

Creating a DEM for the Gorongosa National Park, Mozambique from contours and spot heights

Introduction:

Imagine you have been asked to measure the elevation of an area the size of a football pitch. How many measurements you take will ultimately influence the quality of your survey. You could walk around randomly and measure 100 locations or if you had more time (and money) you could walk a regular grid measuring the elevation every 10m. If you were particularly wealthy you could fly over the area and survey using LIDAR! The important thing to note is it does not matter how much money or time you have, you are taking a sample of points. You can never cover every single location in space.

Interpolation is the mathematic process of extrapolating values from known values to the surrounding un-sampled locations. Interpolation is based on the idea that points that are close to one another in space have similar values than ones further away. There are two types of interpolation: deterministic and stochastic. Deterministic techniques are based on mathematical functions to calculate the surface. Stochastic techniques determine the statistical relationship between sampled points and use this information to predict parameter values for unmeasured points.

Three commonly used interpolation techniques are inverse distance weighting (IDW), spline and kriging. There are many other techniques; some considered superior over others.

Interpolation can be used to visualise surfaces of elevation, temperature, pressure, light; in fact anything which can be modelled using a continuous surface. But just how good are they, especially when comparing different techniques?

Scenario:

You wish to investigate patterns of soil erosion caused by recent forest clearance around the Gorongosa National Park in Mozambique. Because there are no direct measurements of soil erosion, you plan to use the Universal Soil Loss Equation for Southern Africa to estimate soil loss. This equation can be calculated within a GIS, but to use it, you need to have slope data – and to obtain slope data, you need a Digital Elevation Model (DEM).

In this exercise, we will create a DEM using one interpolation technique and then explore the results. The objective of the exercise is therefore to understand how DEMs can be created from contour and spot height data.

Data:

You have been supplied with the following four shape files:

- **spothts**: spot heights for the study area in metres above sea level. Note that the elevation value is in the **data_value** field.
- **Contours_moz**: contours for study area in metres above sea level. Note that the elevation value is in the **data_value** field.
- **Contours_moz2**: ancillary contours for study area in metres above sea level. Note that the elevation value is in the **data_value** field.
- **Drainage_moz**: surface drainage features (rivers and streams) for the study area.

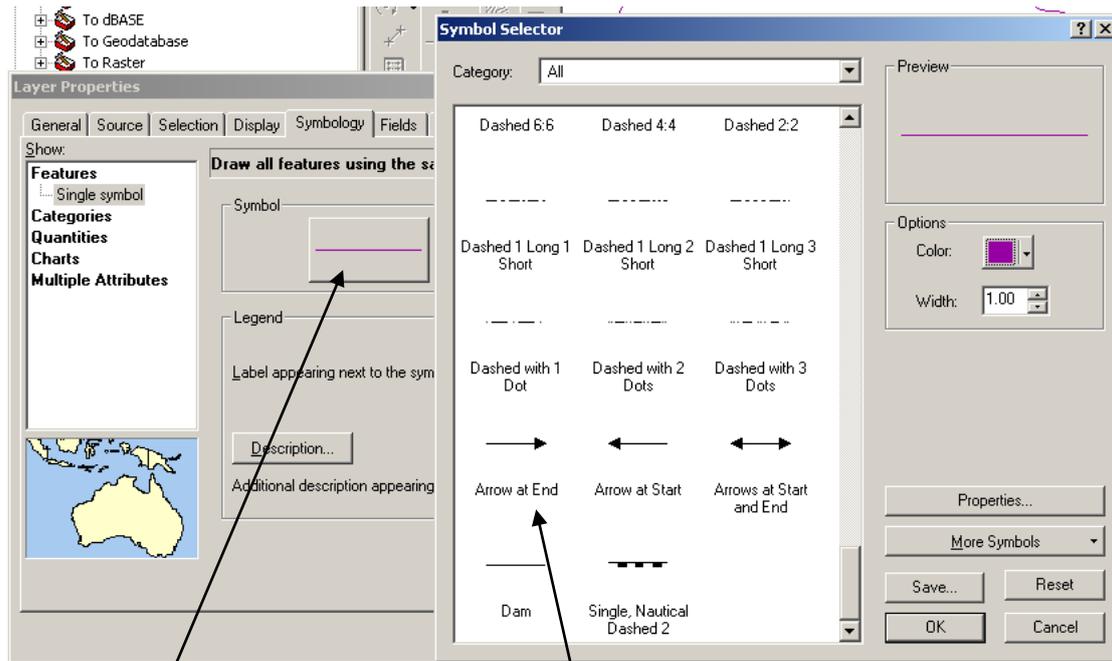
All of these data are in the UTM Zone 36 (South) projection, and make use of the WGS 1984 datum.

Pre-processing the data

The first technique that we will use is based on Hutchinson (1989)'s ANUDEM algorithm (an algorithm is an explicit step-by-step procedure for producing a solution to a given problem), implemented in ArcView as the *topo to raster* tool. The key feature of this method of interpolating contours is that it also takes into account the location of surface drainage features. The method used to create the DEM ensures that rivers and streams always flow downhill.

For the algorithm to work, all the drainage lines need to have been digitised in a particular order, starting at the uphill end and finishing at the downstream end. We will start by checking that this is the case:

- open up all of the data in ArcMap and familiarise yourself with it;
- right-click on the **drainage_moz** shape file and choose *properties*, then click on the *symbolology* tab.
- Click on the button next to *symbol* (see below) and then when the *symbol selector* window comes up, scroll down to the 'arrow at end' symbol and select it (see below).

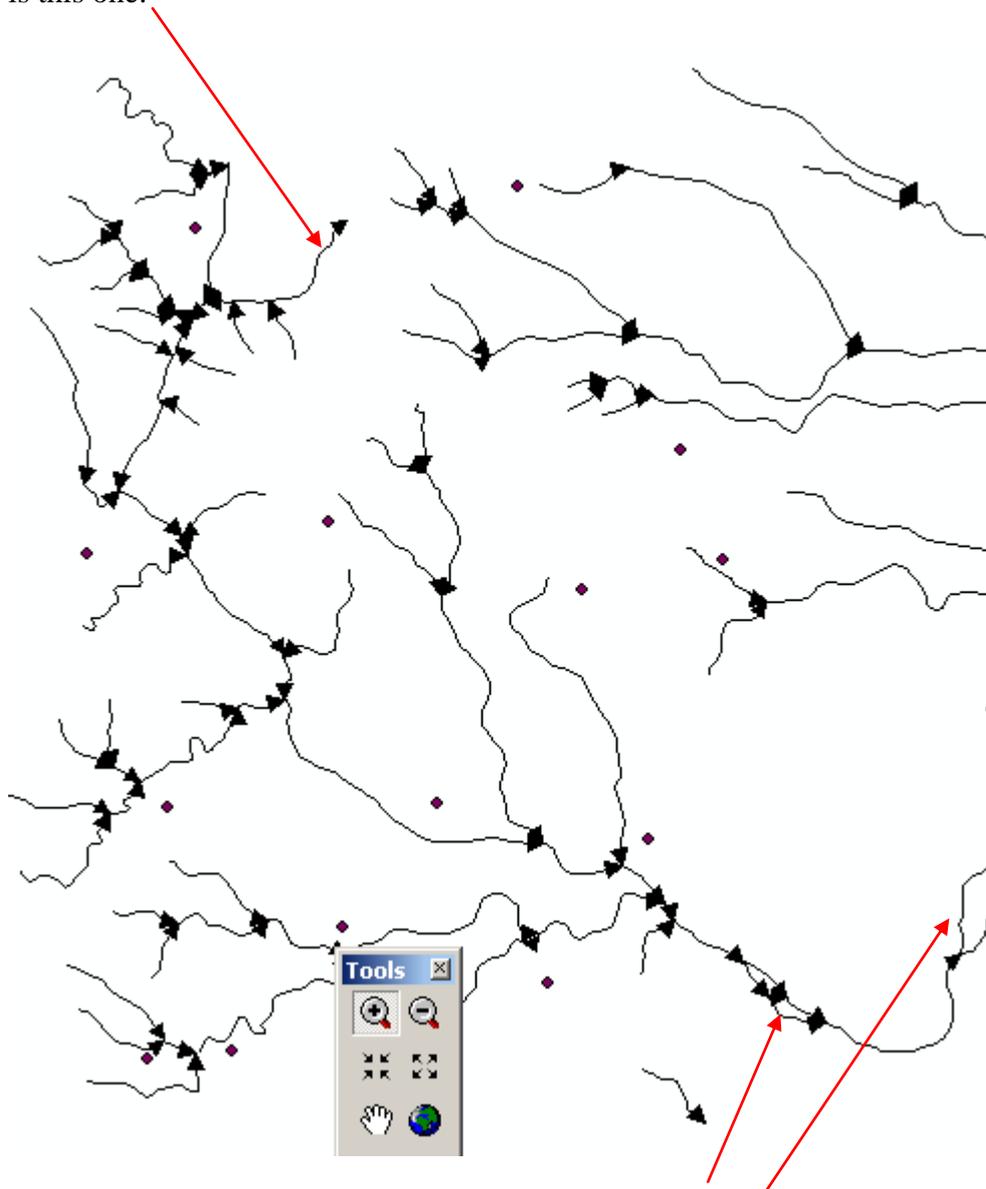


Click on this button..

...and choose this symbol

You should now be able to see the direction of flow of the various sections of stream and river. Most should be digitised starting at the uphill end and finishing at the downhill end – one, however, has not been. Before turning overleaf, can you identify which stream section has not been digitised in this way?

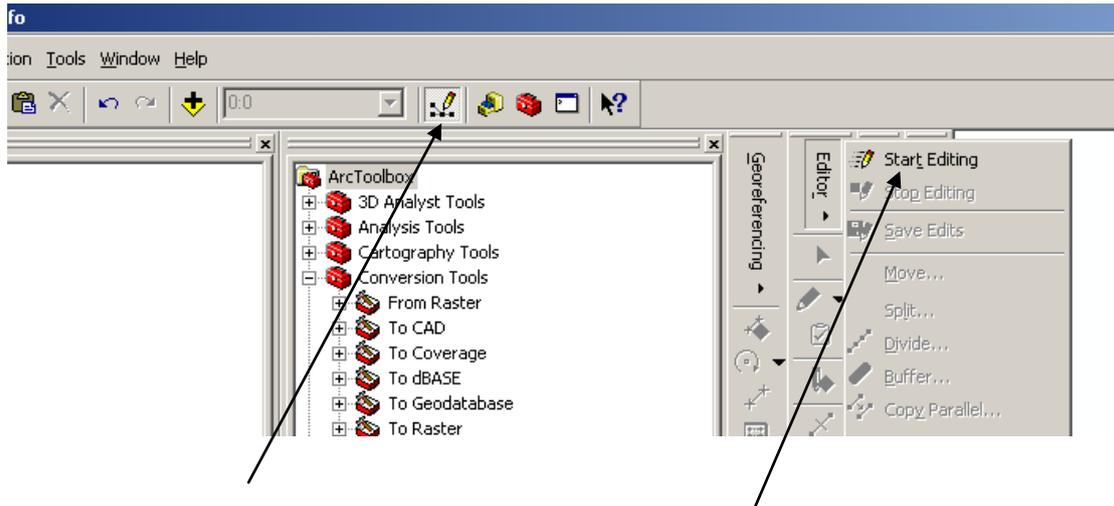
The stream section that has been digitised in the reverse direction (downhill to uphill) is this one.



Note that in some places, there is also evidence of braiding in river channels. Braiding can also cause problems with the *topo to raster* algorithm, so we also need to delete these braided sections before going further.

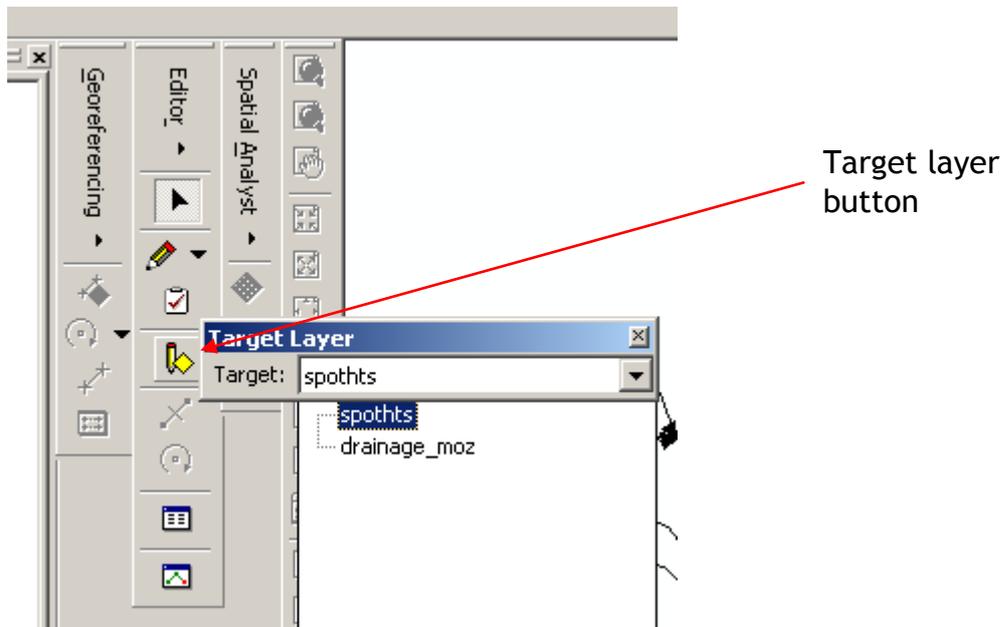
To do this, we need to start editing the **drainage_moz** map layer:

- Make sure that the editor toolbar is visible by clicking on the appropriate button (see below)
- Click on *editor* and choose *start editing* (note that this toolbar may appear in a different place on your screen, depending on how your computer is configured).

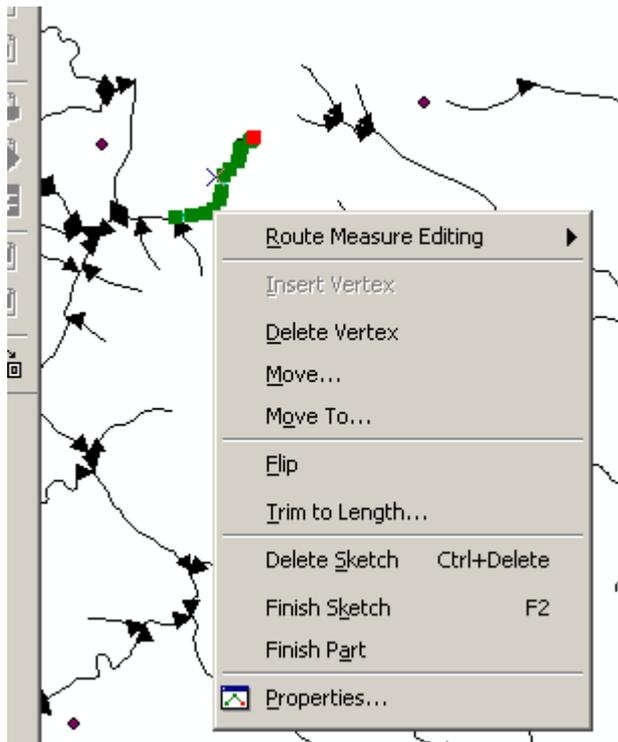


Press this button to view editor toolbar ...here is the toolbar

Click on the *target layer* button and select **drainage_moz** as the shape file to work with:



- Double-click on our stream section that runs in the wrong direction and you should see it change colour. Each vertex along the line is shown in green, whilst the line's end point appears as a red dot.
- We can fix this problem fairly easily: right-click on the selected line and choose *flip*. You should now see the red dot switch from the uphill end of the line to the downhill end of the line.



- In much the same way, we can delete braided sections from our river network. To delete braided sections, simply click on the relevant section of line (it should appear highlighted, usually in blue) and then press the *delete* key on your keyboard.
- When you are finished, click on the *editor* toolbar again, choose *save edits* and then *stop editing*.

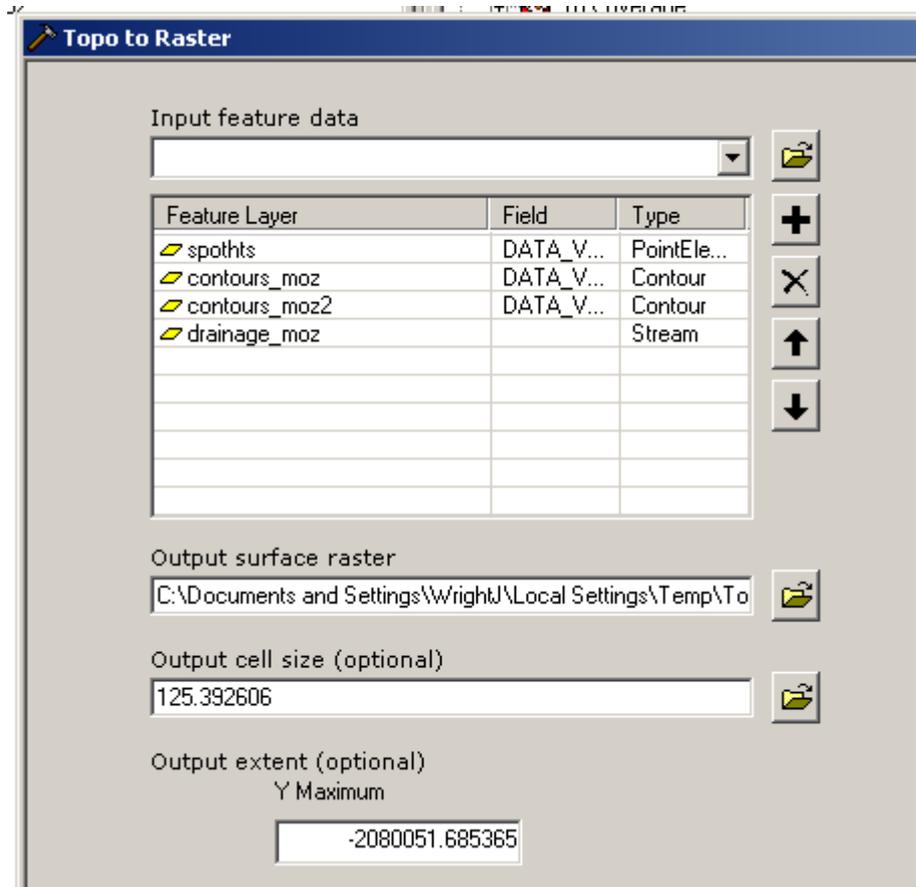
With these problems in our drainage network resolved, we are now in a position to interpolate a DEM using our contours, spot heights, and drainage lines.

Interpolating from contours and spot heights

To interpolate, go to the ArcToolBox, click on the *spatial analyst tools*, choose *interpolation*, and then select *topo to raster*. We can interpolate from our data as follows:

- under *input feature data*, click on **spothts**. Change the *type* to *pointelevation* and change the *field* (i.e. the field containing elevation values) to *data_value*.
- Next click on **contours_moz** under *input feature data* again. The *type* should already be set to *contours*, but you will need to change the *field* to *data_value*.
- Do the same for **contours_moz2** (you can load up more than one contour file for the interpolation).
- Again under *input feature data*, select **drainage_moz**. Change the *type* here to *stream*. Because these are stream lines, there is no need to specify a field containing elevation values.
- Note that although we will not use them here, we also have the option to upload a catchment boundary, the boundaries of lakes, and the locations of sinks. Sinks are depressions in the ground (i.e. low ground surrounded

entirely by higher ground), which are usually rare in nature. Sinks are eliminated by the interpolation process, but under certain conditions (e.g. the presence of chalk or limestone sub-strata), sinks can occur naturally. Any sinks recorded in an input file here will not be removed during the interpolation (provided an appropriate option is specified).



Under *output surface raster*, provide an appropriate name for your new DEM (e.g. **moz_dem**) and store it in a suitable location.

Leave the other settings at their default values. A few points to note here are as follows:

- The *drainage enforcement* option explains how sinks are treated. *Enforce* means sinks will be eliminated; *no_enforce* means sinks will be retained; and *enforce_with_sinks* means that only sinks not specified in an input file will be eliminated. Leave this set to *enforce*.
- Under *optional outputs*, you can ask ArcView to store the locations of any sinks that it finds in a new shape file.
- ArcView can also provide you with a detailed description of the algorithm's working (under *diagnostics*), and attempt to pick out surface drainage features from the resultant DEM automatically. The surface drainage lines can also optionally be stored in a new shape file.
- Click on *OK* to create your new DEM.

Task: How many methods can you think of for assessing the quality of your new DEM?

[Some suggestions are given overleaf, but you should try and note down a few ideas here first before turning the page.]

Answers: Numerous methods are possible. Some of the more commonly used methods are:

- producing contours at twice the resolution of the input contour data set. To do this, go to the ArcToolBox and choose *spatial analyst tools*, then *surface*, and then *contour*. As our input data have a contouring interval of 20 metres (40 metres in some locations), choose a contouring interval of 10 metres. Specify your new **moz_dem** as the input and an appropriate name for the output (e.g. **dem_contours**). You can then see visually whether the contours in between the input contours look sensible.
- Optionally, we could set aside some of the input data (e.g. half of the spot heights) and not use them in the interpolation. The elevation values for these spot heights could then be compared to the interpolated DEM elevation values and a Root Mean Square error (RMSE) calculated for the DEM.
- Producing raster grids depicting slope and aspect (via *spatial analyst tools*, then *surface*, and *slope / aspect*) can also help reveal problem areas in the DEM.
- Other methods are to look at the surface drainage lines that are generated for the DEM and see how sensible these seem, and to examine the output from the *topo to raster* algorithm in the *diagnostics* file in more detail.

Reference:

Note that you are not required to read this reference – it is provided here as the source of the technique used by ArcView:

Hutchinson, M.F. (1989): ‘A new procedure for gridding elevation and stream line data with automatic removal of spurious pits’. *Journal of Hydrology* **106**: 211-232.