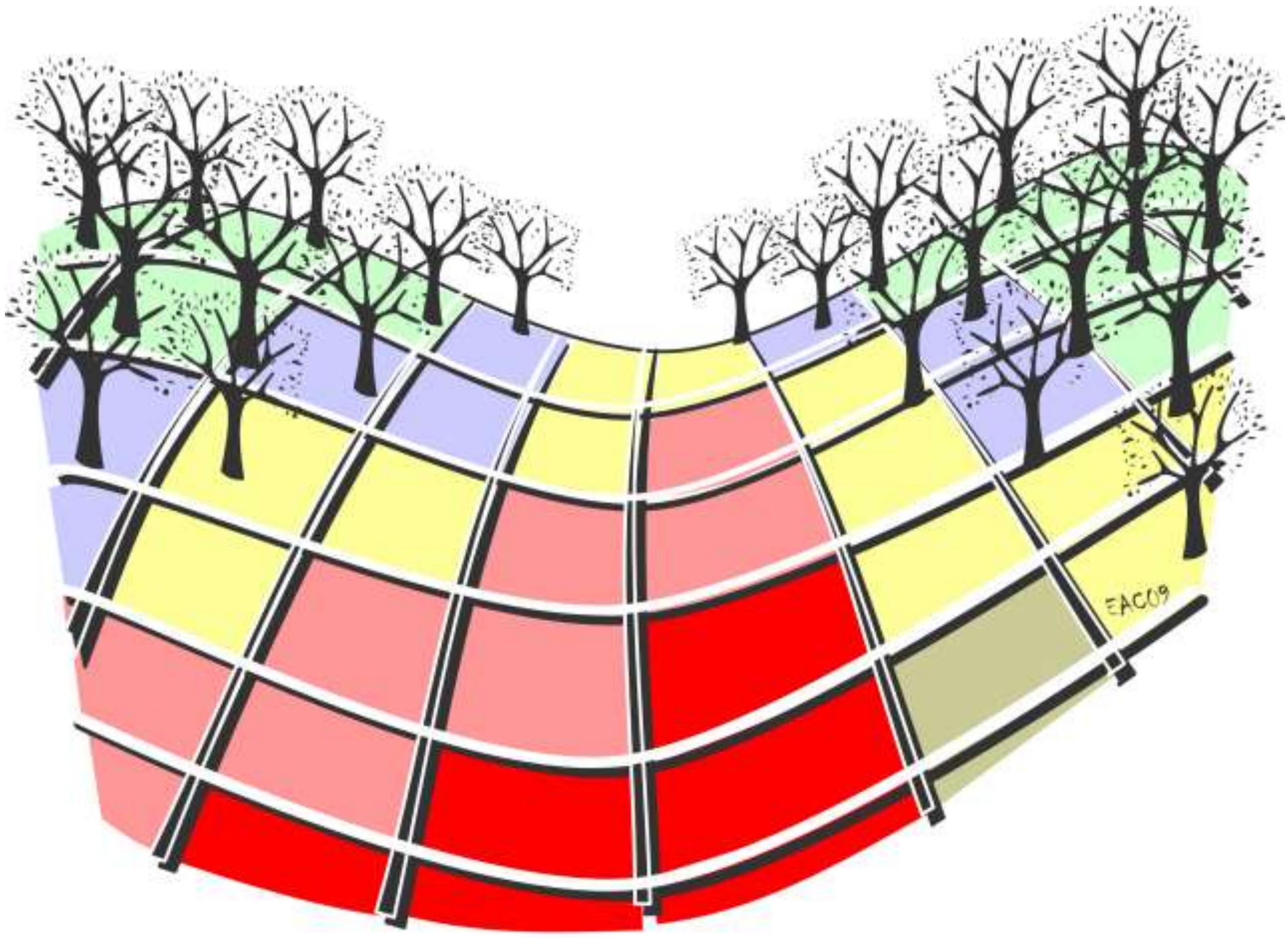
MW-SINMAP
USER'S MANUAL

# MW-SINMAP v1.0

## A STABILITY INDEX APPROACH TO TERRAIN STABILITY HAZARD MAPPING




**Porting project to MapWindow GIS of the original SINMAP code**

Università degli Studi di Milano

RegioneLombardia
Agricoltura

# Disclaimers

The MW-SINMAP project is an alternative version to original SINMAP v1.0 and v2.0 software published on the web site http://hydrology.neng.usu.edu/sinmap2/ (Pack et al., 1998-2005). In this document, the name MW-SINMAP is used in order to refer to this project while the name SINMAP is used to refer to the original project.

Although care has been taken in developing and testing MW-SINMAP, errors and inadequacies may still occur, particularly in new applications. A user must therefore make the final evaluation as to the usefulness of MW-SINMAP for his/her application. MW-SINMAP is a tool to be used by investigators who have some knowledge and experience concerning landslide behavior. It requires engineering judgment and common sense in developing input parameters and interpretation of the results. In making these judgments the user should understand the concepts and limitations of the MW-SINMAP theory presented in the original project document. This understanding should include a comprehension of the geomorphic processes which the program is attempting to model and the model's limitations. Finally, the user should be aware of the accuracy limitations of the DEM, soil, and hydrologic data used as input for these analyses.

The author of MW-SINMAP assume no liability or responsibility for the use of MW-SINMAP, the interpretation of MW-SINMAP results, or the consequences of management decisions that are based upon MW-SINMAP. In no event shall the Author be liable for any damages whatsoever arising out of the use, or attempts to use MW-SINMAP.

In any case, original SINMAP project Authors are not responsible about MW-SINMAP project presented in this document.

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# License

# MW-SINMAP Software User's Guide

# INTRODUCTION

This document should be distributed coupled with the necessary binaries and source code required in order to use or develop MW-SINMAP. Note that some parts, layout and structure of this document are clearly copied from the original SINMAP user guide under the agreements of its Authors. That should help the users of the original SINMAP software to read and analyzed the presented project and compare it to the first one.

The following icons are used in the text with different meaning:

Point of interest or particular passage where the user should pay attention.

Valuable information

Keyboard input passage

MW-SINMAP derives from the original SINMAP project (Pack et al., 1998, Pack et al., 2005). The intent of this first version is to make SINMAP running using a free platform instead of commercial software and so, make it available to a large amount of users. MW-SINMAP starts from SINMAP v1.0. Part of the original code was changed in order to match with particular needs.

The original SINMAP theory is presented in the Part I of the SINMAP manual downloadable from the main page of the project http://hydrology.neng.usu.edu/sinmap2/

The theory has been incorporated into a package of computer routines that can be called to perform computational tasks including calculating stability index and saturation (wetness index). Additionally, library routines are also available to perform many basic tasks of manipulating Digital Elevation Model (DEM) grid data including topographic pit filling, calculating slopes, determining flow directions, and defining the area draining to a specific point. These various routines are written in the C programming language and are contained within an executable (.EXE) file.

Because of the spatial or geographic nature of SINMAP analyses, on-screen or printed maps are required for interpreting some computational output. Rather than create custom routines to provide standard geographic analysis abilities, SINMAP utilizes off-the-shelf Geographic Information System (GIS) software to handle these tasks.

MW-SINMAP uses the MapWindow as base GIS software. To use MW-SINMAP you have to install MapWindow software first and then install the MW-SINMAP plugin as detail explained in the next paragraph. MapWindow GIS can be freely downloaded at this page www.mapwindow.org. At the moment, it can be installed on MS Windows systems only and required the NET platform.

## MapWindow interface

MapWindow desktop GIS offers a graphical interface to the user in order to display and analyze spatially distributed data. MapWindow GIS provides different tool to move in the map, zoom to interesting area, query for attribute of spatial data and perform geometrical and statistical analysis (Figure 1). MW-SINMAP is loaded as a plug-in in MapWindow and it adds functionalities by a new menu.

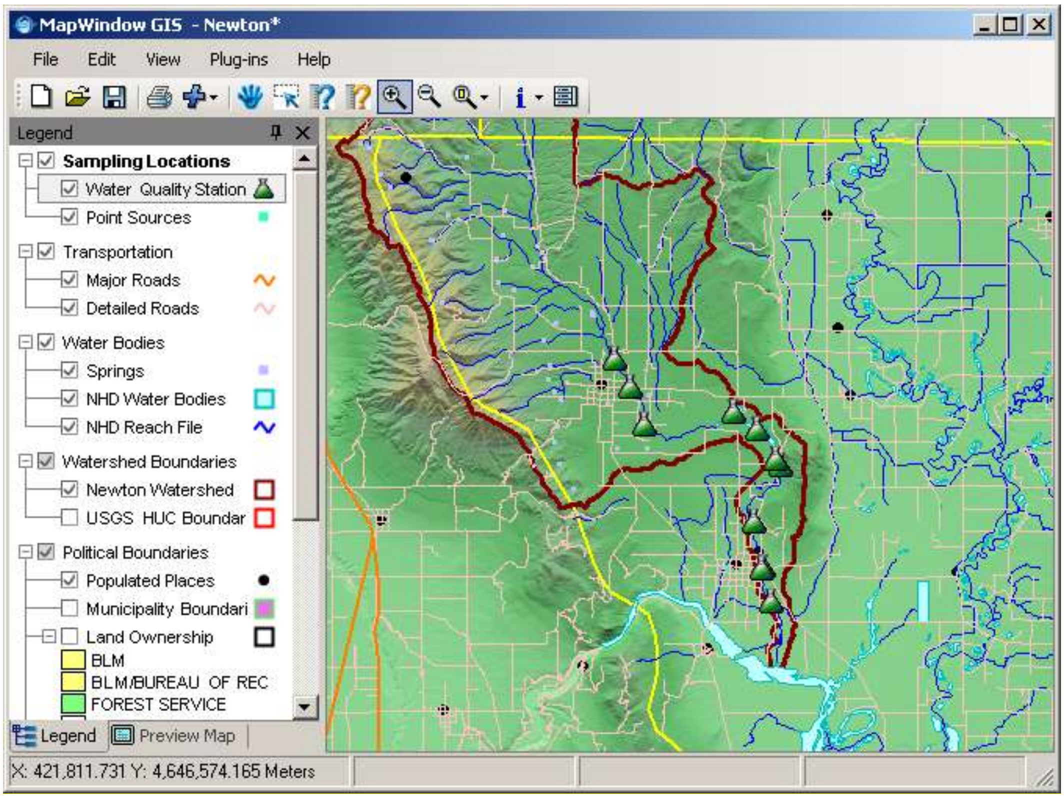


**Figure 1. An example of MapWindow in action (Newton project from MapWindow GIS sample data).**

The main graphical components that you should to pay attention are (Figure 1): 1) the menu bar at the top of the main form; 2) the tool bar below the menu bar; 3) the Table Of Content (TOC) on the left side of the main form, and 4) the main view in the center of the main form.

Base functionalities are: open, save and create new project; print and add layers to the view; move and zoom in the view; measure areas and distances in the view; ask and search for information about loaded data. Referee to the MapWindow GIS user's manual for more details.

Note that when a new MW-SINMAP project is saved, all the MW-SINMAP options are saved too and are available to the user until the next session.

## Slope-Area Plot Chart

In addition to the geographic display of study data in a DEM map document, MW-SINMAP also generates a slope-area chart (graph) of study area data to aid in data interpretation and parameter calibration.

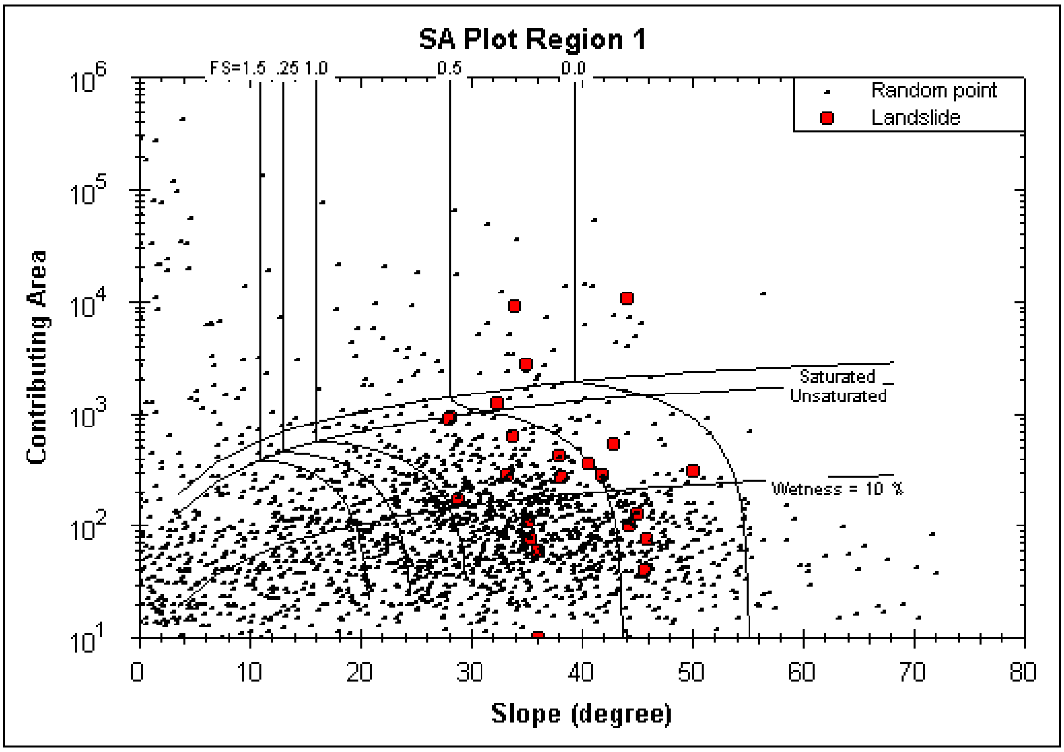


**Figure 2. An example of SA plot.**

The slope-area plot, as explained in the original SINMAP user manual, is generated by SINMAP routines. Plotted on the SA Plot are four types of information:

1. Normal cell data. Specific catchment area versus slope is plotted for a sampling of grid cell points across the study area that does not have landslides.

2. Landslide cell data. Landslides are plotted based upon the slope and specific catchment area values of the cell in which each landslide point lies.

3. Stability index region lines. These five (5) lines provide boundaries for regions within slope-specific catchment area space that have similar potential for stability or instability.

4. Saturation region lines. These three (3) lines provide boundaries for regions within slope-specific catchment area space that have similar wetness potential.

SA-plot generation is performed through the graphic library ZedGraph distributed under LGPL on the web site http://zedgraph.org.

# INSTALLATION

## Hardware and Software Requirements

The current version of MW-SINMAP has been tested on Windows XP operating systems.

You need to install first the Microsoft NET framework (if it is not already running) and then MapWindow Desktop GIS downloadable at the address www.mapwindow.org.

MW-SINMAP consist in three (3) parts:

1. the main plugin, mwsinmap.dll, provides all the necessary to build the menus and the forms in MapWindow GIS;

2. the chart library, zedgraph.dll, necessary to build the SA-plot;

3. the model engine, sinmap.exe, a command line program that performs all the operation on input data and returns resultant maps. Note that it can be run from dos: type for example sinmap.exe in the parent directory.

You will need enough computer memory, usually the more the better. In this version of SINMAP, the grids are dumped into large arrays in memory so as to keep disk input/output down and speed up. If you do not have enough memory to fully contain all the grids, Windows will swap memory pages out to disk. This can slow things down dramatically as a lot of swapping and thrashing can occur. If you plan on using extremely large grid study areas, try to close out all other processes to free up as much memory as possible.

**Table 1. Approximate amount of memory your computer needs to run SINMAP on a particular size DEM grid.**

| DEM Grid Size (cells) | Memory Required (Megabytes) |
|---|---|
| 10,000 (100x100) | 0.16 |
| 250,000 (500x500) | 4 |
| 1,000,000 (1,000x1,000) | 16 |
| 6,250,000 (2,500x2,500) | 100 |

Check Task Manager to see how much memory you actually have available. Table 1 lists the amount of memory your computer needs to run SINMAP with a particular DEM grid size and maintain all operations in memory. The values are approximate only, for the exact value depends on the specifics of your system configuration and the complexity (number of pits and flats) of the DEM being processed.

Note that MapWindow GIS can appear very slow the first time it loads a new very large (more than 10 MB) ASCII raster because it must create an image representation (.BMP file) of the grid.

### Installation Procedure

MW-SINMAP installation is very simple! Just copy and paste all the binaries in the MapWindow GIS plugin folder. Maybe, the very difficult thing is finding the right place to copy in it. Commonly MapWindow folder is placed in the program directory (e.g., c:\Program\MapWindow). Go in it and look for the plugin directory (e.g., c:\Program\MapWindow\Plugins). Enter it and create a new folder (e.g., mwsinmap) where put all the binaries (dll and exe files).

Now MW-SINMAP is ready to run; start MapWindow GIS (or restart it if already open) and, if all is correctly installed, you should see a new item in the plugin list under Plug-ins menu. Select it (flagged) in order to activate the MW-SINMAP interface. Finally, a new menu should compare in the menu bar.

### Start from the code

Both the plug-in library and the model executable are open source software. You are free to modify and compile the source code as you want.

The MW-SINMAP plug-in is developed with Visual Basic 2005 Express Edition. The easiest way is to install the Microsoft IDE and then open the file "MWSinmap.vbproj". You'll probably need to refresh all the references in the project and in particular to the MapWinGIS, MapWindow and ZedGraph libraries.

The SINMAP executable file (sinmap.exe) is compiled with standard C compiler (GCC). You can open the project file "sinmapor.dev" with the Bloodshed Dev C++ IDE.

## QUICK-START TUTORIAL

This section provides a quick introduction to the steps required to undertake a MW-SINMAP analysis. Each of these procedures is explained in more detail in the next paragraph. Sample data files should be provided with the software package for use with the tutorial. The file *sample.asc* is a small ASCII file of DEM data, and the files *samplels.shp*, *samplels.shx*, and *samplels.dbf* are a point shapefile of landslides. These files should be copied to a folder where you want the MW-SINMAP output files to be created.

1. Start up MapWindow GIS. Click on Plug-ins > MW-SINMAP. The MW-SINMAP menu should appear.

2. The MW-SINMAP menu is composed by three sub-menus: Initialization, Grid Processing and Stability Analysis. From the Initialization menu, choose 'Select DEM Grid for Analysis', and then navigate to and select the *sample.asc* grid.

3. From the Initialization menu choose 'Make Single Calibration Region Theme".

4. From the Initialization menu choose 'Select Landslide Point Theme'. Select the file *samplels.shp* in the file navigator box.

5. Under Grid Processing menu, select 'Compute All Steps' to create the pit-filled DEM, slope, flow direction, and specific catchment area grid themes.

6. Under "Stability Analysis" menu, select 'Stability Index and Saturation' to create the stability index and saturation grid themes and to create the SA Plot.

7. Under Stability Analysis menu, select 'SA-Plot' in order to view the calibration chart. Click on the Region 1 in the list box to see the calibration curve and punctual values (random points and landslides).

8. To view a statistical summary of the data, select "Export Statistics" in the "Stability Analysis" menu. Results are saved as a CSV file.

You have completed a MW-SINMAP study.

# DETAILED TUTORIAL

## Starting MapWindow GIS and Loading MW-SINMAP

Start MapWindow GIS within Windows using any of the methods available, like double clicking on an ICON, or file with extension '.mwprj', or by selecting it within Start/Programs in Windows. From the Plug-ins menu, select the MW-SINMAP (Figure 3 note the flag on the left).

The MW-SINMAP should appear in the menu tool bar. If no or error messages appear, please check for the installation procedure.

The MW-SINMAP main menu has three sub menus and a total of 15 items that provide for selecting, creating, and modifying the data used in a terrain stability mapping study.

These menu items are divided into three (3) groups on the menu, with groups distinguished by main menus on the tool bar (see Figure 4, Figure 5 and Figure 6). A study is undertaken by selecting menu items at the top of the menu and working downward within the main menu. Menu items are always enabled but that doesn't mean that they are operative.

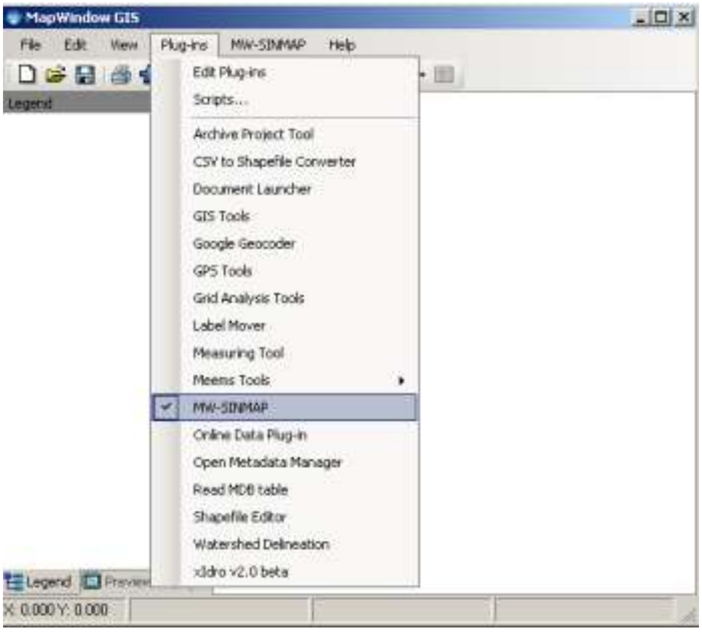


**Figure 3. MW-SINMAP plug-in is correctly installed in MapWindow GIS. If checked, a new menu should appear in the menu bar.**


**Figure 4. Initialization sub-menu: provides customization function.**

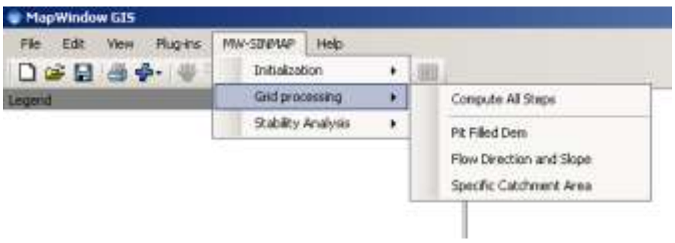


**Figure 5. Grid processing sub-menu: provides hydrological and morphological analysis functions.**


**Figure 6. Stability Analysis sub-menu: provides stability index calculation functions and report constructor.**

## Establishing Model Parameters

The first two items on the MW-SINMAP menu provide access to dialog boxes for establishing various program parameters. Default values are provided for all parameters, so it is not required for a user to input parameter values. However, calibration region parameters will need to be modified by the user to provide realistic values for the user's study area. The user may come back and modify these values at a later time while conducting the study. Other means are also provided within the program (described later) for more easily modifying most of these values 'on the fly' during the calibration process.

From the MW-SINMAP Initialization menu (Figure 4), choose the "Set Defaults" menu item. Selecting the 'Set Defaults' menu item displays a dialog box allowing input of several fundamental physical parameter values and modification of a SA Plot display setting (Figure 7 - left).

Values changeable in this dialog box are:

- **Gravity constant**. Default value: 9.81m/s$^2$.
- **Water density**. Default value: 1000 kg/m$^3$.
- **Number of points in a SA Plot**. Default value: 2000.
- **SA Plot Lower wetness index**. Default value: 10 %.

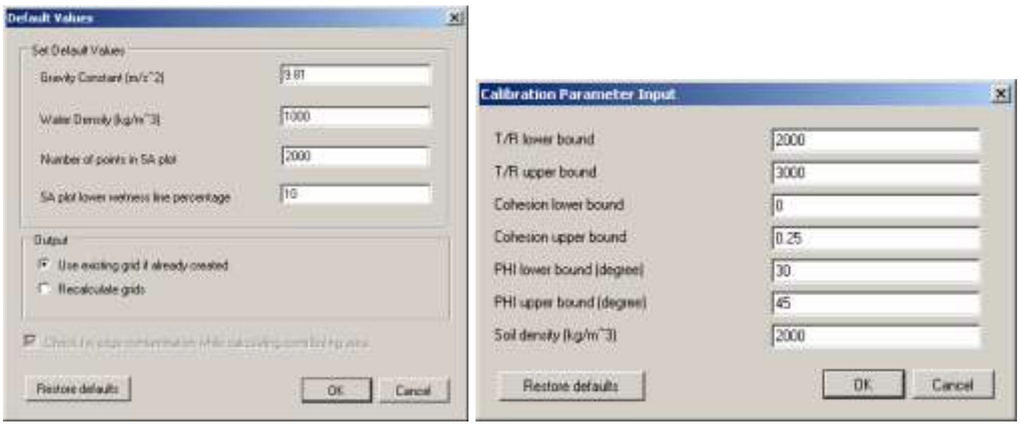


**Figure 7. Default Values form (left) and Calibration Parameter default (right).**

Two radio buttons give options for the grid processing operation. The first radio button enables the possibility to use existing grid if already exist (this option is enable for Grid Processing function only). The second radio button enables grid overwriting if they exist. If this last option is choose, the "checks for edge contamination" check box is available (by default is enabled).

The SA Plot displays all study area landslide points on a slope-area plot, but only a limited number of grid cells are normally displayed in order to speed computations and make a less cumbersome graph. (Remember, a 500 by 500 DEM grid has 250,000 cells, which is a lot of points to display on an x-y graph.) The number of cells displayed in the plot is approximate.

From the Initialization menu on the MW-SINMAP menu, choose the Set Calibration Parameters menu item.

Selecting the 'Set Calibration Parameters' menu item displays a dialog box that allows input of several soil parameters and modification of a SA Plot display setting (Figure 7 - right). Values changeable in the calibration parameter input dialog box are:

- **T/R (lower bound)**. Default value: 2000 m. This is the lower bounding value for the ratio of transmissivity to the effective recharge rate.
- **T/R (upper bound)**. Default value: 3000 m. This is the upper bounding value for the ratio of transmissivity to the effective recharge rate.
- **Dimensionless Cohesion (lower bound)**. Default value: 0.0. This is the lower bounding value that takes into account both root and soil cohesion.
- **Dimensionless Cohesion (upper bound)**. Default value: 0.25. This is the upper bounding value that takes into account both root and soil cohesion.
- **Phi [degrees] (lower bound)**. Default value: 30°. This is the lower bounding value of the soil friction angle.
- **Phi [degrees] (upper bound)**. Default value: 45°. This is the upper bounding value of the soil friction angle.
- **Soil Density**. Default value: 2000 $kg/m^3$.

## Selecting DEM Data

Using a DEM in MW-SINMAP requires two steps: 1) obtaining or creating a grid of DEM data, and 2) selecting that grid for the SINMAP analysis.

MW-SINMAP works only on raster elevation data format. Commonly, public institutional services provide elevation data both in vector and raster format. If you start from vector type data, you need to transform it into raster format by an interpolation method. At the moment, MapWindow GIS doesn't provide a complete set of interpolation tools but there are many free or commercial software to do that. TIN and TOPOGRID method are recommended by the Authors of the original SINMAP project.

This version of MW-SINMAP can manage ASCII grid data type only so other file format must be converted to the first one. Use for example the MapWindow conversion tool under "GIS Tools" plugin > Raster > Change Grid Format. MapWindow can directly load ASCII grid format so you have not to import it.

After the DEM grid is created, the next step is to select the grid for SINMAP analysis. From the Initialization menu on the MW-SINMAP menu, choose "Select DEM Grid for Analysis".


**Figure 8. Select DEM grid mask. The button at the top of the form opens the file browser. Note that all output grids are clearly visible and changeable.**

Choosing the 'Select DEM Grid for Analysis' menu item will display an input mask with several text box. On the right side of the first text box, a button opens the file selection dialog box. The user navigates through the drives and directories to locate the desired DEM grid and chooses OPEN. The selected DEM grid name is added to the mask and also all the other box are filled with the name of the resultant grids. Note that MW-SINMAP use this name as reference to.

After pressing OK in the input mask, the DEM is loaded as s grid theme to the map view of MapWindow GIS and it is automatically renamed to 'Base DEM Grid' (Figure 9) in the Table Of Contents (TOC). A Greens to White color scheme is used. This color scheme can be changed at any time without affecting the operation of MW-SINMAP.

MW-SINMAP uses the name stored in the "Select DEM grid" mask to create, load and analyze results and not the name in the TOC as the original version. So you can change the layer name in the TOC without particular limitations and you can change also the name in the "Select DEM Grid" mask if you wish to recalculate or use a grid from somewhere else.

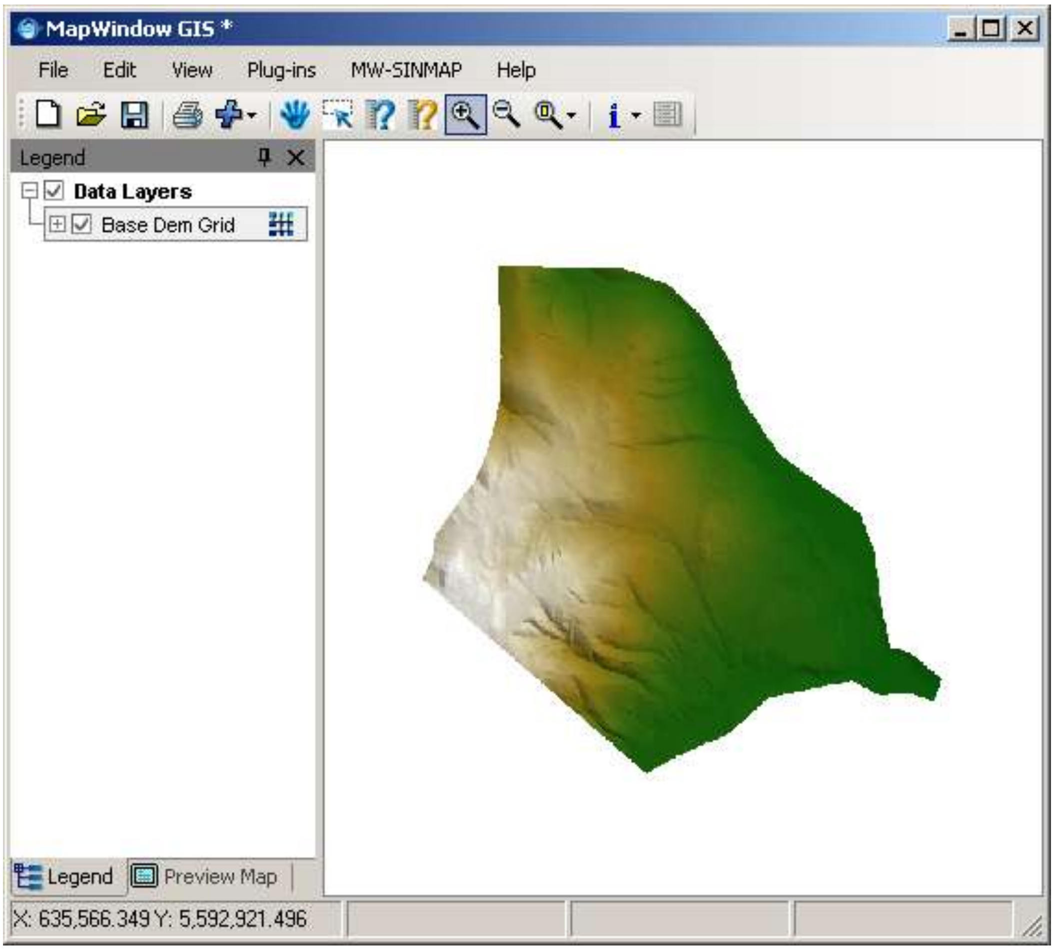


**Figure 9. The base DEM grid correctly loaded in the MapWindow GIS view.**

By default, the name of the selected DEM is used as the base name for all files created during the study. Therefore, if the selected DEM is named *sample.asc*, then names of files created during the study would have names like *samplecal.dbf* and *samplefel.asc*. By default, all of the files created by MW-SINMAP during the study will be located in the folder containing the original DEM grid. It may be useful to create a specific folder for each study where input data files and MW-SINMAP-generated files are stored. This is not a program requirement because the DEM base name identifies files associated with a study, but it is better housekeeping.

## Creating the Calibration Regions Grid Theme

Calibration regions are areas within which single lower bound and upper bound calibration parameters values can represent T/R, dimensionless cohesion, and friction angle (phi). Soil density (rho) may also be specified for each calibration region, although lower and upper bounds are not used. Regions are commonly defined using soils, geologic, vegetation, and land use mapping to identify areas having consistent calibration parameters. For a MW-SINMAP analysis to provide a realistic assessment of terrain stability, the user should understand SINMAP theory and the factors causing the spatial distribution of the calibration parameters.

There are three menu items that may be chosen to create a calibration regions grid (Figure 4). The choice is dependent upon the type of geographic data available and the level of analysis sought.

**Option 1**: From the SINMAP Initialization menu, choose Make Single Calibration Region Theme.

This method create a new shape file called e.g. "*samplecal.shp*" that stores the default values of the calibration parameters. The geometry representation of the calibration region is a simple rectangle; the unique region is called 'Region 1'. The calibration regions grid theme "*samplecal.asc*" is created also with it.

**Option 2**: From the SINMAP Initialization menu, choose Create Multi-Region Calibration Theme.

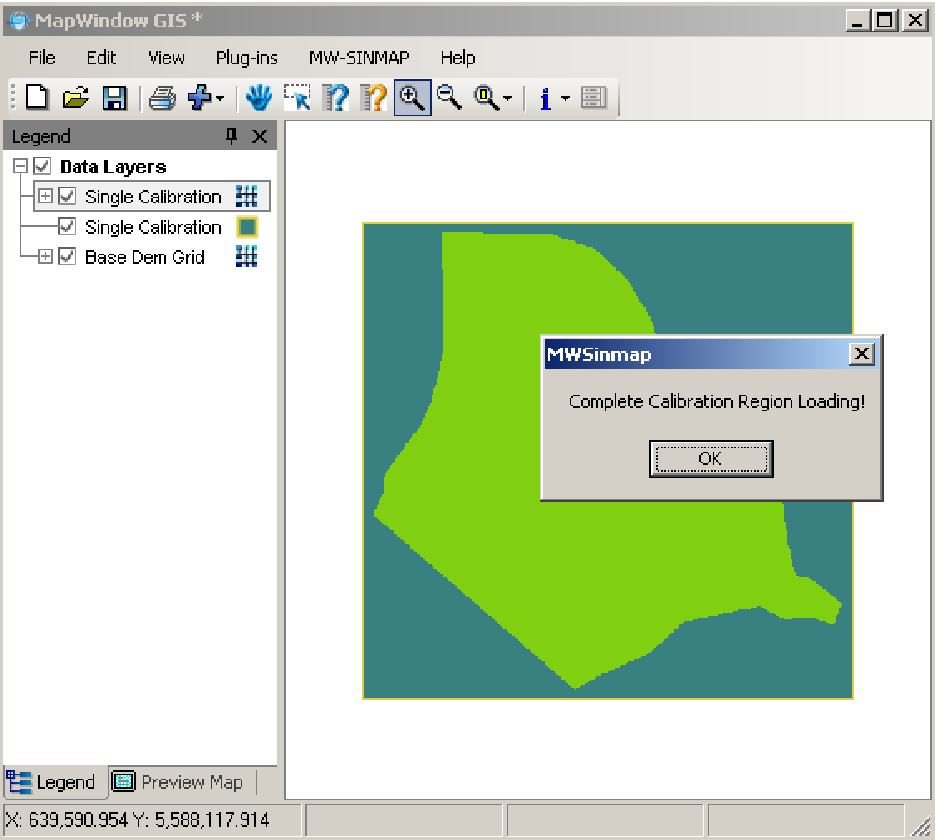


**Figure 10. After creating the (single) calibration region a new grid and a new shapefile are added to the view. Note the message that confirms that calibration parameters are loaded.**

This method can be used if you have a polygon layer (shapefile) of calibration regions. Selection of this menu item pops up a file navigation dialog box that allows you to pick a polygon feature theme. Note that the polygon shapefile must have a numeric field named "Region" in the data table (.DBF file) in order to work correctly. The program looks for parameter fields in the DBF file and if they don't exist, they will be created with default values. Shapefile is then converted to raster format of calibration regions.

**Option 3**: From the SINMAP Initialization menu, choose Use Existing Calibration Region Grid.

This item will add any existing calibration regions shapefile and grid. If you have previously created a calibration regions grid and wish to continue using it, this is the selection to choose.

In all cases, a message with the text "Complete Calibration Region Loading" appears and means that all calibration data are available for the following analysis.

## Adding Landslides to the View

A landslide point theme (shapefile) may be added to the MW-SINMAP study to allow evaluation of conditions where landsliding has occurred. At the moment, there is no classification of the landslide types (that differs from original SINMAP project).

From the SINMAP Initialization menu, choose Select Landslide Point Theme. A file navigation dialog box is presented from which the landslide theme shapefile can be selected.

## Preparatory Grid Processing

A major part of a MW-SINMAP study is the creation of several derivative grids from the DEM grid. These grids are derived solely from the DEM grid and require no other parameters for their construction. The processes for creating these several grids are initiated by selecting menu items in the second sub-menu of the MW-SINMAP main menu. The grids and associated grid themes that are created by the grid processing steps are:

- Pit-Filled DEM
- Flow Direction
- Slope
- Contributing Area

**Option 1**: From the MW-SINMAP Grid Processing menu, choose Compute All Steps.

'Compute all steps' sequentially executes routines for generating the pit-filled, slope, flow direction, and contributing area grids and adds these grids to the MapWindow view. A shell screen should appear for three times. According to the general option sets, if any of the four grid files already exist, having been previously generated, they will be overwritten or load directly without any sort of modifications. In the last case no shell window should appear.

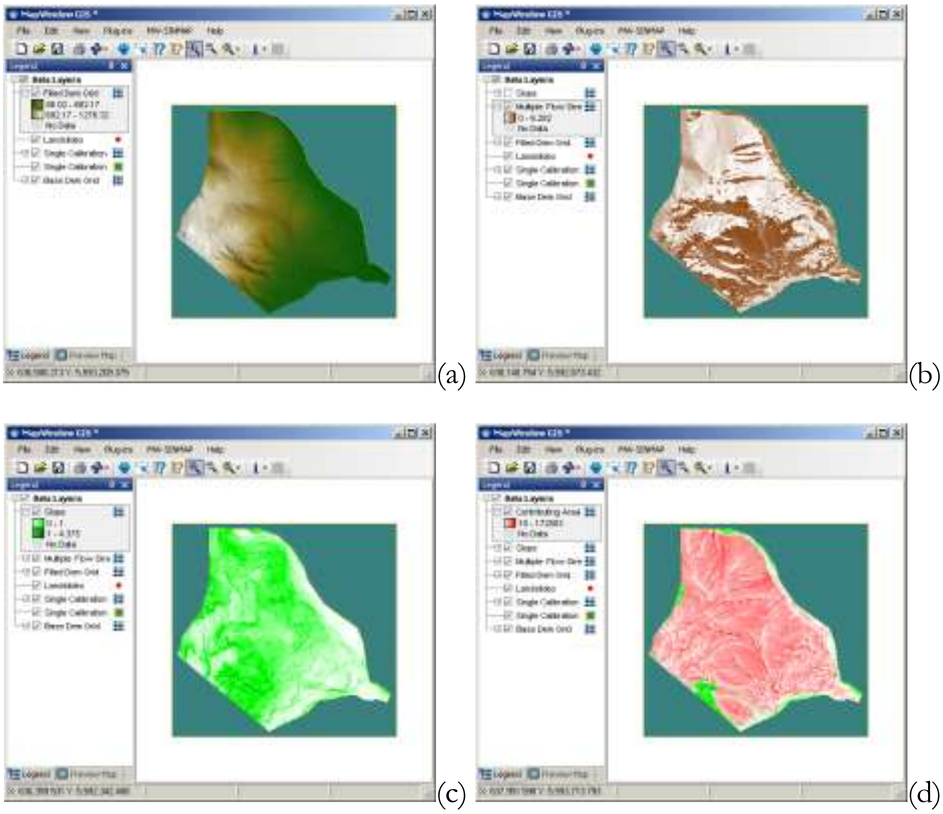


**Figure 11. grid processing steps in four pictures: a) pit filling b) flow direction c) slope and d) accumulation area.**

**Option 2**: From the MW-SINMAP Grid Processing sub-menu, choose each processing step separately by first choosing Pit-Filled DEM.

This selection generates the pit-filled DEM grid and adds the grid theme 'Pit-filled DEM' to the map view. By default, the grid file generated will have the name like *samplefel.asc*. Overwriting rule are still valid as before.

From the MW-SINMAP Grid Processing sub-menu, choose Flow Direction and Slope as the next step.

Choosing this selection causes generation of the flow direction and slope grids, with grid themes of the same names added to the view. By default, the grid files generated will have the names *sampleang.asc* (flow direction) and *sampleslp.asc* (slope). Overwriting rule are still valid as before.

From the MW-SINMAP Grid Processing sub-menu, choose Contributing Area as the final step.

This selection generates the contributing area grid and adds it to the view. The grid file generated will have the name *samplesca.asc*. Overwriting rule are still valid as before.

## Stability Analysis

SINMAP theory discussed in Part I of the user manual of the original project is implemented within the MW-SINMAP program with results displayed as saturation and stability index grid themes and the creation of an SA Plot. These results are generated using menu items in the Stability Analysis menu item group.

From the MW-SINMAP Stability Analysis menu choose "Stability Index and Saturation".

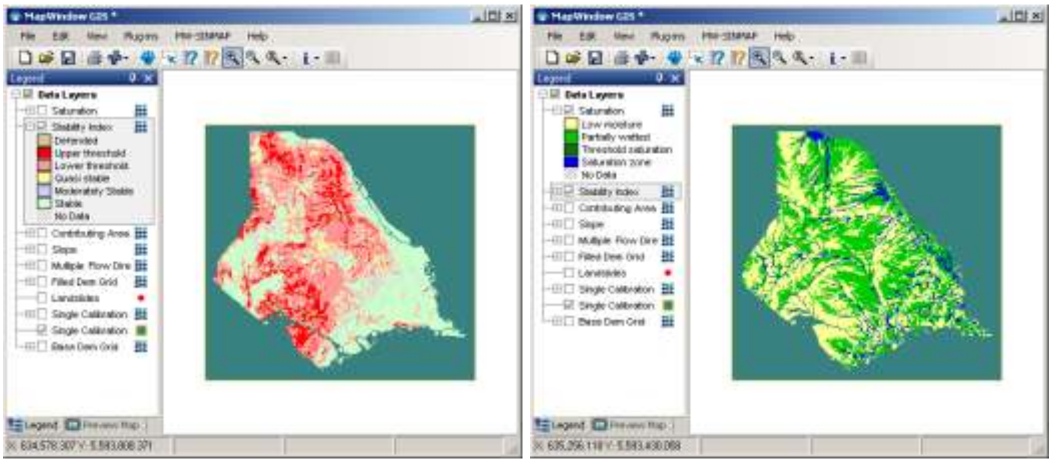

**Figure 12. Stability Index map (left) and Saturation area (right).**

This selection generates two resultant grids: one with a stability index at each grid cell location and the other with the saturation value of each cell (Figure 12).

By default, the Stability Index grid is named e.g. *samplesi.asc*. The file is always overwritten each time that this menu item is pressed. Note the console window starting again. The saturation grid file is then called *samplesat.asc*. The file is always overwritten each time that this menu item is pressed. All the resultant grids are added to the view and if they are already loaded, the view is updated to the new condition.

This version of MW-SINMAP generates a temporary file named "tempsinmapfile.txt" in the same directory of the base grid. This file is necessary to pass to the executable the calibration parameter as text file format.

From the SINMAP Stability Analysis menu, choose SA Plot as the final step.

The SA Plot menu item creates a slope-area plot window (Figure 13). Random point series is generated each time that SA-plot is loaded and on-the-fly when a specific calibration region is chosen, accordingly to the number of points set in the default window (by default 2000). Random point are represented by a small black asterisk. No other file are created.

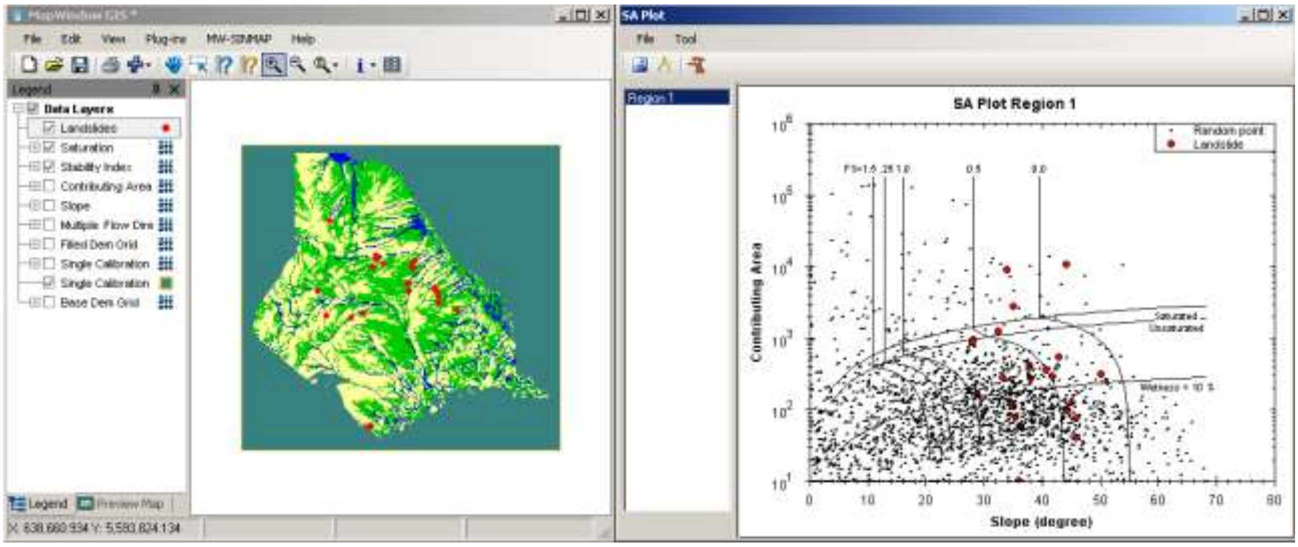


**Figure 13. SA plot compare to MapWindow view.**

Landslide points are loaded each time from the landslide shapefile and plotted as red circular point.

## Calibration Methods

**Option 1**: Adjusting parameters in the DEM view

From the MW-SINMAP Stability Analysis menu, choose “Calibration Parameter Adjust”.

Choosing this selection activates the study’s calibration regions table making it available for the modification of calibration region parameters. Then choose a calibration region from the list box and parameters set for these region will be loaded.

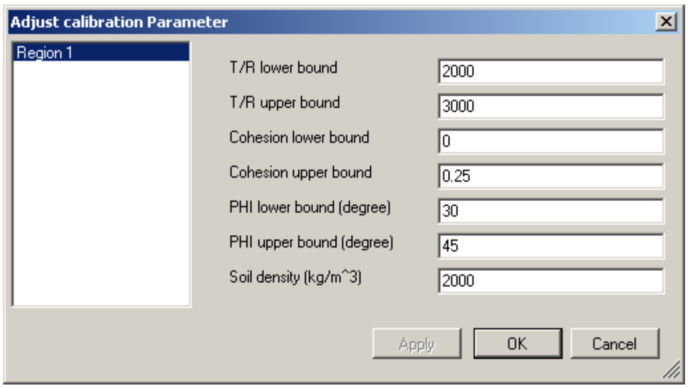


**Figure 14. Adjust Calibration Parameter form. When called from SA plot, only current region is available in the list box on the left, otherwise (calling from the plug-in menu) all the regions are listed.**

After the editing of parameter values are completed, save it with the apply button (new values will be stored in dbf file associated with the shapefile) and then click on the OK button in order to recalculate both Stability Index and Saturation grid. The existing Stability Index and Saturation layers in the view will be updated consequently.

**Option 2**: Adjusting parameters in the SA plot

In the SA Plot, choose the Calibration Parameter Adjustment from the tool menu or press the caliper button. The Adjust Calibration Parameter form will appear as before but the list box on the left shows the current region only (the region loaded in the SA-plot). Then choose Apply to save the modifications and OK to update grids and SA-plot (Figure 14).

A typical work flow sequence would be to iteratively modify calibration region parameters until the stability and saturation lines "fit" the data for a specific region.

Parameters for each region can thereby be adjusted to eventually calibrate the whole study area.

## Statistical Summary

Statistics report can be generated by pressing on "Export Statistics" menu item in the Stability Analysis sub-menu. This function will generate a Comma-Separate Values file type (.CSV) that can be open with every kind of text processor or spreadsheet software.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | MW-SINMAP Stability Index Software for Mapwindow GIS | | | | | | | |
| 2 | Based on the original package version 1.0 3/30/98 | | | | | | | |
| 3 | See http://www.engineering.usu.edu/dtarb/sinmap.html for further informations | | | | | | | |
| 4 | This version is provided by Enrico A. Chiaradia - University of Milan | | | | | | | |
| 5 | e-mail: | enrico.chiaradia@unimi.it | | | | | | |
| 6 | | | | | | | | |
| 7 | | Stable | Moderately Stable | Quasi-stable | Lower Threshold | Upper Threshold | Defended | Total |
| 8 | Region 1 | | | | | | | |
| 9 | Area [km^2] | 2.75 | 0.71 | 1.173 | 3.491 | 1.174 | 0.258 | 9.556 |
| 10 | % of Region | 28.773 | 7.433 | 12.273 | 36.537 | 12.287 | 2.697 | 100 |
| 11 | #Landslides | 0 | 0 | 0 | 11 | 10 | 1 | 22 |
| 12 | % of slides | 0 | 0 | 0 | 50 | 45.455 | 4.545 | 100 |
| 13 | LS Density [#/km^2] | 0 | 0 | 0 | 3.151 | 8.516 | 3.88 | 2.302 |
| 14 | | | | | | | | |

**Figure 15. Statistical analysis report. For each region, the area and the landslide density is evaluated for each stability classes.**

The generated file contains information about the area divided in stability classes and the number or density of landslide events, each for every regions of calibration.

Figure 15 shows an example of statistical data.

## The Rex Tool

Like the original version, also MW-SINMAP implements a tool to connect the SA-plot with the map view. This tool is called Rex Tool and it is represented by a dog figure (Rex) as icon in the SA-Plot. Press on it and then in the chart area over a landslide symbol. Automatically, the map view should be zoomed to the selected landslide and a message box should report the key number of the landslide; the key number is the primitive numeration in the point shapefile). Click again on the Rex Tool in order to disable this function.

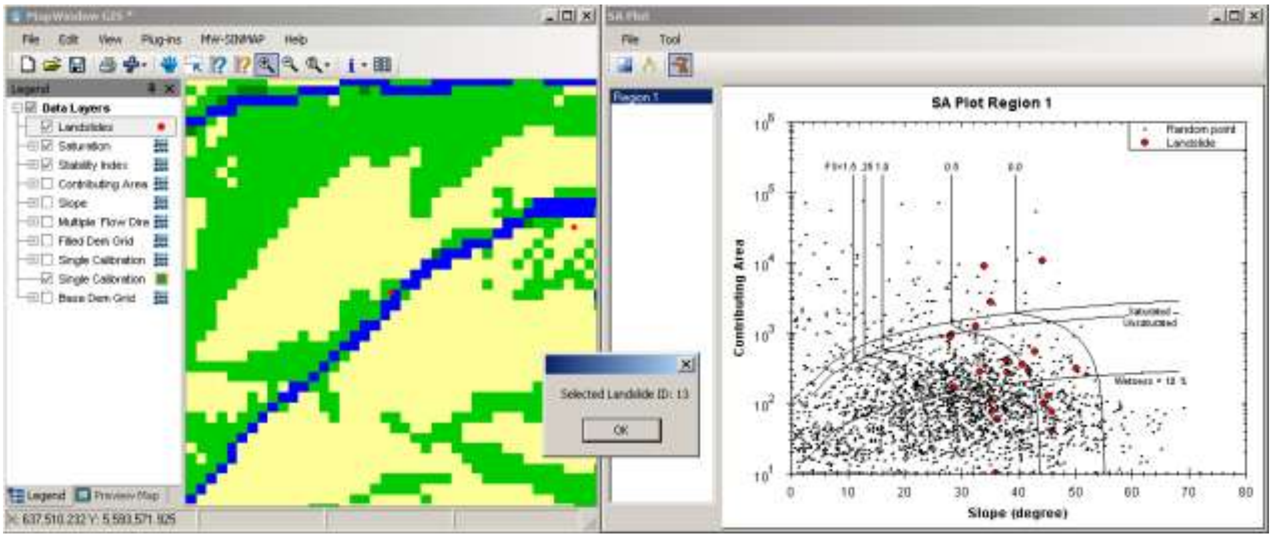


**Figure 16. Rex tool in action: note the dog icon on the right still pressed, the message box in the centre with the number of the landslide and the view zoomed and centered to the selected point.**

## HOW TO USE THE SINMAP.EXE PROGRAM DIRECTLY

If you don't want to install MapWindow GIS or you encounter problem in the use of the plug-in, you have the possibility to run the sinmap.exe program directly from the console.

In the console window, go to the directory that contains the executable file and type sinmap.exe.

The screen shown in Figure 17 should appear. Note that no modeling function starts but there are some indications about the usage of the program.

In general, if you want to start a function analysis, you must type the name of the function (e.g., area) after sinmap.exe command and all the requested parameters that are commonly the name of the input and output grid file name.

Available function are listed in Table 2.

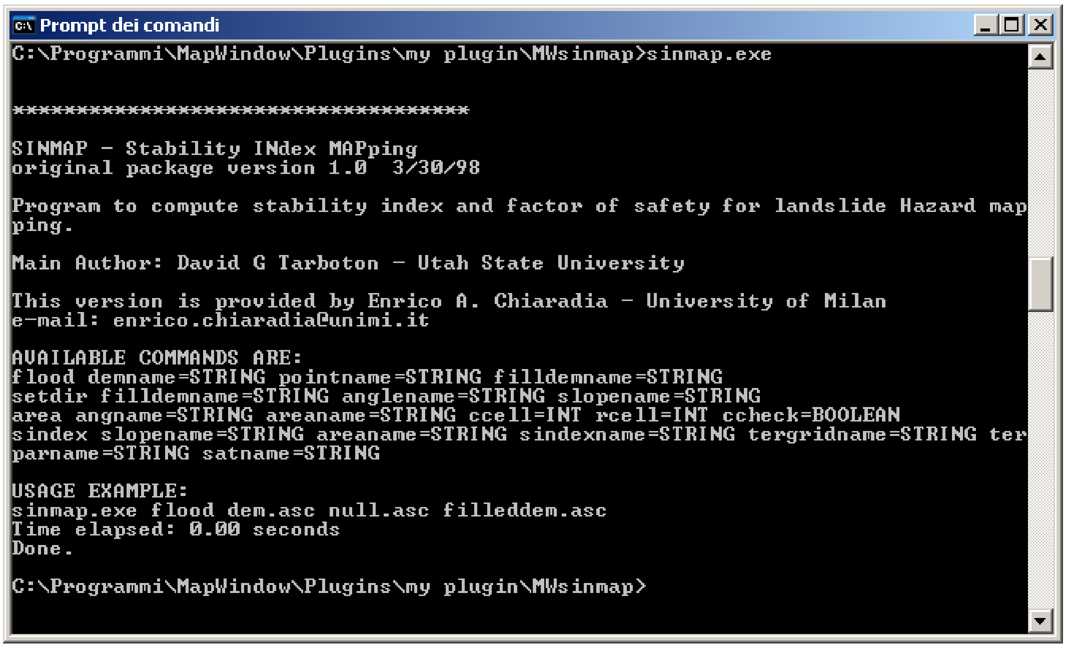


**Figure 17. Example of sinmap.exe file running from console.**

**Table 2. Complete list of available command line options and request parameters.**

| Command | Parameter | Description |
|---|---|---|
| flood | <STRING> *demname*<br><STRING> *pointname*<br><STRING> *filldemname* | Performs pit filling algorithm. *demname* is the base DEM grid; *pointname* is the name of a grid of identified sink, *filldemname* is the output filled DEM |
| setdir | <STRING> *filldemname*<br><STRING> *anglename*<br><STRING> *slopename* | Determines the flow direction (Dinf method), *anglename*, and the slope distribution, *slopename*, of a filled DEM, *filldemname* |
| area | <STRING> *angname*<br><STRING> *areaname*<br><INT> *ccell*<br><INT> *rcell*<br><BOOLEAN> *ccheck* | Determines the flow accumulation area, *areaname*, respect to a point of coordinates *ccell* and *rcell* (matrix references) and a flow direction grid (*angname*). Set *ccell* and *rcell* equal to zero in order to compute all the DEM extension. Set *ccheck* to 1 (or TRUE) to verify edges contamination. |
| sindex | <STRING> *slopename*<br><STRING> *areaname*<br><STRING> *sindexname*<br><STRING> *tergridname*<br><STRING> *terparname*<br><STRING> *satname* | Performs stability index evaluation for each cell in the calibration regions grid, *tergridname*. Requires the slope map, *slopename*, the flow accumulation map, *areaname*, the parameters table, *terparname*, and returns as output the stability index map, *sindexname*, and the saturation map, *satname*. |

Note that you have to prepare the input file in the way request by the program. Grid data are stored in standard ASCII ArcInfo file format. Shapefile are not required (they are used in MapWindow plug-in only!) but a text file with the calibration parameter for each region is absolutely necessary.

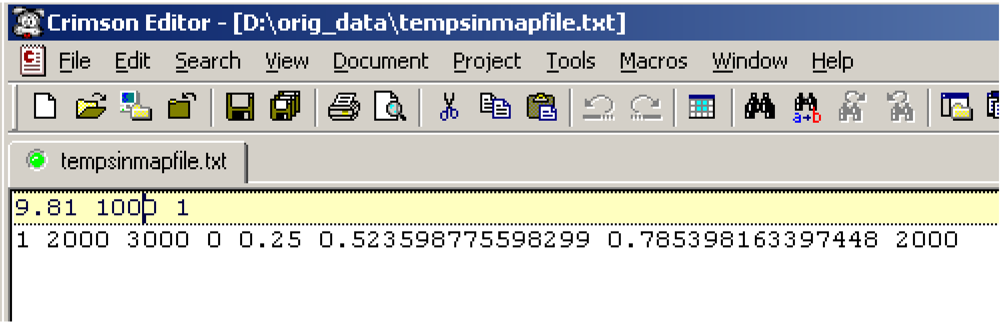


**Figure 18. Calibration parameters text file example.**

This .TXT file should have the structure as shown in Figure 18 and contain these ordered elements:

First line:

1) gravity acceleration constant 2) water density 3) dummy parameter (not used in the original code, set to 1).

Second and following lines (according to the number of calibration regions):

1) region ID 2) R/T min 3) R/T max 4) C min 5) C max 6) PHI min 7) PHI max 8) soil density.

All values must be separate by a blank space. PHI values are expressed in radians!

## KNOWN ISSUES

**Input file type**: currently, MW-SINMAP is tested with ASCII grid only. Grid file header should be similar to this:

```
ncols        200
nrows         189
xllcorner     1534460
yllcorner     5082500
cellsize      40
NODATA_value  -9999
676 675 663 625 579 569 566 564 564 … … … (other values)
```

In particular "DX" and "DY" tag are not recognized. Please change them with "cellsize" instead. Use capital letter or small letter only!

**Problem with point and comma as decimal separator:** for non English users, please set the decimal separator to point in the general settings of the operating system.

**Testing procedure**: MW-SINMAP results from sample data were compared with original SINMAP v1 and Watershed Delineation plug-in for MapWindow. Small differences between output may happen. In particular:

1) pit filled dem:

MW-SINMAP vs SINMAP v1.0 → same result

MW-SINMAP vs Watershed Delineation Plug-in → same result

2) flow direction:

MW-SINMAP vs SINMAP v1.0 → same result

MW-SINMAP vs Watershed Delineation Plug-in → very small differences (< E-06)

3) slope:

MW-SINMAP vs SINMAP v1.0 → same result

MW-SINMAP vs Watershed Delineation Plug-in → very small differences (< E-05)

4) catchment area:

MW-SINMAP vs SINMAP v1.0 → differences in areas in "edge contamination" delimitation. When calculated, catchment area values are equal.

MW-SINMAP vs Watershed Delineation Plug-in → localized small differences (< 0.01)

5) stability index:

MW-SINMAP vs SINMAP v1.0 → differences in areas due to "catchment area delimitation". When calculated, stability index values are equal.

6) saturation:

MW-SINMAP vs SINMAP v1.0 → differences in areas due to "catchment area delimitation". When calculated, saturation values are equal.

7) SA plot:

MW-SINMAP vs SINMAP v1.0 → differences in wetness line (wl). In SINMAP v1.0, wl seems to be lower than in MW-SINMAP. The function that generates the wl in MW-SINMAP derives from SINMAP v2.0 and return values coherent with the meaning of the line graph (wl is a percentage of the saturation line).

8) statistical results:

MW-SINMAP vs SINMAP v1.0 → Consistent with stability index map.

## FUTURE DEVELOPMENTS

In the future version of MW-SINMAP there will be:

1) minor functionalities added and minor bug fixed;

2) translation of the current C code in C# language. That should increase the maintenance of the project and make a deeper integration with MapWindow GIS (e.g., the use of all the supported grid file format);

3) the development of an alternative stability analysis way that is able to manage continuous spatially distributed data;

4) the integration of a database of vegetation types and related contribution effects on slope stability.

All kind of support and suggestions are welcome! Please contact the author at:

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