Package 'ChillModels'

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Title Processing Chill and Heat Models for Temperate Fruit Trees

Version 1.0.2

Description

Calculates the chilling and heat accumulation for studies of the temperate fruit trees. The models in this package are: Utah (Richardson et al., 1974, ISSN:0018-5345), Positive Chill Units - PCU (Linsley-Noaks et al., 1995, ISSN:1017-0316), GDH-A - Growing Degree Hours by Anderson et al.(1986, ISSN:0567-7572), GDH-R - Growing Degree Hours by Richardson et al.(1975, ISSN:0018-5345), North Carolina (Shaltout e Unrath, 1983, ISSN:0003-1062), Landsberg Model (Landsberg, 1974, ISSN:0305-7364), Q10 Model (Bidabe, 1967, ISSN:0031-9368), Jones Model (Jones et al., 2013 <DOI:10.1111/j.1438-8677.2012.00590.x>), Low-Chill Model (Gilreath and Buchanan, 1981, ISSN:0003-1062), Model for Cherry ``Sweetheart'' (Guak and Nielsen, 2013 <DOI:10.1007/s13580-013-0140-9>), Model for apple ``Gala'' (Guak and Nielsen, 2013 <DOI:10.1007/s13580-013-0140-9>), Taiwan Model (Lu et al., 2012 <DOI:10.17660/ActaHortic.2012.962.35>), Dynamic Model (Fishman et al., 1987, ISSN:0022-5193) adapted from the function Dynamic_Model() of the 'chillR' package (Luedeling, 2018), Unified Model (Chuine et al., 2016 <DOI:10.1111/gcb.13383>) and Heat Restriction model.

Depends R (>= 3.6.0)

License GPL-3

Encoding UTF-8

LazyData TRUE

RoxygenNote 6.1.1

Suggests chillR, dplyr, lubridate, ggplot2

NeedsCompilation no

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R topics documented:

`cherry_model` *Sweet Cherry Model*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
cherry_model(x, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units, where 1 chill-unit is when the tree is exposure between -2.1°C and 7°C. When the temperature is above 18°C the chill-unit is -1. The chill-units accumulation is 0 when occurs temperature between 14°C and 16°C.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

Note

This model was make for quantifying the chill accumulation rates to 'Sweetheart' Sweet Cherry. We aren't recommended the application for others species.

References

GUAK, Sunghee & NEILSEN, Denise. (2013). Chill Unit Models for Predicting Dormancy Completion of Floral Buds in Apple and Sweet Cherry.

Examples

```
x <- rnorm(500, 8, 7)
cherry_model(x)
cherry_model(x, FALSE)
```

---

climatedata *Climate data*

Description

A dataset containing the hourly temperatures

Usage

```
data("climatedata")
```

Format

A data frame with 5003 rows and 3 variables.

date Date, in Year-Month-Day format

hora Hour in numeric format

temp Temperature, in Celsius-Degree

count_between *Count between*

Description

Function to quantify temperature hours between x and y.

Usage

```
count_between(tli, tls, x, total = TRUE)
```

Arguments

tli	lower limit
tls	upper limit
x	Vector containing values (data).
total	TRUE Shows the total value of hours.

Details

Function to quantify temperature hours between x and y.

Value

The function returns the total value of hours.

Examples

```
x <- rnorm(500, 7, 3)

count_between(tli = 8, tls = 15, x = x,  total = TRUE)
```

count_down *Count Down*

Description

Function to quantify temperature hours below x.

Usage

```
count_down(tl, x, total = TRUE)
```

Arguments

tl	upper limit
x	Vector containing values (data).
total	TRUE Shows the total value of hours.

Details

Function to quantify temperature hours below x.

Value

The function returns the total value of hours.

Examples

```
x <- rnorm(1000, 15, 5)

count_down(tl = 7.2, x = x, total = TRUE)
```

---

count_up *Count Up*

Description

Function to quantify temperature hours above x.

Usage

```
count_up(tl, x, total = TRUE)
```

Arguments

tl	lower limit
x	Vector containing values (data).
total	TRUE Shows the total value of hours.

Details

Function to quantify temperature hours above x.

Value

The function returns the total value of hours.

Examples

```
x <- rnorm(500, 20, 10)

count_up(tl = 30, x = x, total = TRUE)
```

`dynamic_model` *Dynamic Model*

Description

Quantifies the chill accumulation with dynamic equation (two-steps).

Usage

```
dynamic_model(x, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill for each temperature (TRUE is default).

Details

The model is based on dynamic accumulation, by means of the relationship between temperatures. The dynamic model assumes that the accumulated chill-units are not annulled by high temperatures.

Value

The function returns values the chill for each temperature of vector (Total = FALSE), or returns the chill accumulation (Total = TRUE).

Note

Code adapted from the function `Dynamic_Model`, of the chillR Package

References

FISHMAN, Svetlana, EREZ, A. & COUVILLON, G. A. (1987). The Temperature Dependence of Dormancy Breaking in Plants: Computer Simulation of Processes Studied Under Controlled Temperatures. J. Theor. Biol.

LUEDELING, Eike (2018). chillR: Statistical Methods for Phenology Analysis in Temperate Fruit Trees. R package version 0.70.12. https://CRAN.R-project.org/package=chillR

Examples

```
x <- rnorm(500, 10, 5)
dynamic_model(x)
dynamic_model(x, FALSE)
```

`gala_model` *Gala model*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
gala_model(x, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units, where 1 chill-unit is when the tree is exposure between -2.1°C and 5.5°C. When the temperature is above 18°C, the chill-unit is -1. The chill-units accumulation is 0 when occurs temperature between 13°C and 16°C.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

Note

This model was make for quantifying the chill accumulation rates to 'Gala' apple or varieties of the Gala group. We aren't recommended the application for others species or others groups of the apple tree.

References

GUAK, Sunghee & NEILSEN, Denise. (2013). Chill Unit Models for Predicting Dormancy Completion of Floral Buds in Apple and Sweet Cherry.

Examples

```
x <- rnorm(500, 10, 5)
gala_model(x)
gala_model(x, FALSE)
```

---

gdha_model *GDH Model - Anderson - for heat accumulation*

Description

Quantifies the Growing Degree Hours at between the base and optimum temperatures, by Anderson et al. (1986).

Usage

```
gdha_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of GDH for each temperature (TRUE is default).

Details

The GDH Model is based on base and optimum temperature. The base temperature is 4°C. The optimum and critical temperature are 25°C and 36°C, respectively.

Value

The function returns values the GDH for each temperature of vector.

References

Anderson, J. L. et al. 1986. Validation of chill unit and flower bud phenology models for "Montmorency" sour cherry. Acta Horticulturae - Modelling in Fruit Research.

Examples

```
x <- rnorm(500,8,3)
gdha_model(x)
gdha_model(x, FALSE)
```

gdhr_model *GDH Model - Richardson - for heat accumulation*

Description

Quantifies the Growing Degree Hours at between the base and optimum temperatures.

Usage

```
gdhr_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of GDH for each temperature (TRUE is default).

Details

The GDH model is based on the subtraction of the base temperature of each hourly temperature between 4.5°C and 25°C. The temperature of the base is 4.5°C. Therefore, accumulation under temperatures below 4.5°C and above 25°C is zero.

Value

The function returns values the GDH for each temperature of vector.

References

RICHARDSON, E.A. et al. 1975. Pheno-climatographyof spring 249 peach bud development. HortScience.

Examples

```
x <- rnorm(500,8,3)
gdhr_model(x)
gdhr_model(x, FALSE)
```

heat_restriction *Heat Restriction model*

Description

Quantifies the chill accumulation by Utah Model and North Carolina Model.

Usage

```
heat_restriction(x, model, nh, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
model	Model to be used for calculation. Use "utah" for Utah Model and "nc" for North Carolina Model.
nh	Number of hours of continuous heat.
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units (Utah Model or North Carolina Model). After a certain number of hours of heat, the counting the negative units is interrupted. Negativation of the cold by the heat is restricted to a few days, 24h for Raseira (1982), 96h for Ebert (1986), 30 hours for Fishmann (1987) and 36 hours for Anzanello (2012).

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

Examples

```
x <- rnorm(500, 15, 5)

#5 hours of heat to stop counting the negative units.
heat_restriction(x, model = "nc",nh = 5)

#24 hours of heat to stop counting the negative units.
heat_restriction(x, model = "nc", nh = 24)
```

jones_model *Jones Model*

Description

Quantifies the chill accumulation by means of converting temperatures to exponential units temperature.

Usage

```
jones_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill for each temperature (TRUE is default).

Value

The function returns values the chill for each temperature of vector (Total = FALSE), or returns the chill accumulation (Total = TRUE).

References

JONES, H. G., HILLIS, R. M., GORDON, S. L., and BRENNAN, R. M. (2013). An approach to the determination of winter chill requirements for different Ribes cultivars. Plant. Biol.

Examples

```
 x <- rnorm(500, 8, 5)
jones_model(x)
jones_model(x, FALSE)
```

landsberg_model *Landsberg Model*

Description

Quantifies the chill accumulation based in the base temperature.

Usage

```
landsberg_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on the subtraction of the base temperature of each hourly temperature. The temperature of the base is 5°C.

Value

The function returns values the chill for each temperature of vector (Total = FALSE), or returns the chill accumulation (Total = TRUE).

References

LANDSBERG J. J. (1974). Apple Fruit Bud Development and Growth; Analysis and an Empirical Model. Annals of Botany.

Examples

```
x <- rnorm(500, 8, 5)
landsberg_model(x)
landsberg_model(x, FALSE)
```

---

lowchill_model *Low Chill*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
lowchill_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units, where 1 chill-unit is when the tree is exposure between 1.8°C and 8°C. When the temperature is above 19.5°C, the chill-unit is -1. The chill-units accumulation is 0 when occurs temperature below -1°C and between 14°C and 17°C.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

References

GILREATH, Phyllis R. & BUCHANAN, D. W. (1981). Rest Prediction Model for Low-chilling 'Sungold' Nectarine. J. Amer. Soc. Hort. Sci.

Examples

```
x <- rnorm(500, 12, 5)
lowchill_model(x)
lowchill_model(x, FALSE)
```

---

north_carolina *North Carolina*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
north_carolina(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units and optimum temperature, minimum and maximum temperature limits (They aren't classes), where 1 chill-unit is when the tree is exposure at optimum temperature (7.2°C). When the temperature is above 23°C (maximum temperature limit), the chill-unit is -2. The chill-units accumulation is 0 when occurs temperature below -1.1°C, being the miminum temperature limit.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

References

SHALTOUT, Assem D. & UNRATH, C. R. 1983. Rest Completion Prediction Model for 'Starkrimson Delicious' Apples. J. Amer. Soc. Hort. Sci.

Examples

```
x <- rnorm(500, 5, 4)
north_carolina(x)
north_carolina(x, FALSE)
```

---

pcu_model *Positive Chill Units - PCU*

Description

Quantifies the chill accumulation by means of converting temperatures to positive chill-units - Modified Utah Model.

Usage

```
pcu_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The PCU Model is the modified Utah Model. When the temperature is above 15.9°C, the chill-unit is 0. This modification was made because when the Utah model is applied in warm conditions, accumulation becomes negative.

Value

The function returns values the chill-units for each temperature of vector.

References

Richardson, E. A. et al. 1974. "A Model for Estimating the Completation of Rest for 'Redhaven' and 'Elberta' Peach Trees". Research Reports & Notes.

Linsley-Noakes, G. C. et al. 1995. "Estimating daily positive Utah Chill units using daily minimum and maximum temperatures".

Examples

```
x <- rnorm(500, 15, 4)
pcu_model(x)
pcu_model(x, FALSE)
```

`q10_bidabe` *Bidabe Model*

Description

Quantifies the chill accumulation by means of converting temperatures to temperature coeficients (Q10).

Usage

```
q10_bidabe(x, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on temperature coeficients (Q10). The Q10 coeficient is variable for each specie. The model contains dinamic variables. This model is been aplied in the warm climates. Was based on an exponential function that decreases according to the increase in temperature.

Value

The function returns values for each temperature of vector (Total = FALSE), or returns the accumulation (Total = TRUE).

References

BIDABE, B. 1967. Action de la temperature sur l' evolution des bourgeons de pommier et comparaison de methodes de controle de l' epoque de floraison. Annu. Physiol. Veg.

Examples

```
x <- rnorm(500, 10, 3)
q10_bidabe(x)
q10_bidabe(x, FALSE)
```

`taiwan_model` *Taiwan model*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
taiwan_model(x, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units, where 1 chill-unit is when the tree is exposure below 7.2°C. When the temperature is between 15.1°C and 26.6°C, there isn't accumulation of chill-unit. The chill-units accumulation is negative when occurs temperature above 26.7°C, and the chill-unit is -1 when occurs temperature above 27.8°C.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

References

LU, M. T. et al. 2012. A model for estimating chilling requirement of very low-chill peaches in Taiwan. Acta Horticulturae, n. 962, p. 245.

Examples

```
x <- rnorm(500, 20, 7)
taiwan_model(x)
taiwan_model(x, FALSE)
```

`unified_model` *Unified Model*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
unified_model(x, a = 0.89, b = -28.87, c = -19.44, total = TRUE)
```

Arguments

`x`	Vector containing temperature values (Celsius-degree).
`a`	Parameter defined by the user as the function limits. Default is 0.89.
`b`	Parameter defined by the user as the function limits. Default is -28.87.
`c`	Parameter defined by the user as the function limits. Default is -19.44.
`total`	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The coefficients used in this model are adjusted for the apple tree.The model is based on chill-units, but the limits are unknown.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

References

Chuine, I. et al. 2016. Can phenological models predict tree phenology accurately in the future? The unrevealed hurdle of endodormancy break. Global Change Biology.

Chuine, Isabelle. 2000. A unified model for budburst of trees. Journal of Theoretical Biology

Examples

```
x <- rnorm(500,10,3)
unified_model(x)
unified_model(x, total = FALSE)
```

utah_model *Utah Model*

Description

Quantifies the chill accumulation by means of converting temperatures to chill-units.

Usage

```
utah_model(x, total = TRUE)
```

Arguments

x	Vector containing temperature values (Celsius-degree).
total	TRUE Shows the total value of accumulation, FALSE shows the value of chill-unit for each temperature (TRUE is default).

Details

The model is based on chill-units, where 1 chill-unit is when the tree is exposure between 2.4°C and 9.1°C, being the optimum temperature 6°C . When the temperature is between 9.1°C and 12.4°C, the chill-unit is 0.5. The chill-units accumulation is 0 when occurs temperature below 1.4 and between 12.5°C and 15.9°C. When the temperature is between 16°C and 18°C, the chill-unit is -0.5. When the temperature is above 18°C, the chill-unit is -1.

Value

The function returns values the chill-units for each temperature of vector (Total = FALSE), or returns the chill-units accumulation (Total = TRUE).

References

Richardson, E, A. et al. 1974. "A Model for Estimating the Completation of Rest for 'Redhaven' and 'Elberta' Peach Trees". Research Reports & Notes.

Examples

```
x <- rnorm(500, 5, 3)
utah_model(x)
utah_model(x, FALSE)
```

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