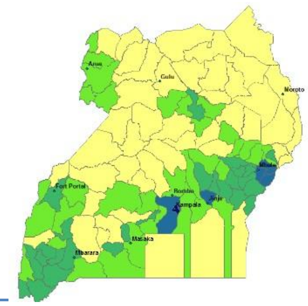
Overlay Analysis II: Using Zonal and Extract Tools to Transfer Raster Values in ArcMap



Created by Patrick Florance and Jonathan Gale, Edited on 10/22/19 for ArcMap 10.7.1

If you have raster data that you want to join to existing vector data, you can transfer these data values in ArcMap using the **Spatial Analyst** toolbar. For detailed instructions about working with Spatial Analyst in ArcMap 10.6.1, see the ArcGIS Desktop Documentation for Extraction tools and Zonal tools.

Skills covered in this Tutorial Include:

- Enabling the **Spatial Analyst** extension
- Using the **Zonal Statistics Tool** to tabulate areas
- Using the **Extraction Tool** to transfer underlying raster data to points
- Calculating a **percent change** using the **Field Calculator**

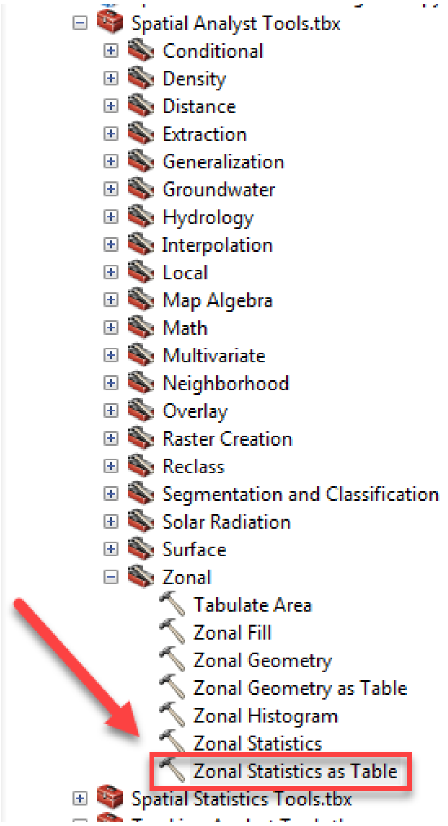
Getting Started

This exercise uses datasets that are available in the S: drive. For this analysis, we will be joining raster data (Land Cover in 2001 and 2012) with associated districts in Uganda. We will use this process to find the **Population per Cropland Area** and **Percent Change in Cropland Cover**. Follow the steps in the graphics below to perform zonal statistics and extract by point raster to vector overlay operations.

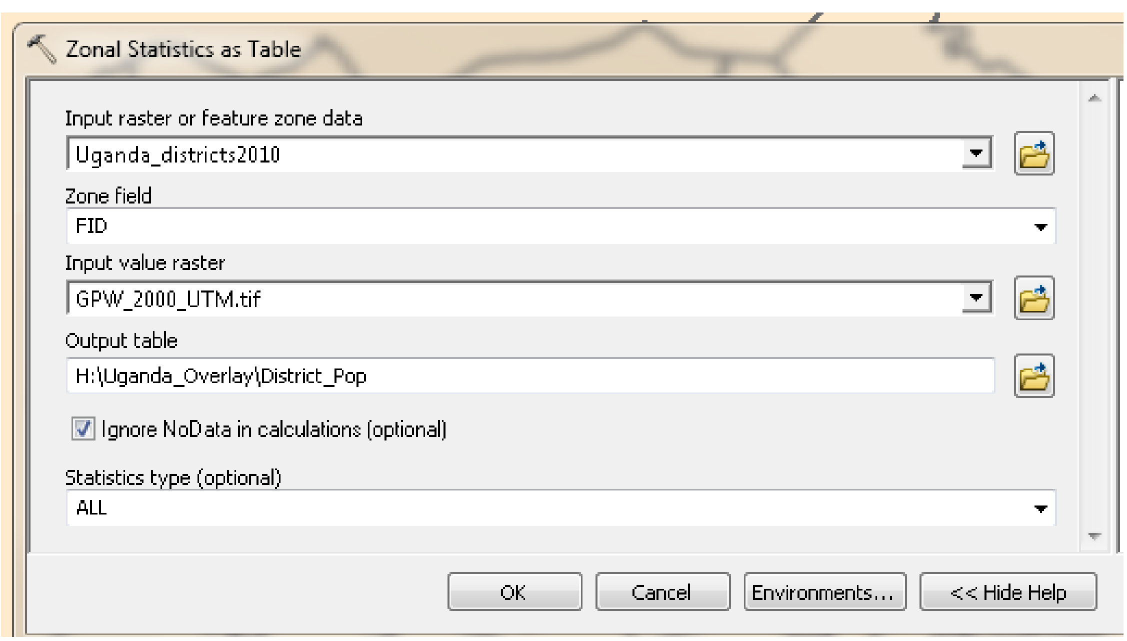
1. Copy the entire folder **S:\Classes\DHP_P207\Uganda_Overlay** to your H: drive.
2. Check the properties of this copied folder in your H drive and ensure that it is not *Read Only.* Make sure to check the *Apply this to all subfolders* option.
3. From your H Drive, open *start.mxd* within the **Uganda_Overlay** folder.
4. In ArcMap, make sure the **Spatial Analyst extension** is enabled by going to **Customize → Extensions** and **check Spatial Analyst** if it is not already checked.
5. Take a moment and review the different layers in the project.
6. All data layers have been projected into UTM Zone 36N. For conducting overlay analysis all data layers must be projected into the same projected coordinate system.

Using Zonal Statistics to summarize the gridded population of the world data within Uganda Districts

1. Open the **ArcToolbox** and then navigate to **Spatial Analyst Tools → Zonal → Zonal Statistics as Table.** Open the tool and click the Show Help window to see exactly what this tool does.



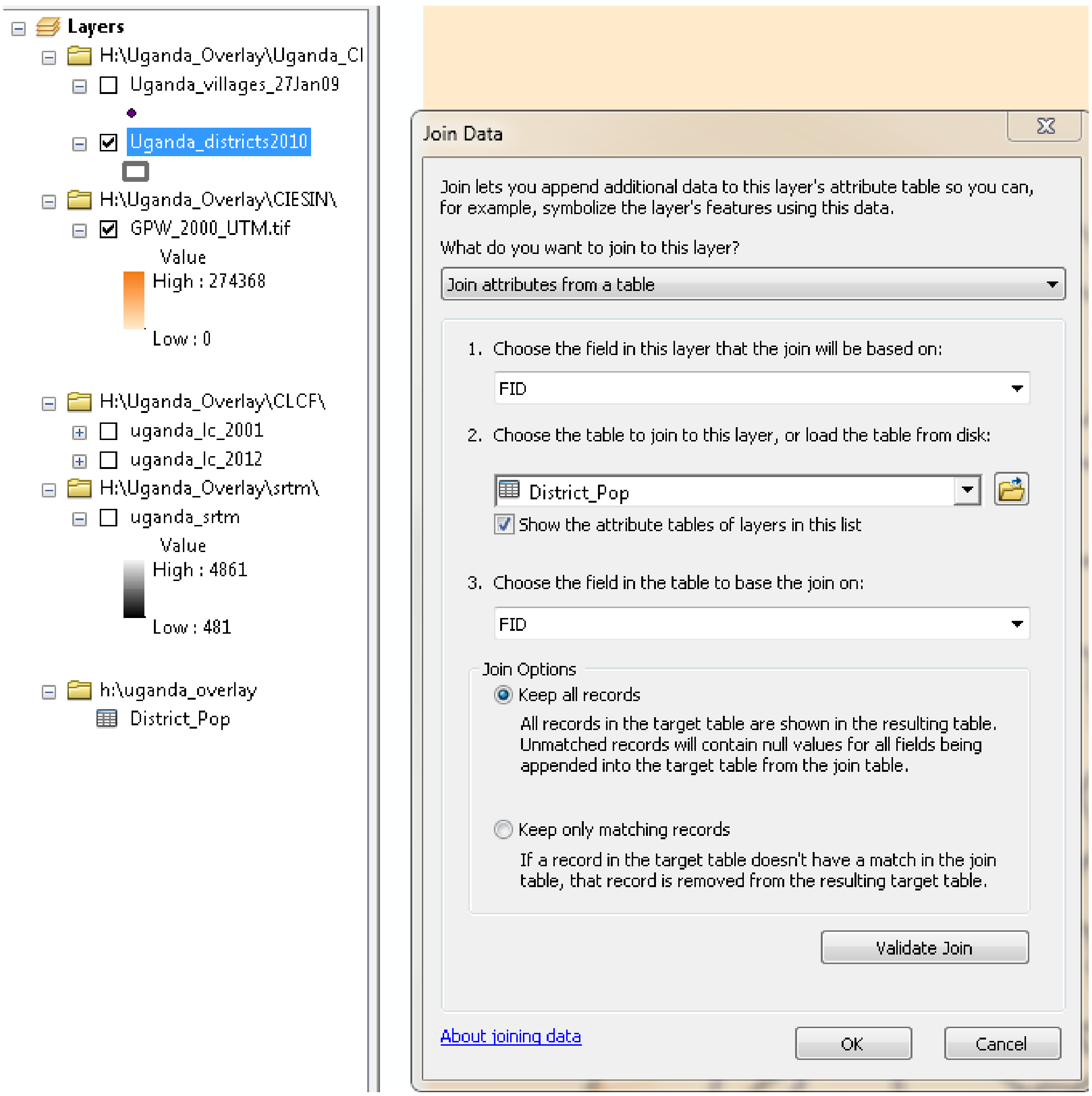
2. Select the *Uganda_districts2010* as the **feature zone data**, *FID* as the **Zone field**, and *GPW_2000_UTM.tif* as the **Input value raster**. In the **Output table**, navigate to your H drive → **Uganda_Overlay** folder and name this table **District_Pop**. Check out all the statistics we can get from this tool under the "Statistics type" drop-down menu. Select **ALL** to get everything. Press **OK.**



This tool selected all the *Gridded Population of the World 2000* raster dataset (*GPW_2000_UTM.tif*) pixels that fall within each Uganda District, calculated summary statistics on the selected pixels PER district, and outputted the results to a table (*District_Pop* above).

Since you chose to create zones based on FID (feature ID number), statistics are calculated for each district polygon. By choosing Statistics type to be "All", six of the possible statistics are calculated (minimum, maximum, mean, range, standard deviation, and sum). Each statistic reflects each individual zone's (district in this case) population raster values.

3. Upon completion, the table should appear in the table of contents. The table of contents will switch to **List by Source** so that you can see a table has been added. Now, we can join this table to the vector data of districts that we used to define our zones. Since we chose our zones based on **FID**, we will be able to **join** the table to the Uganda_districts2010 layer using that FID field.
4. Right click on the *Uganda_districts*2010 layer and select **Joins and Relates → Join.**
5. Make sure the tool is set to *Join attributes from a table* and the new **District_pop** table is selected in step 2 of the tool. Then, under *Choose the field in this that the join will be based on*: Select **FID** from your districts layer. Likely, ArcMap will find the matching field for step 3 (also called FID) that the join will be based on. Click **Ok**. You may be prompted to index this table. It is ok to do so, though not needed to proceed.



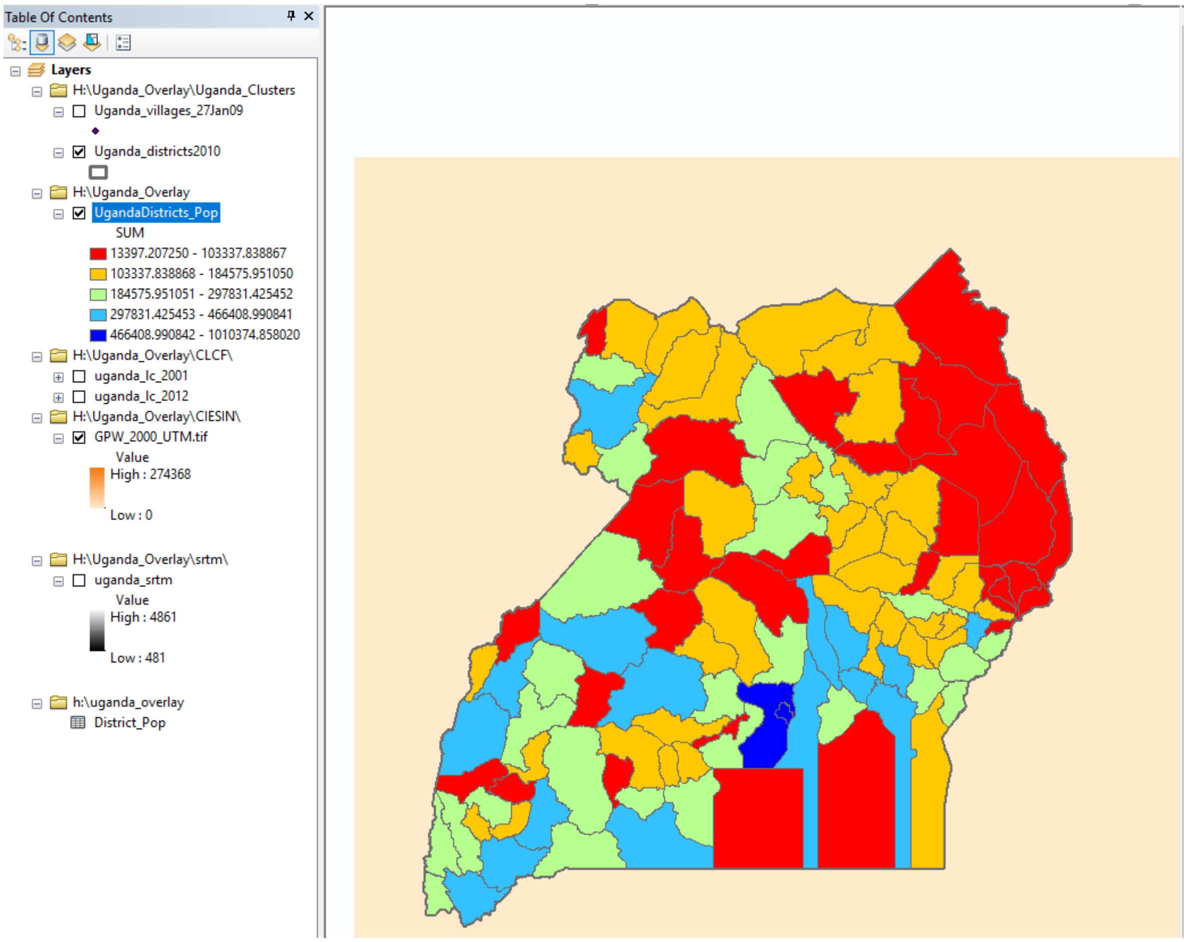
6. Open the attribute table for your Uganda District layer and check that the join was successful.
7. Which field would we use if we wanted to know the total population within a district? Which district has the largest and smallest population? *Right click* on the **sum** field and sort ascending. Now we can see the district with the smallest population all the way to the district with the largest population.
8. Now, in order to make this join **permanent** so the *statistics* remain in the ***Uganda_Districts2010*** attribute table, we must **export** the data! Otherwise, the joined statistics data would be dropped the first time we ran a tool. Right click on

the ***Uganda_Districts2010*** layer and select **Data → Export Data.**

9. Click on the folder icon to choose where you want to save your data. Navigate to your H drive and Uganada_Overlay folder. Name this new shapefile **UgandaDistricts_Pop** and make sure to save it as a **shapefile**. Press save and ok.

10. Press **Yes** when asked if you want to add the exported data to the map as a layer.

11. Open the **symbology** of this new shapefile and set the *graduated colors* to **SUM** so we can visualize the total population per district. Your map should look something like this:



Use Tabulate Area to summarize 2001 & 2012 Land Cover data into the *Uganda Districts*

1. If you have a raster dataset that contains **categorical** data, such as *Land Cover*, the **Zonal** Tool ***Tabulate Area*** can be used to transfer and summarize categorical data to a zone such as *Uganda Districts*.

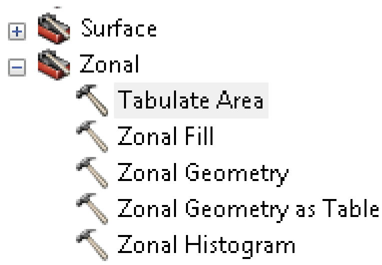
2. Turn off all layers except for **Uganda_Districts2010.** Also, turn on **Uganda_lc_2001** and open the attribute table. What do you think the ***value*** field numbers (0 – 16) represent? If you guessed that they are numerical codes for different types of land uses, you would be correct! The ***Count*** field than represents the number of pixels for each type of land cover category for the entire raster covering all of Uganda plus some. We would not be able to know what these codes represented without first examining the metadata.

   Take a look at what each numerical code represents:

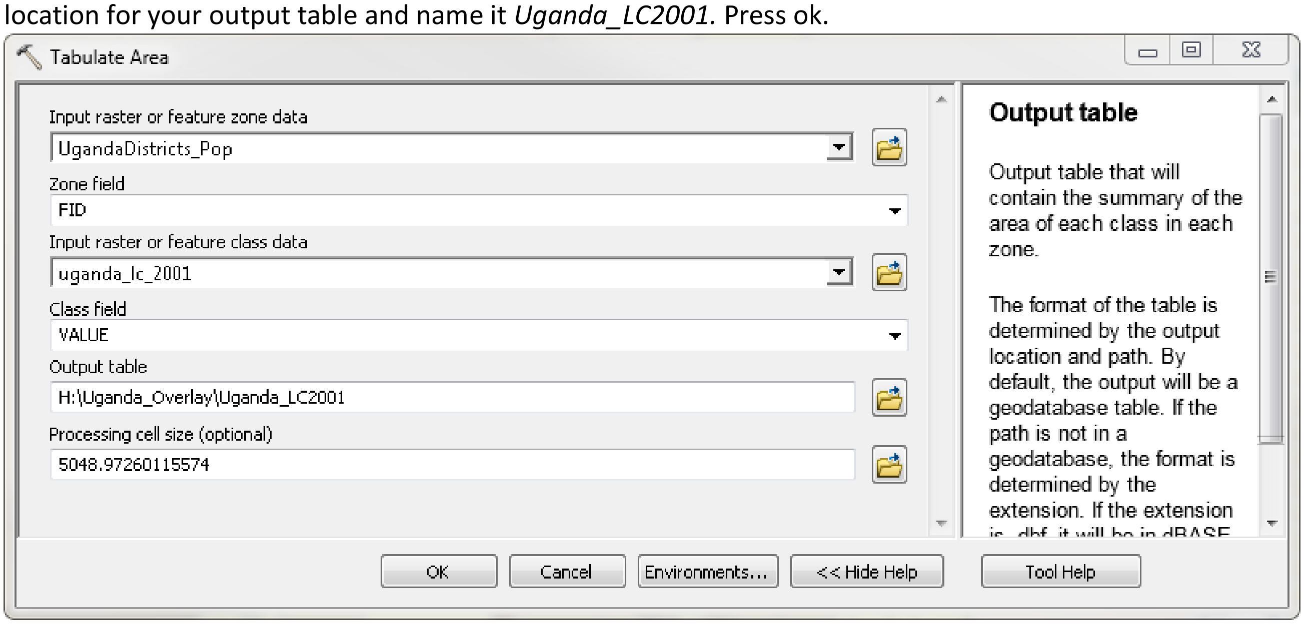
V	**Label**		
0	Water	10	Grasslands
1	Evergreen Needleleaf forest	11	Permanent wetlands

2	Evergreen Broadleaf forest	12	Croplands
3	Deciduous Needleleaf forest	13	Urban and built-up
4	Deciduous Broadleaf forest	14	Cropland/Natural vegetation
5	Mixed forest	15	Snow and ice
6	Closed shrublands	16	Barren or sparsely vegetated
7	Open shrublands	25	Unclassified
8	Woody savannas	25	Fill Value
9	Savannas		

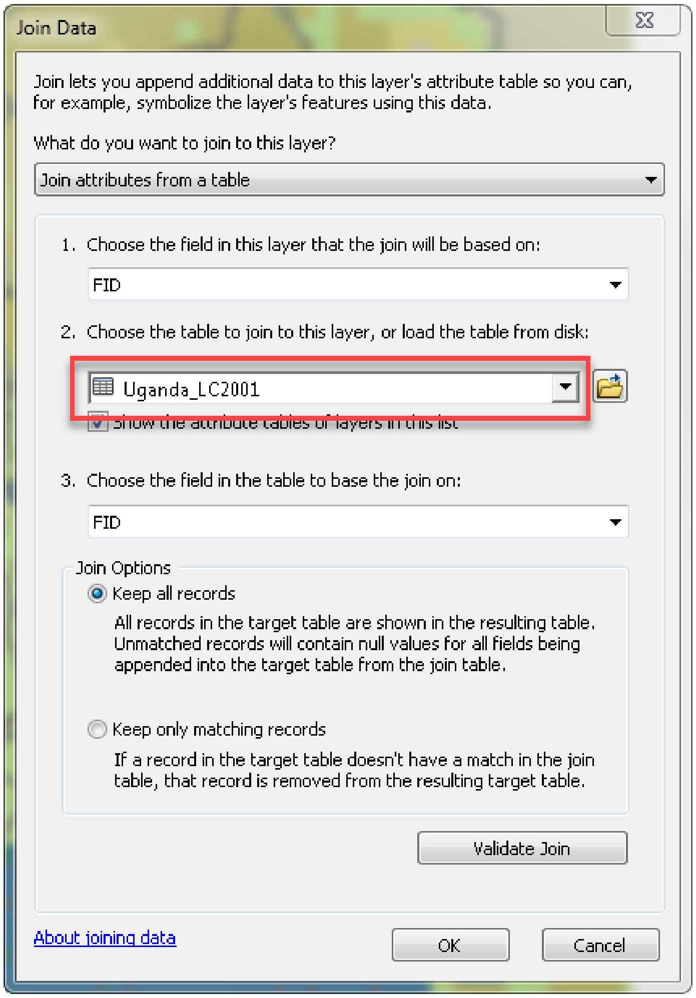
3. Close the attribute table.
4. In the ArcToolbox, navigate to **Spatial Analyst Tools → Zonal → Tabulate Area** and open the tool.



5. Select *UgandaDistricts_Pop* as the **feature zone data** and *FID* as **Zone field** again. Now choose the categorical land cover dataset, *uganda_lc_2001,* as the **Input raster**. Make sure the **class field** is *VALUE.* Once again, choose your location for your output table and name it *Uganda_LC2001.* Press ok.



6. Right click on the resulting output table, *Uganda_LC2001,* and press **Open** (just like we would with an attribute table) to examine its contents. Which new fields do you see? Each column represents each type of land use and each row represents an individual district. Therefore, we can now see in this matrix the **AREA** (in sq meters) for each type of land use for EVERY district.
7. Similarly to the *zonal statistics table*, this new table, *Uganda_LC2001,* generated from the **Tabulate Area Tool** can be joined to the *UgandaDistricts_Pop* layer. **Join** the new *table* to **Uganda Districts_Pop** using the **FID** field as below.



8. Once the *Uganda_LC2001* table has been joined to *UgandaDistricts_Pop*, open the attribute table to make sure it went smoothly. If all looks good, **Export** this layer to preserve the join which makes it permanently part of the attribute table. Name this shapefile ***UgandaDistricts_Pop_LC2001*** and save it in your H drive.

9. Turn on the 2012 land cover dataset, **Uganda_lc_2012,** and see how it compares to the 2001 land cover dataset.

10. Repeat the **Tabulate Area tool** calculation with the **2012 land cover data**, *Uganda_lc_2012.* Select *UgandaDistricts_Pop_LC2001* as the feature zone data and *Zone field* as **FID** again. Choose the land cover dataset *uganda_lc_2012* as the **Input raster**. Make sure the **class field** is *VALUE*, and once again choose a name (**Uganda_LC2012**) and location for your output table.

11. Join this new table to the *UgandaDistricts_Pop_LC2001* layer using the FID field as well. Open it up to make sure the join worked. Check out what all the headings are.

12. Your **Uganda Districts** should now contain data from the *Gridded Population of the World* and *2001 and 2012 Land Cover* datasets. Once more, **Export** the *UgandaDistricts_Pop_LC2001* to create a new **shapefile** that has all 3 of our joined tables. Call it ***UgandaDistricts_join.shp*** and save it in your H drive. Add this new dataset to the map.

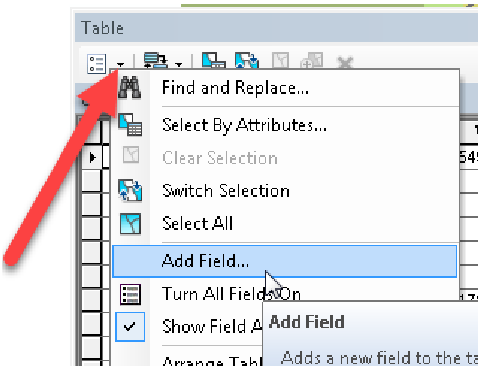
13. Save your map session!

Calculating Population per Cropland Area per District

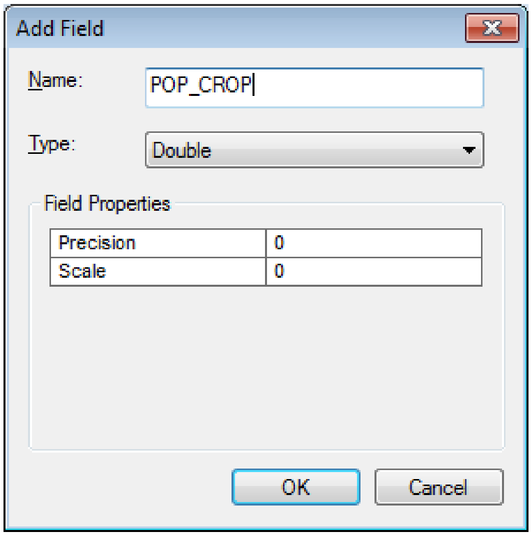
You can now perform calculations on the newly calculated data. Below you will calculate the population per each cropland area for <u>each</u> district.

1. Open the attribute table for this new shapefile, *UgandaDistricts_join.*

2. Add a field to the attribute table by clicking on the **Table Options** dropdown → **Add Field.**



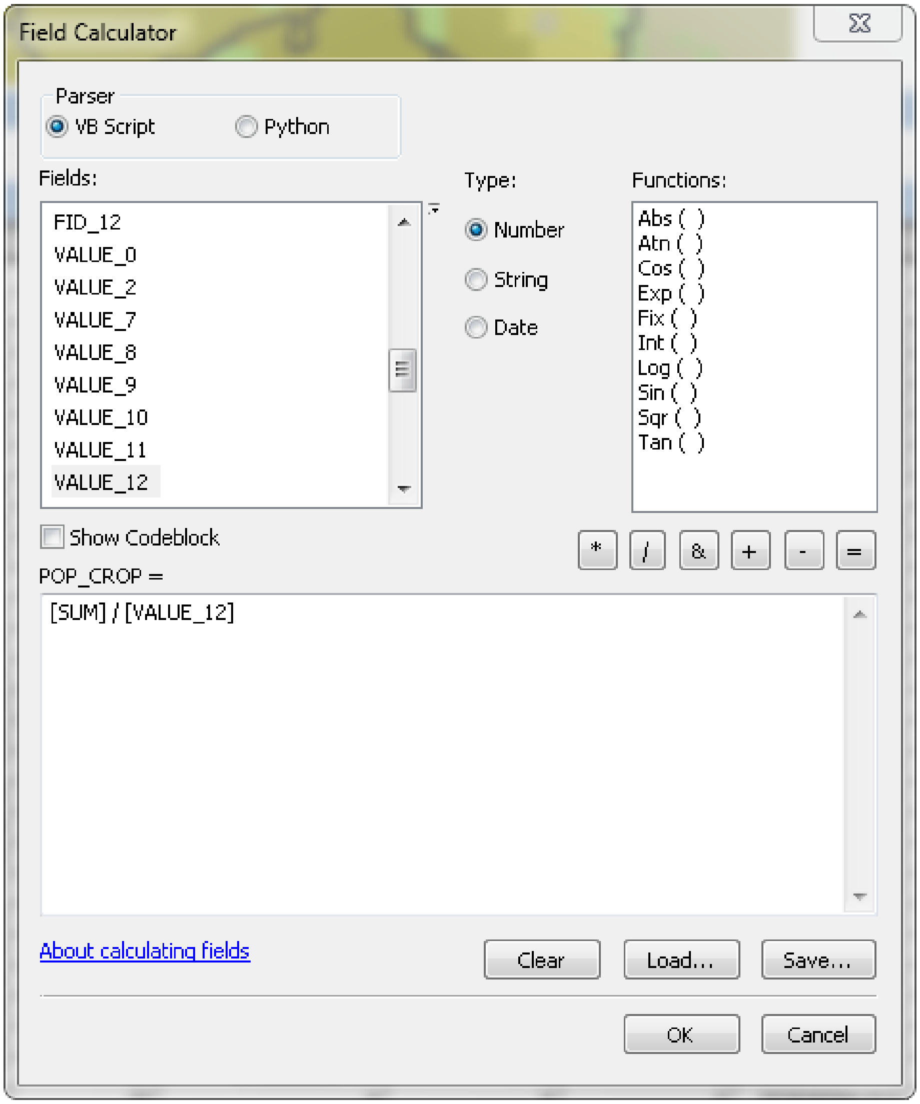
3. Name your new field, *Pop_crop,* and change the **Type** to ***Double*** and click OK.



4. In the attribute table, find this newly created field at the end of the table and right click on the field name → **Field Calculator (click "Yes" when asked about wanting to continue)**. We will now use the newly created field to *estimate the population per cropland area for each zone.*

5. In the calculator, double click the field that holds the total population data (aka the **SUM** field) and divide it by the column for the 2001 cropland code (value 12) as shown in the table below.

    - SUM = *Summarized Gridded Population of the World*
    - VALUE 12 = 2001 Summarized Cropland Area

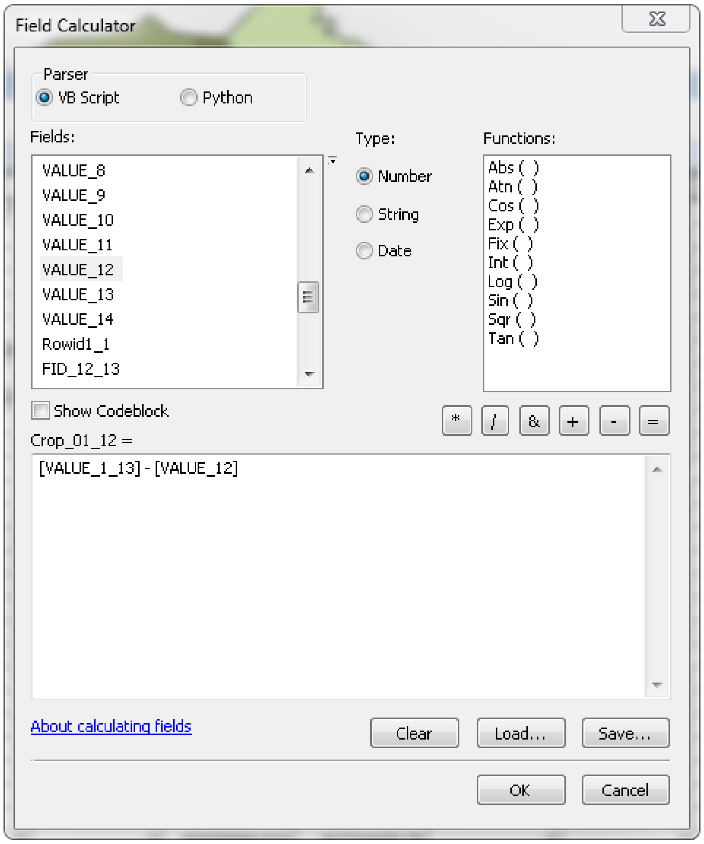


NOTE: If you receive an error message stating "*There was a failure during processing, check the Geoprocessing Results window for details*," this could be because a mathematical rule was violated. As per mathematical principle, dividing by zero to make a new variable will result in an error. If this error occurs, refer to steps 10-13 in the following section for the easy fix!

6. **Symbolize** this **Population-Cropland Area relationship field** using a *sequential color model*.

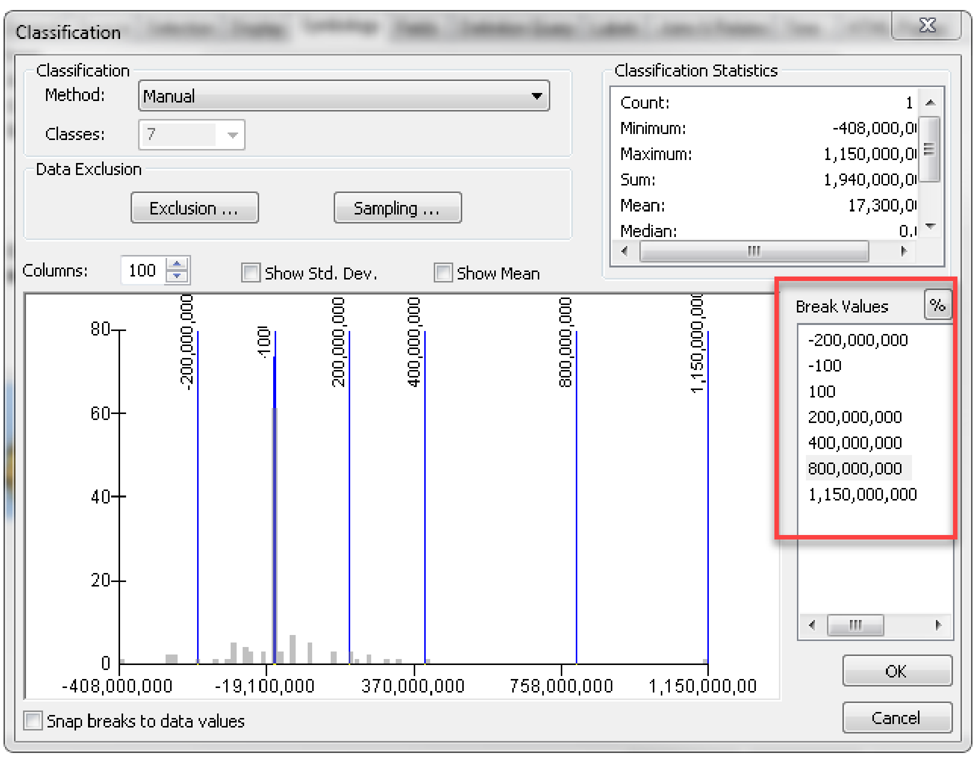
Calculating Change in Cropland Land Cover from 2001 to 2012

1. In the same layer, *UgandaDistricts_Join*, add another field and call it **Crop_01_12** and make it a **double**. This field will be used to calculate the difference in cropland area from 2001 to 2012 *per district*.
2. Using the **Field Calculator**, subtract the Value 12 for 2001 <u>from</u> the Value 12 for 2012 (which is actually field *Value_1_13*). Why do the field names look different for 2012 in this attribute table compared to how they looked when we did the join? That is because there cannot be 2 identical field column headings, so when the join is exported, ArcMap adds the underscore and second number to help distinguish between the 2001 Value 12 and 2012 Value 12. If you're not convinced, look at the attribute table in *UgandaDistrricts_Pop_LC2001* which still has the data as a join and the fields remain in the same order so it's easy for comparisons.

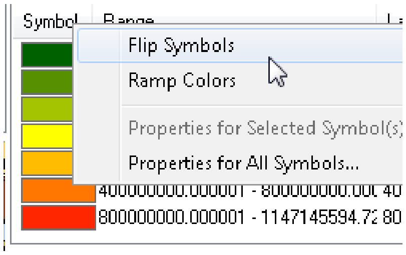


When calculating change, it's always important to put the more recent year first in the calculation (ex 2012 – 2001) so that positive numbers represent an increase and negative numbers represent a decrease over time.

3. Symbolize this difference in cropland area between 2001 and 2012 using a **diverging color ramp.** In Symbology, set the value field to Crop_01_12. Then click **classify**, so we can set the break values. Change the number of classes to **7.** Type in the break values as we have done here. Then press ok.



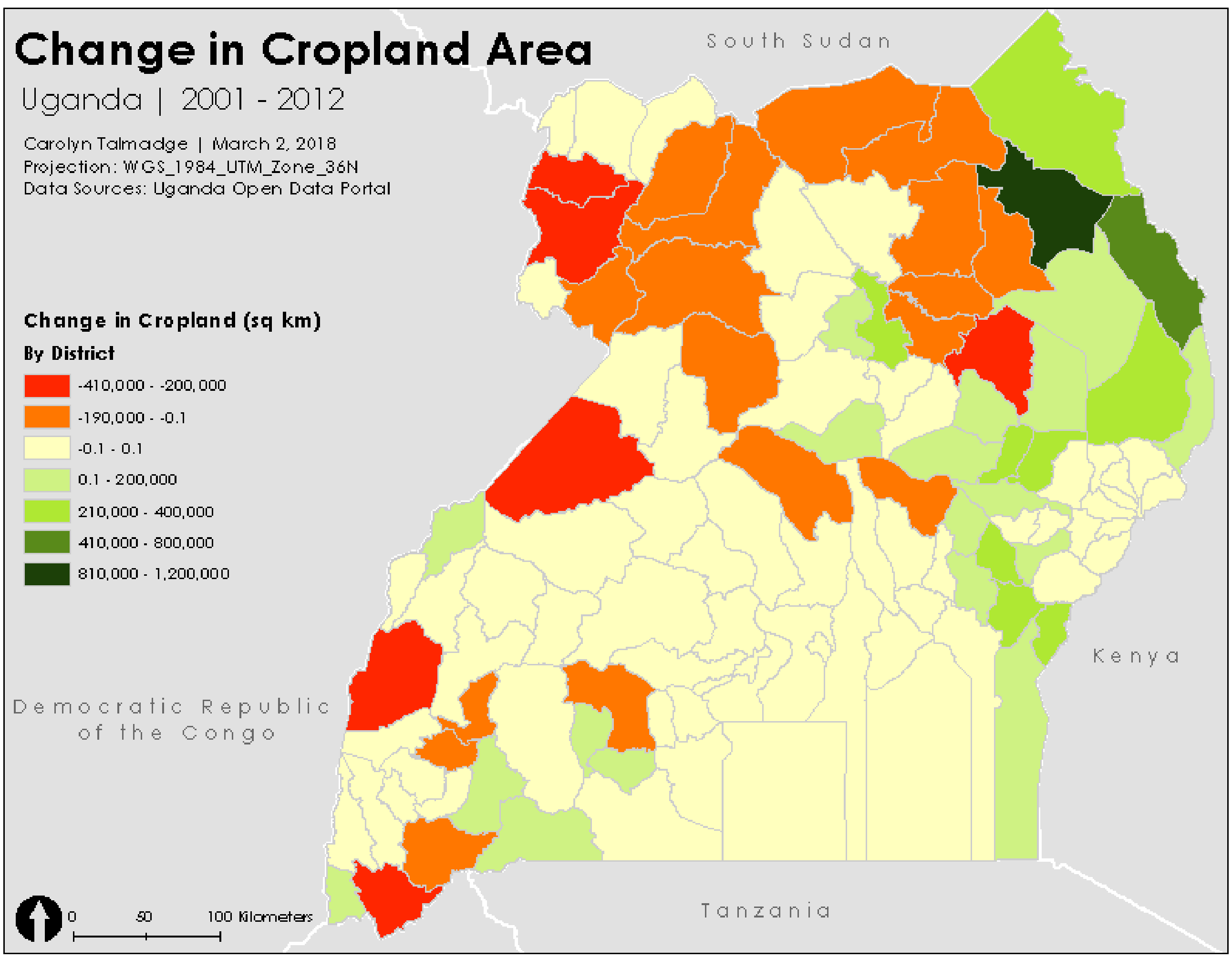
4. Now we need to make sure the colors accurately represent the numbers. Select the green to red color scheme, where green will represent an increase in cropland and red will represent a decrease in cropland. Notice how we need to flip the colors so they represent increase/decreases correctly. Press on **Symbol** and **Flip Symbols.**



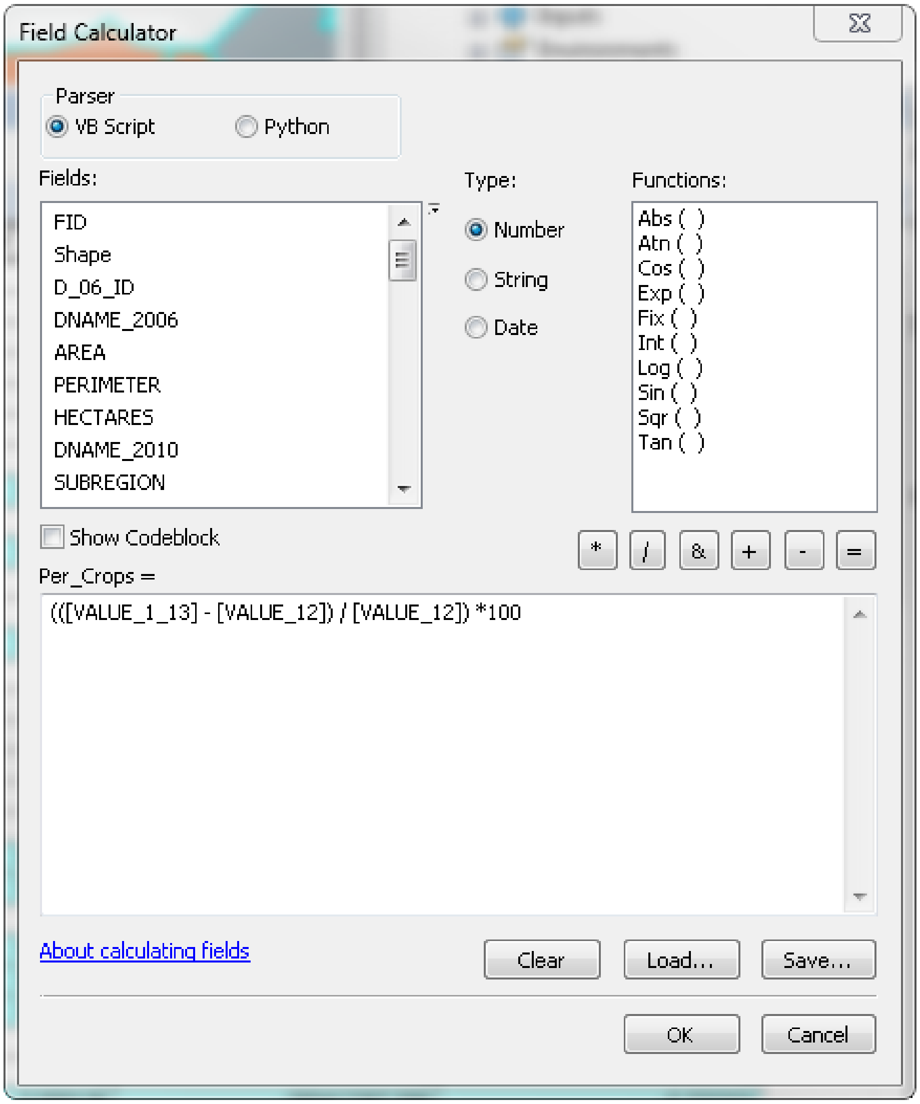
5. The color for -99 – 100 (representing "no change") should actually be yellow, not orange (which would imply still a decrease). Double click on the orange square and set that to a light yellow. Then double click on the 101 – 200000000 color and set that to the lightest green that matches so it starts to represent the increase like so:

Symbol	Range	Label
	-407873989.232000 - -200000000.0(	-408,000,000 - -200,000,000
	-199999999.999999 - -100.000000	-199,000,000 - -100
	-99.999999 - 100.000000	-99 - 100
	100.000001 - 200000000.000000	101 - 200,000,000
	200000000.000001 - 400000000.00(	201,000,000 - 400,000,000
	400000000.000001 - 800000000.00(	401,000,000 - 800,000,000
	800000000.000001 - 1147145594.7:	801,000,000 - 1,150,000,000

6. Adjust the colors individually as you see fit. Press ok and take a look at the map. What message is it sending? Where are there increases in cropland, decreases, and no change? Check out the example map here.



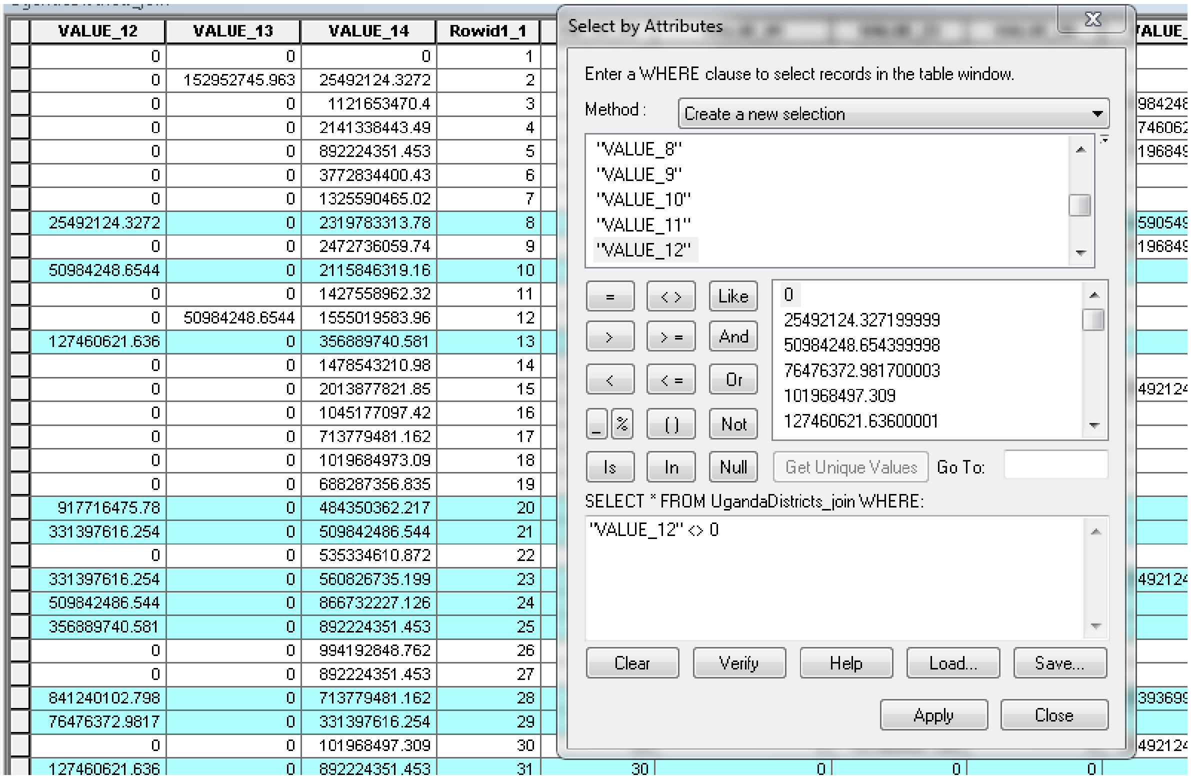
7. Right click on the layer in the table of contents and press **copy**. Then go to up the Edit (next to file) and press **Paste.** We've copied the layer so we can continue to work in this shapefile, but still have a copy with the color scheme we just worked so hard to create.
8. Now, open the attribute table for *UgandaDistricts_join.shp* again (the new copy), and add another field titled *PER_CROPS* and make it a *double*. We will calculate **the percent change** of crop land cover using the Field Calculator.
9. Under PER_CROPS, open the **field calculator** and subtract the Value 12 for 2001 from the Value 12 for 2012 (*Value_1_13*), then divide by the Value 12 for 2001. Then multiply the entire expression by 100 to turn it from a fraction to a percentage. It should look similar to the screenshots below. What happens when you try to do this…?



10. Yikes! An error message will appeared stating "*There was a failure during processing, check the Geoprocessing Results window for details*." This error occurred since **we violated a mathematical rule**. In order to calculate percent change, the program took the change in cropland from 2001 to 2012, and divided it by the amount of cropland in 2001. But some districts had no cropland in 2001 ([VALUE_12] = 0). And what happens when you try to divide a number by 0? You get an error! **Dividing by zero to make a new variable will result in an error!**

   The way to fix this is to only run the analysis on all the districts which had a cropland value > 0 in 2001.

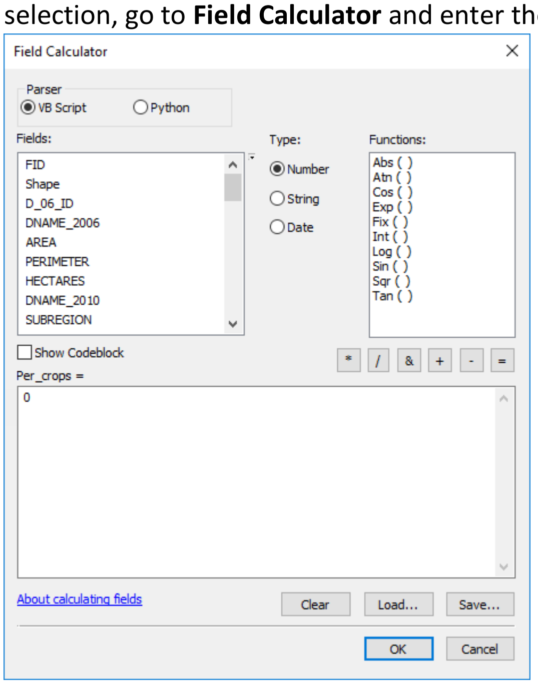
11. In the attribute table, go to ***Select by Attributes***. We are going to select all the districts where value_12 does not equal 0. Make sure the method is set to *Create a new selection*. Double click on the variable **VALUE_12**, click the symbol for *not equal to* (<>), then click *Get Unique Values*, and double click on **0.** Click *Apply*.



12. Now that we have all non 0 fields selected, right click on Per_Crops field again and go to **Field Calculator.** The expression should still be there, so click OK to run the calculation again. This time it should work because **when fields are selected, tools only run on those selected fields!** This is true for all tools in ArcMap (which is why it's important to always double check that we do or do not have things selected).

13. Now, you should see the fields which have non-zero values for cropland in 2001 have been calculated correctly and we did not encounter any error! Which district had the greatest increase in percentage of cropland over the decade?

    (**NOTE:** In some cases, when you field calculate on a selection, the non-selected values will populate as <NULL>. If this occurs but you know the value is zero, not null, there is a simple fix. In the attribute table, select "Switch Selection." This selects all the values that were previously ignored in our initial field calculation. With this newly switched selection, go to **Field Calculator** and enter the expression PER_CROPS = 0. Now, all <NULL> values are replaced with 0.)



14. Go ahead and clear your selection. That is good practice to do so since we don't need those areas selected anymore and we don't want it potentially messing up any future calculations.

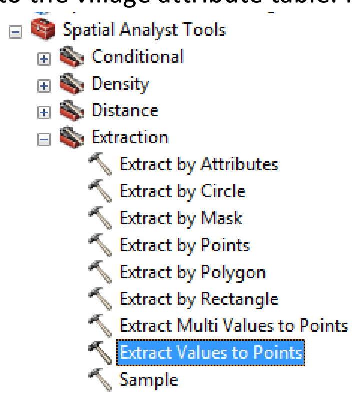
Extract Underlying Raster Elevation Data to Points

Now, we have a layer of villages in Uganda as of January 2009. Perhaps we want to know which of those villages were located within "cropland" areas in 2012. This might help to understand why there was an increase or decrease in cropland.

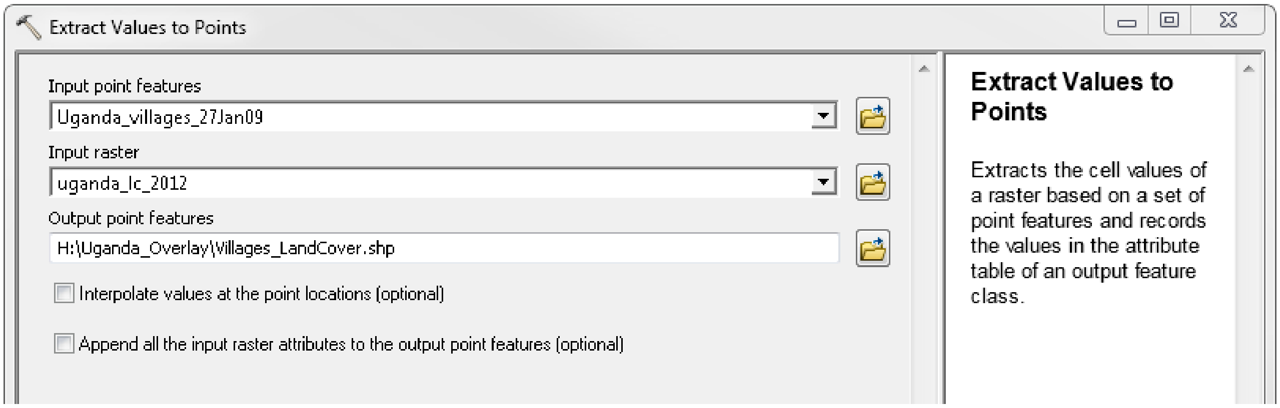
1. Turn off all layers except Uganda_Distrcits2010 (which should still be see through). Now, turn on **uganda_lc_2012.** Take a second to look it over. Remember what all the different codes mean? Here's a reminder:

Valu	Label		
0	Water	10	Grasslands
1	Evergreen Needleleaf forest	11	Permanent wetlands
2	Evergreen Broadleaf forest	12	Croplands
3	Deciduous Needleleaf forest	13	Urban and built-up
4	Deciduous Broadleaf forest	14	Cropland/Natural vegetation
5	Mixed forest	15	Snow and ice
6	Closed shrublands	16	Barren or sparsely vegetated
7	Open shrublands	25	Unclassified
8	Woody savannas	25	Fill Value
9	Savannas		

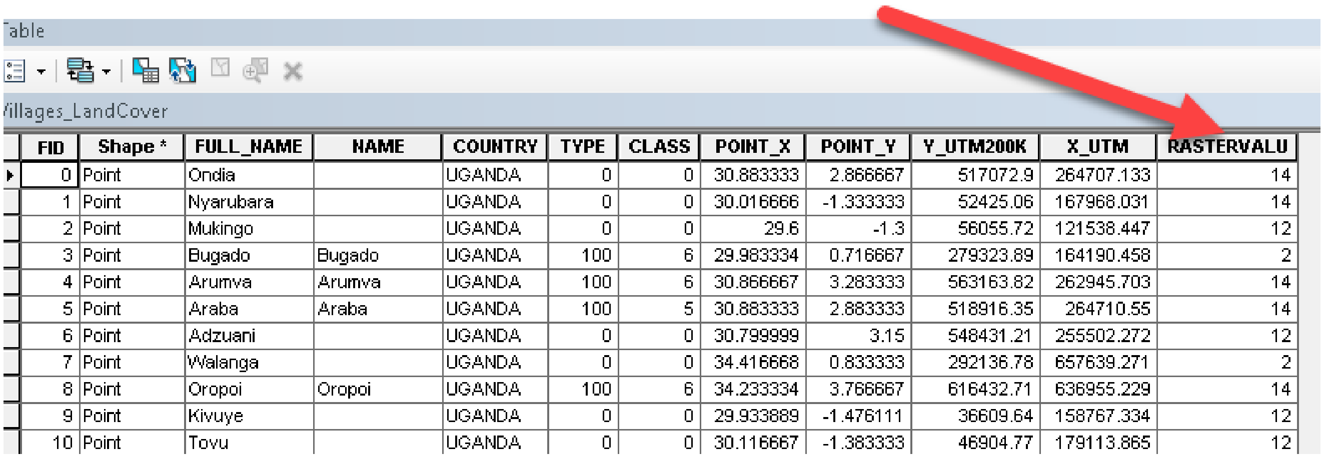
2. Now, turn on **Uganda_villages_27Jan09**. Is it easy to tell which one of these points fall within cropland? Not for me.
3. Open the **attribute table** for the villages. Is there any information about which villages fall under what land use category? Definitely not, but that would be really helpful.
4. We can actually extract information from the underlying land use raster layer and attach it to the points very easily. To combine raster data with point data, we will use the **Extract Values to Points** tool to transferraster values at each point to the village attribute table. Navigate to **Spatial Analyst Tools → Extraction → Extract Values to Points**



5. In the tool, our **input point features** would be the Uganda villages. And the input raster would be the uganda_lc_2012. We want to attach the info about the land use to the points. Save it in your H drive Uganda folder and name it **Villages_LandCover.**



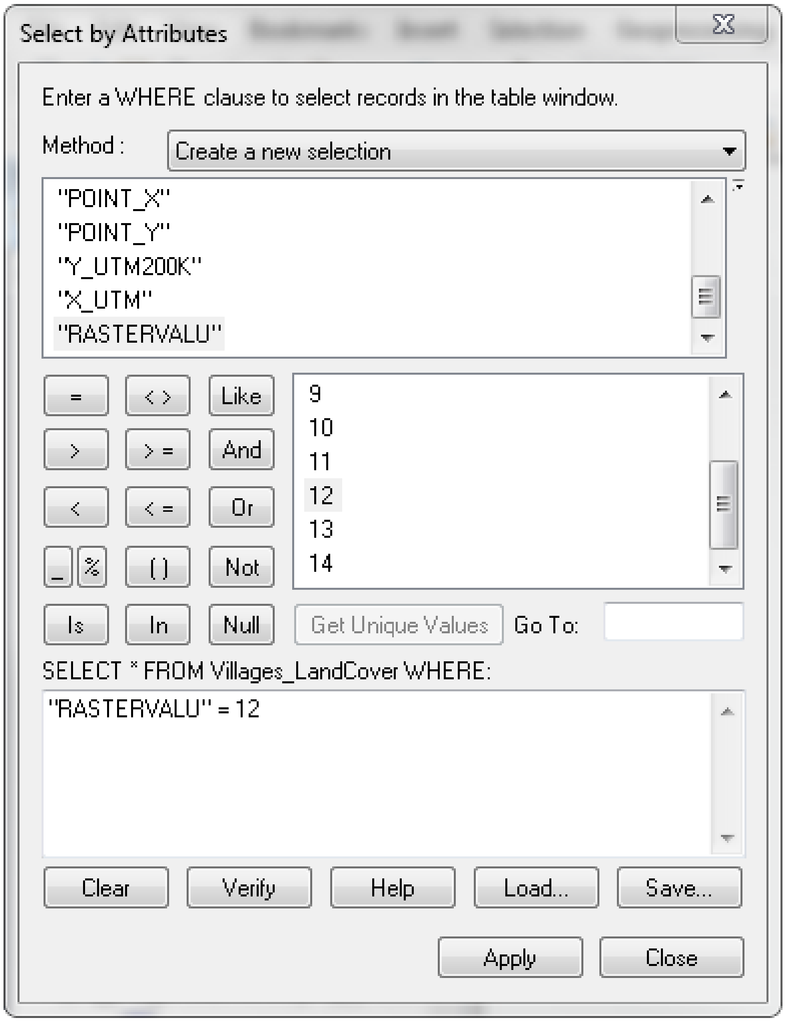
6. Now, we have a new point file of the villages. Open the **attribute table.** A new field has been added to the points that has the raster value from the land cover raster dataset. Here we can see that the code for each land use that the village falls within has now been added.



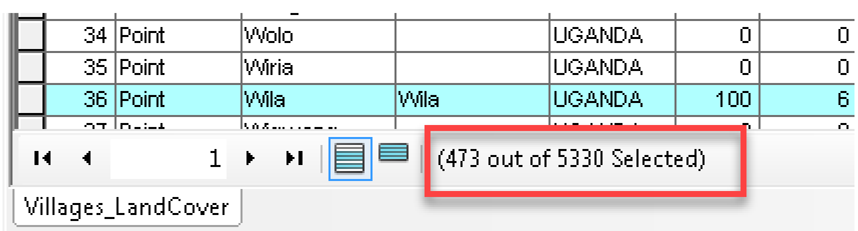
FID	Shape *	FULL_NAME	NAME	COUNTRY	TYPE	CLASS	POINT_X	POINT_Y	Y_UTM200K	X_UTM	RASTERVALU
0	Point	Ondia		UGANDA	0	0	30.883333	2.866667	517072.9	264707.133	14
1	Point	Nyarubara		UGANDA	0	0	30.016666	-1.333333	52425.06	167968.031	14
2	Point	Mukingo		UGANDA	0	0	29.6	-1.3	56055.72	121538.447	12
3	Point	Bugado	Bugado	UGANDA	100	6	29.983334	0.716667	279323.89	164190.458	2
4	Point	Arumva	Arumva	UGANDA	100	6	30.866667	3.283333	563163.82	262945.703	14
5	Point	Araba	Araba	UGANDA	100	5	30.883333	2.883333	518916.35	264710.55	14
6	Point	Adzuani		UGANDA	0	0	30.799999	3.15	548431.21	255502.272	12
7	Point	Walanga		UGANDA	0	0	34.416668	0.833333	292136.78	657639.271	2
8	Point	Oropoi	Oropoi	UGANDA	100	6	34.233334	3.766667	616432.71	636955.229	14
9	Point	Kivuye		UGANDA	0	0	29.933889	-1.476111	36609.64	158767.334	12
10	Point	Tovu		UGANDA	0	0	30.116667	-1.383333	46904.77	179113.865	12

Unlike zonal statistics as table, this land cover data has already been added and we don't have to go through the steps of joining it to the attribute table!

7. Now, let's select all the villages that fall within cropland areas (value 12, remember!). Open **Select by Attributes**. What would the expression be?



8. How many villages are within cropland areas? We can clearly see the answer in the attribute table:



9. We can easily create a new layer with just the villages in cropland areas by exporting the data. Right click on this point data and **Data→ Export Data.** Choose where to save this new file and name it **Villages_Cropland**.

10. Once you've added it to you map, clear the selection and turn off the other village layers so we just see the villages within croplands.

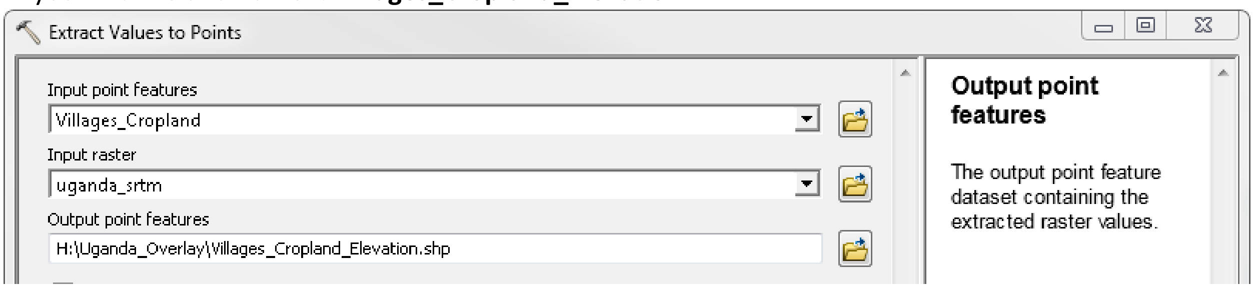
11. Now, perhaps we want to know the elevation at these villages as well. We might care about this because elevation can play a significant role into which crops can and cannot grow efficiently. If we understand the elevation patterns, we can maximize crop growth by only planting crops we know will grow well at that altitude.

12. Turn on **Uganda_srtm** and turn off the **uganda_lc_2012.** This is a digital elevation model (commonly referred to as **DEM**).Elevation in Uganda ranges from a low of 481m to a high of 4861m, which we can see in layer info in the table of contents.

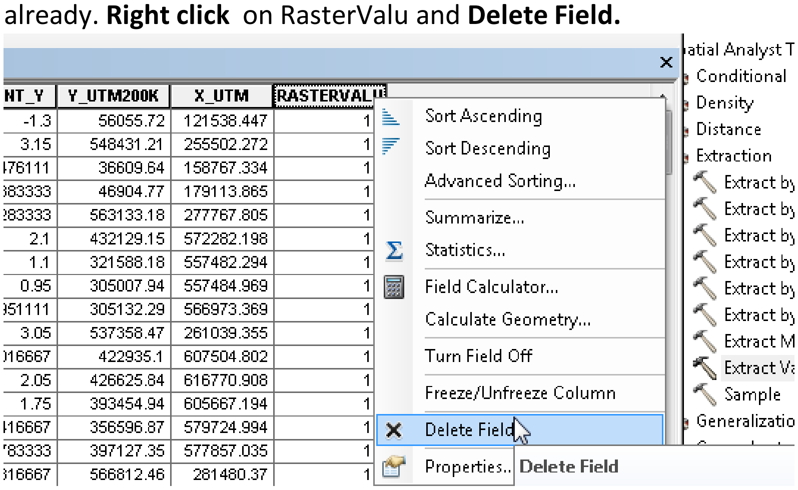
13. Sometimes the black to white color scheme makes it harder to visualize the elevation so let's change it. Open the **Symbology** for the elevation layer. Notice how symbology for rasters looks a bit different than the symbology options

for vectors. Stay in the **stretched** option and pick a different color ramp – perhaps a divulging color ramp so it's easier to see the extreme highs and lows. Press ok. Now we can start to get a much better idea of really high and low lying lands.

14. Open the **attribute table** for Uganda_Srtm. What does the **value** column represent? Those are the individual elevations in *meters*. How do I know they are meters? Because our projection uses meters and therefore so does the data! What does the **Count** field represent? Those are the number of cells that have that specific elevation.
15. Does our **villages_cropland** layer have any info about elevation in the **attribute table**? No, definitely not. But using the same tool, **Extract Values to Points**, we can easily calculate that info!
16. Navigate to **Spatial Analyst Tools → Extraction → Extract Values to Points**
17. Now the input point features are the new **Villages_Cropland** and the input raster is the **uganda_srtm.** Once again, save in your H drive and name it **Villages_Cropland_Elevation.**



18. When we try to run the tool, we get another error. That's frustrating and the error code is not very helpful. The reason we are getting an error is because it's trying to create a new field in the point layer called "**RasterValu**" to hold the elevation values. The problem is there is already a field in this **village_cropland** point layer called "rastervalu" that holds the info from the land cover dataset – so the tool fails because the field name is not unique.
19. However, since we purposefully selected all the points that fall within cropland land cover (12), we don't really need this field. Open the **Villages_Cropland** attribute table. The RasterValue column should ONLY have 12's in it because that is what we selected for. Therefore, we don't really need this field since we know these are villages in cropland already. **Right click** on RasterValu and **Delete Field.**



20. Now, try rerunning the **Extract Values to Points** tool using the same inputs. The tools should run no problem now because it is able to create the new **RasterValu** field that will hold the elevation values.
21. Open the **attribute table** for this new point village's layer. Now there is another RATERVALU field that shows the elevation of these villages that are only within cropland!

NT_Y	Y_UTM200K	X_UTM	RASTERVALU
-1.3	56055.72	121538.447	2025
3.15	548431.21	255502.272	1263
76111	36609.64	158767.334	2071
83333	46904.77	179113.865	2104
83333	563133.18	277767.805	1005
2.1	432129.15	572282.198	1130
1.1	321588.18	557482.294	1052
0.95	305007.94	557484.969	1094

22. What is the minimum, maximum and average elevation of these villages in cropland areas? Right click on RASTERVALU and press **Statistics.** We can clearly see that the minimum elevation is 631 meters, the maximum is 2256m and the average elevation is 1201m.We can also see the histogram for all the elevation data. This could help us figure out which crops could be best grown in which villages!