toolbox.e3d

Contents

Intro

The R wrapper package toolbox.e3d was created to perform often occuring tasks done with the soil erosion model EROSION-3D in an easy usable and reproducable way. It requires a licenced EROSION-3D installation on a Windows system. Download of this software and licence conditions are available at Geognostics (http://bodenerosion.com/e3d_lizenzen.html).

EROSION-3D is designed as software with Graphical User Interface (GUI) with limited command line support introduced in version 3.15. The toolbox.e3d uses only the command line interaction, for fully reproducable work. Each manual change in modelling is seen as non reproducable, or at least failure prone (GMD executive editors 2019).

The toolbox.e3d was developed with the 32-bit EROSION-3D version 3.2.0.9. As the command line interaction is sparesly used up to now, several functions may not work with older versions of EROSION-3D

Command line interaction with E3D

There are three basic commands to run EROSION-3D from command line (Werner 2007):

- '/c' for calculation
- '/r' for preprocessing of relief set
- '/s' for preprocessing of soil set (available from version 3.2.0.9)

All further options (paths to input files, modelling options) are set in a *.PAR file.

This command would run an EROSION-3D calculation from the R-environment:

```
system2("e3d", '/c "C:/E3Dmodel/model/run.par"', wait=TRUE)
```

and as pure command line call:

```
e3d /r C:/E3Dmodel/model/run.par
```

Installation

Use the following commands in R to install toolbox.e3d:

```
# Install devtools from CRAN
install.packages("devtools")

# Install toolbox.e3d
devtools::install_github("jonaslenz/toolbox.e3d")
```

EROSION-3D needs to be installed and licencesed separetely, please refer to the handbook (Werner 2003).

test setup

Once EROSION-3D is installed and activated the interaction with toolbox.e3d can be tested using:

```
toolbox.e3d::get_version.E3D()
#> [1] "3.2.0.9"
```

This function checks, if EROSION-3D can be found in the system PATH-Variable. If it is not present in PATH it searchs for EROSION-3D in the registry and adds it temporarely to PATH for the current R-session.

If this function fails with error message "cannot access e3d instalation" you should check the installtion of EROSION-3D and add the installation folder manually to system PATH.

When succesful this function runs an elevation model preprocessing and returns the version number in the created file relief.log.

determination of calibration parameters Skinfactor and resistance to erosion

Soil input parameters of EROSION-3D include two calibration parameters skinfactor and resistance to erosion. Determination of these two needs to be done to fit model output with runoff/soilloss measurement data obtained in rainfall simulations in field. In previous works these parameters were determined manually with the hillslope erosion modelling tool EROSION-2D (Michael 2000; Schindewolf and Schmidt 2012). Both tools share basic algorithms, but show differences in available model options and possible input accuracy of parameters.

For fully reproducable determination, synthetic landuse and Digital Elevation Models (DEM) are used to model rainfall simulation plots in EROSION-3D. Multiple indepentend plots - identical in relief but differing in target calibration parameter - are calculated simoultanesly. Relevant model output is analyzed and used to iterate calibration parameter values, until a certain accuracy is reached.

fitting targets skinfactor

Skinfactor is a calibration parameter to saturated hydraulic conductivity in infiltration submodule in EROSION-3D. It can be fitted to cumulative runoff from the plot or to an infiltration rate at a certain timestep.

cumulative runoff

To fit calculated to measured cumulative runoff for an experiment on a soil with

- 30 mass-% clay **Cl**
- 40 mass-% silt **Si**
- 30 mass-% sand **Sa** (clay+silt+sand must equal 100 mass-%)
- 1.3 mass-% - content of organic bound carbon **Corg**
- 1300 kg/m^3 dry bulk density **Bulk**
- 22 vol-% intitial soil moisture at start of experiment **Moist**

which produced

- 100 litres total runoff **CumRunoff** after 30 minutes **endmin**

with experimental settings of

- 0.5 mm/min rainfall intensity **intensity**
- 1 metre wide plot **plotwidth**
- 10 metre long plot **plotlength**
- 10 percent slope inclination **slope**

with model option

- limitation of potential infiltration to available water **ponding**
- output of calibration parameter values for each iteration step **silent**

the skinfactor can be determined by:

```
skin_cum <-
toolbox.e3d::determine.skin.runoff.E3D(Cl = 30, Si = 40, Sa = 30,
                            Corg = 1.3, Bulk = 1300, Moist = 22,
                            CumRunoff = 100, intensity = 0.5,
                            plotwidth = 1, plotlength = 10,
                            slope = 10,
                            endmin = 30,
                            ponding = TRUE, silent = FALSE)
#> 1 : 1e-08 100
#> 2 : 0.000220513073990305 0.000278255940220713
#> 3 : 0.000227886500951164 0.000228422512505557
skin_cum
#> [1] 0.0002283277
```

infiltration rate

using the same values as in the preceeding example with a differing fitting target of:

- 0.2 mm/min infiltration rate **infilrate** after 30 minutes **endmin**

the skinfactor can be determined by:

```
skin_inf <-
toolbox.e3d::determine.skin.infil.E3D(Cl = 30, Si = 40, Sa = 30,
                           Corg = 1.3, Bulk = 1300, Moist = 22,
                           infilrate = 0.2, intensity = 0.5,
                           plotwidth = 1, plotlength = 10,
                           slope = 10,
                           endmin = 30,
                           ponding = TRUE, silent = FALSE)
#> 1 : 1e-08 100
#> 2 : 0.000890215085445039 0.00112332403297803
#> 3 : 0.000998826021204293 0.00100117535864183
skin_inf
#> [1] 0.0009989564
```

fitting targets resistance to erosion

Resistance to erosion is a calibration parameter in particle detatchment calculation in erosion submodule in EROSION-3D. It can be fitted to cumulative soil loss from the plot or to a sediment concentration at a certain timestep.

The erosion submodule of EROSION-3D uses nine grain size fractions instead of the three used in infiltration submodule. Therefore Cl, Si and Sa are separated in fine, middle and coarse fractions for the determination functions.

cumulative soil loss

To fit calculated to measured cumulative soil loss for an experiment on a soil with

- 5 mass-% fine clay **FCl**, 10 mass-% middle clay **MCl**, 15 mass-% coarse clay **CCl**
- 10 mass-% fine silt **FSi**, 20 mass-% middle silt **MSi**, 10 mass-% coarse silt **CSi**
- 15 mass-% fine sand **FSa**, 10 mass-% middle sand **MSa**, 5 mass-% coarse sand **CSa** (total sum must equal 100 mass-%)
- 1.3 mass-% - content of organic bound carbon **Corg**
- 1300 kg/m^3 dry bulk density **Bulk**
- 22 vol-% intitial soil moisture at start of experiment **Moist**
- skinfactor **Skin** from previous determination (100 litres total runoff after 30 minutes **endmin**)
- a total soil loss of 1 kg **Soilloss**
- 0.05 s/m^(1/3) mannings n hydraulic surface roughness **Roughness**
- 20 % soil cover by plants, plant residues, stones, … **Cover**

with experimental settings of

- 0.5 mm/h rainfall intensity **intensity**
- 1 metre wide plot **plotwidth**
- 10 metre long plot **plotlength**
- 10 percent slope inclination **slope**

with model option

- limitation of potential infiltration to available water **ponding**
- output of calibration parameter values for each iteration step **silent**

resistance to erosion can be determined by:

```
eros_cum <-
  toolbox.e3d::determine.eros.cumsed.E3D(FCl=5,MCl=10,CCl=15,
                                         FSi=10,MSi=20,CSi=10,
                                         FSa=15,MSa=10,CSa=5,
                                         Corg = 1.3, Bulk = 1300, Moist = 22,
                                         Skin = skin_cum, Roughness=0.05, Cover = 20,
                                         Soilloss = 1,
                                         intensity = 0.5, plotwidth = 1,
                                         plotlength = 10, slope = 10,
                                         endmin = 30, ponding = TRUE, silent = F)
#> 1 : 1e-08 100
#> 2 : 0.000559081018251222 0.000705480231071865
#> 3 : 0.000662119897452795 0.000663677268837001
eros_cum
#> [1] 0.0006635907
```

sediment concentration

To be added …

validation modelling

Validation modelling can be used to check how input parameters and model options will affect modelling results. Due to the high number of possible combinations this section shall describe a possible workflow demonstrating fully reproducable work with EROSION-3D.

The effect of differing skinfactor values (from two determination methods) on runoff volume and soil loss is used as example. The models are run on synthetic elevation and landuse models with independent slope stripes, as described in (Lenz 2017). Independence of single stripes is acuired by setting flow routing option to one neighbour in the *.par file.

create model folders

As first step folders are created including a basic EROSION-3D model:

```
path <- toolbox.e3d::create_folders.E3D(path = "C:/E3Dmodel_toolbox/")
```

Soil set

EROSION-3D needs at least two files for soil set:

- a landuse.asc, defining an ID for each raster cell,
- and a soil_params.csv defining soil parameters for each ID in landuse.asc.

To apply changes to soil parameters soil_params.csv can be read, modified and rewritten:

```
soils <- read.csv(file.path(path,"soil/soil_params.csv"))[1,]

# soil parameters are set according to example in parameter determination
  soils$BLKDENSITY <- 1300
  soils$CORG       <- 1.3
  soils$INITMOIST  <- 22
  soils$FT         <- 5
  soils$MT         <- 10
  soils$GT         <- 15
  soils$FU         <- 10
  soils$MU         <- 20
  soils$GU         <- 10
  soils$FS         <- 15
  soils$MS         <- 10
  soils$GS         <- 5
  soils$ROUGHNESS  <- 0.05
  soils$COVER      <- 20
  soils$ERODIBIL   <- eros_cum

# parameters derived automaticly by EROSION-3D are set to 0
  soils$THETA_R <- 0
  soils$THETA_S <- 0
  soils$ALPHA <- 0
  soils$NORDPOL <- 0
```

```r
# a second soil parameter entry is created
  soils[2,] <- soils[1,]

# ID of second entry is set
  soils$POLY_ID<- 1:nrow(soils)

# skinfactors are set for each entry separately
  soils$SKINFACTOR[1] <- skin_cum
  soils$SKINFACTOR[2] <- skin_inf

  write.csv(soils,file.path(path,"soil/soil_params.csv"),
            row.names = FALSE, quote = FALSE)
```

The synthetic landuse.asc can be created with:

```r
  toolbox.e3d::write.landuse.E3D(POLY_ID = soils$POLY_ID, length = 10,
            path = file.path(path,"soil/"), filename = "landuse.asc")
```

soil set creation since version 3.2.0.9

Since version 3.2.0.9 EROSION-3D can preprocess the soil set from given landuse raster and soil_params file. This allows the analysis of parameters derived by EROSION-3D (*.pid files, THETA_R, THETA_S, ALPHA, . . .)

The input files must be written to the model parent folder, defined in the *.par file and preprocessed by:

```r
# write files to parent folder
  write.csv(soils,file.path(path,"soil_params.csv"),
            row.names = FALSE, quote = FALSE)
  toolbox.e3d::write.landuse.E3D(POLY_ID = soils$POLY_ID, length = 10,
            path = file.path(path), filename = "landuse.asc")

# read, modify and rewrite *.par
  run_par <- ini::read.ini(file.path(path,"run.par"))
  run_par[["Soil_landuse"]][["rdb_dat"]] <- file.path(path,"soil_params.csv")
  run_par[["Soil_landuse"]][["rdb_grd"]] <- file.path(path,"landuse.asc")
  ini::write.ini(run_par,filepath = file.path(path,"run.par"))

# preprocess soil set
  system2("e3d", paste0('/s "',normalizePath(file.path(path,"run.par")),'"'), wait=TRUE)
```

DEM and relief set

A syntethic DEM is created with:

```r
toolbox.e3d::write.relief.E3D(POLY_ID = soils$POLY_ID, length = 10,slope = 11,
                              path = path, filename = "dem.asc")
```

where **length** (in metres) and **slope** (inclination in %) define the slope geometry.

The number of elements in POLY_ID defines the number of indepentend slopes simulated parallel.

The EROSION-3D relief set can be created with:

```
system2("e3d", paste0('/r "',normalizePath(file.path(path,"run.par")),'"'), wait=TRUE)
```

As vertical DEM resolution is limited to 2 decimal digits (0.01 m) in EROSION-3D, steplike artifacts can be introduced. To check for such artifacts one can read unique values from the slope file created by EROSION-3D:

```
slope_E3D <- raster::raster(normalizePath(file.path(path,"relief/slope.asc")))
unique(raster::values(slope_E3D))
#> [1] 6.277298
```

If only one value is returned all slope values are equal and no step artifacts were introduced.

Create rainfile

An EROSION-3D compatible rainfall file can be written by:

```
# 30 minutes * 60 seconds/minute
toolbox.e3d::write.rainfile.E3D(time = c(0,30*60), intens = c(0.5,0), path,
                                filename = "rain_e3d.csv")
```

time and **intens** are numeric vectors of equal length. **time** gives the timesteps in seconds, at which rainfall intensities changes occure. **intens** gives the rainfall intensity for the following time period in mm/min.

Run calculation

Once all input files are prepared the simulation can be run:

```
system2("e3d", paste0('/c "',normalizePath(file.path(path,"run.par")),'"'), wait=TRUE)
```

And results can be analyzed:

```
#read runoff in litres (*1000)
runoff <- raster::raster(file.path(path,"result/sum_q.asc"))[,1]*1000
sed <- raster::raster(file.path(path,"result/sum_sedvol.asc"))[,1]

cbind(soils[,c("POLY_ID","SKINFACTOR")], runoff, sed)
#>   POLY_ID   SKINFACTOR   runoff      sed
#> 1       1 0.0002283277 99.99995 1.028949
#> 2       2 0.0009989564 47.34490 0.410924
```

The hypothetical results show, that runoff and soil loss calculated with skinfactor fitted to cumulative runoff meet the expectations (100 l runoff, 1 kg soil loss) quite well, whereas the results calculated with skinfactor fitted to infiltration rate are less than half the expected value.

delete model folder

To clear workspace and delete all model files:

```r
unlink(file.path("C:/E3Dmodel_toolbox/"), force = T, recursive = T)
```

References

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Michael, Anne. 2000. "Anwendung Des Physikalisch Begründeten Erosionsprognosemodells EROSION 2D/3D - Empirische Ansätze Zur Ableitung Der Modellparameter. Dissertation." PhD thesis, Freiberg: TU Bergakademie Freiberg.

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Werner, Michael von. 2003. *EROSION-3D Ver. 3.0 User Manual*. Berlin: GeoGnostics Software. http://www.bodenerosion.com/demos/e3d300/manual.pdf.

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