SLEEP

Soil-Landscape Estimation and Evaluation Program
For
ArcGIS 10.1

USER's GUIDE

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1. Introduction

1.1 Purpose of the Tool.

SLEEP tool helps the user to generate soil database that is necessary as an input to environmental models. The spatial distribution of soil attributes such as percentage silt, sand, clay, organic content and depth of soil profile varies from one point to another (both in lateral and vertical dimension). It is impractical to measure the soil attributes at each and every point on the earth surface. Spatial interpolation of the measured soil attribute is used to provide continuous representation of soil but there are some limitations owing to the non-uniform distribution of soils over an area. The idea behind SLEEP tool is to divide watershed or area into different zones or "facets" based on the average slope parameters and then derive a model for each facet relating the soil attributes to different terrain and environmental attributes. Further details are presented in (Ziadat et al., 2015).

SLEEP tool is created as a toolbox to facilitate and speed up the complex process involved in the objective explained above. So that many iterations can be carried out by simple mouse click.

1.2 Key Procedures

Load the ArcSWAT extension
Basic DEM processing
Facet Creation
Derivation of the Terrain Attributes
Facet Classification
Derivation of CTI, NDVI and SAVI images
Soil Attribute Regression
Soil Attribute Prediction (In Table and Raster Format)
(Optional) Use the Pedo-Transfer function to get other soil properties to use in the SWATmodel

1.3 References

- Ziadat F M, Dhanesh Y, Shoemate D, Srinivasan R, Narasimhan B, Tech J. Soil–Landscape Estimation and Evaluation Program (SLEEP) to predict spatial distribution of soil attributes for environmental modeling. Int J Agric & Biol Eng, 2015; 8(3), https://ijabe.org/index.php/ijabe/article/view/1270/pdf

- Ziadat, F.M. 2005. Analyzing digital terrain attributes to predict soil attributes for a relatively large area. Soil Sci. Soc. Am. J. 69: 1590–1599.
- Ziadat, F.M. 2007. Land suitability classification using different sources of information: soil maps and predicted soil attributes in Jordan. Geoderma, 140 (1-2): 73 - 80.
- Ziadat, F.M. 2010. Integrating statistical and visual approaches to predict soil depth from digital terrain data. Pedosphere 20(3): 361- 367.
- Mehammednur Seid, N, Yitaferu, B, Kibret, K, Ziadat, F. 2013. Soil-landscape modeling and remote sensing to provide spatial representation of soil attributes for an Ethiopian watershed. Applied and Environmental Soil Science, Volume 2013, Article ID 798094, 11 pages, http://dx.doi.org/10.1155/2013/798094.

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2. Installation

2.1 Software Requirements:

To run this SLEEP tool, ArcGIS 10.1 Service Pack 1 (ArcView license) or later versions of ArcGIS is needed . The Spatial Analyst extension and Arc Hydro Tools are required to run the models (Use default installation directories and note that there may be differences between versions that cause issues with the SLEEP toolset, so it is recommended to use the ArcHydro version compatible with the ArcGIS version installed in the machine, a copy of ArcHydro is provided for the ArcGIS 10.1 Service Pack 1 with the installation package).
The ArcHydro tools can be downloaded from the following link
http://downloads.esri.com/archydro/archydro/Setup/

2.2 Data Requirement

The input Data required to run the SLEEP tool are

1. Points Shape file of the soil measurement observations points (Containing the measured soil properties as attributes)
2. DEM (Digital Elevation Model)
3. Red band of the satellite image
4. Infra-red band of the satellite image
5. Other available and relevant auxiliary layers might be used to improve the prediction (Optional)

2.3 Data Projection:

Prior to setting up an ArcMap document, any initial input data should be examined to ensure that an equal area projection has been used consistently. This will be the projection of the map and all outputs.

2.4 Model Content

The steps included in this toolset can be used to process a DEM into various layers representing surface and hydrology attributes. In the final steps, all outputs from each step in the process and any additional inputs will be sampled by soil observation points and added to the output table. The output table will then be processed externally, and tables with regression intercepts and coefficients for soil attributes (such as soil depth and soil texture) will be used to create prediction maps for soil attributes. The models are listed in order of use below. **Before beginning, note the software requirements and projection recommendation.**

2.5 Folder Organization:

The Toolset is organized into four folders, which are found inside the folder named “SLEEP_TOOL” in your C: Directory (This can be seen after installation). The four folders are the ArcHydro Tools Installer folder, the Data folder, the Doc folder, and the Addin folder. The ArcHydro Tools Installer folder contains a recent version of ArcHydro Tools for ArcGIS 10.1 that can be used to consistently produce outputs without issues related to inconsistent software versions. The Data folder is where the example input and output data is stored. The Soil Attribute Prediction folder contains a regression tool as well as a sample input spreadsheet. The Addin folder contains the toolbox used in the following steps.

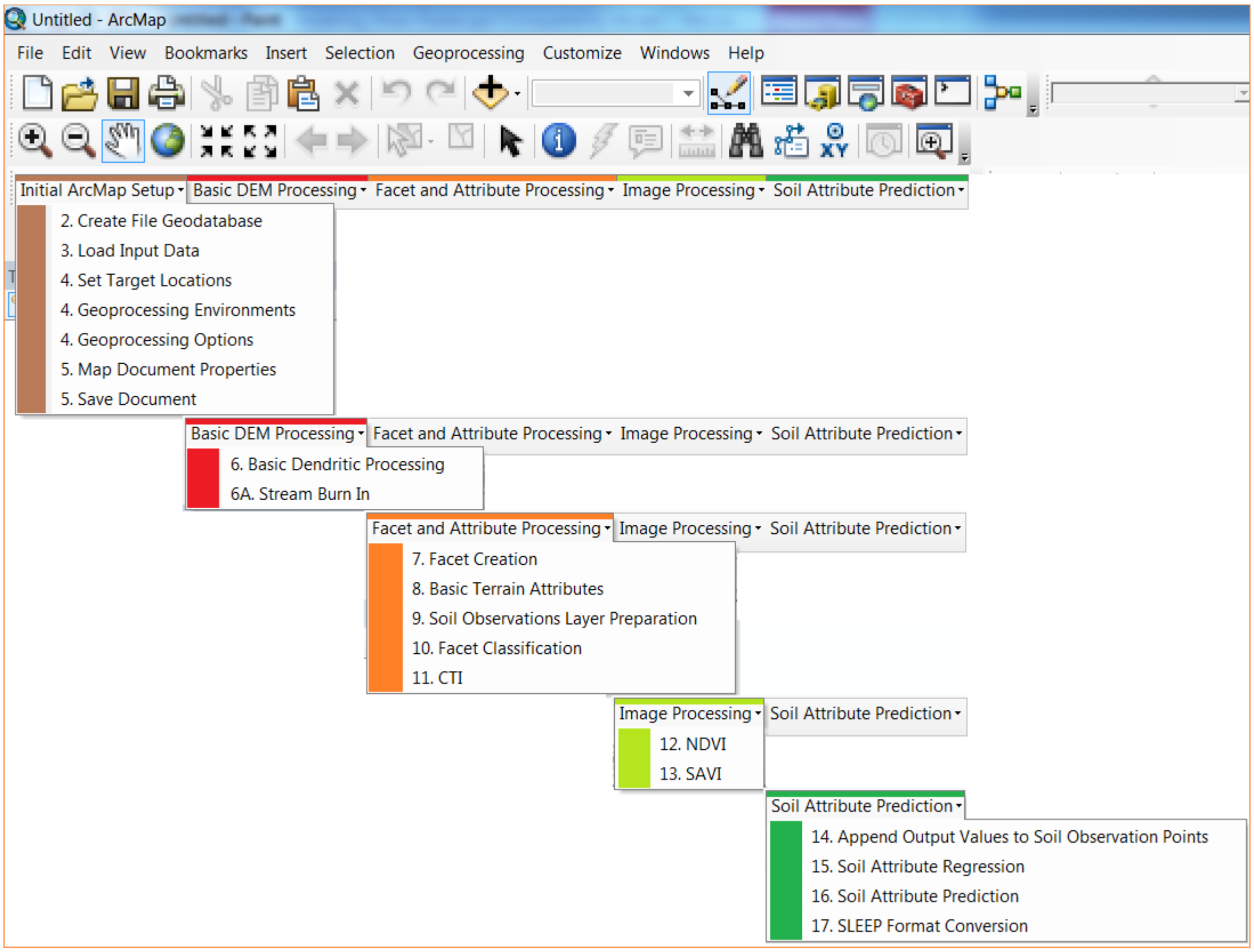
2.5 Example Input Data

The example input data stored inside the data folder. Please note this data is for the users to practice and get a feel for the model, this is not a real data and cannot be used for any publication. The shape file named “soil_measured” is the point shape file which contains the attributes of the measured soil data. “Srtm_dem” is the DEM raster file for that region. “red_band” and “Ir_band” is the raster file for the corresponding red and Infra- red band, respectively.

3. Tutorial

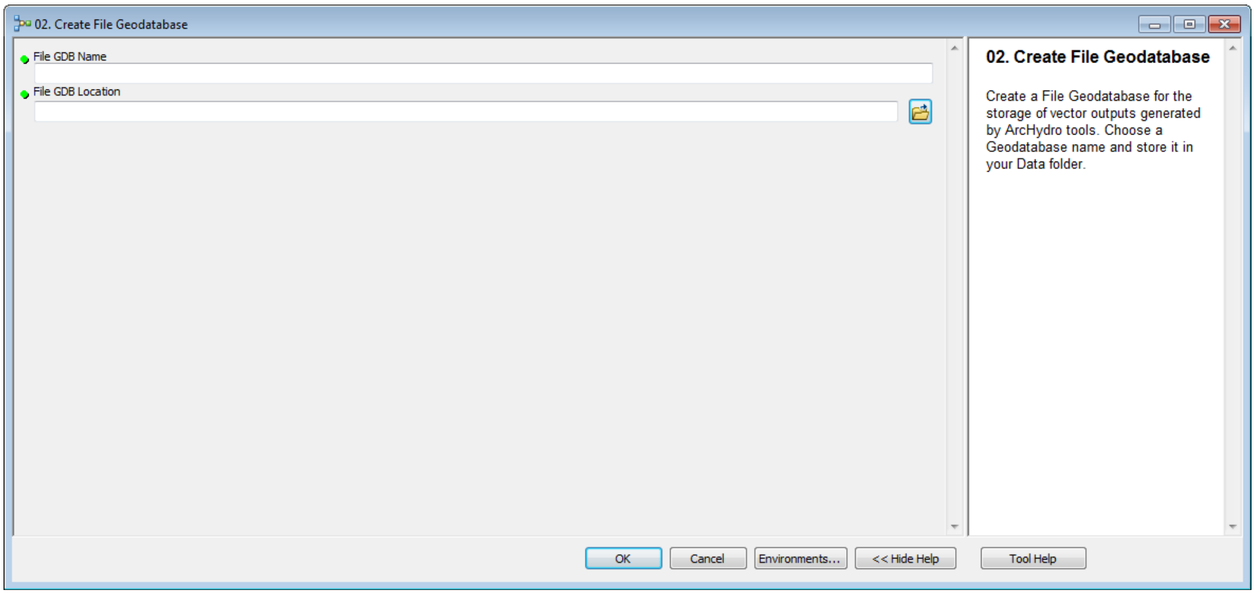
3. 1. Install Python Add-In and open new ArcMap Document

Open a new instance of ArcMap 10.1. . Do not save the ArcMap Document at this time. The Document will be saved in later step. When the tool is installed it looks like the figure below. (If it is not seen, Click '*Customize*', select '*Toolbars*' , then select '*SLEEP Tools*')



3.2. Initial ArcMap Setup -Create File Geodatabase

Before setting up workspaces, a new file geodatabase needs to be created to store feature data. Click on the "Create File Geodatabase" under the tab 'Initial ArcMap Setup'. Set the geodatabase location to any existing data folder (For this example the user can select C:\SLEEP_Tool\Toolset_10_1\Data\InputData. This is where the geodatabase will be placed) and select an appropriate name, perhaps the watershed name. Then Click Ok.



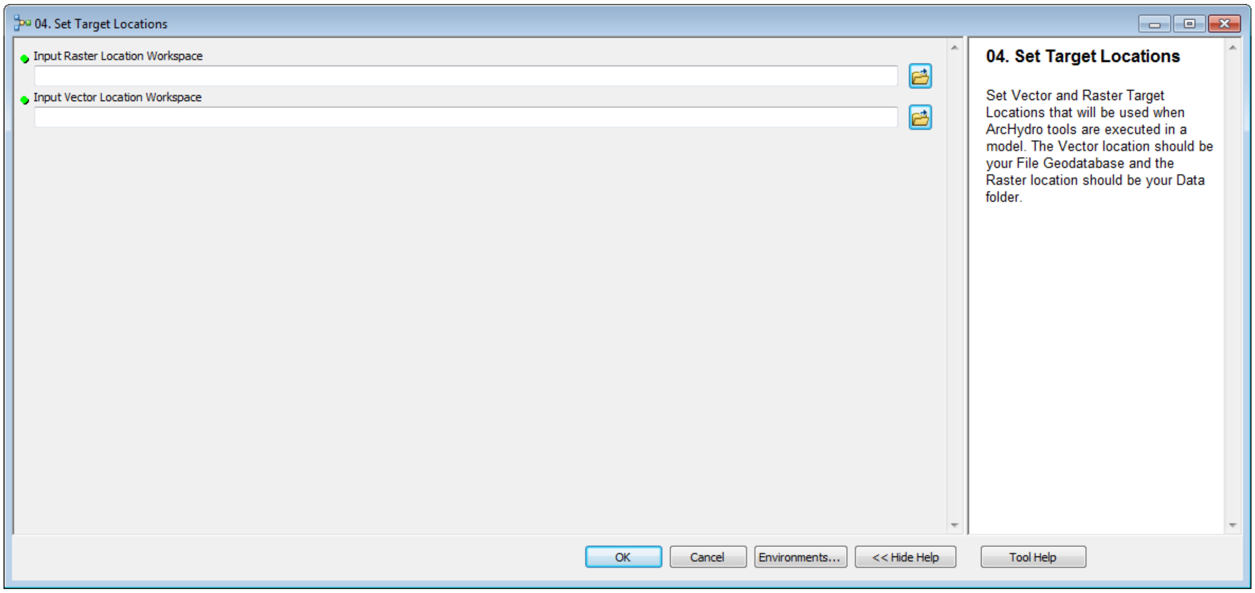
3.3. Load input data

Some of the tabs will have a 'I' mark before that, When the user clicks these menu nothing happens. The user has to manually make changes here. Now, add the input DEM to the ArcMap document (C:\SLEEP_Tool\Toolset_10_1\Data\InputData\srtm_subset2). This sets up the projection and extent of the map document.

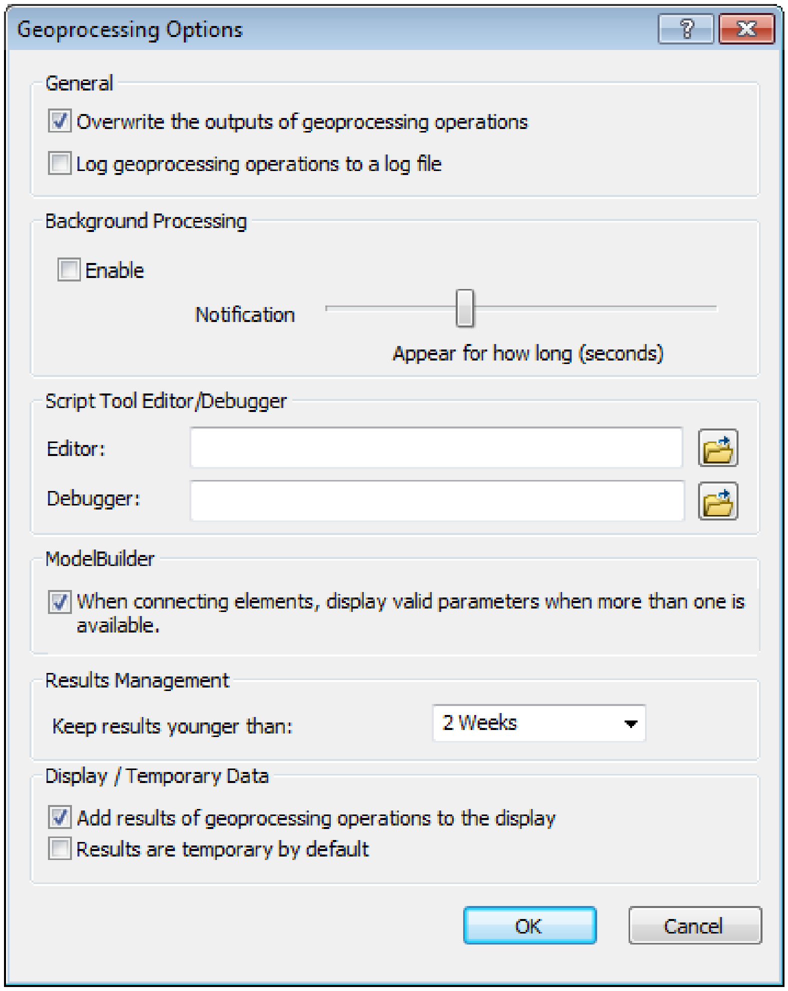
3.4. Set Target Locations, Geoprocessing Environments, and Geoprocessing settings

This step has to be manually done by the user. Before processing the DEM, the workspaces, target locations, and some additional settings need to be set.

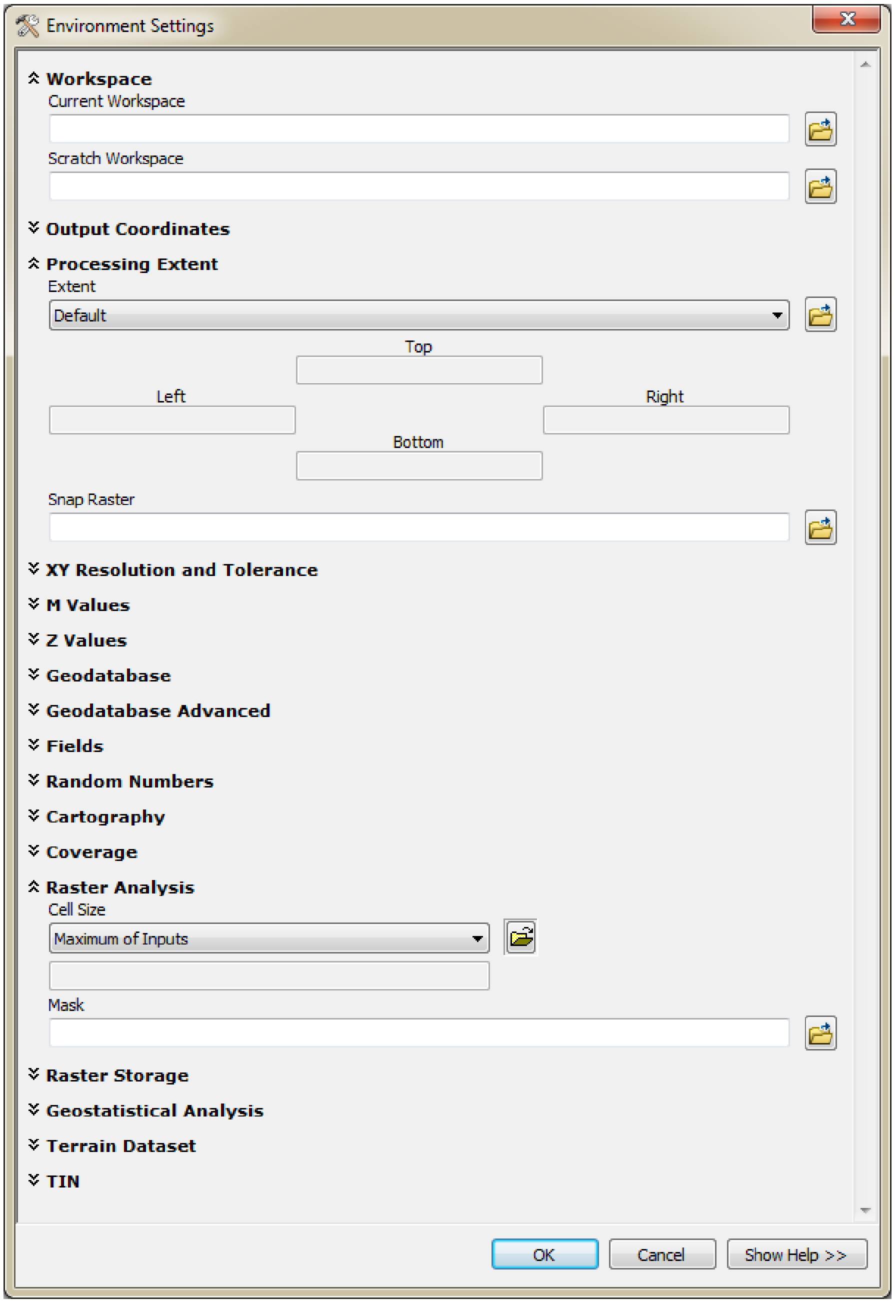
Expand the Initial ArcMap Setup toolbox and open "Set Target Locations". Select the existing "data" folder (*It could be any folder where you have stored your input dataset*) as the raster location and select the file geodatabase created in step 2 as the vector location, then click OK. (A file geodatabase must be selected as the vector target location).



To set the geoprocessing settings, click on *Geoprocessing* in the main toolbar then select *Geoprocessing Options*. In the geoprocessing tab, check the box next to "*Overwrite the outputs of geoprocessing operations*" (This is important when repeating a step and not changing output names). "Log geoprocessing operations to a log file" is optional. Check "Add results of geoprocessing operations to the display". Uncheck "Results are temporary by default", click OK.

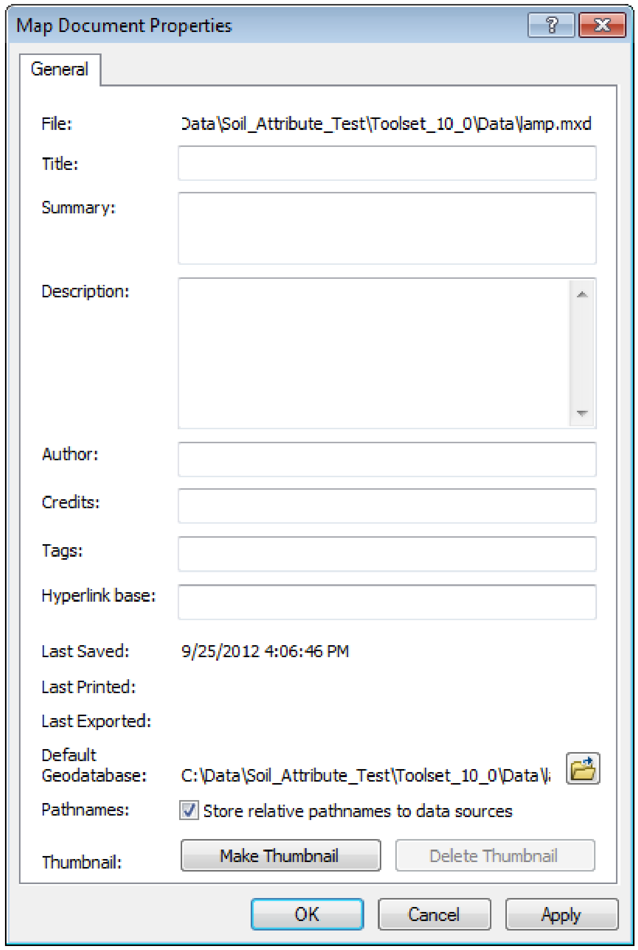


Next, click on the *Geoprocessing* menu again and select "*Environments…*" Expand the *Workspace* menu by clicking on the arrows to the left. Set both workspaces (current and scratch) to the data folder. Additionally, under the *Processing Extent* select your DEM (srtm_subset2) for the extent and snap raster and under Raster Analysis menus select your DEM for the cell size and mask. This is not entirely necessary, but should minimize the chance of issues in the output data. Then Click ok



3.5. Set Map Document Properties and Save ArcMap Document

Nothing happens if the user clicks this menu, this step has to be done manually. Open the *map document properties* from the *file menu* and check the box to the left of "*store relative pathnames to data sources*" (This is important in the event that the main folder is moved. Click Apply then Okay.



Now, any of the model operations run in this document will save non-intermediate outputs to the geodatabase or layers folder unless specified otherwise.

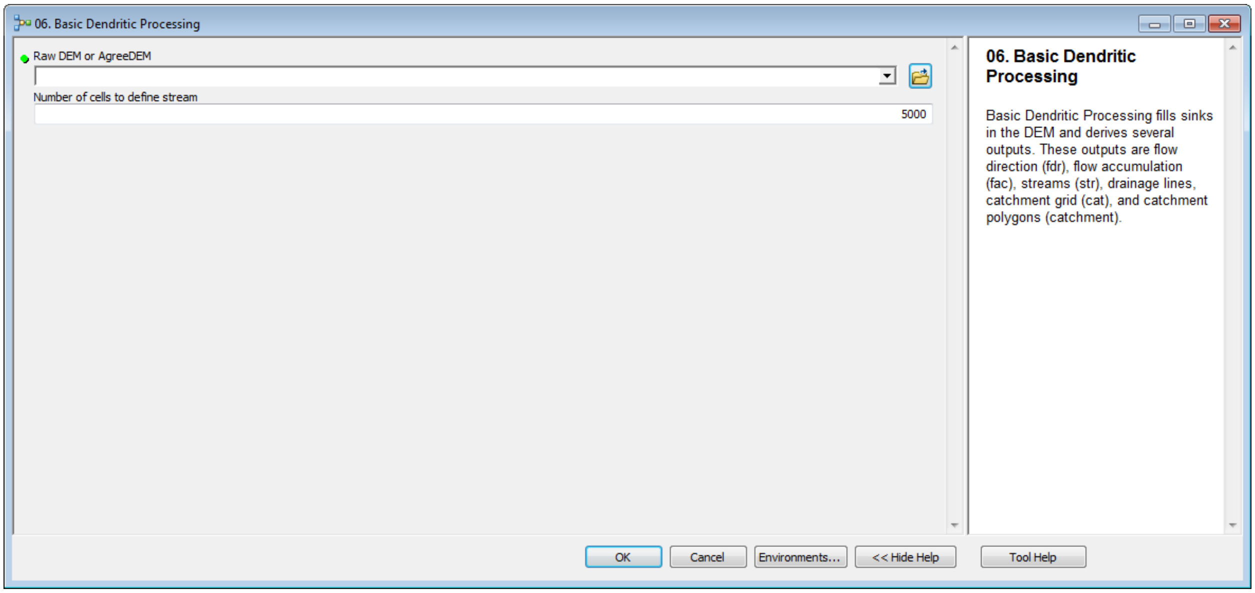
Save the map document.

3.5.2 Create Output Folders

Just click this menu. The output folders will be created.

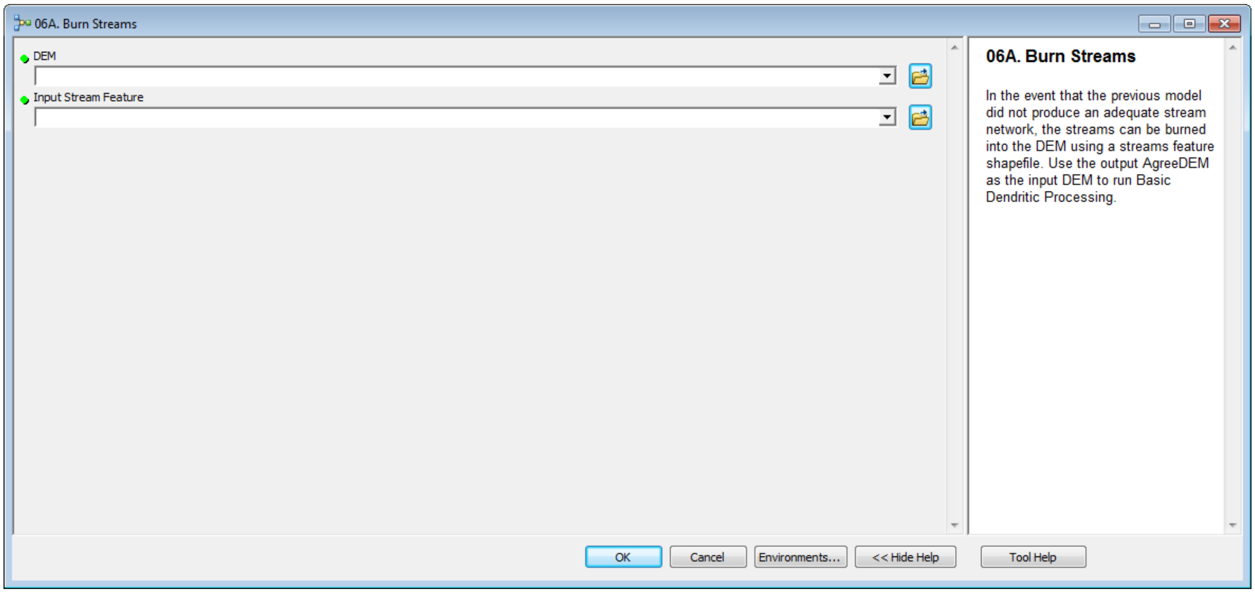
3.6. Basic Dendritic Processing

In this model, the dialog will ask for the Input DEM or AgreeDEM (This is created in step 6A if necessary, while repeating the model for the second time). The number of cells required to define a stream should then be entered. A value representing 1% of all cells in the watershed is typically the value used, but it may be increased to 5% or more if necessary in areas that are very flat. The total number of cells in the DEM can be obtained by multiplying the number of cells in the rows by the number of cells in the columns (these can be obtained by looking at the DEM properties). Click Okay. The model produces several outputs including: dem with filled sinks (fil2), flow direction (fdr), flow accumulation (fac), catchment grid (cat), catchment shapefile (catchment), streams grid (str), streams shapefile (drainageline), and the longest flow path within each catchment (LongestFlowPathCat). The raster outputs will be saved to the data folder which has been chosen in step 3.4 and the shapefile outputs will be saved to the geodatabase. The file names are explained in the glossary. If the output does not appear to be producing reasonable flow lines, proceed to step 6A to manually burn in stream features if they are available.



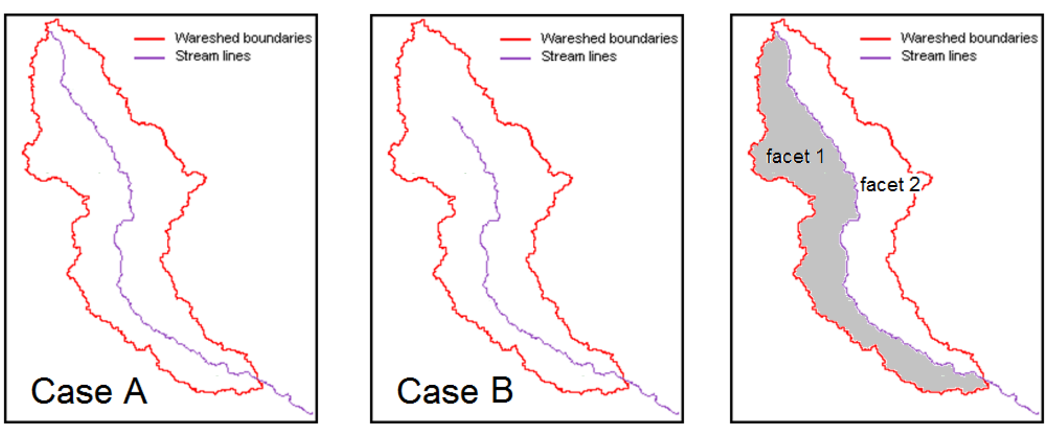
3.6A. Stream Burn In (Optional)

This model allows an optional step of adding the existing streams layer to be used to pre-define streams within the watershed. This model can be used if dendritic processing is not yielding acceptable results and an existing streams layer is available. Simply select the DEM input and Streams Layer input and the model will output a burned streams layer named AgreeDEM. The Basic Dendritic Processing step can be repeated to obtain new results.

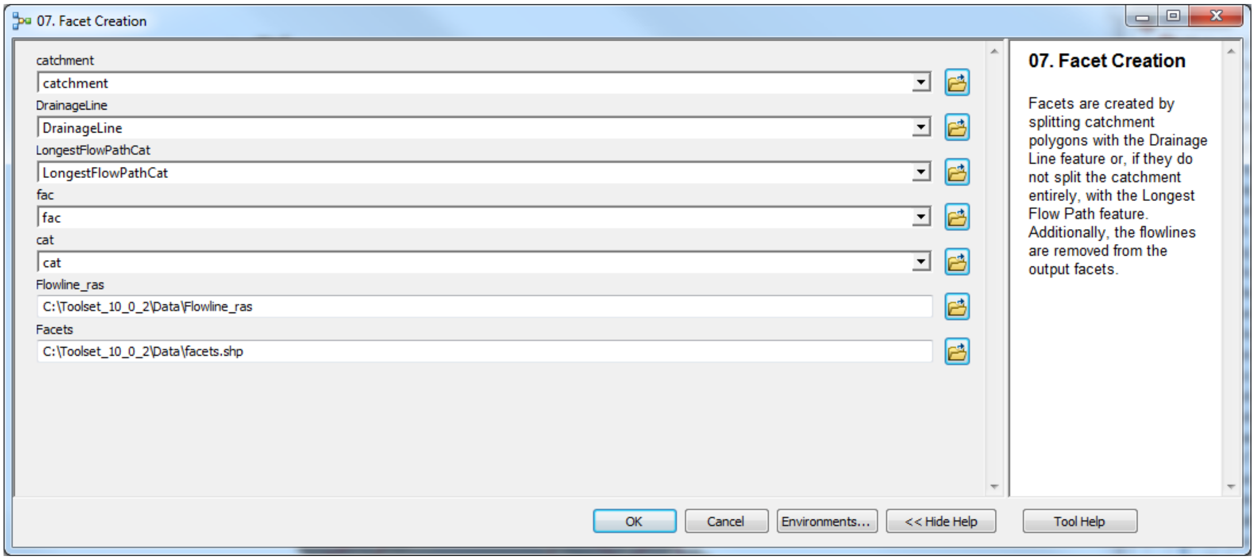


3.7. Facet Creation

Once dendritic processing is complete, the catchments will be divided into facets. Facets represent one side of a catchment divided by the stream or longest flow path. All downstream catchments will have a drainage line flowing all the way from an inlet to an outlet as shown in Case A below. Originating catchments will only have a stream flowing from a source in the catchment based on the stream threshold used previously as shown in Case B below. The drainage lines will be used to split catchments that receive flow, and the longest flow path will be used to split catchments that do not receive flow at their origin. The split will be performed by masking out either the streams or the flow paths in the catchment raster and then converting the raster back to shapefile. After processing, the catchments are split in half with unique identifiers and can then be clustered and classified. The split results in some slivers, which means that the number of features will now be greater than twice the number of catchments, but these slivers are typically resolved during facet classification.



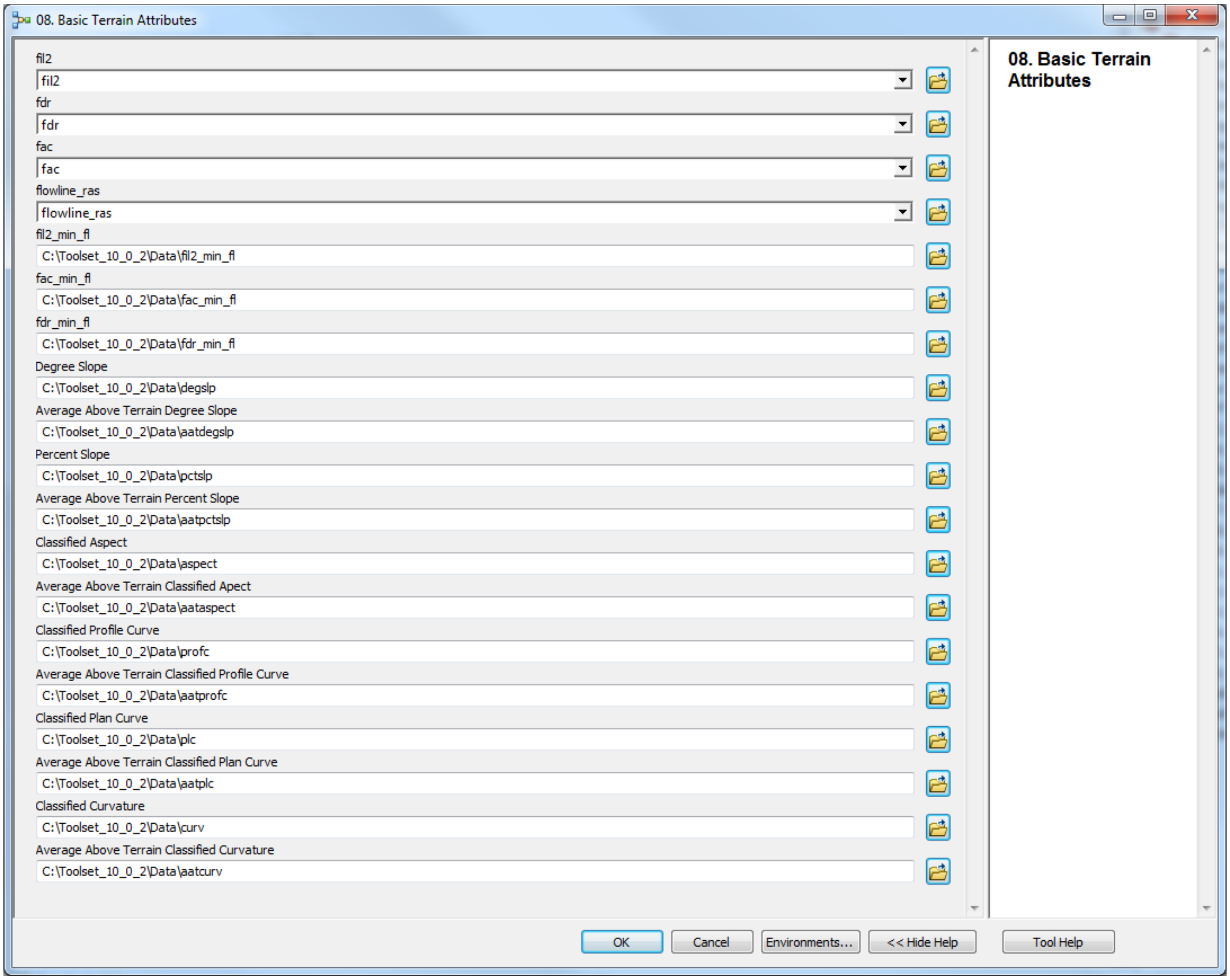
No input is required from the user to perform this process because all input files will be selected by the tool automatically.



3.8. Basic Terrain Attributes

This model produces both local and average above terrain values of basic terrain attributes that are calculated from the DEM. These include aspect, profile curvature, plan curvature, curvature, degree slope, and percent slope. Average above terrain attributes are calculated using flow accumulation of fil2_min_fl as well as weighted flow accumulation of each attribute of interest. All outputs are reclassified as necessary to simplify the data.

All inputs will load automatically if they are currently in the display. The output names are uniquely defined in the model, but they are visible for reference and will be added to the display. The output names can be changed at any time, but it is not recommended. These will primarily be used in the output table for regression analysis while degree slope will be used in the CTI calculations and facet clustering. The inputs are undergo the filtering operation before going to the next step.



3.9. Soil Observations Layer Preparation

This step has to be done manually. Add the Layer to your Input Data folder within the Data folder, or navigate to its current location when it is required for a tool.

First, check that the soil observations layer has a fid field, as well as an attribute field for all of the attributes to be predicted. In the example, the observation layer is a shape file called Soil_Measured.shp.

Also check that soil observations fall within one of the facets generated in the previous steps. If an observation is outside of the watershed boundary, it will need to be deleted from the shapefile before proceeding.

3.10. Facet Classification

This model classifies catchments based on two catchment attributes, average slope within the facet and the area of facet. The model requires the facets shapefile and the degslp output created with the basic terrain attributes tool. The model first clusters facets into classes based on the two attributes mentioned, then each cell in the raster is assigned to one of the classes.

The Iso Cluster function is used to cluster facets using the ISOData algorithm. The following four parameters should be adjusted as necessary to improve clustering:

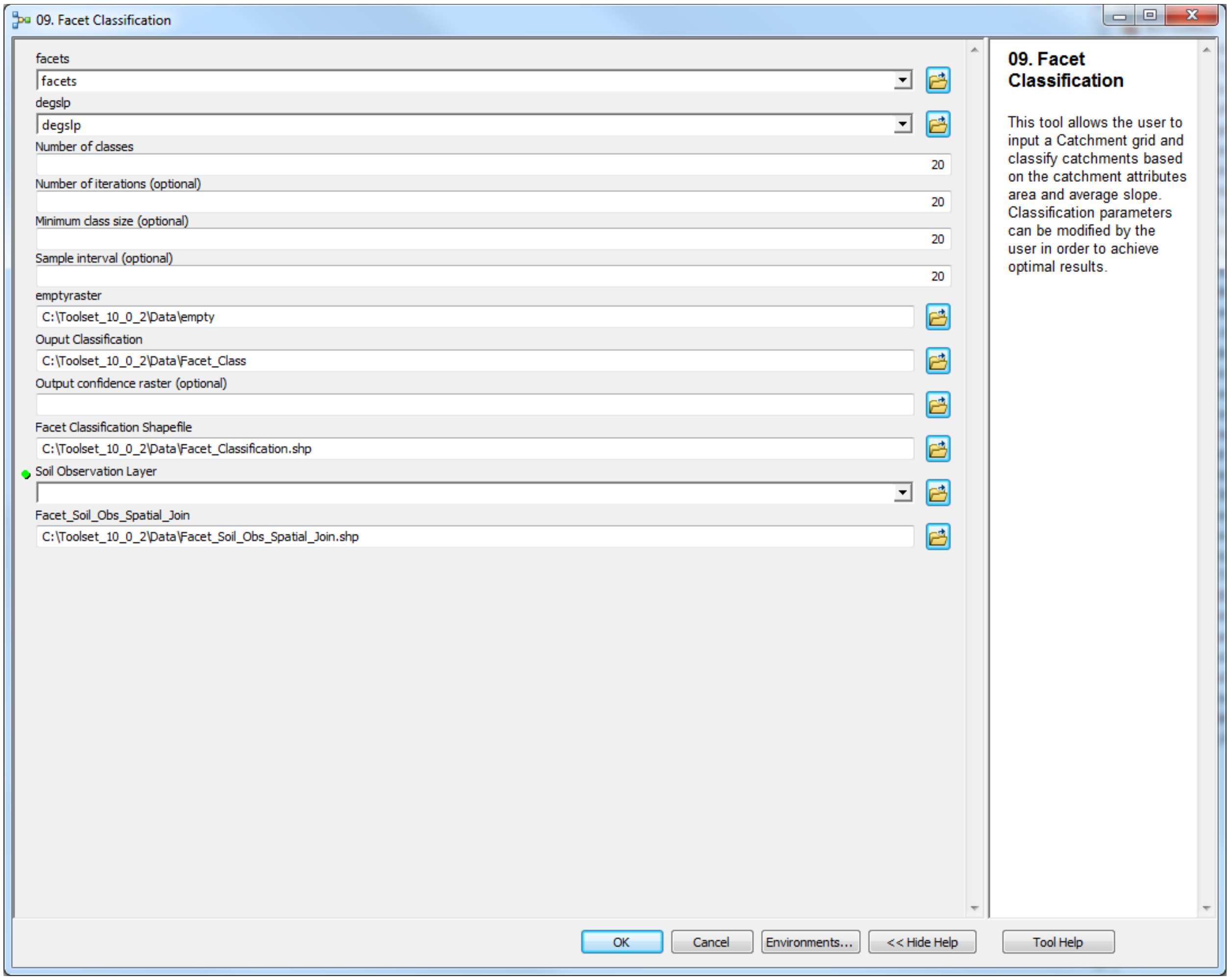
Number of classes: This is the only required parameter. The number can first be decided based on the number of soil observations divided by approximately 30 (the user can select lower number of observations but the robustness of the regression model will be affected). The number of classes can then be reduced or increased and the tool can be run again.

Minimum class size (optional): Minimum class size should be set to at least 10 pixels, however, at least 100 pixels may be a better value. The default for the tool is 20 pixels.

Sample interval (optional): Sample interval is set to a default of 20, but should probably be increased to ensure that slivers produced during facet creation are assigned to a contiguous class.

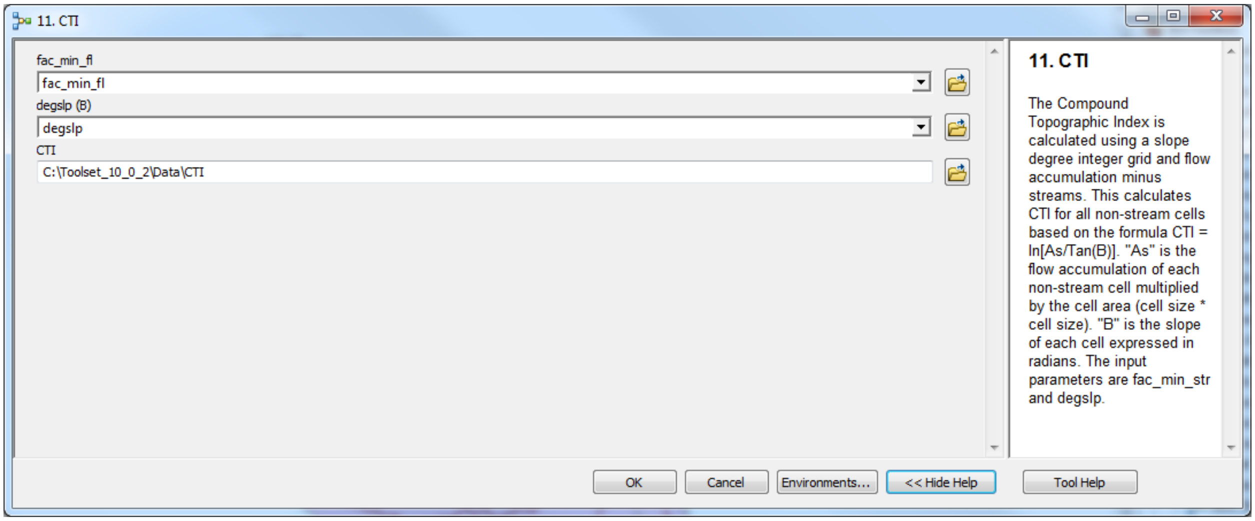
After Iso Cluster is run, a signature file is produced showing the number of classes created as well as the number of cells in each class and information about the raster bands. The results can be inspected by opening the signature file (.gsg) in the data folder. However, for the purposes of this tool, this step can be skipped. The tool then uses the signature file to perform a maximum likelihood classification on the facets based on their area and mean slope. The output is called Facet_Class

A spatial join is performed using the Soil Observation Points and the Facet Classification shapefile. The output is called Facet_Soil_Obs_Spatial_Join and it contains a Join_Count field as well as a GRIDCODE field. The gridcode field contains the facet class and the join_count field contains the number of soil observations within the facet class. This shapefile should be examined to ensure that there are approximately 30 soil observations within each facet class. If the number is satisfactory, move on to the next step, otherwise, repeat as necessary.


09. Facet Classification
facets
facets
degslp
degslp
Number of classes
20
Number of iterations (optional)
20
Minimum class size (optional)
20
Sample interval (optional)
20
emptyraster
C:\Toolset_10_0_2\Data\empty
Ouput Classification
C:\Toolset_10_0_2\Data\Facet_Class
Output confidence raster (optional)
Facet Classification Shapefile
C:\Toolset_10_0_2\Data\Facet_Classification.shp
Soil Observation Layer
Facet_Soil_Obs_Spatial_Join
C:\Toolset_10_0_2\Data\Facet_Soil_Obs_Spatial_Join.shp
09. Facet Classification
This tool allows the user to input a Catchment grid and classify catchments based on the catchment attributes area and average slope. Classification parameters can be modified by the user in order to achieve optimal results.
OK
Cancel
Environments...
<< Hide Help
Tool Help

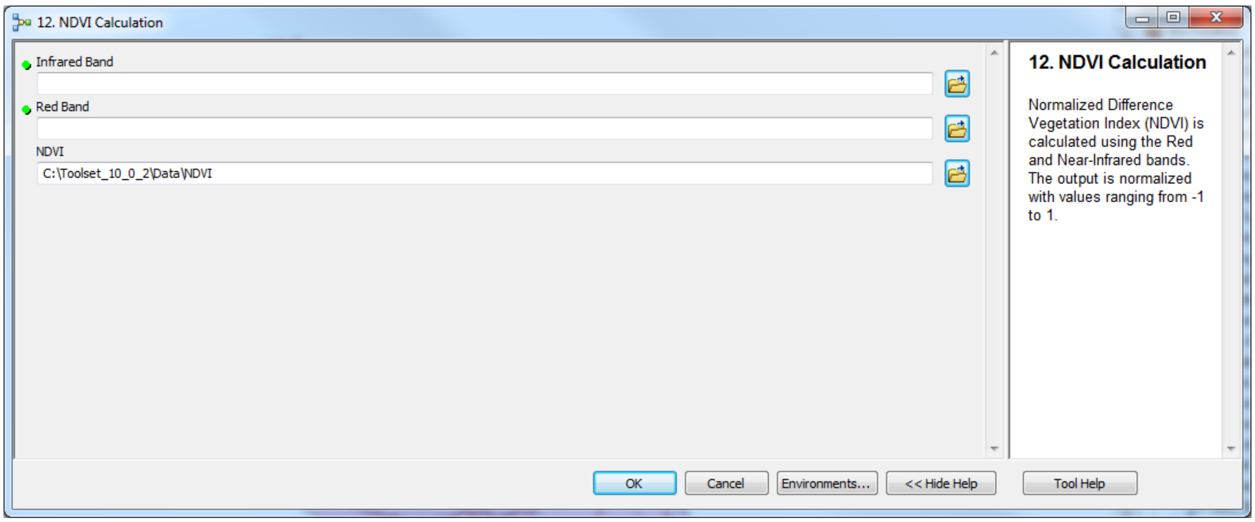
3.11. CTI (Compound Topographic Index)

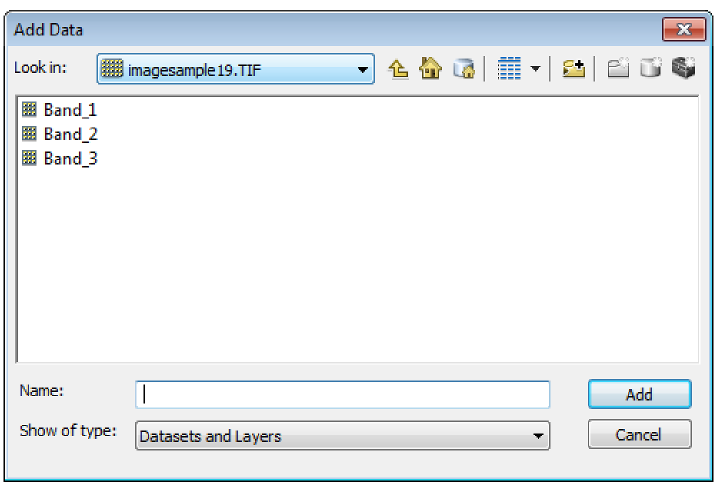
This model calculates CTI based on the DEM using the formula (CTI = ln [As/Tan B]). In this case, "As" is the flow accumulation of each cell multiplied by the cell area ((fac _min_str +1) * cell area) and "B" is the slope of each cell expressed in radians. Load fac_min_str, slpdegint the output name is predefined but it can be changed as needed.



3.12. NDVI Calculation

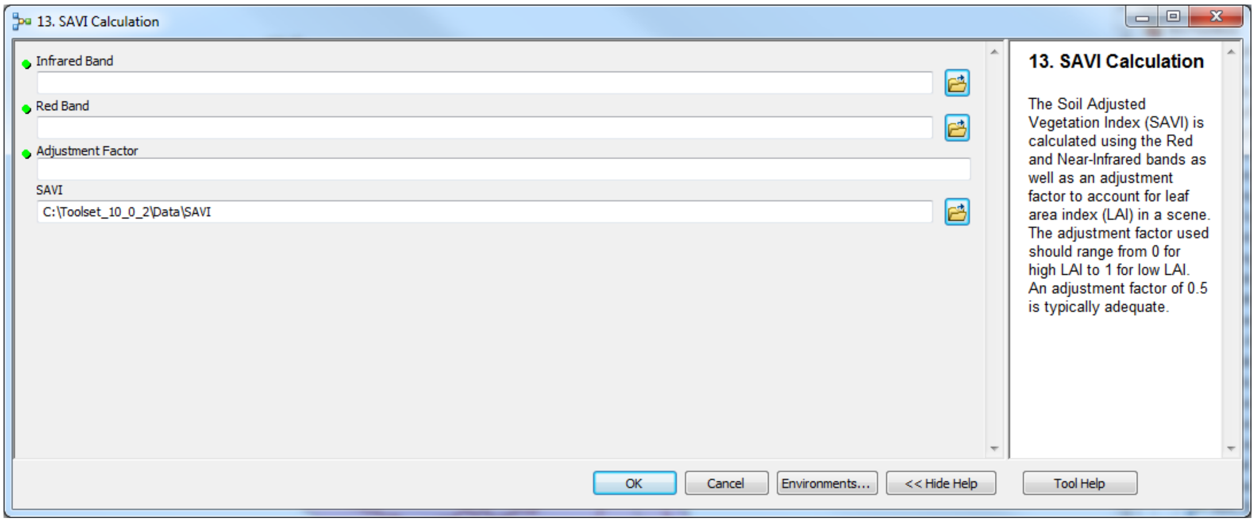
This model calculates Normalized Difference Vegetation Index (NDVI) based on the Red and Near Infrared bands of a satellite image or aerial photo. Those bands will need to be identified beforehand. The red band represents wavelengths from 0.6 to 0.7 microns while the near-infrared band represents wavelengths from 0.7 to 2.0 microns in most cases. To select bands, click on the image file to display the individual bands. They will display in a list as Band 1, Band 2, Band 3, etc. or Layer 1, Layer 2, Layer 3, etc.. The specific band name or value range may not be included in the file or documentation and the image source should be consulted. It is also necessary to check the projection of the image. Load the appropriate bands and name the output appropriately. The typical value of NDVI range between -1 and 1.





3.13. SAVI Calculation

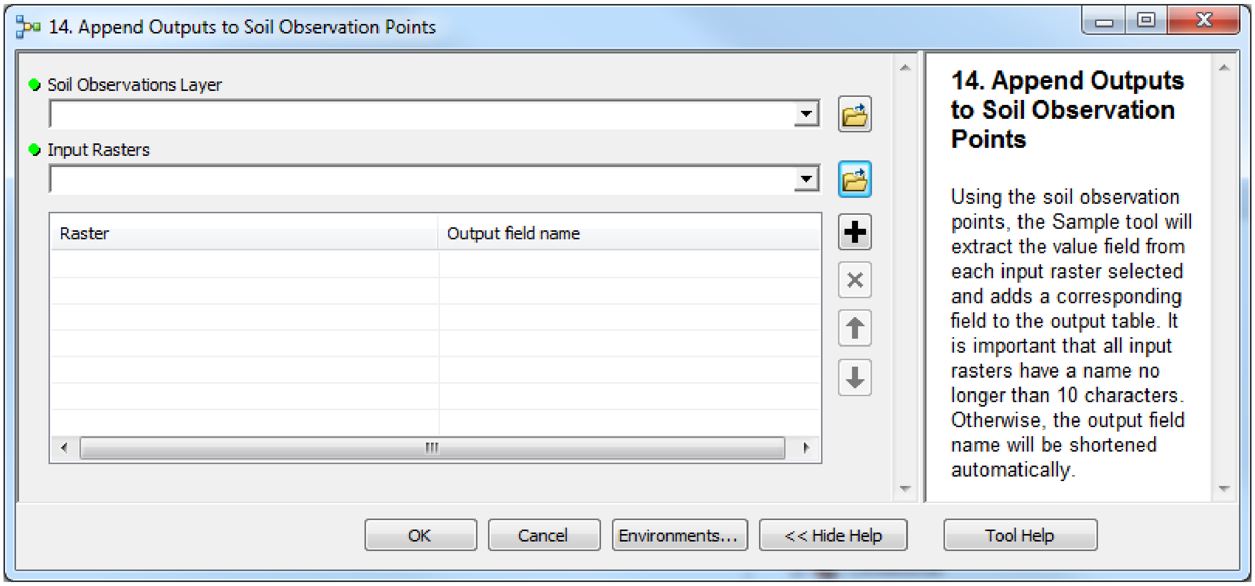
The calculation for Soil Adjusted Vegetation Index (SAVI) is similar to NDVI except that an adjustment factor is used to account for differences in leaf area index (LAI). An adjustment factor of 0 will result in the same values as NDVI and would be required in areas with high LAI. In areas with low LAI, a value closer to 1 should be used. Typically a value of 0.5 is adequate and is used as the default for this tool. Load the appropriate bands, replace “Adjustment Factor” in the Map Algebra expression with a selected value. Load the appropriate bands and enter an adjustment factor Name the output appropriately.



The NDVI and SAVI for different time periods can be calculated by using the step 12 and 13 any number of time, but make sure each time a relevant name is chosen to store the raster.

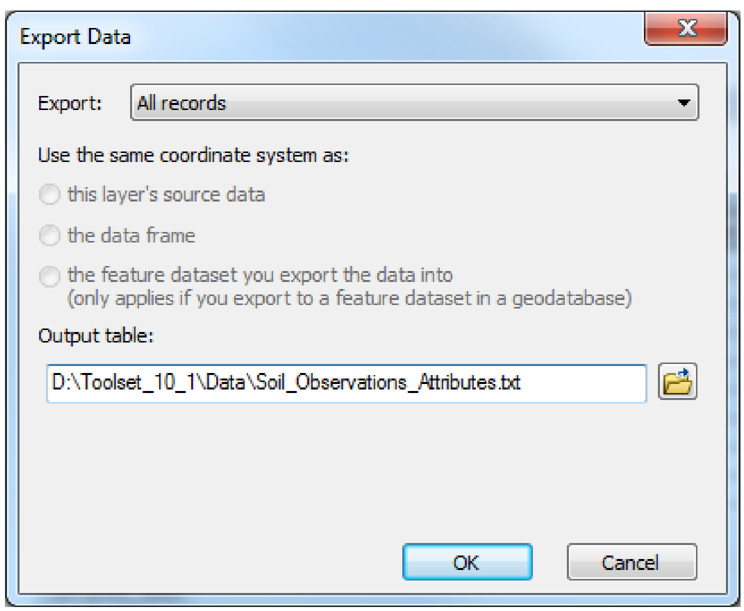
3.14. Append Outputs to Soil Observation Points

The Extract Multi Values to Points function is used to combine all of the previously created layers (which are filtered) necessary for regression in the “DEM_Image_Outputs” folder into one table based on the soil observation points. Any other additional layer(s) or raster(s) may be included in this step. The user needs to select all relevant layers to be considered in the regression model and to avoid intermediate layers that are not necessary. Any layer that is not selected here will not be considered in building the regression model. The output table contains a field for each input raster’s value field and maintains the raster name as long as the formatting is correct (no spaces, use underscores, length equal to 10 or less). The observations layer will first be copied, then output to your current workspace and added to your display under the name “Soil_Observations_Layer_Copy.shp.” Load the Input Point features, the soil observations layer, then, load all of the rasters including FacetClass.



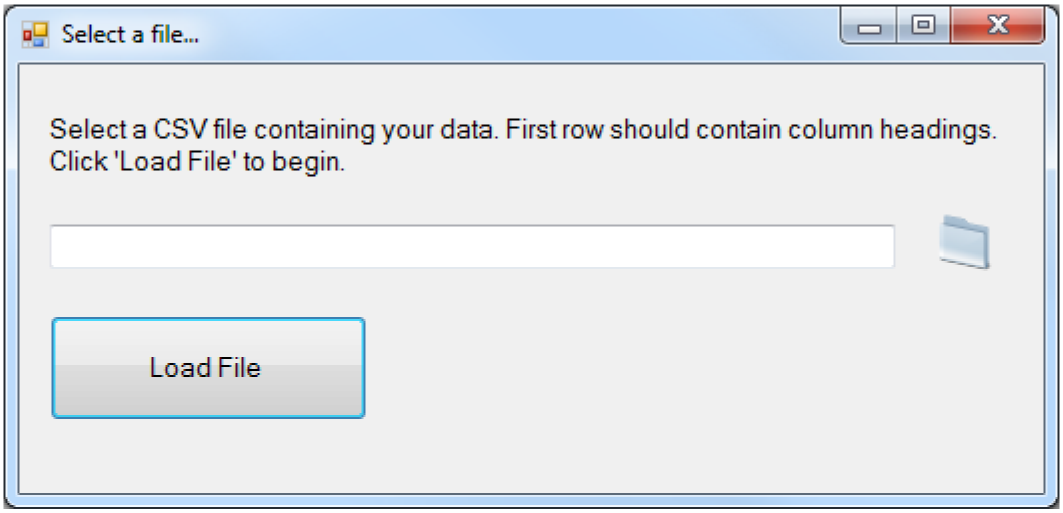
If the user needs to add any other ancillary data for the regression analysis it has to be converted into raster and then added to other rasters in this step.

Once this output is created and added to the display, open the attribute table. Click the "Table Options" menu, then click "Export". The name should be changed to "Soil_Observations_Attributes", or any recognizable name, with ".txt" or text as the file type.

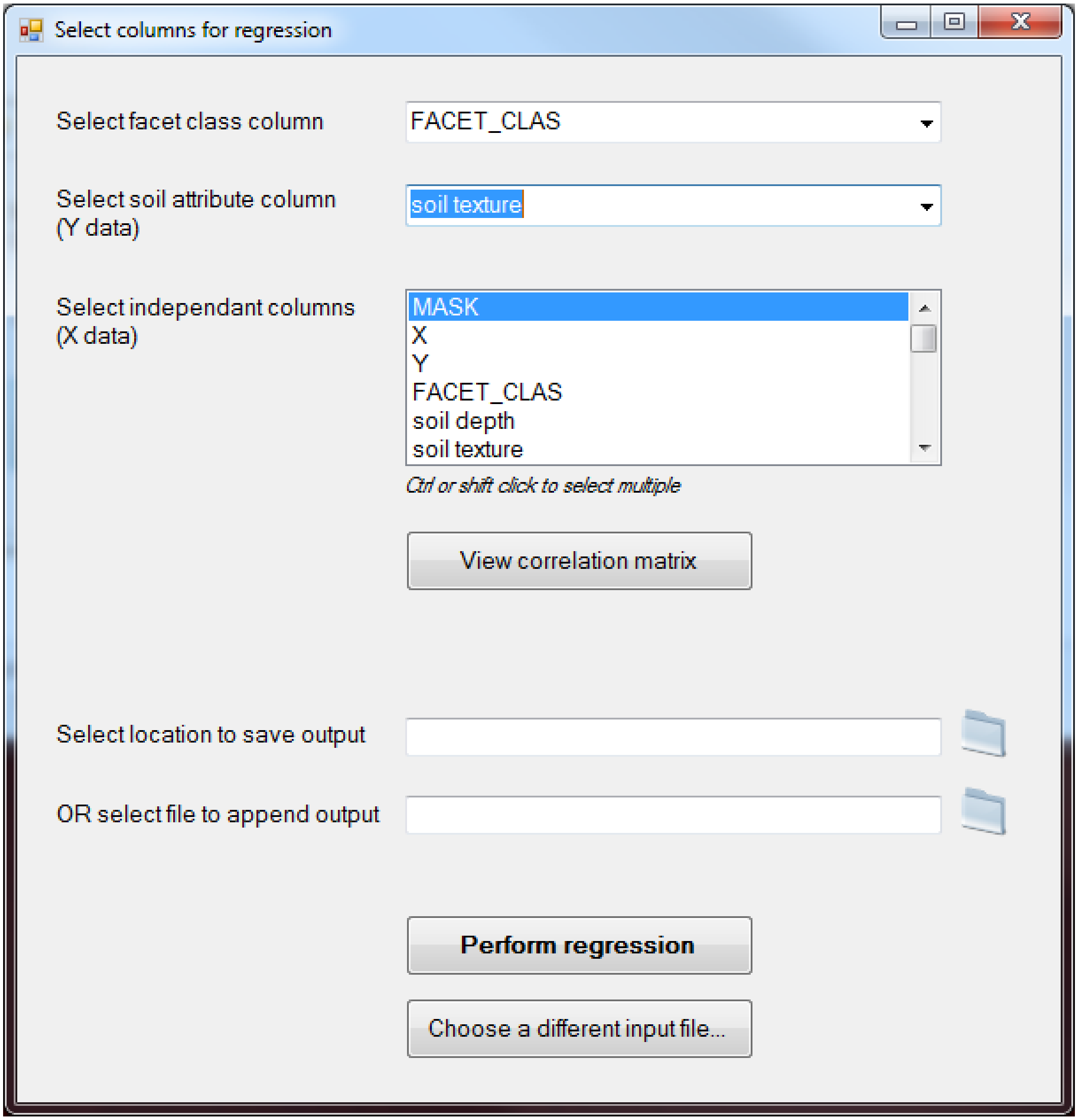


3.15. Produce Soil Attribute Table

cCick on the SoilAttributeregression
Application.   In the previous step a text file be created as the final output, please remember the location of this file which will be used in this step.

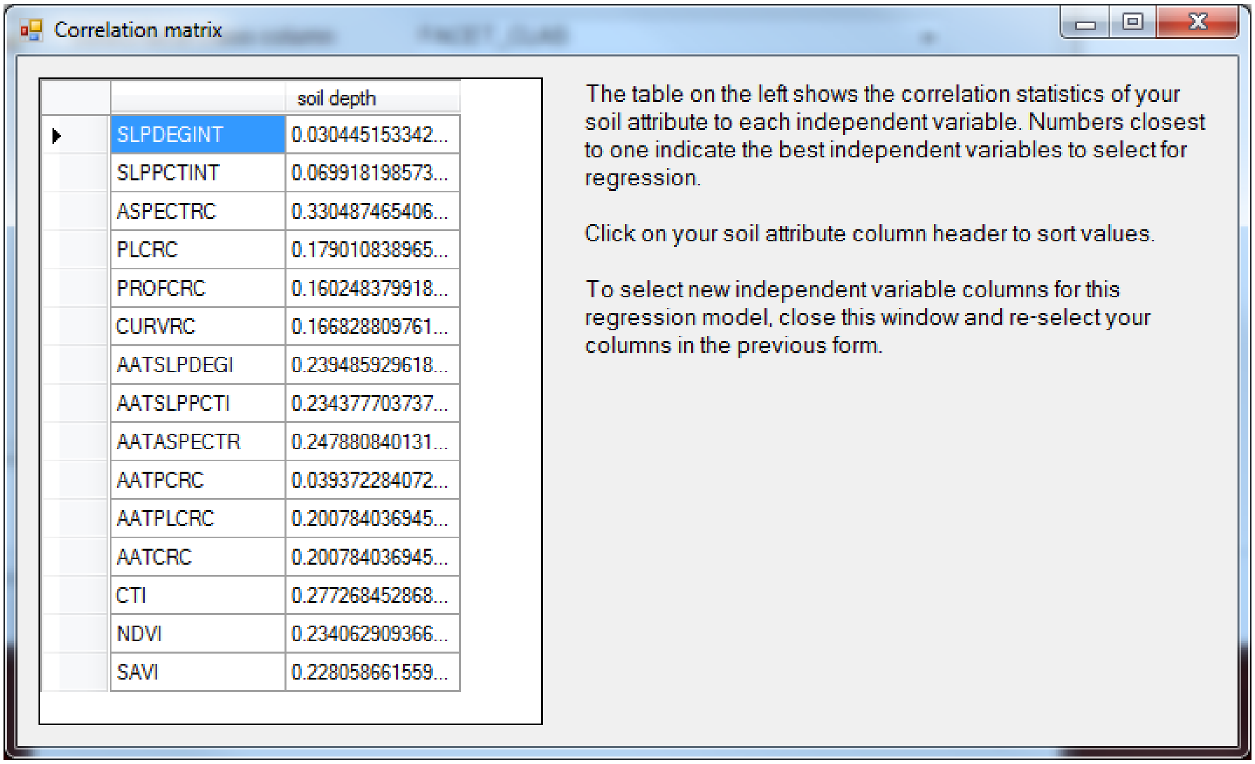


Click the folder button on the right and navigate to the text file created in the end of step 3.14 Click “Load File” to open the regression interface.



First select the facet class column from the output text file then, select the soil attribute column that will be used for prediction (for each soil attribute, this step needs to be repeated separately) . Select the independent variable columns you would like to consider in building the regression model (select one parameter and hold Ctrl to select the others), then click “View correlation matrix” to see which columns represent the best predictors.

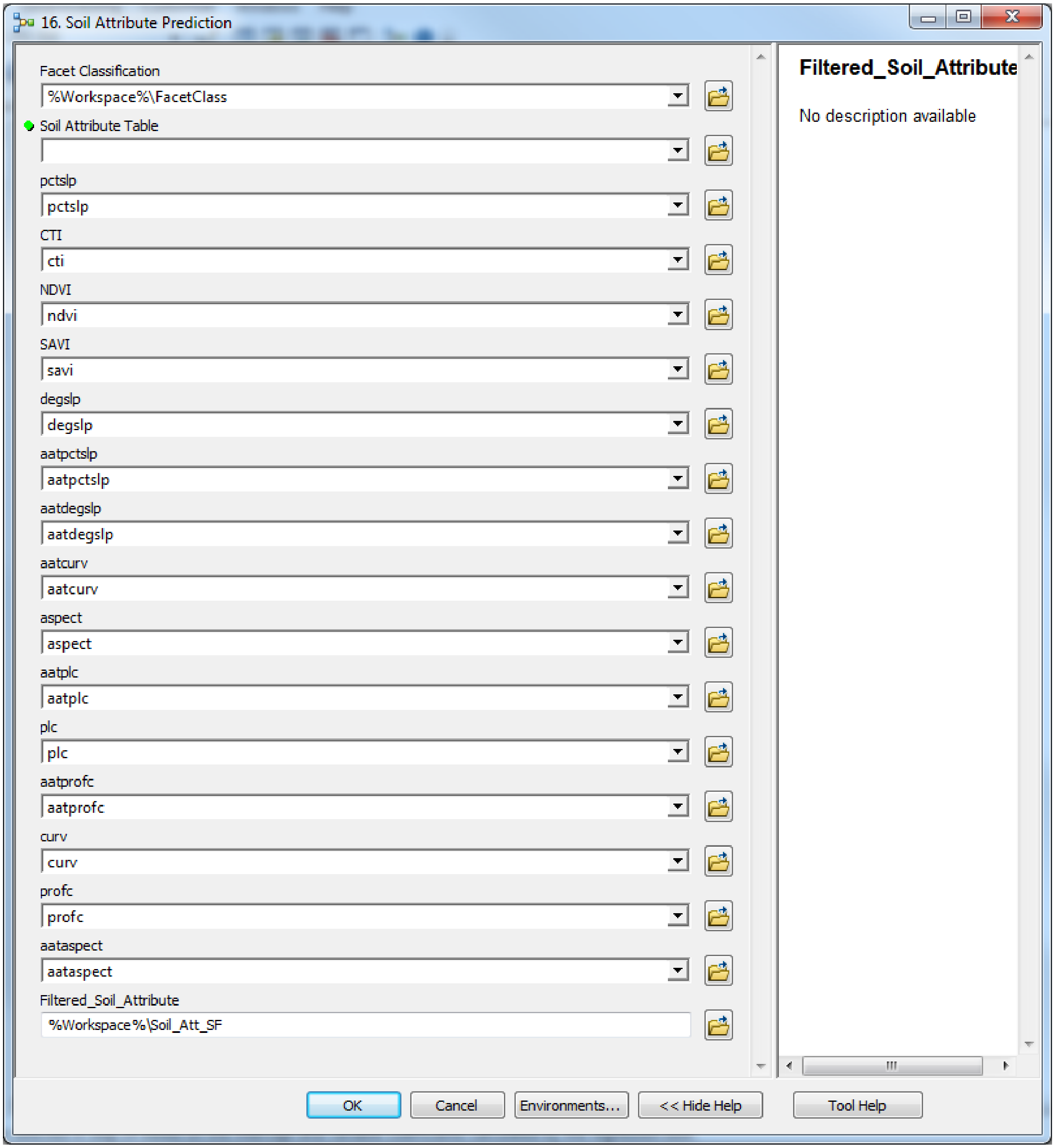
Revise the correlation matrix to choose the best predictors. The user should make the decision based on the value of the correlation coefficient and at the same time to avoid using many attributes and belonging to similar class (i.e. one parameter from NDVI and SAVI can be chosen, in pctslp and aatpctslp one can be chosen), i.e. the user should avoid using two parameters that represent the same variable. Ideally this should be done using stepwise regression, where the regression model will select those terrain and satellite attributes that are best predictor of the soil attribute and come up with the regression model with highest coefficient of determination. In this version, this is not possible and will be adjusted in future releases. Alternatively, if the user is not happy with the regression results, the file generated in the previous step can be used to run the regression in a statistical analysis software and to return the results to SLEE and continue the prediction steps.



Close the Correlation matrix window and reselect the best predictors, then select an output location and click "Perform regression." The output file will be in CSV format and named as "soil-attribute-regression-YYYYMMDDHHMMSS". Rename the CSV file in the following format based on the soil attribute or layer selected for regression: clayX, orcoX, sandX, siltX, and stoneX (where X is 1,2,...10 which represents the layer of soil in which measurements were taken. In the example provided there are three layers). Repeat this step for each attribute or soil layer that needs to be predicted.

3.16. Soil Attribute Prediction

To run the Soil Attribute Prediction model, a table produced in the previous step will need to be loaded along with the facet classification. The model will join the output table to the facet classification. A lookup will then create a raster for each field of interest. If a variable was not used to calculate a coefficient, the value is simply represented by 0 in the table and the tool will ignore this variable. If variable rasters exist in the Data\DEM_Image_Outputs folder, they will automatically be loaded in the tool dialog. If the variable raster does not exist, a red circle with a white x will appear next to the input box. In this case, select "empty" which should be found the drop-down menu (If not in the menu, it will be located in the Data folder). This will ensure that the variable is ignored in the calculation. Repeat this step for each attribute. The model will produce unfiltered and filtered rasters as well as an ASCII file with the same name as the input table in the Data\Predicted_Outputs folder. If the user wishes to change the name of the output raster it can be edited under the Filtered_soil_Attribute tab in the following window.



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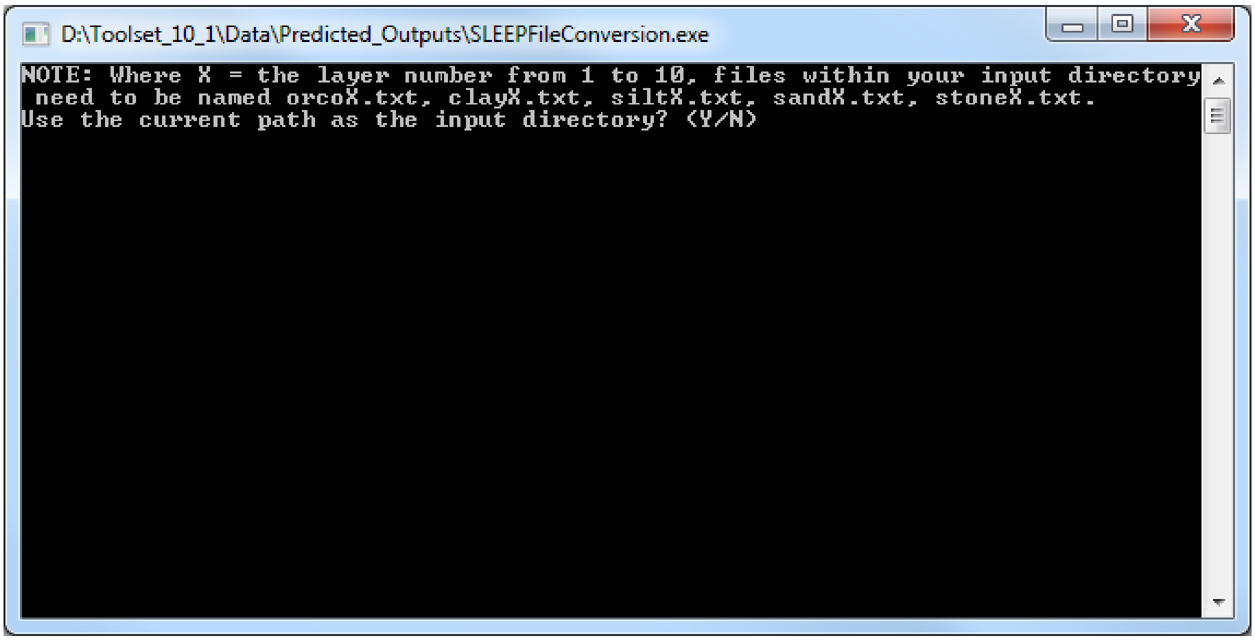
3.17. Outputormat Conversion

The SLEEP Format Conversion tool can be called from ArcMap or it is also present in the Data\Predicted_Outputs folder. If the tool is called from ArcMap, type "N" and hit enter, then manually enter the directory where your predicted outputs are stored: i.e. "C:\Toolset_10_1\Data\Predicted_Outputs". If the tool is accessed directly from the folder, type "Y" and proceed. Next enter the number of soil layer (1-10) and hit enter. Specify the depth of each soil layer and run the program. (For the example we are using the depth of the layer 1 is 25 cms, 2 is 60 cm s and 3 is 100 cms). Each of ASCII files will be read in and an excel spreadsheet will be created based on the combination of all ASCII files.



3.18. Glossary:

Average Above Terrain (aat) Attributes: Outputs of the Basic Terrain Attributes model that represent the average upstream value accumulated in each cell. To calculate the average, the attribute values are accumulated, then divided by the number of cells accumulated.
AgreeDEM: DEM with streams burned in
Aspect: The downslope direction of the maximum rate of change in value from each cell to its neighbors
cat: Catchment grid
catchment: Catchment polygon shapefile
degslp (B): Slope of upslope contributing area or cell
CTI: Compound Topographic Index
Forumula: CTI = ln [As/tan B]
Degree Slope (degslp): Slope grid measured in degrees and converted to an integer grid
drainageline: streams derived from flow direction and stream segementation in shapefile format
fac: Flow Accumulation
fac_min_fl: Flow Accumulation with raster flowlines masked out
facets: catchment polygons divided by the drainage line feature or the longestflowpathcat feature
Facet_Class: Raster of classified facets
Facet_Classification: Shapefile of classified facets
Facet_Soil_Obs_Spatial_Join: Spatial join of facets and soil observations used to identify number of observations per facet class
fdr: Flow Direction
fdr_min_fl: Flow Direction with raster flowlines masked out
fil: Fill Streams executed during Burn in
fil2: Fill Streams executed during dendritic processing
fil2_min_fl: fil2 with raster flow lines masked out
flowline_ras: raster representation of drainage lines or longest flow paths used to split catchments into facets
LongestFlowPathCat: Longest flow path generated for catchments generated from cat and fdr
NDVI: Normalized Difference Vegetation Index
Formula: (IR Band – R band / IR Band + R Band)
Percent Slope (pctslp): Slope grid measured in percent and converted to an integer grid
Plan Curve (plc): Perpendicular to the direction of the maximum slope, influences convergence and divergence of flow, interpreted as convex, concave, or flat.
Profile Curve (profc): Direction of the maximum slope, affects acceleration and deceleration of flow, interpreted as convex, concave, or flat.
Curvature (curv): Curvature of the surface at each cell with respect to the eight surrounding neighbors, the slope of the slope
SAVI: Soil Adjusted Vegetation Index
Formula: (IR Band – R band / IR Band + R Band + L) * (L + 1)
L = Adjustment Factor that may range from 0 to 1
signature.GSG: Signature file generated by the Iso Cluster tool that contains information about the natural groupings of catchment cells
str: Streams grid