Package ‘BIOdry’

April 20, 2017

Type Package

Title Multilevel Modeling of Dendroclimatical Fluctuations

Version 0.5

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Date 2017-04-19

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Description Multilevel ecological data series (MEDS) are sequences of observations ordered according to temporal/spatial hierarchies that are defined by sample designs, with sample variability confined to ecological factors. Dendroclimatic MEDS of tree rings and climate are modeled into normalized fluctuations of tree growth and aridity. Modeled fluctuations (model frames) are compared with Mantel correlograms on multiple levels defined by sample design. Package implementation can be understood by running examples in modelFrame(), and muleMan() functions.

License GPL-3

Depends nlme, ecodist

LazyData TRUE

NeedsCompilation no

Repository CRAN

Date/Publication 2017-04-20 08:42:57 UTC

R topics documented:

`BIOdry-package` *Multilevel Modeling of Dendroclimatical Fluctuations*

Description

Multilevel ecological data series (MEDS) are sequences of observations ordered according to temporal/spatial hierarchies that are defined by sample designs, with sample variability confined to ecological factors. Dendroclimatic MEDS of tree rings and climate are modeled into normalized fluctuations of tree growth and aridity. Modeled fluctuations (model frames) are compared with Mantel correlograms on multiple levels defined by sample design. Package implementation can be understood by running examples in modelFrame(), and muleMan() functions.

Details

The DESCRIPTION file:

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Type:	Package
Title:	Multilevel Modeling of Dendroclimatical Fluctuations
Version:	0.5
Author:	Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>
Date:	2017-04-19
Maintainer:	Wilson Lara <wilarhen@gmail.com>
Description:	Multilevel ecological data series (MEDS) are sequences of observations ordered according to temporal/spatial l
License:	GPL-3
Depends:	nlme, ecodist
LazyData:	TRUE

Index of help topics:

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                        precipitations and monthly average temperatures
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Prings05                Multilevel data set of P. pinaster
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anova.modelFrame        Compare modelFrame objects
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lmeForm                 LME formula
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slitFrame               Multilevel splitting
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wlai                    Walter-Lieth aridity index
```

Maintainer: Wilson Lara <wilarhen@gmail.com>

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

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amod *Allometric scaling.*

Description

Allometric models and parameters are used to scale organic growth.

Usage

```
amod(x, mp = c(1, 1), fun = y ~ a * (x^b))
```

Arguments

`x`	`numeric` vector.
`mp`	`numeric`. Allometric parameters. Default `c(1,1)` (see details).
`fun`	`formula`. Allometric model. To properly specify other formulas, the variables (e.g. x and y) should belong to `letters[20:26]`.

Details

. Allometric models are useful to scale size-components of organisms such as tree diameters (mp = `c(2,1)`) and basal areas (mp = `c(0.25 * pi,2)`). Several parameter groups (`c(a1,b1,a2,b2, ..., an,bn)`) can be recursively processed. This enables computation of complex organic variables. For example, above-ground tree biomass could be computed from two parameter groups for tree-biomass, and over-bark diameter scaling.

Value

`data.frame` of the scaled variable (x) and relative increments (csx). These are computed with `setdiff` function.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
## Simulating TRW records:
set.seed(1)
trw <- ts(abs(rnorm(12,1,1)),start = 1950)
## Cumulative TRW:
cri <- cumsum(trw)
## tree diameters
td <- amod(cri,mp = c(2,1))
## plot of the tree diameters and the
## relative increments:
plot(ts(td))
```

`anova.modelFrame` *Compare modelFrame objects*

Description

Models in `modelFrame` lists are compared with `anova.lme` method.

Usage

```
## S3 method for class 'modelFrame'
anova(object, ..., test, type, adjustSigma, Terms,
    L, verbose)
```

Arguments

`object`	an object inheriting from class "modelFrame".
`...`	other optional fitted model objects inheriting from classes "modelFrame", "lme", "lm", among other (see `anova.lme`).
`test`	optional character string specifying the type of sum of squares to be used in F-tests for the terms in the model (see `anova.lme`).
`type`	optional character string specifying the type of sum of squares to be used in F-tests for the terms in the model (see `anova.lme`).
`adjustSigma`	If TRUE and the estimation method used to obtain object was maximum likelihood, the residual standard error is multiplied by sqrt(nobs/(nobs - npar)), converting it to a REML-like estimate (see `anova.lme`).
`Terms`	optional integer or character vector specifying which terms in the model should be jointly tested to be zero using a Wald F-test (see `anova.lme`).
`L`	optional numeric vector or array specifying linear combinations of the coefficients in the model that should be tested to be zero (see `anova.lme`).
`verbose`	optional logical value. If TRUE, the calling sequences for each fitted model object are printed with the rest of the output, being omitted if verbose = FALSE (see `anova.lme`).

Value

data frame inheriting from class "anova.lme".

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Lara W., F. Bravo, D. Maguire. 2013. Modeling patterns between drought and tree biomass growth from dendrochronological data: A multilevel approach. Agric. For. Meteorol., 178-179:140-151.

Examples

```
##TRW chronology (mm) and inside-bark radii
data(Pchron,envir = environment())

## Parameters of allometric model to compute Diameter at Breast
## Height over bark (DBH, cm) from diameter inside bark (dib, cm)
## and Total Tree Biomass (TTB, kg tree -1 ) from DBH (Lara
## et. al. 2013):
```

```
biom_param <- c(2.87, 0.85, 0.05, 2.5)

## Modeling tree-biomass fluctuations while accounting for
## within-plot source variability (see defaults in "modelFrame"
## function)
trwf <- modelFrame(Pchron,
                   to = 'cm',
                   MoreArgs = list(mp = c(2,1, biom_param)),
                   log.t = FALSE,
                   on.time = FALSE)

## Fitting a single linear regression of the "tdForm" formula
## without random effects to the tree-biomass data:
trwfl <- lm(log(x) ~ log(csx) + year,
            data = trwf$'model'$'data')
## Comparing model likelihoods with anova method:
anova(trwf, trwfl)
```

`arguSelect` *Argument selection*

Description

Arguments of specific functions are selected from arbitrary numbers and varieties of arguments.

Usage

```
arguSelect(rd = NULL, fun = c("mapply", "ringApply"), ...)
```

Arguments

`rd`	`NULL` or `data.frame`. Multilevel ecological data series. If `NULL` then this argument is ignored.
`fun`	`character` or `NULL`. Vector of function names.
`...`	Further arguments not necessarily contained in the processed function(s).

Details

Closures with ellipsis terms use this function to extract and pass arguments to other functions. Arguments in `MoreArgs` lists are also extracted and stored again as `MoreArgs` lists.

Value

`list` of selected arguments.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##Multilevel ecological data series of tree-ring widths:
data(Prings05,envir = environment())
## Radial increments measured on 2003:
data(Pradii03,envir = environment())

## Selection of arguments in some functions:
ar1 <- arguSelect(fun = c('amod'),
                  only.dup = TRUE,
                  mp = c(0.5,1),
                  rf.t = 2003)
str(ar1)

ar2 <- arguSelect(fn = 'amod',
                  only.dup = TRUE,
                  mp = c(0.5,1),
                  rf.t = 2003)
str(ar2)
ar3 <- arguSelect(rd = Prings05,
                  fn = 'amod',
                  only.dup = TRUE,
                  mp = c(0.5,1),
                  rf.t = 2003)
str(ar3)

ar4 <- arguSelect(rd = Prings05,
                  fun = 'scacum',
                  sc.c = Pradii03,
                  MoreArgs = list(only.dup = TRUE,
                                  mp = c(0.5,1),
                                  rf.t = 2003))
str(ar4)

ar5 <- arguSelect(rd = Prings05,
                  fun = 'scacum',
                  ref = Pradii03,
                  rf.t = rep(2003:2011),
                  MoreArgs = list(only.dup = TRUE,
                                  mp = c(0.5,1)))
str(ar5)
```

`cClass` *Column-class extraction.*

Description

Column names of multilevel data sets are extracted according to three classes: `numeric` values, `integer` sequences, and `factor` levels.

Usage

```
cClass(rd, cl = "all")
```

Arguments

`rd`	`data.frame`. Multilevel data series.
`cl`	`character` or `NULL`. Character vector of classes to be considered. These can be 'numeric', 'integer', or 'factor'. If `'all'` then all column names of `rd` are extracted.

Value

`character` names.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##Multilevel data frame of tree-ring widths:
data(Prings05,envir = environment())
## Names of variables in Prings05 data containing numeric classes:
cClass(Prings05, 'numeric') # 'x'
## Names of variables containing time units:
cClass(Prings05, 'integer') # 'year'
## Names of variables containing factors:
cClass(Prings05, 'factor') # 'sample', 'tree', 'plot'
```

---

frametoLme *LME modeling*

Description

LME models are fitted to detrend multilevel ecological data series.

Usage

```
frametoLme(rd, form = "lmeForm", res.data = TRUE, ...)
```

Arguments

`rd`	`data.frame`. Multilevel ecological data series.
`form`	`character`. Any of two lme formulas: 'lmeForm' and 'tdForm' (see details).
`res.data`	`logical`. Save residuals as a multilevel ecological data series. If TRUE then a data frame of name 'fluc' is added to output list.
`...`	Further arguments to be passed to `lme` function or to the lme formula in `form`.

Details

This function implements lme function to fit linear mixed-effects models on multilevel ecological data series processed by the modelFrame function. Two kind of model formulas can be fitted: 'lmeForm' and 'tdForm'; these characters implement functions with same names (tdForm and lmeForm). Other lme formulas can be specified by modifying arguments in any of these two functions. After the lme models are fitted, they can be extended by implementing methods in nlme package.

Value

groupedData object.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Pinheiro J. C., D. M. Bates. 2000. Mixed-effects models in S and S-PLUS. Springer, New York.

Examples

```
##Multilevel data frame of tree-ring widths:
data(Prings05,envir = environment())
## Radial increments measured on 2003:
data(Pradii03,envir = environment())
## Monthly precipitation sums and average temperatures:
data(PTclim05,envir = environment())

##Modeling TRW fluctuations:
mpin <- modelFrame(Prings05,
                   sc.c = Pradii03,
                   rf.t = 2003)

## Detrending the TRW fluctuations by fitting a (l)td-form model
## with Maximum-likelihood method (ML):
pdata <- mpin$'model'$'data'
rlme <- frametoLme(pdata,
                   form = 'tdForm',
                   method = 'ML',
                   log.t = TRUE)
summary(rlme$model)

##a plot of the modeled fluctuations
d <- groupedData(lmeForm(rlme$fluc,lev.rm = 1),data = rlme$fluc)
plot(d,groups = ~ sample,auto.key = TRUE)

## A model of aridity:
cf <- modelFrame(PTclim05,
                 lv = list('year','year'),
                 fn = list('moveYr','wlai'),
```

```
                 form = NULL)
summary(cf)

## An lme model of aridity at 'plot' level:
cdata <- cf$'model'$'data'
rmod <- frametoLme(cdata,form = 'lmeForm')
summary(rmod$model)

rk <- groupedData(lmeForm(rmod$fluc),data=rmod$fluc)
plot(rk,ylab = 'detrended AI')
```

---

levexp *Vector releveling*

Description

Expansion or reduction of a numeric vector by matching its level names with the ecological factors of a multilevel ecological data series.

Usage

```
levexp(x, levels)
```

Arguments

x	numeric vector with names of the vector representing the levels to be matched.
levels	data.frame. Multilevel ecological data series, or character vector of levels.

Value

numeric vector with expanded/reduced levels.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##Multilevel ecological data series of tree-ring widths:
data(Prings05,envir = environment())
## tree radii measured at 2003:
data(Pradii03,envir = environment())

## Releveling the tree radii
refs <- levexp(Pradii03,Prings05)
refs
```

`lmeForm` *LME formula*

Description

This function computes LME formulas from multilevel ecological data series (MEDS).

Usage

```
lmeForm(rd, prim.cov = FALSE, resp = NULL, covar = NULL, lev.rm = NULL)
```

Arguments

`rd`	`data.frame`. Multilevel ecological data series
`prim.cov`	`Logical`: should the LME formula only be printed in primary covariate form: '~ cov'? If FALSE then a complete form: 'resp ~ covar | group' is formulated.
`resp`	`NULL` or `character`. Column name of the response. If NULL then the name of the first numeric column of the MEDS is used.
`covar`	`NULL` or `character`. Column name(s) of the covariate(s). If `NULL` then the name of the first time-unit column in the MEDS is used.
`lev.rm`	`NULL`, `character` or `numeric` vector of levels in the MEDS to be removed from the groups.

Details

Formulas of the form `resp ~ cov | group` (see `groupedData` function) are computed from MEDS. The formulas can be implemented by `modelFrame` function to detrend MEDS

Value

`formula` with any of the forms: `resp ~ cov | group` or `~ cov`.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Pinheiro J. C., D. M. Bates. 2000. Mixed-effects models in S and S-PLUS. Springer, New York.

Examples

```
##Multilevel ecological data series of tree-ring widths:
data(Prings05,envir = environment())

## LME formula:
form1 <- lmeForm(Prings05,prim.cov = FALSE)
print(form1)
## removing the sample level from the formula
form2 <- lmeForm(Prings05,lev.rm = 'sample')
form2 <- lmeForm(Prings05,lev.rm = 1)

## groupedData object with the LME formula
gdata <- groupedData(lmeForm(Prings05,lev.rm = 1),
                     data = Prings05)
plot(gdata,groups = ~ sample)
```

---

modelFrame *Dendroclimatic-fluctuations modeling*

Description

This function develops recursive evaluation of functions for one-level modeling (FOLM) and LME detrending of dendroclimatic chronologies.

Usage

```
modelFrame(rd, fn = list("rtimes", "scacum", "amod"), lv = list(2,
    1, 1), form = "tdForm", ...)
```

Arguments

rd	data.frame or list. Dendroclimatic chronology or Multilevel ecological data series.
fn	list. Names of the functions for one-level modeling to be recursively implemented.
lv	list. numeric positions in the factor-level labels of rd to implement the one-level functions. If rd is a MEDS, then character names of the factor-level columns.
form	character or NULL. Name of a detrending formula. Two in-package methods are available: the default tdForm or lmeForm.
...	Further arguments in mUnits, or in the functions for one-level modeling, or in the lme function/methods, or in the detrending formula.

Details

Defaults model fluctuations in tree-ring width chronologies via recursive implementation of four FOLM: rtimes, scacum, amod, and frametoLme. Nevertheless, other FOLM can be implemented to model aridity-index fluctuations(see example with climatic data). Processed chronologies are detrended with lme function and other nlme methods . Internal algorithm uses shiftFrame arguSelect and ringApply functions. Consequently, arguments that are not iterated over factor-level labels in the processed data are specified in 'MoreArgs' lists (see examples). Arguments in modelFrame objects can be updated with update function.

Value

Threefold list with fluctuations in fluc, groupedData object in model, and model call in call.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Lara W., F. Bravo, D. Maguire. 2013. Modeling patterns between drought and tree biomass growth from dendrochronological data: A multilevel approach. Agric. For. Meteorol., 178-179:140-151.

Examples

```
    ##TRW chronology (mm) and inside-bark radii
data(Pchron,envir = environment())
data(Pradii03,envir = environment())
## Tree-ring width fluctuations:
trwf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                   log.t = TRUE)
summary(trwf$'model')

## Tree-diameter fluctuations:
tdf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                  log.t = TRUE,
                  MoreArgs = list(mp = c(pi,2)))

summary(tdf$'model')


## Climatic records:
data(Temp,envir = environment())
data(Prec,envir = environment())
## Aridity-index fluctuations:
aif <- modelFrame(rd = list(Prec, Temp),
                  fn = list('moveYr','wlai'),
                  lv = list('year','year'),
```

```
                  form = 'lmeForm')
summary(aif$'model')
```

---

moveYr *Seasonal years*

Description

Monthly records in time-series replicates (usually of climate) are labeled for the years can begin in a month other than January.

Usage

```
moveYr(cd, ini.mnt = "Oct")
```

Arguments

cd	data.frame. Multilevel ecological data series or numeric vector of repeated years with vector names belonging to month.abb.
ini.mnt	character, or numeric from 1 to 12. Initial month of the seasonal year. If character then the months are built-in constants in R-package base. Default 'Oct' makes the years begin in October, for example.

Details

character months as defined in month.abb or month.name.

Value

data.frame object with the months being numeric values and the years beginning at ini.mnt argument.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
## Climatic records of monthly precipitation sums and monthly
## average temperatures
data(PTclim05,envir = environment())

## Making the year 1955 in plot 'P16106' to begin on 'April'
cl1 <- slitFrame(PTclim05,c('year','plot'))[[1]]
cl2 <- moveYr(cl1,ini.mnt = 'Mar')
head(cl2)

## a simple vector of years
yr <- rep(2005,12)
```

```
names(yr) <- month.abb[1:12]
moveYr(yr)
```

---

muleMan *Multilevel dendroclimatic correlograms*

Description

Multivariate correlograms between TRW fluctuations and climatic fluctuations.

Usage

```
muleMan(rd, cd, rd.var = NULL, cd.var = NULL, ...)
```

Arguments

rd	`dataframe` or `groupedData`. TRW fluctuations such as that produced by `modelFrame`.
cd	`dataframe` or `groupedData`. Aridity-index fluctuations such as that produced by `modelFrame`.
rd.var	`character` or `NULL`. Column name of the TRW fluctuations to be compared. If `NULL` then the first column is processed.
cd.var	`character` or `NULL`. Column name of the aridity-index fluctuations to be compared. If `NULL` then the first column is used.
...	Further arguments in `mgram`

Details

Function `mgram` in package `ecodist` is implemented to compare the dendroclimatic fluctuations. Models being compared should have common higher-level factors (see example).

Value

`data.frame` object of multivariate correlations.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Lara W., F. Bravo, D. Maguire. 2013. Modeling patterns between drought and tree biomass growth from dendrochronological data: A multilevel approach. Agric. For. Meteorol., 178-179:140-151.

Examples

```
##TRW chronology (mm) and inside-bark radii
data(Pchron,envir = environment())
data(Pradii03,envir = environment())
## TRW fluctuations:
trwf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                   log.t = TRUE)
## Climatic records:
data(Temp,envir = environment())
data(Prec,envir = environment())
## Aridity-index fluctuations:
aif <- modelFrame(rd = list(Prec, Temp),
                  fn = list('moveYr','wlai'),
                  lv = list('year','year'),
                  form = 'lmeForm')

##Multivariate comparison:
mcomp <- muleMan(trwf,
                    aif,
                 nperm = 10^3)
str(mcomp)
```

---

mUnits *Metric system*

Description

This function control metric units.

Usage

```
mUnits(x, from = "mm", to = "mm")
```

Arguments

x	numeric vector.
from	character. Initial metric unit.
to	character. Final metric unit.

Details

Characters in from and to arguments have the form ’p_’, where ’p’ is the metric prefix and ’_’ is a base unit. Sixteen metric prefixes are supported: atto ’a’, femto ’f’, pico ’p’, nano ’n’, micro ’mm’, mili ’m’, centi ’c’, deci ’d’, deca ’da’, hecto ’h’, kilo ’k’, mega ’M’, giga ’G’, tera ’T’, peta ’P’, and exa ’E’.

Value

`numeric` vector.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
## Simulation of TRW data
set.seed(1)
w <- abs(rnorm(12,1,1))
trw <- ts(w,start = 1970)
## transforming metric units of trw vector from milimeters to meters
sr <- mUnits(trw, from = 'mm', to = 'm')
attributes(sr)
```

`Pchron` *Tree-ring width (TRW) chronology*

Description

TRW chronology for Pinus pinaster forests from two sample plots in northern Spain (Soria) and east-central Spain (Cuenca). The data set contains eight TRW series. To account for source variability, two trees were selected per site, and two samples were extracted from each tree.

Usage

```
data(Pchron)
```

Format

`data.frame` object with eight columns.

Row names of the data set are time-units labels (years of formation).

Column names represent levels in three within-stand ecological factors that are common to most TRW data and represent variability in stand qualities (stand), tree-radial morphology (sample), and tree genetics/phenotypes (tree). The names are dot-separated labels representing the hierarchy of the three ecological factors, where higher ecological-factor levels are defined first and lower levels after. For example, code 'P16106.17.a' is the column name of sample replicate 'a' in tree '17' in plot 'P16106'.

Details

This data set belongs to a more extensive tree-ring chronology which was processed in previous studies (Bogino and Bravo, 2008) by measuring TRW in polished-core samples (5 mm diameter) using the Windendro program and cross-dating the tree-ring chronologies using COFECHA software. Time units for the TRWs are formation years spanning from 1861 to 2005. The cross-dating records suggested that maritime pine chronologies had high SNR: (23-28 in northern Spain, and 38-61 in east-central Spain) and high EPS (0.96 in northern Spain, and 0.98 in east-central Spain).

References

Bogino, S., and Bravo, F. (2008). Growth response of Pinus pinaster Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65, 1-13.

Examples

```
str(Pchron)
```

---

plot.modelFrame *Plot modelFrame objects*

Description

Diagnostic Trellis plot for fluctuations in `modelFrame` objects are obtained.

Usage

```
## S3 method for class 'modelFrame'
plot(x, ...)
```

Arguments

`x`	An object inheriting from class `modelFrame`.
`...`	further arguments passed to the Trellis plot function.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##TRW chronology (mm) and reference inside-bark radii (mm)
##measured at 2003:
data(Pchron,envir = environment())
data(Pradii03,envir = environment())
## Tree-ring width fluctuations:
trwf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                   log.t = TRUE)
plot(trwf, grid = FALSE)
```

plot.muleMan *Plot muleMan objects*

Description

Diagnostic Trellis plot for fluctuations in muleMan objects are obtained.

Usage

```
## S3 method for class 'muleMan'
plot(x, ...)
```

Arguments

x	An object inheriting from class muleMan.
...	further arguments passed to the Trellis plot function.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##TRW chronology (mm) and inside-bark radii
data(Pchron,envir = environment())
data(Pradii03,envir = environment())
## TRW fluctuations:
trwf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                   log.t = TRUE)
## Climatic records:
data(Temp,envir = environment())
data(Prec,envir = environment())
## Aridity-index fluctuations:
aif <- modelFrame(rd = list(Prec, Temp),
                  fn = list('moveYr','wlai'),
                  lv = list('year','year'),
                  form = 'lmeForm')

##Multivariate comparison:
mcomp <- muleMan(trwf,
                    aif,
                    nperm = 10^3)

plot(mcomp, grid = FALSE)
```

plot.wlai *Plot an wlai object*

Description

A Walter-Lieth climate diagram is produced.

Usage

```
## S3 method for class 'wlai'
plot(x, ...)
```

Arguments

x	`vector` or `data.frame`. An object inheriting from class `wlai`, representing the Aridity Index.
...	`logical`. Further arguments passed to `plot` function.

Details

Areas between temperature and precipitation lines when precipitation exceeds temperature (moist seasons) are plotted in gray color, and areas where temperature exceeds precipitation (dry seasons) are plotted in black color. Monthly cumulative precipitations over 100 mm are scaled such that 1 degree C of average temperature is equal to 5 mm of precipitation.

Value

A `plot` of the Walter-Lieth diagram.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Manrique E., A. Fernandez-Cancio. 2000. Extreme climatic events in dendroclimatic reconstructions from Spain. Clim. Chang., 44: 123-138.

Examples

```
##random simulation of climatic records
set.seed(1)
pr <- rnorm(12,1,1)
tm <- rnorm(12,0,1)
cld <- data.frame(pr,tm)
##labels of months from october to september
rownames(cld) <- month.abb[c(10:12,1:9)]
rownames(cld) <- c(10:12,1:9)
```

```
##computation of the aridity index and climate diagram
AI <- wlai(cld)
plot.wlai(AI)
```

Pradii03 *Vector of radii measured on P.pinaster*

Description

Vector of radii measured in dominant trees of P.pinaster (2003) growing on the Ebro river basin, Spain

Usage

```
data(Pradii03)
```

Format

A numeric vector with names of the vector indicating the measured tree.

Details

This vector contains inside-bark radii, measured in four trees during 2003 (mm). This radial vector was derived from the over-bark diameters at breast height (cm), with allometric estimation of inside-bark diameters from the over-bark diameters. Names of the vector correspond to labels at tree level

Source

Sustainable Forest Management Research Institute, Universidad de Valladolid (UVa)-INIA.

Examples

```
str(Pradii03)
```

Prec *Cumulative precipitations*

Description

Monthly cumulative precipitation (mm).

Usage

```
data(Prec)
```

Format

`data.frame` object with 24 records.

Column names contain plot codes and monthly abbreviations

Details

Recorded months begin at January and end at December, and observed years span from 1951 to 2005. Factor in data set defines one sample level (plot)

References

Bogino, S., and Bravo, F. (2008). Growth response of Pinus pinaster Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65, 1-13.

Examples

```
str(Prec)
```

Prings05 *Multilevel data set of P. pinaster*

Description

Radial increments of Pinus pinaster from two sample plots located on Northern and Southern portions of Ebro river basin, Spain.

Usage

```
data(Prings05)
```

Format

A data frame with the following 5 variables.

`x` A numeric vector with the radial increments in mm year-1

`year` A numeric vector with the recorded year

`sample` A factor indicating the sample replicate

`tree` A factor indicating the tree number

`plot` A factor indicating the plot code

Details

This data set contains eight series of tree-ring widths of maritime pine (Pinus pinaster), with recorded years spanning from 1810 to 2005. The cores were sampled from dominant trees of two sites, with sample plots being located on both: northern Spain (plot code: P44005) and center-east portion of the same country (plot code: P16106). Two trees were selected by plot, and two core samples were extracted by tree. Consequently, the sample design defined three levels: sample in tree on plot (plot level), sample in tree (tree level), and sample level.

References

Bogino, S., and Bravo, F. (2008). Growth response of Pinus pinaster Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65, 1-13.

Examples

```
str(Prings05)
```

PTclim05 *Multilevel data set of monthly cumulative precipitations and monthly average temperatures*

Description

Monthly precipitation sums and average temperatures of two climatic locations.

Usage

```
data(PTclim05)
```

Format

A data frame with the following 5 variables.

`pr` A numeric vector with the monthly cumulative precipitations (mm month-1)

`tm` A numeric vector with the monthly average temperatures (degree C month-1)

`month` A numeric vector of months

`year` A numeric vector of years

`plot` A factor vector of plot codes

Details

Recorded months begin at January and end at December, and observed years span from 1951 to 2005. Factor in data set defines one sample level (plot)

References

Bogino, S., and Bravo, F. (2008). Growth response of Pinus pinaster Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65, 1-13.

Examples

```
str(PTclim05)
```

ringApply *Multilevel apply*

Description

Wrapper of Map to apply functions on multilevel data series and preserve factor-level structure in the outputs.

Usage

```
ringApply(rd, lv = 1, fn = "scacum", ...)
```

Arguments

rd	data.frame. Multileve ecological data series.
lv	numeric position, or character name, of an ecological factor in the processed MEDS.
fn	character name of the function to be evaluated (see details). Default 'scacum' computes scaled-cumulative radii.
...	Further arguments in the function being specified fn argument (see details)

Details

Other functions such as rtimes, scacum, amod, or wlai can be implemented. Function arguments should be formulated as suggested in mapply, with constant arguments being stored in a MoreArgs list. This function is implemented by modelFrame for recursive modeling of MEDS.

Value

data.frame object preserving initial factor-level columns.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Lara, W., F. Bravo, D. Maguire. 2013. Modeling patterns between drought and tree biomass growth from dendrochronological data: A multilevel approach. Agric. For. Meteorol., 178-179:140-151.

Examples

```
##Multilevel ecological data series (MEDS) of tree-ring widths:
data(Prings05,envir = environment())
## Radial increments measured on 2003:
data(Pradii03,envir = environment())
## MEDS of monthly precipitation sums and average temperatures:
```

```
data(PTclim05,envir = environment())

##Tree-level scaling of years of formation
##with 'rtimes' function:
dfm1 <- ringApply(Prings05,
                  lv = 2,
                  fn = 'rtimes')
str(dfm1)
##Relative time-units from year 1 to year 9:
subset(dfm1,time%in%c(1:9,NA))

## Sample-level scaling of TRW chronologies around reference radii
## which were measured at 2003:
dfm2 <- ringApply(dfm1,
                  lv = 'sample',
                  sc.c = Pradii03,
                  rf.t = 2003,
                  fn = 'scacum')
str(dfm2)
##Sample-level modeling of basal areas (mm2) via allometric
##scaling:
dfm3 <- ringApply(dfm2,
                  lv = 'sample',
                  fn = 'amod',
                  MoreArgs = list(mp = c(2,1,0.25 * pi,2)))
str(dfm3)

## Seasonal years from 'October' to 'September':
cl1 <- ringApply(PTclim05,
                 lv = 'year',
                 fn = 'moveYr')
tail(cl1,15)

##Year-level aridity indexes:
wl <- ringApply(cl1,
                lv = 'year',
                fn = 'wlai')
str(wl)

## Plot of aridity-index fluctuations:
d <- groupedData(lmeForm(wl),wl)
plot(d)
```

`rtimes` *Time-units synchronization*

Description

Unique observations in time-series replicates are excluded

Usage

```
rtimes(x, only.dup = TRUE)
```

Arguments

`x`	multilevel ecological data series containing a column of time units, or `numeric` vector with names representing the time units.
`only.dup`	`logical`. Extract only duplicated times. If TRUE then unique times are replaced with NA. If all computed times are unique then this argument is ignored.

Value

`data.frame` object with the initial vector and its time units.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
## row names of a vector
fy <- function(y,span){(y - span):y}
x <- c(fy(2005,5),fy(2007,10))
## (not run) Simulating the vector
r <- abs(rnorm(length(x)))
names(r) <- x
## (not run) computing the synchronized times:
rtimes(r,only.dup = TRUE)
## (not run) Extracting only duplicated times:
na.omit(rtimes(r,only.dup = TRUE))
```

`scacum` *Cummulative-scaled sums*

Description

This function computes cummulative and scaled sums of time-series replicates.

Usage

```
scacum(x, sc.c = NA, rf.t = NA)
```

Arguments

x	`numeric` vector of time-series replicates with names of the vector being time units.
sc.c	`numeric` constant. Scaling constant. If `NA` then the computed cumulative sums are not scaled.
rf.t	`NA`, or `numeric` constant. Reference time of the scaling constant. If `NA` then maximum time in vector-name range is used.

Details

Cummulative sums of time-series replicates (e.g. tree-ring widths) are scaled around reference values (e.g. tree radii).

Value

data frame with the original vector, and its scaled-cummulative sums.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
x <- c(0.79,0.32,0.53,0.43,0.18)
names(x) <- 1948:1952
scacum(x,sc.c = 4,rf.t = 1951)

##If sc.c = NA then cummulative values are scaled arround
##max(cumsum(x)):
max(cumsum(x))
scacum(x,NA,1951)
```

`shiftFrame` *MEDS formatting*

Description

dendroclimatic chronologies (trw, and climatic data) are formatted into multilevel ecological data series. SI units of continuous variables in the data can be transformed.

Usage

```
shiftFrame(rd, f.nm = NULL, x.nm = names(rd)[1L], t.nm = "year",
    ...)
```

Arguments

- `rd` — `data.frame` or `list`. Dendroclimatic chronology DC (see details) or list of two DCs (e.g. precipitation and temperature records), or multilevel ecological data series (MEDS).
- `f.nm` — `character` vector. In the case of formatting ring-data frames, column names of the factors in the new MEDS. If `NULL` then this argument is recycled from attributes in `rd`. If such an attribute is also `NULL` then a sequence of codes (F1, F2, ..., Fn) is used.
- `x.nm` — `character`. In the case of formatting MEDS, name of the variable to be reshaped. Default uses name of first variable of `rd`.
- `t.nm` — `character`.In the case of formatting MEDS, name of the time-units variable .
- `...` — Further arguments in `mUnits`.

Details

Row names of dendroclimatic data frames are time units (e.g. years). Column names are dot-separated labels representing the hierarchy of ecological or time-units factors, where the higher levels are defined first and the lower levels after. For example, code 'P16106.17' is the column name of core 'a' in tree '17' in plot 'P16106'. Labels containing monthly abbreviations are also formatted.

Value

When `rd` argument is a dendroclimatic chronology (see details) then the output is a `groupedData` object, and viceversa.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##tree-ring widths formated as a groupedData object:
data(Prings05,envir = environment())

## Formatting the groupedData object into a ring-data frame:
pwide <- shiftFrame(Prings05, from = 'mm', to = 'mmm')
str(pwide)
## Formatting the ring-data frame into a groupedData object, and
## changing SI units from micrometers to milimeters:
plong <- shiftFrame(pwide,from = 'mmm', to = 'mm')
plot(plong)
```

slitFrame *Multilevel splitting*

Description

This function splits a Multilevel data frame into factor levels.

Usage

```
slitFrame(rd, lv = cClass(rd, "factor"))
```

Arguments

rd	`data.frame` object with factor-level columns.
lv	`Numeric` or `character`. Position number in the factor-level columns of `rd`, or correspondant column name to split the data. If the spliting column is not a factor, the character name of the column should be used.

Value

`list` of `data.frame` objects.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
##Ring data frame:
##Multilevel data frame of tree-ring widths:
data(Prings05, envir = environment())
data(PTclim05, envir = environment())
## split multilevel data into its second factor-level column:
spl <- slitFrame(Prings05)
str(spl)
## split the data into the factor-level: 'year':
spl <- slitFrame(Prings05,'year')
str(spl)
spl <- slitFrame(PTclim05,'year')
str(spl)
```

summary.modelFrame *summarize a modelFrame object*

Description

A summary of a modelFrame object is obtained.

Usage

```
## S3 method for class 'modelFrame'
summary(object, ...)
```

Arguments

object	an object inheriting from class modelFrame.
...	additional optional arguments passed to summary.lme method.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

Examples

```
## An object from class \code{\link{summary.lme}}.
data(Pchron,Pradii03,envir = environment())
## Tree-ring width fluctuations:
trwf <- modelFrame(Pchron,
                   sc.c = Pradii03,
                   rf.t = 2003,
                   log.t = TRUE)
summary(trwf)
```

tdForm *ltd formulas*

Description

This function formulates linear time-decline formulas (ltd) from categorical variables in multilevel ecological data series.

Usage

```
tdForm(rd, prim.cov = FALSE, on.time = TRUE, log.t = FALSE, lev.rm = NULL)
```

Arguments

rd	`data.frame` or `character` vector. Multilevel ecological data series or vector of ecological factors.
prim.cov	`logical`. Print a primary covariate form: `'~ cov'`. If FALSE then a complete formula: `'resp ~ cov	group'` is printed.
on.time	`logical`. If TRUE then `t = 'time'` (see `rtimes`). If FALSE then `t = 'year'`.
log.t	`logical`. If TRUE then `f(time) = ln(time)`. Default FALSE produces a log-linear time-decline formula.
lev.rm	NULL or `character` name of the ecological factor(s) in the MEDS to be removed from the formula.

Details

the ltd formulas belong to following general equation: log (x) = log (csx) + f(time); where the relative organic growth (x) is explained by the cumulative organic growth (csx) plus a function of time f(time); with f(time) being either the time or a logarithmic transformation the time. The ltd can be implemented by `modelFrame` function to subtract trends in organic MEDS

Value

`formula` with the forms: 'resp ~ cov | group' or '~ cov'.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Zeide B. 1993. Analysis of Growth Equations. For. Sci., 39: 594-616.

Examples

```
## an ltd formula:
lev <- c('plot','tree')
tdeq <- tdForm(lev,log.t = TRUE)
tdeq
## (not run) only primary covariate:
tdeq1 <- tdForm(lev,prim.cov = TRUE)
tdeq1
##Multilevel data frame of tree-ring widths:
data(Prings05,envir = environment())
## removing two levels: 'plot' and 'tree' from the formula
tdea2 <- tdForm(Prings05, lev.rm = c('plot','tree'))
tdea2 <- tdForm(Prings05, lev.rm = 2:3)
```

`Temp` *Average temperatures*

Description

Monthly average temperatures (degree C).

Usage

```
data(Temp)
```

Format

`data.frame` object with 24 records.

Column names contain plot codes and monthly abbreviations

Details

Recorded months begin at January and end at December, and observed years span from 1951 to 2005. Factor in data set defines one sample level (plot)

References

Bogino, S., and Bravo, F. (2008). Growth response of Pinus pinaster Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65, 1-13.

Examples

```
str(Temp)
```

`wlai` *Walter-Lieth aridity index*

Description

Computing the annual aridity index from Walter-Lieth climate diagrams

Usage

```
wlai(cd, sqt = TRUE)
```

Arguments

`cd`	`data.frame`. Multilevel climatic data series of monthly precipitation sums (mm), and monthly average temperatures (degree C), with row names being monthly characters in `month.abb` or `month.name`.
`sqt`	`logical`. Print the square root of the aridity index. If TRUE then computed aridity index is normalized with a square root transformation.

Details

Areas between temperature and precipitation lines when precipitation exceeds temperature are calculated as indicators of moist seasons, and areas where temperature exceeds precipitation are calculated as indicator of dry season. The aridity index is defined as the quotient between the areas of dry and wet seasons. Those precipitations over 100 mm are scaled such that 1 degree C is equal to 5 mm.

Value

`numeric` aridity index and plot of the Walter-Lieth diagram.

Author(s)

Wilson Lara <wilarhen@gmail.com>, Felipe Bravo <fbravo@pvs.uva.es>

References

Manrique E., A. Fernandez-Cancio. 2000. Extreme climatic events in dendroclimatic reconstructions from Spain. Clim. Chang., 44: 123-138.

Examples

```
##random simulation of climatic records
set.seed(1)
pr <- rnorm(12,1,1)
tm <- rnorm(12,0,1)
cld <- data.frame(pr,tm)
##labels of months from october to september
rownames(cld) <- month.abb[c(10:12,1:9)]
rownames(cld) <- c(10:12,1:9)
##computation of the aridity index and climate diagram
AI <- wlai(cld)
AI
```

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