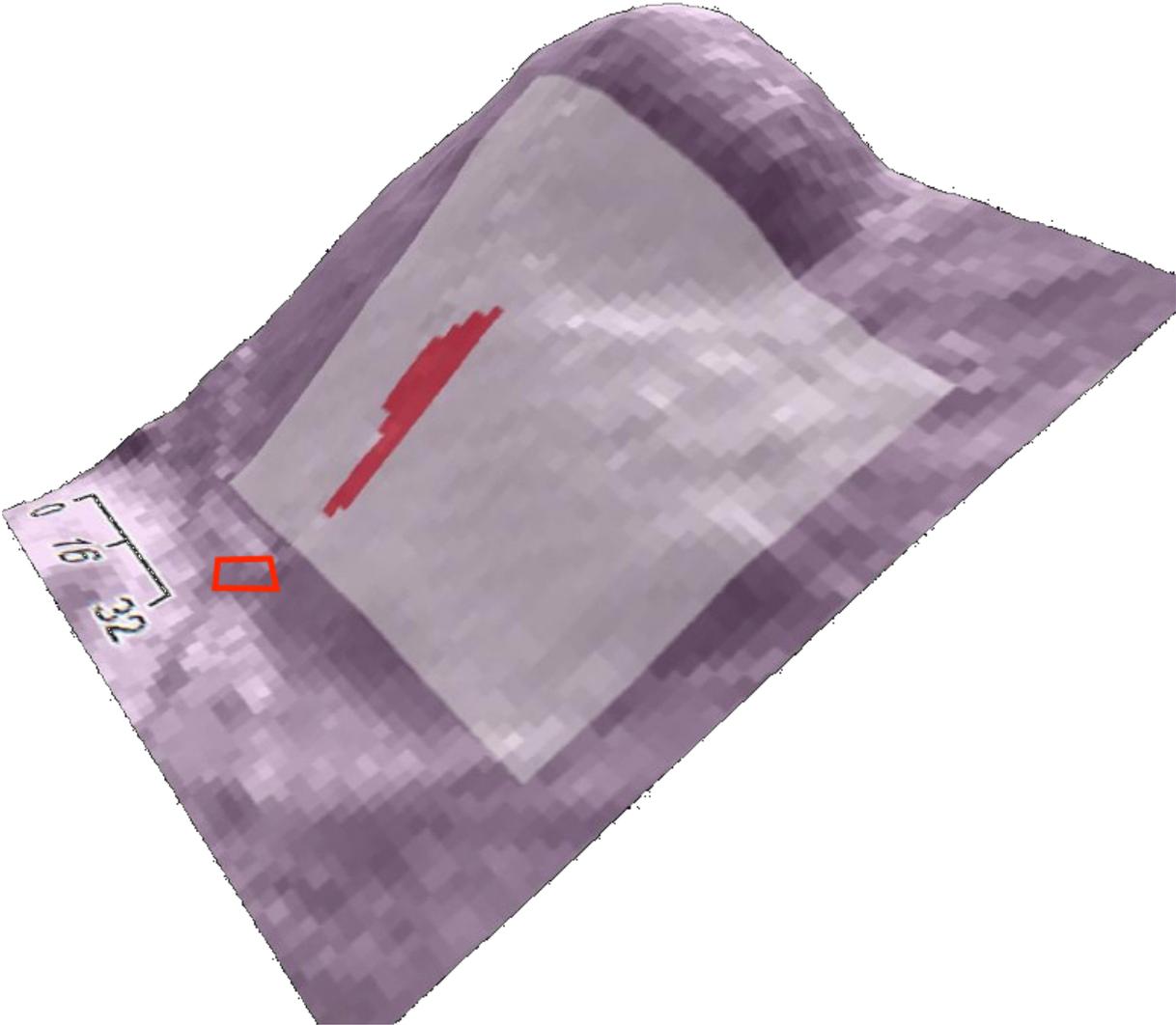


SOSlope (v1.3)

User manual of the „self organized slope“ model



Publication information

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Publisher

Int. ecorisQ Association

Geneva

Switzerland

Citation

Cohen, D., and Schwarz M., 2017. SOSlope (v1.3) User manual of the „self organized slope“ model. ecorisQ paper (www.ecorisq.org): 33 p.

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Date: 17.12.2017

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Thanks go to the following colleagues for valuable suggestions

Dr. Luuk Dorren (BFH, CH)

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1. Introduction

SOSlope is a hydro-mechanical model of slope stability that computes the factor of safety on a hillslope discretized into a two-dimensional array of blocks connected by bonds. Bonds between adjacent blocks represent mechanical forces acting across the blocks due to roots and soil (Cohen et al., 2009). These forces can either be tensile or compressive depending on the relative displacements of the blocks. A digital elevation model (DEM) is used to divide the hillslope into squares in plan view, where the centers of the squares are points of the DEM

SOSlope has been developed since 2009, specifically in order to consider the spatial distribution of root reinforcement due to different forest structure and tree species (Schwarz et al., 2012). Additionally, research results on the stress-strain behavior of rooted soil under tension and compression has been implemented (Schwarz et al., 2010; Schwarz et al., 2013; Schwarz et al., 2015). The calibration of the root reinforcement model for different tree species is based on field measurements and is continuously under extension. The unsaturated soil mechanics and the hydrological modules of SOSlope are adapted from literature references (for details see Cohen and Schwarz, 2017).

The required input data consists of two ASCII rasters (ESRI format, explanation see chapter 2), which define the topography (DEM) and the „topographic wetness index“ (TWI). Under the assumption that each simulation with SOSlope is done within a unique soil representative unit (homogeneous soil properties), the soil properties can be selected from the USCS classification system or by user defined values. The rainfall triggering scenario must be defined in terms of a mean rainfall intensity and a duration. These input data, short instructions for running SOSlope, and output data are described in details in the following chapters.

2. Model input and quick start

2.1. Raster input data

The minimum input data required by SOSlope consists of a set of 2 raster maps. **These two raster maps need to have identical spatial extent and identical cell size.** Smaller cell size, while providing higher spatial resolution, will increase the accuracy of the simulated force redistributions on the slope, but will increase computation time. Based on experiences, a 2 m × 2 m resolution will result in a good compromise between computational costs and details of results. Furthermore, considering the effects of vegetation on slope stability, a resolution of 1 or 2 meters allows to consider the spatial heterogeneity of root distribution in a realistic way.

All rasters should be in ESRI ASCII Grid format, which is readable by all text editors. Below, an example of a small raster in such format is presented. The header provides information on the number of rows and columns in the raster (nrows and ncols), the cell size or resolution of the raster (cellsize in m), the x and y coordinates of the centre (or lower left corner) of the lower left cell (xllcenter/xllcorner and yllcenter/yllcorner) and the value that represents missing data (NODATA_value; default = -9999). In

SOSlope, however, all values MUST be elevation data. DEM containing NODATA will likely cause SOSlope to crash. Decimals should be preceded by a point (.) and not by a comma (,).

The following **two** rasters are required for using SOSlope:

Nr.	Raster name	Description
1	<i>dem.asc</i>	<p>A rasterised Digital Elevation Model (DEM), which describes the topography (double type raster). Laserscanning (LiDAR) generally provides accurate DEMs. A small example <i>dem.asc</i> is given below:</p> <pre data-bbox="647 663 1278 927"> ncols 5 nrows 3 xllcorner 123456.123 yllcorner 1234567.123 cellsize 2.5 NODATA_value -9999.00 1115.81 1114.28 1109.25 1107.74 1105.01 1110.31 1109.35 1107.33 1103.57 1102.00 1006.55 1005.00 999.62 998.02 996.10 </pre>
2	<i>TWI.asc</i>	<p>A raster map with the calculated values of Topographic Wetness Index (TWI) (Beven and Kirkby, 1979). The TWI is calculated as the natural log of the contributing area divided by the tangent of the slope angle. The format of this file is identical to the DEM file described above.</p>

Hint for preparing rasters nr. 2 :

- 1) Prepare a *DEM.asc* of the area of interest with an extension that includes the basin area that contributes to the near surface water flow accumulation near the area where slope stability should be calculated.

- 2) Generate a fill version of the DEM.asc for the basin.
- 3) Calculate the TWI.asc using toolbox in SAGA or the QGIS plugin.
- 4) Clip the fill_DEM.asc and the TWI.asc with the extension of the area where slope stability calculation should be done.
- 5) Again, **all the raster maps must have the same map extent and the same cell size!** An example raster dataset can be [downloaded here](#).

2.2. Input of soil mechanical properties

SOSlope has two options to set soil mechanical properties: USCS soil types or user defined. These options are available under the drop-down bar named “Soil type”.

For user defined soils the following four parameters need to be defined:

- 1) **Cohesion** [kPa]. By definition, the model uses the effective soil cohesion representative for the depth at the failure surface of the landslide. This value corresponds to the saturated-drained condition for shear box or triaxial tests. This parameter considerably influences the results of the model and we suggest to perform a sensitivity analysis in order to set a realistic value for the simulations.
- 2) **Friciton angle** [°]. The model uses the effective soil friction angle representative for the depth at the failure surface of the landslide.
- 3) **Density** [kg/m³]. This parameter is the soil dry density.
- 4) **Porosity** [-]. Porosity is defined as the ratio between soil pore volume [m³] over the total soil volume [m³]. This parameter allows the user to consider different densities for the soil solid phase.

2.3. Input of hydrological scenario

SOSlope has two options to impose a hydrological scenario for the simulations: either a rainfall scenario or a fixed soil saturation scenario.

1. The **rainfall scenario** has to be defined in term of a rainfall intensity [mm/h] and a rainfall duration [h]. The centennial rainfall rate is unused in this version of SOSlope.
2. The **fixed soil saturation** option allows to calculate the slope stability for conditions where measurements or results of hydrological models are available.

2.4. Simulation with forest

If a simulation “with forest” is to be carried out, SOSlope has three options for integrating forest data:

1. The first option is using a tree file, which contains x- and y-coordinates of each and every single tree, as well as their stem diameter at breast height (DBH, given in cm). Apart from exhaustive field measurements, these data can also be obtained automatically using an analysis of a normalized surface model derived from airborne laser scanning data following methods described by

Popescu et al. (2002), Dorren et al. (2007), Monnet et al. (2010) (the [program FINT](#) can be used for doing this). This tree file must be called *treefile.txt* and should be available in the working directory where the DEM and the TWI raster files are located. This file needs to have the following format (**without a header !**):

```
136578.55  2236789.45  43
136554.89  2236793.22  27
136531.39  2236801.37  34
...
```

2. The second option is to represent the forest by generating a regular grid of trees with a fixed DBH.
3. The third option is to represent the forest by generating a random distribution of trees with a normal distribution of DHB defined by a mean value of DBH and the standard deviation.

2.6. How to run SOSlope

To run SOSlope, the file **setup.exe** should be used to install the program. If this is done, the program can be opened as is usually done with other programs. The first step is to choose the working directory (cf. Fig. 5) that includes the **required input raster files** (*dem.asc*, *twi.asc*). Then all other simulation settings can be defined and the simulations can be started by pushing the corresponding button (Run). If an error occurs, the user will be informed in the Messages window; unknown errors might lead to a program crash. In that case, do not give up hope and start over, sometimes computers have a will of their own. After finishing the simulations, the output raster data (cf. chapter 4) are saved in a subdirectory (MyProject) inside the working directory. The output rasters can be opened in standard GIS software, such as the open source programs SAGA-GIS (www.saga-gis.org) or QGIS (www.qgis.org), or the ESRI product ArcGIS.

SOSlope has the option to print additional information for a specific point in the area of the DEM by activating the „print probe“ option. The position (x,y) of the point where results should be printed needs to be given in the coordinate system used in the DEM.asc file.

The „progress window“ displays the evolution of the model calculation printing out, at each loading step, the values of cumulative rainfall, number of cell movements, maximum displacement, and minimum factor of safety calculated. At the end of the simulation, the total landslide area in m² and percentage of the total area of the DEM are indicated.

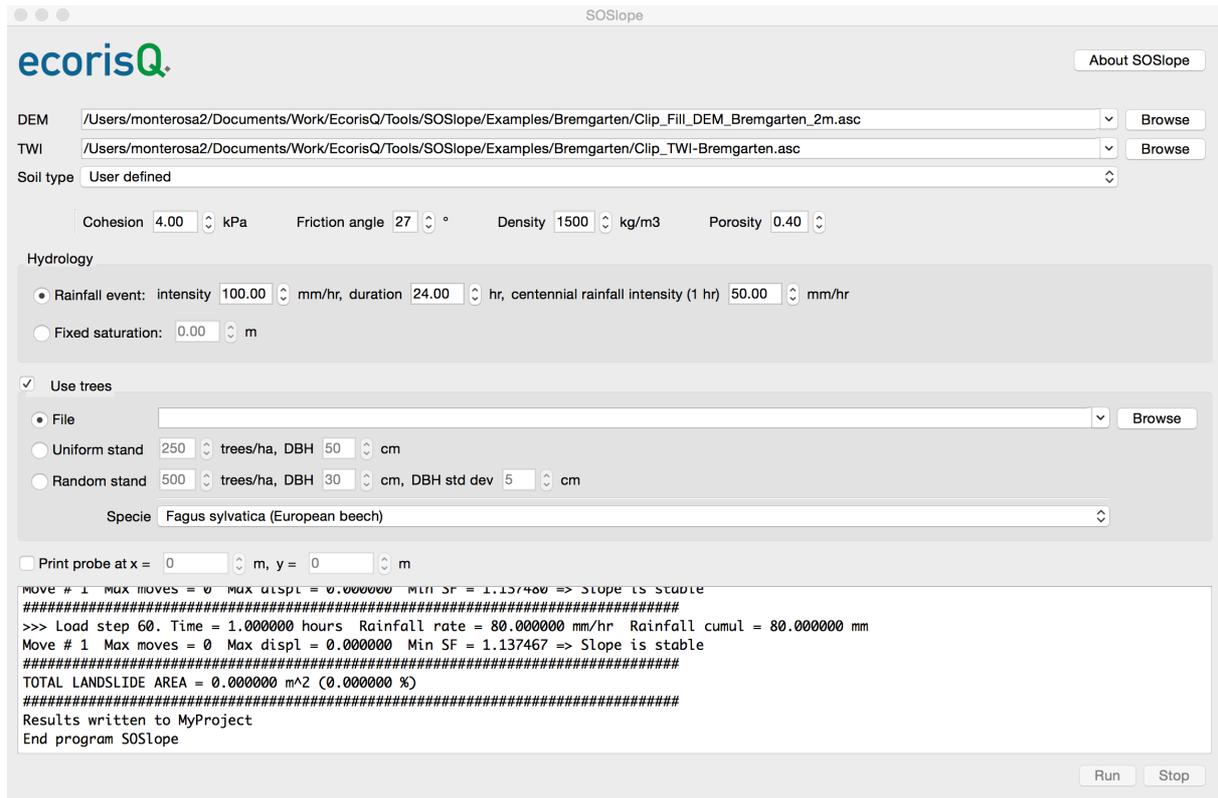


Fig. 5. The graphical user interface (GUI) of SOSlope.

3. Main components of the model

A detailed description of the model is given in Cohen and Schwarz (2017).

4. Model output data

For each run, SOSlope outputs a number of files describing the results. Files are saved in a directory called MyProject which is created automatically. **Re-running a simulation by pressing the Run button will automatically erase the previous results and produce a new set of files in this directory.**

The output files created by SOSlope are:

- *disp.asc*: A raster file of the total displacement in meters of each cell of the DEM at the end of the simulation.
- *fos.asc*: A raster file of the factor of safety of each cell at the end of the simulation.
- *ls.dat*, *ls.hdr*: *ls.dat* is an ASCII file that lists all landslides (one per line) that occurred during the simulation. Each landslides is characterized by its location (x and y coordinates of barycenter), the number of failed cells, its area and its volume. The file *ls.hdr* is a header file that describes what is found in each of the columns of the file *ls.dat*. An empty *ls.dat* indicates that no landslide occurred during the simulation.
- *lsindex.asc*: A raster file of the numbered landslides that occurred by the end of the simulation (same numbering as in *ls.dat* described above).
- *maxrootcomp.asc*: A raster file containing the maximum value of root compression in Newtons obtained during the simulation.
- *maxroottens.asc*: A raster file containing the maximum value of root tension in Newtons obtained during the simulation.
- *maxsoiltens.asc*: A raster file containing the maximum value of soil compression in Newtons obtained during the simulation.
- *maxsuction.asc*: A raster file containing the maximum value of matrix suction in Pascals obtained during the simulation.
- *maxwaterpress.asc*: A raster file containing the maximum value of pore water pressure in Pascals in the macropores obtained during the simulation.
- *result.dat*: An ASCII Tecplot formatted file containing all values of computed variables during the simulation
- *run.log*: A log of the run.
- *soildepth.asc*: A raster file containing the soil depth in meters used in the simulation.
- *wetness.dat*: An ASCII file containing the area and percent area of the DEM where the value of the wetness index reached 1 as a function of time during the simulation.

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List of changes

SOSlope Version	Date	Changes in the model (<i>m</i>) or in this description (<i>d</i>), compared to de original version published in Cohen & Schwarz (2017)
1.3.2	17.12.2017	<ul style="list-style-type: none"> <input type="checkbox"/> First version of the manual (<i>d</i>) <input type="checkbox"/> New analytical model for the calculation of force-displacement of root bundles (<i>m</i>) <input type="checkbox"/> New calibrated coefficients of the RBM for Spruce (<i>Picea abies</i>), Beech (<i>Fagus sylvatica</i>), Chestnut (<i>Castanea sativa</i>), radiata pine (<i>Pinus radiata</i>) <input type="checkbox"/> Calculation of temporal and spatial variability of pore water pressure based on the TWI. (<i>m</i>)