GIS training module – Lesson 9

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Lake Tanganyika Regional Integrated Management Project

A United Nations Development Programme (UNDP) / Global Environmental Facility (GEF) project covering the Lake Tanganyika riparian countries, Burundi, the Democratic Republic of Congo, Tanzania and Zambia.

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LESSON 9 – Decision support for identifying landscape erosion risk

Lesson overview

In this lesson you will learn about different using GIS for participatory decision support, specifically to use multiple criteria to evaluate the landscape erosion risk. This lessons draws on the previous lessons to create a set of criteria factors that are then combined to evaluate the areas most susceptible to erosion. The criteria (or drivers or agents) include both biophysical and socioeconomic factors.

Note on how to do this lesson

If you want to do this lesson properly you should start by doing an iterative decision process for identifying and weighting factors (drivers or agents) that you feel contributes to erosion susceptibility. This is descried on this and the next page. Only when you have filled the table on the next should you proceed with the implementation in DIVA-GIS on the following page. If you continue reading beyond next page, you will learn how to implement the decision result, but you will also see factors and weights derived at a workshop held in Kasulu, Tanzania in September 2010. Seeing these factors might bias your own ideas of factors contributing to erosion. To do an independent evaluation you should rather not look at these results. Only when you have your own factors and weights you should continue the lesson, and use the approaches in the latter half of the lesson to derive your own decision factors and their weights.

Introduction to spatial decision support

The first step in spatial decision support is to define the spatial issue that is to be addressed. This can for instance be the problem of drawing the path of a new road, finding the optimal location for a certain activity, or for identifying the most likely area for finding a certain resource or problem. This lesson will try to locate the areas most susceptible to erosion in the Lake Tanganyika Basin. The problem of

identifying areas of susceptibility to erosion can be approached either as an engineering problem, or as a participatory decision process. In the engineering approach a statistical or numerical model is applied to (biophysical) data and the result will be a map showing the erosion (for example in tonnes of soil loss per hectare and year). The advantage with the engineering approach is that it will generate precise results, but it demands a lot of data and cannot consider non-biophysical factors. The participatory decision support approach utilizes expert opinions also for non-biophysical criteria. It also has the advantage of being less data hungry. The result will not be quantitative, but a susceptibility or risk map with ranked values. The approach used in lesson 6 was based on expert opinions on erosion factors, whereas in this lesson you must decide the drivers (factors) of erosion yourself.

One approach to participatory decision support is the use of Multi-Criteria Evaluation (MCE). The first step in the MCE is to identify the factors (agents or drivers) that can be used for identifying a spatial solution, in this case for identifying areas susceptible to erosion. Ideally such a decision support exercise should be repeated each time as a step identifying factors contributing to erosion.

Deriving and weighting decision factors

When creating the decision factors, it is advisable to either create a special folder for storing the data. When joining the factors in the final Multi Criteria Evaluation (MCE) you need to have the factor maps in the same folder. In this Multi Criteria Evaluation lesson, we suggest that you aim for 4 to 6 factors that are to be derived in consensus as drivers or agents causing increased risk of soil erosion. To assign weights to each factors, you need to do a pair-wise comparison of each factor-pair. You do that by filling in the factors in the table below, and then fill in the pair-wise weights in the upper right half of the table. The first figure in each cell refers to the row factor, the second to the column factor.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1		2\3	1\1	…	…	…
Factor 2			…	2\3	…	…
Factor 3				…	…	2\3
Factor 4					…	…
Factor 5						5\2
Factor 6						

Once the pair-wise weighting is done, you can derive the normalized weight (i.e with the weights summing up to 1). For the numbers given in the table above the factors are given below.

Factor	Weight
Factor 1	0.08
Factor 2	…
Factor 3	...
Factor 4	...
Factor 5	...
Factor 6	0.14

Please do not proceed with this lesson until you have filled the table above independently!

The rest of this lessons assumes that you have derived independent factors and their relative weights. For illustrative reasons this lesson will use the results of a decision support workshop held in Kasulu, Tanzania in October 2010.

The 6 factors identified as the most important agents in increasing the risk for soil erosion included: terrain slope, vegetation cover, rainfall intensity, market access, land use practices and soil type. The pair-wise weighting of the relative importance gave the following result:

	Slope	Veg. cover	Rainfall	Market acc	Land use	Soil type
Slope		2\3	1\1	1\3	2\5	1\2
Veg cover			3\2	2\3	2\5	3\2
Rainfall				2\3	1\2	2\3
Market acc					2\5	5\3
Land use						5\2
Soil type						

Normalizing the result of the pair-wise weighting give the final weight of each factor:

Factor	Weight
Slope	0.08
Vegetation cover	0.15
Rainfall	0.09
Market Access	0.22
Land Use Practices	0.32
Soil type	0.14

Creating the decision factors

When creating the decision factors you first need to decide on a scale for the factors. In this lesson a scale from 0 (no erosion risk) to 100 (highest erosion risk) will be used. You can choose any scale, but either 0 to 100 or 0 to 255 is preferable. Some factors have the scale 0 to 100 by default (for example the percentage of slope is from 0 to 100, with 100 being the steepest). Other factors need to be rescaled or inverted.

Creating the slope factor

Slope is generated from a Digital Elevation Model (DEM). The DEM for Lake Tanganyika is under the folder /data_spatial/srtm/elevation.grd, Add this layer to your project, and make it the active theme. From the menu select Modeling – Terrain Modeling.
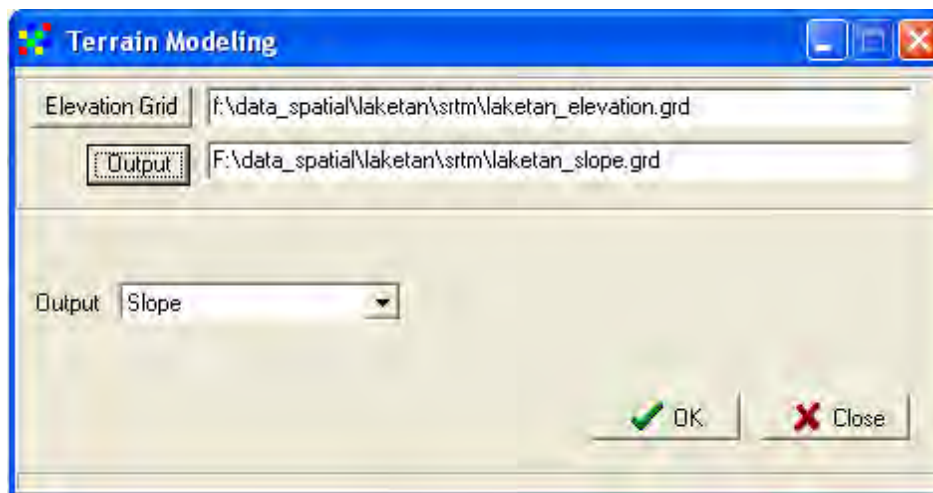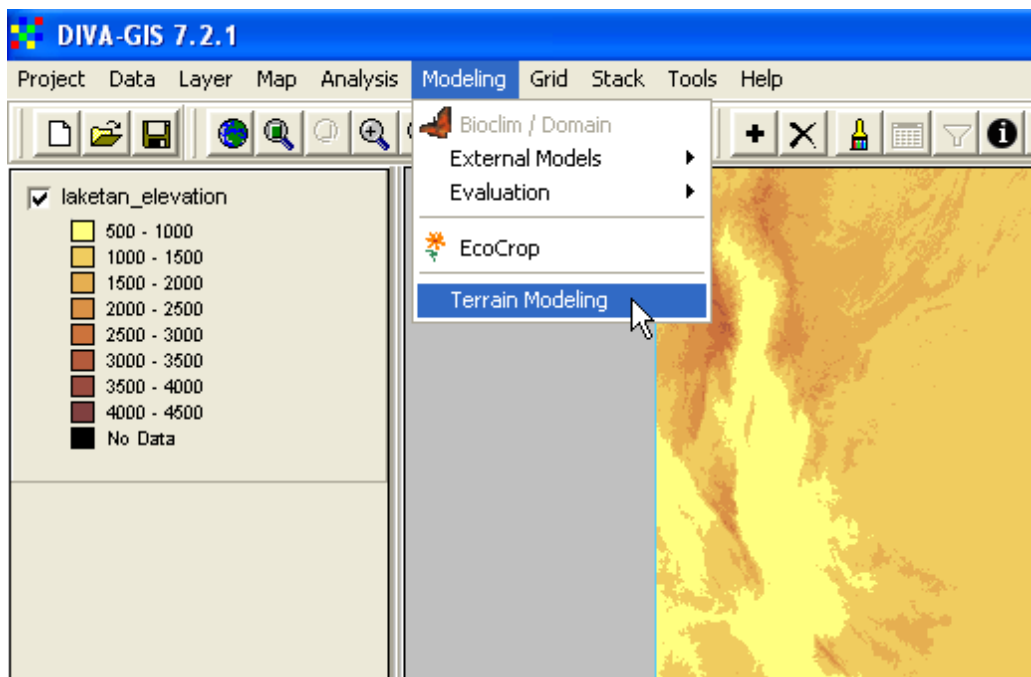
In the terrain modeling dialog select the elevation layer as the input and set the output to slope, and the output type Slope, then click OK to calculate slope. The slope map can be directly used as the slope factor for the MCE, so also make a copy for the folder where you will put all the factor maps.

Creating the rainfall factor

Rainfall influence on soil erosion is more related to short term rainfall intensity, rather than average rainfall levels. The rainfall intensity (usually 30 to 60 minutes durations are used for erosion modeling) is not available, and we will hence use average annual rainfall as a proxy for rainfall intensity. There are several rainfall layers included in the dataset over Lake Tanganyika Basin, the best being the rainfall estimate produced by the African Data Dissemination Service. This data is under /data_spatial/climate/rfe/ - choose the grid layer with the long term average resampled to fit the other factor maps (500m) resolution – precip500m.
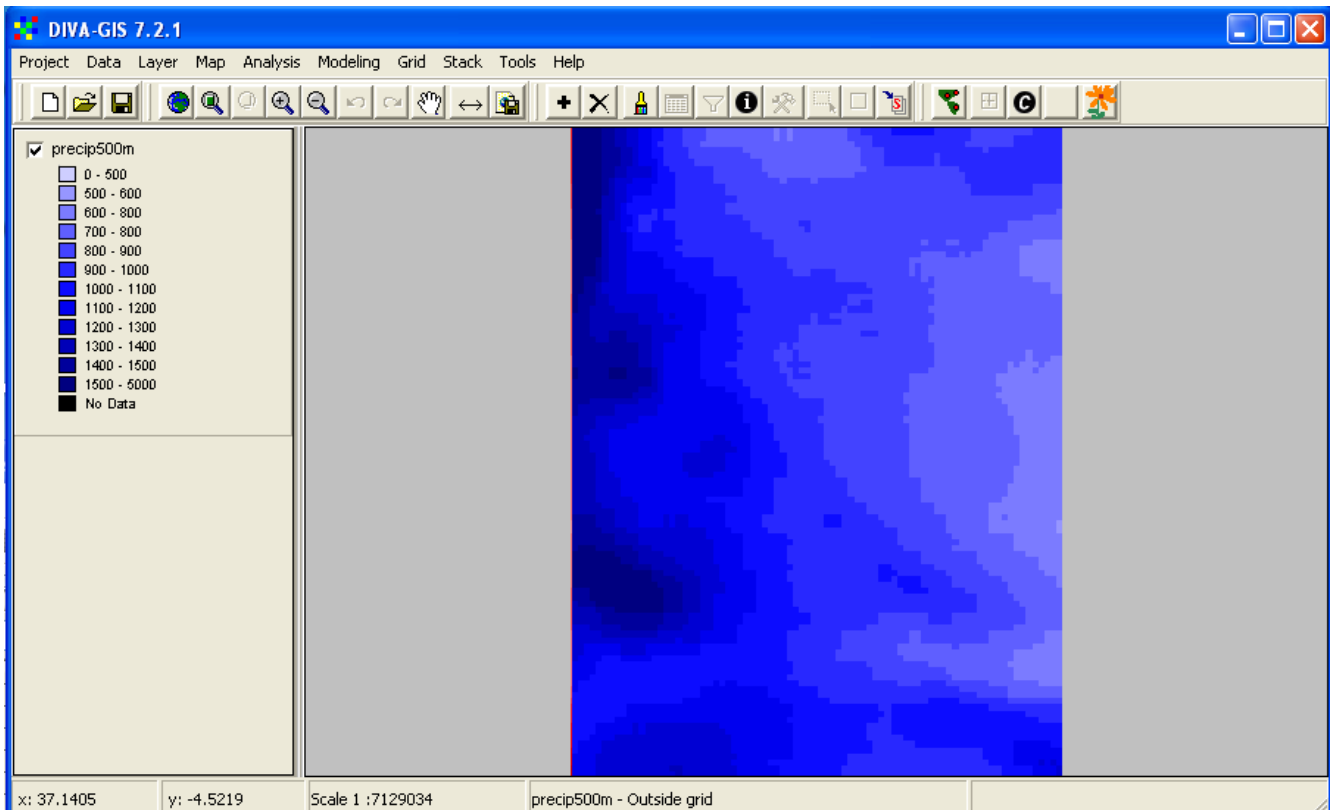
The more it rains the higher the erosion risk, so all you need to do is to rescale the rainfall map to range between 0 (no erosion risk) and 100 (highest erosion risk). To rescale the map use the menu: Grid – scalar to open the scalar operator.
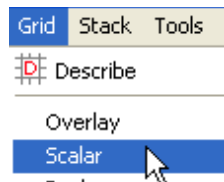
You can simply divide the rainfall (in mm per year) with a constant (50 in the example below) to force it to a scale between 0 and 100.
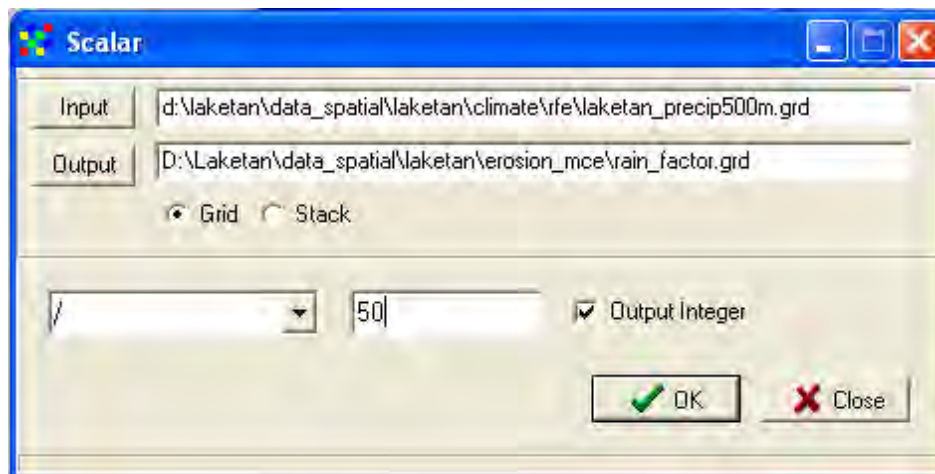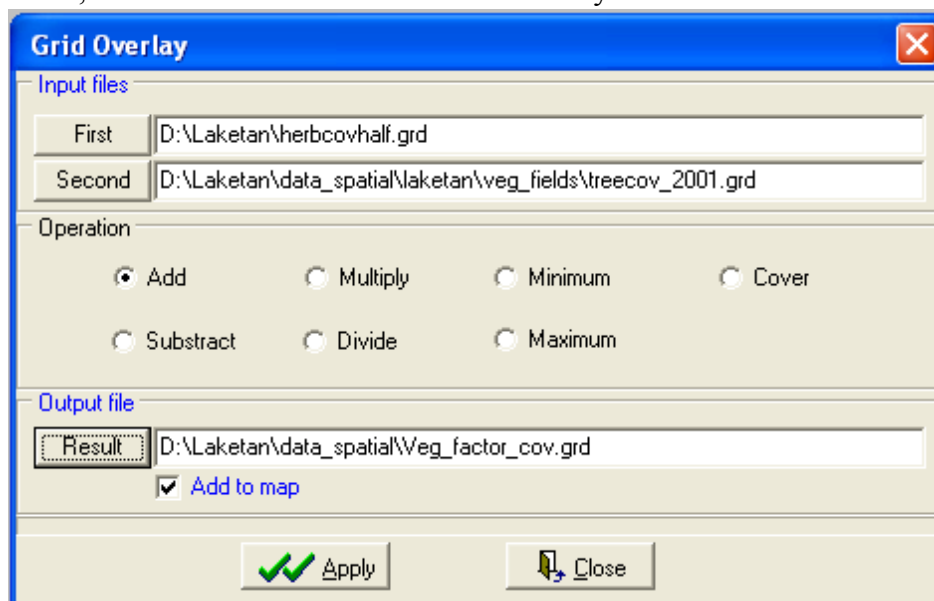
Creating the vegetation cover factor

There are several vegetation maps available in the dataset, Including the Enhanced Vegetation Index (EVI) and the vegetational fields (percentage tree cover, percentage herbaceous cover and percentage bare cover). You can use any of these layers to create the factor for vegetation cover. In the example below the percentage tree cover (/data_spatial/laketan/veg_fields/treecov_2001.grd) and the percentage herbaceous cover (/data_spatial/laketan/veg_fields/treecov_2001.grd) was used. The formula used to create the vegetation cover (VC) factor was:

$$VC = 100 - (treecov + herbcov/2)$$

To implement this formula you need to go through several steps.

In the example here, the herbaceous cover was considered less protective for erosion compared to trees by a factor of 2, and the herbaceous layer was hence divided by 2 prior to summing up the total vegetation cover factor. This is done under Grid – scalar, setting the operator to "/" and the number to 2 (see previous figure above). The result is only an intermediate file, so you can call it anything.

Next you need to calculate the sum of the tree cover and (half) the herbaceous cover. This you do with the Overlay function, available from the menu: Grid – overlay.


The resulting grid map will have high values where vegetation cover is high, but erosion risk is higher where vegetation cover is low, so you must invert the values before you can use it in the MCE. This can be done by first creating a new grid which has a value of 100 for all cells, and then subtract the vegetation cover grid from this grid. To create a new grid go to the menu: Grid – New. Use any of the grids you worked with above to use as template (Select Existing Gridfile for Parameters), click the radio button for Single Number and fill in 100, select an output grid and click apply.
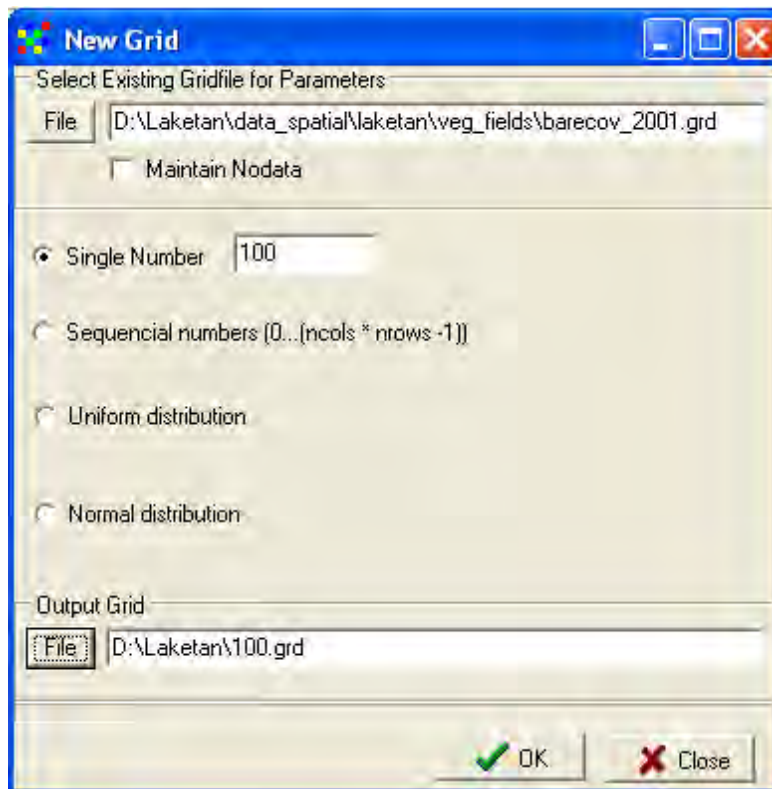
Again use the overlay function, and subtract the vegetation cover from the new file with the value of 100 in each cell.
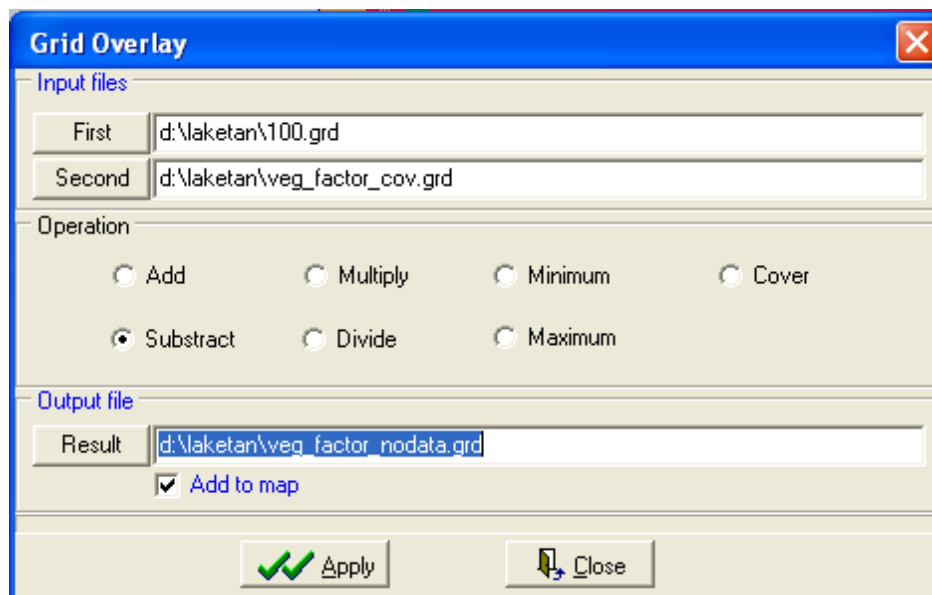

The result is almost ready to be used as the factor for vegetation cover in the MCE. The only thing remaining is the "Nodata" value from the original treecov_2001 and barecov_2001 grids. The Nodata in these grids are 253, and they will now have to be set to 0. If you followed the steps as described here, the Nodata from the original vegetation cover maps will have negative values (-279), You must reclass these negative number to a value of zero (0). To achieve this use the menu: Grid – Reclass. Put the result from the Reclass in the folder where you are storing the other MCE factors.
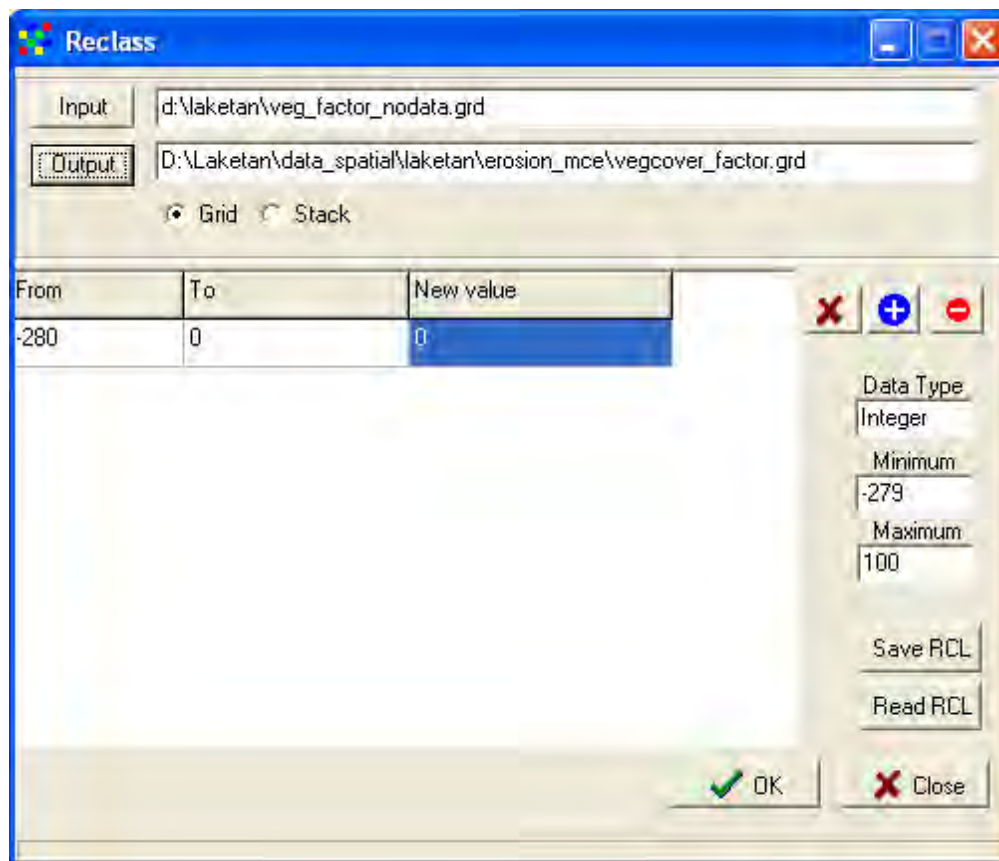
Creating the Market Access factor

Market access is dependent on infrastructure and population centers, and should ideally be produced from data on roads, income and population. This kind of data is more difficult to capture and not available in the dataset. Instead you will use population density as a proxy for market access. The population data is available under /data_spatial/population/afpopd00. The population density goes up to about 3500 persons per square kilometer in the Lake Tanganyika Basin. So we need to rescale this to fit the span 0 to 100. As area is a 2-dimensional entity, in the example here the square root of the population density was considered a candidate for representing market access. Use the scalar operator from the menu: Grid – Scalar.
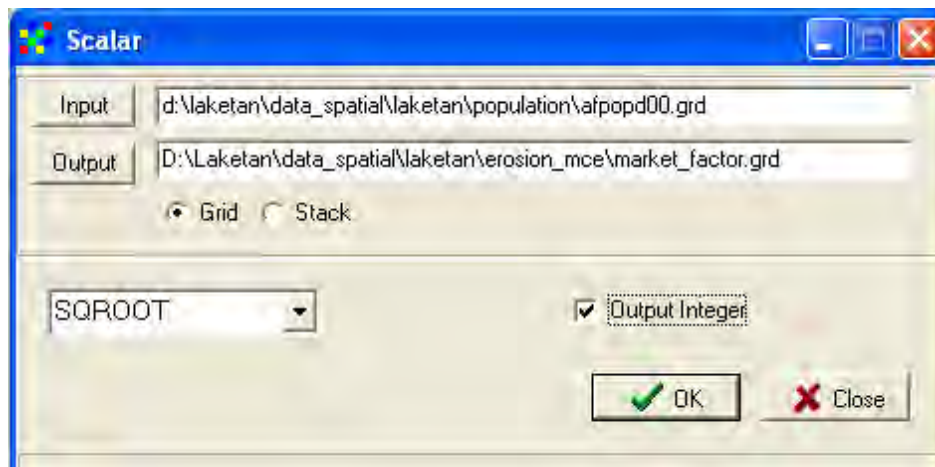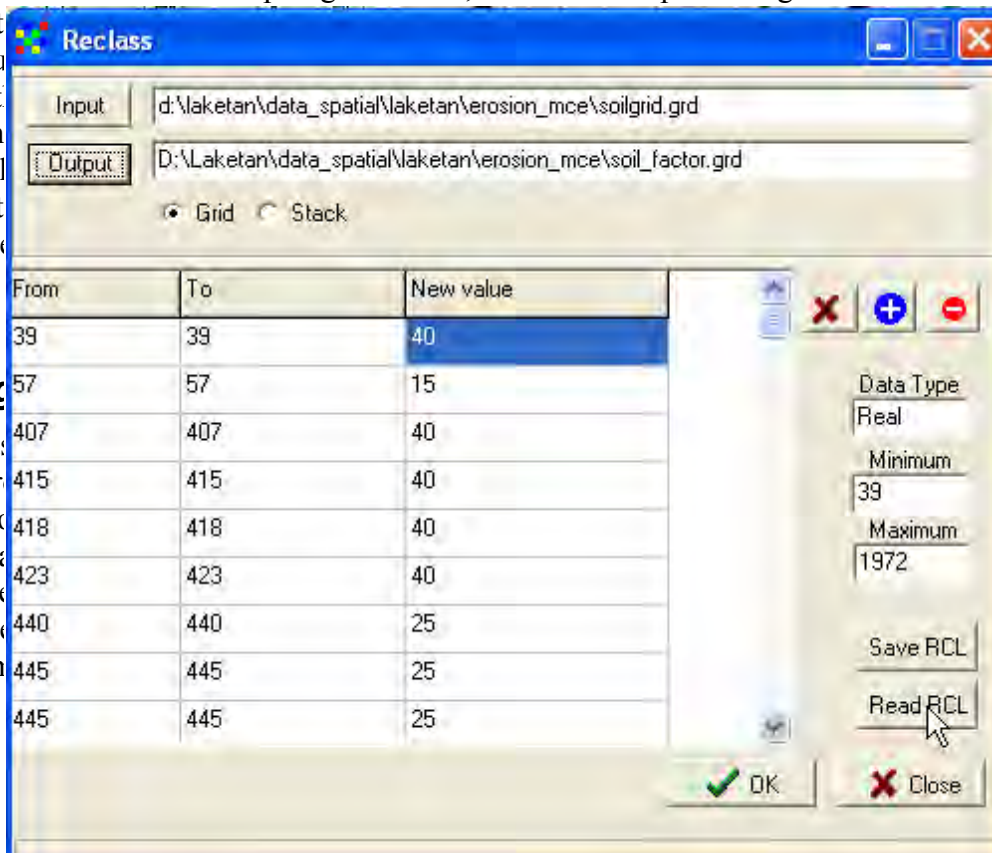
As population density is zero (0) in large parts of the basin (including in the lake itself) and the square root of zero is undefined, the resulting map will have large areas of Nodata. You can bypass this by either using reclass or scalar. But you can also leave it with Nodata, it will not affect the final result of the MCE if you follow these instructions to the point.

Creating the soil factor

The soil factor need to be created from the FAO soil map (/data_spatial/soil/vector/afscntll_fao.shp). First you must convert the vector file to a grid file with the same extent and resolution as the other factor maps. In DIVA you can convert a vector polygon to a grid (and vice versa). This operator is available under the menu: Data – Polygon to grid. Set the FAO soil map to the input file, any grid used above to the template, and select the field SNUM as the field to determine the cell values of the output grid. Select an output file and click apply.
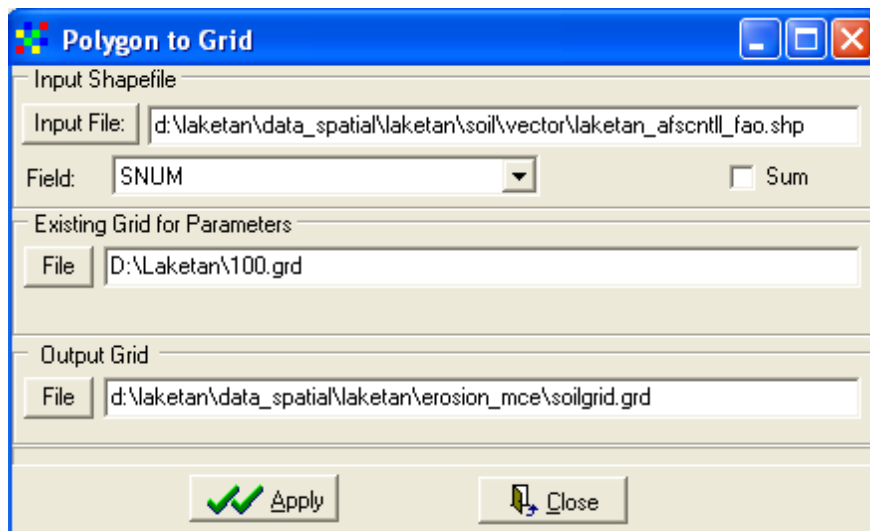
You should now have a soil map in grid format, with values representing the soil number (SNUM). You now need t̶[...]̶ re a soil expert, you[...] facilitate the reclass of t[...]ilable with the FAO soilm[...] active theme, and go to th[...]CL (see figure below), set[...] Click OK to preform th[...]

Creating[57]

The land u[...] This is different fr[...]ion on land cover and[...]nd cover data is under /da[...]vever reveal some of the[...]rid in your view. There[...]sceptibility to. In the exan[...]s.

Land cover	Erosion susceptibility
Water	0
Evergreen Needleleaf forest	10
Evergreen Broadleaf forest	10
Deciduous Needleleaf forest	10
Deciduous Broadleaf forest	10
Mixed forest	20
Closed Shrubland	30
Open Shrubland	40
Woody Savannah	40
Savannah	50
Grassland	60
Wetland	20
Cropland	80
Urban	100
Cropland/Natural mixed	70
Snow and ice	0
Barren or sparse	100

You can either enter this data in the reclass window, or load it from a pre-defined reclass file (/data_sparial/landcover/rsderived/lc-erosionrisk). You can change the values according to your own knowledge. When you have filled the reclass table click OK to execute the reclassification. The result should be put in the folder where you saved the other MCE factors.

Viewing the decision factors

You should now have 6 decision factors, and before applying the weight to each factor you should visually inspect them. Add all six factor to your view, and symbolize one of them. In the example the legend was set to contain 11 classes, one class of zero (0) susceptibility, and then 10 classes for values from 0 to 100. A color scale from white (0) to black (100) was ramped. This was done for only one of the factors, for the other factors, the color ramp was loaded from this template symbolized factor (the Read from File Button as indicated in the figure below).
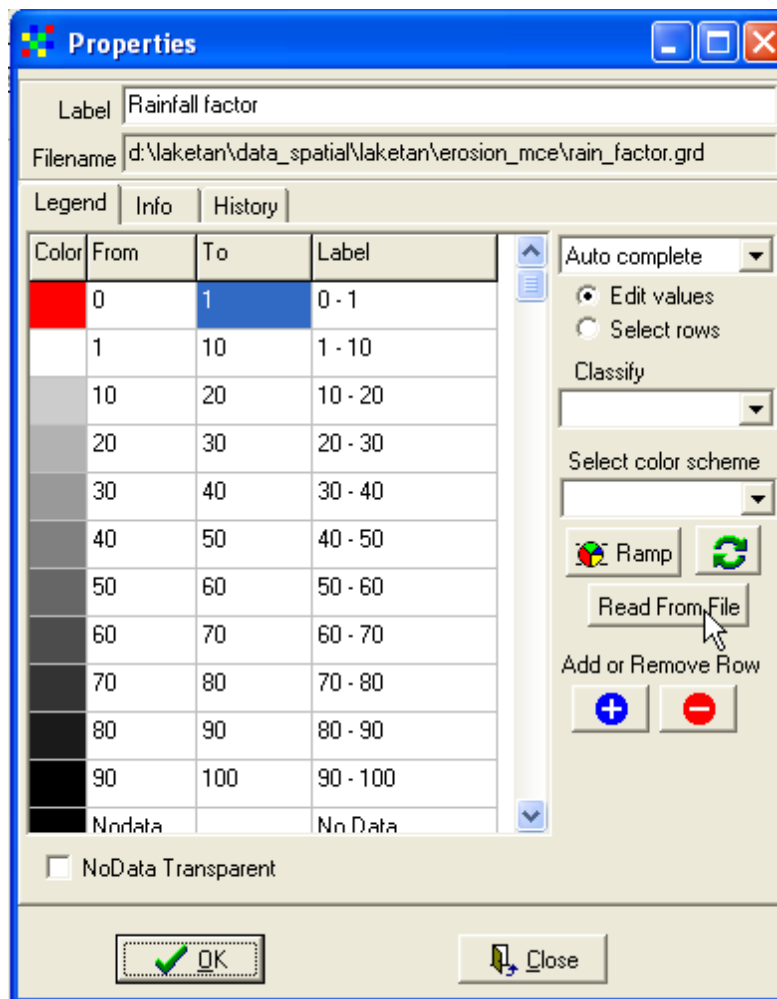
If you inspect the factors, they should all have the same size, and values from 0 to 100. If some factor is outside this range, or has a different size, you need to go back and remake it.

Assigning the factor weights

For each factor map you need to assign the relative weight. You can do that either with the calculator, or using scalar (both available under the menu: Grid). In the example, the scalar operator was used (as it is more stable under various operating systems). It is preferable to force the output to integer values. Repeat this for each factor, changing the numerical values to those given at the beginning of the lesson.

Scalar

Input: d:\laketan\data_spatial\laketan\erosion_mce\rain_factor.grd

Output: D:\Laketan\data_spatial\laketan\erosion_mce\rain_mce.grd

⦿ Grid ◯ Stack

* ▼ | 0.09 ☑ Output Integer

✔ OK   ✖ Close
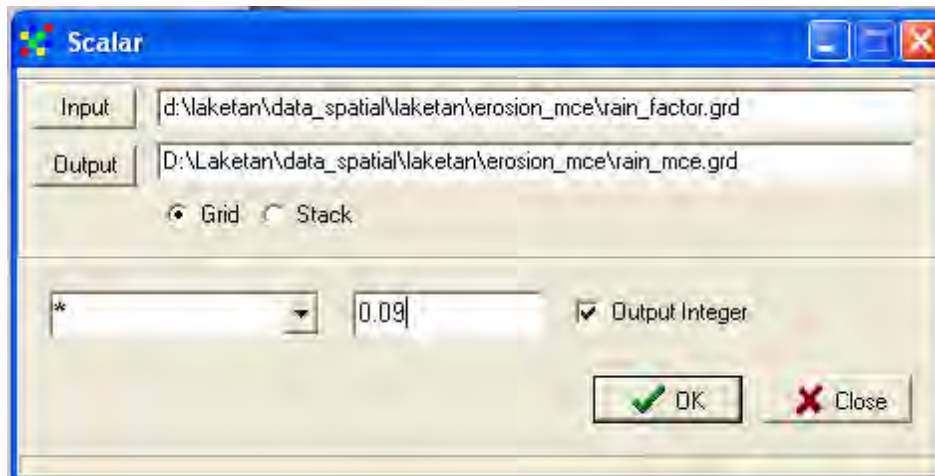
Performing the Multi Criteria Evaluation

To combine the weighted decision factors, start by creating a grid consisting of the six weighted factors (under the menu: Stack – Make stack).

Make Stack

Make Stack | Check Stack

Add Grid | Remove Grid | Remove All

File name	Rows	Cols	ResolutionX	ResolutionY	MinX	MaxX	MinY	MaxY
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.004500000	0.004500000	28.42835141	34.18835143	-9.81755914	-2.18555854
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559
d:\laketan\data_spatial\laketan\erosio	1696	1280	0.0045	0.0045	28.428351	34.188351	-9.817559	-2.185559

Stack | D:\Laketan\data_spatial\laketan\erosion_mce\mce.grs

✔ Apply   ✖ Close

The Rows and Cols, as well as MinX, MaxX, MinY and MaxY must be the same, otherwise the stack procedure will not work, If there is any anomalous gird, you must recreate it using the correct input. Make sure to click Apply to save the grid.

The final step in the MCE is to calculate the compounded erosion susceptibility index. With all the weighted factors in the stack, choose Stack – Calculate. Choose the stack you just created as input, set the calculation to be Sum, and click the option for NULL as zero (this will override any Nodata remaining in the input layers). Select an Output file and click Apply to perform the calculation.

Symbolize the result, and the erosion susceptibility evaluation is finished.

Erosion Risk Map

Watershed

0 ——————— 200
kilometers

Map produced from Multi-Criteria Evaluation
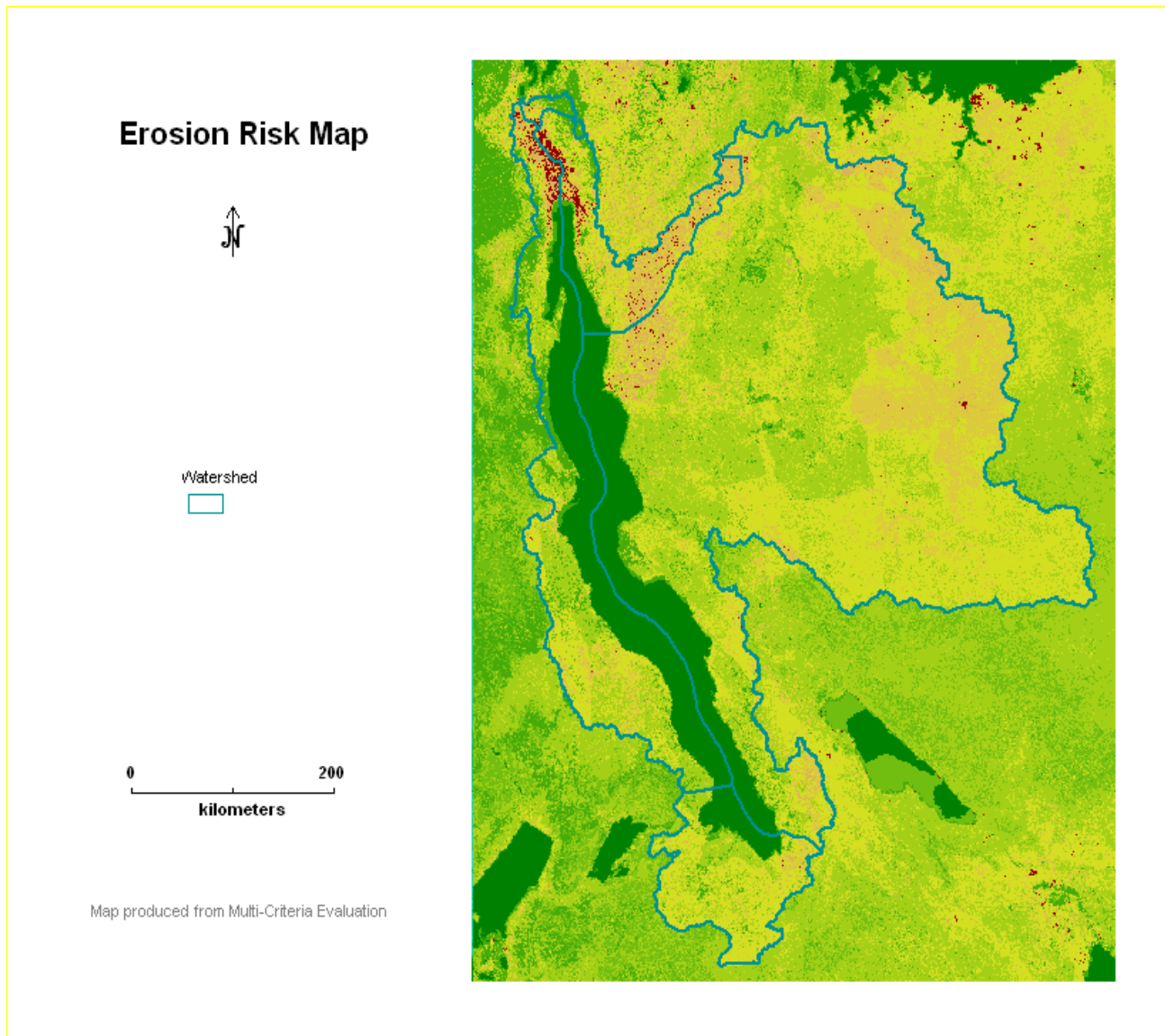
Interpretation of the Erosion risk Map

Using the stack tool of DIVA-GIS, it is possible to visually interpret the contribution of each factor to the risk value of each pixel. As learnt in previous lessons, the stack is plotted by following the procedure, on the view window of the main project, click on the Stack menu and the in the scroll down list select Plot. The stack file that was created to combine the Erosion factors is used in the analysis.