USING GIS TO HELP INTEGRATE BIODIVERSITY AND ECOSYTEM SERVICES INTO REDD+ DECISION MAKING

STEP-BY-STEP TUTORIAL: EVALUATING THE IMPORTANCE OF FORESTS FOR SOIL STABILIZATION AND LIMITING SOIL EROSION, A SIMPLE "QUALITATIVE" APPROACH USING A CUSTOMISED TOOL IN ARCGIS 10.0

UN-REDD PROGRAMME

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Introduction

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, to include the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. This will involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging or rehabilitating degraded forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests such as water regulation, erosion control and non-timber forest products. Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through identifying areas where REDD+ actions might have the greatest impact using spatial analysis.

This tutorial provides a mapping methodology to evaluate the importance of forests for soil stabilization and limiting soil erosion, using a simple "qualitative" approach. In this example, importance is evaluated as a function of slope, rainfall and the presence of important economic, social and environmental sites downstream that could be adversely affected by soil erosion, such as a dam or water body. For example, forests may play an important role in soil stabilization on steep slopes in areas of high rainfall, with implications for downstream activities that benefit from clear water such as population centres, hydroelectric plants and navigation routes. Such an analysis can be used to help answer questions such as:

- Where is forest loss likely to result in erosion and consequent sedimentation – and where is this important?
- Where might retaining or restoring forest in areas play an important role in retaining soil/reducing sedimentation?

The analysis is undertaken by using an overlay approach, where data on mean precipitation (annual or the average for a subset of particular months if just the wet season is used), slope, and dam catchment are generated and combined with forest data. The process involves generation of single layers with 3 classes (low medium and high) for mean precipitation and for slope. A binary layer is generated for the presence or absence of a dam catchment. These can then be combined additively. Since there are 3 classes for slope (1-3) , 3 classes for mean precipitation (1-3) and 2 for the presence or absence of a dam catchment (0-1) the resulting output has a maximum value of 8, and a minimum value of 2, and therefore 7 classes. **These classes represent a low – high potential importance of forests for soil stabilization and limiting soil erosion. Highest values represent higher erosion impact in the absence or degradation of forests.** No weighting is used in this approach – the relative importance of high precipitation is the same as that for steep slopes. This approach could be further refined for example by adding in additional layers such as soil type.

Prepared by Julia Thorley and Corinna Ravilious, UNEP-WCMC 2013. Updated 2014.

Data requirements

Download **void-filled** hydrosheds DEM data at 3 arc second resolution from
http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=3demg
The 3 arc second data is served in 1-degree tiles, therefore depending on the size of your study area you will probably need more than 1 tile.

A "void-filled" DEM has been modified to fill in areas of no-data (i.e. over large water bodies). The existence of no-data in a DEM causes significant problems for deriving hydrological products, which require continuous flow surfaces. Therefore, a void-filling procedure is applied to provide a continuous DEM for HydroSHEDS. A "conditioned" DEM has had a number of conditioning procedures applied to it (e.g. sink filling, stream burning, deepening of open water surfaces). The conditioning process alters the original DEM and may render it incorrect for applications other than deriving drainage directions.

IMPORTANTwhen using HydroSHEDS data to undertake the analysis described below, a void-filled DEM must be used.

In order to know which tiles to download, look at the tile numbers in the layer package: Hydrosheds_3arc_seconds_grid.lpk. Make sure your area of study is in lat/lon WGS84 and select the tiles for download. Once all the tiles have downloaded, unzip all the files in the folder.

Download WorldClim precipitation data at 30 arc seconds from:
http://www.worldclim.org/current as ESRI grid files. This data is available on large tiles or at global extent. Download for the global precipitation data is around 700MB and consists of 12 global monthly data grids.

Download dams data from:
http://sedac.ciesin.columbia.edu/data/set/grand-v1-dams-rev01

The examples above are global datasets. You may have better data available for your area of interest which you can easily use as substitutes for the above

Running the analysis

Before running the next steps make sure you have installed the ExploringMultipleBenefits toolbox_v10.tbx (see exploring MultipleBenefits manual for details of installation).

1. Tool SE a: Mosaic DEM tiles, project to units meters and generate slope

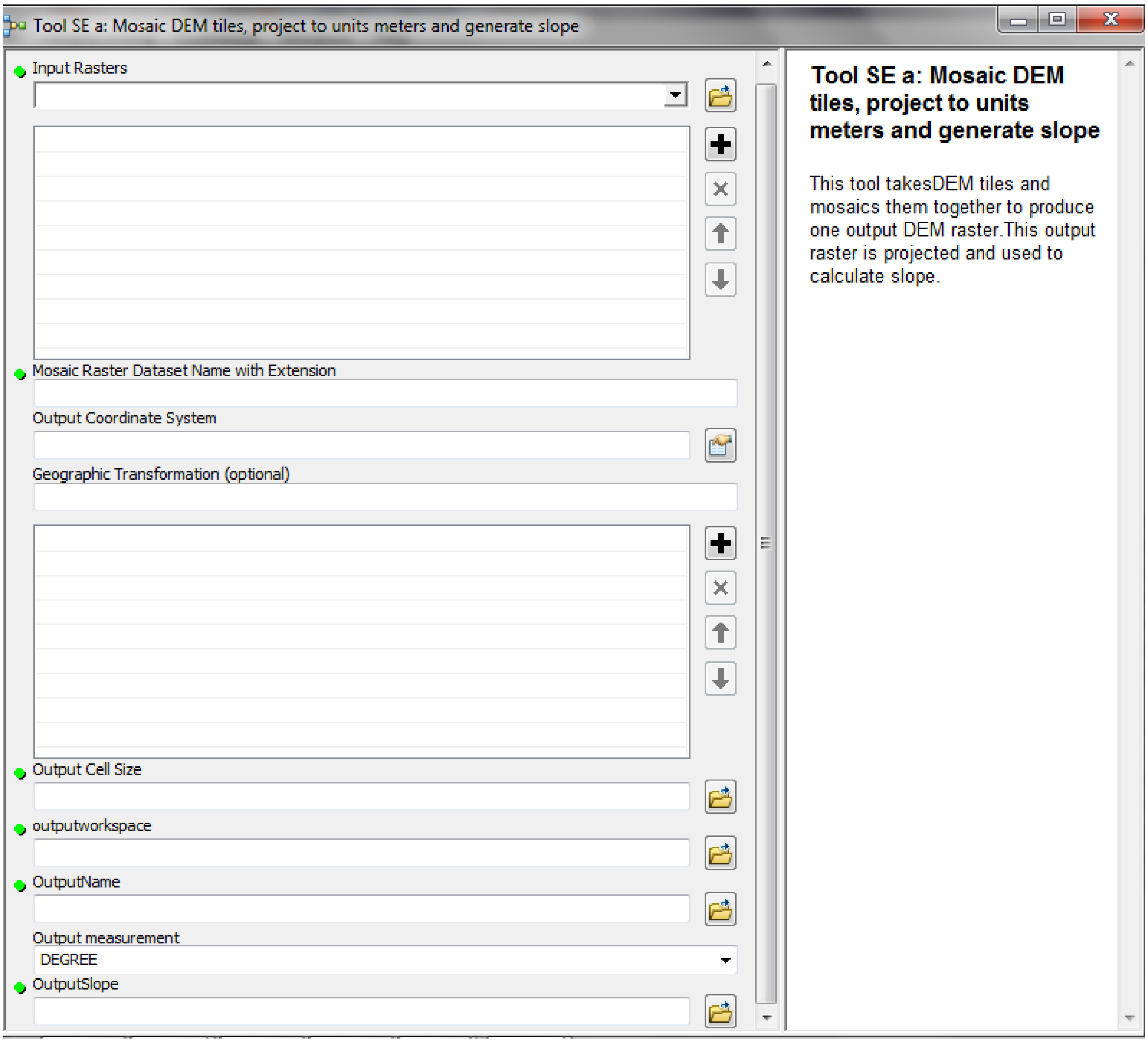
This tool undertakes the following steps.

- Stitching DEM tiles for the study area together into a single raster dataset.
- Projecting the raster to a chosen output coordinate system (the dataset cannot be left in geographic EPSG 4326 as the units need to be in meters).
- Calculating slope from the projected raster dataset.
  Note: The Slope calculations depend on resolution. Steeper slopes are better identified with higher resolution DEMs e.g. 3-arc seconds or less

How to Run the Tool

- Double click on the tool '**Tool SE a: Mosaic DEM tiles, project to units meters and generate slope'**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly. When each white box is clicked on, explanations/help will appear in the panel on the right. The parameter descriptions are also described below.

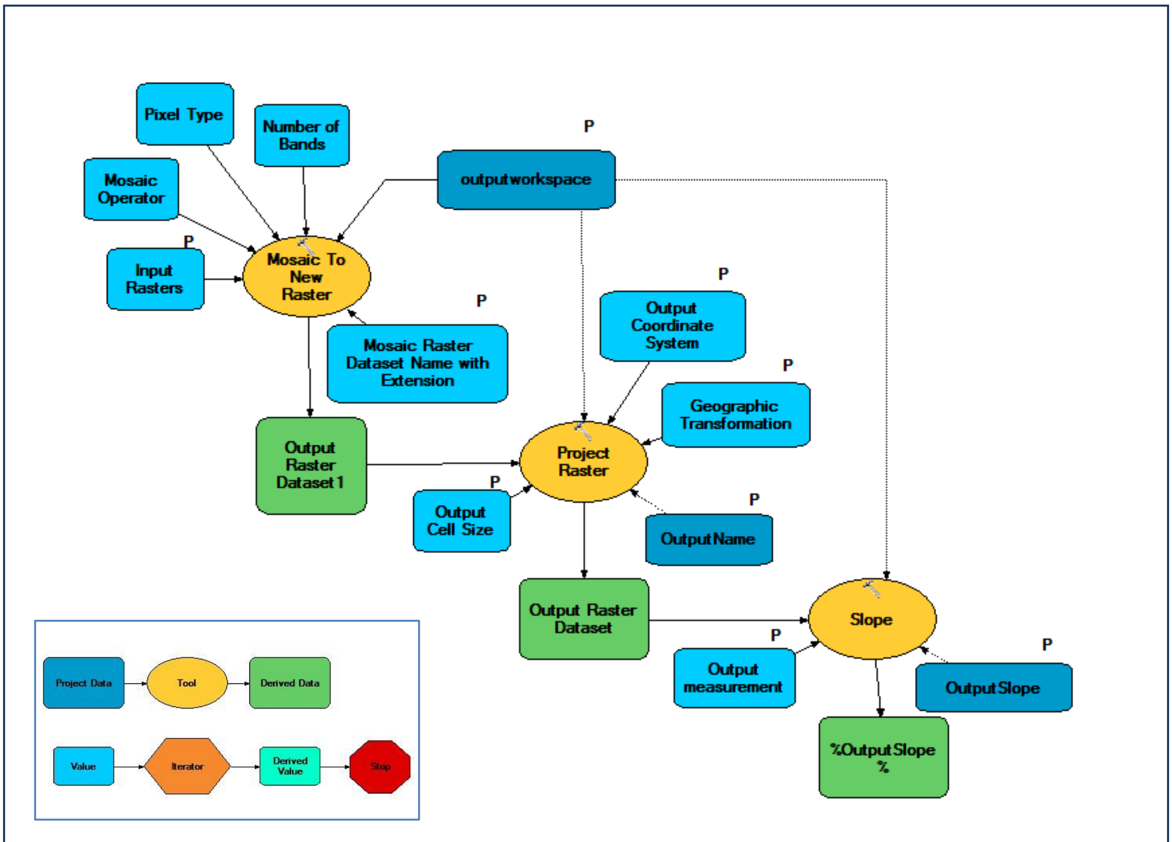
❖ Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Input_Rasters>	Input DEM rasters	Multiple Value
<Mosaic Raster Dataset Name with Extension>	The output name for the mosaic DEM raster with file extension (use the same extension as your input rasters, e.g. .tif)	String
<Output_Coordinate_System>	Output coordinate system for the new projected raster	Coordinate System
<Geographic_Transformation (Optional)>	select from dropdown, some projections require this	Multiple Value
<Output_Cell_Size>	Set the output cell size to be consistent with the resolution of your input DEM rasters	Analysis cell size
<outputworkspace>	Workspace in which to save the output	Workspace or Raster Catalog
<OutputName>	Name of new projected raster	Any value
<Output measurement>	The slope can be calculated as a percentage or degrees	String
<OutputSlope>	Name of new output slope raster	Any value

Technical diagram



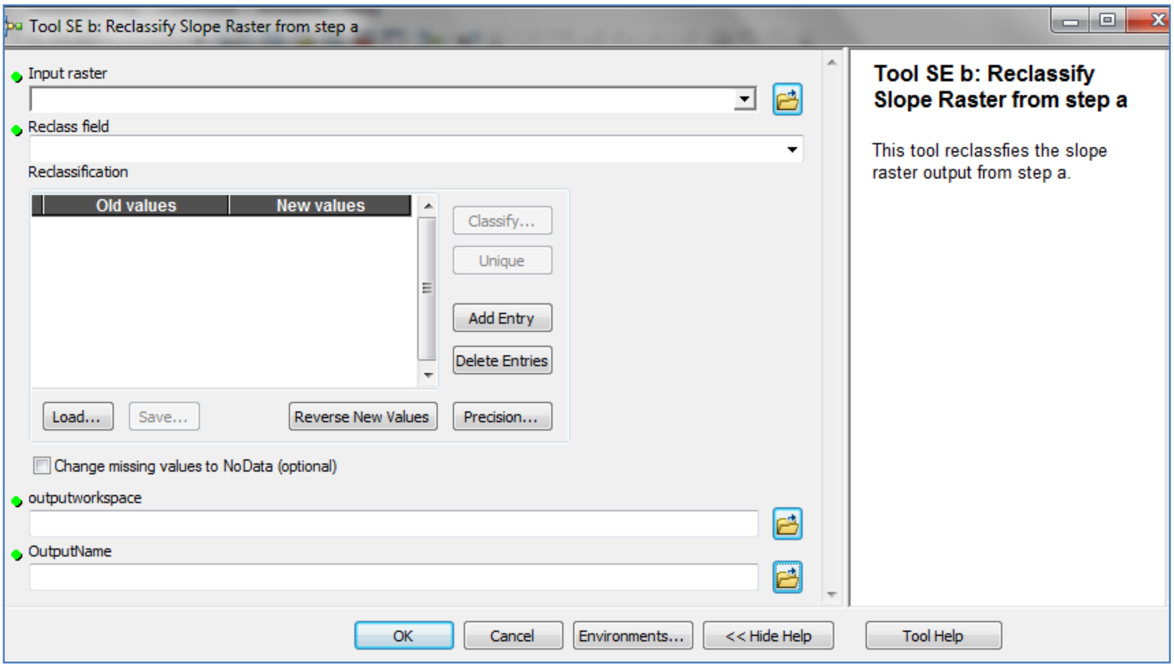
2. Tool SE b: Reclassify Slope Raster from step a

This tool undertakes the following steps.

- Reclassifies the slope output from '**Tool SE a'** into 3 classes

How to Run the Tool

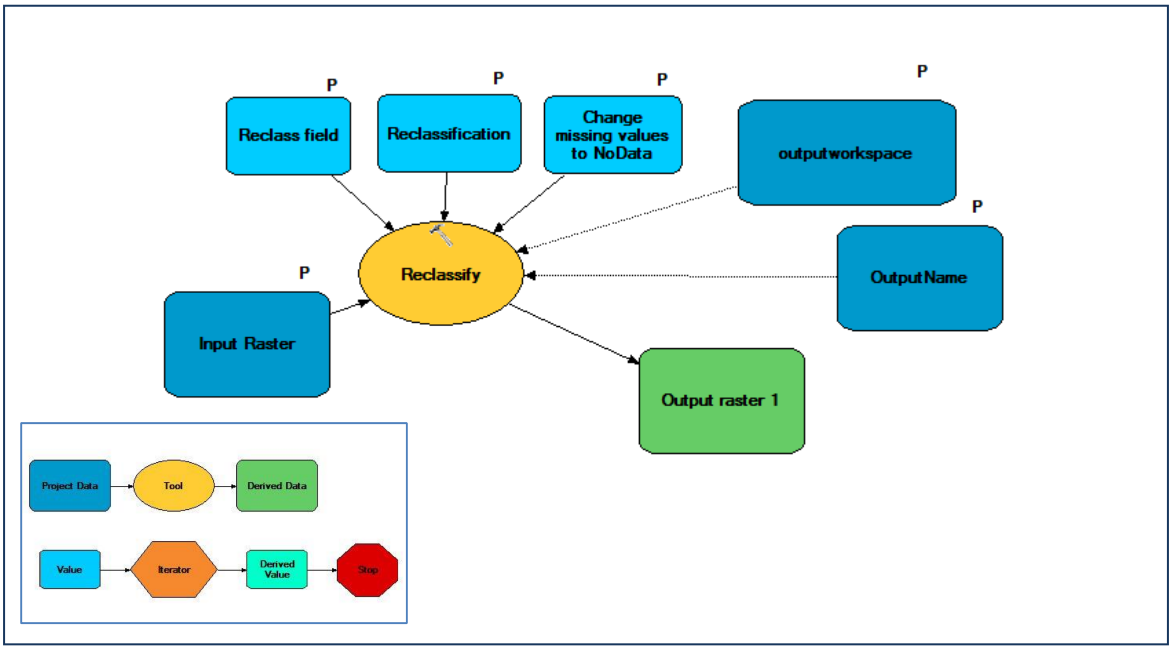
- Shade the slope raster in 3 classes (chose classes to represent low - high slope (e.g. 0-15, 15-30, >30 in % or degrees (units chosen in step a)
- Double click on the tool '**Tool SE b: Reclassify Slope Raster from step a'**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly. *Note: Once the input slope raster is selected, ArcMap will guess that the reclassification is the same as the 3 class shading you chose above.*
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Input_raster>	Slope calculation raster from step a	Composite Geodataset
<Reclass field>	The field upon which the reclass will be based - i.e. the degrees or percentage value of the slope	Field
<Reclassification>	Reclass slope values into 3 classes	Remap
<Change_missing_values_to_NoData (Optional)>	Leave blank as all values are reclassed	Boolean
<outputworkspace>	Workspace in which to save the output	Workspace
<OutputName>	Name of new output reclassed slope raster	Any value

Technical diagram



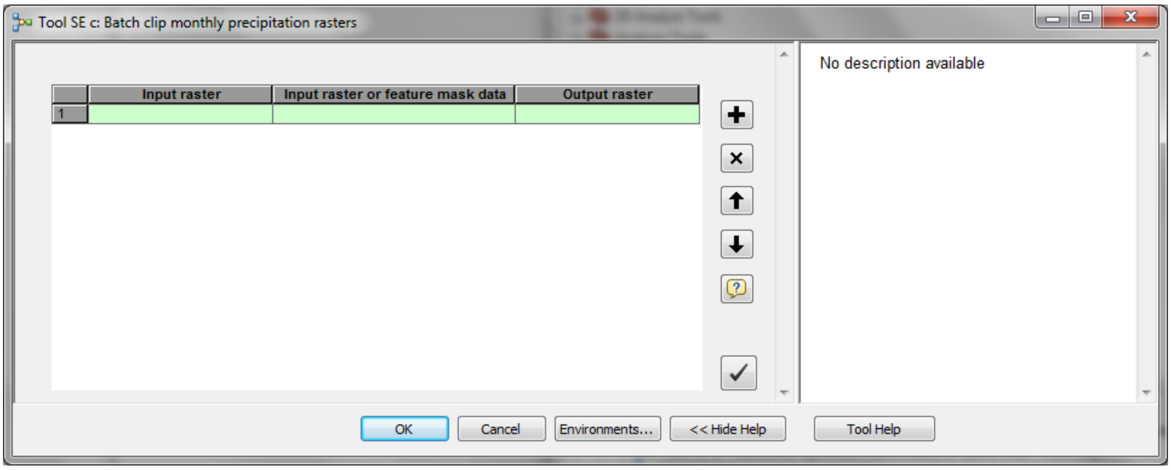
3. Tool SE c: Batch clip monthly precipitation rasters

This tool undertakes the following steps.

- Batch clips monthly precipitation rasters to the extent of your study area using a mask of the study region

How to Run the Tool

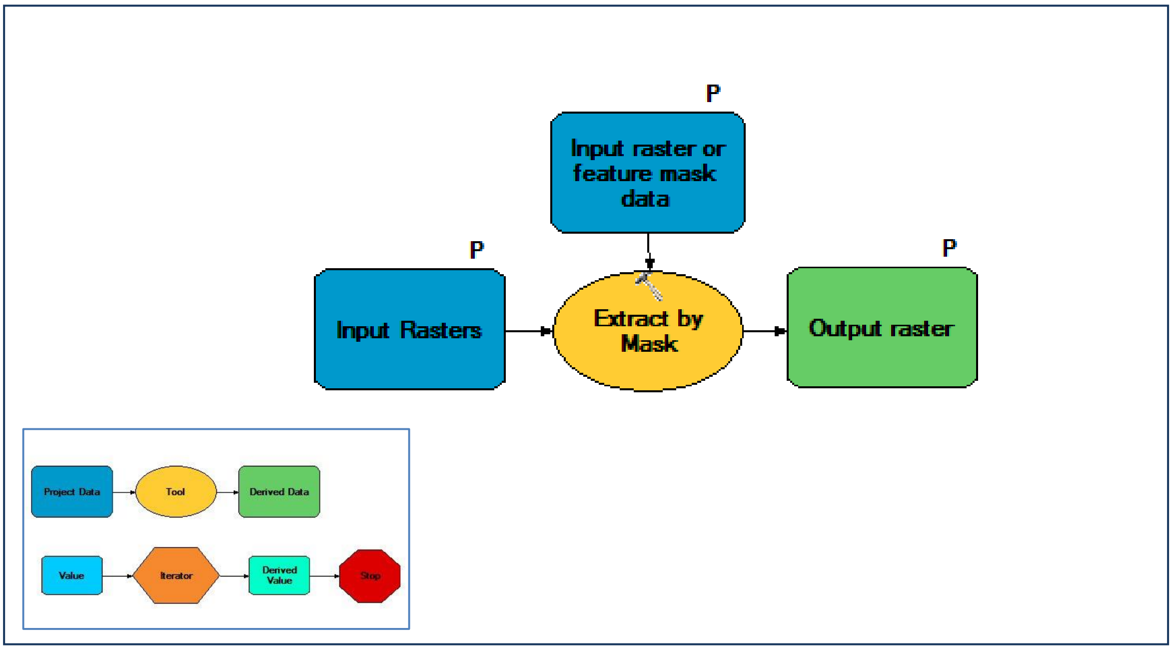
- Add the monthly grids to Arcmap
- **<u>Right</u> click** on the tool '**Tool SE c: Batch clip monthly precipitation rasters'** and click batch
- In the box which appears (see below), fill in the white boxes (parameters) accordingly.
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Input_raster>	input monthly precipitation raster	Composite Geodataset
<Input_raster_or_feature_mask_data>	dataset defining study area	Composite Geodataset
<Output_raster>	monthly precipitation raster clipped to study area	Raster Dataset

Technical diagram



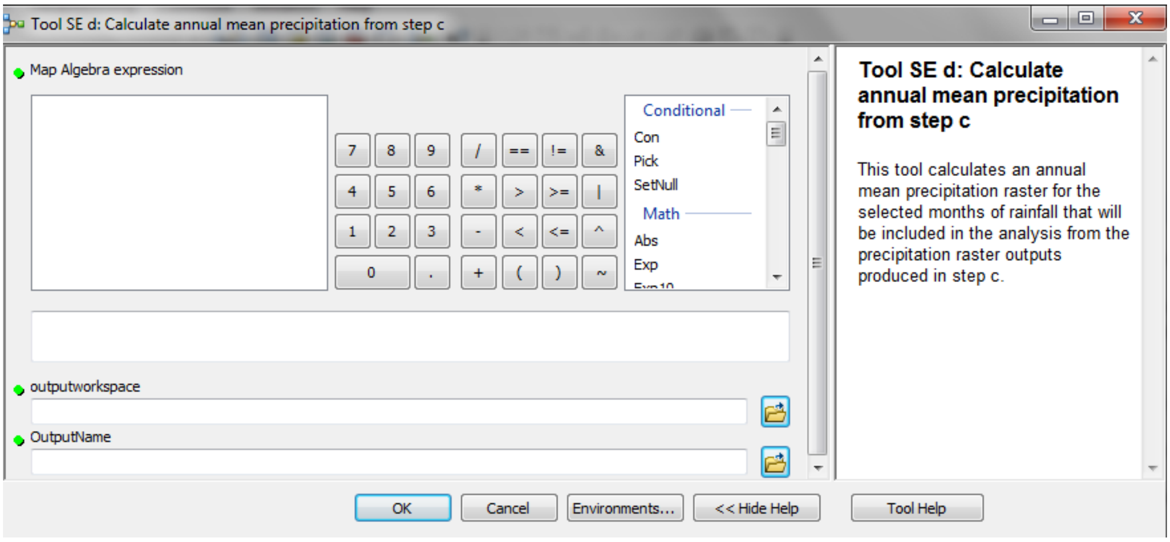
4. Tool SE d: Calculate annual mean precipitation from step c

This tool undertakes the following steps.

- Uses the raster calculator tool from the spatial analyst toolbox (map algebra) to create an annual mean grid for precipitation. *At this point it is possible to decide whether an annual mean of precipitation will be used in the analysis, or the rainy season months only. E.g. Panama analysis used May – August wet season precipitation only.*
- Adds the required months precipitation rasters together, and then divides by the total number of months used.

How to Run the Tool

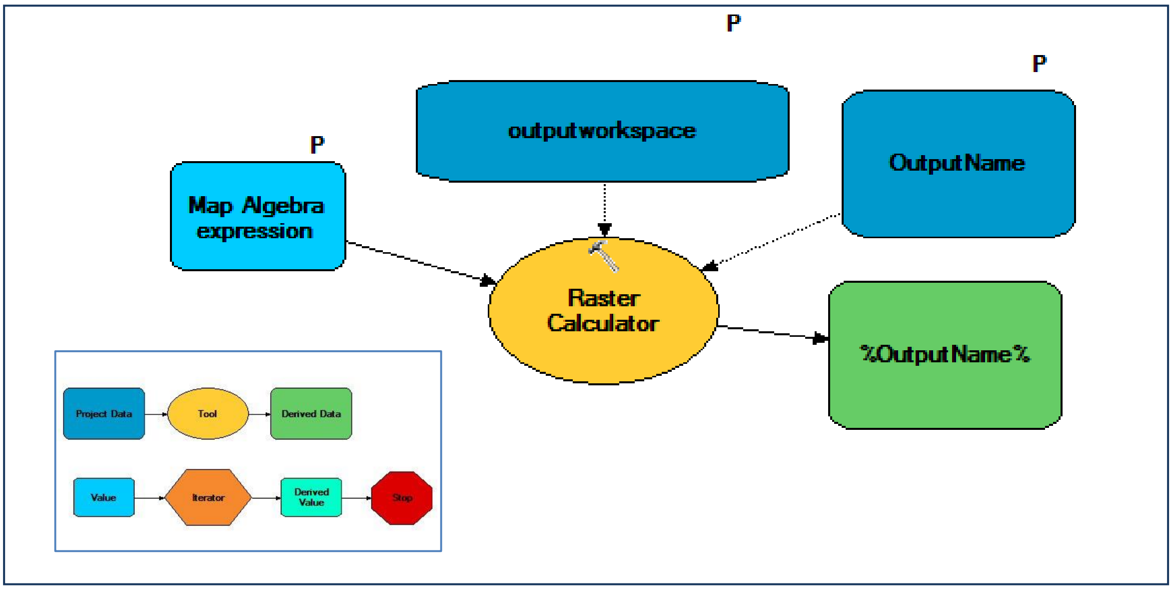
- Double click on the tool '**Tool SE d: Calculate annual mean precipitation from step c**'
- In the box which appears (see below), fill in the white boxes (parameters) accordingly.
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Map_Algebra_expression>	Add together the clipped precipitation rasters from step c and divide by the total number of months used (i.e. annual average will be 12 input rasters added together / 12)	Raster Calculator Expression
<outputworkspace>	Workspace in which to save the output	Workspace
<OutputName>	Name of new output average precipitation raster	Any value

Technical diagram



5. Tool SE e: Reclassify Precipitation Raster from step d

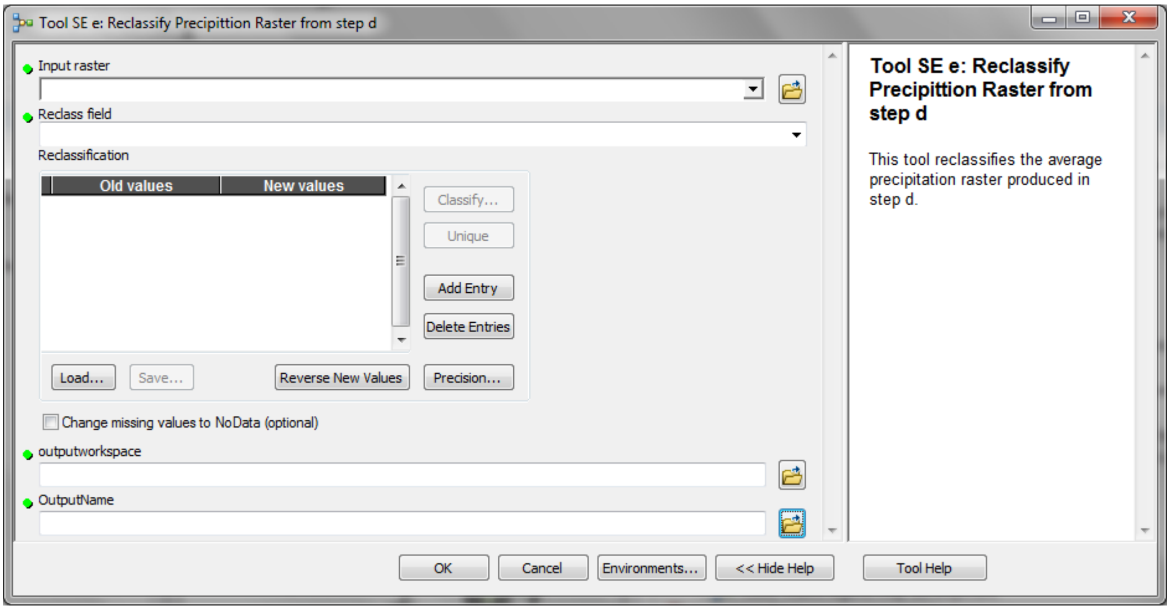
ArcToolbox — Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

- Reclassifies the precipitation output from '**Tool SE d'** into 3 classes

How to Run the Tool

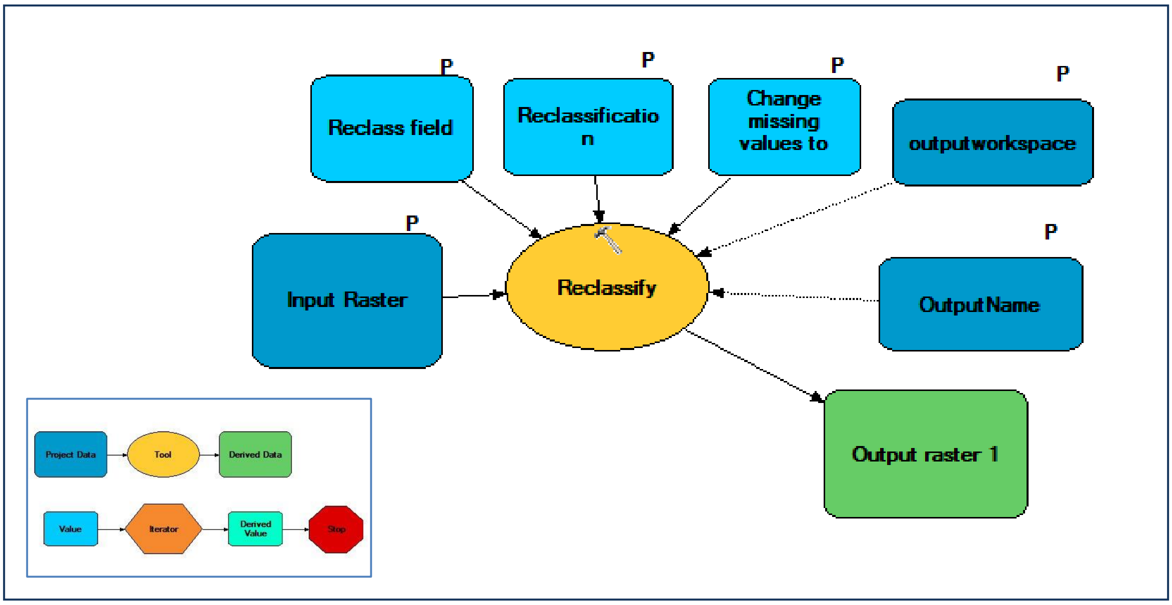
- Shade the precipitation raster in 3 classes to represent low - high (e.g. you could use define class breaks using a quantile or equal interval classification)
- Double click on the tool **Tool SE e: Reclassify Precipitation Raster from step d**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly. *Note: Once the input precipitation raster is selected, ArcMap will guess that the reclassification is the same as the 3 class shading you chose above.*
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Input_raster>	precipitation calculation raster from step d	Composite Geodataset
<Reclass field>	The field upon which the reclass will be based - i.e. the degrees or percentage value of the slope	Field
<Reclassification>	Reclass slope values into 3 classes	Remap
<Change_missing_values_to_NoData (Optional)>	Do not use	Boolean
<outputworkspace>	Workspace in which to save the output	Workspace
<OutputName>	Name of new output reclassed precipitation raster	Any value

Technical diagram



6. Tool SE f: Fill DEM from step a and generate hydrological datasets

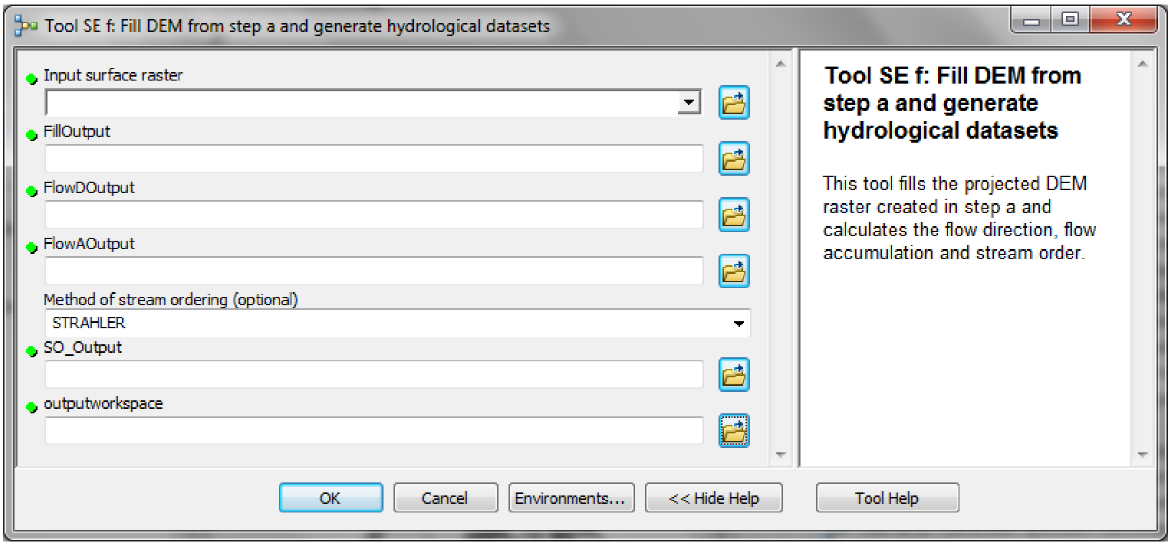
ArcToolbox Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

- Fill the DEM from step a
- Create flow direction raster from filled DEM
- Create flow accumulation raster from flow direction raster
- Create steam order raster from flow accumulation raster

How to Run the Tool.

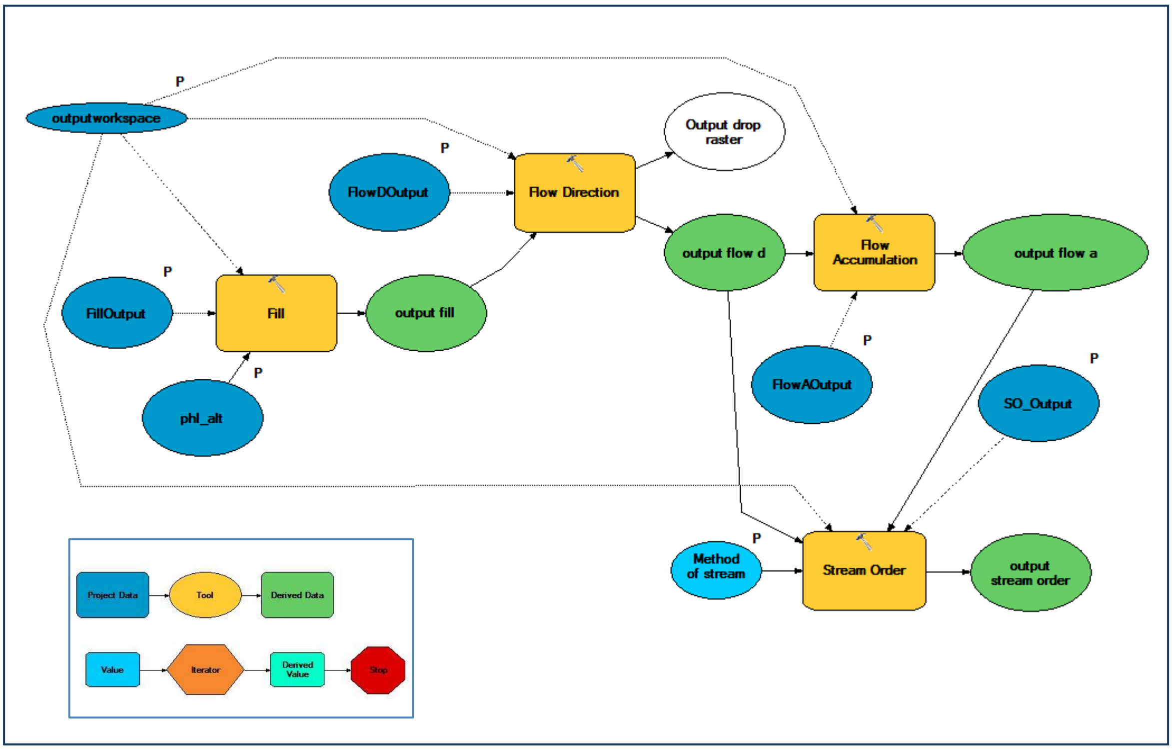
- Double click on the tool **'Tool SE f: Fill DEM from step a and generate hydrological datasets'**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly.
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
Input_surface_raster	Projected DEM raster output file from step a	Composite Geodataset
FillOutput	Name of the new filled DEM output raster	Any value
FlowDOutput	Name of thenewflow direction output raster	Any value
FlowAOutput	Name of the new flow accumulation output raster	Any value
Method_of_stream_ordering (Optional)	Leave as defaulrt i.e. STRAHLER	String
SO_Output	Name of the new stream order output raster	Any value
outputworkspace	Workspace in which to save the output	Workspace

Technical diagram



7. Tool SE h1: Convert Dam points and Lake polygons to raster (Dams and Lakes)

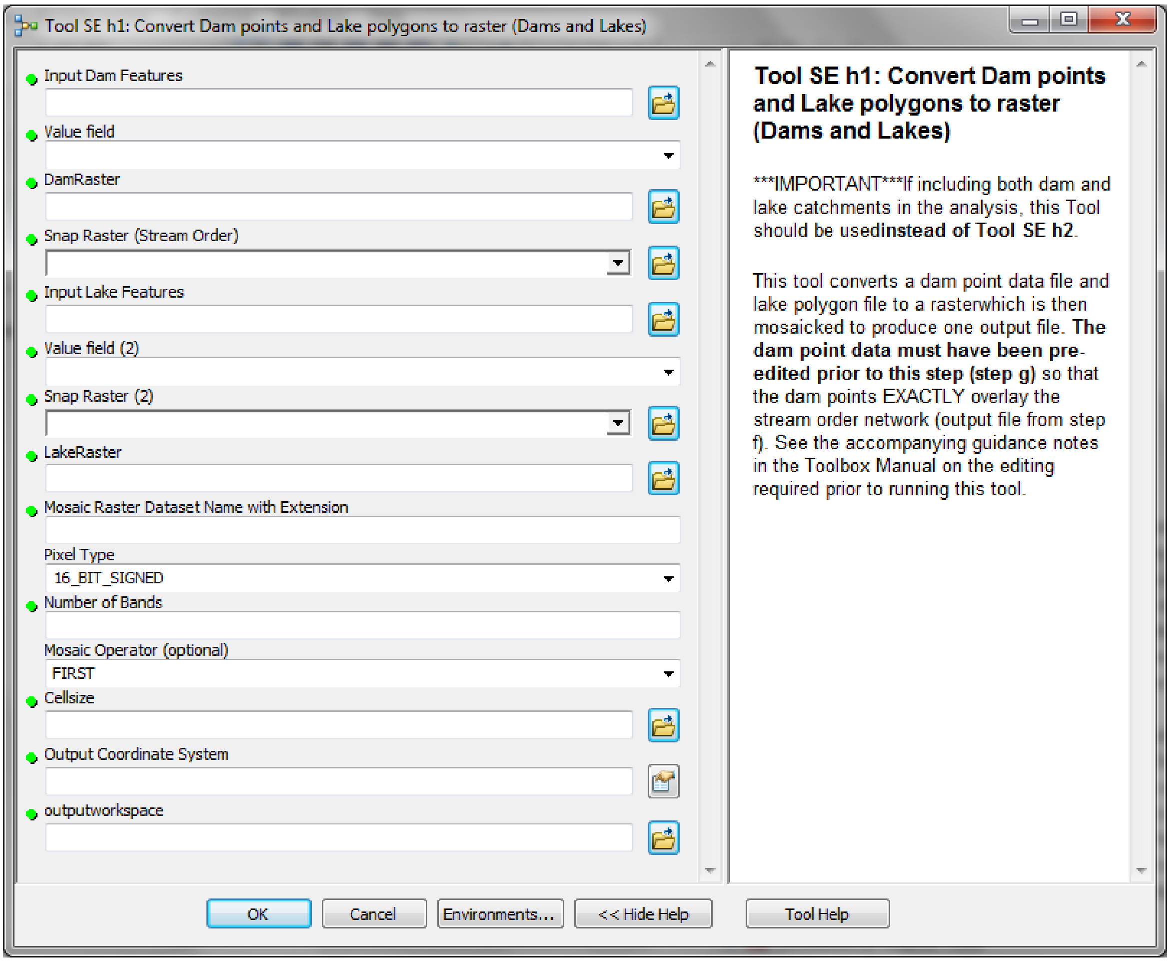
ArcToolbox — Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

- Convert the dam shapefile to a raster
- Convert the lakes shapefile to a raster
- Dams and lakes mosaicked into single raster

How to Run the Tool

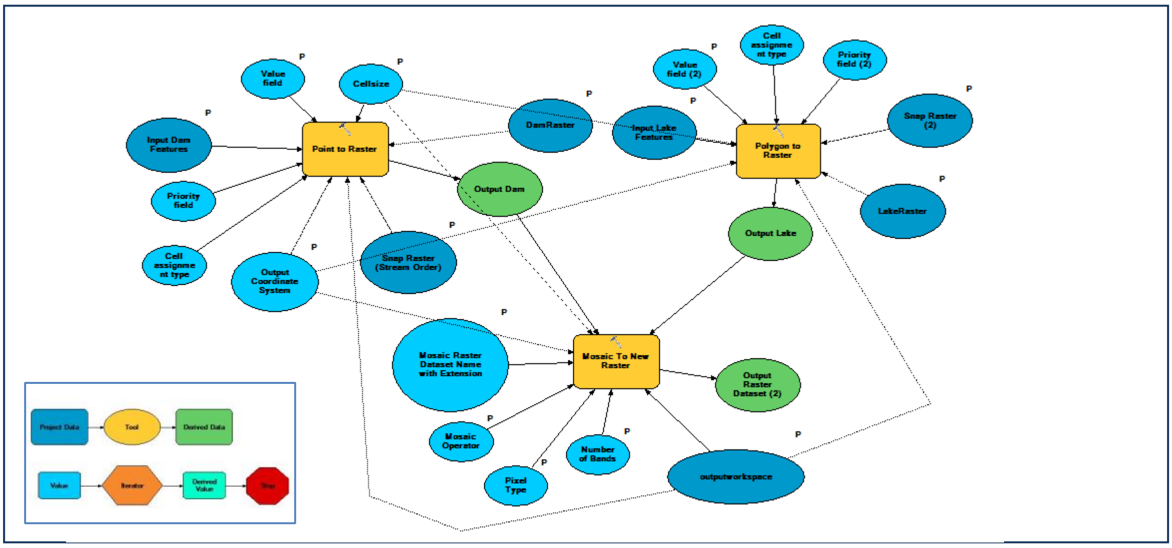
- Double click on the tool '**Tool SE h1: Convert Dam points and Lake polygons to raster (Dams and Lakes)**'
- In the box which appears (see below), fill in the white boxes (parameters) accordingly.
- Click OK to run the tool



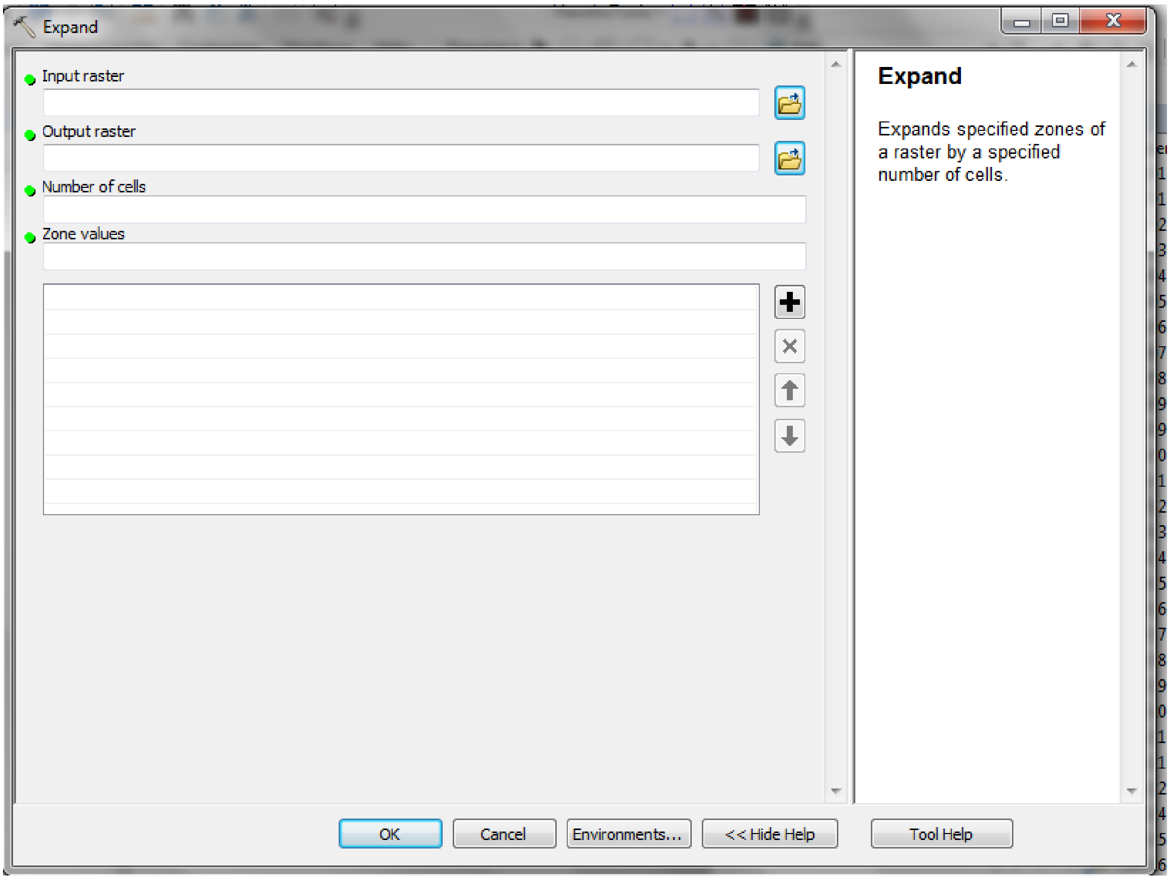
Parameter descriptions

Parameter	Explanation	Data Type
Input_Dam_Features	Edited dam point data file	Feature Layer
Value_field	A new field ID must be created in the point dam data file - Having a FID which contains a value 0 will not work to create dam catchments. See accompanying guidance notes in the Toolbox Manual on this step.	Field
DamRaster	The name for the newoutput dam raster	Any value
Snap_Raster__Stream_Order_	Set the snap raster to be the stream order raster output created in step f	Raster Layer
Input_Lake_Features	Input lake polygon file	Feature Layer
Value_field__2_	**A new field ID must be created in the lake polygonfile** - Having a FID which contains a value 0 will not work to create lakecatchments.These must be different values to those in the newFID created in the dam point file. See accompanying guidance notes in the Toolbox Manual on this step.	Field
Snap_Raster__2_	Set the snap raster to be the stream order raster output created in step f	Raster Layer
LakeRaster	Name for the new output lake raster file	Any value
Mosaic_Raster_Dataset_Name_with_Extension	Name for the new mosaicked dam and lake raster output	Raster Layer
Pixel_Type	16_BIT_SIGNED	String
Number_of_Bands	1	Long
Mosaic_Operator (Optional)	FIRST	String
Cellsize	Same as snapgrid	Analysis cell size
Output_Coordinate_System	Same as snapgrid	Coordinate System
outputworkspace	Workspace in which to save the output	Workspace or Raster Catalog

Technical diagram



8. Use the EXPAND tool in ArcGIS Spatial Analyst to ensure the dam points overlay the stream flow network correctly



You will need to first run « Reclassify » to reclassify all your dam points into one category after you convert your shapefile to raster

Input – dam points as a raster

Number of cells – This will be trial and error – The number of cells you need to expand your dam point by will depend on how far certain dams are from the stream order network. The dams need to expand to touch the nearest high order stream in order to generate the catchments correctly.

Zone value – 1.

9. Tool SE i1: Generates upstream catchments of dams AND water bodies from step 8

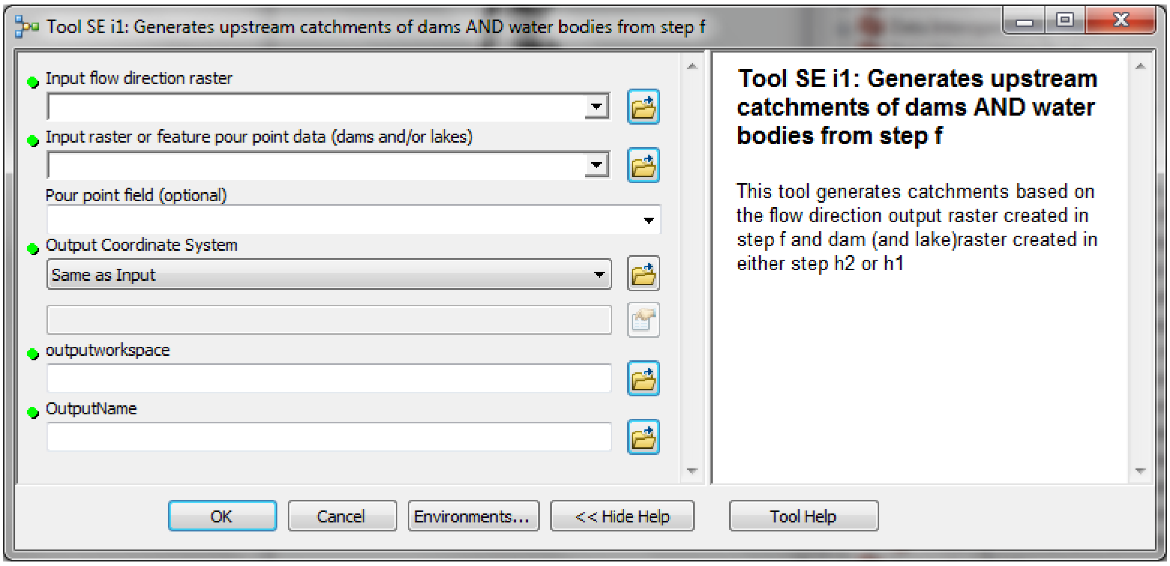
ArcToolbox — Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

- Generate catchments to determine the contributing area above a set of cells in a raster (i.e. the upstream catchment of dams and lakes)

How to Run the Tool

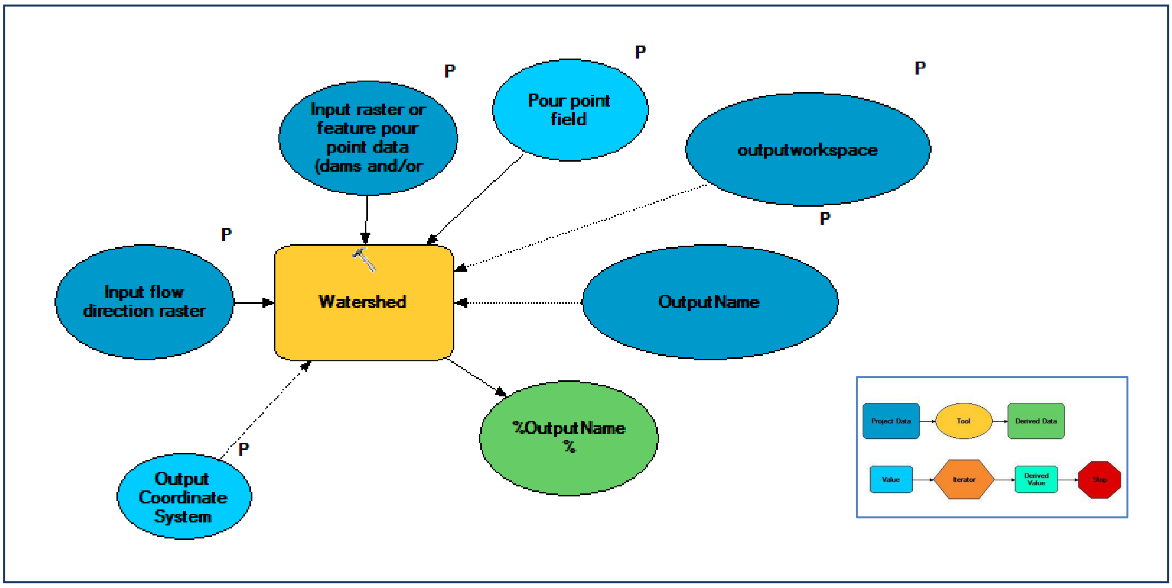
- Double click on the tool '**Tool SE i1: Generates upstream catchments of dams AND water bodies from step f'**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly.
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
Input_flow_direction_raster	Input flow direction raster created in step f	Composite Geodataset
Input_raster_or_feature_pour_point_data__dams_and_or_lakes_	The dams and lakes raster created in step h1	Composite Geodataset
Pour_point_field (Optional)	Optional - leave blank	Field
Output_Coordinate_System	Same as snapgrid	Coordinate System
outputworkspace	Workspace in which to save the output	Workspace
OutputName	Name for new upstream catchments output raster	Any value

Technical diagram



10. Tool SE j: Reclassify upstream catchments from step i

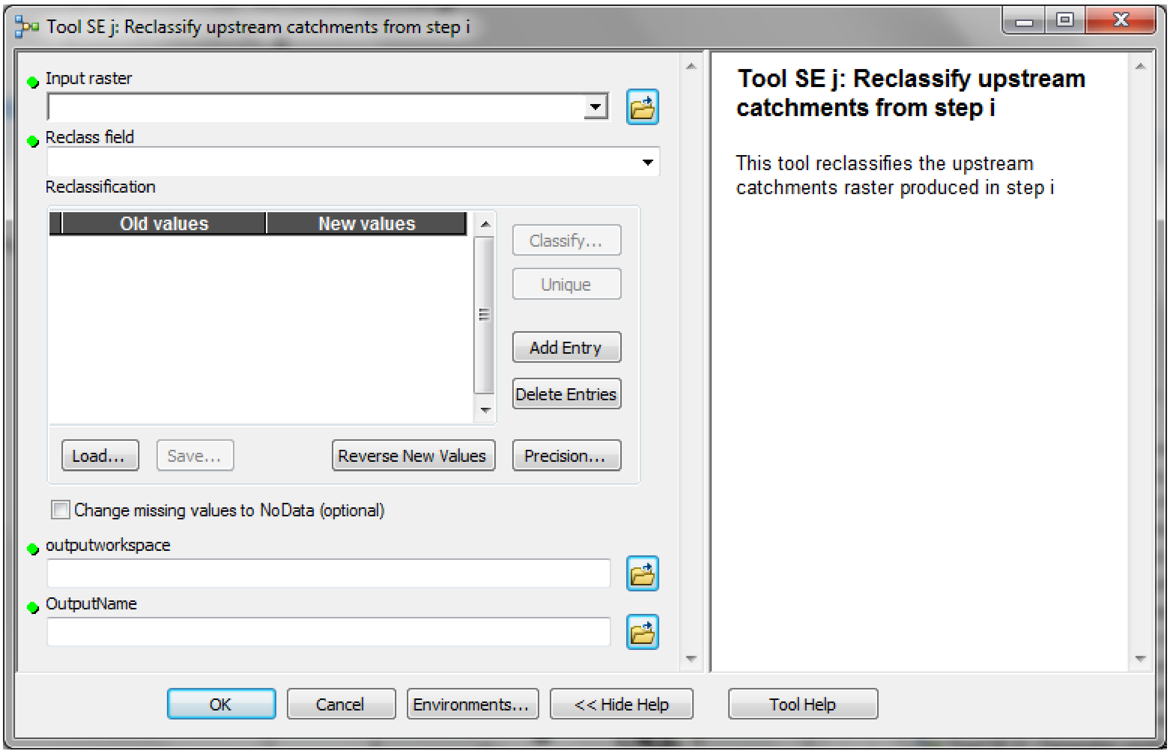
ArcToolbox Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

- Reclassifies the upstream output from '**Tool SE i'** into 2classes (1 = presence of dam catchment and 0 = not upstream catchment.

How to Run the Tool

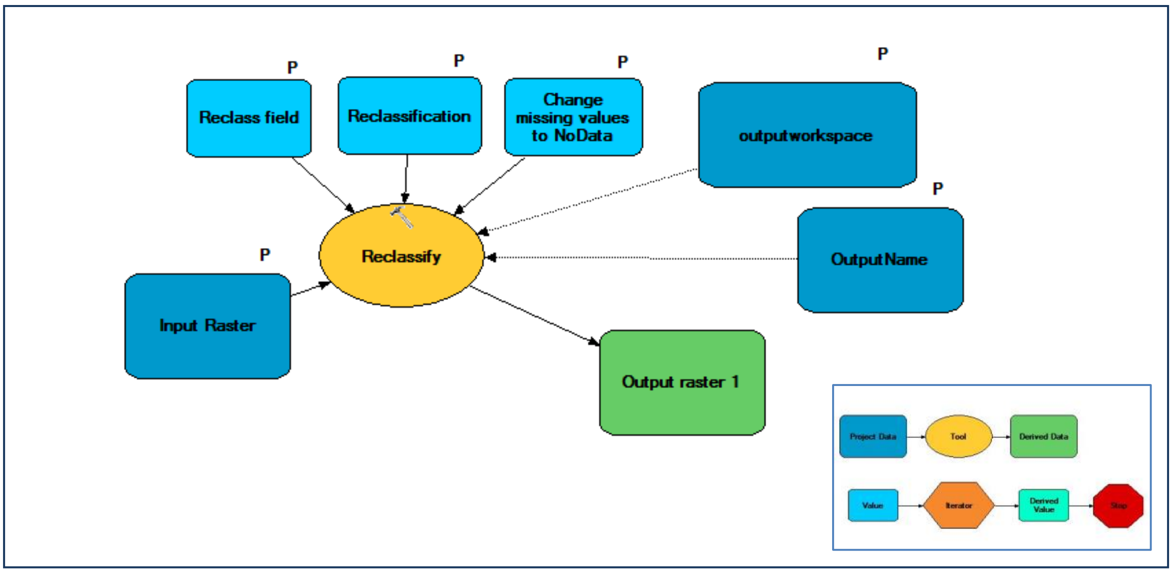
- Double click on the tool '**Tool SE j: Reclassify upstream catchments from step i'**
- In the box which appears (see below), fill in the white boxes (parameters) accordingly. *Note: Once the input catchment raster is selected, ArcMap will guess what reclassification so manually enter the values for the 2 classes.*
- Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Input_raster>	Upstream catchments raster produced in step i	Composite Geodataset
<Reclass field>	The field upon which the reclass will be based	Field
<Reclassification>	All the values for watersheds which contain a dam (and/or lake) should be reclassed to "1"	Remap
<Change_missing_values_to_NoData (Optional)>	Do not use	Boolean
OutputName	Workspace in which to save the output	Any value
<OutputName>	Name for new reclassified catchment raster	Any value

Technical diagram



11. Tool SE k: Sum outputs from b, e, and j and clip to forest extent

ArcToolbox Exploring Multiple Benefits toolbox

This tool undertakes the following steps.

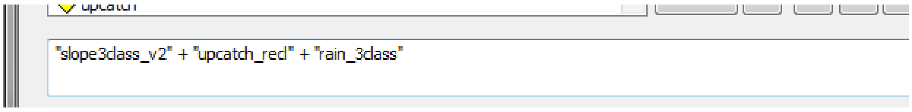
- Sum outputs a, e, and i to create a new raster
- Clip the new raster (result of sum) to forest extent

An additive 'importance of forests for soil stabilization and limiting soil erosion' layer is created using this overlay approach with the data prepared in the above tools. Since there are 3 classes for slope (1-3) , 3 classes for mean annual or wet season precipitation (1-3) and 2 for the presence or absence of a dam catchment (0-1) there is a maximum of 8, and a minimum of 2, and therefore 7 classes.

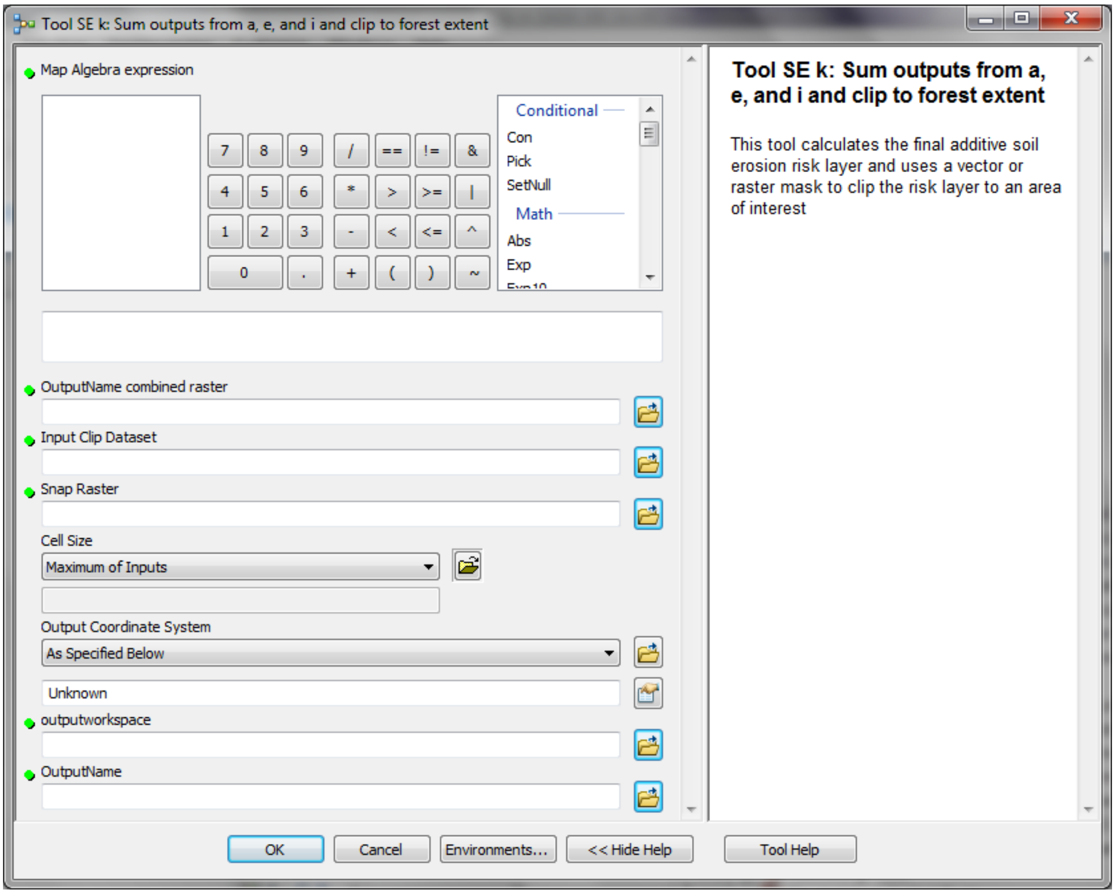
How to Run the Tool

- ❖ Double click on the tool '**Tool SE j: Reclassify upstream catchments from step i'**
- ❖ In the box which appears (see below), fill in the white boxes (parameters) accordingly.

  (Map algebra example below)



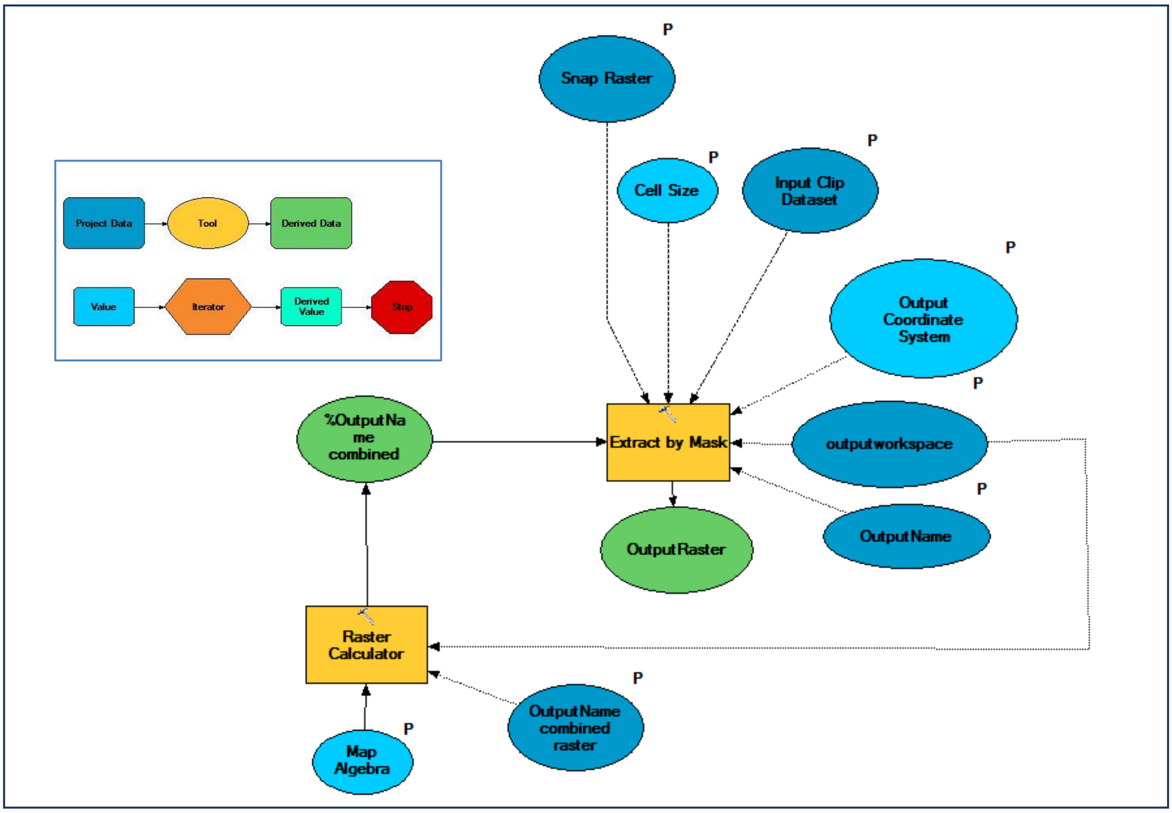
- ❖ Click OK to run the tool



Parameter descriptions

Parameter	Explanation	Data Type
<Map_Algebra_expression>	Add together the reclassed rasters from steps b; e and j	Raster Calculator Expression
OutputName_combined_raster	Name for the new soil erosion risk output raster	Any value
Input_Clip_Dataset	Vector or raster mask to clip the risk layer to an area of interest	Composite Geodataset
Snap_Raster	Set the snap raster to be the stream order raster output created in step f.	Raster Layer
cell_size	Set the cell size to besame asthe stream order raster output created in step f.	Cell Size
Output_Coordinate_System	Coordinate system of the output Raster dataset (this will be the same as the Snap Raster)	Coordinate System
outputworkspace		Workspace
OutputName	Name of the new output raster dataset	Any value

Technical diagram



END

Example map for Panama