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Title Quantitative Evaluation of the Native Fertility of Tropical Soils

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Imports meteor, methods, Rcpp (>= 0.12.4)

Suggests terra, limSolve

Description An implementation of the QUEFTS (Quantitative Evaluation of the Native Fertility of Tropical Soils) model. The model (1) estimates native nutrient (N, P, K) supply of soils from a few soil chemical properties; and (2) computes crop yield given that supply, crop parameters, fertilizer application, and crop attainable yield. See Janssen et al. (1990) <doi:10.1016/0016-7061(90)90021-Z> for the technical details and Sattari et al. (2014) <doi:10.1016/j.fcr.2013.12.005> for a recent evaluation and improvements.

License GPL (>= 3)

BugReports `https://github.com/cropmodels/Rquefts/issues`

URL `https://CRAN.R-project.org/package=Rquefts`

NeedsCompilation yes

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Contents

`Rquefts-package` *Quantitative Evaluation of the Native Fertility of Tropical Soils*

Description

This package provides implments the QUEFTS model.

QUEFTS (Quantitative Evaluation of the Native Fertility of Tropical Soils) model (1) estimates native nutrient (N, P, K) supply of soils from a few soil chemical properties; and (2) computes crop yield given that supply, fertilizer application and crop parameters. See Janssen et al. (1990) <doi:10.1016/0016-7061(90)90021-Z> for the technical details and Sattari et al. (2014) <doi:10.1016/j.fcr.2013.12.005> for a recent evaluation and improvements.

The package is particularly useful if you want to make spatial predictions with QUEFTS.

There are also a few functions that can help with computing the amount of nutriets supplied with fertilizer (blends) and compute the optimal use of fertilizer given a goal in nutrients, available products, and their prices.

`batch` *Batch QUEFTS model predictions*

Description

Make many predictions with a QUEFTS model.

Usage

```
## S4 method for signature 'Rcpp_QueftsModel'
batch(x, supply, fert, yatt, leaf_ratio, stem_ratio, var="yield")
```

Arguments

x	QUEFTSModel
supply	matrix or data.frame with soil nutrient supply data for N, P, and K
fert	matrix or data.frame with fertilizer nutrient supply data for N, P, and K
yatt	numeric. Attainable yield
leaf_ratio	positive numeric (typically between 0 and 1) indicating the leaf weight relative to the storage organ weight. For example: 0.46 for maize, 0.17 for potato, and 0.18 for rice
stem_ratio	positive numeric (typically between 0 and 1) indicating the stem weight relative to the storage organ weight, For example: 0.56 for maize, 0.14 for potato, and 0.67 for rice
var	character. Output variable name. Either "yield" or "gap"

Value

numeric or matrix (if `var="gap"`)

Examples

```
potato <- quefts_crop("potato")
q <- quefts(crop=potato)
fert=cbind(c(0,100), c(0,200), c(0,30))
supply=cbind(50,50,25)
yatt <- 10000
batch(q, supply, fert, yatt, 0.45, 0.4)

batch(q, supply, fert, yatt, 0.45, 0.4, var="gap")
```

---

fertApp — *Optimal fertilizer application*

Description

Compute the optimal fertilizer application rates given a target nutrient application and the available products (fertilizer blends) and their prices.

Usage

```
fertApp(nutrients, fertilizers, price, exact=TRUE, retCost=FALSE)
```

Arguments

`nutrients`	data.frame with columns "N", "P", "K" in kg (per unit area)
`fertilizers`	data.frame with fertilizer products (see examples)
`price`	numeric. Vector with fertilizer product prices. Should have length of `nrow(fertilizers)`
`exact`	logical. If `FALSE` the cheapest solution is returned that includes at least as much of each nutrient as desired, but possibly more, if that is cheaper than the exact solution; or when there is no exact solution
`retCost`	logical. If `FALSE` the optimal solution is returned (the amounts of fertilizers). If `TRUE`, the price of the optimal solution is returned

Examples

```
# fertilizer product list
fert <- fertilizers()
# shortening some of the names for display
fert[,2] = substr(fert[,2], 1, 20)
# contents are expressed as a percentage.
ferts <- fert[c(8,15:17), 2:5]
ferts

x <- fertApp(data.frame(N=100, P=50, K=50), ferts, c(1, 1.5, 1.25, 1))
# show that it is correct
nutrientRates(ferts, x[,2])

fertApp(data.frame(N=seq(0,200,50), P=50, K=50), ferts, c(1, 1.5, 1.25, 0.75))
fertApp(data.frame(N=seq(0,200,50), P=50), ferts[,-3], c(1, 1.5, 1.25, 0.75))
fertApp(data.frame(N=seq(0,200,50), P=50), ferts[,-3], c(1, 1.5, 1.25, 5.75))
```

`Fertilizers` *Helper functions to go from fertilizers to nutrients*

Description

Computes the amount of nutrients given a rate of fertilizer.

Usage

```
fertilizers()
nutrientRates(supply, treatment)
```

Arguments

`supply`	data.frame with columns "N", "P", "K" expressed as percentage of the product (row)
`treatment`	amounts applied

Examples

```
# fertilizer product list
fert <- fertilizers()
# shortening some of the names for display
fert[,2] = substr(fert[,2], 1, 20)
# contents are expressed as a percentage.
fert

myferts <- fert[c(8,15), ]
nutrientRates(myferts, c(100,50))
```

`nutSupply` *Soil nutrients supply for QUEFTS model*

Description

`nutSupply1` computes the base (unfertilized) soil supply of N, P and K according to Janssen et al. (1990), Table 2. For use with the QUEFTS model.

`nutSupply2` is a modified version following Sattari et al. (2014). It has an additional variable "temperature", and P-total is required. Sattari et al suggest that, for soils that have not been fertilized with P, you can estimate P-total as `95 * P-Olsen`. Using AfSIS data I found `55 * P-Olsen`.

Usage

```
nutSupply1(pH, SOC, Kex, Polsen, Ptotal=NA)
nutSupply2(temp, pH, SOC, Kex, Polsen, Ptotal)
```

Arguments

`temp`	average growing season temperature (C)
`pH`	soil pH (H2O)
`SOC`	soil organic carbon (g/kg)
`Kex`	exchangeable K in the soil (mmol/kg)
`Polsen`	soil P measured with the P-Olsen method (mg/kg)
`Ptotal`	total soil P (mg/kg)

Value

Matrix with three columns: Nsup, Psup and Ksup. These are the potential supply of N, P and K of the unfertilized soil (kg/ha).

References

Janssen B.H., F.C.T. Guiking, D. van der Eijk, E.M.A. Smaling, J. Wolf and H. van Reuler, 1990. A system for the quantitative evaluation of the fertility of tropical soils (QUEFTS). Geoderma 46: 299-318

Sattari, S.Z., M.K. van Ittersum, A.F. Bouwman, A.L. Smit, and B.H. Janssen, 2014. Crop yield response to soil fertility and N, P, K inputs in different environments: Testing and improving the QUEFTS model. Field Crops Research 157: 35-46

Examples

```
s1 <- nutSupply1(6, c(23, 11, 35), 15, c(1.6, 2.6, 2.4))
s1
s2 <- nutSupply2(20, 6, c(23, 11, 35), 15, c(1.6, 2.6, 2.4), 225)
s2
```

---

predict *Spatial QUEFTS model predictions*

Description

Make spatial predictions with a QUEFTS model. First create a model, then use the model with a SpatRaster of soil properties to make spatial predictions.

Usage

```
## S4 method for signature 'Rcpp_QueftsModel'
predict(object, supply, yatt, leaf_ratio, stem_ratio,
  var="yield", filename="", overwrite=FALSE, ...)
```

Arguments

`object`	QUEFTSModel
`supply`	SpatRaster with nutrient supply data (Ns, Ps, Ks)
`yatt`	SpatRaster with attainable yield
`leaf_ratio`	positive numeric (typically between 0 and 1) indicating the leaf weight relative to the storage organ weight. For example: 0.46 for maize, 0.17 for potato, and 0.18 for rice
`stem_ratio`	positive numeric (typically between 0 and 1) indicating the stem weight relative to the storage organ weight, For example: 0.56 for maize, 0.14 for potato, and 0.67 for rice
`var`	character. Output variable name. Either "yield" or "gap"
`filename`	character. Output filename. Optional
`overwrite`	logical. If `TRUE`, `filename` is overwritten
`...`	list. Options for writing files as in `writeRaster`

Value

SpatRaster

Examples

```
library(terra)

ff <- list.files(system.file("sp", package="Rquefts"), full.names=TRUE)
r <- rast(ff)

soil <- r[[c("Tavg", "pH", "SOC", "Kex", "Pex", "Ptot")]]
supply <- lapp(soil, nutSupply2)
plot(supply)

yatt <- rast(system.file("sp/Ya.tif", package="Rquefts"))

maize <- quefts_crop("Maize")
fertilizer <- list(N=0, P=0, K=0)
q <- quefts(crop=maize, fert=fertilizer)

p <- predict(q, supply, yatt, 0.46, 0.56)
plot(p)

g <- predict(q, supply, yatt, 0.46, 0.56, "gap")
plot(g)
```

---

quefts *QUEFTS model*

Description

Create a QUEFTS model, set parameters, and run it to compute nutrient requirements and nutrient limited yield.

A number of default crop parameter sets are available from quefts_crop, and an example soil from quefts_soil. You need to provide attainable or target crop production (in this context that is the maximum production in the absence of nutrient limitation), expressed as dry-matter biomass for leaves, stems and the storage organ (e.g. grain, root or tuber). See quefts_biom. Some crops are grown for the stems/leaves, in which case there is no relevant storage organ (e.g. sugarcane, jute). production yield estimates can be obtained with a crop growth model.

Usage

```
quefts(soil, crop, fert, biom)
crop(x) <- value
soil(x) <- value
fert(x) <- value
biom(x) <- value
run(x, ...)
```

Arguments

`soil`	list with named soil parameters. See Details. An example is returned by `quefts_soil`
`crop`	list with named crop parameters. See Details. An example is returned by `quefts_crop`
`fert`	list with named fertilizer parameters (N, P and K). An example is returned by `quefts_fert`
`biom`	list with named biomass and growing season length parameters. An example is returned by `quefts_biom`
`x`	QueftsModel object
`value`	list with soil, crop, fertilizer, or biomass parameters as above
`...`	Additional arguments. None implemented

Details

For input parameters see `quefts_crop`, `quefts_soil`, `quefts_fert` and `quefts_biom`

Crop yield (biom)	.
`leaf_att, stem_att, store_att`	Attainable (in the absence of nutrient limitation), or target cr
`SeasonLength`	Length of the growing season (days)
.	
.	
Output Variables	**Explanation**
`N_actual_supply, P_actual_supply, K_actual_supply`	nutrient uptake from soil (not fertilizer) (kg/ha)
`leaf_lim, stem_lim, store_lim`	nutrient limited biomass of leaves, stems, and storage organ
`N_gap, P_gap, K_gap`	fertilizer required to reach the specified biomass (kg/ha)

Value

vector with output variables as described in the Details

References

Janssen B.H., F.C.T. Guiking, D. van der Eijk, E.M.A. Smaling, J. Wolf and H. van Reuler, 1990. A system for the quantitative evaluation of the fertility of tropical soils (QUEFTS). Geoderma 46: 299-318

Sattari, S.Z., M.K. van Ittersum, A.F. Bouwman, A.L. Smit, and B.H. Janssen, 2014. Crop yield response to soil fertility and N, P, K inputs in different environments: Testing and improving the QUEFTS model. Field Crops Research 157: 35-46

Examples

```
# create a QUEFTS model
# 1. get parameters
soiltype <- quefts_soil()
barley <- quefts_crop("Barley")
fertilizer <- list(N=0, P=0, K=0)
```

```
att_yield <- list(leaf_att=2200, stem_att=2700, store_att=4800, SeasonLength=110)

# 2. create a model
q <- quefts(soiltype, barley, fertilizer, att_yield)

# 3. run the model
run(q)

# change some parameters
q$SeasonLength <- 162
q$leaf_att <- 2651
q$stem_att <- 5053
q$store_att <- 8208

q$N <- 100
q$P <- 50
q$K <- 50

run(q)


## note that Rquefts uses C++ reference classes.
## This means that if you copy a quefts model, you do not create a
## new instance of the model, but you point to the same one!
q <- quefts()
q["N"]
k <- q
k["N"] <- 150
k["N"]
# the value of q has also changed!
q["N"]

## different ways of subsetting / replacement
q <- quefts()
q$N
q$N <- 30
q["N"]
q["N"] <- 90
q["model", "N"]
q["model", "N"] <- 60
q$N

q$soil$N_recovery
q["soil$N_recovery"]
q["soil$N_recovery"] <- .6
q["soil", "N_recovery"]
q["soil", "N_recovery"] <- .4
q$soil$N_recovery
```

quefts_biom — *biomass parameters*

Description

Crop biomass parameters

For a cereal crop you can generally assume that about 50% of the total biomass is grain, and about 30% is stem and 20% is leaf biomass.

Usage

```
quefts_biom()
```

Details

Crop yield (biom)	.
`leaf_att, stem_att, store_att`	Attainable (in the absence of nutrient limitation), or target crop biomass (dry-matter, I
`SeasonLength`	Length of the growing season (days)

Value

list

Examples

```
b <- quefts_biom()
str(b)
```

quefts_crop — *Crop parameters*

Description

A number of default crop parameter sets are provided

Usage

```
quefts_crop(name="")
```

Arguments

`name`	character. crop name

Details

Input Parameters	Explanation
`_minVeg, _maxVeg, _minStore, _maxStore`	minimum and maximum concentration of "_" (N, P, or K) in vegetative org
`Yzero`	the maximum biomass of vegetative organs at zero yield of storage organs
`Nfix`	the fraction of a crop's nitrogen uptake supplied by biological fixation

Value

list with crop parameters. See Details

Examples

```
barley <- quefts_crop("Barley")
str(barley)
```

`quefts_fert` *fertilizer parameters*

Description

Get a list with the default fertilization parameters

Usage

```
quefts_fert()
```

Details

Input Parameters	Explanation
Management (fert)	.
`N, P, K`	N, P, and K fertilizer applied.

Value

list

Examples

```
f <- quefts_fert()
str(f)
```

quefts_soil *soil parameters*

Description

Example soil parameters.

Usage

```
quefts_soil()
```

Details

Input Parameters	**Explanation**
`N_base_supply`, `P_base_supply`, `K_base_supply`	Potential supply (kg/ha) of N, P and K of the (unfertilized) soil in a
`N_recovery`, `P_recovery`, `K_recovery`	Fertilizer recovery, that is, the fraction of applied fertilizer that can b
`UptakeAdjust`	Two-column matrix to compute the fraction uptake from soil supply

Value

list with soil parameters

Examples

```
soiltype <- quefts_soil()
str(soiltype)
```

revSupply *Estimate soil nutrients supply*

Description

Estimate the apparent base (unfertilized) soil supply of N, P and K based on nutrient omission trial data and a "reverse" QUEFTS approach. The apparent supply is found with optimization.

Usage

```
revSupply(obs, crop, soil, Ya, leaf_ratio, stem_ratio, SeasonLength = 120, ...)
```

Arguments

obs	data.frame with observed data from a nutrient omission trial. It must have these four columns: "N", "P", "K" and "Y"; that give the N, P, and K fertilizer application and the crop yield in kg/ha
Ya	numeric. Attainable yield
soil	list with named soil parameters. See quefts_soil
crop	list with named crop parameters. See quefts_crop
leaf_ratio	positive numeric (typically between 0 and 1) indicating the leaf weight relative to the storage organ weight. For example: 0.46 for maize, 0.17 for potato, and 0.18 for rice
stem_ratio	positive numeric (typically between 0 and 1) indicating the stem weight relative to the storage organ weight, For example: 0.56 for maize, 0.14 for potato, and 0.67 for rice
SeasonLength	positive integer
...	additional arguments supplied to optim

Value

numeric vector with the N, P, and K supply in kg/ha

References

?

Examples

```
set.seed(777)
trial_data <- data.frame(treat = c("CON", "NPK", "NPK", "PK", "NK", "NP"),
                  N = c(0, 120, 120, 0, 120, 120),
                  P = c(0, 30, 30, 30, 0, 30),
                  K = c(0, 60, 60, 60, 60, 0),
                  Y = c(2000, 6000, 6000, 2500, 4500, 5500) + rnorm(6, 0, 500))
Ya <- max(trial_data$Y) + 1000
crop <- quefts_crop("Potato")
soil <- quefts_soil()

revSupply(trial_data, crop, soil, Ya, leaf_ratio=.17, stem_ratio=.14)
```

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