Package ‘GSIF’

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Description

A merge of the Africa Soil Profiles Database (AFSP) with 17,000+ geo-referenced legacy soil profile records, and AfSIS Sentinel Site database with 9000+ sampling locations.

Usage

data(afsp)

Format

The afsp data set contains two data frames — sites and horizons. Sites table contains the following columns:

- SOURCEID factor; unique label to help a user identify a particular site (ProfileID in the AFSP)
- SOURCEDB factor; source data base
- LONWGS84 numeric; longitude in decimal degrees on the WGS84 datum (X_LonDD in the AFSP)
- LATWGS84 numeric; latitude in decimal degrees on the WGS84 datum (Y_LatDD in the AFSP)
- TIMESTRR character; the date on which this particular soil was described or sampled (T_Year in the AFSP)
- TAXGWRB factor; abbreviated soil group based on the WRB classification system (WRB06rg in the AFSP)
- TAXNUSDA factor; Keys to Soil Taxonomy taxon name e.g. "Plinthic Udoxic Dystropept" (USDA in the AFSP)
- BDRICM numeric; depth to bedrock in cm
- DRAINFAO factor; drainage class based on the FAO guidelines for soil description: E (excessively drained), S (somewhat excessively drained), W (well drained), M (moderately well drained), I (somewhat poorly drained) and V (very poorly drained)

Horizons table contains the following columns:

- SOURCEID factor; a short label to help a user identify a particular site
- UHDICM numeric; upper horizon depth from the surface in cm
- LHDICM numeric; lower horizon depth from the surface in cm
- MCOMNS factor; Munsell color moist
- ORCDRC numeric; soil organic carbon content in permilles
- PHIOHOC numeric; pH index measured in water solution
- SNDPPT numeric; weight percentage of the sand particles (0.05–2 mm)
- SLTPPT numeric; weight percentage of the silt particles (0.0002–0.05 mm)
- CLYPPT numeric; weight percentage of the clay particles (<0.0002 mm)
CRFVOL numeric; volume percentage of coarse fragments (> 2 mm)
BLD numeric; bulk density in tonnes per cubic-meter
CEC numeric; Cation exchange capacity (fine earth fraction) in cmolc/kg
NTO numeric; total N content in permille or g/kg
EMGX numeric; exchangeable Mg in cmolc/kg

Author(s)
The Africa Soil Profiles Database have been prepared by Johan Leenaars <johan.leenaars@wur.nl>. This is a subset of the original database that can be downloaded via www.isric.org. The AfSIS Sentinel Site database is one of the main deliverables of the Africa Soil Information Service project.

References
• Africa Soil Information Service (http://africasoils.net)

Examples
```r
## Not run:
library(rgdal)
library(aqp)
library(sp)

data#afsp)
sites <- afsp$sites
coordinates(sites) <- ~ LONWGS84 + LATWGS84
proj4string(sites) <- "+proj=longlat +datum=WGS84"
## obtain country borders:
library(maps)
country.m <- map("world", plot=FALSE, fill=TRUE)
IDs <- sapply(strsplit(country.m$names, ":"), function(x) x[1])
require(maptools)
country <- as(map2SpatialPolygons(country.m, IDs=IDs), "SpatialLines")
proj4string(country) = "+proj=longlat +datum=WGS84"
## overlay and plot points and maps:
plot(country, col="darkgrey", xlim=c(-25.3,57.8), ylim=c(-34.8, 37.4))
points(sites, pch=21, bg="white", cex=.6, col="black")

## End(Not run)
```
as.data.frame

Description
Converts an object of class "SoilProfileCollection" to a data frame with both site and horizon data sorted in one row. Each original column name in the horizons table receives a suffix A, B, ..., Z where alphabetic letters represent horizon sequence.

Usage
```r
## S4 method for signature 'SoilProfileCollection'
as.data.frame(x, row.names = NULL, optional = FALSE, ...)
```

Arguments
- `x`: object of class "SoilProfileCollection"
- `row.names`: character; giving the row names for the data frame (missing values are not allowed)
- `optional`: logical; if `TRUE`, setting row names and converting column names (to syntactic names: see 'make.names') is optional
- `...`: optional arguments

Details
The advantage of converting the "SoilProfileCollection" data to a single table is that, once both tables have been merged to a single data frame, it can be more easily exported and visualized in a GIS and/or imported into a data base.

Note
Few profiles with a large number of horizons can make the whole data frame become large. Consider removing such locations or aggregating measured values per horizon to a lower number of horizons.

Author(s)
Tomislav Hengl and Brendan Malone

See Also
as.geosamples, mpspline
Examples

library(aqp)
library(plyr)
library(rgdal)
library(sp)

## Sample profile from Nigeria:
lon = 3.90; lat = 7.50; id = "ISRIC:NG0017"; FAO1988 = "LXp"
top = c(0, 18, 36, 65, 87, 127)
bottom = c(18, 36, 65, 87, 127, 181)
ORCDRC = c(18.4, 4.4, 3.6, 3.6, 3.2, 1.2)

## Prepare a SoilProfileCollection:
prof1 <- join(data.frame(id, top, bottom, ORCDRC),
              data.frame(id, lon, lat, FAO1988),
              type='inner')
depths(prof1) <- id + top + bottom
site(prof1) <- lon + lat + FAO1988
coordinates(prof1) <- lon + lat
proj4string(prof1) <- CRS("+proj=longlat +datum=WGS84")

## Convert to a simple table:
x <- as.data.frame(prof1)
str(x)

## Horizons only
horizons <- getHorizons(x, idcol="id", sel=c("top", "bottom", "ORCDRC"))

as.geosamples

Converts an object to geosamples class

Description

Converts an object of class "SoilProfileCollection" or "SpatialPointsDataFrame" to an object of class "geosamples" with all measurements broken into individual records. Geosamples are standardized spatially and temporally referenced samples from the Earth’s surface.

Usage

## S4 method for signature 'SoilProfileCollection'
as.geosamples(obj,
               registry = as.character(NA), sample.area = 1, mxd = 2, TimeSpan.begin, TimeSpan.end)

## S4 method for signature 'SpatialPointsDataFrame'
as.geosamples(obj,
               registry = as.character(NA), sample.area = 1, mxd = 2, TimeSpan.begin, TimeSpan.end)

Arguments

obj object of class "SoilProfileCollection"

... optional arguments
as.geosamples

registry URI specifying the metadata registry (web-service that carries all metadata connected to the certain method ID and/or sample ID)
sample.area standard sample area in square meters (assumed to be 1 by 1 m)
mxd maximum depth of interest in meters
TimeSpan.begin vector of class "POSIXct": begin of the measurement period
TimeSpan.end vector of class "POSIXct": end of the measurement period

Value

Returns an object of type "geosamples". Many columns required by the "geosamples" class might be not available and will result in NA values. To ensure compatibility, when building an object of type "SoilProfilesCollection", use some standard naming convention to attach attributes to each measurement (horizons and sites slots in the "SoilProfileCollection-class"):

"locationError" can be used to attach location errors in meters to each spatial location
"sampleArea" can be used to attach spatial support to each measurement (usually 1 by 1 meter)
"measurementError" can be used to attach specific measurement errors to each measurement in both site and horizons table
"IGSN" can be used to attach the unique identifier (International Geo Sample Number) to each specific observation (corresponds to the "observationid" column)

Author(s)

Tomislav Hengl and Hannes I. Reuter

See Also

geosamples-class, as.data.frame, aqp::SoilProfileCollection

Examples

library(aqp)
library(plyr)
library(rgdal)
library(sp)

# sample profile from Nigeria:
lon = 3.90; lat = 7.50; time = as.POSIXct("1978", format="%Y")

id = "ISRIC:NG0017"; TAXNFAO8 = "Lxp"
top = c(0, 18, 36, 65, 87, 127)
bottom = c(18, 36, 65, 87, 127, 181)
ORCDRC = c(18.4, 4.4, 3.6, 3.6, 3.2, 1.2)

methodid = c("TAXNFAO8", "ORCDRC")
description = c("FAO 1988 classification system group",
               "Method of Walkley-Black (Org. matter = Org. C x 1.72)"
               )
units = c("FAO 1988 classes", "permille")
detectionLimit = c(as.character(NA), "0.1")

# prepare a SoilProfileCollection:
prof1 <- join(data.frame(id, top, bottom, ORCDRC),
              data.frame(id, lon, lat, time, TAXNFAO8), type='inner')
autopredict-methods

Auto predict numeric or factor type variables

Description

Fits either geostatistical model via the fit.gstatModel function (in the case of numeric variable) or a multinomial logistic regression model via the spmultinom function (factor-type variable) and generates predictions.

Usage

```r
## S4 method for signature 'SpatialPointsDataFrame, SpatialPixelsDataFrame'
autopredict(target, covariates, 
            auto.plot=TRUE, ...)
```

Arguments

- `target`: object of class "SpatialPointsDataFrame" containing observations of the target variable
covariates: object of class "SpatialPixelsDataFrame"; spatial covariates
auto.plot: logical; specifies whether to immediately plot the data via the plotKML function
... other optional arguments that can be passed to fit.gstatModel or spmultinom

Author(s)

Tomislav Hengl

See Also

fit.gstatModel, spmultinom

Examples

```r
## Ebergotzen data:
library(sp)
library(gstat)
library(randomForest)
library(plotKML)

## load input data:
data(eberg)
eberg <- eberg[runif(nrow(eberg))<.1,]
coordinates(eberg) <- ~X+Y
proj4string(eberg) <- CRS("+init=epsg:31467")
data(eberg_grid)
gridded(eberg_grid) <- ~x+y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")

## predict sand content:
SNDMHT_A <- autopredict(eberg["SNDMHT_A"], eberg_grid,
                          auto.plot=FALSE)
plot(SNDMHT_A)

## predict soil types:
soiltype <- autopredict(eberg["soiltype"], eberg_grid,
                         auto.plot=FALSE)
spplot(soiltype@predicted)
```

**Description**

Derive available soil water capacity (in cubic-meter per cubic-meter) based on a Pedo-Transfer Function developed using the Africa Soil Profile Database (Hodnett and Tomasella, 2002; Wösten et al. 2013).
Usage

AWCPTF(SNDPPT, SLTPPT, CLYPPT, ORCDRC,
BLD=1400, CEC, PHIHOX, h1=-10, h2=-20, h3=-31.6,
pwp=-1585, PTF.coef, fix.values=TRUE, print.coef=TRUE)

Arguments

SNDPPT numeric; sand content in percent
SLTPPT numeric; silt content in percent
CLYPPT numeric; clay content in percent
ORCDRC numeric; soil organic carbon concentration in permille or g / kg
BLD numeric; bulk density in kg / cubic-meter for the horizon/solum
CEC numeric; Cation Exchange Capacity in cmol per kilogram
PHIHOX numeric; soil pH in water suspension
h1 numeric; moisture potential in kPa e.g. -10 (pF 2.0)
h2 numeric; moisture potential in kPa e.g. -20 (pF 2.3)
h3 numeric; moisture potential in kPa e.g. -31.6 (pF 2.5)
pwp numeric; moisture potential at wilting point in kPa e.g. -1585 (pF 4.2)
PTF.coef data.frame; optional conversion coefficients (Pedo-Transfer Function) with rows
"ai1","sand","silt","clay","oc","bd","cec","ph","silt^2","clay^2",
"sand+silt","sand+clay" and columns "lnAlfa","lnN","tetaS" and "tetaR"
(see Wösten et al. 2013 for more details)
fix.values logical; specifies whether to correct values of textures and bulk density to avoid
creating nonsensical values
print.coef logical; specifies whether to attach the PTF coefficients to the output object

Value

Returns a data frame with the following columns:
- AWC1: available soil water capacity (volumetric fraction) for h1;
- AWC2: available soil water capacity (volumetric fraction) for h2;
- AWC3: available soil water capacity (volumetric fraction) for h3;
- WWP: available soil water capacity (volumetric fraction) until wilting point;
- tetaS: saturated water content;

Note

Pedotransfer coefficients (PTF.coef) developed by Hodnett and Tomasella (2002). fix.values
will correct sand, silt and clay fractions so they sum up to 100, and will replace bulk density values
using global minimum maximum values.

Author(s)

Johan Leenaars, Maria Ruiperez Gonzalez and Tomislav Hengl
References


Examples

```r
SNDPPT = 30
SLTPPT = 25
CLYPPT = 48
ORCDRC = 23
BLD = 1200
CEC = 12
PHIHOX = 6.4
x <- AWCPTF(SNDPPT, SLTPPT, CLYPPT, ORCDRC, BLD, CEC, PHIHOX)
str(x)
attr(x, "coef")
```

```r
## predict AWC for AfSP DB profile:
data(AfSP)
names(AfSP$horizons)
## profile of interest:
sel <- AfSP$horizons$SOURCEID=="NG 28440.25"
hor <- AfSP$horizons[sel,]
## replace missing values:
BLDF <- ifelse(is.na(hor$BLD),
               mean(hor$BLD, na.rm=TRUE), hor$BLD)
hor <- cbind(hor, AWCPTF(hor$SNDPPT, hor$SLTPPT,
                         hor$CLYPPT, hor$ORCDRC, BLD=BLDF+1000, hor$CEC,
                         hor$PHIHOX))
str(hor)
```

cookfarm

The Cook Agronomy Farm data set

Description

The R.J. Cook Agronomy Farm (cookfarm) is a Long-Term Agroecosystem Research Site operated by Washington State University, located near Pullman, Washington, USA. Contains spatio-temporal (3D+T) measurements of three soil properties and a number of spatial and temporal regression covariates.

Usage

data(cookfarm)
Format

The `cookfarm` data set contains four data frames. The `readings` data frame contains measurements of volumetric water content (cubic-m/cubic-m), temperature (degree C) and bulk electrical conductivity (dS/m), measured at 42 locations using 5TE sensors at five standard depths (0.3, 0.6, 0.9, 1.2, 1.5 m) for the period "2011-01-01" to "2012-12-31":

- **SOURCEID** factor; unique station ID
- **Date** date; observation day
- **Port*VW** numeric; volumetric water content measurements at five depths
- **Port*C** numeric; soil temperature measurements at five depths
- **Port*EC** numeric; bulk electrical conductivity measurements at five depths

The `profiles` data frame contains soil profile descriptions from 142 sites:

- **SOURCEID** factor; unique station ID
- **Easting** numeric; x coordinate in the local projection system
- **Northing** numeric; y coordinate in the local projection system
- **TAXNUSDA** factor; Keys to Soil Taxonomy taxon name e.g. "Caldwell"
- **HZUSD** factor; horizon designation
- **UHDICM** numeric; upper horizon depth from the surface in cm
- **LHDICM** numeric; lower horizon depth from the surface in cm
- **BLD** bulk density in tonnes per cubic-meter
- **PHIHOX** numeric; pH index measured in water solution

The `grids` data frame contains values of regression covariates at 10 m resolution:

- **DEM** numeric; Digital Elevation Model
- **TWI** numeric; SAGA GIS Topographic Wetness Index
- **MUSYM** factor; soil mapping units e.g. "Thatuna silt loam"
- **NDRE.M** numeric; mean value of the Normalized Difference Red Edge Index (time series of 11 RapidEye images)
- **NDRE.sd** numeric; standard deviation of the Normalized Difference Red Edge Index (time series of 11 RapidEye images)
- **Cook_fall_ECa** numeric; apparent electrical conductivity image from fall
- **Cook_spr_ECa** numeric; apparent electrical conductivity image from spring
- **X2011** factor; cropping system in 2011
- **X2012** factor; cropping system in 2012

The `weather` data frame contains daily temperatures and rainfall from the nearest meteorological station:

- **Date** date; observation day
- **Precip_wrcc** numeric; observed precipitation in mm
- **MaxT_wrcc** numeric; observed maximum daily temperature in degree C
- **MinT_wrccc** numeric; observed minimum daily temperature in degree C
Note

The farm is 37 ha, stationed in the hilly Palouse region, which receives an annual average of 550 mm of precipitation, primarily as rain and snow in November through May. Soils are deep silt loams formed on loess hills; clay silt loam horizons commonly occur at variable depths. Farming practices at Cook Farm are representative of regional dryland annual cropping systems (direct-seeded cereal grains and legume crops).

Author(s)

Caley Gasch, Tomislav Hengl and David J. Brown

References


Examples

```r
## An example for 3D+T modelling applied to the cookfarm data set can be assessed via
## demo(cookfarm_3DT_kriging)
## demo(cookfarm_3DT_RF)
## Please note that the demo's might take 10-15 minutes to complete.
library(rgdal)
library(sp)
library(spacetime)
library(aqp)
library(splines)
library(randomForest)
library(plyr)
library(plotKML)
data(cookfarm)

## Gridded data:
grid10m <- cookfarm$grids
gridded(grid10m) <- ~x+y
proj4string(grid10m) <- CRS(cookfarm$proj4string)
spplot(grid10m["DEM"], col.regions=SAGA_pal[[1]])

## Soil profiles:
profs <- cookfarm$profiles
levels(cookfarm$profiles$HJDUSD)
## Bt horizon:
sel.Bt <- grep("Bt", profs$HJDUSD, ignore.case=FALSE, fixed=FALSE)
profs$Bt <- 0
profs$Bt[sel.Bt] <- 1
depths(profs) <- SOURCEID ~ UHDCM + LHDCM
site(profs) <- ~ TAXUSUSDA + Easting + Northing
coordinates(profs) <- ~East + Northing
proj4string(profs) <- CRS(cookfarm$proj4string)
profs.geo <- as.geosamples(profs)
```
## The Edgeroi Data Set

**Description**

Soil samples and covariate layers for the Edgeroi area in NSW, Australia (ca 1500 square-km).

**Usage**

```r
data(edgeroi)
```

**Format**

The `edgeroi` data set contains two data frames — sites and horizons. Sites table contains the following columns:

- **SOURCEID** factor; unique label to help a user identify a particular site (ID in the NatSoil)
- **LONGDA94** numeric; longitude in decimal degrees on the GDA94 datum
- **LATGDA94** numeric; latitude in decimal degrees on the GDA94 datum
- **TAXGAUC** factor; **Australian Great Soil Groups** (GSG; see details)
- **NOTEOBS** character; free-form observation notes

Horizons table contains the following columns:

- **SOURCEID** factor; unique identifier used in the NatSoil DB
- **LSQINT** integer; a layer sequence number 1 to N
- **HZDUSD** factor; horizon designation (primary letter)
- **UDHICM** numeric; lower horizon depth from the surface in cm
- **LHDICM** numeric; upper horizon depth from the surface in cm
- **CLYPPT** numeric; weight percentage of the clay particles (<0.0002 mm)
- **SNDPPT** numeric; weight percentage of the silt particles (0.0002–0.05 mm)
- **SLTPPT** numeric; weight percentage of the sand particles (0.05–2 mm)
- **PHIHOU** numeric; pH index measured in water solution (pH_h2o in the NSCD)
- **ORCDRC** numeric; soil organic carbon content in permille

## edgeroi

```r
## fit model for Bt horizon:
m.Bt <- GSIF::fit.gstatModel(profs.geo, Bt=DEM+TWI+MUSYM+Cook.fall_ECa
  +Cook_spr_ECa+ns(altitude, df = 4), grid10m, fit.family = binomial(logit))
plot(m.Bt)

## fit model for soil pH:
m.PHI <- fit.gstatModel(profs.geo, PHIHOX=DEM+TWI+MUSYM+Cook.fall_ECa
  +Cook_spr_ECa+ns(altitude, df = 4), grid10m)
plot(m.PHI)
```
The edgeroi_grids data frame contains a list of covariates at 250 m resolution:

**DEMSRT5** numeric; SRTM DEM  
**TWISRT5** numeric; SAGA Topographic Wetness Index based on the SRTM DEM  
**PMTGEO5** factor; parent material class based on the National Geological map at scale 1:250,000 — sand with minor silty sand ("Qd"), alluvium gravel, sand, silt, clay ("Qrs"), quartz sandstone obscured by quartenary sands ("Qrt/Jp"), quartz sandstone obscured by talus material ("Qrt/Rn"), basalt obscured by talus material ("Qrt/Tv"), mottled clay, silt, sandstone and gravel ("Ts"), and basalt, dolerite, trachyte, techenite ("Tv")  
**EV1MOD5** numeric; first principal component of the MODIS EVI (MOD13Q1) time series data (year 2011)  
**EV2MOD5** numeric; second principal component of the MODIS EVI (MOD13Q1) time series data (year 2011)  
**EV3MOD5** numeric; third principal component of the MODIS EVI (MOD13Q1) time series data (year 2011)  
**x** numeric; x-coordinate in the GDA94 / MGA zone 55  
**y** numeric; y-coordinate in the GDA94 / MGA zone 55

The edgeroi_grids100 data frame contains a list of covariates at 100 m resolution prepared for the study area:

**LNUAB56** factor; Australian National scale land use data  
**MVBSRT6** numeric; SAGA GIS Multi-resolution Index of Valley Bottom Flatness based on the SRTM DEM  
**TI1LAN6** numeric; principal component 1 for the Landsat band 7 (thermal) based on three periods of the Global Land Survey Landsat images (GLS1990, GLS2000, GLS2005)  
**TI2LAN6** numeric; principal component 2 for the Landsat band 7 (thermal) based on three periods of the Global Land Survey Landsat images (GLS1990, GLS2000, GLS2005)  
**PCKGAD6** numeric; percentage of Potassium estimated based on the gamma radiometrics radmap09 (GADDS)  
**RUTGAD6** numeric; ratio Uranium over Thorium estimated based on the gamma radiometrics radmap09 (GADDS)  
**PCTGAD6** numeric; parts per million of Thorium estimated based on the gamma radiometrics radmap09 (GADDS)  
**x** numeric; x-coordinate in the GDA94 / MGA zone 55  
**y** numeric; y-coordinate in the GDA94 / MGA zone 55

**Details**

The Edgeroi is one of the standard soil data sets used to test soil mapping methods in Australia. Out of 359 profiles, 210 sites were sampled on a systematic, equilateral triangular grid with a spacing of 2.8 km between sites, the other sites are distributed more irregularly or on transects. The data set is described in detail in Malone et al. (2010) and McGarry et al. (1989). The edgeroi contains only a subset of the original NatSoil records. Observed soil classes for TAXGAUC are (alphabetically): Alluvial soil ("A"), Brown clay ("BC"), Black earth ("BE"), Earthy sand ("ES"), Grey clay ("GC"),
Grey earth ("GE"), No suitable group ("NSG"), Prairie soil ("PS"), Rendzina ("R"), Red-brown earth ("RBE"), Red clay ("RC"), Red earth ("RE"), Red podzolic soil ("RP"), Solodic soil ("SC"), Soloth ("SH"), Solonchak ("SK"), Siliceous sand ("SS"), and Solonetz ("SZ").

Note

The Landsat images and SRTM DEM have been obtained from the Global Land Cover Facility. Scanned geology map (paper sheets) has been obtained from the Geoscience Australia, then georeferenced and rasterized to 250 m resolution. The land use map has been obtained from the Australian Collaborative Land Use and Management program. The Radiometric Map of Australia grids has been downloaded using the Geophysical Archive Data Delivery System (GADDS) on the Australian Government’s Geoscience Portal (Mitny et al, 2009). Listed gridded layers follow a standard naming convention used by WorlGrids.org (the standard 8.3 filename convention with at most eight characters): first three letter are used for the variable type e.g. DEM (digital elevation model); the next three letters represent the data source or collection method e.g. SRT (SRTM mission); the 6th character is the effective scale e.g. 5 indicates the 5th standard scale i.e. 1/600 decimal degrees (in this case 250 m).

Author(s)

The original detailed profile description and laboratory analysis was funded by a Cotton Research and Development Corporation project in the mid-late 1980’s by the CSIRO Division of Soils and available via the NatSoil DB. The gamma radiometrics images are property of the NSW Department of Primary Industries — Mineral Resources.

References


Examples

```r
library(rgdal)
library(aqp)
library(sp)

data(edgeroi)
edgeroi$sites[edgeroi$sites$SOURCEID=="399_EDGEROI_ed095_1",]
edgeroi$horizons[edgeroi$horizons$SOURCEID=="399_EDGEROI_ed095_1",]
## spPoints:
sites <- edgeroi$sites
coordinates(sites) <- ~ LONGDA94 + LATGDA94
proj4string(sites) <- CRS("+proj=longlat +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +no_defs")
sites <- spTransform(sites, CRS("+init=epsg:28355"))
## Not run:
```
ERDICM

Effective Rooting Zone depth

Description

Derive Effective Rooting Zone depth i.e. an effective depth suitable for plant growth. Usually minimum depth of soil out of three standard rooting depths: limiting soil properties, depth to water-stagnating layer and depth to bedrock.

Usage

```
ERDICM(UHDICM, LHDICM, minimum.LRI, DRAINFAO, BDRICM, 
threshold.LRI=20, srd=150, drain.depths, smooth.LRI=TRUE)
```

Arguments

- **UHDICM** numeric; upper horizon depth in cm
- **LHDICM** numeric; lower horizon depth in cm
- **minimum.LRI** numeric; minimum Limiting Rootability index
- **DRAINFAO** factor; FAO drainage class e.g. "V", "P", "I", "M", "W", "S", "E"
- **BDRICM** numeric; depth to bedrock in cm
- **threshold.LRI** numeric; treshold index for LRI
- **srd** numeric; maximum depth of interest
- **drain.depths** data.frame; estimate effective rooting depth per drainage class (DRAINFAO)
- **smooth.LRI** logical; specify whether to smooth LRI values using splines
Value

Returns a vector of effective rooting depth in cm.

Author(s)

Johan Leenaars, Maria Ruiperez Gonzalez and Tomislav Hengl

See Also

LRI

---

**extract**  
*Extracts values at points from a list of files*

**Description**

Overlays and extracts values at points from a list of raster layers defined as file names (e.g. Geo-Tiffs). Extends the `extract` function from the `raster` package. Especially suitable for extracting values of a large list of rasters that have not been organized into a mosaic (a virtual stack), for example a list of Landsat scenes.

**Usage**

```r
## S4 method for signature 'SpatialPoints,character'
extract(x, y,  
     path = ".", ID = "SOURCEID",  
     method = "simple", is.pattern = FALSE, force.projection = TRUE,  
     NAflag = ",", show.progress=TRUE, isFactor=FALSE, ...)
## S4 method for signature 'SpatialPointsDataFrame,character'
ex...
FAO.SoilProfileCollection-class  

A class for FAO SoilProfileCollection

Description

A class for harmonized (FAO) soil profile records. Extends the "SoilProfileCollection" class from the aqp package.

Slots

- idcol: object of class "character"; column name containing IDs
- depthcols: object of class "character"; two element vector with column names for horizon top, bottom depths
- metadata: object of class "data.frame"; metadata table
- horizons: object of class "data.frame"; table containing observations at different depths
- site: object of class "data.frame"; table containing observations at site locations
- sp: object of class "SpatialPoints"; locations of profiles
- diagnostic: object of class "data.frame"; table containing diagnostic properties

Data of class "FAO.SoilProfileCollection" must satisfy all of the following requirements (class validity):

- All variable names must be registered in the Global Soil Data Registry;
• All variable domains must correspond to the FAO Guidelines (2006 or later) for soil description or similar;
• All values must pass the validity checks i.e. numeric values must be within physical limits defined in the SoilGrids Global Soil Data Registry;

Author(s)

Tomislav Hengl

References


See Also

SoilGrids-class, SpatialComponents-class, geosamples-class

Examples

library(aqp)
library(sp)

LONWGS84 = 3.90
LATWGS84 = 7.50
UHDICM = 0
LHDICM = 30
SOURCEID = "ISRIC:NG0017"
SOURCEDB = "AfSP DB"
SPDFAO = "3"
TEXMHMT = "SCL"
DCOMNS = "7.5YR_3_2"

sp1 <- new("FAO.SoilProfileCollection",
    depthcols=c("UHDICM","LHDICM"),
    metadata=soil vars,
    horizons=data.frame(SOURCEID, UHDICM, LHDICM, TEXMHMT, DCOMNS),
    site=data.frame(SOURCEID, SPDFAO, SOURCEDB),
    sp=SpatialPoints(data.frame(LONWGS84, LATWGS84),
        proj4string=CRS("+proj=longlat +datum=WGS84"))
)
str(sp1)
Methods to fit a regression-kriging model

Description

Tries to automatically fit a 2D or 3D regression-kriging model for a given set of points (object of type "SpatialPointsDataFrame" or "geosamples") and covariates (object of type "SpatialPixelsDataFrame"). It first fits a regression model (e.g. Generalized Linear Model, regression tree, random forest model or similar) following the formulaString, then fits variogram for residuals using the fit.variogram method from the gstat package. Creates an output object of class gstatModel-class.

Usage

```r
# S4 method for signature
# 'SpatialPointsDataFrame,formula,SpatialPixelsDataFrame'
fit.gstatModel(observations, formulaString, covariates,
               method = list("GLM", "rpart", "randomForest", "quantregForest")[[1]],
               dimensions = list("3D", "2D", "2D+T", "3D+T")[[1]],
               fit.family = gaussian(), stepwise = TRUE, vgmFun = "Exp",
               subsample = 5000, subsample.reg = 10000, ...)
# S4 method for signature 'geosamples,formula,SpatialPixelsDataFrame'
fit.gstatModel(observations, formulaString, covariates,
               method = list("GLM", "rpart", "randomForest", "quantregForest")[[1]],
               dimensions = list("3D", "2D", "2D+T", "3D+T")[[1]],
               fit.family = gaussian(), stepwise = TRUE, vgmFun = "Exp", subsample = 5000, subsample.reg = 10000, ...)
# S4 method for signature 'geosamples,formula,list'
fit.gstatModel(observations, formulaString, covariates,
               method = list("GLM", "rpart", "randomForest", "quantregForest")[[1]],
               dimensions = list("3D", "2D", "2D+T", "3D+T")[[1]],
               fit.family = gaussian(), stepwise = TRUE, vgmFun = "Exp", subsample = 5000, subsample.reg = 10000, ...)
# S4 method for signature 'geosamples,list,list'
fit.gstatModel(observations, formulaString, covariates,
               method = list("GLM", "rpart", "randomForest", "quantregForest")[[1]],
               dimensions = list("3D", "2D", "2D+T", "3D+T")[[1]],
               fit.family = gaussian(), stepwise = TRUE, vgmFun = "Exp", subsample = 5000, subsample.reg = 10000, ...)
```

Arguments

- **observations**: object of type "SpatialPointsDataFrame" or "geosamples-class"
- **formulaString**: object of type "formula" or a list of formulas
- **covariates**: object of type "SpatialPixelsDataFrame", or list of grids
method character; family of methods considered e.g. "GLM"
dimensions character; "3D", "2D", "2D+T", "3D+T" models
fit.family character string defining the GLM family (for more info see stats::glm)
stepwise specifies whether to run step-wise regression on top of GLM to get an optimal subset of predictors
vgmFun variogram function ("Exp" by default)
subsample integer; maximum number of observations to be taken for variogram model fitting (to speed up variogram fitting)
subsample.reg integer; maximum number of observations to be taken for regression model fitting (currently only used for randomForest)
... other optional arguments that can be passed to glm and/or fit.variogram

Details
The GLM method by default assumes that the target variable follows a normal distribution fit.family = gaussian(). Other possible families are:

normal distribution fit.family = gaussian() (default setting)
log-normal distribution fit.family = gaussian(log)
binomial variable fit.family = binomial(logit)
variable following a poisson distribution fit.family = poisson(log)

Note
Residuals (response residuals from the model) will be checked for normality and problems reported by default. The warning messages should be taken with care, as when the sample size is small, even big departures from normality will not be reported; when the sample size is large, even the smallest deviation from normality might lead to a warning. Likewise, if the variogram fitting fails, consider fitting a variogram manually or using the fit.vgmModel method.

Author(s)
Tomislav Hengl, Gerard B.M. Heuvelink and Bas Kempen

References

See Also
gstatModel-class, fit.regModel, test.gstatModel, geosamples-class, stats::glm, gstat::fit.variogram
Examples

# 2D model:
library(sp)
library(boot)
library(aqp)
library(plyr)
library(rpart)
library(splines)
library(gstat)
library(randomForest)
library(quantregForest)
library(plotKML)

## load the Meuse data set:
demo(meuse, echo=FALSE)

## simple model:
omm <- fit.gstatModel(meuse, om~dist+ffreq, meuse.grid,
    family = gaussian(log))
om.rk <- predict(omm, meuse.grid)
plot(omm.rk)
## it was succesful!

## fit a GLM with a gaussian log-link:
omm <- fit.gstatModel(meuse, om~dist+ffreq, meuse.grid,
    fit.family = gaussian(log))
summary(omm@regModel)
om.rk <- predict(omm, meuse.grid)
plot(omm.rk)

## fit a regression-tree:
omm <- fit.gstatModel(meuse, log1p(om)-dist+ffreq, meuse.grid,
    method="rpart")
summary(omm@regModel)
## plot a regression-tree:
plot(omm@regModel, uniform=TRUE)
text(omm@regModel, use.n=TRUE, all=TRUE, cex=.8)

## fit a randomForest model:
omm <- fit.gstatModel(meuse, om~dist+ffreq, meuse.grid,
    method="randomForest")
## plot to see how good is the fit:
plot(omm)
## plot the estimated error for number of bootstrapped trees:
plot(omm@regModel)
omm@vgmModel
om.rk <- predict(omm, meuse.grid)
plot(omm.rk)
## Compare with "quantregForest" package:
omm <- fit.gstatModel(meuse, om~dist+ffreq, meuse.grid,
    method="quantregForest")
## fit.gstatModel-methods

```r
## Not run:
om.rk <- predict(omm, meuse.grid, nfold=0)
plot(om.rk)
## plot the results in Google Earth:
plotKML(om.rk)
## End(Not run)

## binary variable (0/1):
meuse$soil.1 <- as.numeric(I(meuse$soil==1))
som <- fit.gstatModel(meuse, soil.1-dist+ffreq, meuse.grid,
  fit.family = binomial(logit))
summary(som@regModel)

## Not run: # plot the results in Google Earth:
plotKML(som.rk)
## End(Not run)

## 3D model:
library(plotKML)
data(eberg)
## list columns of interest:
s.lst <- c("ID", "soiltype", "TAXGRSC", "X", "Y")
h.lst <- c("UHDICM","LHDICM","SNDSMH","SLTMHT","CLYMHT")

## create object of type "SoilProfileCollection"
eberg.spc <- join(ehorizons, eberg, type = "inner")
depths(eberg.spc) <- ID ~ UHDICM + LHDICM

## convert to geosamples:
eberg.geo <- as.geosamples(eberg.spc)
## covariates:
data(eberg.grid)
gridded(eberg_grid) <- ~x+y
proj4string(eberg.grid) <- CRS("+init=epsg:31467")
glm.formulaString = as.formula("SNDSMH ~ ",
  paste(names(eberg.grid), collapse="+"), "+ ns(altitude, df=4))")
SNDMHT.m <- fit.gstatModel(observations=eberg.geo, glm.formulaString,
  covariates=eberg.grid)
plot(SNDMHT.m)
## problems with the variogram?
## Not run: ## remove classes from the PRMGeo06 that are not represented in the model:
sel = !(levels(eberg_grid$PRMGeo06) %in% levels(SNDMHT.m@regModel$model$PRMGeo06))
fix.c = levels(eberg_grid$PRMGeo06)[sel]
summary(eberg_grid$PRMGeo06)
```
for(j in fix.c){
  eberg_grid$PRMGE06[eberg_grid$PRMGE06 == j] <- levels(eberg_grid$PRMGE06)[7]
}
## prepare new locations:
new3D <- sp3D(eberg_grid)
## regression only:
SNDMHT.rk.sd1 <- predict(SNDMHT.m, new3D[[1]], vgmmodel=NULL)
## regression-kriging:
SNDMHT.rk.sd1 <- predict(SNDMHT.m, new3D[[1]])
## plot the results in Google Earth:
plotKML(SNDMHT.rk.sd1, z.lim=c(5,85))
## End(Not run)

fit.regModel-methods  Fits a regression model to spatial data

Description

Fits a regression or a trend model (e.g. a GLM) and, if not available, a variogram for the response residuals using the default settings.

Usage

## S4 method for signature
## 'formula,data.frame,SpatialPixelsDataFrame,character'
fit.regModel(formulaString, rmatrix, predictionDomain, 
  method = list("GLM", "rpart", "randomForest", "quantregForest", "lme")[[1]], 
  dimensions = NULL, fit.family = gaussian(), stepwise = TRUE, rvgm, 
  GLS = FALSE, random, steps, subsample, subsample.reg, ...)

Arguments

formulaString object of class "formula" — regression model
rmatrix object of class "data.frame"; regression matrix produced as a result of spatial overlay
predictionDomain object of class "SpatialPixelsDataFrame"; spatial domain of interest
method character; family of methods considered e.g. "GLM", "rpart" (regression trees), 
  "randomForest" (random forest)
dimensions character; "3D", "2D", "2D+T", "3D+T" models
fit.family family to be passed to the glm (see examples below)
stepwise specifies whether to run step-wise regression on top of GLM to get an optimal subset of predictors
rvgm residual variogram (to avoid fitting the variogram set as NULL)
fit.regModel-methods

GLS
fit trend model using Generalized Least Squares implemented in the nlme package

random
specify the random function model; see nlme::lme for more details

steps
integer; the maximum number of steps to be considered for step-wise regression; see stats::step for more details

subsample
integer; maximum number of observations to be taken for variogram model fitting (to speed up variogram fitting)

subsample.reg
integer; maximum number of observations to be taken for regression model fitting (especially important for randomForest modelling)

other optional arguments that can be passed to gstat::fit.variogram

Details

Produces an object of class "gstatModel" that contains: (1) fitted regression model (e.g. a GLM, cubist model, or randomForest model), (2) fitted variogram, and (c) object of class "SpatialPoints" with observation locations. To combine overlay and model fitting operations, consider using fit.gstatModel.

Author(s)
Tomislav Hengl, Mario Antonio Guevara Santamaria and Bas Kempen

See Also

fit.gstatModel, stats::glm, gstat::fit.variogram, randomForest::randomForest

Examples

## Meuse data:
library(sp)
library(rpart)
library(nlme)
library(gstat)
library(randomForest)
library(quantregForest)

## load the Meuse data set:
demo(meuse, echo=FALSE)

## prepare the regression matrix:
ov <- over(meuse, meuse.grid)
ov <- cbind(data.frame(meuse["om"]), ov)
## skip variogram fitting:
m <- fit.regModel(om-dist+ffreq, rmatrix=ov, meuse.grid,
                  fit.family=gaussian(log), method="GLM", rvgm=NULL)
m@regModel
m@vgmModel
plot(m)
## fit a GLM with variogram:
m1 <- fit.regModel(om-dist+ffreq, rmatrix=ov, meuse.grid,
                  fit.family=gaussian(log), method="GLM")
**Description**

Fits a 2D or 3D variogram model based on a regression matrix and spatial domain of interest.

**Usage**

```r
## S4 method for signature 'formula, data.frame, SpatialPixelsDataFrame'
fit.vgmModel(formulaString, rmatrix, predictionDomain, vgmFun = "Exp",
              dimensions = list("3D", "2D", "2D+T", "3D+T")[[1]],
              anis = NULL, subsample = nrow(rmatrix), ivgm, cutoff = NULL,
              width, cressie = FALSE, ...)
```

**Arguments**

- `formulaString`: object of class "formula" — regression model
- `rmatrix`: object of class "data.frame"; regression matrix produced as a result of spatial overlay
- `predictionDomain`: object of class "SpatialPixelsDataFrame"; spatial domain of interest
- `vgmFun`: character; variogram function ("Exp" by default)
dimensions character; "3D", "2D", "2D+T", "3D+T" models
anis vector containing 2, 5 or more anisotropy parameters; see gstat::vgm for more info
subsample integer; size of the subset
ivgm vgm; initial variogram model
cutoff numeric; distance up to which point pairs are included in semivariance estimates
width numeric; sample variogram bin width
cressie logical; specifies whether to use cressie robust estimator
... other optional arguments that can be passed to gstat::fit.variogram

Details

It will try to fit a variogram to multidimensional data. If the data set is large, this process can be time-consuming, hence one way to speed up fitting is to subset the regression matrix using the subsample argument (i.e. randomly subset observations).

Author(s)

Tomislav Hengl

See Also

fit.regModel, fit.gstatModel, gstat::fit.variogram

Examples

library(sp)
library(gstat)

## fit variogram to the Meuse data:
demo(meuse, echo=FALSE)
# produce a regression matrix:
ov <- over(meuse, meuse.grid)
ov <- cbind(data.frame(meuse[,"om"]), ov)
# fit a model:
v <- fit.vgmModel(om-1, rmatrix=ov, meuse.grid, dimensions="2D")
plot(variogram(om ~ 1, meuse[!is.na(meuse$om),]), v$vgm)

Description

A subset of the National Geochemical Survey (NGS) samples covering the Indiana and Illinois State. Contains a total of 2681 point samples.
Usage
data(geochm)

Format

Data frame; contains the following columns:

REC_NO factor; unique record identifier
DATASET factor; abbreviated dataset group e.g. "AK+MI"
TYPEDESC factor; abbreviated description of sample type: stream, pond, spring, soil etc
COLL_DATE integer; sampling date
LONGITUDE numeric; longitude in decimal degrees (NAD27 datum)
LATITUDE numeric; latitude in decimal degrees (NAD27 datum)
DATUM factor; geodetic datum if different from NAD83
RELIEF factor; relief in drainage basin from which sample was collected
FORMATION factor; code or name of geologic formation in which sample area was located
ROCK_TYPE factor; rock type in area of sample collection e.g. "carbonate"
SOIL_HORIZ factor; soil horizon from which the sample was collected
COLOR factor; observed color of powdered sample during splitting
MEDIUM factor; sample medium — rock, sediment, standard, or unknown
SOURCE factor; geological source of the sample medium that was collected e.g. "Beach"
AS_ICP40 numeric; As (ppm) by Inductively Coupled Plasma Spectrometry (ICP) after acid dissolution
CD_ICP40 numeric; Cd (ppm)
CR_ICP40 numeric; Cr (ppm)
CU_ICP40 numeric; Cu (ppm)
NI_ICP40 numeric; Ni (ppm)
ZN_ICP40 numeric; Zn (ppm)
AS_AA numeric; As (ppm) by Hydride Atomic Absorption
Hg_AA numeric; Hg (ppm) by Hydride Atomic Absorption
PB_ICP40 numeric; Pb (ppm)
C_TOT numeric; total carbon (weight percentage) by combustion
C_ORG numeric; organic carbon (weight percentage) as a difference between C_TOT and C_C03
C_C03 numeric; carbonate carbon (weight percentage) by Coulometric Titration
S_TOT numeric; total sulfur (weight percentage) by combustion

Note

Negative values of the heavy metal concentrations indicate a determination that is below the limit of detection for the analytic method used. The magnitude of the negative number indicates the detection limit. For example, -10 ppm means the result should be regarded as < 10 ppm.
Author(s)

National Geochemical Survey database is maintained by the USGS National Geochemical Survey Team (contact: Peter Schweitzer). This subset has been prepared for the purpose of testing various geostatistical mapping algorithms by Tomislav Hengl (tom.hengl@wur.nl).

References

- National Geochemical Survey database (http://tin.er.usgs.gov/geochem/)

Examples

```r
library(sp)
# Load the NGS data:
data(geochn)
coordinates(geochn) <- ~LONGITUDE+LATITUDE
proj4string(geochn) <- CRS("+proj=longlat +ellps=clrk66 +datum=NAD27 +no_defs")
## Not run:
require(plotKML)
data(SAGA_pal)
# replace the missing values with half the detection limit:
geochm$PB_ICP40 <- ifelse(geochn$PB_ICP40 < 0, 0, 2, geochn$PB_ICP40)
shape = "http://maps.google.com/mapfiles/kml/pal2/icon18.png"
km1(geochn, shape = shape, colour = log1p(PB_ICP40), labels = ",
colour_scale = SAGA_pal[1]), kmz = TRUE)
## End(Not run)
```

### geosamples-class

A class for spatially and temporally referenced samples

Description

A class for spatially and temporally referenced samples with fixed column names (standardized geosamples). Corresponds to the point "Placemark" in the KML schema.

Slots

- registry: object of class "character"; URI of the online registry i.e. the URL where the "producerid" column can be linked to all other connected metadata
- methods: object of class "data.frame"; a table with method names ("methodid"), a one sentence description of each method ("description"), measurement units or levels ("units"), and associated detection limits ("detectionLimit")
data: object of class "data.frame"; a standardized table with fixed column names: "observationid" (unique observation ID; as specified in the data registry service), "sampleid" (producer's ID; usually site ID and horizon ID or sequence number), "longitude" (longitude on the WGS84 ellipsoid), "latitude" (latitude on the WGS84 ellipsoid), "locationError" (error radius in meters), "TimeSpan.begin" (begin of the measurement period), "TimeSpan.end" (end of the measurement period), "altitude" (height above ground or above the sea level in meters), "altitudeMode" (one of the KML schema altitude modes), "sampleArea" (spatial support in square meters), "sampleThickness" (thickness of horizons in meters or vertical support), "observedValue" (measured value), "methodid" (method name; see methods table), "measurementError" (estimated measurement error for that specific observation)

The column names in the data slot largely reflect the KML schema elements. Geosamples are interoperable with the OGC Observations and measurements specifications, but do not necessarily contain all required fields (i.e. there is no validity check for the OGC specifications). Geosamples-class can be used to store and manipulate geological, hydrological, geochemical, biodiversity, soil science and similar field samples near or below land surface. Geological and soil samples can also be registered via the geosamples.org, in which case the "observationid" will correspond to the unique sample identifier. "sampleid" column allows linking geosamples to the original ID's.

Methods

- **show** signature(obj = "geosamples"): summarize object by listing methods, total number of observations, total area covered etc.
- **subset** signature(obj = "geosamples"): subset to a single variable type; returns a data frame
- **over** signature(x = "SpatialPixelsDataFrame" or "RasterStack", y = "geosamples"): overlay geosamples and spatial pixels
- **stack** signature(x = "geosamples"): stacks all observed values into a single table using reshape function
- **write.data** signature(obj = "geosamples"): write geosamples to an external format e.g. GeoEAS

Author(s)

Tomislav Hengl

References

- International Geo Sample Number (http://en.wikipedia.org/wiki/International_Geo_Sample_Number)
- KML Reference (https://developers.google.com/kml/documentation/kmlreference)
- OGC Observations and Measurements standard (http://www.opengeospatial.org/standards/om/)
- SESAR, the System for Earth Sample Registration (http://www.geosamples.org)

See Also

as.geosamples
Derive 1 degree cell IDs

Description
Derives ID's of the 1 degree cells in the default land mask for a given polygon defining the spatial domain of interest.

Usage
```r
## S4 method for signature 'SpatialPolygons'
getID(obj, pixsize = 3/3600, empty.tif = FALSE,
       compress = FALSE, zipname = set.file.extension(tempfile(tmpdir = getwd()), "zip"))
```

Arguments
- **obj**: object of class "SpatialPolygons"; must be in geographical coordinates (WGS84)
- **pixsize**: grid cell size in decimal degrees (set at 0.000833333 or 100 m around equator)
- **empty.tif**: logical; specify whether a GeoTiff mask file should be created
- **compress**: logical; specify whether to compress GeoTiffs
- **zipname**: (optional); zip archive file name

Value
The output is a vector of grid cell ID names e.g. W79_N83. These can be further used to automate digital soil mapping for large areas.

Note
This operation can be time consuming for large areas (e.g. continents).

Author(s)
Tomislav Hengl

See Also
- landmask

Examples
```r
library(sp)
## Bounding box for Malawi:
bbox <- expand.grid(lon=c(32.67152, 35.915046), lat=c(-17.12721, -9.363796))
bbox[5,] <- bbox[1,]
crs = CRS("+proj=longlat +datum=WGS84")
x <- SpatialPolygons(list(Polygons(list(Polygon(bbox)), ID="1")), proj4string=crs)
ID.lst <- getID(x)
```
getSpatialTiles

Get a list of tiles (regular blocks)

Description

Creates a list of tiles ("SpatialPolygons") for a given spatial domain i.e. extent. Input can be any object of class "Spatial" or "GDALobj".

Usage

```r
## S4 method for signature 'Spatial'
getSpatialTiles(obj, block.x, block.y = block.x,
               overlap.percent = 0, limit.bbox = TRUE, return.SpatialPolygons = TRUE)
## S4 method for signature 'ANY'
getSpatialTiles(obj, block.x, block.y = block.x,
               overlap.percent = 0, limit.bbox = TRUE, return.SpatialPolygons = FALSE)
```

Arguments

- `obj` object of class "Spatial*
- `block.x` numeric; size of block in x-direction (meters or corresponding mapping units)
- `block.y` numeric; size of block in y-direction (meters or corresponding mapping units)
- `overlap.percent` numeric; percentage overlap (must be a positive number)
- `limit.bbox` logical; specifies whether to limit the extent of tiles to the bounding box only
- `return.SpatialPolygons` logical; specifies whether to return a list of tiles as "SpatialPolygons" or a data frame with bounding box coordinates

Details

The first output tile starts by default at the lower left corner. `getSpatialTiles`-method can only be used to generate regular tiles.

Value

Returns a list of tiles either as a list of "SpatialPolygons" or a data frame with with bounding box coordinates.

Author(s)

Tomislav Hengl

See Also

tile, sp::spsample
GlobalSoilMap-class

A class for GlobalSoilMap soil property maps

Description

A class containing predictions of target soil property at six standard depths following the GlobalSoilMap.net specifications: \( sd1 = 2.5 \text{ cm (0–5)}, \) \( sd2 = 10 \text{ cm (5–15)}, \) \( sd3 = 22.5 \text{ cm (15–30)}, \) \( sd4 = 45 \text{ cm (30–60)}, \) \( sd5 = 80 \text{ cm (60–100)}, \) \( sd6 = 150 \text{ cm (100–200)}. \)

Slots

- **varname:** object of class "character"; abbreviated variable name registered in the Global Soil Data registry
- **timeSpan:** object of class "list"; contains begin and end of the sampling period of class "POSIXct"
- **sd1:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 2.5 cm (0–5)
- **sd2:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 10 cm (5–15)
- **sd3:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 22.5 cm (15–30)
- **sd4:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 45 cm (30–60)
- **sd5:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 80 cm (60–100)
- **sd6:** object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 150 cm (100–200)

References


See Also

SoilGrids-class, SpatialComponents-class, geosamples-class
**GSIF.env**

**GSIF specific environmental variables / paths**

**Description**

Sets the environmental, package specific parameters and settings (URLs, names, default cell size and similar) that can be later on passed to other functions.

**Usage**

```r
GSIF.env(wps.server = "http://wps.worldgrids.org",
    ref_CRS = "+proj=longlat +datum=WGS84",
    NAflag = -99999,
    license_url = "http://creativecommons.org/licenses/by/3.0/",
    project_url = "http://gsif.r-forge.r-project.org/",
    stdepths = c(-2.5, -10, -22.5, -45, -80, -150)/100,
    stsize = c(5, 10, 15, 30, 40, 100)/100,
    cellsize = rev(c(6/120, 3/120, 1/120, 1/240, 1/600, 1/1200, 1/3600)),
    REST.server = 'http://rest.soilgrids.org/",
    attributes = c("ORCDOC", "PHIHOX", "SNDPPT", "SLTPPT", "CLYPPT", "CFRVOL", "CEC", "BLD", "TAXGWRB", "TAXOUSDA"),
    TimeSpan = list(begin=as.POSIXct("1950-01-01"), end=as.POSIXct("2005-12-30")),
    show.env = TRUE)
```

**Arguments**

- `wps.server` character; location of the WPS server
- `ref_CRS` the referent CRS proj4string ("+proj=longlat +datum=WGS84")
- `NAflag` the default missing value flag (usually "-99999")
- `license_url` the default license URL
- `project_url` the default location of the package documentation
- `stdepths` numeric; standard depths
- `stsize` numeric; standard horizon thicknesses
- `cellsize` numeric; standard grid cell sizes on WGS84 geographical coordinates
- `REST.server` character; location of the SoilGrids REST service
- `attributes` character; default soil variables of interest
- `TimeSpan` list; default begin end times (temporal coverage of SoilGrids)
- `show.env` logical; specify whether to print all environmental parameters
Note

To further customize the GSIF options, consider putting:

library(GSIF); GSIF.env(..., show.env = FALSE)

in your "/etc/Rprofile.site".

Author(s)

Tomislav Hengl

Examples

# environmental variables:
GSIF.env()
get("cellsize", envir = GSIF.opts)

gstatModel-class  A class for a geostatistical model

Description

A class containing fitted parameters of a geostatistical model to be used to run predictions by regression-kriging. It comprises regression model (e.g. a GLM), variogram model, and observation locations of sampled values used to fit the model.

Details

Any model passed to the regModel slot must come with generic functions such as residuals, fitted.values, summary, formula and predict.

Slots

regModel: object of class "ANY"; output of fitting a generalized linear model (GLM) or any similar regression model
svgmModel: object of class "data.frame"; sample variogram with semivariances and distances
vgmModel: object of class "data.frame"; the fitted gstat variogram model parameters containing variogram model, nugget, sill, range and the five anisotropy parameters
sp: object of class "SpatialPointsDataFrame"; observation locations
Methods

**predict** signature(obj = "gstatModel"): makes predictions for a set of given predictionLocations (gridded maps) at block support corresponding to the cellsize slot in the object of class "SpatialPixelsDataFrame"; to produce predictions at point support, submit the predictionLocations as "SpatialPointsDataFrame"

**validate** signature(obj = "gstatModel"): runs $n$-fold cross-validation of the existing gstatModel (it re-fits the model using existing formula string and model data, then estimates the mapping error at validation locations)

**plot** signature(obj = "gstatModel", ...): plots goodness of fit and variogram model

Note

"SpatialPredictions" saves results of predictions for a single target variable, which can be of type numeric or factor. Multiple variables can be combined into a list. When using nsim argument with the predict method, the output result will be of type:

`plotKML::RasterBrickSimulations-class`

i.e. $N$ number of equiprobable realizations. To generate an object of type:

`plotKML::SpatialPredictions-class`

set nsim = 0.

Author(s)

Tomislav Hengl and Gerard B.M. Heuvelink

See Also

- `predict.gstatModel`
- `test.gstatModel`
- `plotKML::SpatialPredictions-class`
- `plotKML::RasterBrickSimulations-class`
- `gstat::gstat`
- `stats::glm`

Examples

```r
# load observations:
library(plotKML)
library(sp)
demo(meuse, echo=FALSE)
data(meuse)
coordinates(meuse) <- ~x+y
proj4string(meuse) <- CRS("+init=epsg:28992")

# load grids:
data(meuse.grid)
coordinates(meuse.grid) <- ~x+y
gridded(meuse.grid) <- TRUE
proj4string(meuse.grid) <- CRS("+init=epsg:28992")
```
isis

### fit a model:
```r
omm <- fit.gstatModel(meuse, om.dist+ffreq,
  fit.family=gaussian(link="log"), meuse.grid)
plot(omm)
```

### produce SpatialPredictions:
```r
om.rk <- predict(omm, predictionLocations = meuse.grid)
plot(om.rk)
```

### run a proper cross-validation:
```r
rk.cv <- validate(omm)
```

RMSE:
```r
sqrt(mean((rk.cv$validation$var1.pred-rk.cv$validation$observed)^2))
```

---

isis

**ISRIC Soil Information System**

**Description**

ISRIC’s collection of global soil monoliths that represent the main soil reference groups of the World Reference Base for Soil Resources (WRB). Includes some 950 monoliths (785 with coordinates) from over 70 countries with detailed soil profile and environmental data.

**Usage**

data(isis)

**Format**

The isis data set contains two data frames — sites and horizons. Sites table contains the following columns:

- **SOURCEID** factor; unique ISIS code
- **LONWGS84** numeric; longitude in decimal degrees on the WGS84 datum
- **LATWGS84** numeric; latitude in decimal degrees on the WGS84 datum
- **TIMESTR** date; the date on which this particular soil was described or sampled
- **TAXGWRB** factor; soil group based on the WRB classification system
- **TAXNUSDA** factor; Keys to Soil Taxonomy taxon name e.g. "Natraqulf"
- **BDRICM** numeric; depth to bedrock (R horizon) if observed
- **SOURCEDB** factor; source data base

Horizons table contains the following columns:

- **SOURCEID** factor; unique ISIS code
- **UHDICM** numeric; upper horizon depth from the surface in cm
- **LHDICM** numeric; lower horizon depth from the surface in cm
- **CRFVOL** numeric; volume percentage of coarse fragments (> 2 mm)
- **PHIHOX** numeric; pH index measured in water solution
PHIKCL numeric; pH index measured in KCl solution
ORCDRC numeric; soil organic carbon content in permilles
SNDPPT numeric; weight percentage of the sand particles (0.05–2 mm)
SLTPPT numeric; weight percentage of the silt particles (0.0002–0.05 mm)
CLYPPT numeric; weight percentage of the clay particles (<0.0002 mm)
CEC numeric; Cation Exchange Capacity in cmol+/kg
BLD bulk density in tonnes per cubic-meter

Author(s)
ISRIC — World Soil Information

Examples
library(rgdal)
library(sp)

data(isis)
sites <- isis$sites
coordinates(sites) <- ~ LONWGS84 + LATWGS84
proj4string(sites) <- "+proj=longlat +datum=WGS84"
## Not run:
## obtain country borders:
library(maps)
country.m = map('world', plot=FALSE, fill=TRUE)
IDs <- sapply(strsplit(country.m$names, ":"), function(x) x[1])
require(maptools)
country <- as(map2SpatialPolygons(country.m, IDs=IDs), "SpatialLines")
proj4string(country) = "+proj=longlat +datum=WGS84"
## overlay and plot points and maps:
plot(country, col="darkgrey")
points(sites, pch=21, bg="red", cex=.6, col="black")
## End(Not run)

Description
Land mask showing the 1-degree cells (about 19 thousand in total) in the geographical coordinates, and the productive soils mask (areas with a positive Leaf Area Index at least once in the period 2002–2011). The land mask is based on the Global Self-consistent, Hierarchical, High-resolution Shoreline Database data (GSHHS 2.1), the productive soils mask on the MODIS Leaf Area Index monthly product (MOD15A2), and the water mask is based on the MOD44W product. The map of the Keys to Soil Taxonomy soil suborders of the world at 20 km is based on the USDA-NRCS map of the global soil regions.
Usage

```r
data(landmask)
```

Format

A `landmask` data set is a data frame with the following columns:

- **mask** percent: land mask value
- **soilmask** boolean: soil mask value
- **watermask** percent: water mask value
- **Lon_it** indication of the longitude quadrant (W or E)
- **Lat_it** indication of the latitude quadrant (S or N)
- **cell_id** cell id code e.g. W79_N83
- **x** longitudes of the center of the grid nodes
- **y** latitudes of the center of the grid nodes

A `landmask20km` data set is an object of class `SpatialGridDataFrame` with the following columns:

- **mask** percent: land mask value
- **suborder** factor: Keys to Soil Taxonomy suborder class e.g. Histels, Udolls, Calcids, ...
- **soilmask** factor: global soil mask map based on the land cover classes (see: SMKISR3)

Note

The land mask has been generated from the layer `GSHHS_shp/GSHHS_h_L1.shp` (level-1 boundaries).

References

- Global Self-consistent, Hierarchical, High-resolution Shoreline Database (http://en.wikipedia.org/wiki/GSHHS)
- USDA-NRCS Global Soil Regions Map (http://www.nrcs.usda.gov/)

See Also

`rworldmap::rworldmapExamples`, `maps::map`
Examples

```r
library(rgdal)
library(sp)

data(landmask)
gridded(landmask) <- ~x+y
proj4string(landmask) <- "+proj=longlat +datum=WGS84"
## Not run: ## plot maps:
library(maps)
country.m = map('world', plot=FALSE, fill=TRUE)
IDs <- sapply(strsplit(country.m$names, ""), function(x) x[1])
library(maptools)
country <- as(map2SpatialPolygons(country.m, IDs=IDs), "SpatialLines")
spplot(landmask["mask"], col.regions= "grey", sp.layout=list("sp.lines", country))
spplot(landmask["soilmask"], col.regions= "grey", sp.layout=list("sp.lines", country))

## End(Not run)
## also available in the Robinson projection at 20 km grid:
data(landmask20km)
image(landmask20km[1])
summary(landmask20km$suborder)
summary(landmask20km$soilmask)
```

---

**LRI**

**Limiting Rootability**

Description

Derive Limiting Rootability using observed soil properties at at least three depths.

Usage

```r
LRI(UHDICM, LHDICM, SNDPPT, SLTPPT, CLYPPT, CRFVOL, BLD,
    ORCDRC, ECN, CEC, ENA, EACKCL, EXB, PHIHOX, CRB, GYP, tetaS,
    fix.values=TRUE, thresholds, print.thresholds=FALSE)
```

Arguments

- **UHDICM**
  - numeric; upper horizon depth in cm
- **LHDICM**
  - numeric; lower horizon depth in cm
- **SNDPPT**
  - numeric; sand content in percent
- **SLTPPT**
  - numeric; silt content in percent
- **CLYPPT**
  - numeric; clay content in percent
- **CRFVOL**
  - numeric; volume percentage of coarse fragments (> 2 mm)
- **BLD**
  - numeric; bulk density in kg per cubic-meter for the horizon/solum
- **ORCDRC**
  - numeric; soil organic carbon concentration in permille or g per kg
Value

Returns a vector with TRUE / FALSE values where FALSE indicates rooting not possible. Threshold values used to derive Limiting Rootability scores are set based on common soil agricultural productivity thresholds (e.g. in this case for maize), and can be adjusted via the thresholds argument. This function also accounts for textural changes (sudden changes in sand and clay content) and saturated water content.

Note

Horizons need to be sorted by depth e.g. 0-5, 5-15, 15-30... For each soil property at least three depths are needed otherwise the function reports an error. Missing values are automatically replaced using smoothing splines.

Author(s)

Johan Leenaars and Maria Ruiperez Gonzalez

References

make.3Dgrid

Methods to prepare 3D prediction locations

Description

Generates a list of objects of type "SpatialPixelsDataFrame" with longitude, latitude and altitude coordinates (these names are used by default for compatibility with the geosamples-class).

See Also

AWCPTF, ERDICM

Examples

```r
## sample profile from Nigeria (ISRIC:NG0017):
UHDICM = c(0, 18, 36, 65, 87, 127)
LHDICM = c(18, 36, 65, 87, 127, 181)
SNDDPT = c(66, 70, 54, 43, 35, 47)
SLTPPT = c(13, 11, 14, 14, 18, 23)
CLYPPT = c(21, 19, 32, 43, 47, 30)
CRFVOL = c(17, 72, 73, 54, 19, 17)
BLD = c(1.57, 1.60, 1.52, 1.58, 1.40, 1.42)*1000
PHIHOX = c(6.5, 6.9, 6.5, 6.2, 6.2, 6.0)
CEC = c(9.3, 4.5, 6.0, 8.0, 9.4, 10.9)
ENA = c(0.1, 0.1, 0.1, 0.1, 0.1, 0.2)
EACKCL = c(0.1, 0.1, 0.1, NA, NA, 0.5)
EXB = c(8.9, 4.0, 5.7, 7.4, 8.9, 10.4)
ORDCRC = c(18.4, 4.4, 3.6, 3.6, 3.2, 1.2)
x <- LRI(UHDICM=UHDICM, LHDICM=LHDICM, SNDDPT=SNDDPT,
    SLTPPT=SLTPPT, CLYPPT=CLYPPT, CRFVOL=CRFVOL,
    BLD=BLD, ORDCRC=ORDCRC, CEC=CEC, ENA=ENA, EACKCL=EACKCL,
    EXB=EXB, PHIHOX=PHIHOX, print.thresholds=TRUE)
x
## Most limiting: BLD.f and CRFVOL, but nothing < 20

## Effective Rootable Depth:
sel <- x==FALSE
if(all(sel==FALSE)){
    UHDICM[which(sel==TRUE)[1]]
} else {
    max(LHDICM)
}

xI <- attr(x, "minimum.LRI")
## derive Effective rooting depth:
ERDICM(UHDICM=UHDICM, LHDICM=LHDICM, minimum.LRI=xI, DRAINFAO="M")
```
Usage

```r
## S4 method for signature 'SpatialPixelsDataFrame'
make.3Dgrid(obj,
  proj4s = get("ref_CRS", envir = GSIF.opts),
  pixsize = get("cellsize", envir = GSIF.opts)[2],
  resampling_method = "bilinear",
  NAflag = get("NAflag", envir = GSIF.opts),
  stdepths = get("stdepths", envir = GSIF.opts),
  tmp.file = TRUE, show.output.on.console = TRUE, ...)
## S4 method for signature 'RasterBrick'
make.3Dgrid(obj,
  proj4s = get("ref_CRS", envir = GSIF.opts),
  pixsize = get("cellsize", envir = GSIF.opts)[2],
  resampling_method = "bilinear",
  NAflag = get("NAflag", envir = GSIF.opts),
  stdepths = get("stdepths", envir = GSIF.opts),
  tmp.file = TRUE, show.output.on.console = TRUE, ...)
```

Arguments

- `obj`: object of class "SpatialPixelsDataFrame" or "RasterBrick"
- `proj4s`: character; proj4string describing the target coordinate system
- `pixsize`: grid cell size in decimal degrees (set by default at 1/1200 (0.0008333333 or 100 m around equator)
- `resampling_method`: character; resampling method to be passed the reprojection algorithm
- `NAflag`: character; missing value flag
- `stdepths`: numeric; list of standard depths
- `tmp.file`: logical; specifies whether a temporary file name should be generated
- `show.output.on.console`: logical; specifies whether to print out the progress
- `...`: optional arguments that can be passed to the reprojection algorithm

Value

The output is list of objects of class "SpatialPixelsDataFrame" where the number of elements in the list corresponds to the number of standard depths.

Note

If the input object is of class "SpatialPixelsDataFrame", the method by default uses FWTools (warp command) to resample grids, otherwise the raster::projectRaster command is passed. FWTools must be installed separately.
Note: this operation can be time consuming for large areas (e.g. » 1e6 pixels).
make.3Dgrid

Author(s)

Tomislav Hengl

References

- FWTools (http://fwtools.maptools.org)
- gdalUtils package (http://CRAN.R-project.org/package=gdalUtils)
- Raster package (http://CRAN.R-project.org/package=raster)

See Also

spc, geosamples-class, plotKML::reproject

Examples

```r
## grids Ebergotzen:
library(plotKML)
library(rgdal)
library(raster)

data(eberg_grid)
gridded(eberg_grid) <- ~x+y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")
## convert to spatial components:
formulaString <- ~ PRMGE06+DEMSRT6+TWISRT6+TIRAST6
eberg_spc <- spc(eberg_grid, formulaString)
## create 3D locations in the original coordinate system:
eberg_Sdxy <- sp3(eberg_spc@predicted)
## Not run: ## wrapper function to create 3D locations in the default WGS84 system:
eberg_3D <- make.3Dgrid(eberg_spc@predicted)
image(eberg_3D[[1]]["PC1"])
## downscale 100 m resolution imagery to 25 m:
data(eberg_grid25)
gridded(eberg_grid25) <- ~x+y
proj4string(eberg_grid25) <- CRS("+init=epsg:31467")
eberg_grid25@data <- cbind(eberg_grid25@data,
    warp(eberg_grid, pixsize=eberg_grid25@grid@cellsize[1],
    GridTopology=eberg_grid25@grid, resampling_method="cubicspline")@data)
## this function requires FWTools!

## End(Not run)
```
makeGstatCmd  

Make a gstat command script

Description

Generates a command script based on the regression model and variogram. This can then be used to run predictions/simulations by using the pre-compiled binary gstat.exe.

Usage

makeGstatCmd(formString, vgmModel, outfile, easfile,
  nsim = 0, nmin = 20, nmax = 40, radius, zmap = 0,
  predictions = "var1.pred.hdr", variances = "var1.svar.hdr",
  xcol = 1, ycol = 2, zcol = 3, vcol = 4, Xcols)

Arguments

formString  object of class "formula" — regression model
vgmModel  object of class "vgmmodel" or "data.frame"
outfile  character; output file for the command script
easfile  character; file name for the GeoEAS file with observed values
nsim  integer; number of simulations
nmin  integer; smallest number of points in the search radius (see gstat user’s manual)
nmax  integer; largest number of points in the search radius (see gstat user’s manual)
radius  numeric; search radius (see gstat user’s manual)
zmap  numeric; fixed value for the 3D dimension in the case of 3D kriging
predictions  character; output file name for predictions
variances  character; output file name for kriging variances
xcol  integer; position of the x column in the GeoEAS file
ycol  integer; position of the y column in the GeoEAS file
zcol  integer; position of the z column in the GeoEAS file
vcol  integer; position of the target variable column in the GeoEAS file
Xcols  integer; column numbers for the list of covariates

Details

To run the script under Windows OS you need to obtain the pre-compiled gstat.exe program from the www.gstat.org website, and put it in some directory e.g. c:/gstat/. Then add the program to your path (see environmental variable under Windows > Control panel > System > Advanced > Environmental variables), or copy the exe program directly to some windows system directory.
**Note**

The advantage of using gstat.exe is that it loads large grids much faster to memory than if you use gstat in R, hence it is potentially more suited for computing with large grids. The drawback is that you can only pass simple linear regression models to gstat.exe. The stand-alone gstat is not maintained by the author of gstat any more.

**Author(s)**

Tomislav Hengl

**References**


**See Also**

`write.data, fit.gstatModel, gstat::krige`

**Examples**

```r
## Not run:
library(sp)
library(gstat)

# Meuse data:
demo(meuse, echo=FALSE)
# fit a model:
omm <- fit.gstatModel(observations = meuse, formulaString = om-dist,
  family = gaussian(log), covariates = meuse.grid)
str(omm@vgmmodel)
# write the regression matrix to GeoEAS:
meuse$log_om <- log1p(meuse$om)
write.data(obj=meuse, covariates=meuse.grid[,"dist"],
  outfile="meuse.eas", methodid="log_om")
writeGDAL(meuse.grid[,"dist"], "dist.rst", drivename="RST",
  mvFlag="-99999")
makeGstatCmd(log_om-dist, vgmModel=omm@vgmModel,
  outfile="meuse_om_sims.cmd", easfile="meuse.eas",
  nsim=50, nmin=20, nmax=40, radius=1500)
# compare the processing times:
system.time(system("gstat meuse_om_sims.cmd"))
vgmModel = omm@vgmModel
class(vgmModel) <- c("variogramModel", "data.frame")
system.time(om.rk <- krige(log_om-dist, meuse[!is.na(meuse$log_om)],
  meuse.grid, nmin=20, nmax=40, model=vgmModel, nsim=50))

## End(Not run)
```
MaxEnt

*Prediction and cross-validation using the Maximum Entropy*

**Description**

Runs MaxEnt algorithm on a set of observations ("ppp" class from the spatstat package) and environmental covariates (of "SpatialPixelsDataFrame" class) and returns predicted probability of occurrence and cross-validation of models with presence/absence data.

**Usage**

```r
## S4 method for signature 'ppp,SpatialPixelsDataFrame'
MaxEnt(occurrences, covariates,
     nfold = 5, Npoints = 1000, sciname = as.character(NA),
     period = c(Sys.Date()-1, Sys.Date()), ...)
```

**Arguments**

- `occurrences` object of type "ppp"; occurrences
- `covariates` object of type "SpatialPixelsData"; list of covariate layers
- `nfold` object of type "integer"; number of folds used for cross-validation
- `Npoints` object of type "integer"; number of points used for cross-validation
- `sciname` object of type "character"; usually species latin name (it can also be a surveyor’s team name or a sampling design)
- `period` object of type "Date"; sampling period
- `...` for more additional arguments see dismo::predict

**Value**

Returns an object of type "SpatialMaxEntOutput" with the following slots: `sciname` (usually latin "genus" and "species" name), `occurrences` (occurrence-only records), `TimeSpan.begin` (begin of sampling), `TimeSpan.end` (end of sampling), `maxent` (object of class "MaxEnt" produced as an output of the dismo::maxent function), `sp.domain` (assumed spatial domain), and `predicted` (results of prediction produced using the MaxEnt software).

**Note**

MaxEnt is one of the standard tools used in ecology for Niche analysis and species distribution modelling. What makes it especially robust is the fact that it can take both continuous and factor data as inputs, and has no requirements considering the distribution of covariates (Phillips et al., 2006). In the example below, I use MaxEnt to analyze representation of feature space by a given soil sampling pattern (i.e. mis-representation or the sampling preference by the surveyors). For more information on how to install MaxEnt and use it in R, see dismo package documentation.
Author(s)

Tomislav Hengl

References

- MaxEnt software (http://www.cs.princeton.edu/~schapire/maxent/)
- Dismo package (http://CRAN.R-project.org/package=dismo)

See Also
dismo::maxent, plotKML::SpatialMaxEntOutput-class

Examples

```r
# load data:
library(plotKML)
library(rJava)
library(spatstat)
library(maptools)
library(dismo)

data(eberg)
data(eberg_grid)

## prepare data for spatial analysis:
eberg.xy <- eberg[runif(nrow(eberg)) < .3,]
coordinates(eberg.xy) <- ~X+Y
proj4string(eberg.xy) <- CRS("+init=epsg:31467")

## format gridded data:
gridded(eberg_grid) <- ~x+y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")

## convert to a "ppp" object:
eberg.ppp <- as.ppp(eberg.xy)

## run MaxEnt analysis (evaluates sampling bias or mis-representation):
jar <- paste(system.file(package="dismo"), "/java/maxent.jar", sep="")
if(file.exists(jar)){
  me.eberg <- MaxEnt(occurrences=eberg.ppp, covariates=eberg_grid)
  ## NOTE: MaxEnt can be time-consuming!
  ## plot the results:
  par(mfrow=c(1,2), mar=c(0.5,0.5,0.5,0.5), oma=c(0,0,0,0))
  image(as(me.eberg@predicted, "SpatialPixelsDataFrame"),
        col=rev(heat.colors(25)), xlab="", ylab="")
  points(me.eberg@occurrences, pch="+", cex=.7)
  image(me.eberg@sp.domain, col="grey", xlab="", ylab="")
}
```
**merge**

**Merge multiple predictions**

**Description**

Merges objects of class "SpatialPredictions" or "RasterBrickSimulations" and produces average predictions where the two objects overlap spatially. If the predictions are available at different resolutions, then it down scales all other grids to the smallest grid cell size using bicubic splines (for predictions) i.e. nearest neighbor algorithm (for simulations). Weights can be passed via the RMSE.l argument, otherwise they will be estimated from validation slot (if objects are of the class "SpatialPredictions").

**Usage**

```r
## S4 method for signature 'SpatialPredictions, SpatialPredictions'
merge(x, y, ..., RMSE.l = NULL, silent = TRUE)
```

**Arguments**

- `x`: object of class "SpatialPredictions" or "RasterBrickSimulations"
- `y`: object of class "SpatialPredictions" or "RasterBrickSimulations"
- `...`: additional objects of class "SpatialPredictions" or "RasterBrickSimulations"
- `RMSE.l`: numeric; list of mean prediction errors for each object (these are used as weights during the averaging)
- `silent`: logical; specifies whether to print out the progress and used RMSE’s

**Value**

Returns an object of type "SpatialPixelsDataFrame" or "RasterBrickSimulations" that contains only the merged values.

**Note**

Merging of multiple spatial predictions using weighted averaging is a heuristic approach to mapping. This method assumes that the predictions are completely independent (independent covariates, independent models), but this not might be the case and hence the merged predictions will be sub-optimal. Merging multiple predictions is however attractive for situations where the predictions do not have the same extent, so that spatial predictions with larger coverage can be used to fill in the gaps in locally produced predictions.

**Author(s)**

Tomislav Hengl and Gerard B.M. Heuvelink
mpspline

References


mpspline

Fits a mass preserving spline

Description

Fits a mass preserving spline to a soil profile data.

Usage

```r
## S4 method for signature 'SoilProfileCollection'
mpspline(obj, var.name,
        lam = 0.1, d = t(c(0,5,15,30,60,100,200)), vlow = 0,
        vhigh = 1000, show.progress=TRUE)
```

Arguments

- **obj**: object of class "SoilProfileCollection"
- **var.name**: character; target variable name (must be a numeric variable)
- **lam**: numeric; lambda the smoothing parameter
- **d**: numeric; standard depths
- **vlow**: numeric; smallest value of the target variable (smaller values will be replaced)
- **vhigh**: numeric; highest value of the target variable (larger values will be replaced)
- **show.progress**: logical; specifies whether to display the progress bar

Value

Returns a list with four elements:

- **idcol**: site ID column
- **var.fitted**: matrix; are are spline-estimated values of the target variable at observed depths (upper and lower depths are indicated as attributes)
- **var.std**: matrix; are spline-estimated values of the target variable at standard depths
- **var.1cm**: matrix; are spline-estimated values of the target variable using the 1 cm increments

Note

Target variable needs to be a numeric vector measured at least 2 horizons for the spline to be fitted. Profiles with 1 horizon are accepted and processed as per output requirements, but no spline is fitted as such. Only positive numbers for upper and lower depths can be accepted. It is assumed that soil variables collected per horizon refer to block support i.e. they represent averaged values for the whole horizon. This operation can be time-consuming for large data sets.
mpspline

Author(s)

Brendan Malone and Tomislav Hengl

References


See Also

stats::spline

Examples

library(aqp)
library(plyr)
library(sp)

## sample profile from Nigeria:
lon = 3.90; lat = 7.50; id = "ISRIC:NG0017"; FAO1988 = "Lxp"
top = c(0, 18, 36, 65, 87, 127)
bottom = c(18, 36, 65, 87, 127, 181)
ORCDRC = c(18.4, 4.4, 3.6, 3.6, 3.2, 1.2)
munsell = c("7.5YR3/2", "7.5YR4/4", "2.5YR5/6", "5YR5/8", "5YR5/4", "10YR7/3")

## prepare a SoilProfileCollection:
prof1 <- join(data.frame(id, top, bottom, ORCDRC, munsell),
               data.frame(id, lon, lat, FAO1988), type='inner')
depths(prof1) <- id ~ top + bottom
site(prof1) ~ lon + lat + FAO1988
coordinates(prof1) <- lon + lat
proj4string(prof1) <- CRS("+proj=longlat +datum=WGS84")

## fit a spline:
ORCDRC.s <- mpspline(prof1, var.name="ORCDRC")
str(ORCDRC.s)

## Example with multiple soil profiles
## Make some fake, but reasonable profiles:
rand.prof <- ldply(1:20, random_profile, n=c(6, 7, 8), n_prop=1, method='LPP')
## promote to SPC and plot
depths(rand.prof) <- id ~ top + bottom
plot(rand.prof, color='p1')
## fit MP spline by profile
try( m <- mpspline(rand.prof, 'p1') )
**Soil organic carbon stock**

**Description**

Derive soil organic carbon stock / storage (in kilograms per square-meter) and propagated uncertainty for a given horizon/solum depth and based on soil organic carbon concentration, horizon/solum thickness, bulk density and percentage of coarse fragments.

**Usage**

```r
OCSKGM(ORCDRC, BLD=1400, CRFVOL=0, HSIZE,
     ORCDRC.sd=10, BLD.sd=100, CRFVOL.sd=5, se.prop=TRUE)
```

**Arguments**

- `ORCDRC` numeric; soil organic carbon concentration in permille or g / kg
- `BLD` numeric; bulk density in kg / cubic-meter for the horizon/solum
- `CRFVOL` numeric; percentage of coarse fragments (above 2 mm in diameter) in the sample
- `HSIZE` numeric; thickness of the horizon/solum in cm
- `ORCDRC.sd` numeric; standard error of estimating `ORCDRC` (must be positive number)
- `BLD.sd` numeric; standard error of estimating `BLD` (must be positive number)
- `CRFVOL.sd` numeric; standard error of estimating `CRFVOL` (must be positive number)
- `se.prop` logical; specifies whether to derive propagated error

**Value**

Soil organic carbon stock in kilograms per square-meter. To convert to tonnes per hectare multiply by 10.

**Note**

Propagated error (attached as an attribute) is estimated using the Taylor Series Method and shows only an approximate estimate. A more robust way to estimate the propagated uncertainty would be to use (geostatistical) simulations. See Heuvelink (1998) for more info.

**Author(s)**

Tomislav Hengl, Niels Batjes and Gerard Heuvelink

**References**

predict.gstatModel-method

Predict from an object of class "gstatModel"

Description

Predicts from an object of class gstatModel-class using new prediction locations. The function combines predictions by regression (e.g. GLM) and interpolation of residuals (kriging) via the Regression-Kriging (RK) or Kriging with External Drift (KED, also known as Universal Kriging) framework.

Usage

## S4 method for signature 'gstatModel'
predict(object, predictionLocations, nmin = 10, nmax = 30, debug.level = -1, predict.method = c("RK", "KED")[1], nfold = 5, verbose = FALSE, nsim = 0, mask.extra = TRUE, block, zmin = -Inf, zmax = Inf, subsample = length(object@sp), coarsening.factor = 1, vgmmodel = object@vgmModel, subset.observations = !is.na(object@sp@coords[,1]), betas = c(0,1), extend = .5, ...)

## S4 method for signature 'list'
predict(object, predictionLocations, nmin = 10, nmax = 30, debug.level = -1, predict.method = c("RK", "KED")[1], nfold = 5, verbose = FALSE, nsim = 0, mask.extra = TRUE, block, zmin = -Inf, zmax = Inf, subsample = length(object@sp), ...)

Arguments

object object of type "gstatModel"

Examples

Area <- 1E4 ## 1 ha
HSIZE <- 30 ## 0--30 cm
ORCDEC <- 50 ## 5%
ORCDEC.sd <- 10 ## +/-1%
BLD <- 1500 ## 1.5 tonnes per cubic meter
BLD.sd <- 100 ## +/-0.1 tonnes per cubic meter
CRFVOL <- 10 ## 10%
CRFVOL.sd <- 5 ## +/-5%
x <- OCSKGM(ORCDEC, BLD, CRFVOL, HSIZE, ORCDEC.sd, BLD.sd, CRFVOL.sd)
x # 20.25 +/-4.41 kg/m^2
## in tonnes per ha:
x[[1]] * Area / 1000
predict.gstatModel-method

predictionLocations
  object of type "SpatialPixelsDataFrame" prediction locations (must contain all covariates from the model)

nmin
  integer; minimum number of nearest observations sent to gstat::krige

nmax
  integer; maximum number of nearest observations sent to gstat::krige

debug.level
  integer; default debug level mode sent to gstat::krige

predict.method
  character; mathematical implementation of the gstat::krige interpolation method with covariates: Regression-Kriging (RK) or Kriging with External Drift (KED)
nfold
  integer; n-fold cross validation sent to gstat::krige.cv

verbose
  logical; specifies whether to suppress the progress bar of the gstat::krige.cv

nsim
  integer; triggers the geostatistical simulations

mask.extra
  logical; specifies whether to mask out the extrapolation pixels (prediction variance exceeding the global variance)

block
  numeric; support size (block support for objects of type "SpatialPixelsDataFrame" is chosen by default)

zmin
  numeric; lower physical limit for the target variable

zmax
  numeric; upper physical limit for the target variable

subsample
  integer; sub-sample point observations to speed up the processing

coarsening.factor
  integer; coarsening factor (1:5) to speed up the processing

vgmmodel
  object of class data.frame corresponding to the gstat::vgm variogram

subset.observations
  logical; vector specifying the subset of observations used for interpolation

extend
  numeric; fraction of the range for which the spatial domain should be extended when searching for observations for kriging

betas
  numeric; vector of the beta coefficients to be passed to the gstat::krige

... other optional arguments that can be passed to gstat::krige and/or predict.glm

Details

Selecting predict.method = "KED" invokes simple kriging with external drift with betas set at 0 (intercept) and 1 (regression predictions used as the only covariate). This assumes that the regression model already results in an unbiased estimator of the trend model.

If not specified otherwise, subset.observations by default selects only observations within the spatial domain (bounding box) of the predictionLocations plus 50% of the one third of the extent of the area (extend). In the case of spatial duplicates in 2D or 3D, subset.observations will automatically remove all duplicates before running kriging. All points in 3D that stand exactly above each other will be removed by default.

Predictions can be speed up by using a larger coarsening.factor e.g. 2 to 5, in which case the ordinary kriging on residuals will run at a coarser resolution, and the output would be then downscaled to the original resolution using splines (via the warp method). In the case of predict.method = RK, the kriging variance is derived as a sum of the GLM variance and the OK variance, which is statistically sub-optimal.
**Note**

Predictions using `predict.method = "KED"` (the default gstat setting) can be time consuming for large data set and can result in instabilities (singular matrix problems) if the search radius is small and/or if all covariates contain exactly the same values. Predictions using `predict.method = "RK"` on the other hand can be speed up, but will typically underestimate the prediction variance (taken as a simple sum of the regression and ordinary kriging variances). Compare to the "KED" variance that includes also a cross-term (see Hengl et al. 2007 for more details).

**Author(s)**

Tomislav Hengl, Gerard B.M. Heuvelink and Bas Kempen

**References**


**See Also**

`gstatModel-class`, `fit.gstatModel`

---

**Description**

A class for SoilGrids REST API Service. Can be used to overlay points or fetch grid values from SoilGrids Soil Information System.

**Slots**

- `server`: object of class "character"; contains the location of the server that executes REST.SoilGrids calls
- `query`: object of class "list": contains parameters or REST.SoilGrids query
- `stream`: object of class "character": contains parameters or REST.SoilGrids stream operation

**Methods**

`over` signature(`x = "REST.SoilGrids", y = "SpatialPoints"): overlays spatial points and the target grids defined via the REST.SoilGrids-class (point-by-point) and returns list of objects of "SpatialPixelsDataFrame"-class

**Note**

More examples of overlay and download functions are available via [http://rest.soilgrids.org/](http://rest.soilgrids.org/). *over* method is not recommended for large point data sets.
Author(s)
Tomislav Hengl & Jorge S. Mendes de Jesus

References
• SoilGrids — a system for automated soil mapping (http://www.soilgrids.org)

See Also
SoilGrids-class, WPS-class

Examples

```r
## Not run:
library(rjson)
library(sp)
## 2 points:
pnts <- data.frame(lon=c(10.65,5.36), lat=c(51.81,51.48), id=c("p1","p2"))
coordinates(pnts) <- -lon+lat
proj4string(pnts) <- CRS("+proj=longlat +datum=WGS84")
pnts
## REST example:
soilgrids.r <- REST.SoilGrids(c("ORCDRC","PHIHOX"))
ov <- over(soilgrids.r, pnts)
ORCDRC.pnt1 <- data.frame(
  top=unlist(ov[1, grep("depthCodesMeters", names(ov))]) * 100,
  M=unlist(ov[1, grep("ORCDRC.M", names(ov))]),
  L=unlist(ov[1, grep("ORCDRC.L", names(ov))]),
  U=unlist(ov[1, grep("ORCDRC.U", names(ov))]))
ORCDRC.pnt1$variable <- "ORCDRC"
## plot the result:
library(lattice)
library(aqp)
data(soil.legends)
## Soil organic carbon:
ORCDRC.range = range(soil.legends[["ORCDRC"]]$MIN, soil.legends[["ORCDRC"]]$MAX)
dev.new(width=5, height=6)
xyplot(top ~ M | variable, data=ORCDRC.pnt1, ylab='Depth in cm',
  xlab='5th and 95th percentiles', xlim=ORCDRC.range,
  lower=ORCDRC.pnt1$L, upper=ORCDRC.pnt1$U, ylim=c(150,0),
  panel=panel.depth_function,
  alpha=0.25, sync.colors=TRUE,
  par.settings=list(superpose.line=list(col='RoyalBlue', lwd=3)),
  strip=strip.custom(bg=grey(0.8))
)
## Soil pH:
PHIHOX.range = range(soil.legends[["PHIHOX"]]$MIN, soil.legends[["PHIHOX"]]$MAX)
for(i in 1:nrow(ov)){
  PHIHOX.pnt <- data.frame(
    top=unlist(ov[i, grep("depthCodesMeters", names(ov))]) * 100,
    M=unlist(ov[i, grep("PHIHOX.M", names(ov))]),
```
soil.legends

soil.legends

Standard color palettes for soil properties and classes

Description

Standard color palettes for soil properties and classes that can be used to display global soil data.

Usage

data(soil.legends)

Format

Contains a list of color palettes (data frames with class names / break points, and cumulative probabilities) for:

ORCDRC numeric; soil organic carbon content in permille
PHIHOX numeric; pH index measured in water solution
PHIKCL numeric; pH index measured in KCl solution
BLD numeric; bulk density in kg per cubic meter
CEC numeric; Cation Exchange Capacity
SNDPPT numeric; weight percentage of the sand particles (0.05–2 mm)
SLTPPT numeric; weight percentage of the silt particles (0.0002–0.05 mm)
CLYPPT numeric; weight percentage of the clay particles (<0.0002 mm)
CRFVOL numeric; volumetric percentage of coarse fragments (>2 mm)
TAXGWRB factor; World Reference base groups
TAXOUSDA factor; Keys to Soil Taxonomy suborders

Note

Breaks for continuous soil properties were determined using the quantiles function and by visually inspecting the histograms to maximize the contrast in output maps. Based on a compilation of global soil profile data (http://soilprofiles.org).

Author(s)

Tomislav Hengl

References

• Global Soil Information Facilities (http://gsif.isric.org)

Examples

data(soil.legends)
pal <- soil.legends$ORCDRC$COLOR
names(pal) <- signif((soil.legends$ORCDRC$MAX + soil.legends$ORCDRC$MIN)/2, 3)
pal
data(soil.vars)
soil.vars[soil.vars$varname=="ORCDRC",]
## make SAGA GIS palette:
makeSAGAlegend(x=as.factor(names(pal)), col_pal=pal,
filename="ORCDRC.txt")

SoilGrid.validator Validate SoilGrid (spatial predictions)

Description

Validate SoilGrid (spatial predictions) i.e. soil property maps following the GSIF validation protocol.

Usage

SoilGrid.validator(obj, domain, ground.trutht, N.sample=2000,
xml.file, z.lim, md.type="INSPIRE", test.URL=FALSE)
SoilGrid.validator

Arguments

- obj: "GDALobj" object i.e. a pointer to a spatial layer of interest (single slice)
- domain: "GDALobj" object i.e. a pointer to a spatial layer contain soil mask
- ground.truth: "SpatialPointsDataFrame": contains values of the target variable at exactly the same depth / same support size sampled either using Simple Random Sampling or regular sampling on a grid
- N.sample: integer; random sampling size
- xml.file: character; metadata file (should have the same name as obj file)
- z.lim: numeric; upper and lower physical limits
- md.type: character; metadata standard (currently INSPIRE)
- test.URL: logical; specifies whether to validate XML schema / test download times and proj4 string

Value

Returns a list with validation results. Explanation of codes is available in the SoilGrids.org data validation protocol.

Note

One SoilGrid layer (2D slice) basically contains predictions on a regular grid for a specific soil depth (at either point or block support). The ground.truth data must refer to the exactly the same depth and the same support size and should ideally be collected using some probability spatial sampling (see e.g. sp::spsample). To estimate values of soil properties at standard depths, consider using mpspline function.

Numeric resolution is derived as estimated RMSE/2. Numeric resolution can be best specified as Attribute.Measurement.Resolution (the smallest unit increment to which an attribute value is measured).

Increasing N.sample can lead to more precise results at the cost of higher computing time.

Author(s)

Tomislav Hengl

See Also

plotKML::spMetadata
Description

A class containing predictions and prediction error (or multiple realizations) of some of the target global soil property at six standard depths. Standard depths used are based on the GlobalSoilMap.net specifications: sd1 = 2.5 cm (0–5), sd2 = 10 cm (5–15), sd3 = 22.5 cm (15–30), sd4 = 45 cm (30–60), sd5 = 80 cm (60–100), sd6 = 150 cm (100–200).

Slots

- varname: object of class "character"; abbreviated variable name registered in the Global Soil Data registry
- TimeSpan: object of class "list"; contains begin and end of the sampling period of class "POSIXct"
- sd1: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 2.5 cm (0–5)
- sd2: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 10 cm (5–15)
- sd3: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 22.5 cm (15–30)
- sd4: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 45 cm (30–60)
- sd5: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 80 cm (60–100)
- sd6: object of class "SpatialPixelsDataFrame"; predictions and variances, or number of realizations of the target variable at depth 150 cm (100–200)

Gridded data submitted to sd* slots of the "SoilGrids" class must satisfy all of the following requirements (class validity):

- All grids submitted must have the same grid topology (identical grid slot in the object of class "SpatialPixelsDataFrame");
- All grids must be projected in the referent coordinate system WGS84 (geographical coordinates), with 3D dimension (altitude) expressed as distance from the land surface in meters (e.g. altitude of −0.25 corresponds to the 2.5 cm depth);
- The grid cell size must correspond to some standard resolution e.g. 0.0008333333 (1/1200 or about 100 m), 0.0016666667 (1/600 or about 250 m) or similar;
- Only standard abbreviated names registered in the Global Soil Data registry can be used in the varname slot;

Methods

summary signature(x = "SoilGrids"): generates summary statistics for the object
Author(s)
Tomislav Hengl and Robert A. MacMillan

References
- SoilGrids — a system for automated soil mapping (http://www.soilgrids.org)

See Also
GlobalSoilMap-class, SpatialComponents-class, geosamples-class

Examples
# load soil samples from the plotKML package:
library(plotKML)
library(aqp)
library(plyr)
library(splines)
library(rgdal)
library(raster)

data(eberg)
## subset data to 10%:
eberg <- eberg[runif(nrow(eberg)) < .1,]
## sites table:
s.lst <- c("ID", "soiltype", "TAXGRSC", "X", "Y")
h.lst <- c("UHDICM","LHDICM","SNDMHT","SLTMHT","CLYMHT")
sites <- eberg[,s.lst]
## get horizons table:
horizons <- getHorizons(eberg, idcol="ID", sel=h.lst)
## create object of type "SoilProfileCollection"
eberg_spc <- join(horizons, sites, type='inner')
depths(eberg_spc) <- ID ~ UHDICM + LHDICM
site(eberg_spc) <- as.formula(paste("-", paste(s.lst[-1], collapse="+"), sep=""))
coordinates(eberg_spc) <- ~x+y
proj4string(eberg_spc) <- CRS("+init=epsg:31467")
## convert to logits:
eberg_spc@horizons$SNDMHT.t <- log((eberg_spc@horizons$SNDMHT/100)/
   (1- eberg_spc@horizons$SNDMHT/100))
## convert to geosamples:
eberg.geo <- as.geosamples(eberg_spc)
## load gridded data:
data(eberg_grid)
grided(eberg_grid) <- ~x+y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")
## derive spc's:
formulaString <- ~ PRMGE06+DEMSRT6+TWISRT6+TIRAST6
eberg_spc <- spc(eberg_grid, formulaString)
## build a 3D "gstatModel":
glm.formulaString = as.formula(paste("SNDMHT.t ~ ",
   paste(names(eberg_spc@predicted), collapse="+"), "+ ns(altitude, df=4)"))
## Not run:
A class for gridded components derived using the spc method
Description
A class containing a list of gridded components and results of principal component analysis.

Slots
- predicted: object of class "SpatialPixelsDataFrame"; predicted values for components
- pca: object of class "list"; output objects from the stats::prcomp process — contains objects: 'stdev', 'rotation', 'center' and 'scale'

Author(s)
Tomislav Hengl

See Also
spc

SpatialMemberships-class
A class for membership maps derived using the fkmeans classification

Description
A class containing a list of gridded maps and results of model fitting.

Slots
- predicted: object of class "SpatialPixelsDataFrame"; predicted values (factor)
- model: object of class "multinom"; output object from the nnet::multinom method
- mu: object of class "SpatialPixelsDataFrame"; a list of predicted memberships
- class.c: object of class "matrix"; class centres
- class.sd: object of class "matrix"; class deviations
- confusion: object of class "matrix"; confusion matrix

Author(s)
Tomislav Hengl

See Also
spfkm, SpatialComponents-class
Derive Spatial Predictive Components

Description

Derives Spatial Predictive Components for a given set of covariates. It wraps the stats::prcomp method and predicts a list principal components for an object of type "SpatialPixelsDataFrame".

Usage

```r
## S4 method for signature 'SpatialPixelsDataFrame,formula'
spc(obj, formulaString, scale. = TRUE,
     silent = FALSE, ...)
## S4 method for signature 'list,list'
spc(obj, formulaString, scale. = TRUE,
     silent = FALSE, ...)
```

Arguments

- **obj**: object of class "SpatialPixelsDataFrame" (must contain at least two grids) or a list of objects of type "SpatialPixelsDataFrame"
- **formulaString**: object of class "formula" or a list of formulas
- **scale.**: object of class "logical"; specifies whether covariates need to be scaled
- **silent**: object of class "logical"; specifies whether to print the progress
- **...**: additional arguments that can be passed to stats::prcomp

Value

spc returns an object of type "SpatialComponents". This is a list of grids with generic names PC1,...,PCp, where p is the total number of input grids.

Note

This method assumes that the input covariates are cross-correlated and hence their overlap can be reduced. The input variables are scaled by default and the missing values will be replaced with 0 values to reduce loss of data due to missing pixels. This operation can be time consuming for large grids.

Author(s)

Tomislav Hengl

See Also

stats::prcomp, SpatialComponents-class
Examples

```r
# load data:
library(plotKML)
library(sp)

col = rev(rainbow(65)[1:48])
data(heberg_grid)
grided(heberg_grid) <- ~x+y
proj4string(heberg_grid) <- CRS("+init=epsg:31467")
formulaString <- ~ PRMGE06+DEMSRT6+TWISRt6+TIRAST6
eberg_spc <- spc(heberg_grid, formulaString)
names(heberg_spc@predicted) # 11 components on the end;
## Not run: # plot maps:
rd = range(heberg_spc@predicted@data[,1], na.rm=TRUE)
sq = seq(rd[1], rd[2], length.out=48)
spplot(heberg_spc@predicted[1:4], at=sq, col.regions=col)
## End(Not run)
```

---

**spfkm**

*Supervised fuzzy k-means on spatial pixels*

Description

Runs supervised fuzzy k-means (Hengl et al., 2004) using a list of covariates layers provided as "SpatialPixelsDataFrame-class" object. If class centres and variances are not provided, it first fits a multinomial logistic regression model (spmultinom), then predicts the class centres and variances based on the output from the nnet::multinom.

Usage

```r
## S4 method for signature
## 'formula, SpatialPointsDataFrame, SpatialPixelsDataFrame'
spfkm(formulaString,
      observations, covariates, class.c = NULL, class.sd = NULL, fuzzy.e = 1.2)
```

Arguments

- `formulaString`: formula string
- `observations`: object of type "SpatialPointsData"; occurrences of factors
- `covariates`: object of type "SpatialPixelsData" or "RasterBrick"; list of covariate layers
- `class.c`: object of type "matrix"; class centres (see examples below)
- `class.sd`: object of type "matrix"; class deviations (see examples below)
- `fuzzy.e`: object of type "numeric"; fuzzy exponent
spfkm

Value

Returns an object of type "SpatialMemberships" with following slots: predicted (classes predicted either by the multinomial logistic regression or fuzzy k-means), model (the multinomial logistic regression model; if available), mu (memberships derived using the fuzzy k-means), class.c (submitted or derived class centres), class.sd (submitted or derived class deviations), confusion (confusion matrix).

Note

Although nnet::multinom is consider to be robust and suited for large data sets, function might not converge in some cases or result in artifacts. If this happens try setting up the class centres and variances manually.

Author(s)

Tomislav Hengl and Bas Kempen

References


See Also

spmultinom, SpatialMemberships-class, nnet::multinom

Examples

# load data:
library(plotKML)
library(sp)

data(eberg)
# subset to 20%:
eberg <- eberg[runif(nrow(eberg))<.2,]
data(eberg_grid)
coordinates(eberg) <- ~X+Y
proj4string(eberg) <- CRS("+init=epsg:31467")
gridded(eberg_grid) <- ~X+Y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")
# derive soil predictive components:
eberg_spc <- spc(eberg_grid, ~PRMGE06+DEMSRT6+TWISRT6+TIRAST6)
# predict memberships:
formulaString = soiltype ~ PC1+PC2+PC3+PC4+PC5+PC6+PC7+PC8+PC9+PC10
eberg_sm <- spfkm(formulaString, eberg, eberg_spc@predicted)
## Not run: # plot memberships:
pal = seq(0, 1, 1/50)
spline.krige

Kriging combined with splines

Description

Combines kriging and spline interpolation to speed up the kriging with minimal loss in precision, whilst reducing generation of artifacts. Spline interpolation is implemented via the SAGA GIS function "Multilevel B-Spline Interpolation" (SAGA GIS needs to be installed separately).

Usage

spline.krige(formula, locations, newdata, newlocs = NULL, model, te = as.vector(newdata@bbox), file.name, silent = FALSE, t_cellsize = newdata@grid@cellsize[1], optN = 20, quant.nndist = .5, nmax = 30, predictOnly = FALSE, resample = TRUE, saga.env, saga.lib=c("grid_spline","grid_tools"), saga.module=c(4,0), ...)

Arguments

formula formula that defines the dependent variable as a linear model of independent variables; usually in the form z~1
locations object of class SpatialPoints; sampling locations
newdata object of class SpatialPixels*: spatial domain of interest
newlocs object of class SpatialPoints*: prediction locations produced using the resample.grid function (if missing it will be generated using the resample.grid function)
model variogram model of dependent variable (or its residuals); see gstat::krige
te numeric; a vector in the form c(xmin,ymin,xmax,ymax); sets bounding box of the kriging predictions
file.name character; optional output file name pattern (without any file extension)
silent logical; specifies whether to print out the progress
t_cellsize numeric; target cell size (output grid)
optN integer; optimal number of prediction locations per sampling location e.g. 1 sampling location is used to predict values for 20 new pixels
quant.nndist numeric; threshold probability to determine the search radius (sigma)
spline.krige

**Value**

Returns an object of class "SpatialGridDataFrame", or an output file name.

**Note**

This function adjusts grid density (prediction locations) in reference to the actual local sampling intensity. High resolution grids are created where sampling density is higher and vice versa (Hengl, 2006). Low resolution grids (due to sparse data) are then downscaled to the target resolution using spline interpolation. This allows for speeding up the kriging with minimal loss in precision, whilst reducing generation of artifacts. Spline interpolation is implemented via the SAGA GIS v2.1 function "Multilevel B-Spline Interpolation" using the default settings. This function is especially suitable for producing predictions for large grids where the sampling locations show high spatial clustering. It is NOT intended for predicting using point samples collected using sampling designs with constant spatial sampling intensity e.g. point samples collected using simple random sampling or grid sampling.

**Author(s)**

Tomislav Hengl

**References**

- SAGA GIS [http://saga-gis.org](http://saga-gis.org)
- SpatStat package [http://www.spatstat.org](http://www.spatstat.org)

**Examples**

```r
## Not run:
library(plotKML)
library(spastat)
library(RSAGA)
library(gstat)
library(raster)
data(eberg)
data(eberg_grid)
data(eberg_grid25)
library(sp)
```
coordinates(eb) <- ~X+Y
proj4string(eb) <- CRS("+init=epsg:31467")
m <- vgm(psill=320, model="Exp", range=1200, nugget=150)
plot(variogram(SNDMHT_A-1, eb[[is.na(eb$SNDMHT_A),]]), m)
## prediction locations:
grided(egrid) <- ~x+y
proj4string(egrid) <- CRS("+init=epsg:31467")
grided(egrid25) <- ~x+y
proj4string(egrid25) <- CRS("+init=epsg:31467")
## prepare prediction locations for spline.krige:
newdata=egrid["SNDMHT_A"], t_cells=25,
newdata=egrid25, optN=5, quant.nndist=.9)
## plot resampled grid:
plot(raster(grd$density))
plot(grd$newlocs)
points(egrid, pch=19, col="red", cex=.7)
env <- rsaga.env()
if(exists("env") & env$version=="2.1.0"){
  ## compare processing time:
system.time(SND.sok <- spline.krige(locations=egrid["SNDMHT_A"],
t_cells=25, newdata=egrid25,
newdata=egrid$newlocs, model=m, nmax=30))
system.time(SND.ok <- krige(SNDMHT_A-1,
egrid[is.na(egrid$SNDMHT_A),],
newdata=egrid25, m,
debug.level = -1, nmax=30))
system.time(SND.ok25 <- krige(SNDMHT_A-1,
newdata=egrid25, m,
debug.level = -1, nmax=30))
## compare outputs visually:
par(mfrow=c(1,3))
plot(raster(SND.sok[1]), main="spline.krige (25 m)"
plot(raster(SND.ok25[1]), main="krige (25 m)"
plot(raster(SND.ok[1]), main="krige (100 m)"
}
## End(Not run)
## conclusion: spline.krige produces less artifacts,
## and is at order of magnitude faster than simple 'krige'

spmultinom

Multinomial logistic regression on spatial objects

Description

Runs the multinomial logistic regression via nnet::multinom to produce spatial predictions of the target factor-type variable. It requires point locations of observed classes and a list of covariate layers provided as "SpatialPixelsDataFrame-class" object. The resulting predicted classes are then used to estimate class centres and variances per class.
**Usage**

```r
## S4 method for signature
## 'formula,SpatialPointsDataFrame,SpatialPixelsDataFrame'
spmultinom(formulaString,
    observations, covariates, class.stats = TRUE, predict.probs = TRUE, ...)
```

**Arguments**

- `formulaString`: formula string
- `observations`: object of type "SpatialPointsData"; occurrences of factors
- `covariates`: object of type "SpatialPixelsData"; list of covariate layers
- `class.stats`: logical; species wether to estimate class centres
- `predict.probs`: logical; species wether to predict probabilities per class
- `...`: optional arguments

**Value**

Returns an object of type "SpatialMemberships" with following slots: `predicted` (classes predicted by the multinomial logistic regression), `model` (the multinomial logistic regression model), `mu` (probabilities derived using the mutinom model), `class.c` (derived class centres), `class.sd` (derived class deviations), `confusion` (confusion matrix).

**Author(s)**

Bas Kempen and Tomislav Hengl

**References**

- Nnet package ([http://CRAN.R-project.org/package=nnet](http://CRAN.R-project.org/package=nnet))

**See Also**

`spfkm`, `SpatialMemberships-class`

**Examples**

```r
# load data:
library(plotKML)
library(sp)

data(eberg)
# subset to 20%:
eberg <- eberg[runif(nrow(eberg))<.2,]
data(eberg_grid)
coordinates(eberg) <- ~X+Y
proj4string(eberg) <- CRS("+init=epsg:31467")
gridded(eberg_grid) <- ~x+y
```
proj4string(eberg_grid) <- CRS("+init=epsg:31467")
# derive soil predictive components:
eberg_spc <- spc(eberg_grid, ~PRMEO6+DEMSRT6+TWISRT6+TIRAST6)
# predict memberships:
formulaString = soiltype ~ PC1+PC2+PC3+PC4+PC5+PC6+PC7+PC8+PC9+PC10
eberg_sm <- smultinom(formulaString, eberg, eberg_spc@predicted)
## Not run: # plot memberships:
pal = seq(0, 1, 1/50)
spplot(eberg_sm@mu, col.regions=pal)
image(eberg_sm@mu[,1], col=pal)
text(eberg@coords, paste(eberg$soiltype), cex=.6, col="black")
# classes predicted:
Ls = length(levels(eberg_sm@predicted$soiltype))
pnts = list("sp.points", eberg, pch="+", cex=.6, col="black")
spplot(eberg_sm@predicted, col.regions=rainbow(Ls)[rank(runif(Ls))], sp.layout=pnts)
## End(Not run)

spsample.prob  Estimate occurrence probabilities of a sampling plan (points)

Description

Estimates occurrence probabilities as an average between the kernel density estimation (spreading
of points in geographical space) and MaxLike analysis (spreading of points in feature space). The
output 'iprob' indicates whether the sampling plan has systematically missed some important
locations / features, and can be used as an input for geostatistical modelling (e.g. as weights for
regression modeling).

Usage

## S4 method for signature 'SpatialPoints,SpatialPixelsDataFrame'
spsample.prob(observations, covariates,
quant.nndist=.95, n.sigma, ...)

Arguments

- observations: object of class SpatialPoints; sampling locations
- covariates: object of class SpatialPixelsDataFrame; list of covariates of interest
- quant.nndist: numeric; threshold probability to determine the search radius (sigma)
- n.sigma: numeric; size of sigma used for kernel density estimation (optional)
- ...: other optional arguments that can be passed to function spatstat::density

Value

Returns a list of objects where 'iprob' ("SpatialPixelsDataFrame") is the map showing the
estimated occurrence probabilities.
Note

Occurrence probabilities for geographical space are derived using kernel density estimator. The sampling intensities are converted to probabilities by dividing the sampling intensity by the maximum sampling intensity for the study area (Baddeley, 2008). The occurrence probabilities for feature space are determined using MaxLike algorithm (Royle et al., 2012). The lower the average occurrence probability for the whole study area, the lower the representation efficiency of a sampling plan.

MaxLike function might fail to produce predictions (e.g. if not at least one continuous covariate is provided and if the optim function is not able to find the global optima) in which case an error message is generated. Running Principal Component analysis i.e. standardizing the covariates prior to running spsample.prob is, thus, highly recommended.

This function can be time consuming for large grids.

Author(s)

Tomislav Hengl

References


See Also

maxlike-package, spatstat-package

Examples

library(plotKML)
library(maxlike)
library(spatstat)
library(maptools)

data(eberg)
data(eberg_grid)
## existing sampling plan:
sel <- runif(nrow(eberg)) < .2
epberg.xy <- eberg[sel,c("X","Y")]
coordinates(epberg.xy) <- -X+Y
proj4string(epberg.xy) <- CRS("+init=epsg:31467")
## covariates:
gridded(eberg_grid) <- ~x+y
proj4string(eberg_grid) <- CRS("+init=epsg:31467")
## convert to continuous independent covariates:
formulaString <- ~ PRMGE06+DEMSRT6+TWISRT6+TIRAST6
eberg_spc <- spc(eberg_grid, formulaString)
## Description

Derives a statistical summary for an object of class "SpatialPredictions".

## Usage

```r
## S4 method for signature 'SpatialPredictions'
summary(object)
```
Arguments

- object: object of class "SpatialPredictions"

Details

The function creates a summary table with standard column names. These tell us what is the summary accuracy of the spatial predictions and what are the effective bytes of information produced.

Value

The summary returns a data.frame with the following columns:

- "variable": variable name
- "minium": lowest value observed
- "maximum": largest value observed
- "npoints": number of observations
- "area": lowest value observed
- "area.units": area units either square-m or square-arcdegrees
- "covariates": list of covariates used
- "family": GLM family (if applicable)
- "RMSE": RMSE derived using cross-validation
- "tvar": variance percent explained by the model using the cross-validation
- "npixels": total number of produced pixels
- "breaks": breaks based on the half RMSE
- "bonds": lower and upper boundaries for effective classes
- "Bytes": effective bytes produced (see Hengl et al (2012) for more details)
- "compress": compression algorithm used

Author(s)

Tomislav Hengl

References


See Also

plotKML::SpatialPredictions-class
Examples

```r
## load observations:
library(sp)
library(rgdal)
library(gstat)
demo(meuse, echo=FALSE)
## fit a model:
omm <- fit.gstatModel(meuse, om~dist,
                   fit.family=gaussian(link="log"), meuse.grid)
show(omm@regModel)
## produce SpatialPredictions:
om.rk <- predict(omm, predictionLocations = meuse.grid)
x = summary(om.rk)
str(x)
```

test.gstatModel-methods

Methods to test predictability of a regression-kriging model

Description

Tests predictability of a regression-kriging model on a sample data set. Automates model fitting, cross-validation and prediction and prints out: (1) RMSE at validation points under different sampling intensities, (2) number of predictions per second and (3) number of prediction failures (failure = predictions where cross-validation z-scores exceed value of +/- 1.5 or cross-validation residuals exceed three standard deviations of the observed values).

Usage

```r
## S4 method for signature
test.gstatModel(observations, formulaString, covariates, Ns,
predictionLocations, save.predictions = TRUE, debug.level = 0, nfold = 5, ...)
```

Arguments

- `observations` object of type "SpatialPointsDataFrame" or "geosamples-class"
- `formulaString` object of type "formula" or a list of formulas
- `covariates` object of type "SpatialPixelsDataFrame", or list of grids
- `Ns` vector; list of sampling intensities (maximum should not exceed the total number of samples)
predictionLocations
object of class "SpatialPixelsDataFrame"; if not specified then passes the
object covariates

save.predictions
logical; indicates whether the prediction results should also be saved
default: TRUE

d debug.level
integer; gstat's setting to hide the progress output

nfold
integer; number of folds for cross-validation

... other optional arguments that can be passed to fit.gstatModel

Note
Vector of sampling intensities, if not provided, will be estimated as: sequence of 10 numbers on
square root scale (where N minimum is determined as 20 + number of covariates times 10 and N
maximum is the total number of observations). Where no model can be fitted, function returns an
empty set. This function can be time consuming for large data sets and is hence recommended only
for testing a mapping algorithm using sample data.

Author(s)
Tomislav Hengl, Gerard B.M. Heuvelink

See Also
fit.gstatModel, gstatModel-class

Examples

# 2D model:
library(sp)
# load the Meuse data set:
demo(meuse, echo=FALSE)
# model diagnostics:
t1 <- test.gstatModel(meuse, om=dist+ffreq, meuse.grid,
  fit.family = gaussian(log), Ns=c(80, 155))
t1[[1]]

---

tile  
Tiles (subsets or clips) a spatial object to regular blocks

Description
Tiles objects of class "Spatial*" or "RasterLayer*" into regular blocks.
Usage

```r
## S4 method for signature 'SpatialPointsDataFrame'
tile(x, y, block.x, ...)
## S4 method for signature 'SpatialPixelsDataFrame'
tile(x, y, block.x, ...)
## S4 method for signature 'SpatialPolygonsDataFrame'
tile(x, y, block.x, tmp.file = TRUE,
       program, show.output.on.console = FALSE, ...)
## S4 method for signature 'SpatialLinesDataFrame'
tile(x, y, block.x, tmp.file = TRUE,
       program, show.output.on.console = FALSE, ...)
## S4 method for signature 'RasterLayer'
tile(x, y, block.x, tmp.file = TRUE,
       program, show.output.on.console = FALSE, ...)
```

Arguments

- `x`: object of class "Spatial" "RasterLayer"
- `y`: list of "SpatialPolygons"; if missing will be derived based on `block.x`
- `block.x`: numeric; size of block in meters or corresponding mapping units
- `tmp.file`: logical; specifies whether to generate a temporary file
- `program`: character; location of the auxiliary program in the system
- `show.output.on.console`: logical; specifies whether to print the progress of a function
- `...`: optional arguments that can be passed to the `getSpatialTiles`

Details

When working with objects of type "SpatialLinesDataFrame", "SpatialPolygonsDataFrame" and or "RasterLayer", the function looks for FWTools binary files `ogr2ogr` and `warp`. FWTools is a separate program and must be installed separately.

Value

Returns a list of objects of the same class as the input object.

Author(s)

Tomislav Hengl

See Also

gSpatialTiles
Examples

```r
## spatial pixels:
library(sp)
data(meuse.grid)
gridded(meuse.grid) <- ~x+y
tl <- getSpatialTiles(meuse.grid, block.x=1000)
image(meuse.grid)
lines(as(tl, "SpatialLines"))
## all at once:
pix.lst <- tile(meuse.grid, block.x=1000)
## Not run: ## lines:
library(plotKML)
data(eberg_contours)
line.lst <- tile(eberg_contours, block.x=5000)
spplot(line.lst[[1]][2])
## polygons:
data(eberg_zones)
## this one requires ogr2ogr function:
pol.lst <- tile(eberg_zones, block.x=5000)
spplot(pol.lst[[1]][1])
## raster files via rgdal:
library(rgdal)
fn = system.file("pictures/SP27GTIF.TIF",
    package = "rgdal")
obj <- GDALinfo(fn)
ras.lst <- getSpatialTiles(obj, block.x=1000)
offset <- c(ras.lst$offset.y[1], ras.lst$offset.x[1])
region.dim <- c(ras.lst$region.dim.y[1],
    ras.lst$region.dim.x[1])
## read the first tile:
SP27GTIF_T1 <- readGDAL(fn, offset=offset,
    region.dim=region.dim)
str(SP27GTIF_T1)
## End(Not run)
```

**USDA.TT.im**  
*Probability density for texture triangle*

**Description**

Probability density for texture triangle (USDA system) based on global soil profile data ([http://soilprofiles.org](http://soilprofiles.org)).

**Usage**

data(USDA.TT.im)
Format
The USDA.TT.im data frame contains the following columns:

- **v** numeric; probability density derived using the `soiltexture::TT.kde2d` function and global soil profile data
- **TEXMHT** factor; USDA soil texture class estimated by hand (one of the following: "C", "SiC", "SC", "Cl", "SiCl", "SCL", "L", "SiL", "SL", "Si", "LS", "S")
- **s1** numeric; horizontal coordinate (sand content 0–1) in the texture triangle system
- **s2** numeric; vertical coordinate (0–0.85) in the texture triangle system

Note
Texture by hand class can be converted to sand, silt, clay content fractions by using the `TT2tri` function. This function uses the **v** column in the USDA.TT.im (i.e. prior probability densities) to adjust for texture fraction combinations that are more probable.

Author(s)
Tomislav Hengl

References

See Also
- `FAO.SoilProfileCollection`, `soil.dom`

Examples
```r
## plot prior probabilities:
library(sp)
data(USDA.TT.im)
gridded(USDA.TT.im) <- ~s1+s2
spplot(USDA.TT.im[, "v"])

## Not run: library(soiltexture)
## convert textures by hand to sand, silt and clay:
TEXMHT <- c("CL", "C", "SiL", "SiL", "missing")
x <- TT2tri(TEXMHT)
x

## End(Not run)
```
**Description**

Reproject and resample using (GDAL) warp program.

**Usage**

```r
## S4 method for signature 'SpatialPixelsDataframe'
warp(obj, proj4s = proj4string(obj),
    GridTopology = NULL, pixsize,
    resampling_method = "bilinear",
    NAflag = get("NAflag", envir = GSIF.opts),
    tmp.file = FALSE, show.output.on.console = FALSE, program)
## S4 method for signature 'RasterLayer'
warp(obj, proj4s = proj4string(obj),
    GridTopology = NULL, pixsize,
    resampling_method = "bilinear",
    NAflag = get("NAflag", envir = GSIF.opts),
    tmp.file = FALSE, show.output.on.console = FALSE, program)
```

**Arguments**

- `obj` object of class "SpatialPixelsDataFrame" or class "RasterLayer"
- `proj4s` character; proj4string describing the target coordinate system
- `GridTopology` optional grid topology from sp package
- `pixsize` grid cell size in decimal degrees
- `resampling_method` character; resampling method (see gdalwarp options)
- `NAflag` character; missing value flag
- `tmp.file` logical; specifies whether a temporary file name should be generated
- `show.output.on.console` logical; specifies whether to print out the progress
- `program` full path to the (GDAL) warp program

**Note**

FWTools must be installed separately. See also gdalUtils package.

**Author(s)**

Tomislav Hengl

**See Also**

make.3Dgrid, plotKML::reproject
**WPS-class**

*A class for a Web Processing Service*

**Description**

A class for a Web Processing Service. Can be used to overlay points or fetch grid values for rasters located remotely on a server and specified via the `inrastername` slot.

**Slots**

- `server`: object of class "list"; contains the location of the CGI script that executes WPS ("URI"); service name ("service.name"), version ("version"), request type ("request"), identifier ("identifier")
- `inrastername`: object of class "character"; name of the objects on the server

**Methods**

- `show` signature(object = "WPS"): gets the complete server capabilities
- `getProcess` signature(x = "WPS"): gets a list of processes available from a server
- `describe` signature(x = "WPS"): lists parameters specific to some service identifier
- `over` signature(x = "WPS", y = "SpatialPoints"): overlays spatial points and the target grids defined via the WPS-class (point-by-point)
- `subset` signature(x = "WPS"): subsets a grid (from server) and loads it to R; use `bbox` argument to specify the bounding box

**Note**

More examples of overlay, subset and aggregation functions are available via WorldGrids.org. WPS WorldGrids.org uses the PyWPS module on a Debian system with Webserver, GDAL, Python and Scipy. The standard format for the gridded data on the WorldGrids.org repository is "GeoTiff". Use of the "bbox" object to obtain grids that cover more than 30 percent of the global coverage is not recommended. Consider instead downloading the compressed images directly from WorldGrids.org.

**Author(s)**

Tomislav Hengl & Hannes I. Reuter

**References**

- PyWPS module ([http://pywps.wald.intevation.org](http://pywps.wald.intevation.org))
- WorldGrids.org ([http://worldgrids.org](http://worldgrids.org))

**See Also**

`landmask`
Examples

```r
## Not run:
library(XML)
library(sp)
URI = "http://wps.worldgrids.org/pywps.cgi"
server <- list(URI=URI, request="execute",
               version="version=1.0.0", service.name="service=wps",
               identifier="identifier=sampler_localpt_nogml")
glcesa3.wps <- new("WPS", server=server, inRastename="glcesa3a")
# show(bioc115.wps)
prl <- getProcess(glcesa3.wps)
prl[7]
describe(glcesa3.wps, identifier="overlay")
pl <- data.frame(lon=15, lat=15)
coordinates(pl) <- -lon+lat
proj4string(pl) <- CRS("+proj=longlat +datum=WGS84")
pl
over(glcesa3.wps, pl)
# fetch grids and load the to R:
glcesa3 <- subset(glcesa3.wps, bbox=matrix(c(20,40,22,42), nrow=2))
image(glcesa3)

## End(Not run)
```
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