Package: soilwatR (via r-universe)

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Type Package

Title Simulation of Soil Water Flow Based on Darcy's Law

Version 0.1.1

Description Provides a simple model to simulate soil water content and water flux changes at multiple soil depths. Calculations mainly follow Allen et al. (1998, ISBN:92-5-104219-5) and Teh (2017, ISBN:9789673447626).

License GPL (>= 3)

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Contents

cal_ActualVapourPressure_from_RHmean 2
cal_atmosphericPressure 3
cal_ET0 4

cal_ET0_from_PM 4
cal_extraterrestrialRadiation_for_daily 6
cal_FC 6
cal_inverseRelativeDistance_Earth_sun 7
cal_Kcend_for_singleKc 7
cal_Kcini_for_SingleKc 8
cal_Kcmid_for_singleKc 9
cal_meanSaturationVapourPressure 10
cal_netLongwaveRadiation 10
cal_netRadiation 12
cal_netRain 12
cal_netSolarRadiation 13
cal_PET 13
cal_psychrometriCconstant 14
cal_Red_PETc 14
cal_Red_PETs 15
cal_Sat 15
cal_saturationVapourPressure 16
cal_skySolarRadiation_withas_elevation 17
cal_slopeOfSaturationVapourPressureCurve 17
cal_solarDeclination_in_FAO 18
cal_sunsetHourAngle 18
cal_WP 19
convert_angert_to_radian 20
convert_degreesCelsius_to_Fahrenheit 20
linear_interpolation 21
plot_result 21
SIalfalfa 22
soilwatr 22

Index **24**

`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

`RHmean`	mean relative humidity(%).
`Tmax`	daily maximum temperature (degrees Celsius).
`Tmin`	daily minimum temperature (degrees Celsius).

Value

A vector of actual vapour pressure

References

FAO Irrigation and drainage paper 56 (P39)

`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 thepsychrometric constant. The effect is, however, small and in the calculation procedures, the average value for a location is sufficient.

Value

A vector of atmospheric pressure (Kpa)

References

FAO Irrigation and drainage paper 56 (P31)

cal_ET0 — *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(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 of reference evapotranspiration (mm/day)

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 °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 °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 of 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

FAO Irrigation and drainage paper 56 (P65)

cal_extraterrestrialRadiation_for_daily

Calculating extraterrestrial radiation for daily periods

Description

The extraterrestrial radiation, Ra, 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_extraterrestrialRadiation_for_daily(J, lat)
```

Arguments

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

Value

A vector of extraterrestrial radiation for daily(MJ m-2 day-1)

References

FAO Irrigation and drainage paper 56 (P45-47)

cal_FC

calculating field capacity

Description

calculating field capacity

Usage

```
cal_FC(Sand_frac, Clay_frac, OM)
```

Arguments

Sand_frac	Sand fraction
Clay_frac	Clay fraction
OM	Organic matter content percentage

Value

A vector of field capacity

---

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 of inverse relative distance Earth-sun (radian)

References

FAO Irrigation and drainage paper 56 (P46)

---

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

```
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 vector for the K value of the late season stage

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

FAO Irrigation and drainage paper 56 (P125-126)

---

cal_Kcini_for_SingleKc

Calculating Kcini value

Description

Calculating Kcini value

Usage

```
cal_Kcini_for_SingleKc(Pmean, ET0, tw, type, fw)
```

Arguments

Pmean	is the average depth od 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 vector for the K value of initial stage

References

FAO Irrigation and drainage paper 56 (P263-269)

---

cal_Kcmid_for_singleKc

Crop coefficient for the mid-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.For specific adjustment in climates where RHmin differs from 45 % or where u2 is larger or smaller than 2.0 m/s.

Usage

```
cal_Kcmid_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 (mls), 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 vector for the K value of the mid-season stage

References

FAO Irrigation and drainage paper 56 (P122-123)

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 sauration 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 of mean saturation vapour pressure (es)

References

FAO Irrigation and drainage paper 56 (P36)

cal_netLongwaveRadiation

Calculating net longwave radiation Rnl

Description

Calculating net longwave radiation Rnl

Usage

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

Arguments

TKmax	maximum absolute temperature during the 24-hour period [K].
TKmin	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 of 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 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 <= 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

FAO Irrigation and drainage paper 56 (P51-52)

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 of net radiation

cal_netRain *calculating the net rain*

Description

calculating the net rain

Usage

```
cal_netRain(lai, rain)
```

Arguments

lai	leaf area index m2 m-2
rain	rain mm

Value

A vector of net rain (mm)

cal_netSolarRadiation *Calculating net solar (shortware radiation) Rns*

Description

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

Usage

```
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 of net solar or shortwave radiation [MJ m-2 day-1].

References

FAO Irrigation and drainage paper 56 (P51)

cal_PET *Calculation of potential evaporation and potential transpiration*

Description

This function calculates the potential evapotranspiration according to the single crop coefficient method, and then converts the potential evapotranspiration into potential evaporation and potential transpiration based on LAI

Usage

```
cal_PET(data, Kc_mid, Kc_end, fw, soil_type)
```

Arguments

data	A data frame.
Kc_mid	value for Kc mid
Kc_end	value for Kc end
fw	the fraction of surfaces wetted by irrigation or rain (0-1)
soil_type	soil type:"coarse soil textures" and "medium and fine soil textures"

Value

A data frame including the potential evaporation and potential transpiration

Note

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

---

cal_psychrometriCconstant *Calculating psychrometric constant*

Description

Calculating psychrometric constant

Usage

```
cal_psychrometriCconstant(atmospheric_pressure)
```

Arguments

`atmospheric_pressure` atmospheric pressure (kPa).

Value

A vector of psychrometric constant (kPa/degree Celsius)

References

FAO Irrigation and drainage paper 56 (P32)

---

cal_Red_PETc *calculating reduction rate for Potential transpiration*

Description

calculating reduction rate for Potential transpiration

Usage

```
cal_Red_PETc(C3, vwc_root, pwp_root, sat_root)
```

Arguments

`C3`	Judge whether it is a C3 plant. If not, it is C4
`vwc_root`	Current volume moisture content of root zone
`pwp_root`	Volume moisture content of wilting point in root zone
`sat_root`	Saturated volume moisture content of root zone

Value

A vector for the reduction rate of transpiration

`cal_Red_PETs` *calculating reduction rate for Potential evaporation*

Description

calculating reduction rate for Potential evaporation

Usage

```
cal_Red_PETs(vwc1, sat1)
```

Arguments

`vwc1`	Volumetric moisture content of topsoil fraction
`sat1`	Saturated volume moisture content of topsoil fraction

Value

A vector for the reduction rate of evaporation

`cal_Sat` *calculating Soil saturated water content*

Description

calculating Soil saturated water content

Usage

```
cal_Sat(Sand_frac, Clay_frac, OM, THETA_33)
```

Arguments

`Sand_frac`	Sand fraction
`Clay_frac`	Clay fraction
`OM`	Organic matter content percentage
`THETA_33`	wilting point from cal_FC function

Value

A vector of Soil saturated water content

`cal_saturationVapourPressure` *Calculating saturation vapour pressure*

Description

saturation vapour pressure at the air temperature T.

Usage

```
cal_saturationVapourPressure(Tem)
```

Arguments

`Tem`	air temperature (degrees Celsius).

Value

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

References

FAO Irrigation and drainage paper 56 (P36)

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

```
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 of clear-sky solar radiation [MJ m-2 day-1].

References

FAO Irrigation and drainage paper 56 (P51)

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

FAO Irrigation and drainage paper 56 (P3)

---

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 of solar declination (radian)

References

FAO Irrigation and drainage paper 56 (P46)

---

cal_sunsetHourAngle *Calculating sunset hour angle*

Description

Calculating sunset hour angle

Usage

```
cal_sunsetHourAngle(lat, solar_declination)
```

Arguments

`lat` latitude (radian), positive for the northern hemisphere and negative for the southern hemisphere.

`solar_declination` solar declination(radina).

Value

A vector of sunset Hour Angle(radian)

References

FAO Irrigation and drainage paper 56 (P46)

---

cal_WP *calculating wilting point*

Description

calculating wilting point

Usage

```
cal_WP(Sand_frac, Clay_frac, OM)
```

Arguments

`Sand_frac`	Sand fraction
`Clay_frac`	Clay fraction
`OM`	Organic matter content percentage

Value

A vector of wilting point

convert_angert_to_radian

Converting angert to radian

Description

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

Usage

```
convert_angert_to_radian(anger)
```

Arguments

anger	Longitude or latitude in angle.

Value

A vector of longitude or latitude in radian

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 of temperature in Fahrenheit(°F)

References

FAO56

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 vector

plot_result *Graphically display the output results of the model*

Description

Graphically display the output results of the model

Usage

```
plot_result(Result)
```

Arguments

Result	The output result of the soilwatr function

Value

A combined plot if ggpubr is installed; otherwise a list of ggplot objects.

SIalfalfa — *A example dataset of alfalfa under flood irrigation*

Description

teh data including Input data, soilProfileSet data and obs data. Input data is a form of data frame includes daily upper boundary layer data of two irrigation treatments. The soilProfileSet is a matrix data that stores the soil profile setting information. Obs is the measured change of soil water content at different soil depths.

Usage

```
SIalfalfa
```

Format

A list with 3 data.

soilwatr — *Simulation of soil water flow in different soil layers*

Description

Simulation of soil water flow in different soil layers

Usage

```
soilwatr(data, param, soilProfileSet, verbose = FALSE)
```

Arguments

`data`	A data frame. The model input data, including Day, rain_mm, lai, T_mm, E_mm.
`param`	A list. Input parameters of the model.
`soilProfileSet`	A matrix. Definition of soil profile and its physical characteristics.
`verbose`	Logical; if `TRUE`, print progress for each simulated day.

Value

A matrix of simulated results.

Examples

```
data(SIalfalfa)
param <- list(
  initialRootingDepth = 1.2,
  RootGrowthRate = 0.0035,
  has_watertable = FALSE,
  subintervals = 20,
  maxsteps = 5
)
SIalfalfa_T1 <- SIalfalfa$Input[SIalfalfa$Input$Tre2 == "T1", ]
soilProfileSet_T1 <- SIalfalfa$soilProfileSet
soilProfileSet_T1["THETA_v_curr", ] <- c(0.12, 0.13, 0.28, 0.31, NA)
SI_T1_result <- soilwatr(
  data = SIalfalfa_T1,
  param = param,
  soilProfileSet = soilProfileSet_T1
)
head(SI_T1_result)
```

Index

∗ **datasets**
SIalfalfa, 22

cal_ActualVapourPressure_from_RHmean, 2
cal_atmosphericPressure, 3
cal_ET0, 4
cal_ET0_from_PM, 4
cal_extraterrestrialRadiation_for_daily, 6
cal_FC, 6
cal_inverseRelativeDistance_Earth_sun, 7
cal_Kcend_for_singleKc, 7
cal_Kcini_for_SingleKc, 8
cal_Kcmid_for_singleKc, 9
cal_meanSaturationVapourPressure, 10
cal_netLongwaveRadiation, 10
cal_netRadiation, 12
cal_netRain, 12
cal_netSolarRadiation, 13
cal_PET, 13
cal_psychrometriCconstant, 14
cal_Red_PETc, 14
cal_Red_PETs, 15
cal_Sat, 15
cal_saturationVapourPressure, 16
cal_skySolarRadiation_withas_elevation, 17
cal_slopeOfSaturationVapourPressureCurve, 17
cal_solarDeclination_in_FAO, 18
cal_sunsetHourAngle, 18
cal_WP, 19
convert_angert_to_radian, 20
convert_degreesCelsius_to_Fahrenheit, 20

linear_interpolation, 21

plot_result, 21

SIalfalfa, 22
soilwatr, 22