cLiNUs: Computational Landslide Initiation through Numerical Simulations

Version 1.0

User Manual

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Contents

1 Preparation

Note that this application only suitable for MATLAB R2019a or later version.

1.1 Installation

Open the MATLAB and press "Install App" icon, one need to choose the integrated file in the popup window.

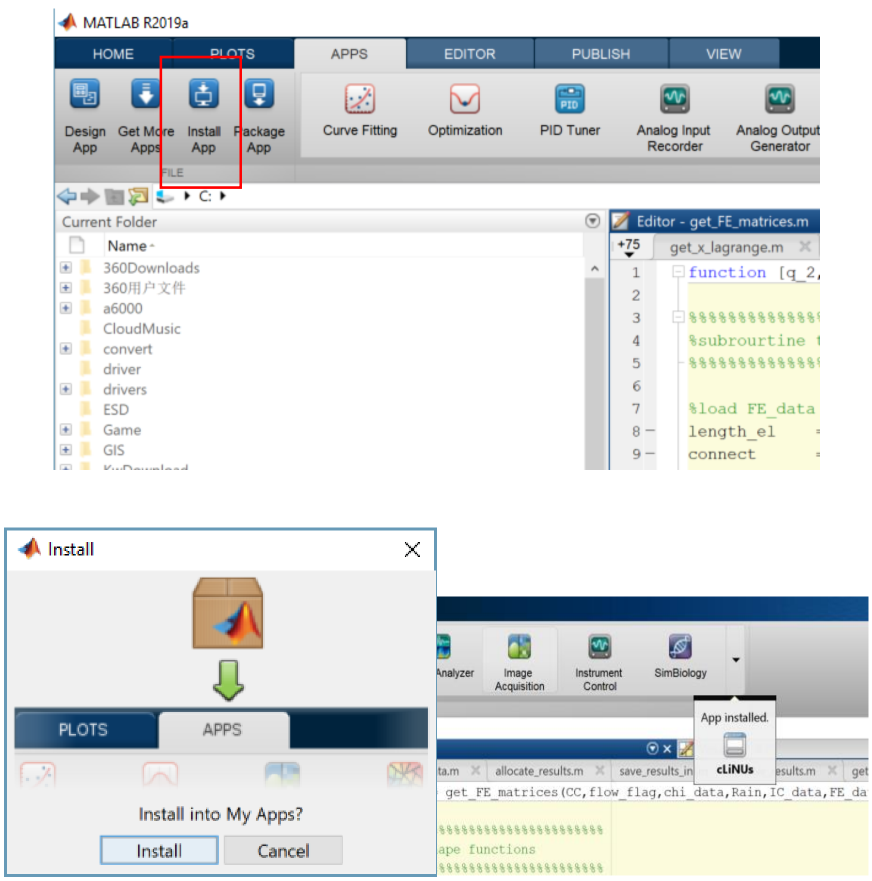


Figure 1-1 App installation

1.2 Create folder

Create a new fold in your C drive and name as "convert". It will used to save files from .ascii to .raster format. ("C:\convert").

2 Introduction of cLiNUs

2.1 FE Settings

The "*FE settings*" interface is designed to facilitate the specification of any FE solved initial boundary-value problem and input of elemental arguments required to use cLiNUs. It provides two options: Single slope vs. Regional slope simulation. By selecting either option, the corresponding subpanel will be enabled. As shown in Figure 2-1, "Single slope" will be chosen by default. Several parameters are required to initialize the FE setting (i.e. time stepping, nodal discretization, total simulation time). Noted that the initial time step will be given as the suggestion value of 5000 steps and if the results is not convergent, the user need to increase the number by trial-and-error procedure. Slope geometry information only requires the height of the slope and its inclination. The discrete knob allows recording nodes of interests throughout the soil column.

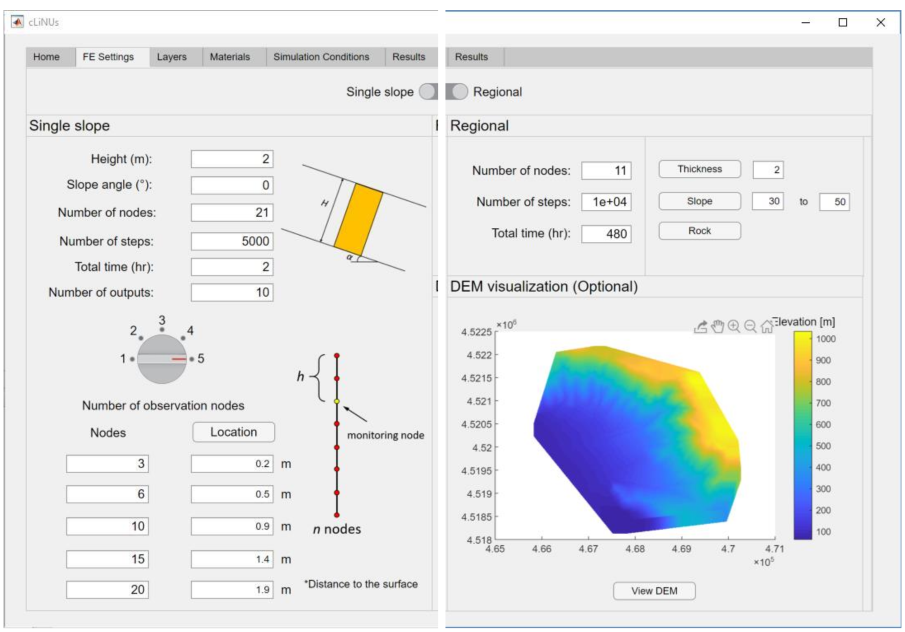


Figure 2-1 View of *FE Settings* window: the left side shows the settings for single slope analysis while the right side shows the input interface for regional scale simulations

If "Regional" option is selected, three geo-referenced maps provided in the form of ASCII files with a specific header are required to input to the program (See Figure 2-1 Right). The header is a georeferenced dataset which contains the size of the map, the coordinates of the corner and the cell size, etc. In Figure 2-2, line1 to line6 demonstrates the basic regulation for the header. Users are allowed to restrict the computation further by specifying slope angle range and thickness value.

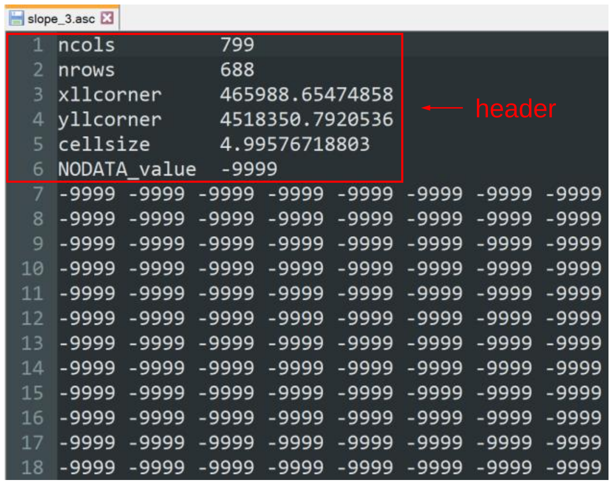


Figure 2-2 Header component.

2.2 Layers

This part involves the specification of the heterogeneity of a given soil layer as well as the assignation of the soil properties, as shown in Figure 2-3. A cumulative depth weight, α_i (i<=n), is used for computing the location of layers. For the moment, the tolerant maximum number of the layer is five. By turning the knob, the corresponding layer location input will be activated and required α input. In Figure 2-3, a four layered soil is defined and the location of layer's bottom is equals to α times height. In this rule, the α for the bottom layer is always be “1”. By default, the soil is homogenous.

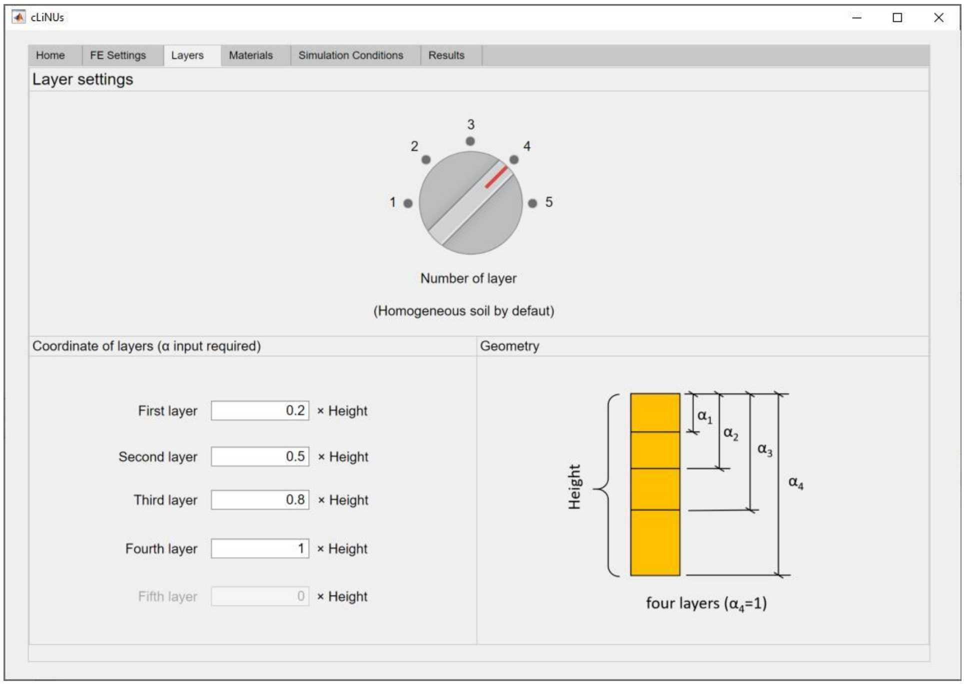


Figure 2-3 *Layer* interface through which the stratigraphy can be defined through the cumulative depth weight (CDW).

2.3 Materials

For convenience, the "*Materials*" interface is organized in two sub- sections as shown in Figure 2-4 (a). Hydraulics sub-page provides three options for water retention curve (WRC) and hydraulic conductivity function (HCF) models, namely Van Genuchten mode, Gardner model and Brooks and Corey model. For each layer, users are required to define the property completely. The "Root Water Uptake Model" (RWUM) (Prasad, 1988) is inactivated by default and will be used only when "Sink term" switch is on (See 2.6). The "flow rate" switch allows users to calculate the infiltration/runoff rate. A user-defined threshold is required to determine the saturated condition for unsaturated soils. As for the "Mechanical" sub-page, it mainly used for the stability analysis. The user can choose either Bishop single effective stress or Independent stress variables approach to compute the FS (Figure 2-4 (b)). Table 1 shows the required parameter in Mechanical sub-page.

Figure 2-4 *Materials* interface through which hydraulic and mechanical models can be specified.

Table 1 Mechanical parameter required in cLiNUs

<table>
<tr><td rowspan="4">Stress approach</td><td rowspan="3">Effective stress approach</td><td>$\chi = S_\mathrm{r}$</td></tr>
<tr><td>$\chi = \begin{cases} \left(\frac{s}{s_e}\right)^{-0.55} & if \; s > s_e \\ 1 & if \; s \leq s_e \end{cases}$</td></tr>
<tr><td>χ = constant</td></tr>
<tr><td>Independent stress variables approach</td><td>Suction elastic modulus, F (Pa)</td></tr>
<tr><td rowspan="2">Elastic modulus</td><td colspan="2">Elastic modulus, E (Pa)</td></tr>
<tr><td colspan="2">Shear modulus, G (Pa)</td></tr>
<tr><td rowspan="3">Strength parameters</td><td colspan="2">Friction angle, φ' (°)</td></tr>
<tr><td colspan="2">Cohesion, c (Pa)</td></tr>
<tr><td colspan="2">Unit weight (N/m^3)</td></tr>
</table>

2.4 Simulation conditions

The *"Simulation conditions"* window interface includes two main components, namely the initial condition settings and the flow boundary conditions (flow BCs), as shown in Figure 2-5. The initial condition is defined as the water head profile along the slope depth at the onset of the simulation. Such profile can be readily assigned in the form of depth-dependent suction conditions. The GUI offers two options for the definition of the flow boundary conditions: flux control and pressure (water head) control, as shown in Table 2. The former requires the assignation of the hydraulic forcing (e.g., rainfall), mathematically represented by a Neumann boundary condition, while the latter requires the prescription of water pressure or water head at one of the boundaries of the domain, mathematically representing a Dirichlet boundary condition.

Table 2 Two options to apply loading

Option	Loading
Flux control	Rainfall, q (m/hr)
Water head control	Water head, h_w (m)

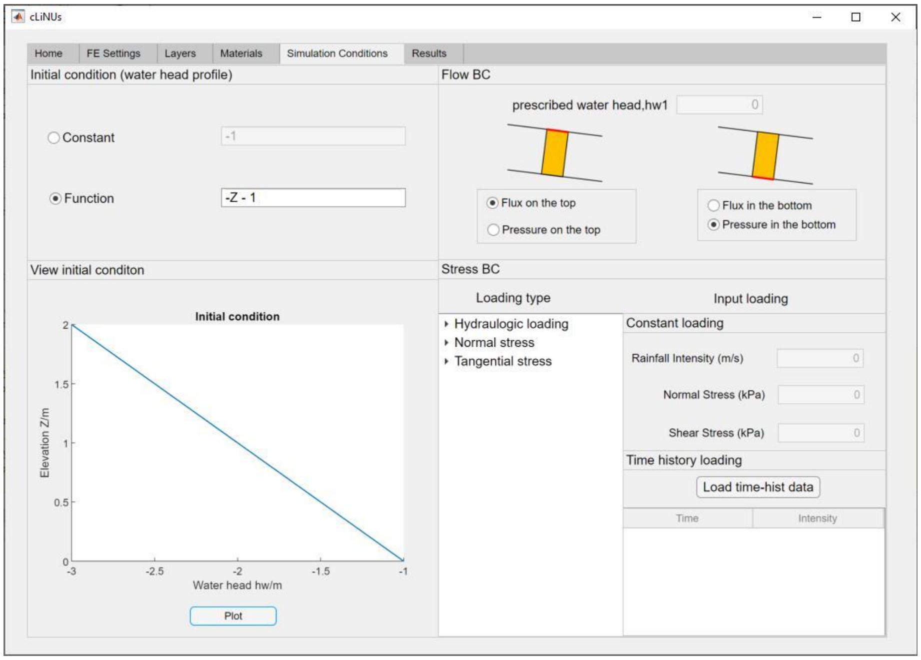


Figure 2-5 View of Boundary condition window. cLiNUs provides several combinations of boundary conditions for various of simulation purpose.

2.5 Loadings

The "*Loading*" interface enables the definition of the forcing agents driving the simulation. The loading type is designed to a two-level tree frame. In the first level, users can choose hydrologic loading, normal loading and tangential loading. Within each level, the second level provides two options for processing loading data: (i) by typing constant loading data or (ii) by importing time-history loading data directly from existing files by choosing the "*load time-hist data*" button. A browsing window will appear to help users select appropriate files easily. Noted that for the moment version, the App only support .xls file.

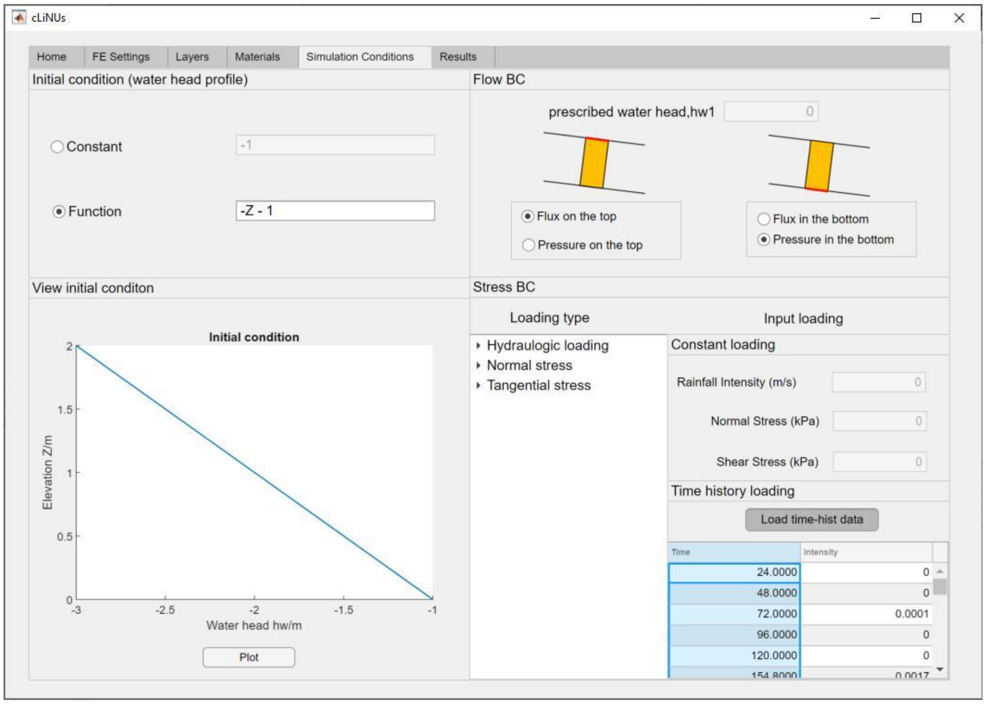


Figure 2-6 View of the *Loading* window

2.6 Results

2.6.1 Single slope

The format of the “Results” interface will adapt correspondingly to the initial choice for the type of the analysis. For single slope analysis, two functional switches are available: “Coupling effects” and “Sink term”.

(i) “Coupling effects” switch

When “Coupling effects” is on, it allows simulating rigid, swelling or compacting behavior of the unsaturated soil upon wetting. Note that it requires the “Independent variables” approach to be chosen in the mechanical material settings.

Table 3 soil behavior controlled by suction elastic modulus, *F*

Sign	Soil behavior
$F = 0$	Rigid soil
$F < 0$	Collapsible soil
$F > 0$	Swelling soil

* when “Coupling effects” is off, it assumes $F = 0$.

(ii) “Sink term” switch

When “Sink term” is on, the “Root Water Uptake Model” panel will be activated in *Materials* window.

(iii) Plot option

Once finishing a simulation, users can plot results by firstly choosing plotting category.

Table 4 Plot option in cLiNUs

Items	Variables
Load	Rainfall
Profile variation	Water head
	Degree of saturation
Time history	Infiltration rate
	Runoff rate
	Cumulative infiltration
	Cumulative runoff
Factor of safety	Factor of safety

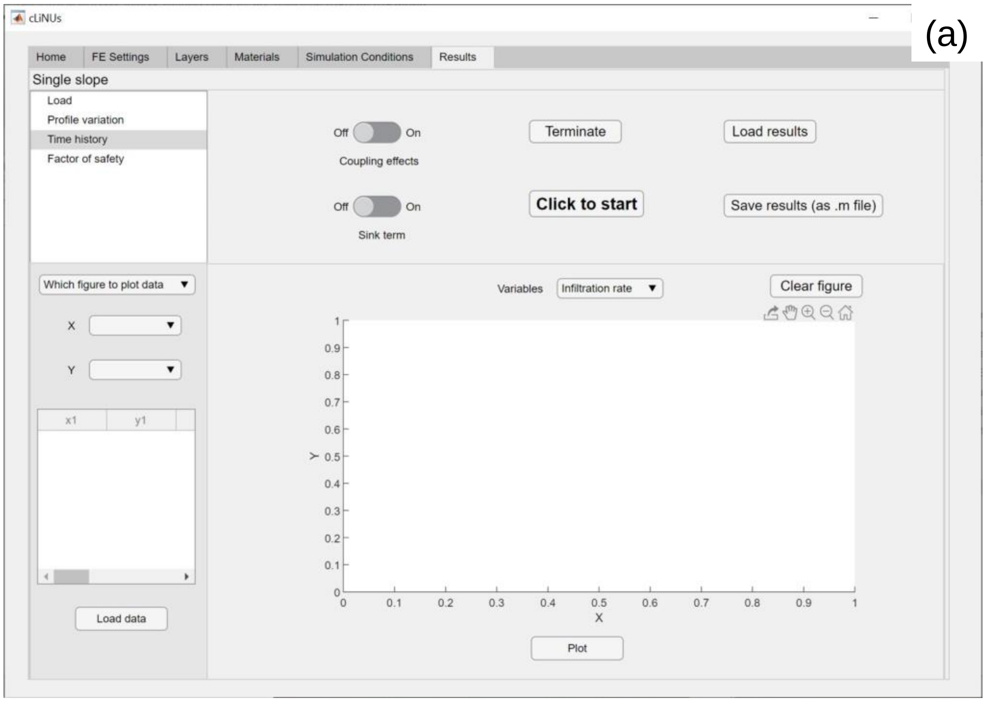
Users are also allowed to check the plotting result by superposing data from existing files (.xls) through "*Load data*" button, as shown in Figure 2-7 (a). The data source can derive from experiment data or field test data.

2.6.2 Regional analysis

In regional analysis, in order to visualize results, it is necessary to keep output files be consistent with input maps. Therefore, three steps needed for processing results: converting maps→ loading maps → visualizing maps, as shown in Figure 2-7 (b).

Table 5 Detailed introduction for displaying regional results

Function	icon	Description
Calculation	**Click to start**	Run regional simulation
	Save results	Save results as .mat
	Load results	Load existed results as .mat
Convert .ascii to .raster	Abstract header	Abstract header from any geo-referenced map (e.g. slope map, property map and thickness map)
	Transfer to .raster file	The app will automatically save results as .asc file
Load geo-raster	Load DEM	Load DEM map (.asc file)
	Load source area	Load landslide area (polygon)
	Load Failure time	Load Failure time map (.asc file)
	Load Failure depth	Load Failure depth map (.asc file)
	Load Cumu_IR	Load cumulative infiltration (.asc file)
	Load Cumu_Runoff	Load cumulative runoff (.asc file)
Visualization	View map	Display maps
	Clear map	Clear maps



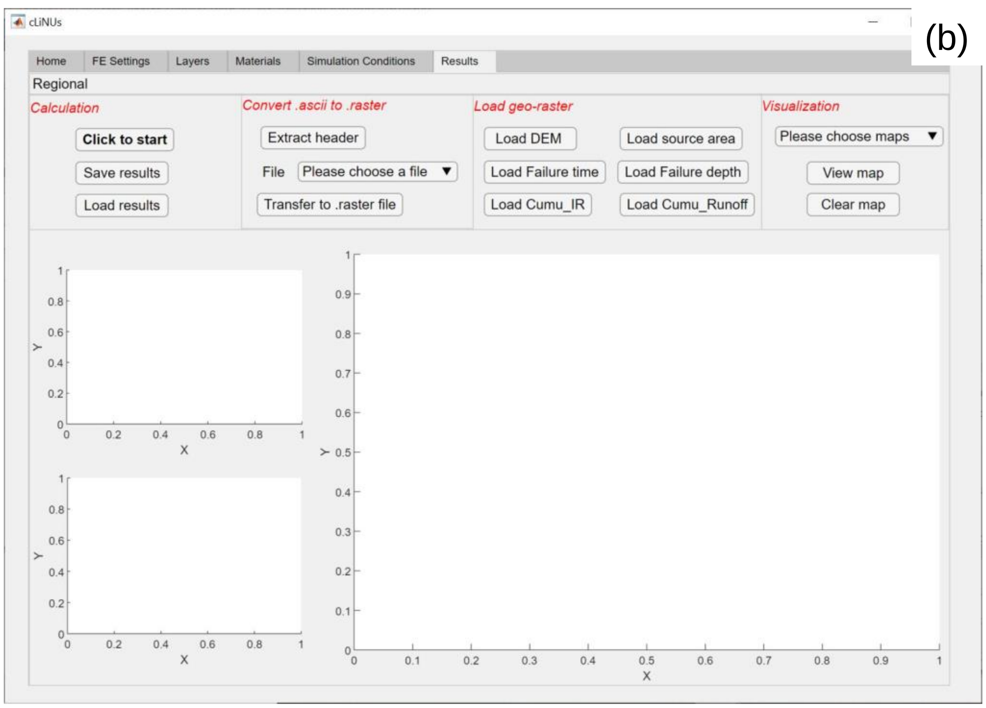


Figure 2-7 Results interface, through which the output of: a) Single slope analyses and b) regional analyses can be visualized

3 Examples of cLiNUs running

3.1 Runoff simulation on single slope infiltration

3.1.1 Steady rainfall

Consider a homogeneous soil L = 50 cm in length of loamy sand. Its hydraulic conductivity is given by Brooks and Corey's model with K_s = 2cm/h, h_w = -0.226m, θ_s = 0.43, θ_r = 0.08, λ =0.53. The initial condition of the water head h_{w_ini} = 0.8828m. Below are specific steps for parameter settings:

a. FE_Settings

- Choose "Single slope" switch to enable corresponding window
- Basic parameters can be set as:

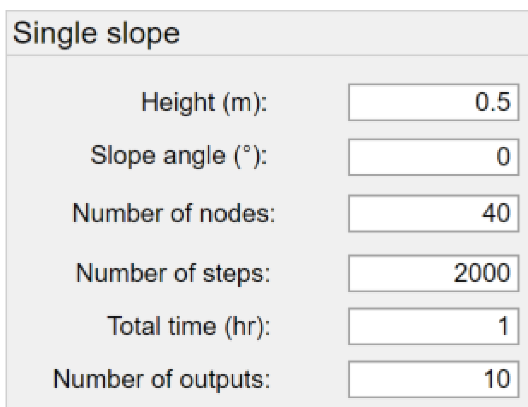


Figure 3-1 FE Settings.

- Choose any observation node as you want.

b. Layer setting

For homogeneous soil, let's set single layer.

c. Materials

- Active the "Flow rate" button and set hw2 to be -0.226 m

- Choose Brooks and Corey model in the dropdown list for the hydraulics model.

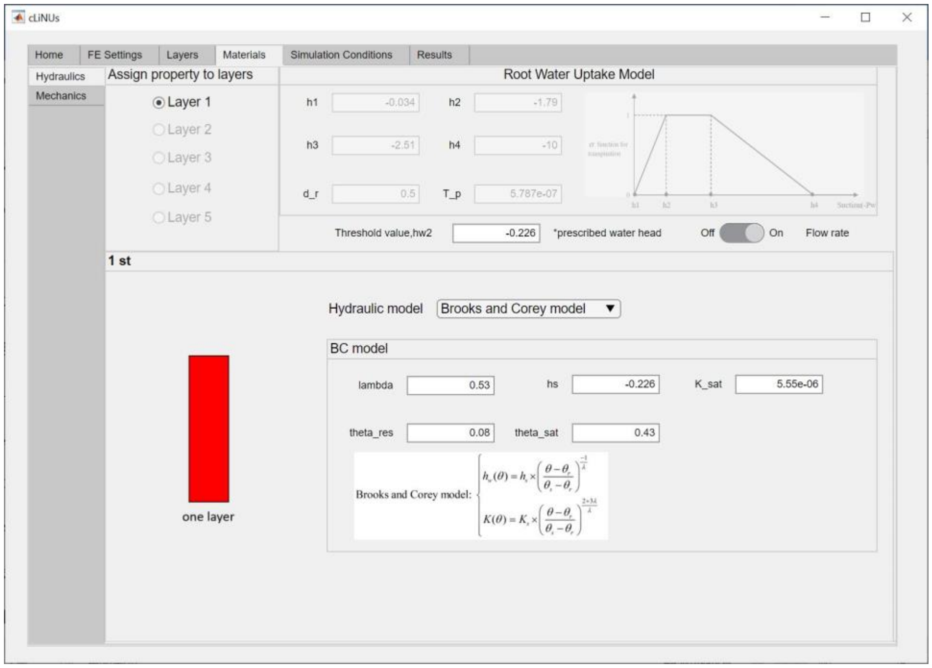


Figure 3-2 Hydraulic model choose for WRC and HCF.

- Keep default set for the stress approach and set corresponding parameters.

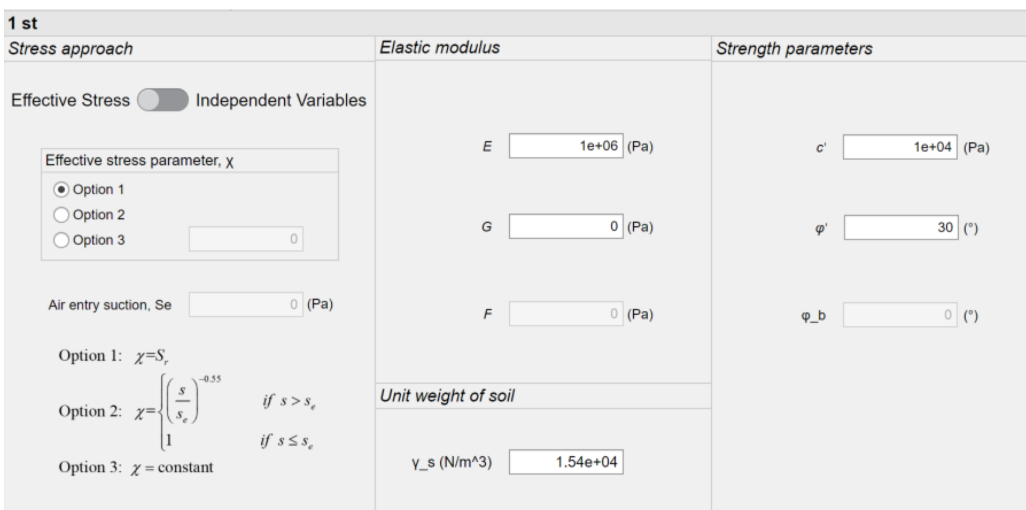


Figure 3-3 Mechanic model choose for slope stability analysis.

d. Boundary condition

- Set constant water head as -0.8828m

- Keep rest settings by default

e. Loading

- Set constant rainfall as intensity of 1.11e-5 m/s

f. Results

- Turn on “Flow rate” switch
- Input the threshold value “hw2” as -0.226m. This value controls the saturated condition and will used for infiltration/runoff calculation.
- Press “Click to start”

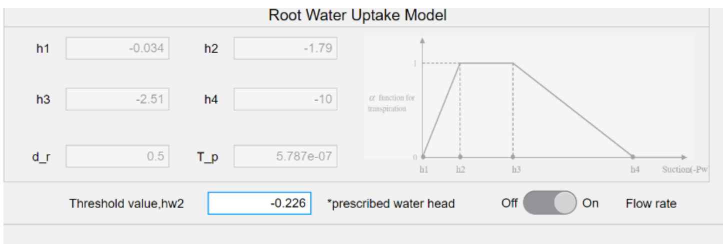
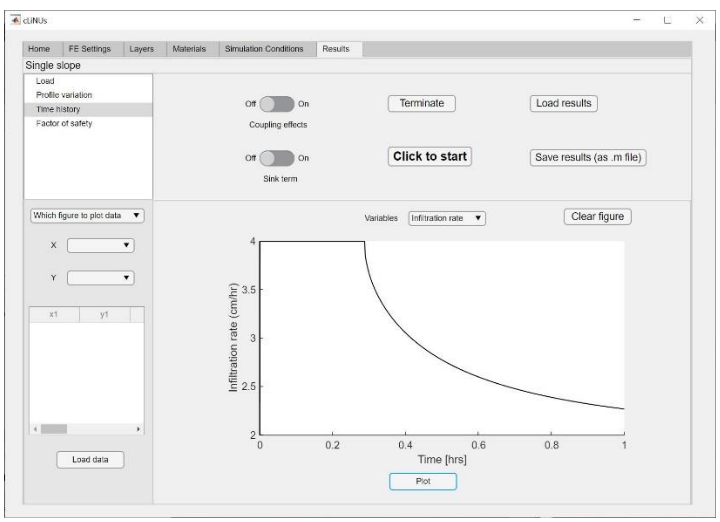


Figure 3-4 setting runoff calculation condition

- Visualize results



3.2 Visualize regional landslides susceptibility mapping: loading from results

Consider the long-time calculation of regional scale analysis, this case is about how to load existed results and view them.

1. Load results

   Press “Load results” button to choose and load an existed .mat file. After loading, you will see a popup window.

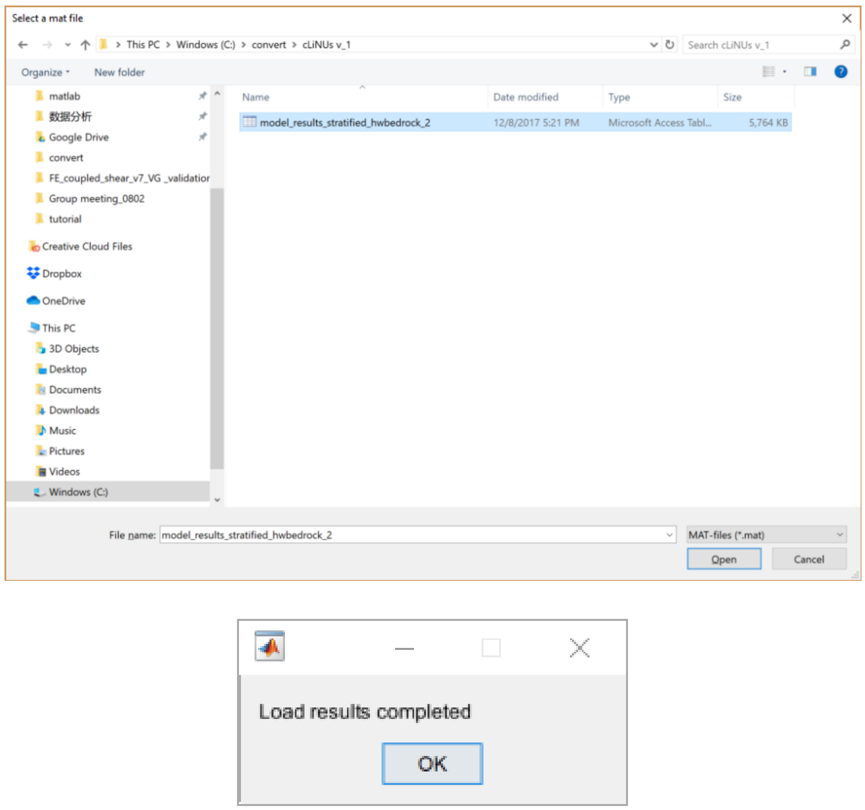


Figure 3-5 Loading results and popup window

2. Convert results to the geo-referenced .raster format.

   1) Press “Abstract header” and choose the header from any three input maps.

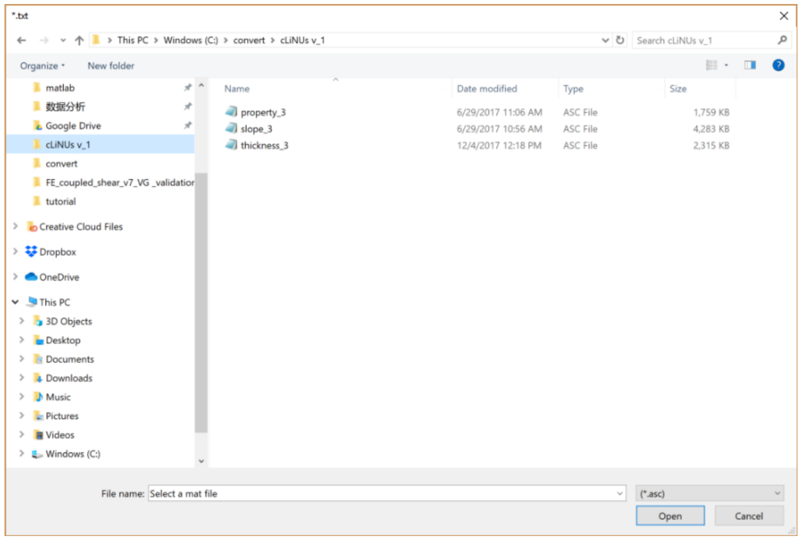


Figure 3-6 Select header

2) Choose variable from the dropdown list:

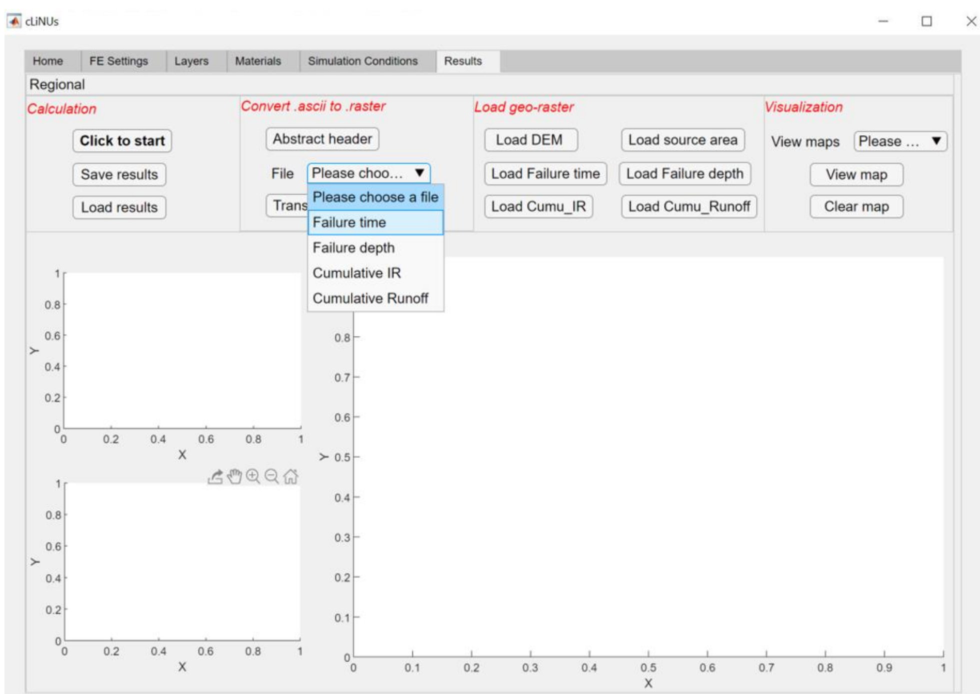


Figure 3-7 Select variable

3) Press “Transfer to .raster” button and you can see a popup window:

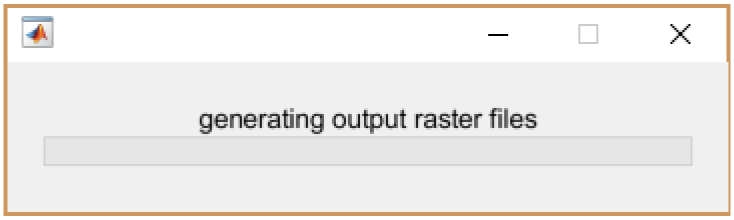


Figure 3-8 Generate raster file

4) Overlap maps by loading .raster files

   e.g. overlap DEM with Failure time

5) View maps

   After selecting the map, users need to specify its corresponding variable by a dropdown list.

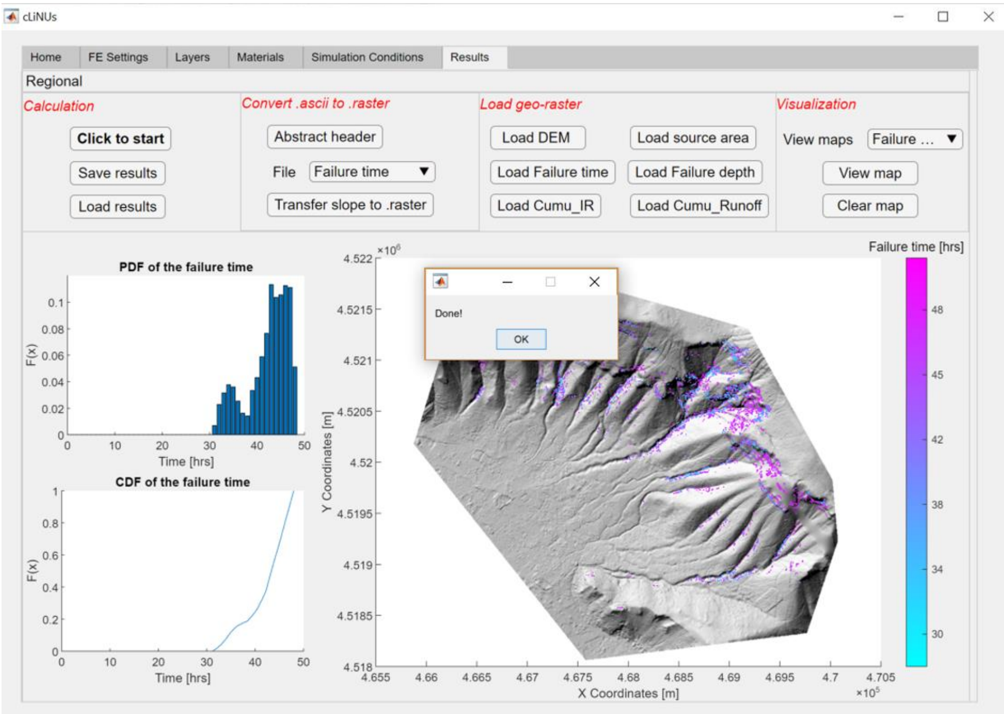


Figure 3-9 View results

4 Trouble shooting

1. The app has its "memory" which means when users want to repeat the simulation, you don't need to reinput all parameters, except "**Loading**":

```
Undefined function or variable 'i_q'.

Error in get_LD_data (line 73)
    LD_data.qr           = i_q(1);

Error in App_v14/ClicktostartButtonPushed2 (line 2667)
        LD_data = get_LD_data(app.time_final,app.Loading_Index,app.q_r,app.q_py,app.q_px, app.RI_Table2.Data);

Error using matlab.ui.control.internal.controller.ComponentController/executeUserCallback (line 335)
Error while evaluating Button PrivateButtonPushedFcn.
```

This mean the loading (rainfall) has not been specified. You just need to go back to the "loading panel" and input the intensity then such this problem will be solved.