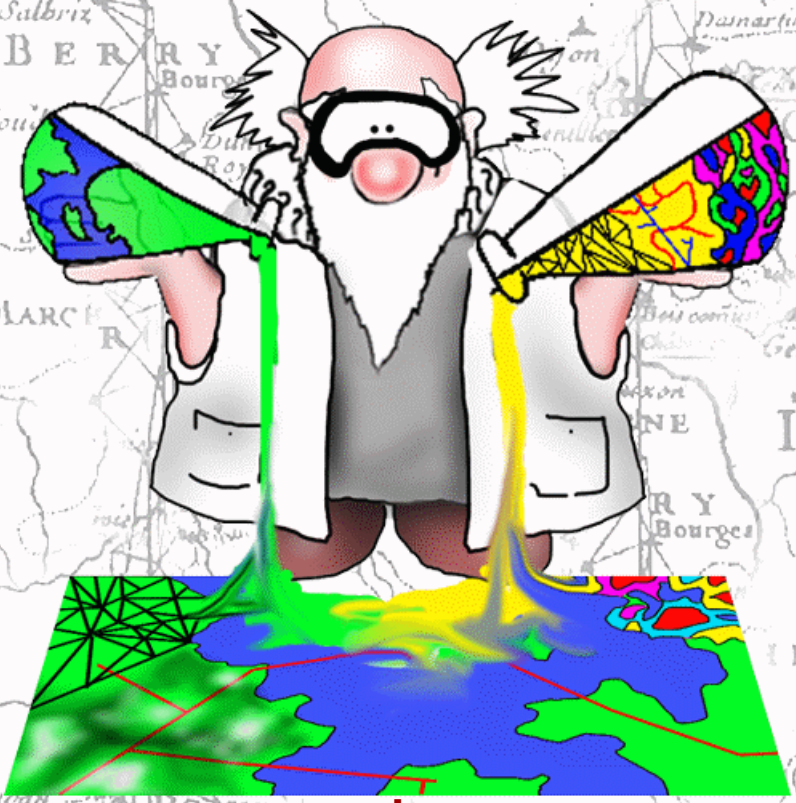
GEOFORMULAS

Tutorial

Using Geospatial Formulas



in

TNTmips®

TNTedit™

TNTview®

Before Getting Started

This booklet introduces techniques for using GeoFormulas™ in TNTmips®, TNTedit™, and TNTview®. Geospatial objects from TNT Project Files can be combined dynamically in the display process to achieve "data fusion" effects. This booklet introduces you to the basic GeoFormula tools in the Display and GeoFormula processes.

Prerequisite Skills This booklet assumes that you have completed the exercises in the tutorials *Displaying Geospatial Data* and *TNT Product Concepts*. The exercises in those booklets present essential skills and basic techniques that are not covered again here. Please consult those booklets for any review you need. You will also find it helpful to complete the exercises in the *Writing Scripts with SML* tutorial, since GeoFormula constructions use SML syntax.

Sample Data The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products DVD, you can download the data from MicroImages' web site. In particular, this booklet uses objects in the CB_DATA and GEOFRMLA data collections.

More Documentation This booklet is intended only as an introduction to data fusion with GeoFormulas. Details of the processes discussed here can be found in a variety of tutorial booklets, Technical Guides, and Quick Guides, which are all available from MicroImages' web site.

TNTmips® Pro and TNTmips Free TNTmips (the Map and Image Processing System) comes in three versions: the professional version of TNTmips (TNTmips Pro), the low-cost TNTmips Basic version, and the TNTmips Free version. All versions run exactly the same code from the TNT products DVD and have nearly the same features. If you did not purchase the professional version (which requires a software license key) or TNTmips Basic, then TNTmips operates in TNTmips Free mode. All of the exercises can be completed in TNTmips Free using the sample geodata provided.

Randall B. Smith, Ph.D., 14 October 2013
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You can print or read this booklet in color from MicroImages' web site. The web site is also your source for the newest tutorial booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTlite:

http://www.microimages.com

Introducing Geospatial Formulas

A GeoFormula is a script that combines information from one or more input objects to derive a result. In the TNTmips Display process you can create GeoFormula layers, which give you a way to combine objects "on the fly" rather than running separate processes to prepare output objects for display. A GeoFormula layer is a dynamic display layer that contains a "virtual object." The GeoFormula layer does not create an output object that is saved in a Project File. Instead, it creates a display layer that releases all its system resources (such as disk space and memory) when you are finished with it.

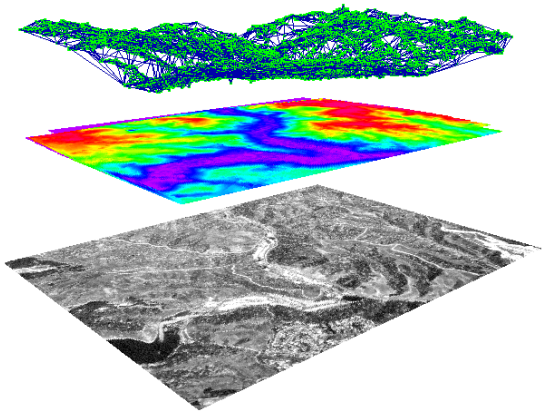
For example, red and infrared bands of raster imagery can be combined to produce a Normalized Difference Vegetation Index (NDVI). Of course TNTmips offers a simple process that produces an NDVI output raster object from selected input objects if you want to retain the TVI output for other uses. But if you just want to view the NDVI result and do not care to keep the output object, you can use a GeoFormula display layer. (The exercise on page 6 provides a NDVI GeoFormula script.)

A GeoFormula script can be saved as a reusable file. A GeoFormula layer can be combined with any number of other layers in the TNTmips display process to create a complex visualization of multiple geospatial objects.

The GeoFormula feature is primarily provided for dynamic visualization tasks in the display process. You can also run a separate GeoFormula process (Script / GeoFormula) to create permanent output objects for other uses (see pages 19-23).

☑ choose Main / Display from the TNTmips menu

One or more layers in a display may be dynamically computed from a **GeoFormula** that refers to several input objects.



Geoformula display layers perform file access and multi-object processing on the fly. Thus you may notice that this processing overhead results in slower display times that may seem sluggish compared to other display layers.

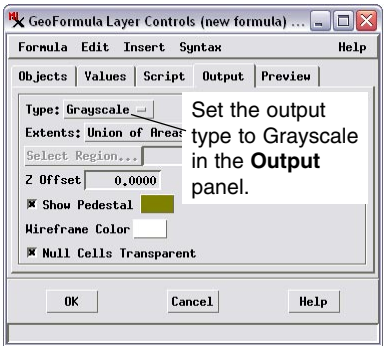
Simple one-object GeoFormulas are introduced on pages 4-7. Pages 8-14 present a number of multi-raster scripts. The exercises on pages 15-17 show how to use values from both raster and vector objects in a GeoFormula. Pages 19-23 introduce the GeoFormula process for creating output rasters.

A Simple GeoFormula

STEPS

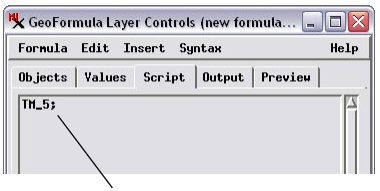
- ☑ from the Display Manager choose Display / New / Empty 2D
- ☑ choose Add / Layer / GeoFormula / Add GeoFormula Layer
- ☑ select Formula / New in the GeoFormula Layer Controls dialog
- ☑ select CB_DATA / CB_TM / TM_5 in the Select Objects dialog
- ☑ select the Output tab and set the Type menu button to Grayscale

A GeoFormula layer allows you to perform calculations and combinations using numerical values from the spatial elements in one or more georeferenced spatial objects. The numerical values can be the cell values of raster objects or attribute values from geometric objects (vector, CAD, or shape). The computations are carried out separately for each raster cell or spatial element to produce a temporary grid of values (raster) that is displayed in the View. The output of the computations can be either grayscale (a single set of values) or color (sets of values for red, green, and blue color components).

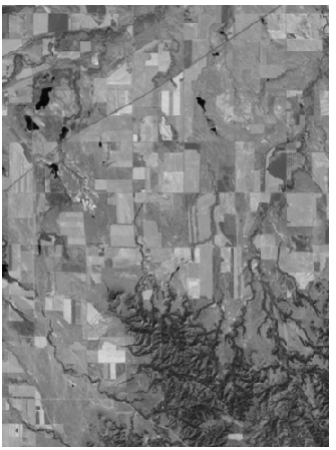


GeoFormula layers are added to an already open group (either empty or containing other layers). Since a GeoFormula must refer to at least one georeferenced object, the process prompts you to select one or more input objects in the standard Select Objects dialog. The objects you select are listed on the Objects tabbed panel of the GeoFormula Layer Controls. To get started, our initial GeoFormula will simply display the unmodified cell values of the TM_5 raster object in grayscale (shown below).

- ☑ select the Script tab and type in "TM_5;"
- ☑ press [OK] to close the GeoFormula Layer Controls dialog
- ☑ click [No] in the Question dialog that asks if you want to save changes



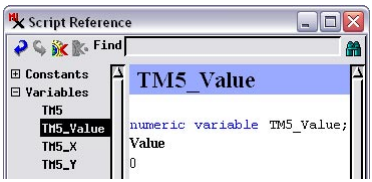
In the **Script** panel, this GeoFormula expression simply uses the unmodified raster cell values from TM_5.



Predefined Variables

When you select an input object to use in a GeoFormula layer, its name becomes the default object variable name shown on the Objects tabbed panel. You can edit this variable name if you like to simplify writing the script. For a raster object, the object variable represents the raw numeric value of each raster cell, as we saw in the previous exercise.

Several other predefined variables are also automatically created for each input object. These predefined variables are shown in the Variables list in the Script Reference window, which you can open by choosing the Symbol option on the Insert menu. You can insert any of these pre-defined variables into your GeoFormula from the Script Reference window.

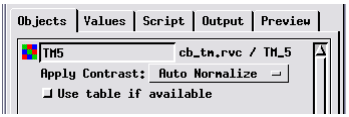


Raster inputs are provided with a predefined variable consisting of the object variable name followed by "_Value". This variable represents cell values contrast-adjusted for display using either an auto-contrast method selected from the Apply Contrast menu on the Object panel, or the last-used saved contrast table (by turning on the *Use table if available* toggle button.

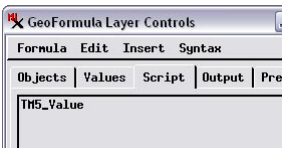
GeoFormula layer showing contrast-enhanced values (using Auto Normalize) from the input raster TM_5.

STEPS

- ☑ in the Display Manager, left-click on the GeoFormula layer icon to reopen the GeoFormula Layer Controls window
- ☑ turn on the Show Details toggle in the Objects tab



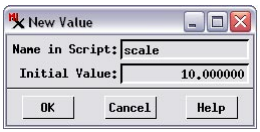
- ☑ change the object variable name to "TM5"
- ☑ select Auto Normalize from the Apply Contrast menu
- ☑ on the Script tabbed panel, select and delete the previous text
- ☑ choose Insert / Symbol
- ☑ in the Script Reference window, expand the Variables listing by clicking on the ⊞ symbol
- ☑ select TM_5_Value in the variable list and press the Insert icon button
- ☑ press [OK] to close the GeoFormula Layer Controls dialog



Using Values

STEPS

- ☑ open the GeoFormula Layer Controls window
- ☑ click on the Values tab and press the Add New Value button
- ☑ in the New Value window, enter "scale" in the *Name in script* field and "10" in the *Initial Value* field



- ☑ turn on the Show Details toggle at the bottom of the Values panel
- ☑ in the Script panel, construct the following expression:

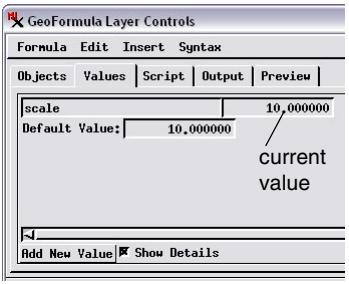
```
TM5 * sqrt(TM5_x) / scale;
```

- ☑ press [OK] to close the GeoFormula Layer Controls dialog

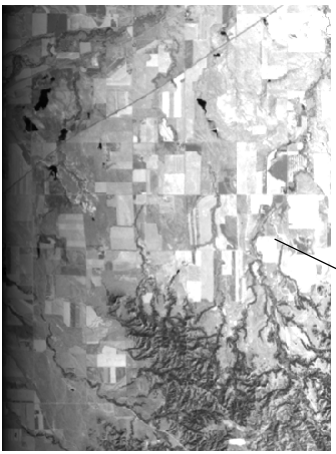
A GeoFormula script can include numeric variables that you declare and assign values to, such as:

```
numeric scale = 10;
```

But you do not need to define such variables in the script itself. The Values tabbed panel on the GeoFormula Layer Controls allows you to name numeric variables and assign them initial values, which become default values when you save the GeoFormula. You can then not only use the variable in the script, but also return to the Values panel and adjust the value of the variable without editing the script itself. This feature makes it easier for users of your script to make adjustments in variable values to get the best visual result with different input objects.



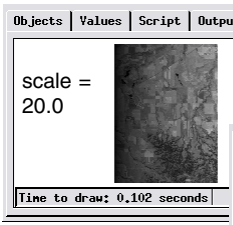
GeoFormulas can use standard mathematical operators as well as many of the predefined functions that are part of the TNTmips geospatial scripting language (see the tutorial entitled *Writing Scripts in SML* for full details). Mathematical operators and predefined functions can be inserted from the Script Reference window.



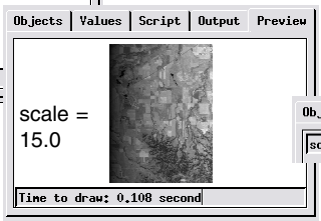
Additional predefined variables, in this example named TM5_X and TM5_Y, stand for the X and Y coordinates of each cell (respectively). You can use these variables to apply mathematical expressions whose effects vary spatially over the object, though this is not likely to be a common application of GeoFormulas. This sample script produces image brightness values that vary with the square root of the x-coordinate.

Preview and Save

The Preview panel in the GeoFormula Layer Controls window is essentially a miniature view window, giving you a quick preview of the result of the current GeoFormula. It allows you to make repeated adjustments in a script (such as adjusting a value on the Values panel) and preview the results without having to close the GeoFormula layer controls and redraw the View window.

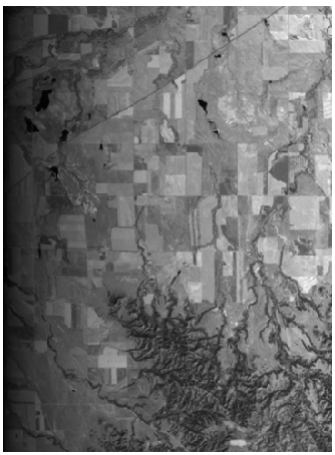


Open the Preview panel for a quick preview of the result from the current script.



Preview is especially useful with complex GeoFormulas involving multiple large input objects, where redrawing the full View window may be slow.

You can save a GeoFormula at any time. The resulting .gsf file contains the script, variable definitions, and other parameters used in the GeoFormula. The .gsf file created in this exercise is shown below.



GeoFormula result with scale = 15

STEPS

- ☑ open the GeoFormula Layer Controls window
- ☑ on the Values panel change the scale variable value to 20.0

- ☑ click on the Preview panel to view the result
- ☑ return to the Values panel and change the scale variable value to 15.0

- ☑ click on the Preview panel to view the result
- ☑ click on the Formula menu on the GeoFormula Layer Controls window menu bar and choose Save As
- ☑ in the Select text file window, name the GeoFormula file and press OK
- ☑ press [OK] to close the GeoFormula Layer Controls dialog

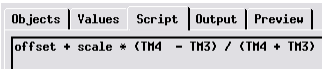
```
[GeoFormula]
NumValues=1
Value0_Default=10.00000000
Value0_Name=scale
NumObjects=1
Object0_ContUseTable=No
Object0_ContType=2
Object0_DataType=0
Object0_Type=3
Object0_Name=TM5
ExtentsMode=2
Type=0
Script=TM5 * sqrt(TM5_X) / scale;
```

GeoFormula with Two Input Rasters

When you open an existing GeoFormula, as in this exercise, the process loads the script and immediately opens the Select Objects dialog, prompting you for the specified input objects.

STEPS

- ☑ open the GeoFormula Layer controls dialog and select Formula / Open
- ☑ select GEOFRMLA / NDVI.GSF
- ☑ in the Select Rasters window, select PHOTO_IR and RED from the CB_TM Project File
- ☑ examine the script on the Script panel

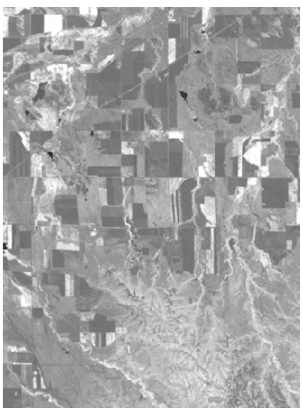


- ☑ click on the Preview panel to view the result
- ☑ click on the Values tab and turn on the Show Details toggle
- ☑ change the scale value to 200
- ☑ press [OK] to close the GeoFormula Layer Controls dialog

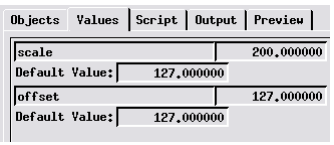
The strength of the GeoFormula feature in the Display Process is that it lets you perform operations on multiple input objects "on the fly." For example, to view a Normalized Difference Vegetation Index (NDVI) result (showing vegetation vigor computed from near-infrared and red spectral bands), you could run the Predefined Raster Combination process (Image / Combine / Predefined), select input objects, create an output raster, and view the result. By contrast, the GeoFormula feature lets you view the NDVI result dynamically in a "virtual object," without running a separate process to create a raster object.

The grayscale output type assumes an 8-bit unsigned data range (values 0 to 255). Values computed by a GeoFormula that fall outside this range are assigned the null value and by default display transparently in the view. You should analyze your GeoFormula expression and incorporate scale and offset values if necessary to produce the appropriate output range.

In the example normalized difference GeoFormula, the expression (TM4 - TM3) / (TM4 + TM3) can range in value from -1 to + 1. The script by default applies a scaling factor (multiplier) of 127, which results in a range from -127 to +127. An offset factor with default value of 127 is also added, shifting the range of possible output values to 0 to 254, within the allowed range for grayscale GeoFormula output. Using the image bands in this example, the output brightness values fill only a portion of the brightness range, so the default result has low contrast. Increasing the scale value to 200 produces a result with better contrast.



NDVI result for the Crow Butte PHOTO_IR and RED bands with scale =200.



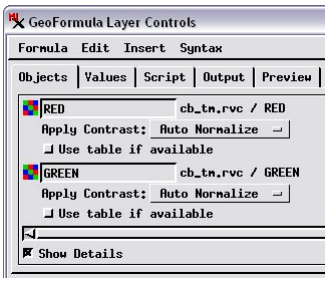
A First Look at Color

In the previous exercises, the GeoFormula scripts have been simple expressions that yield numeric values for grayscale display. When the output type is grayscale, the result of the numeric expression is used directly for 8-bit grayscale display intensity.

When you change the output type to color, the process automatically creates three color component variables (Output_Blue, Output_Green, and Output_Red) in addition to the predefined variables we have seen previously. For color output, your script must assign values in the range from 0 to 255 to each of the output component variables. The simple script for this exercise simply displays a contrast-enhanced rendering of the three input bands.

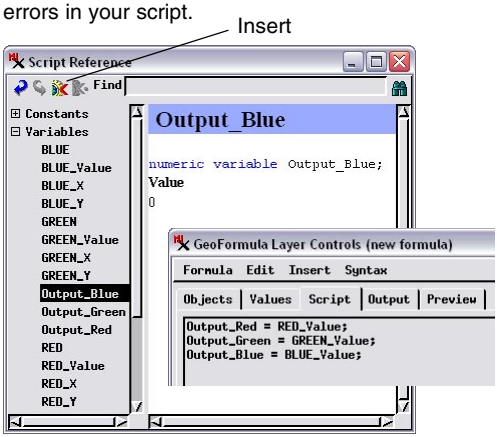
STEPS

- ☑ open the GeoFormula Layer controls dialog and select Formula / New
- ☑ select RED, GREEN, and BLUE from the CB_TM Project File
- ☑ in the Objects panel select Auto Normalize for contrast for all three objects
- ☑ in the Output panel select Color for Output Type
- ☑ open the Script Reference window and expand the Variables list
- ☑ on the Script panel, insert the variables to construct the script shown below



When you select input objects for a new GeoFormula, the Show Details toggle on the Objects tabbed panel is automatically turned on to allow you to set contrast options for each input. This toggle is not on by default if you later reopen the Objects panel.

Using the Script Reference Variables list to insert predefined variables helps avoid typographical errors in your script.



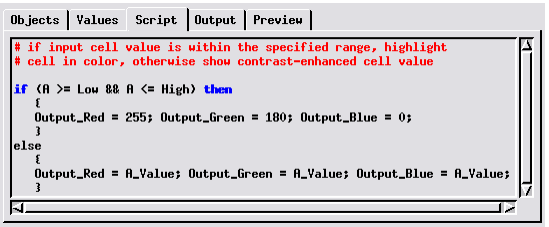
This GeoFormula result is a simple RGB color rendering of the three input bands with normalized contrast enhancement.

Highlight Range in Color

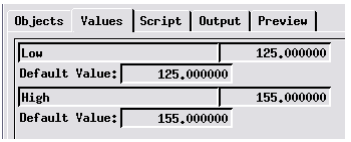
STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / Open and select GEOFRMLA / RANGERGB.GSF
- ☑ for input TM_5 from CB_TM
- ☑ examine the script on the Script panel

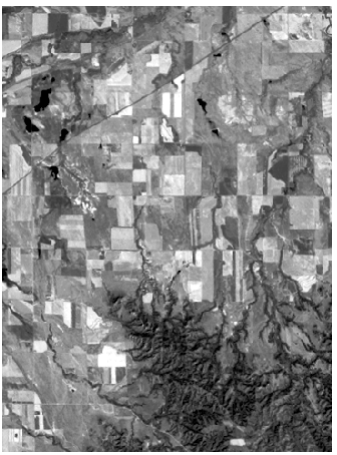
The simple color GeoFormula in this example uses only one input raster. It is designed to highlight in color the areas of the input raster whose cells fall within the designated range of values. Cells within the range (inclusive) are shown in an orange highlight color. For cells outside the range, the contrast-enhanced cell value is assigned to all three of the output color components, so these areas appear in gray equivalent to a simple grayscale display of the input raster. The range to highlight can be adjusted by changing the values for the Low and High variables on the Values tabbed panel.



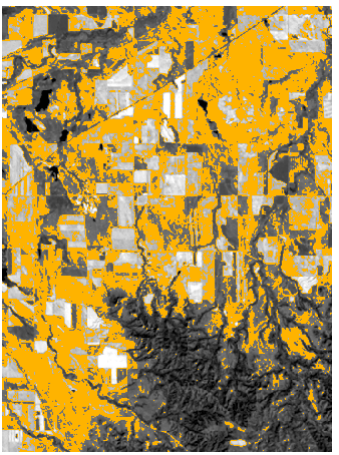
- ☑ click [OK] to close the GeoFormula Layer Controls dialog



Edit the Low and High values on the Values panel to adjust the highlight range.



Input raster TM_5



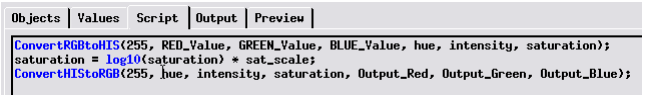
GeoFormula result for range = 125 to 155

Transforming Image Color

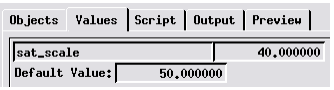
A GeoFormula with color output can be used to transform and enhance the color of a set of RGB input components. In this exercise the GeoFormula performs a *saturation stretch*. The input color values (with normalized contrast from saved contrast tables) are transformed to the Hue-Intensity-Saturation color space using the ConvertRGBtoHIS() function. Then a logarthmic stretch is applied to the saturation values and the HIS components are transformed back to the RGB color space for display. [Note that the Output_Red, Output_Green, and Output_Blue predefined variables are used as the output color components for the ConvertHIStoRGB() function]. This transformation preserves the hues in the original image but makes the colors more vivid. The value for the sat_scale variable (scaling factor for the saturation stretch) can be adjusted to vary the color enhancement.

STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / Open and select GEOFRMLA / STRETCH3.GSF
- ☑ for input, select RED, GREEN, and BLUE from CB_TM
- ☑ examine the script on the Script panel



- ☑ on the Values panel change the value for the sat_scale variable to 40



- ☑ click [OK] to close the GeoFormula Layer Controls dialog

Color display of TM3, TM2, and TM1 with normalized contrast.

GeoFormula result with saturation stretch to enhance colors.

Tasseled Cap Transformation

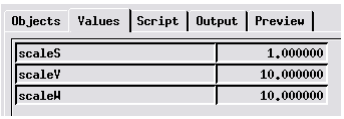
STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / Open and select GEOFRMLA / TCAPRGB.GSF
- ☑ for input, select the CB_TM Project File
- ☑ select BLUE, GREEN, RED, PHOTO_IR, TM_5, and TM_7 for the input objects as prompted
- ☑ examine the script on the Script panel
- ☑ click [OK] to close the GeoFormula Layer Controls dialog

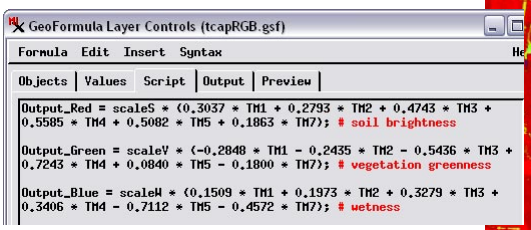
NOTE: use the Syntax / Check menu option to check the structure and syntax of your complex GeoFormulas.

A GeoFormula with color output can be used with any number of input objects as long as the formula computes the required three output color components. The script in this exercise uses six bands of the Crow Butte Landsat scene as input for the Tasseled Cap Transformation. This transformation computes three derived properties: soil brightness, vegetation greenness, and soil wetness. Each of these factors is a linear combination of the six input bands. To compute each property, the cell value in each band is multiplied by a coefficient, the resulting values are summed, and the result is multiplied by a scale factor. The three scale factors can be varied to adjust the colors in the display result.

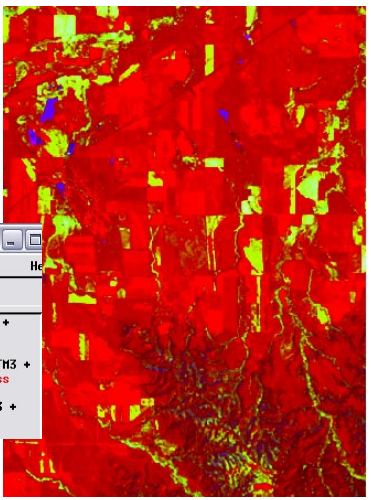
In this GeoFormula the soil brightness factor is assigned to the red output color, vegetation greenness to green, and wetness to blue. The resulting display is dominated by red colors from bare soils in the croplands. The areas with the most green vegetation appear green, and scattered ponds and lakes are shown in blue.



scaleS is the scale factor for soil brightness, scaleV for vegetation greenness, and scale W for wetness.



The coefficients used here were determined empirically for use with Thematic Mapper images from the Landsat 4 satellite.



Brovey Transformation

Another use of color implements the Brovey transform, which merges color information from three bands of low-resolution imagery with grayscale brightness from a higher-resolution panchromatic image covering all or part of the same area. The result is a color display with higher apparent spatial resolution than that of the input color bands. The example in this exercise produces a higher-resolution "color-infrared" display from 30-meter Landsat TM imagery in the CB_TM Project File and a 10-meter SPOT panchromatic image in the CB_SPOT Project File.

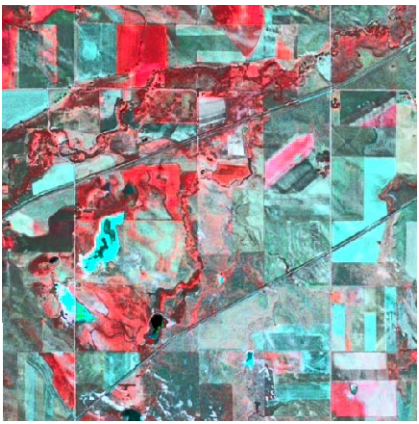
This GeoFormula (illustrated below) uses the contrast-enhanced values from each input raster. For each cell in the high-resolution band a scale factor is computed that is effectively the high-res value divided by the average of the corresponding values in the low-res color bands. The value of each output color component is computed as the input color component value multiplied by this scale factor.

STEPS

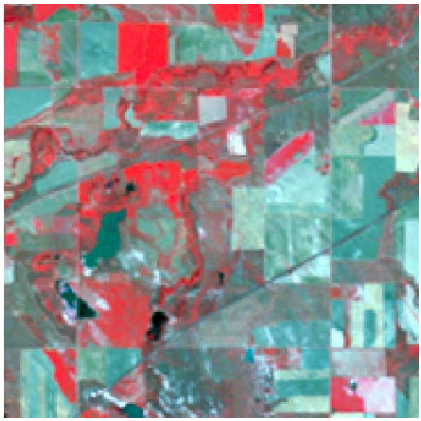
- ☑ open the GeoFormula Layer Controls window
- ☑ select Formula / Open and select GEOFRMLA / BROVEY1.GSF
- ☑ for input, select the CB_TM Project File and PHOTO_IR, RED, and GREEN for the input objects
- ☑ select CB_SPOT / SPOT_PAN_LITE for the HIGHRES input object
- ☑ examine the script on the Script panel
- ☑ click [OK] to close the GeoFormula Layer Controls dialog

Objects | Values | Script | Output | Preview

```
# Brovey transform
# enhance low-resolution RGB rasters
# with high-resolution grayscale
#
numeric scale;
scale = 3 * HIGHRES_Value / (RED_Value + GREEN_Value + BLUE_Value + 1);
Output_Red = RED_Value * scale;
Output_Green = GREEN_Value * scale;
Output_Blue = BLUE_Value * scale;
```



Brovey GeoFormula result.



RGB display of the input color bands for the same area.

Inputs with Different Extents

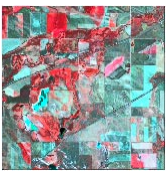
STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / Open and select GEOFRMLA / BROVEY3.GSF
- ☑ for input, select the CB_TM Project File and PHOTO_IR, RED, and GREEN for the input objects
- ☑ select CB_SPOT / SPOT_PAN_LITE for the HIGHRES input object
- ☑ click [OK] to close the GeoFormula Layer Controls dialog
- ☑ reopen the GeoFormula Layer Controls dialog
- ☑ on the Output panel set the Extents menu to Common Area
- ☑ click [OK] to close the GeoFormula Layer Controls dialog

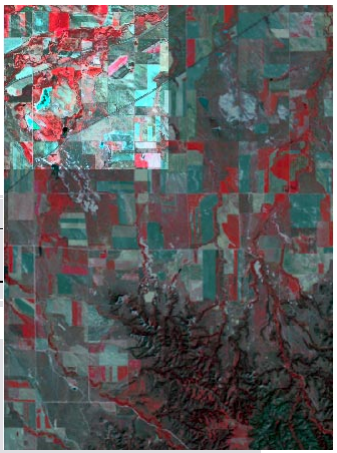
The Brovey example in the previous exercise uses input rasters with different cell sizes and different spatial extents (the SPOT image covers only the upper left corner of the TM bands). As we have seen, GeoFormulas automatically cope with input rasters with different cell sizes. For inputs with different extents, the default behavior is to process only the common overlap area between all inputs (and to zoom the result to the full extents of that common area).

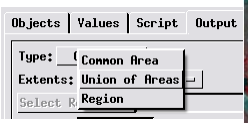
When using inputs with different extents you can use the Extents menu on the Output tabbed panel to choose either Common Area and Union of Areas. (You can also use this menu to use a region object to control the extents). Choosing Union of Areas in the previous exercise results in a display matching the full extents of the TM bands, but the area outside the extents of the smaller SPOT image are automatically treated as null and are transparent.

Result with Extents = Common Area



Result with Extents = Union of Areas






```
numeric scale;
if ( IsNull(HIGHRES) )
{
Output_Red = RED_Value * 0.6;
Output_Green = GREEN_Value * 0.6;
Output_Blue = BLUE_Value * 0.6;
}
else
{
scale = 3 * HIGHRES_Value / (RED_Value + GREEN_Value + BLUE_Value + 1);
Output_Red = RED_Value * scale;
Output_Green = GREEN_Value * scale;
Output_Blue = BLUE_Value * scale;
}
```

In this exercise we use a Brovey GeoFormula that has been modified to process the areas outside the hires image differently by testing whether the hires value is null. In those areas the GeoFormula shows a darkened color display of the input TM bands. The normal Brovey result is computed for areas with valid hires raster values. Although this result is not very useful, it illustrates how separate processing can be applied to non-overlap areas.

Vector Objects in GeoFormulas

GeoFormulas can include vector objects by referencing values stored in numeric database fields associated with polygon elements. These database values are referenced in the form

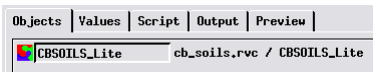
ObjectName.poly.Table.Field

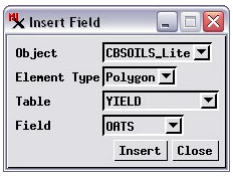
Precise spelling, including use of upper and lower case, is essential in referencing database fields. The Insert Field window allows you to choose the element type, table name, and field name and insert the correctly-formed reference into your GeoFormula.

The simple example in this exercise uses attributes of soil polygons, specifically potential crop-yield values for oats associated with different soil types. For the CBSOILS_LITE vector, these potential yield values ranges from 0 to 46 bushels per acre. The GeoFormula multiplies the oat yield value by 5 to produce a grayscale output result.

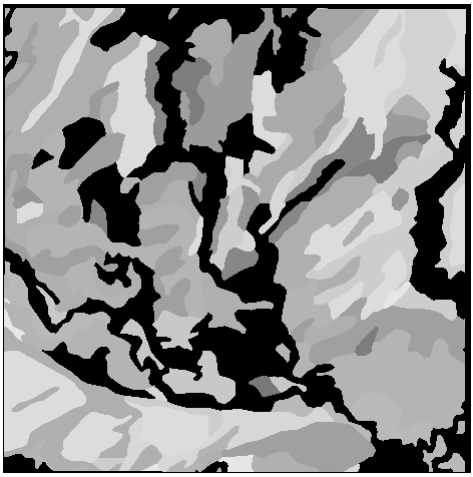
STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / New and select CB_DATA / CB_SOILS / CBSOILS_LITE as the single input object
- ☑ click on the Script tab and choose Insert / Field
- ☑ in the Insert Field window, choose Polygon for Element Type, YIELD for the Table, and OATS for the Field and press [Insert]
- ☑ add "* 5;" at the end of the expression
- ☑ on the Output panel choose Grayscale from the Type menu
- ☑ click [OK] to close the GeoFormula Layer Controls dialog





Use the Insert Field window to insert correct Table.Field references into your GeoFormula.



NOTE: numeric attributes of line or point elements in vector objects cannot be used to produce a valid GeoFormula result.

Using Both Vectors and Rasters

STEPS

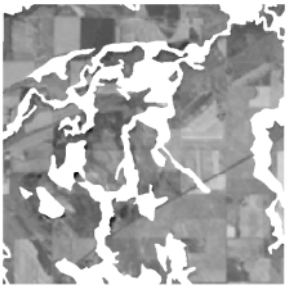
- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / New and select CBSOILS_LITE and TM_5 as input
- ☑ on the Object panel turn on the *Use table if available* toggle for TM_5
- ☑ enter the two-line script illustrated
- ☑ change the output type to grayscale, turn on the Null Cells Transparent toggle, and view the result
- ☑ select Formula / Open and select YIELD432.GSF with CB_TM and CBSOILS_LITE inputs
- ☑ click [OK] to close the GeoFormula Layer Controls window

The GeoFormula feature offers a great deal of potential for complex combinations of objects of different types. You can construct an endless number of expressions and statements that reference attributes and values from multiple input objects of different types.

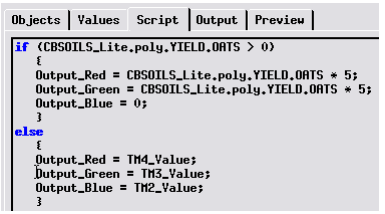
In this exercise the CBSOILS_LITE vector object is combined with one band of the TM imagery from CB_TM. The vector expression is similar to the expression in the previous exercise, with the addition of a conditional structure. Make a new GeoFormula for grayscale output, select TM_5 and CBSOILS_LITE for input, and type in the expression

```
if (CBSOILS_Lite.poly.YIELD.OATS > 0)
return TM_5_Value;      else return 255;
```

That expression works like a mask, taking the display value from TM_5 except where the YIELD.OATS value is zero.



For a more complex GeoFormula, open YIELD432.GSF which displays the YIELD_OATS.OATS values where they are larger than 1, and the composite color TM4, TM3, and TM1 bands elsewhere.



The color image of Crow Butte TM bands 432 is visible where YIELD_OATS.OATS has no value. The color spread is achieved by assigning the same value to the red and green output color components.

Universal Soil Loss Equation (USLE)

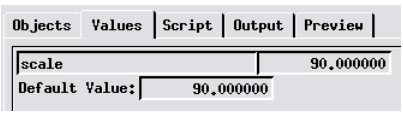
The Universal Soil Loss Equation is used to create a soil erosion map from data that include rainfall amounts (R), soil erodibility (K), surface slope (LS), and conservation (C) and management (P) practices. The basic form of the equation is:

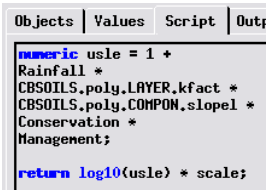
$$A = R * K * LS * C * P$$

A GeoFormula script (USLELOG.GSF) implements the Universal Soil Loss Equation for the Crow Butte map area. It uses the CBSOILS_LITE vector object to access soil erodibility (K = LAYER.kfact) and slope-length factor (LS = COMPON.slopel). It uses three raster objects for the remaining inputs: RAINFALL (R), MANAGEMENT (C), and CONSERVATION (P), all found in the CB_DATA / LANDUSE Project File. The basic USLE expression has been modified for the display environment by adding 1 to the USLE product, applying the log10 function (to compute the log to the base 10 of that value), then multiplying by a scale factor (with value set on the Values tabbed panel) to spread the resulting grayscale values over most of the 0-255 display range.

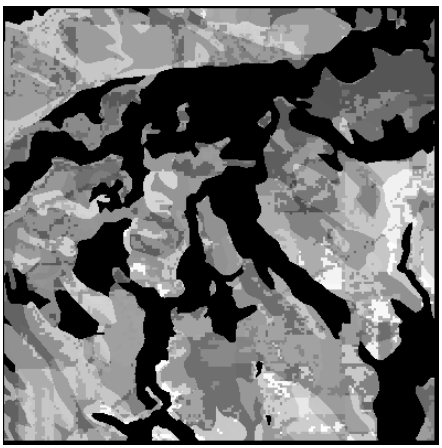
STEPS

- ☑ open the GeoFormula Layer Controls dialog
- ☑ select Formula / Open and select GEOFRMLA / USLELOG.GSF
- ☑ select input rasters CB_DATA / LANDUSE / MANAGEMENT, CONSERVATION, and RAINFALL
- ☑ select input vector object CB_DATA / CB_SOILS / CBSOILS_LITE
- ☑ click [OK] to close the Select Objects dialog
- ☑ click [OK] to close the GeoFormula Layer Controls dialog





The resulting display layer is a grayscale map of erosion effects. Black areas are those where the USLE product = 0; these are mostly low-lying flat areas (slope factor = 0) with little erosion potential. Brighter grayscale tones in the remainder of the area indicate increasing potential for erosion and soil loss.



USLELOG.GSF is a good candidate for use in the stand-alone GeoFormula process (Process / GeoFormula). You can examine the output raster object to quantify erosion estimates, and create color maps for display.

Speeding Up GeoFormula Display

GeoFormula layer display times vary with the complexity of the GeoFormula and the size, number, and type of input objects.

Geoformula display layers perform file access and multi-object processing on the fly. This processing is very fast if all input objects are rasters, but can seem slow if the GeoFormula uses vector attributes. Below are some tips for speeding up processing.

Use the Preview Pane. The Preview pane in the GeoFormula Layer Controls window presents a small preview image quickly. Use the Preview pane especially as you compare the effects of different variable values and other script changes during development.

Reduce the View Window Size. Just as the small image in the Preview pane displays quickly, so does a small View window. The GeoFormula layer samples its input objects according to the size of the View window, so a small View results in less input data to process.

```
scale = 3 * HIGHRES_Value / (RED_Value +
   GREEN_Value + BLUE_Value + 1);
Output_Red = RED_Value * scale;
Output_Green = GREEN_Value * scale;
Output_Blue = BLUE_Value * scale
```

BROVEY1.GSF computes the **scale** value once at the beginning rather than in each output statement.

Calculate Values Once. Find ways to optimize your script. See if you can precalculate a value so that it is derived once rather than repeatedly. For example, in BROVEY1.GSF (see p. 13), a **scale** variable is calculated once rather than with each output statement.

Use Nested If/Else. Test multiple logical conditions with nested if/else statements, always putting the most likely cases first and the least likely cases last. When the script encounters a true condition, it skips the rest of the conditions. By contrast, if you use a simple sequence of if statements, the process tests every condition, every time.

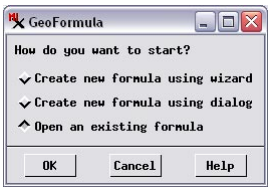
```
if ((SPOT_PAN >=36) and (SPOT_PAN < 47)) return (128);
else if ((SPOT_PAN >=32) and (SPOT_PAN < 36)) return (86);
else if ((SPOT_PAN >=47) and (SPOT_PAN < 50)) return  (170);
else if ((SPOT_PAN >=19) and (SPOT_PAN < 32)) return (42);
else if ((SPOT_PAN >=50) and (SPOT_PAN < 54)) return (212);
else if (SPOT_PAN < 19)  return (0);
else if (SPOT_PAN >= 54) return (255);
```

NESTEDIF.GSF puts higher-probability conditions earlier.

GeoFormula Process

Up to now we have worked with GeoFormula display layers, which create only a transient visual result. The separate GeoFormula process (Script / GeoFormula) can be used to create a raster object that permanently records the result of the GeoFormula.

When you start the GeoFormula process, you are presented with a dialog from which you can choose how you want to start working. If you want to create a new formula, you can do so using a wizard (a series of dialogs that prompt you for actions) or simply using the GeoFormula window controls as you have done in previous exercises. You also have the option to open an existing formula, which is how we will begin exploring the GeoFormula process. In this exercise we open the NDVI GeoFormula that we used in an earlier exercise.

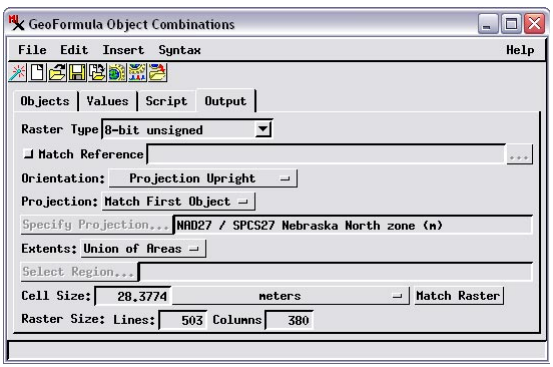


The Raster Type menu on the Output panel lets you pick the type of grayscale raster for the NDVI result. You can choose from signed or unsigned integer types with varying bit-depth, or use a floating point raster. Because the script in this example already is designed to produce output in the range from 0 to 255, we choose the 8-bit unsigned raster type.

We also need to set the cell size or raster size for the output. Here we choose to match the cell size of the input rasters, which also sets the dimensions in lines and columns for the output raster.

STEPS

- ☑ choose Script / GeoFormula from the TNTmips menu
- ☑ in the GeoFormula prompt window, select Open an existing formula and press [OK]
- ☑ when prompted for the script, select GEOFRMLA / NDVI.GSF
- ☑ in the Select Rasters window, select PHOTO_IR and RED from the CB_TM Project File
- ☑ on the Output tabbed panel, choose 8-bit unsigned from the Raster Type menu
- ☑ press the Match Raster button near the bottom of the panel to set the cell size and output raster size
- ☑ press the Run icon button
- ☑ in the Select Output Raster window, name a new Project File and press [Create File]
- ☑ name the output NDVI raster object and press [OK]



The Output panel is exposed automatically when you load an existing GeoFormula.

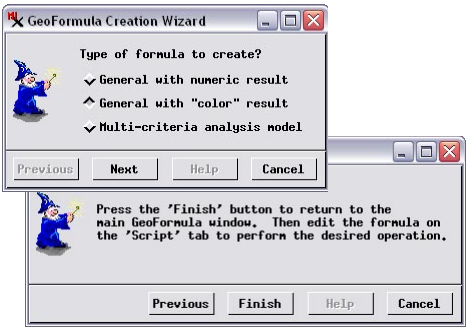
Using the GeoFormula Wizard

STEPS

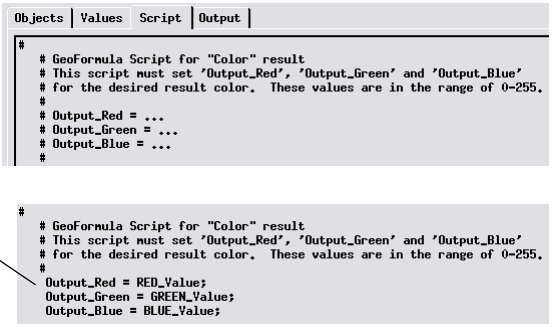
- ☑ press the New Formula (wizard) icon button
- ☑ select RED, GREEN, and BLUE from the CB_TM Project File
- ☑ in the next wizard window, choose *General with "color" result* and press [Next]
- ☑ press [Finish] in the final wizard window
- ☑ in the Objects panel, turn on the Show Details toggle and turn on the *Use table if available* option for all three input objects
- ☑ in the Script panel, remove the comment characters (#) from the lines that assign the output colors
- ☑ assign Red_Value, Green_Value, and Blue_Value to the corresponding output color
- ☑ on the Output panel note the default Raster Type setting is 24-bit RGB composite
- ☑ press the Run icon button and name the output raster

In this example we simply assign the contrast-enhanced value from each input color to its corresponding output, as in our first color GeoFormula result from page 9.

You can use the GeoFormula Creation Wizard to create a new formula when you first launch the GeoFormula process or at any time from the GeoFormula window by pressing the *New Formula (wizard)* icon button. You are first prompted to select the input objects. A wizard window then prompts you to choose the type of output the formula will create: general numeric result (grayscale), general color result, or a multi-criteria analysis model (see page 22).

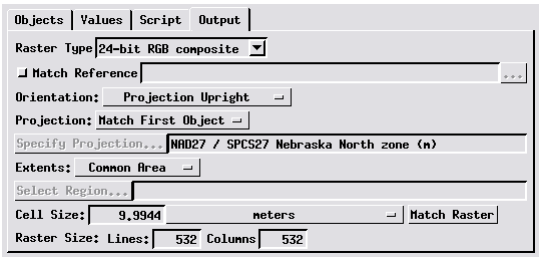


When you choose one of the two general script options, the wizard creates a skeletal script with all lines commented out, along with guidelines on how that type of script must be structured. You then edit the script, removing the comment character from the functional lines and adding lines to perform the desired computation.



Spatial Options for the Result

The Output panel on the GeoFormula window has the same Extents menu (with options of Union of Areas and Common Area) that we used for controlling the extents of GeoFormula display layers. But since the result is now a saved raster object, a number of additional controls are provided. You can set the cell size of the result raster manually or press the Match Raster button to use the smallest cell size among the input rasters. This button also works in conjunction with the Extents option to set the Raster Size values.

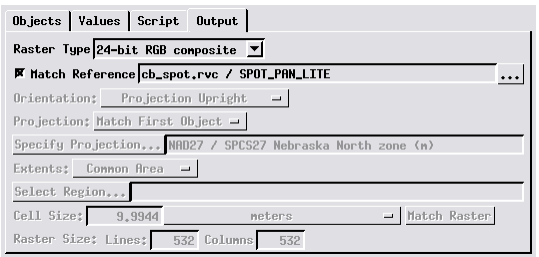


By default the coordinate reference system used for the result raster matches that of the first object selected, but you can choose User-Defined from the Projection menu, then press the Specify Projection button to choose any reference system. You can also use the Orientation menu to change the orientation of the data in the result raster (for example, placing south to the top).

You can also match the cell size, extents, orientation, and coordinate reference system of the result to a reference raster (including any of the input rasters). When the Match Reference toggle is turned on, all other spatial controls (and any previous selections) are disabled.

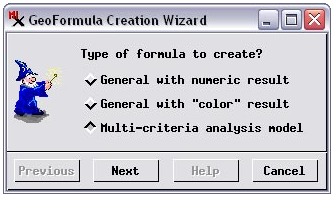
STEPS

- ☑ press the Open icon button on the GeoFormula window
- ☑ select GEOFRMLA / BROVEY3.GSF
- ☑ for input, select the CB_TM Project File and PHOTO_IR, RED, and GREEN for the input objects
- ☑ select CB_SPOT / SPOT_PAN _LITE for the HIGHRES input object
- ☑ on the Output panel, choose Union of Areas from the Extents menu, then press [Match Raster]
- ☑ now choose Common Area for Extents and press [Match Raster]; note the change in the Raster Size fields
- ☑ turn on the Match Reference toggle button; when prompted, choose CB_SPOT / SPOT_PAN _LITE for the reference
- ☑ note that the other spatial option controls are now inactive
- ☑ press the Run icon button and name the output raster
- ☑ display the output raster



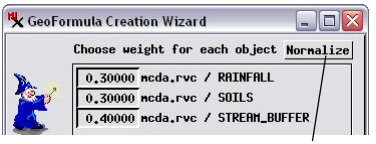
The easiest way to specify the spatial properties of the result is to match it to a reference raster; here we match the result to the SPOT_PAN_LITE input raster.

Multi-Criteria Decision Analysis I



The new script wizard in the GeoFormula process includes the option to construct a multi-criteria decision analysis (MCDA) script. MCDA is a quantitative approach to evaluating decision problems that involve multiple spatial variables (input spatial objects). Different conditions in each object (polygon attributes or ranges of raster cell values) are assigned numeric scores (indicating relative benefit or cost) and each object is assigned a weighting factor. The result for each cell in the output raster is a weighted linear combination: the score for each object is multiplied by the object's weighting factor, and the weighted scores are summed.

When you choose this option in the wizard, you are first prompted to choose the input objects, then to enter a set of weighting factors for these objects. You are then prompted to choose a table containing the scores for each object.



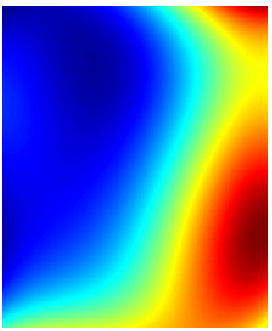
If the weight values you enter don't sum to 1.0, press the Normalize button to automatically rescale them.

STEPS

- ☑ press the New Formula (wizard) icon button
- ☑ from the MCDA Project File in the GEOFRMLA data collection select RAINFALL, STREAM_BUFFER, and SOILS
- ☑ in the next wizard window, choose *Multi-criteria analysis model* and press [Next]
- ☑ in the next wizard window, set the weight values: 0.3 for RAINFALL, 0.3 for STREAM_BUFFER, and 0.4 for SOILS and press [Next]
- ☑ when prompted for the Score for raster RAINFALL, choose table MCASCORE and field SCORE, then press [Next]

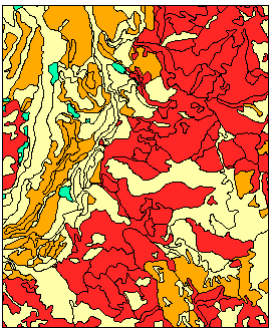
(continue to the next page)

Average Annual Rainfall



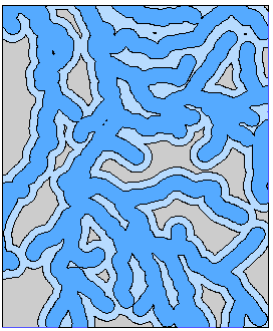
591 985 mm

Soil Erodibility



Severe.....100
Moderate.....60
Slight.....10
None.....0

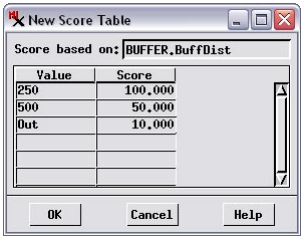
Stream Buffer Distance



<250 m..... 100
250 to 500 m..... 50
>500 m..... 10

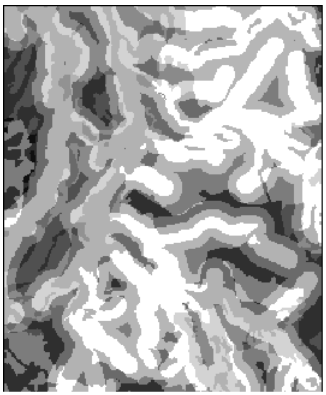
Multi-Criteria Decision Analysis II

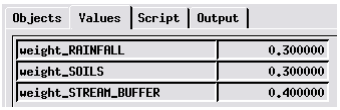
You can prepare a score table ahead of time for each input object and then select the tables when prompted by the wizard. But you can also create scores tables using the wizard. Simply press the New Table button in the score table prompt window to set up the new table and assign scores. In this exercise you choose existing scores tables for the RAINFALL and SOILS objects and create a new table for the STREAM_BUFFER vector.



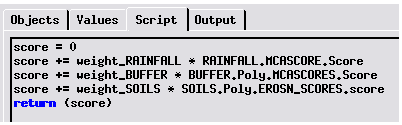
The hypothetical MCDA example in these exercises identifies areas of a forest where clearcut logging should be avoided due to potential adverse impacts on streams from soil erosion and sediment runoff. The criteria objects (illustrated on the opposite page) are a raster showing variations in average annual rainfall, a vector soil map scored by soil erodibility, and a vector map with nested stream buffer zones. Higher scores in this case indicate higher severity of potential impact on streams. Therefore higher values in the output raster (lighter grayscale tones) indicate areas to avoid in clearcut logging operations.

- ☑ when prompted for the Score for vector SOILS, choose table ERODIBILITY and field SCORE, then press [Next]
- ☑ when prompted for the Score for vector STREAM_BUFFER, press [New Table]
- ☑ accept the default setting for the attribute to associate with Score and press [OK]
- ☑ in the New Score Table window, in the Score field enter 100 for value 250, 50 for value 500, and 10 for value Out and press [OK]
- ☑ press [Next] in the wizard window for STREAM_BUFFER
- ☑ press [Finish] in the final wizard window
- ☑ note the variables set on the Values panel and examine the script in the Script panel
- ☑ on the Output panel press [Match Raster]
- ☑ press the Run icon button and name the output raster
- ☑ display the output raster





Weighting factors can be edited on the Values panel.



Grayscale raster result from the multi-criteria decision analysis (MCDA) GeoFormula using the input objects shown on the opposite page. Brighter tones indicate higher erosion potential.

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