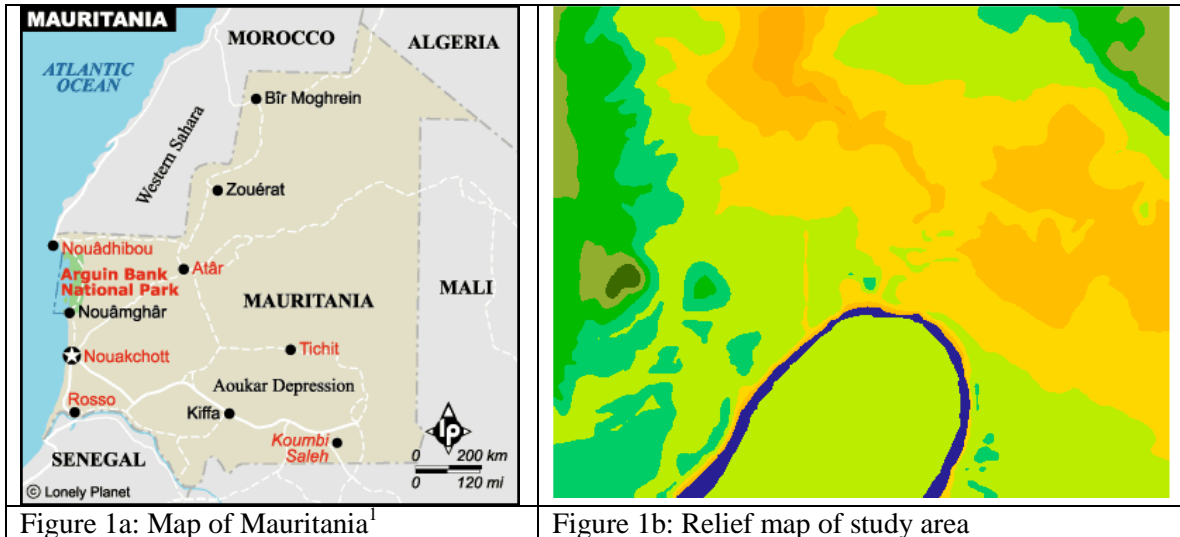


GIS Lab: Sorghum Exercise – ArcMap 9

1.0 INTRODUCTION

The location of the data set is western Africa, more specifically in the south of Mauritania, adjacent to Senegal (see figure 1a). In the study area you will notice a river bend in the southern portion of the relief map (see Figure 1b). The river itself is the Senegal River; the small area contained within the bend is in Senegal; and the rest of the area is in Mauritania.



The analytical aim of this tutorial is to determine the area suitable for growing sorghum, a cereal crop originating in the subtropics of Africa. It is the fifth most important crop cereal in the world and now the southern US states are the greatest producers. Its primary uses are livestock feed and ethnic foods (e.g. porridge, grits & beer 😊). Traditionally it is grown in areas prone to flooding and is planted after the floods recede.

In our exercise two criteria for growing sorghum have to be met:

- clay soils (as they hold water better than other soils), and
- an elevation of 9 metres or less (i.e. subject to annual flooding).

Thus the two data sets provided are of soils (*Dsoils*) and elevation (*Drelief*).

The educational aim of this tutorial is to introduce students to the process of:

- setting up a GIS project in ArcMap (note that it is properly known as an ArcMap document),
- examining the data provided and
- conducting a few basic raster functions (specifically: the use of reclassify, map query and map calculator).

A bullet indicates that action is required on your part, i.e.

- Turn the page and begin the tutorial.

¹ Source: Lonely Planet. <http://www.lonelyplanet.com/mapshells/africa/mauritania/mauritania.htm>

Estimated time to complete this lab: 50 minutes

2.0 INITIAL PROJECT SET-UP

This section covers the basic housekeeping chores of starting a map document:

1. copying the data to your directory
2. starting ArcGIS and adding these data to your new map document
3. activating the Spatial Analyst toolbar
4. setting the working directory (so the new data are saved to **your** directory)
5. saving the ArcMap document thus far.

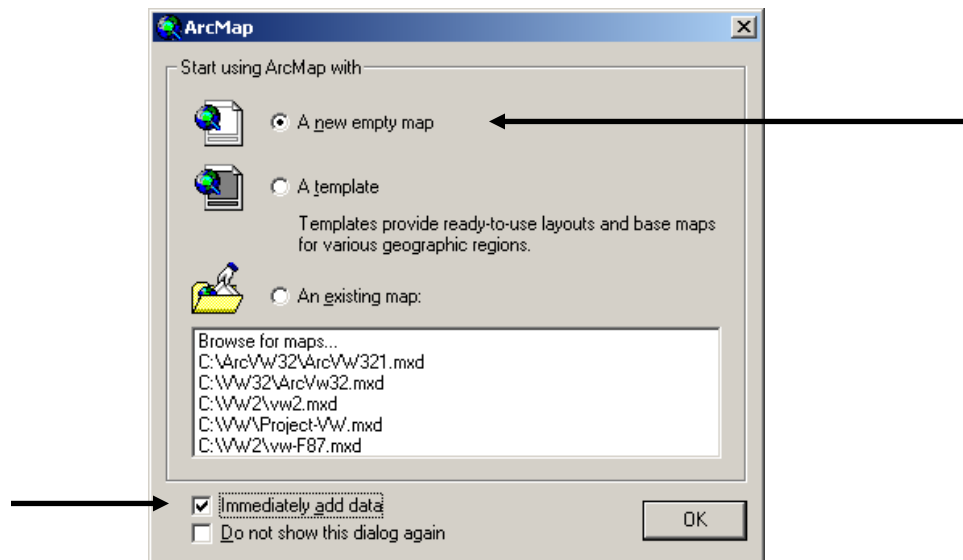
2.1 Copy Data

The data for this project is in the folder *Sorghum*.

- Copy the *Sorghum* folder to your U: drive. Rename the folder to *YourNameSorghum* (i.e. *CorrinSorghum*).

2.2 Starting a New Project and Adding Data

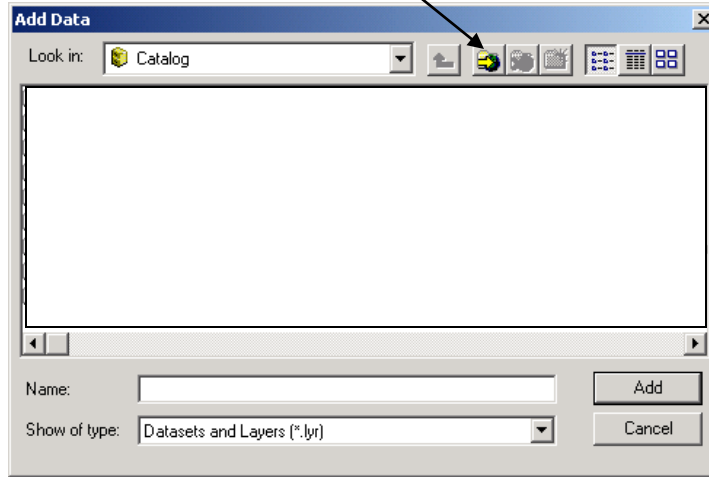
- Start ArcMap (click **Start** → **Programs** → **ArcGIS** → **ArcMap**), on the next screen:
 - Ensure the radio button for *A new empty map* is selected
 - Ensure the *Immediately add data* check box indeed has a “check”



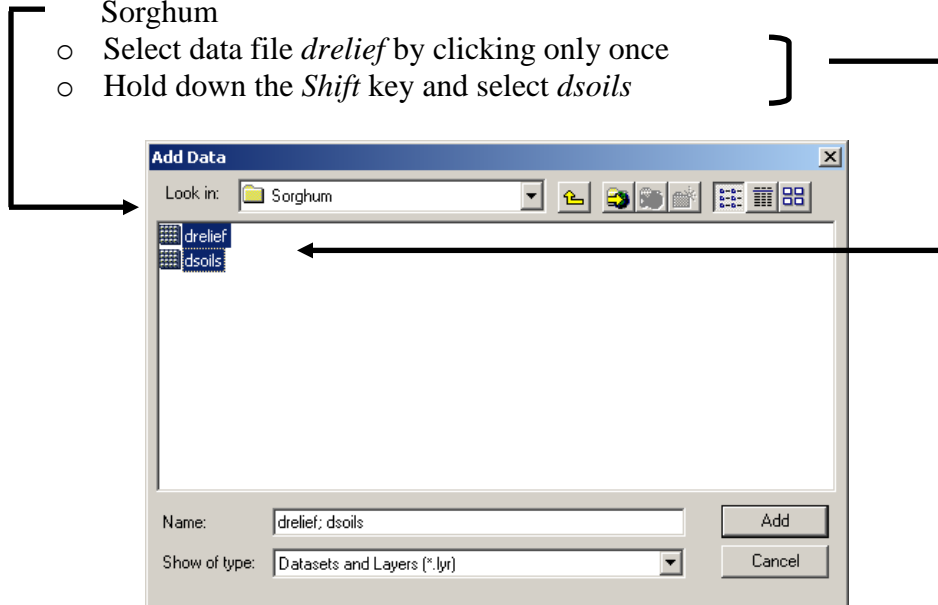
- Click OK

The *Add Data* window appears.

- Click the *Connect to* button

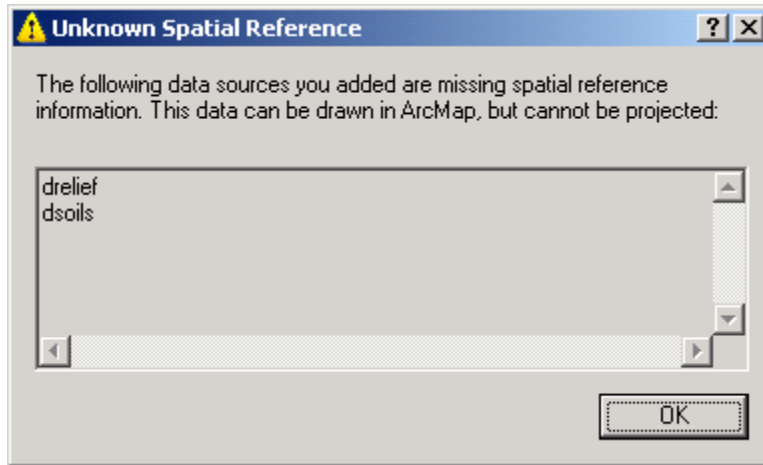


- From the next drop-down list, select your U: drive and click OK
- Navigate to the appropriate folder (i.e. *U:\Sorghum*) and double click Sorghum
- Select data file *drelief* by clicking only once
- Hold down the *Shift* key and select *dsoils*



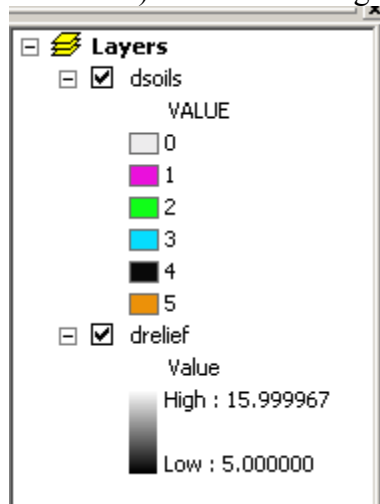
- Click the Add button

These data lack some spatial reference information and therefore cannot be converted to different projections. An error message appears. But we don't really care about re-projecting anyhow so we can blissfully ignore this.



- Click OK

The *Table of Contents* section on the left side of the window should look similar (colours for dsoils may vary – that’s OK for now) to the following:



It is OK if the order of dsoils and drelief are reversed. However, you can *click-and-drag* dsoils above drelief if you wish.

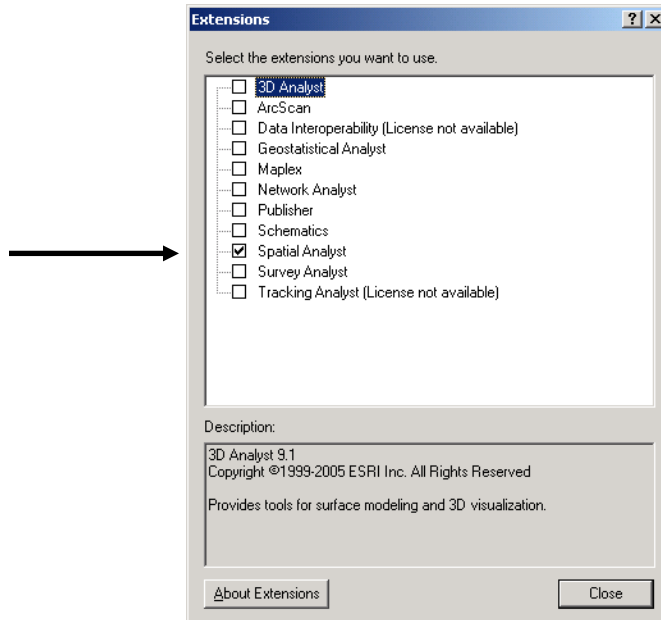
2.3 Enabling *Spatial Analyst*

As we will be working with raster grids we will need to ‘turn on’ the *Spatial Analyst* module.

- From the *Tools* menu select *Extensions*

- Ensure the *Spatial Analyst* check box has a tic mark and click the

Close



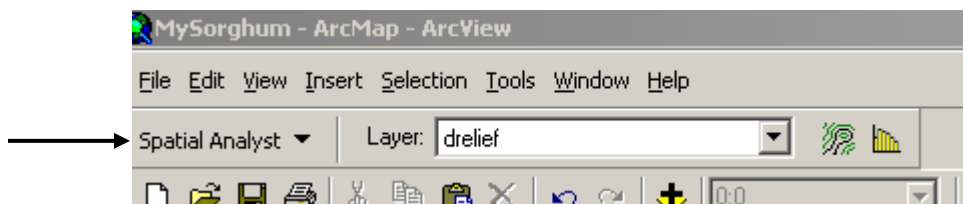
Even though we have loaded the *Spatial Analyst* extension, its toolbar may not be activated. To activate the *Spatial Analyst* menu ...

- From the *View* menu select *Toolbars* and then ensure the *Spatial Analyst* option is elected

The *Spatial Analyst* toolbar will appear. If it is 'free floating' you may wish to anchor it.

- drag and drop the toolbar on the gray toolbar section at the top of the screen

The *Spatial Analyst* toolbar consists of four parts: a drop-down analysis menu, a combo-box for choosing the raster layer, a contour tool and a histogram tool.



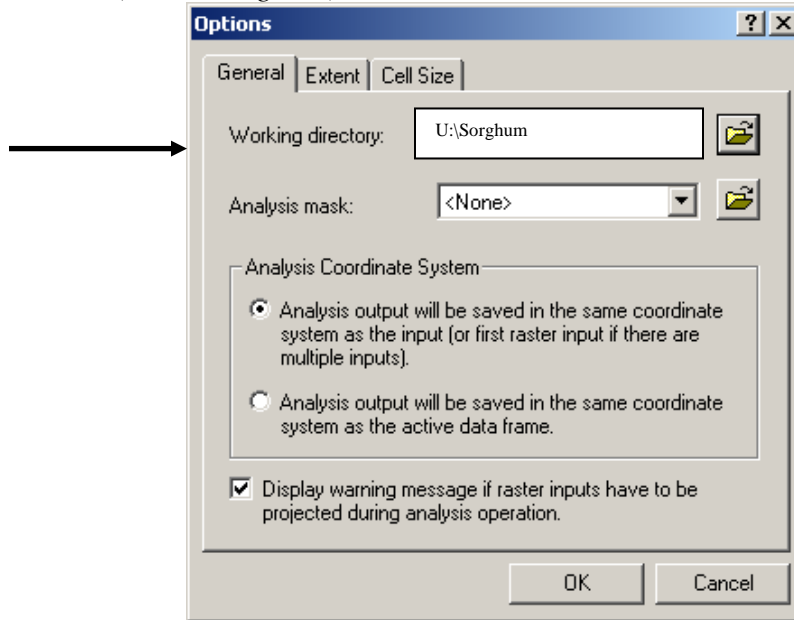
2.4 Setting the Working Directory

By default the working directory for a new project in ArcView is set to *\Temp* and all newly created files are stored here. To ease file management we will set the working directory to the same directory as our data (e.g. *U:\Sorghum*).

- Click on the *Spatial Analyst* drop-down menu and then select *Options*



- Ensure the *General* tab is selected and browse to the appropriate directory (i.e. *U:\Sorghum*)



- Click OK

We should also set the map document to store relative path names. In this way you can copy your Sorghum folder to a flash drive (or your laptop) and the data layers will not be “lost”.

- Click the File menu
 - then select Document Properties
 - click the Data Source Options button
 - select Store relative path names to data sources
 - click OK twice

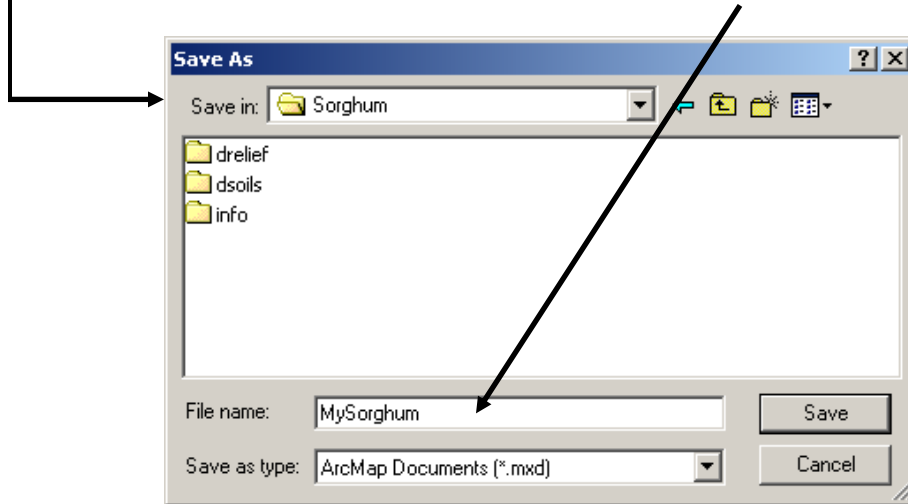
Full path name “starts” with the drive and the exact path (set of folders) for the data. Thus, if you copied the Sorghum folder to *U:/GIS*, then ArcGIS would use the path *U:/GIS/Sorghum* to find the data. So if you then copied the folder to your *C:* drive on your laptop, ArcGIS would not be able to “find” your data as your laptop is not connected to the *U:* drive.

Relative path name “starts” in the same location as the map document. Most often the data is simply stored in this folder (or a sub-folder). Thus, it would not matter if you copied to any other drive (laptop, flash drive, etc.) as ArcGIS would simply look in the same folder as the map document for the data (in this case, the Sorghum folder).

2.5 Saving the Map Document

The previous step ensures that **new** map layers will be saved to our chosen folder (directory). But now, we need to name and save this *map document* to this point. Remember, the *map document* is a file that tells ArcGIS what map layers we need and how we want them displayed (coloured).

- From the *File* menu select *Save As*
 - Navigate to the appropriate directory (i.e. *U:\Sorghum*)
 - Type in an appropriate project name (i.e. *MySorghum*)



- Click 

The map document has now been created and the source data added. That ends the housekeeping chores. If none of the steps made any sense that is OK. We are here to explore the map data and do an analysis, which is covered in sections 3 and 4 respectively.

3.0 EXPLORING THE DATA

When first starting out on a map document it is a good idea to explore the data and alter how it is displayed in order to better understand and express the information in the various layers.

3.1 Examining the Attribute Data and Altering Display of Data

The first task is to quickly examine the attribute data for each map layer. The attribute data is the **descriptive** information attached to the features on the map.

- Right click on *dsoils*
 - Click on *Open Attribute Table*

ObjectID	Value	Count	Soil
0	0	65417	No Data
1	1	12581	Heavy Clay
2	2	58365	Clay
3	3	9931	Sandy Clay
4	4	49355	Levee
5	5	11411	Stony

Record: 1 Show: All Selected Records (0 out of 6 Selected.) Options

Make a note of the following:

1. The soils map is divided into discrete soil types (e.g. clay, sandy clay, etc.). Note the pixel values associated with each soil type (e.g. clay = 2).
 2. The *Count* field provides the total number of pixels for each category; the total for clay is 58,365 pixels.
 - o Close the *Attributes of dsoils* window (click the “x” in the top right corner).
- Right click on the *drelief* map layer.

You will notice that you cannot access the *Open Attribute Table* option (it should be inoperable and ‘grayed out’), indicating there is no table to be accessed.



*We interrupt this tutorial to give you an **Alert!!** Sometimes when you right-click *drelief* immediately after examining *dsoils* it will appear as though the *Open Attribute Table* is accessible (shows up in black and is not grayed out). This is a minor program error- you will NOT be able to open the table and the next time you right click the map layer that option will indeed be grayed out – as it should have been in the first place*

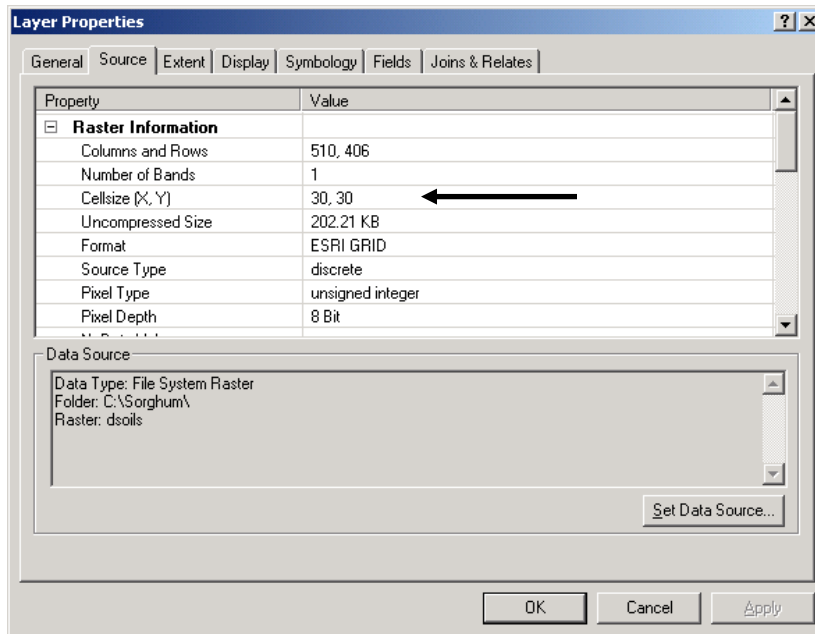
The reason why there is no table to open is that *drelief* is a continuous variable that depicts elevation. Since the data set is truly continuous it is conceivable that no two pixels would contain exactly the same number. Thus the data table would need a record (row) for each and every pixel – there is nothing to be gained from looking at such a table.

3.2 Pixel Resolution and Quick Calculation of Area

One of the common metadata items is pixel resolution.

- Right click on *dsoils* and select *Properties* from the drop down menu
 - o Click on the *Source* tab at the top

Note the cell size is 30 by 30. The units, although not specified, are metres. Thus a square pixel measuring 30m on edge would occupy 900 square metres.



- Click OK to close the window.

Remember that the clay soil type was composed of 58,365 pixels. An estimate of area would simply be:

$$\text{Area} = 58,365 \text{ pixels} * 900 \text{ m}^2/\text{pixel} = 52,528,500 \text{ m}^2$$

$$\text{Area} = 52,528,500 \text{ m}^2 / 10,000 \text{ m}^2 / \text{ha} = 5,253 \text{ ha}$$

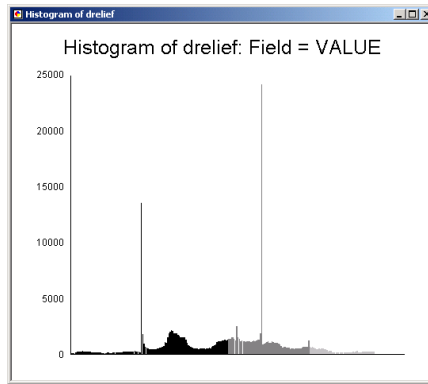
3.3 Viewing a Histogram of Pixel Values

You will recall that we could not open an attribute table for the theme *drelief*. We can, however, look at the frequency distribution of the pixel values.

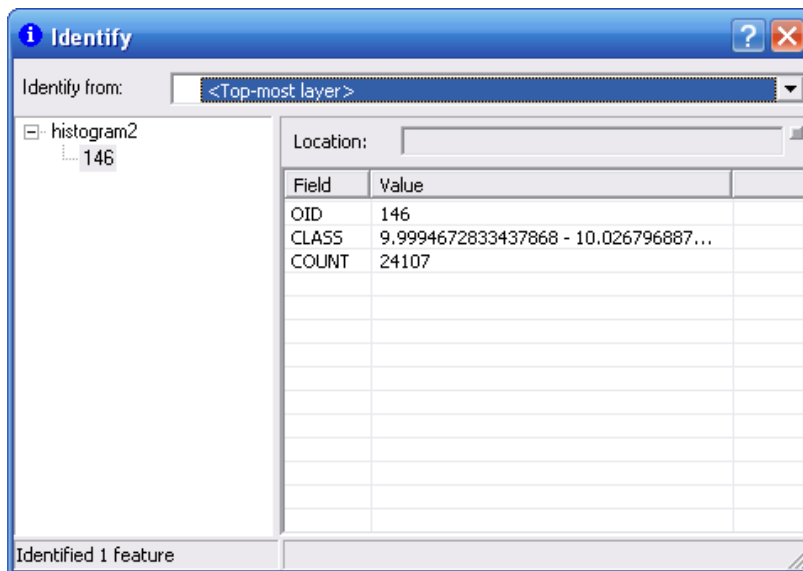
- In the *Layer* drop down box on the *Spatial Analyst* toolbar select *drelief*.
 - Then click the histogram button



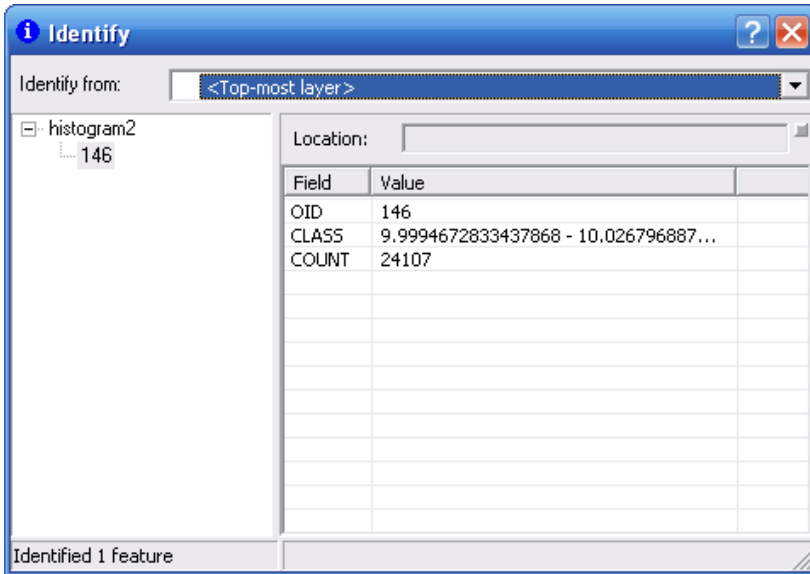
Note the distribution is shaded with the same gray scale colours as used in the legend.



- Position the cursor over the tallest spike (the line under the “i” in “Field”) and right click and select Identify. The pixel value range (CLASS) should be 9.999 – 10.026 (or essentially 10m) with a count of 24107. ** You may need to widen the columns if the data is not visible.



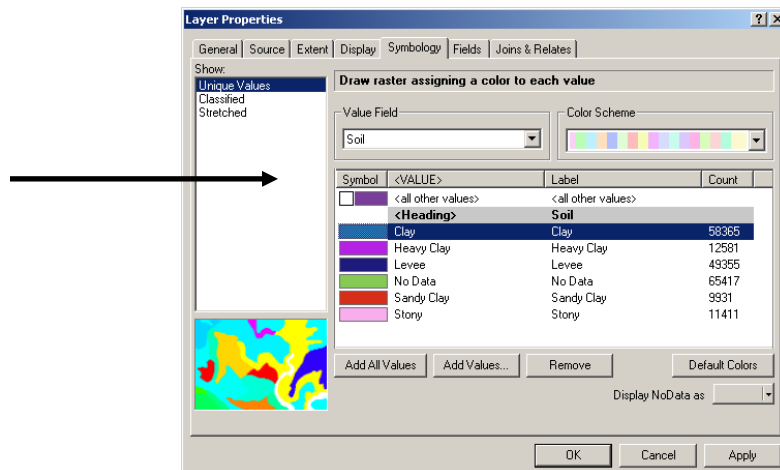
- What is the value of the second highest spike? Note that spikes such as these usually indicate something “unusual” about the data – in this case it is because the area across the river is in another country with no data available – so an arbitrary value of 10m was used. To see this turn-off the dsoils map layer.
- What is the pixel range of the “black peak”?
- Click the “X’s” to close the Identify Results and Histogram windows.



3.4 Altering the Display of the Data

Remember from section 3.1 that the data table had values for soils types (e.g. 2 for clay) and a soil description. It would be better if the legend displayed the soil descriptions rather than the numbers.

- Right click *dsoils* and then select *Properties*
- On the *Layer Properties* window click *Symbology* tab
 - Select *Soil* from the *Value Field* combo box



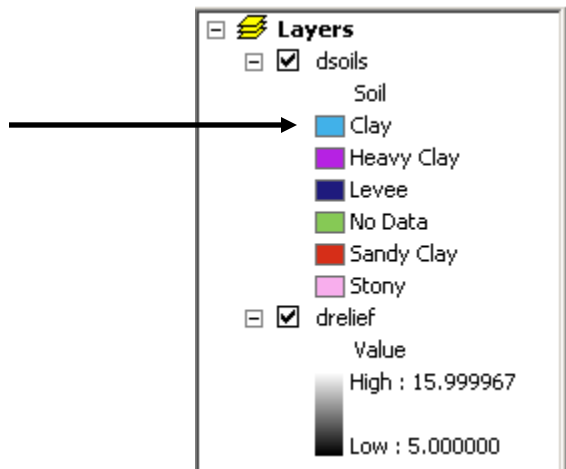
Notice that the Labels have descriptions instead of numbers. Choosing *Soil* for the *Value Field*, the legend is more meaningful.

- Click OK

Note the change in the legend.

Colours for discrete data sets are chosen at random. Controlling colours can highlight data types of interest – in our case we are interested in clay soils.

- Click on the colour box to the left of ‘clay’ in the Table of Contents



A *Color Selector* box will appear.

- Click on the **pink** color in the ‘rainbow bar’



- Click OK

Using the same procedure set the colours as follows: Heavy Clay – purple, Levee – brown, No Data – black, Sandy Clay – medium green, Stony – dark green.

Next we will alter the display of *drelief*. However, in order to view any changes, we will need to turn off the *dsoils* map layer, since it displays on top of *drelief*.

- Click the box next to *dsoils* to turn off its display (there should be no tic mark)
- Click on the black & white colour bar under *drelief*



- Select the colour scheme 14th from the bottom (i.e. scroll to the bottom of the color ramp, as 6 colour schemes are shown at once, click the ‘up arrow’ 8 times – the colour scheme has green on the left, brown in the middle and purple-white on the right).



- Click OK

Hopefully we have provided more meaning to our map by altering the colours and the labeling in the legend.

4.0 DETERMINING THE COINCIDENT AREA

The analytical task is a simple one: find the area where both of the following conditions occur:

- clay soils, and
- elevation \leq 9 meters.

This is known as constraint mapping (or restrictive modeling) and, prior to the advent of a more versatile and functional interface, required several steps. The following is a brief overview of the steps required.

Phase 1: Create Boolean (Logic) Layers

The first phase is creating *Boolean* (or logic) layers from the raw data layers. A *Boolean* layer contains pixels with values of only 0's and 1's, whereby the 1's indicate areas that meet our criteria and 0's do not. A *Boolean* layer is created for each parameter of interest. In our case we would create two *Boolean* layers:

1. one from *Dsoils*, where 1's would indicate clay and 0's would indicate all other soil types, and
2. a second from *Drelief*, where 1's would indicate an elevation of 9 or less (i.e. the flood area) and 0's for all higher ground

Phase 2: Combine Boolean Layers

The second phase involves combining the *Boolean* layers in such a way that the resultant layer would have 1's only where all the parameters are satisfied. In our case this means that the soil type is clay and the elevation is less than or equal to 9 meters.

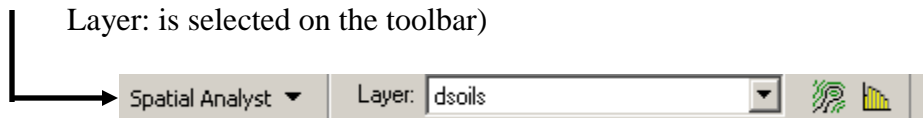
We will now determine the area that is suitable for growing sorghum. We have a few options for conducting this analysis. As **the objective of the exercise is to learn about raster functionality and become familiar with the *Spatial Analyst* interface**, we will conduct the analysis two different ways. Luckily each method will only take a few minutes.

4.1 The “Old Way”: Creating Intermediate Data Layers

As previously described, it can take several steps to complete a simple operation. Normally this is not done today, unless there is value in producing the intermediate raster layers. We will complete the task ‘the old way’ to ensure we understand exactly what is happening and to gain exposure to several raster functions.

Phase one is to create a *Boolean* layer for each criteria, namely soil = clay and elevation \leq 9 meters. To complete this task we will use the *Reclassify* function. When we reclassify in raster we create a new map layer that is a simplified version of the original.

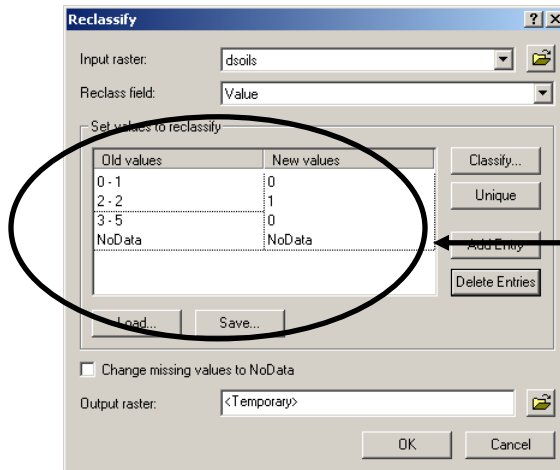
- Click on the *Spatial Analyst* menu and select *Reclassify* (it does not matter which Layer: is selected on the toolbar)



- From the *Input Raster* drop-down box select *dsoils*
- From the *Reclass Field* drop-down box select *Value* (note that *Value* contains the codes for soil types).

Remember that the pixel value for clay was ‘2’. As we are making a *Boolean* layer for clay we want to create a new layer where the pixel locations that had 2’s will now have 1’s and all else will have 0’s.

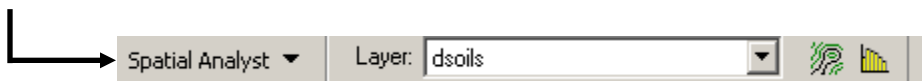
- In the first row type **0 - 1** under *Old Values* and **0** under *New Values* (pixels with a value of 0 or 1 in the *dsoils* layer will have a value of 0 in the new layer). ** Be sure to enter as “0 - 1” and not “0-1” (i.e. spaces are important)
- In the second row enter 2 - 2 and 1
- In the third row enter 3 - 5 and **0**
- Use the **Delete Entries** button to delete any excess rows – but keep the NoData row..



- Click OK

A new layer, ***Reclass of dsoils***, is added to the project, where 1’s indicate clay and 0’s indicate all else. Next we will reclassify the relief layer to delineate the flood area. Compare the new data layer to the Solis map – does it make sense? Next reclassify elevations to create a “flood map”.

- Click on the *Spatial Analyst* menu and select *Reclassify*



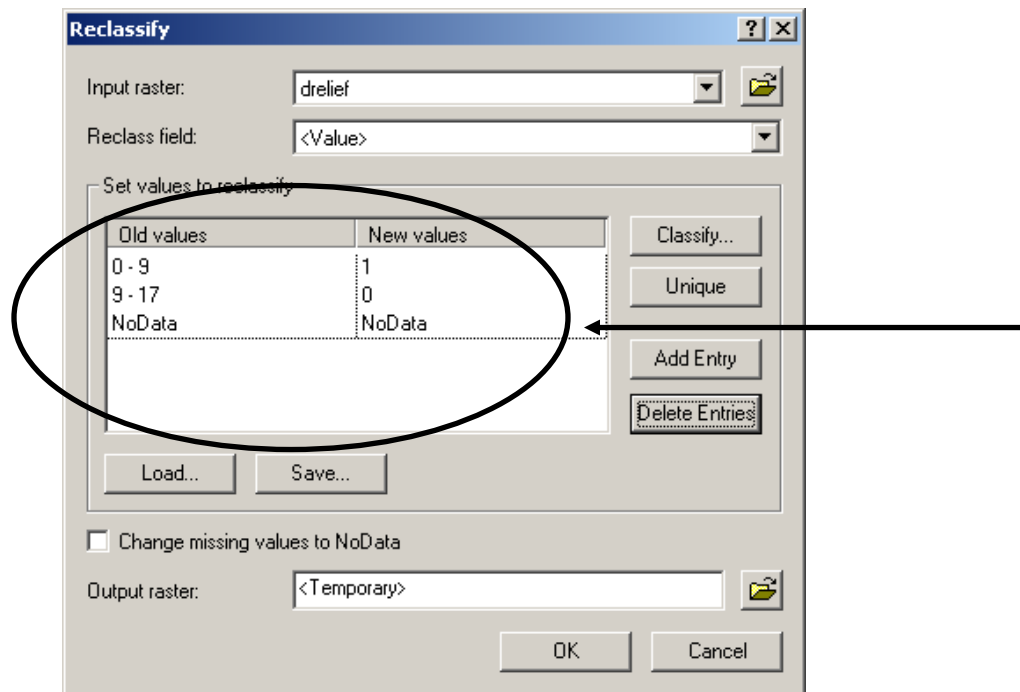
- From the *Input Raster* drop-down box select *drelief*

Remember that the pixel values less than or equal to 9 are subject to annual flooding and are suitable for sorghum. Notice that the list for “Old values / New values” is very long. In order to avoid having to manually delete the excessive rows do the following:

- Click the Classify button
- From the “Classes” drop down choose “2” and click OK.

Note that there are now only two rows in the “Old values / New values” list. Now we just have to edit the values.

- In the first row, under *Old Values*, type **0 - 9** (remember the spaces are important, it's 0 - 9, not 0-9) and, under *New Values*, type **1**
- In the second row enter **9 - 17** and **0**



- Click OK

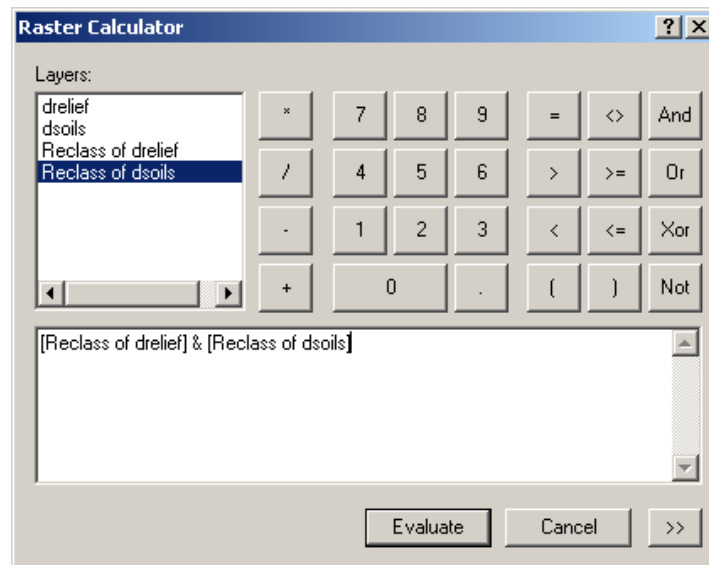
Two points to note:

- a) There is no problem repeating the ‘9’ for the minimum value in row 2 as all of the exact values of ‘9’ will have been allocated to the value of ‘1’ (as per row 1), and now any value ever so slightly higher than ‘9’ will receive a value of ‘0’ – this way we ensure there are no missed values (i.e. if we entered 9.01-99 and there was a pixel with a value of 9.001 it would be missed in the reclass and remain as 9.001 in the new raster layer).
- b) We enter ‘17’ as the maximum value just to be sure to capture all the data (note the legend had ‘16’ as the highest value, thus we need to enter any value higher than this).

A new layer, **Reclass of drelief**, is added to the project, where 1's indicate flood area (less than or equal to 9m) and 0's indicate non-flood areas (i.e. higher ground).

Next we need to combine these two *Boolean* layers to delineate areas where both criteria are met (i.e. where the 1's overlap).

- Click on the *Spatial Analyst* menu and select *Raster Calculator*
 - From the *Layers* double click *Reclass of drelief*
 - Click the **And** button
 - From the *Layers* double click *Reclass of dsoils*



It is understood that

([Reclass of drelief] & [Reclass of dsoils]) is equivalent to
([Reclass of drelief = 1] and [Reclass of dsoils = 1]).

What this means is that the new map layer will have 1's where the soils were clay and flooded.

Please note that it is very important to get the 'syntax' of the expression exact – if not, a "Syntax Error" message will appear. Syntax errors are usually not obvious. To correct the situation it is easiest to close the Raster Calculator window and then reselect it from the menu and begin fresh.

- Click the 'Evaluate' button

A new raster layer is added to the project, entitled *Calculation*. On this layer the 1's represent areas suitable for growing sorghum, where clay soils and elevations ≤ 9 metres coincide.

As we only had two criteria, the ‘old way’ requires only 3 steps: the creation of two *Boolean* layers and the overlay of these two layers. This process exposed us to two functions:

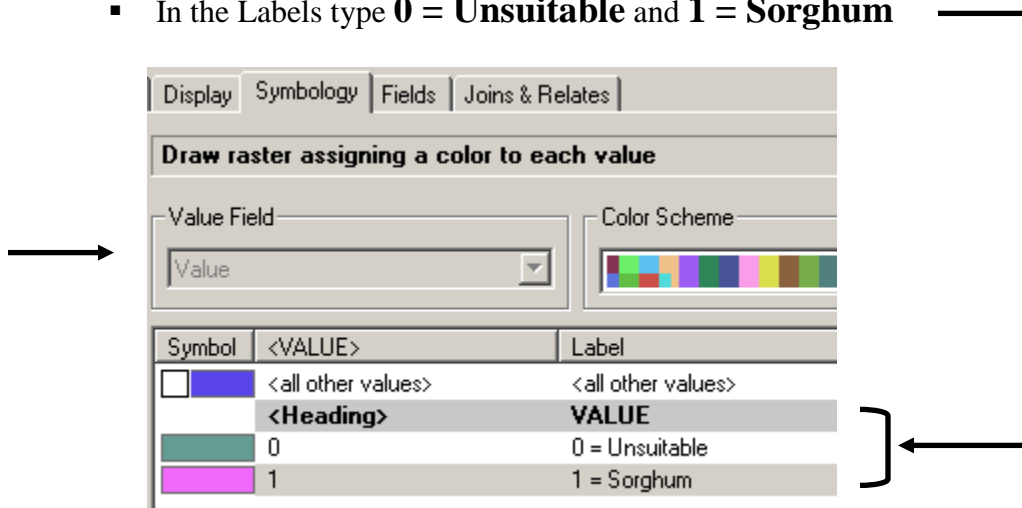
- **Reclass**: which is used to **simplify** a raster data set (can be into *Boolean* with only 1’s and 0’s, or it could also be used to put continuous data, such as elevation, into classes)
- **Raster Calculator**: which can be used to **combine** layers.

To aid in discerning the results from other approaches we will rename this theme “Old Way”

- Right-click on this newly created theme *Calculation* and select *Properties*
 - Select the *General* tab
 - In the *Layer Name* box type **Old Way**.

To further aid in understanding the results let’s add to the legend

- Click on the *Symbology* tab
 - In the Labels type **0 = Unsuitable** and **1 = Sorghum**






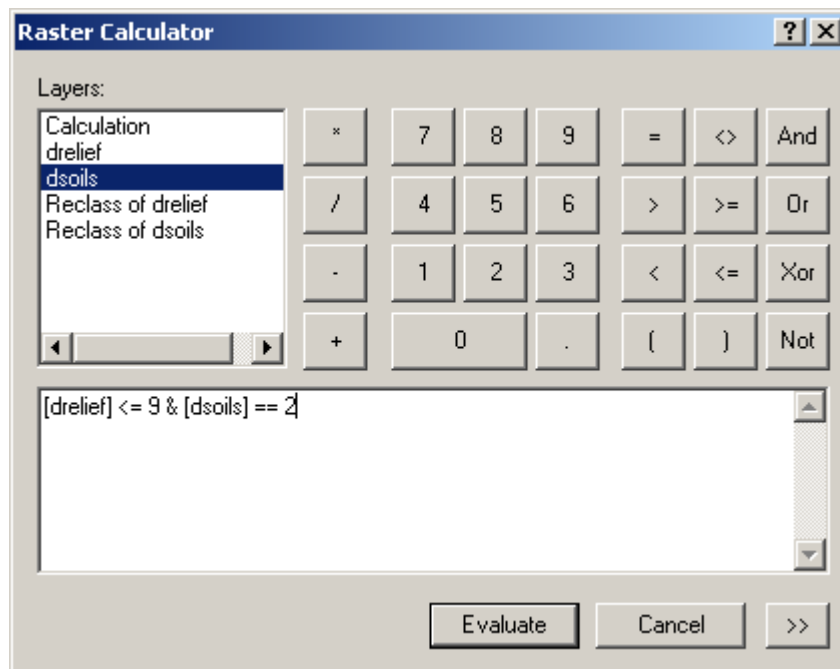
- Click OK

- Do the same to the other two layers you created
 - layer names should be “**Clay**” and “**Flood**”
 - legend entries should be “**Unsuitable**” and “**Clay Soils**” or “**Flood Area**”
- Examine the 3 layers (*Clay*, *Flood*, and *Old Way*) and see if the results make sense.

4.2 One Step

We can by-pass the creation of the two initial *Boolean* layers and simply use *Raster Calculator* to conduct this analysis. We will utilize only the two original raster layers. Also, remember that on *dsoils* clay soils have a value of 2.


- Click on the *Spatial Analyst* menu and select *Raster Calculator*
 - From the *Layers* double-click *drelief*
 - Click the  button
 - Type **9**
 - Click the  button (notice the ‘&’ symbol appears)
 - From the *Layers* double-click *dsoils*
 - Click the  button (notice that two = signs appear)
 - Type **2**



- Click the ‘Evaluate’ button
- As before, rename the map layer and the legend entries (e.g. New Way, 0 = Unsuitable, 1 = Sorghum)

You will notice the results are the same. So once we understand the process the intermediate steps can be by-passed and this operation can be conducted in only one step.

We are finished with the tutorial portion of this lab exercise. Note that all the raster layers you created so far in this exercise are temporary. To save all the data layers created ...

- Click on the save button 

5.0 SUMMARY

When setting up a map document in ArcMap one of first the issues that needs to be addressed is that of file management. A project can utilize data from a variety of locations. There are three issues to contend with: the ‘raw’ source data (e.g. *Dsoils*), newly generated data (*Old Way*), and the project itself (*MySorghum*). For simple projects it is often most convenient to locate all data in one directory (folder). This requires three steps:

- Create a project folder and copy source data to it, OR make a copy of the data folder
- Set the *working directory* to this same directory (folder) so newly generated data is created here, and
- Save the project to the same directory.

Setting relative path names will allow you to copy your folder (with your data and map document to another source) to another location with issues of ‘lost data layers’.

When first starting a project it is necessary to be familiar with the data. Changing the way data is displayed can make the map more meaningful. Take for example the soils data; its legend displayed the pixel values. These numbers had little meaning, but by changing the legend to display soil types the map became more informative.

The analysis just conducted can be considered a *spatial query* with two criteria, specifically – “*where is the area where clay soils and an elevation of 9 metres or less coincide?*” A spatial query can be conducted with many criteria. For this type of analysis each criteria has two categories: area that satisfies the criteria and area that does not. If it were useful to create intermediate layers, it is standard to use 1’s for satisfactory area (i.e. meets the criteria) and 0’s for unsatisfactory areas. Such a layer with only 1’s and 0’s is known as a logic, or *Boolean* layer. The final step is to query for where 1’s occur in all the Boolean layers. As experienced in this exercise, this type of analysis can also be accomplished in only one step, by-passing the creation of the intermediate layers.

Now, you are ready to perform the assignment portion of this lab. Good luck!