Map Algebra Exercise (Beginner) – ArcView 9

1.0 INTRODUCTION

The location of the data set is eastern Africa, more specifically in Nakuru District in Kenya (see Figure 1a). The Great Rift Valley runs through the study area from the northwestern corner down to the southeast (the flatter light blue area noted in Figure 1b).

Figure 1a: Kenya, Nakuru is east of Lake Victoria[1].

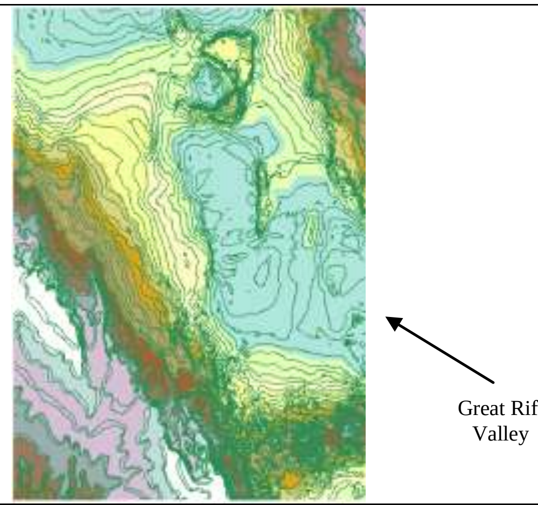


Figure 1b: Relief of study area.

Use Google Earth to "fly to": **nakuru rift valley** (copy/paste bold text to the "fly to" box). If you zoom out to an 'eye alttitude' of ~1,000 km (see bottom right corner of screen for altitude), you will see an image that roughly matches Figure 1a. If you zoom to an altitude of ~250 km you will see the area in Figure 1b (the dark green area between Kericho and Nakuru is the Great Rift Valley indicated in light blue in Figure 1b).

The analytical aim of this tutorial is to create an agro-climatic zone map of the study area. The map will capture two parameters of interest: moisture availability and temperature. Moisture availability is calculated as the ratio between precipitation and evapotranspiration (i.e. moisture availability = precipitation / evapotranspiration). This is a moderately sophisticated exercise in classification, utilizing two parameters. The three data sets provided are *Nrelief* (elevation), *Nrain* (precipitation) and *Evapo* (evapotranspiration, a measure of moisture demand).

The educational aim of this tutorial is to:

- re-enforce the processes of setting up a project and examining the data provided,
- demonstrate the value of cartographic modeling, and
- further develop skills in conducting raster functions (Reclassify & Raster Calculator)

Typographic notation: a bullet indicates that action is required on your part, i.e.

- Turn the page and begin the tutorial.

[1] Lonely Planet, http://www.lonelyplanet.com/mapshells/africa/kenya/kenya.htm

Estimated time to complete this lab: 45 minutes

2.0 Initial Project Set-up

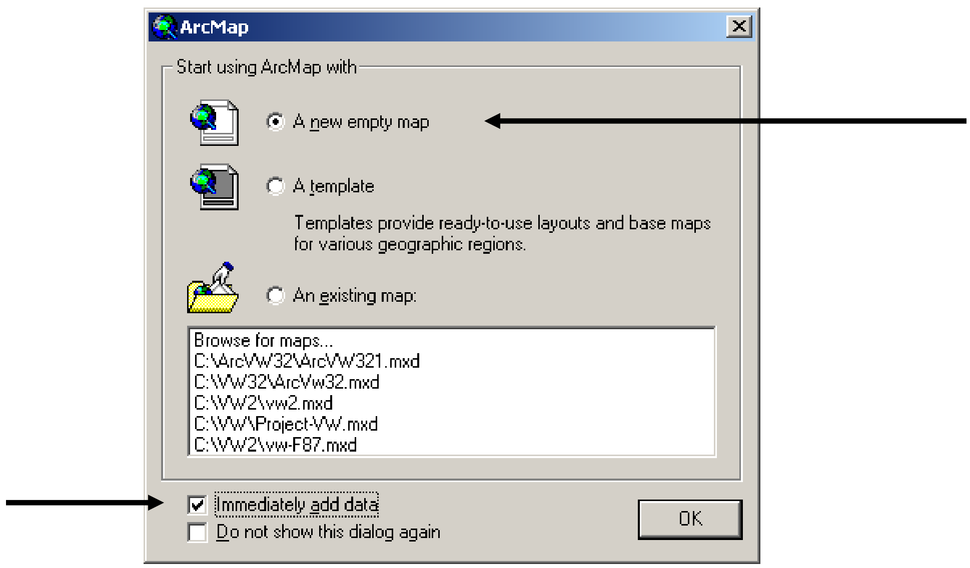
2.1 Copy Data

The data for this project is in the folder *Algebra*, which contains within 4 subdirectories: *Evapo*, *Nrain*, *Nrelief*, and *info.* You will need to copy the *Algebra* folder to an appropriate drive.

- Copy the *Algebra* folder from G:\ drive to your student U: drive.

2.2 Starting a New Project and Adding Data

- Start ArcMap.
    - Click the radio button for *A new empty map*
    - Click the *Immediately add data* check box

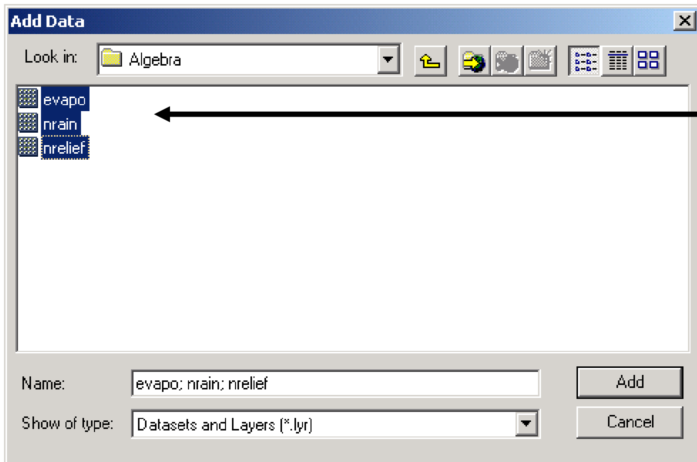


    - Click OK

The *Add Data* window appears.

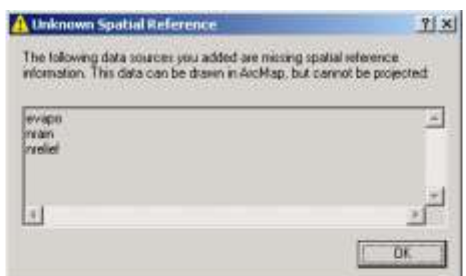
- If necessary "connect to" your Algebra folder (on your U:\ drive).

- Select your working folder (i.e. *U:\Algebra*)
- Click once on the data file *evapo*
- Hold down the *Shift* key and select *nrelief* … all 3 files should be highlighted



- Click Add

This data was converted from *Idrisi* and it lacks some spatial reference information and therefore cannot be converted to different projections. An error message appears.

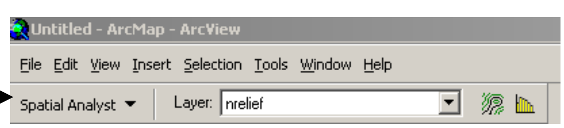


- Click OK

The *Table of Contents* section on the left side of the window should list the three map layers – all with a black-white colour ramp.

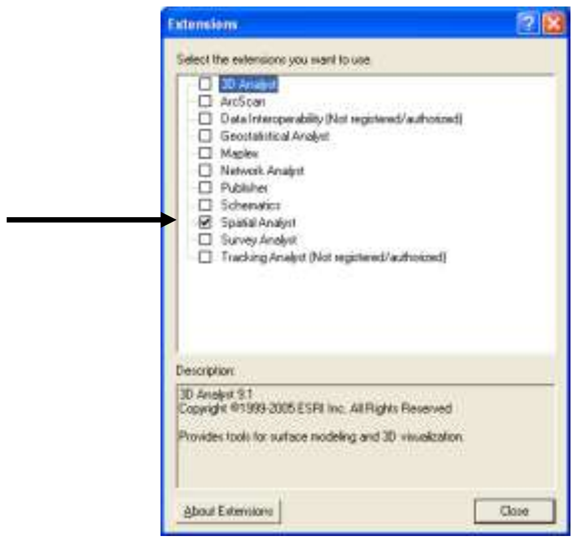
2.3 Enabling *Spatial Analyst*

As we will be working with raster grids we will need to 'turn on' the *Spatial Analyst* module. *Spatial Analyst* may already be 'turned on' – if so the toolbar will be visible.



If *Spatial Analyst* is not turned on then conduct the following steps, otherwise skip to section 2.4.

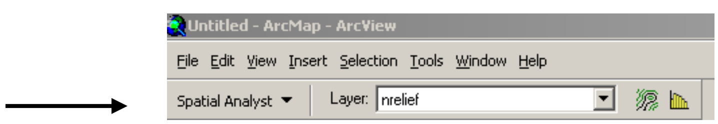
- From the *Tools* menu select *Extensions*
    - Click the *Spatial Analyst* check box and click the  button



Even though we have loaded the *Spatial Analyst* extension, its menu is not activated. To activate the *Spatial Analyst* menu …

- From the *View* menu select *Tools* and then select *Spatial Analyst*

The Spatial Analyst menu will appear on its own bar below the menu. This menu consists of four parts: a drop-down analysis menu, a combo-box for choosing the raster layer, a contour tool and a histogram tool.

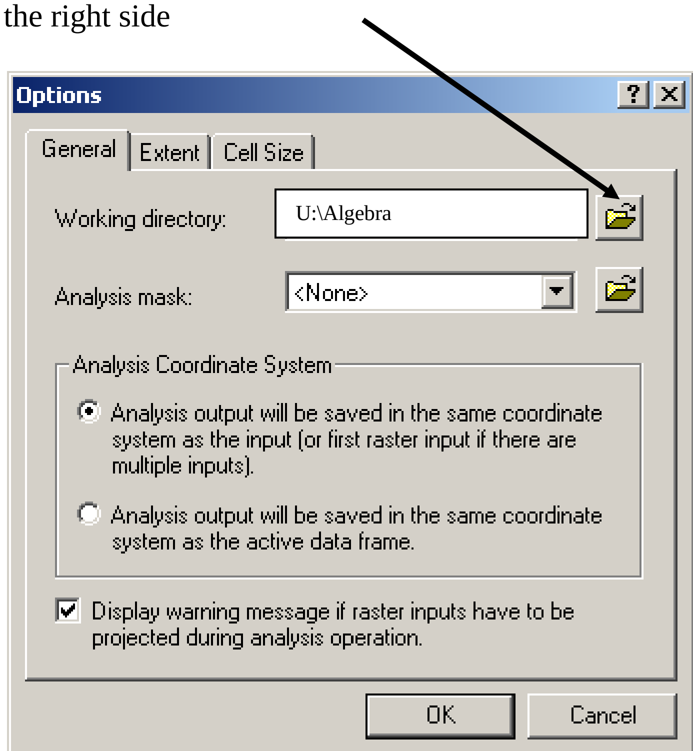


2.4 Setting the Working Directory

To ease file management we will set the working directory to the same directory as our data (U:\Algebra).

- Click on the *Spatial Analyst* drop-down menu
    - Select *Options*

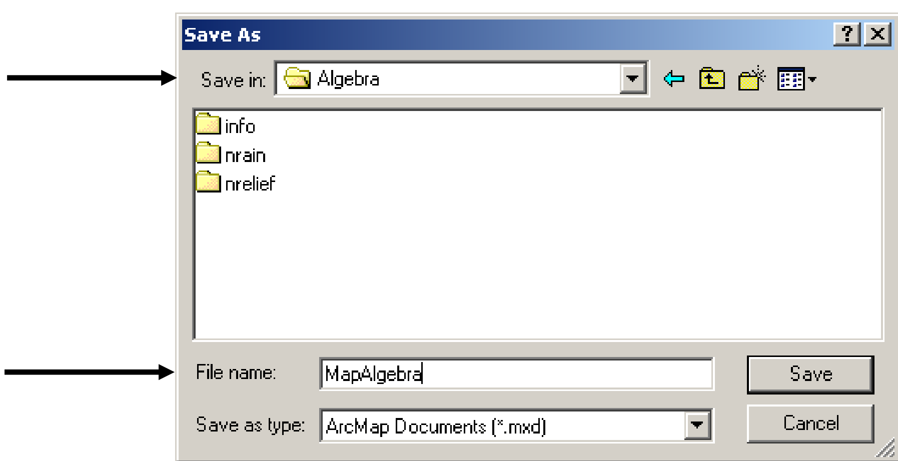
- Ensure the *General* tab is selected and browse to the appropriate directory (i.e. U:\Algebra) – note, you start browsing by clicking the folder button on the right side



- Click OK

2.3 Saving the Project
Next we will name and save this project.

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



- o Click 

The project has now been created and has the source data added.

3.0 EXPLORING THE DATA

When first starting out on a project it is a good idea to explore the data and alter how it is displayed in order to better understand the information in the various layers. Note that:

1. the pixel resolution is 250 metres
2. the values for elevation are in feet and
3. the units for rainfall and evapotranspiration are in millimeters.

3.1 Altering the Display of the Data

We will now alter the display to make the data more intuitive.

- Ensure that <u>only</u> *nrelief* is checked in the table of contents (otherwise *nrain* or *evapo* may be drawn overtop of the *nrelief* layer)
- Double click on *nrelief* in the table of contents
    - Select the *Symbology* tab
    - Click the *Color Ramp* drop-down box and choose a desired color scheme (suggested scheme can be selected by clicking the down arrow 11 times – this should access a color ramp good for elevations – it is green on the left, brown in the middle and purple-white on the right – select it).
    - Click OK

The low elevation valley bottom is light green and higher elevations are light purple to white. Note with gentle slopes the color gradually fades from one color to another whereas steep areas have abrupt colour changes.

Let’s pick a color scheme that is more intuitive for the rainfall data, e.g. where drier areas are light blue and wetter areas are dark blue.

- Ensure there is a check mark beside *nrain*
- Double click on *nrain* in the table of contents
    - Select the *Symbology* tab
    - Click the *Color Ramp* drop-down box and choose a blue color scheme (light blue on left and dark blue on right))
    - Click OK

Remember that lighter areas are drier and darker areas are wetter. Try to determine if there is a relationship between elevation and mean annual rainfall. You can casually do this by …

- keep the *nrelief* map layer on, and then turn on and off the display of the *nrain* map layer.

Indeed there appears to be a directly proportional relationship between the two variables, such that mean annual rainfall increases with elevation.

Evapo (a.k.a. evapotranspiration, which is a measure of moisture demand) is another climatic parameter that is proportional to elevation. Try to determine if there is a relationship between elevations and evapotranspiration.

- ensure that *nrain* is "off"
- keep the *nrelief* map layer on, and turn on and off the display of the *evapo* map layer.

Where is there greater moisture demand, the valley bottom or hilltops?

4.0 CONDUCTING THE ANALYSIS

Assessing the landscape for suitability for growing crops usually involves an assessment of temperature and moisture availability. Typically it is far easier to evaluate the landscape for temperature and moisture availability if the data have been simplified (generalized). Thus, both of these factors will be generalized into zones. The value ranges for these moisture availability and temperature zones are given in tables 1 and 2, respectively.

Table 1: Moisture Zones

Range of Values	Moisture Availability Zone
0 – 0.15	7
0.15 – 0.25	6
0.25 – 0.40	5
0.40 – 0.50	4
0.50 – 0.65	3
0.65 – 0.80	2
0.80 – 1.10	1

Table 2: Temperature Zones

Range of Values	Temperature Zone
0 – 10	9
10 – 12	8
12 – 14	7
14 – 16	6
16 – 18	5
18 – 20	4
20 – 22	3
22 – 24	2
24 – 99	1

These moisture and temperature zones are utilized for agriculture suitability analysis in Africa. You should be aware that some of these classes may not 'apply' to our data set. That is, some of the classes may represent areas that are hotter, colder, drier or wetter than the area contained within our study area.

The end result of our analysis will be the creation of a climatic zone map that combines these moisture and temperature zones. Obviously before we create our final climatic zone map we will need to create a moisture zone map and a temperature zone map. Figure 2 shows this portion of our analysis.

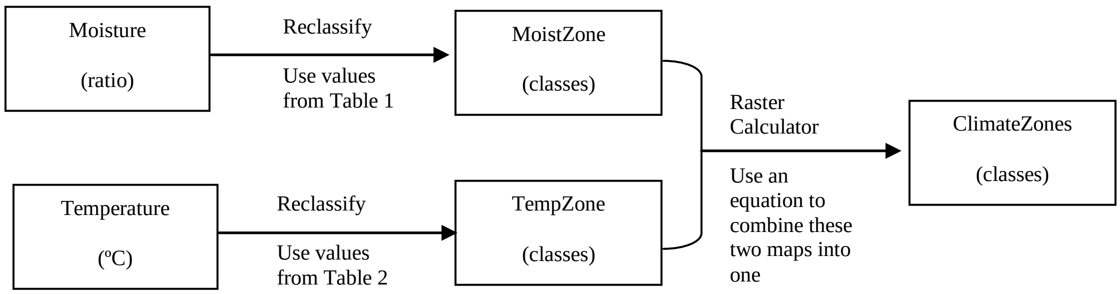


Figure 2: Cartographic Model

This cartographic model outlines the <u>final</u> steps required to conduct our analysis. Note: the boxes indicate a data layer (with the units provided in brackets) and the arrow indicates an analytical operation (with parameters provided below the arrow).

Unfortunately we don't have the *Moisture* (moisture availability) or *Temperature* data sets – you have to create them. The only data provided are elevations (*Nrelief*), mean annual precipitation (*Nrain*) and evapotranspiration (*Evapo*).

Deriving Moisture Availability

Moisture availability is the water available to plants. This is depicted as *Moisture* in figure 2. It is often expressed as a ratio of rainfall/evapotranspiration (ET). Consider the following:

if rainfall = 50 cm and ET = 50 cm then the ratio equals 1 (i.e. water is balanced)
if rainfall = 50 cm and ET = 25 cm then the ratio equals 2 (i.e. water excess)
if rainfall = 50 cm and ET = 100 cm then the ratio equals 0.5 (i.e. water deficit)

Deriving Temperature

Creating a temperature layer will actually be quite straightforward as there is a known relationship between temperature and elevation. This relationship is in the form of an equation.

$$Y \text{ (temperature ºC)} = -0.0016 X \text{ (elevation feet)} + 26.985$$

If the elevation value for any given pixel from the *Nrelief* layer is plugged into this equation we will get the mean annual temperature for that location. Thus we can create a temperature layer by applying an equation to each pixel in the elevation layer.

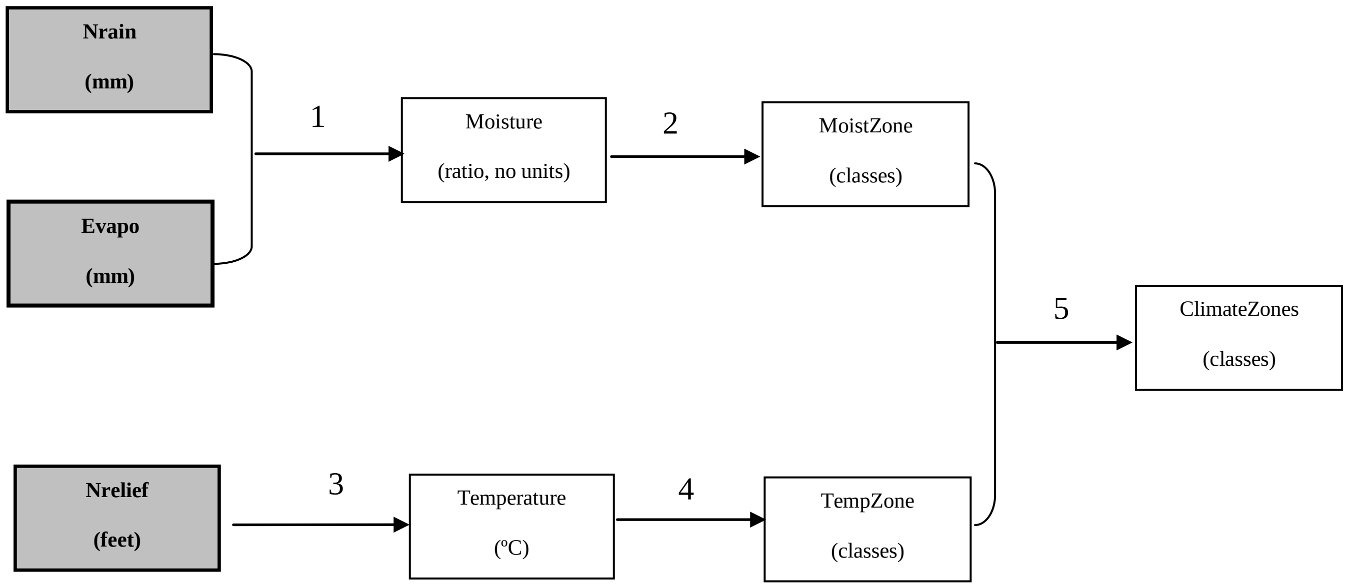
Using a Cartographic Model

A complete model of all the steps required to complete this analysis follows in figure 3. The numbers over the arrows indicate the operations conducted and are described in the accompanying table. Note that *Nrelief, Nrain* and *Evapo* are the only raster layers supplied; all other layers are derived from an analytical operation.

You will find that referring to the cartographic model as you conduct each step will aid in understanding where you are in the grand scheme of this multi-step procedure. The cartographic model is reproduced at the end of the tutorial.

- Tear off the last page and use it as a reference as you conduct the analysis (e.g. 'mark off' each step as it is completed).

Note that the cartographic model is provided on the next page for you to ponder. The shaded boxes indicate map layers provided. The clear boxes are map layers you need to create. If it does not make sense, then ask an Instructor for help.



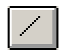
Step	Function	Comment
1	Raster Calculator	Apply equation: Nrain / Evapo
2	Reclassify	Classify data according to Table 1
3	Raster Calculator	Apply equation Y (temperature ºC) = –0.0016 X (elevation feet) + 26.985
4	Reclassify	Classify data according to Table 2
5	Raster Calculator	Combine the data from both layers

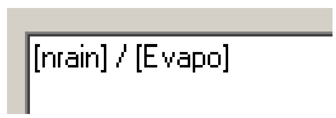
Figure 3: Complete Cartographic Model

Note: for the Raster Calculator *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.*

4.1 Creating Moisture (Availability)

First let's create the moisture availability layer. Remember this is a ratio of precipitation / evapotranspiration. Thus we have to divide the pixels of one map by those of a second.

- From the *Spatial Analyst* drop down menu select *Raster Calculator*
    - Double click on *Nrain*
    - Click the divide button 
    - Double click on *Evapo*



- - Click the 

 button

Values displayed in the legend should vary from 0.361 to 1.019. Next we will rename this layer to something more meaningful.

- Right click on the *Calculation* theme and then select *Properties*
    - Click the *General* tab
    - In the *Layer Name:* box, type ***Moisture***
    - Click OK

This completes step 1 by combining *Nrain* and *Evapo* to create *Moisture*. Remember that lower values indicate drier conditions (less than 1.0 means that the moisture demands are greater than the rainfall – drought tolerant plants would be needed).

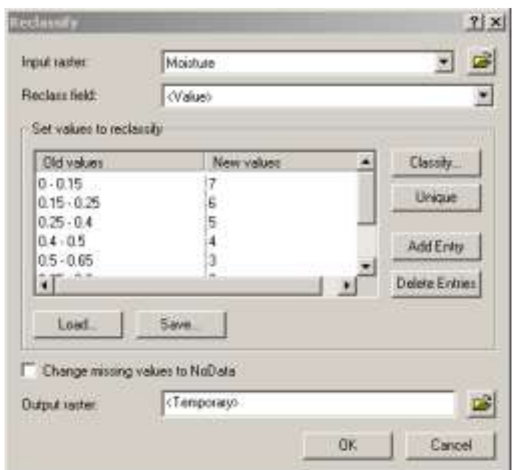
4.2 Creating Moisture Zones

By reclassifying the values in *Moisture* according to Table 1 we can create a layer depicting moisture zones – this is step 2. Table 1 is reproduced below.

Table 1: Moisture Zones

Range of Values	Moisture Availability Zone
0 - 0.15	7
0.15 – 0.25	6
0.25 – 0.40	5
0.40 – 0.50	4
0.50 – 0.65	3
0.65 – 0.80	2
0.80 – 1.10	1

- From the *Spatial Analyst* drop down menu select *Reclassify*
    - Click the *Classify* button on the right side, then select 7 for *Classes*
    - Refer to Table 1 and enter in the appropriate values under the column headings: *Old Values* and *New Values* (** Note that the last two rows are not shown in the diagram below, although you still need to enter them from Table 1).



    - Note that the last range has a value of '1.1' entered as the upper limit. We know from the legend that the largest value in the layer is 1.019. Any value larger than this will suffice (e.g. 1.02 or even 99, I just happened to choose 1.1).
    - Click OK

The resultant layer, *Reclass of Moisture*, only contains classes of 1 through 5 – there are no areas in classes 6 or 7 (no areas are that dry). The moisture class layer should look similar to the following image (colors may vary).

To keep consistent with our cartographic model, let's rename this layer.

- Right click on the *Reclass of Moisture* theme and then select *Properties*
    - Click the *General* tab
    - In the *Layer Name:* box, type ***MoistZone***
    - Click OK

4.3 Creating Temperature

For step 4 use the Raster Calculator and apply the equation Y = –0.0016 * X + 26.985 to each pixel in the elevation layer to create temperature.

- From the Spatial *Analyst* drop down menu select *Raster Calculator*
    - Double click on *Nrelief*
    - Click the multiply button
    - Type –**0.0016 + 26.985**

You equation should look as follows

[nrelief] * -0.0016 + 26.985

- Click the Evaluate button

Values displayed in the legend should vary from 11.236 to 17.878. Next, rename this layer.

- Right click on the *Calculation* theme and then select *Properties*
    - Click the *General* tab
    - In the *Layer Name:* box, type ***Temperature***
    - Click OK

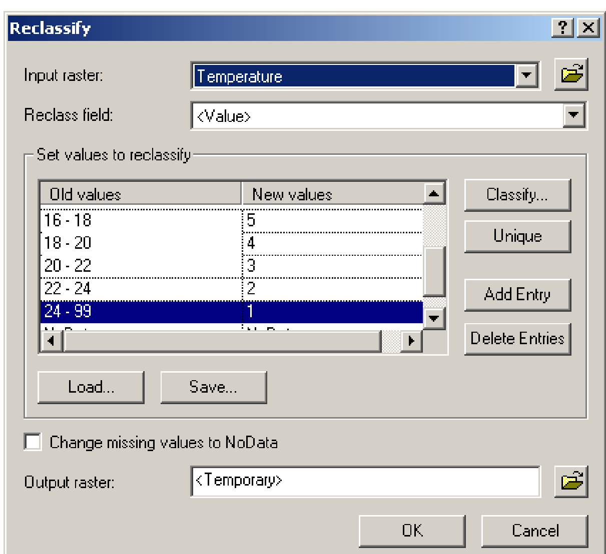
4.4 Creating Temperature Zones

By reclassifying the values in *Temperature* according to Table 2 we can create a layer depicting temperature zones. For the sake of convenience, Table 2 is reproduced below.

Table 2: Temperature Zones

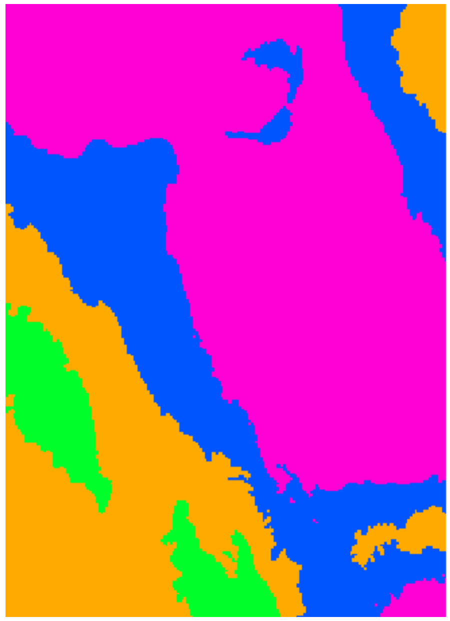
Range of Values	Temperature Zone
0 - 10	9
10 – 12	8
12 – 14	7
14 – 16	6
16 – 18	5
18 – 20	4
20 – 22	3
22 – 24	2
24 - 99	1

- From the *Spatial Analyst* drop down menu click *Reclassify*
    - Click the *Classify* button on the right side, then select 9 for *Classes*
    - Refer to Table 2 and enter in the appropriate values from Table 2 under the column headings: *Old Values* and *New Values* (see following image, note the top four ranges don't show in this window).



Note that '99' was entered as the upper value in the last range – this just ensures that no temperature values are missed in this reclassification. The resultant layer, *Reclass of*

Temperature, only has temperature classes 5 through 8 – if you consider the temperature range for this area, this makes sense. The temperature zone layer should look similar to the following image.



Again, to keep consistent with our cartographic model, let's rename this layer.

- Right click on the *Reclass of Temperature* theme and then select *Properties*
    - Click the *General* tab
    - In the *Layer Name:* box, type ***TempZone***
    - Click OK

4.5 Creating the Agro-Climatic Zones

The last step is to combine the moisture and temperature zones into one image. This again is done with the *Raster Calculator*. Remember a pixel can only hold one value; hence it cannot contain two separate values, one from each image. This is unfortunate because if a pixel location were to have a moisture zone of 4 and a temperature zone of 5, it would be nice if the pixel value in the resultant layer had something like **4 : 5**. In this way information from both layers would be retained. One way around this would be to multiply the values in the moisture layer by 10, whereby '4' becomes '40'. Then if we were to add the two layers we would get similar results, i.e. **45** instead of **4 : 5**. Provided we remember the 10's digit place represents moisture and the 1's digit place represents temperature, we retain the information from both layers.

- From the *Spatial Analyst* drop down menu click *Raster Calculator*.
    - From the *Layers* list double click *MoistZone*
    - Click the multiply button *
    - Type **10**
    - Click the + button

- From the *Layers* list double click *TempZone*

The equation should look like …

[MoistZone] * 10 + [TempZone]

- Click the Evaluate button

There should be 13 values in the legend, ranging from 16 to 55. The layer should look like the following:

Let's rename this final layer.

- Right click on the *Calculation* theme and then select *Properties*
  - Click the *General* tab
  - In the *Layer Name:* box, type ***ClimateZones,*** then click OK

We have completed the exercise. Based on known temperature and moisture requirements of crop plants and utilizing a map such as this one, agro-planners can create crop suitability maps. Such a suitability map could then be compared to actual crops planted to determine if there is any gain to be had from switching crops.

We are finished with this exercise. Note that all the raster layers you created in this exercise are temporary. To save your completed project …

- Click on the save button 

You are now ready to read the summary below and undertake the lab assignment …

5.0 SUMMARY

As with the previous tutorial, file management is the first issue to address when starting a project. In brief, it is often most convenient to locate all data in one directory (folder). This requires three steps:

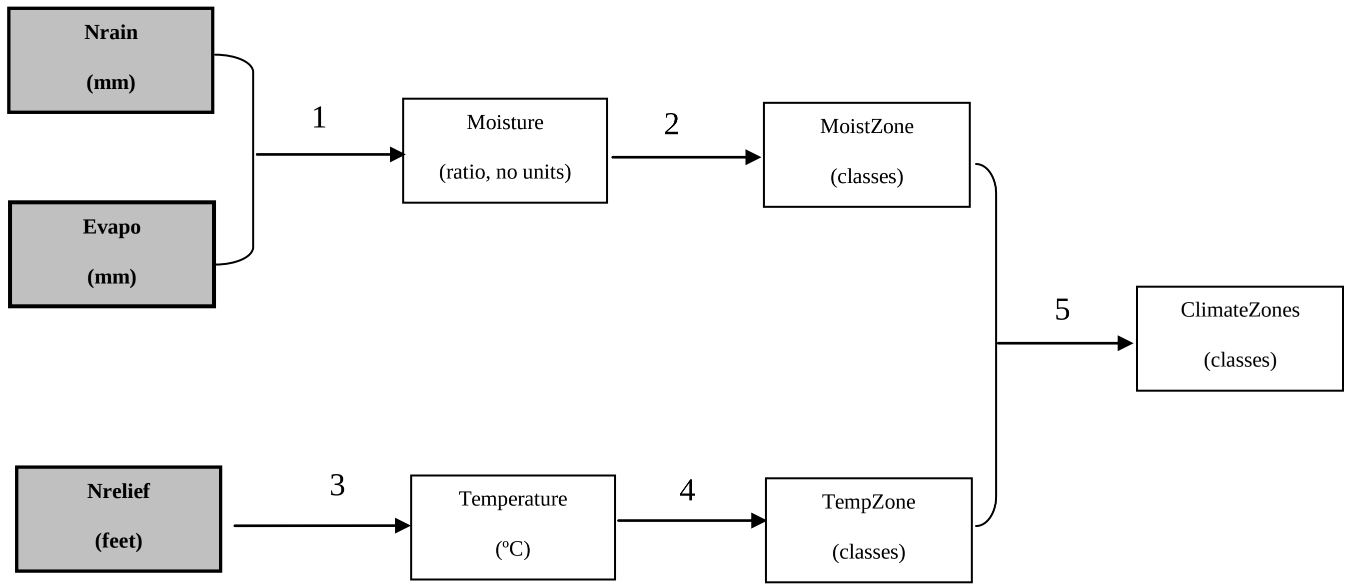
1. Create a project directory and copy source data to it,
2. Set the *working directory* to this same directory so newly generated data is created here, and
3. Save the project to the same directory.

This was a multi-step analytical procedure, which is typical of many GIS applications. Some complex analyses utilize a great many data sets and can have many more times the number of steps. Creating a cartographic model requires the analyst to have a clear understanding of the entire procedure at the very outset. The model itself can then act as a 'road map' for conducting the analysis.

The *Reclassify* function is fairly straightforward in that raw data can be simplified; in our case continuous data (temperature and moisture availability) were put into previously defined categories. The *Raster Calculator* function served three different purposes:

1. The first was the application of an algebraic equation to each pixel in a raster layer to convert it to a new 'form' (e.g. from elevation to temperature).
2. Second, it was used divide the pixel values from one layer by a second layer to derive a ratio (i.e. precipitation / evapotranspiration to give a measure of moisture availability).
3. And finally, it was used to combine the data from two layers.

Pull off this sheet and use as a reference when conducting the analysis.



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3	Raster Calculator	Apply equation Y (temperature ºC) = -0.0016 X (elevation feet) + 26.985
4	Reclassify	Classify data according to Table 2
5	Raster Calculator	Combine the data from both layers