
linear_interpolation(DataVector)
```

**Arguments**

- **DataVector**: data vector. Note that the starting value of vector needs to be no missing value.

**Value**

A interpolated vector
Model_DualKc  

### Description

Simulation of evapotranspiration using dual crop coefficient method

### Usage

```r
Model_DualKc(data, param)
```

### Arguments

- **data**: A data box. Contains the daily data required by the model. You can refer to the function `create_modelData()`
- **param**: A list. Contains additional parameters. `list(Kini,Kmid,Kend,fw,rootDepth,Dei_start,Dri_start,FCe,WPe,Ze,REW,TAW,p,FCrmm,CR_param)`

### Value

A list for the model result including a data frame of daily model result, a list of plots, a data frame of summary data

### Note

The stages of data should include all four stages. If a crop has multiple growth cycles, each cycle should include all four stages.

### Examples

```r
library(simET)
data("FAlfalfa")
names(FAlfalfa)
#--Model parameter
Dparam_FI<-list(Kini=0.3,#Kcb for initial stage
Kmid=1.15,#Kcb for mid-season stage
Kend=1.1,#Kcb for late season stage
DI=FALSE,#Is it drip irrigation?
fw=1,# The fraction of the surface wetted
rootDepth=1.2,#Maximum root depth
Dei_start=0,#Initial depletion of evaporation layer
Dri_start=35,#Initial depletion of root layer
FCe=0.22,#Field capacity of evaporation layer
WPe=0.15,#Wilting point of evaporation layer
Ze=0.15,#Depth of the surface soil layer
REW=6,#Readily evaporable water
TAW=297,#Total available soil water of the root zone
p=0.55,#Evapotranspiration depletion factor
FCrmm=430,#Field capacity of root layer
CR_param=c(430,-0.32,310,-0.16,-1.4,6.8,1.11,-0.98))
```
# Model single Kc

# Capillary rise model parameters

#--Run model
Model_re_FI <- Model_DualKc(data = FIalfalfa, param = Dparam_FI)
#-- The Result data
Model_re_FI$Result
Model_re_FI$Plot
#-- The goodness of Fit
estimate_goodnessOfFit(Sim = Model_re_FI$Result$Sim_SoilWater,
OBS = Model_re_FI$Result$SoilWater)

---

## Model single Kc

**Simulation for evapotranspiration using single crop coefficient method**

### Description

Simulation for evapotranspiration using single crop coefficient method

### Usage

```r
Model_single_Kc(data, param)
```

### Arguments

- **data**: A data box. Contains the daily data required by the model. You can refer to the function `create_modelData()`
- **param**: A list. Contains additional parameters.

### Value

A list for the model result including a data frame of daily model result, a list of plots, a data frame of summary data.

### Note

The stages of data should include all four stages. If a crop has multiple growth cycles, each cycle should include all four stages.

### Examples

```r
library(simET)
#-- Data preparation
data("FIalfalfa")
#-- Parameter preparation
param_SingleKc <- list(Kc_mid = 1.2, #Kcb for mid-season stage
Kc_end = 1.15, #Kcb for late season stage
rootDepth = 1.2, #Maximum root depth
# The soil type used for calculating
# Kc for initial stage
```
Model_SW

Simulation of evapotranspiration using Shuttleworth-Wallace model

Description
Simulation of evapotranspiration using Shuttleworth-Wallace model

Usage
Model_SW(data, param)

Arguments
- **data**: A data box. Contains the daily data required by the model. You can refer to the function create_modelData()
- **param**: A list. Contains additional parameters.

Value
A list for the model result including a data frame of daily model result, a list of plots, a data frame of summary data

Note
The stages of data should include all four stages. If a crop has multiple growth cycles, each cycle should include all four stages.
library(simET)
#--Data preparation
data("FIalfalfa")
#--Parameter preparation
param_SW<-list(  
  plant=list(  
    #the canopy extinction coefficient for net radiation
    kRn=0.3,
    #Canopy reflectance
    alpha_plant=0.3,
    #Leaf width
    w=0.01,
    #Leaf stomatal resistance coefficients
    Lmax=10,
    #Maximum leaf area index
    a1=10,
    #Leaf stomatal resistance coefficients
    a2=0.005,
    #the param of reduction factor for T
    p=0.5,
    #Maximum root depth
    rootDepth=1.2
  ),
  Soil=list(  
    zs0=0.04,#The soil surface roughnesslength (m)
    tau2=2, #Soil tortuosity
    PHI_p=2, #Soil porosity
    #The soil pore-size distribution index
    #from the Brooks-Corey equation.
    lambda_p=0.18,
    #Depth of the surface soil layer (m)
    l1=0.02,
    #Depth of the root layer (m)
    l2=1.2,
    #Saturation water content of evaporation layer
    THETA_v_sat_1=0.36,
    THETA_v_sat_2=0.40, #Saturation water content of root layer
    THETA_start_1=0.2, #Initial water content of evaporation layer
    THETA_start_2=0.36, #Initial water content of root layer
    THETA_wp1=0.15, #Wilting point of evaporation layer
    THETA_wp2=0.15, #Wilting point of root layer
    #Empirical coefficient of evaporation layer.
    alpha1=14,
    #Empirical coefficient of root layer.
    alpha2=14,
    #Saturated hydraulic conductivity of evaporation layer
    Ksat_1=13.52,
    #Saturated hydraulic conductivity of root layer
    Ksat_2=0.02,
    #Capillary rise model parameters
    CR_param=c(430,-0.32,313,-0.16,-1.4,6.8,0.5,-0.98)
  ),
  Mete=list(  
    nu=2, #The wind speed extinction coefficient
    nK=2, #The eddy diffusivity extinction coefficient(taken as 2)
    zr=2, #The reference height (m)
    #The vapor diffusion coefficient in air (24.7 10^-6 m2 s^-1)
    Dm_v=24.7*10^-6,
    #Time step difference (day)
    deltaT=1
  )
)
#--Run model
Re_SW<-Model_SW(data = FIalfalfa, param = param_SW)
#--The Result data
Re_SW$Result
Re_SW$Plot
#--The goodness Of Fit
estimate_goodnessOfFit(Sim = Re_SW$Result$Sim_SoilWater, Obs = Re_SW$Result$SoilWater)

SDIalfalfa

A example dataset of alfalfa under subsurface drip irrigation

Description
A example dataset of alfalfa under subsurface drip irrigation

Usage
SDIalfalfa

Format
A data frame with 161 rows and 22 variables
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