Topic 3

Comparing Mapped Data

3.1 Comparing Yield Maps (Discrete)

One of the most fundamental operations in map analysis is the comparison of two maps. Questions like "how different are the maps?", "how are they different?" and "where are they different?" immediately spring to mind. Quantitative answers are needed because visual comparison cannot fully consider all of the detail in an objective manner.

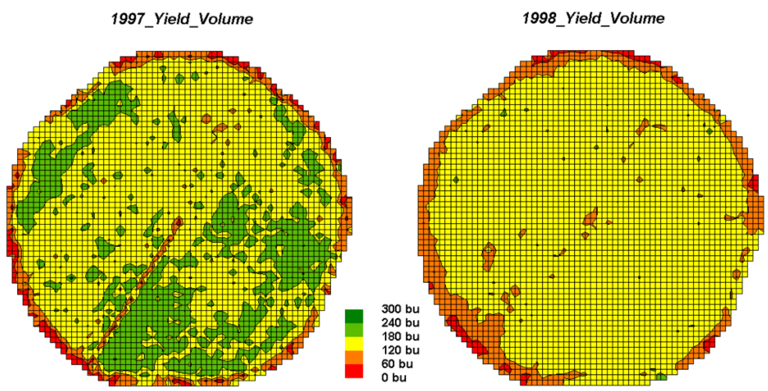


Figure 3-1. Discrete yield maps for consecutive years.

Recall that there are two basic forms of mapped data used in precision farming—discrete and continuous.

Discrete maps are comprised of distinct point, line and polygon features, such as a soil type map. Continuous map surfaces, on the other hand, characterize a spatial gradient, such as elevation.

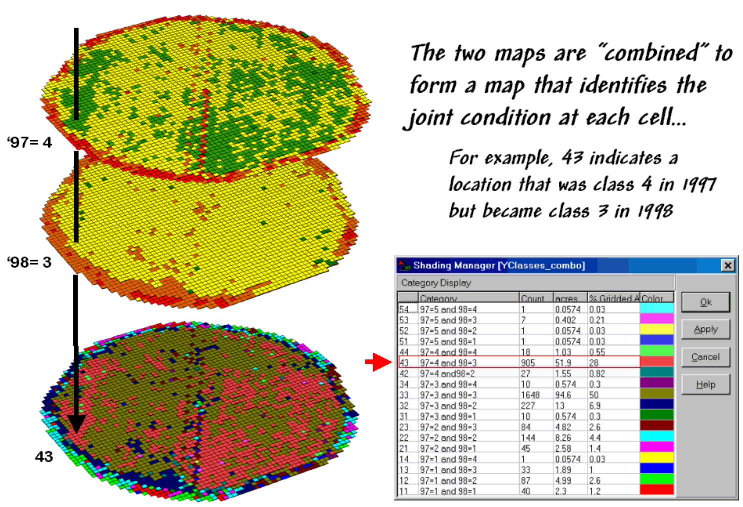


Figure 3-2. Coincidence map identifying the joint conditions for both years.

Let's consider discrete map comparison first. The two maps shown in figure 3-1 identify corn yield for successive seasons (1997 and 1998) on the central-pivot cornfield used in this case study. Note that the maps have a common legend from 0 to 300bu/ac and displayed using the same color pallet. *How different are they? How are they different? And where are they different?*

While your eyes flit back and forth in an attempt to compare the maps, the computer approaches the problem more methodically (note the common legend).

The first step converts the vector contour lines to a grid value for each cell. An analysis grid resolution is chosen (50ft cells are used in this example) and geometrically aligned with the maps. The dominant yield class within each cell is assigned its interval value (values 1= low yield of 0-60bu/ac through 5= high yield of 240-300 corresponding to the color ranges in the map display).

The next step, as shown in figure 3-2, combines the two maps into a single map that indicates the "joint condition" for both years. Since the two maps have an identical grid configuration, the computer simply retrieves the two class assignments for a grid location, then converts them to a single number.

The map-ematical procedure computes the "first value times ten plus the second value" to form a two-digit code. In the example shown in the figure, the value "forty-three" is interpreted as class 4 in the first year but decreasing to class 3 in the next year.

	A	B	C	D	E	F	G	H	I
1			1997 Yield						
2			1 (0-60)	2 (60-120)	3 (120-180)	4 (180-240)	5 (240-300)	Subtotal	Percent
3	1998Yield	1 (0-60)	40	45	10	0	1	96	41.67
4		2 (60-120)	87	144	227	27	1	486	29.63
5		3 (120-180)	33	84	1648	905	7	2677	61.56
6		4 (180-240)	1	0	10	18	1	30	60.00
7		5 (240-300)	0	0	0	0	0	0	0.00
8		Subtotal	161	273	1895	950	10	3289	
9		Percent	24.84	52.75	86.97	1.89	0.00		56.25

Figure 3-3. Coincidence summary matrix.

The final step sums up the changes to generate a coincidence table (see figure 3-3). The columns and rows in the table represent the class assignments on the 1997 and 1998 yield maps, respectively. The body of the table reports the number of cells for each joint condition. For example, column 4 and row 3 notes that there are 905 occurrences where the yield class slipped from level four (180-240bu/ac) to level three (120-180bu/ac).

The off-diagonal entries indicate changes between the two maps—the values indicate the relative importance of the change. For example, the 905 statistic for the "four-three" change is the largest and therefore identifies the most frequently occurring change in the field. The 0 statistic for the "four-one" combination indicates that level four never slipped all the way to level 1.

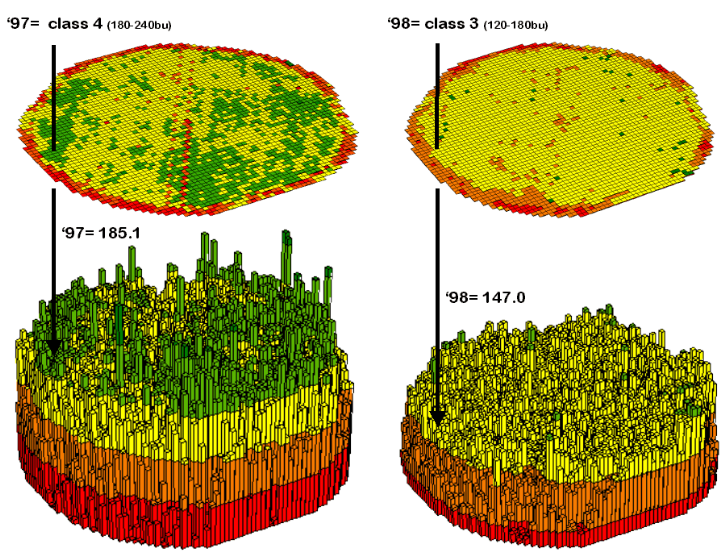


Figure 3-4. 3-D Views of yield surfaces for consecutive years.

The diagonal entries summarize the agreement between the two maps. The greatest portion of the field that didn't change occurs for yield class 3 ("three-three" with 1640 cells). The statistic in the extreme lower-right (56.25%) reports that only a little more than half the field didn't change its yield class.

Generally speaking, the maps are very different (only 56.25% unchanged). The greatest difference occurred for class 4 (only 1.89% didn't change). And a detailed picture of the spatial patterns of change is depicted in the coincidence map shown in figure 3-2.

That's a lot more meat in the answers to the basic map comparison questions (how much, how and where) than visceral viewing can do.

The next section looks at even more precise procedures for reporting differences between mapped data.

3.2 Comparing Yield Surfaces (Continuous)

Contour maps are the most frequently used and familiar form of presenting precision agriculture data. The two 3D perspective-plots in the top of figure 3-4 show the color-coded ranges of yield (0-60, 60-120, etc. bushels per acre) and are identical to the discrete maps discussed in the previous section. The color-coding of the contours is draped for cross-reference onto the continuous 3D surface of the actual yield data.

Note the "spikes and pits" in the surfaces that graphically portray the variance in yield data for each of the contour intervals. While discrete map comparison identifies shifts in broadly defined yield classes, continuous surface comparison identifies the precise difference at each location.

For example, a yield value of 179 bushels on one map and 121 on the other are both assigned to the third contour interval (120 to180; yellow). A discrete map comparison would suggest that no change in yield occurred for the location because the contour interval remained constant. A continuous surface comparison, would report a fairly significant 58-bushel decline.

Figure 3-5 shows the calculations using the actual values for the same location highlighted in the previous section’s discussion. The discrete map comparison reported a decline from yield level 4 (180 to 240) to level 3 (120 to 180).

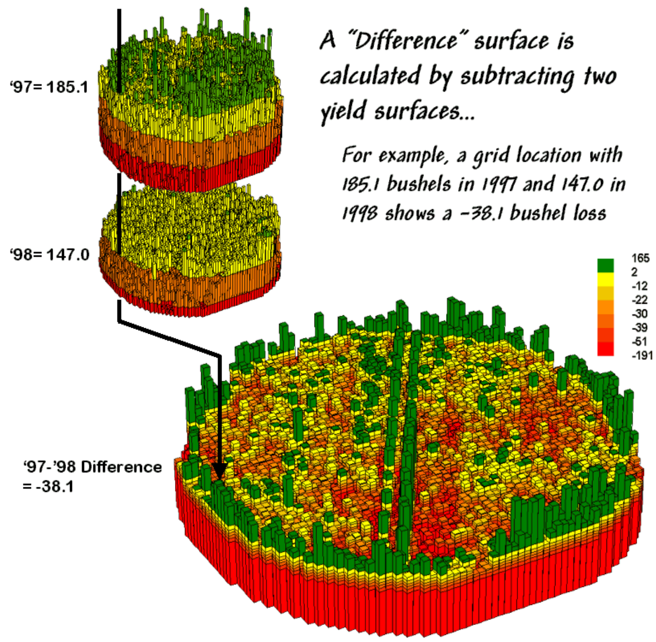


Figure 3-5. A difference surface identifies the actual change in crop yield at each map location.

The continuous surface comparison more precisely reports the change as –38.1 bushels. The differences for other 3,289 grid cells are computed to derive a ***Difference Surface*** that tracks the subtle variations in the spatial pattern of the changes in yield.

The MapCalc command, *“Compute Yield_98 minus Yield_97 for Difference”* generates the difference surface. If the simple “map algebra” equation is expanded to *“Compute (((Yield_98 minus Yield_97) / Yield_97) *100)”* a percent difference surface would be generated. Keep in mind that a map surface is merely a spatially organized set of numbers that awaits detailed analysis then transformation to generalized displays and reports for human consumption.

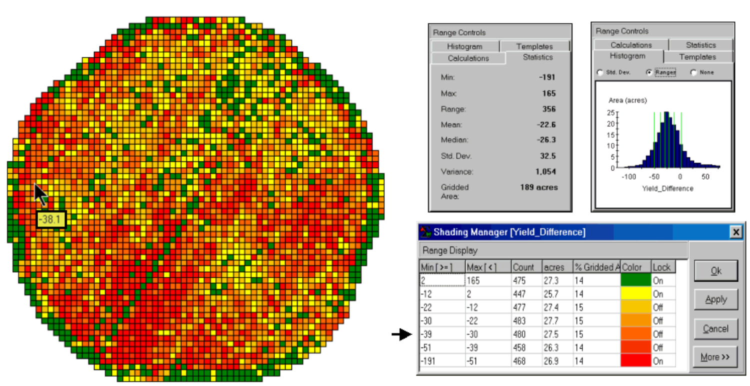


Figure 3-6. A 2-D map and statistics summarize the differences in crop yield between two periods.

In figure 3-5, note that the wildest differences (side-by-side green spikes and red pits) occur at the field edges and along the access road—from an increase of 165 bushels to a decrease of 191 bushels between the two harvests. However, notice that most of the change is about a 25 bushel decline (mean= -22.6; median= -26.3) as identified in the summary table shown in figure 3-6.

The histogram of the yield differences in the figure shows the numerical distribution of the difference data. Note that it is normally distributed and that the bulk of the data is centered about a 25 bushel decline. The vertical lines in the histogram locate the contour intervals used in the 2D display of the difference map in the left portion of figure 3-6.

The detailed legend links the color-coding of the map intervals to some basic frequency statistics. The example location with the calculated decline of –38.1 is assigned to the –39 to –30 contour range and is displayed as a mid-range red tone. The display uses an *Equal Count* method with *seven intervals*, each representing approximately 15% of the field. Green is locked for the only interval of increased yield. The decreased yield intervals form a color-gradient from yellow to red. All in all, surface map comparison provides more information in a more effective manner discrete map comparison. Both approaches, however, are far superior to simply viewing a couple yield maps side-by-side and guessing at the magnitude and pattern of the changes.

The ability to quantitatively evaluate continuous surfaces is fundamental to precision agriculture. A difference surface is one of the simplest and most intuitive forms. While the math and stat of other procedures are fairly basic, the initial thought of *"you can't do that to a map"* is usually a reflection of our non-spatial statistics and paper-map legacies. In most instances, precision agriculture is simply an extension of current research and management practices from a few *sample plots* to extensive *mapped data sets*. The remainder of this case study investigates many of these extensions.

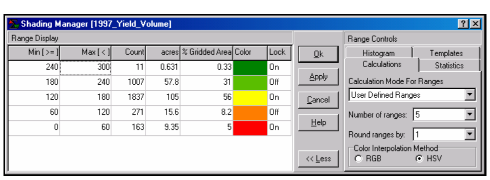
3.3 Exercises

Access MapCalc using the *Agdata.rgs* data set by selecting **Start→ Programs→ MapCalc Learner→ MapCalc Learner→ Open existing map set→ PA_AgData.rgs**. The following set of exercises utilizes this database.

3.3.1 Simultaneously Viewing Yield Maps

Use the *View* button to access the **1997_Yield_Volume** map.

Use the *Shading Manager* button (or right-click on the map and select **Shading Manager**) to pop-up the display settings. Create a custom display of the data by completing the dialog box shown below.



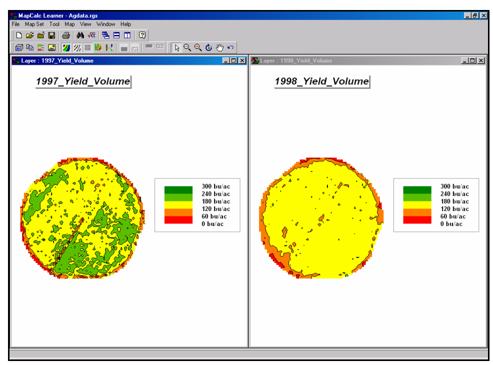
- ✓ Set the *Number of Ranges* to **5**
- ✓ Set the *Calculation Mode* to **User Defined Ranges**
- ✓ Under the *Min [>=]* column enter the values **0**, **60**, **120**, **180** and **240** from bottom to top
- ✓ Under the *Max [Max <]* column enter the value **300**
- ✓ Under the *Lock* column click **off** the lock beside the yellow box
- ✓ Click on the color box in the 120-180 range row of the table then select **yellow** from the *Basic Colors* pallet and press **OK** to lock yellow as a color inflection.

Before leaving the Shading Manager dialog box click on the *Templates* tab then the *Save As* button and enter **Yield_5levels0-300** as the template name. Click **OK** to save the name and **OK** again to re-display the map with the new display settings.

Use the *View* button, select the **1998_Yield_Volume** map then click on the *Shading Manager* button to pop-up the map's default display settings. Click on the *Templates* tab, select **Yield_5levels0-300** as the template and click OK to re-display the map with the new display settings.

Use the *Arrange windows vertically* button to display all of the open map windows.

Use the *"X" Close* button in the upper right corner of the window to close all of the windows except the views of the *1997_Yield_Volume* and *1997_Yield_Volume* maps. Press the *Arrange windows vertically* button again to tile just the two maps.



Note the dramatic differences in yield between the two years.

3.3.2 Comparing Yield Maps

Press the **Map Analysis** button to access the analytical operations, select **Reclassify→ Renumber** and complete the dialog box shown below to enter the MapCalc command:

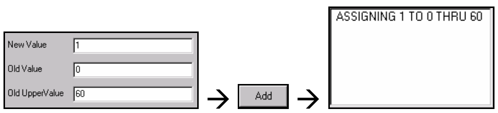
RENUMBER 1997_Yield_Volume
ASSIGNING 1 TO 0 THRU 60

ASSIGNING 2 TO 60 THRU 120
ASSIGNING 3 TO 120 THRU 180
ASSIGNING 4 TO 180 THRU 240
ASSIGNING 5 TO 240 THRU 300
FOR 97Yield_classes

…that identifies five levels of yield from low (class 1= 0-60bu) to high (class 5= 240-300bu).

First specify **1997_Yield_Volume** as the input map.

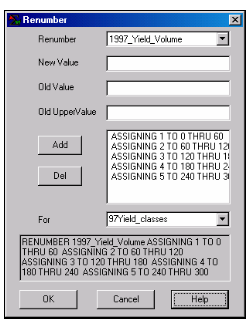
Next, enter the first *Assignment Phrase*:



ASSIGNING 1 TO 0 THRU 60 then press the **Add** button to append the phrase to the assignment list.

Repeat for the *"NewValue, OldValue, OldUpperValue* then *Add"* sequence for the other four assignment phrases.

Finally, specify **97Yield_classes** as the output map and press **OK** to derive the map. Close the *Map Analysis* window to view the result.

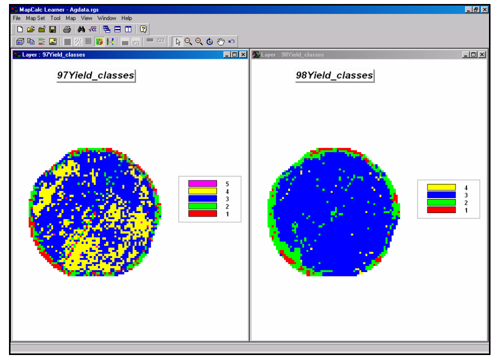


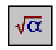
RENUMBER 1997_Yield_Volume ASSIGNING 1 TO 0 THRU 60 ASSIGNING 2 TO 60 THRU 120 ASSIGNING 3 TO 120 THRU 180 ASSIGNING 4 TO 180 THRU 240 ASSIGNING 5 TO 240 THRU 300 FOR 97Yield_classes

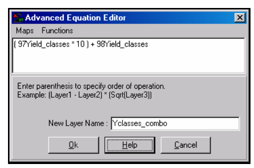
Repeat the same classification procedure using the *1998_Yield_Volume* map to derive the *98Yield_classes* map:

- ✓ Click on the **Map Analysis** button
- ✓ Select **Reclassify→ Renumber**
- ✓ Specify **1998_Yield_Volume** as the input map
- ✓ Complete the *Assignment Phrases* using **Add** button
- ✓ Specify **98Yield_classes** as the output map
- ✓ Click **OK** to derive the result
- ✓ Close the *Map Analysis* window

Display as side-by-side maps in 2D Grid format (*Use Cells* button…remember?).

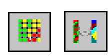


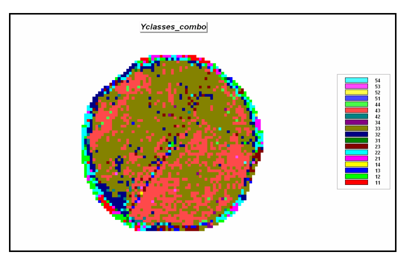
 Press the **Map Analysis** button to access the analytical operations, select **Overlay→ Calculate** and complete the dialog box shown below.



*Calculate (97Yield_classes * 10) + 98Yield_classes For Yclasses_combo*

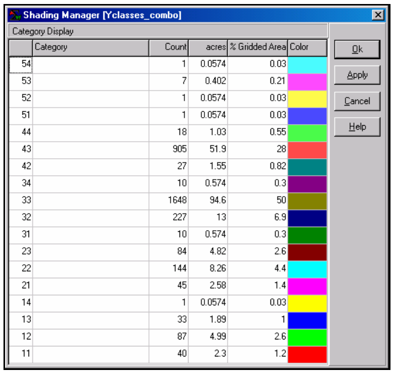
For convenience, use the *Maps* menu pull-down to select the input and output maps as you construct the equation. You can use the *Functions* pull-down menu to select mathematical operators or simply enter them via the keyboard.

 Click on the **Use Cells** and **Data Type** buttons to switch the default *2D continuous lattice* display to *2D discrete grid* format.



The values on the derived map *Yclasses_combo* form a two-digit code with the first value (tens digit) identifying the 1997 yield class and the second value (ones digit) identifying the 1998 yield class. For example, the value "forty-three" is interpreted as yield class 4 (180-240bu) in 1997 but decreasing to yield class 3 (120-1280bu) in 1998.

Clicking on the **Shading Manager** button pops-up a summary of the joint coincidence of the two yield maps.



Shading Manager [Yclasses_combo]

Category Display

	Category	Count	acres	% Gridded Area	Color
54		1	0.0574	0.03	
53		7	0.402	0.21	
52		1	0.0574	0.03	
51		1	0.0574	0.03	
44		18	1.03	0.55	
43		905	51.9	28	
42		27	1.55	0.82	
34		10	0.574	0.3	
33		1648	94.6	50	
32		227	13	6.9	
31		10	0.574	0.3	
23		84	4.82	2.6	
22		144	8.26	4.4	
21		45	2.58	1.4	
14		1	0.0574	0.03	
13		33	1.89	1	
12		87	4.99	2.6	
11		40	2.3	1.2	

Ok Apply Cancel Help

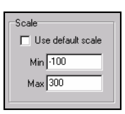
Note that most of the field was classified as class three (120-180bu) in both periods— code 33= 1648 cells representing 94.6 acres representing 50 percent of the field.

3.3.3 Comparing Yield Surfaces


Create side-by-side displays of the **1997_Yield_Volume** and the **1998_Yeld_Volume** maps.

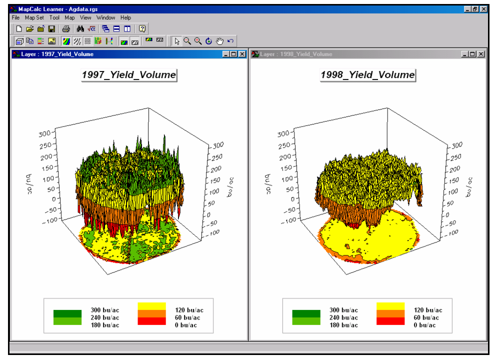

Use the **3D** buttons to change the display format of both maps. Right-click on the *1997_Yield_Volume* map and select **Properties→ Legend Tab**.

Select **Bottom** in the *Position Legend* window.

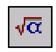


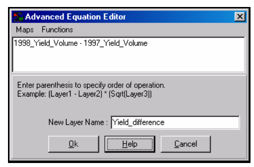
Select the **Plot Cube** tab and un-check the *Use Default Scale* checkbox then enter **-100** as the *Min* and **300** as the *Max* for the Z-axis.

Repeat the same custom display settings for the *1998_Yield_Volume* map.

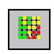


Note the relationship between the 2D projected display and the 3D surface in both displays. Also note the relative height of both plots using a common Z-axis scale. The 1998 plot displays considerably less yield variability (peaks and valleys).

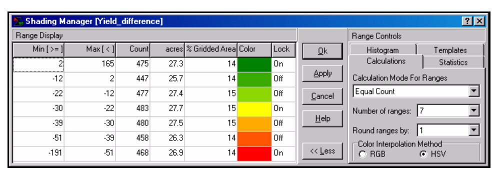

Press the **Map Analysis** button to access the analytical operations, select **Overlay→ Calculate** and complete the following dialog box.



Calculate 1998_Yield_Volume - 1997_Yield_Volume for Yield_difference


Use the **Use Cells** button to switch to grid display format.

Right-click on the map, select the **Shading Manager** option and change the *Calculation Mode* from *Equal Ranges* to **Equal Counts**. Press **OK** to re-display.



Shading Manager [Yield_difference]

Range Display

Min [>=]	Max [<]	Count	acres	% Gridded Area	Color	Lock
2	165	475	27.3	14		On
-12	2	447	25.7	14		Off
-22	-12	477	27.4	15		Off
-30	-22	483	27.7	15		On
-39	-30	480	27.5	15		Off
-51	-39	458	26.3	14		Off
-191	-51	468	26.9	14		On

Ok Apply Cancel Help << Less

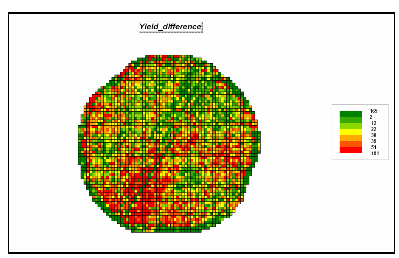
Range Controls: Histogram, Templates, Calculations, Statistics

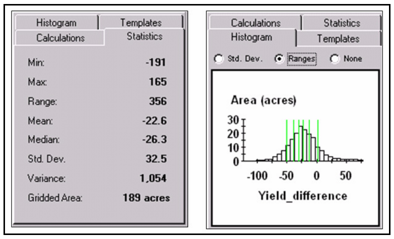
Calculation Mode For Ranges: Equal Count

Number of ranges: 7

Round ranges by: 1

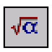
Color Interpolation Method: RGB, HSV



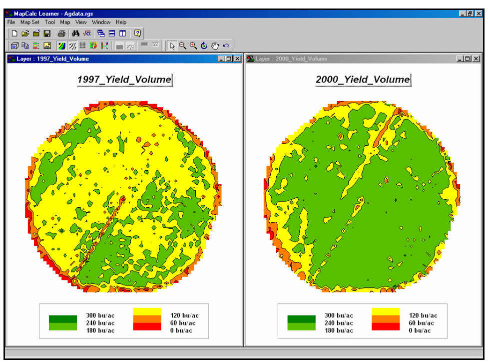


Note that the yield difference ranges from a -191 bu/ac decrease to a 165 bu/ac increase with an average difference of -22.6.

3.3.4 Other Map Comparisons

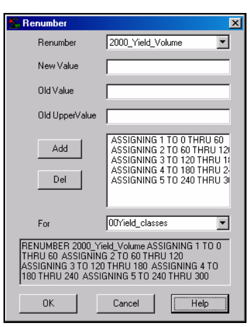

Press the **Map Analysis** button to access the analytical operations. Repeat the comparison analysis you just completed using the **1997_Yield_Volume** and **2000_Yield_Volume** maps.

Simultaneously Viewing Yield Maps:

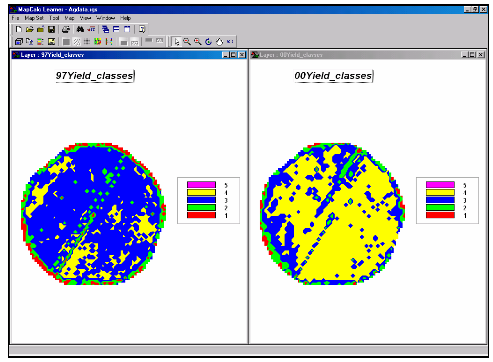


Side-By-Side views of '97 and '00 Yield

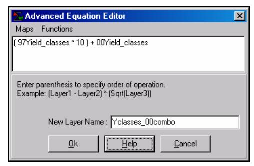
Comparing Yield Maps:



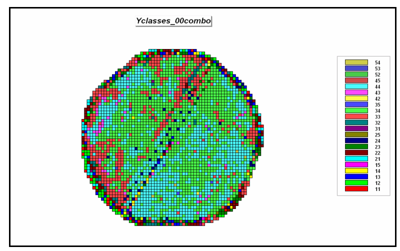
RENUMBER 2000_Yield_Volume ASSIGNING 1 TO 0 THRU 60 ASSIGNING 2 TO 60 THRU 120 ASSIGNING 3 TO 120 THRU 180 ASSIGNING 4 TO 180 THRU 240 ASSIGNING 5 TO 240 THRU 300 FOR 00Yield_classes



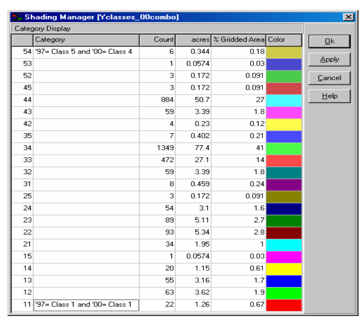
Side-by-Side displays of '97 and '00 Yield class maps



*Calculate (97Yield_classes * 10) + 00Yield_classes For Yclasses_00combo*



Joint Coincidence map of '97 and '00 yield classes


Shading Manager [Yclasses_00combo]

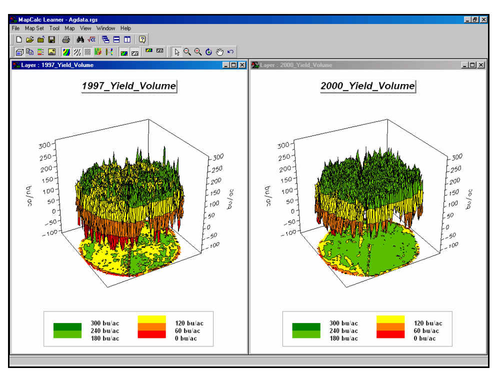
Category Display

	Category	Count	acres	% Gridded Area	Color
54	'97= Class 5 and '00= Class 4	6	0.344	0.18	
53		1	0.0574	0.03	
52		3	0.172	0.091	
45		3	0.172	0.091	
44		884	50.7	27	
43		59	3.39	1.8	
42		4	0.23	0.12	
35		7	0.402	0.21	
34		1349	77.4	41	
33		472	27.1	14	
32		59	3.39	1.8	
31		8	0.459	0.24	
25		3	0.172	0.091	
24		54	3.1	1.6	
23		89	5.11	2.7	
22		93	5.34	2.8	
21		34	1.95	1	
15		1	0.0574	0.03	
14		20	1.15	0.61	
13		55	3.16	1.7	
12		63	3.62	1.9	
11	'97= Class 1 and '00= Class 1	22	1.26	0.67	

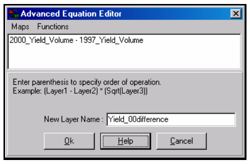
Ok Apply Cancel Help

Summary of Joint Coincidence (2-digit code)

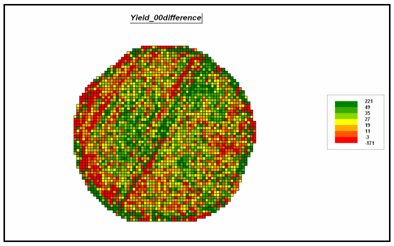
Comparing Yield Surfaces:



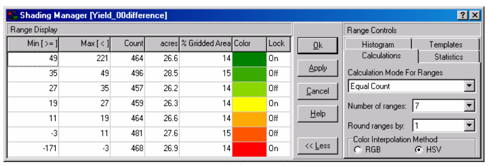
Side-by-Side 3D plots of '97 and '00 yield surfaces



Calculate 2000_Yield_Volume - 1997_Yield_Volume for Yield_00difference

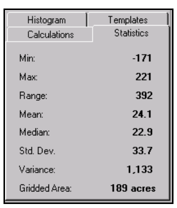


Difference map between '97 and '00 yield surfaces

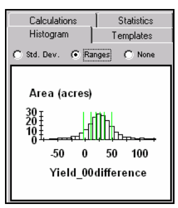


Min [>=]	Max [<]	Count	acres	% Gridded Area	Color	Lock
49	221	464	26.6	14		On
35	49	496	28.5	15		Off
27	35	457	26.2	14		Off
19	27	459	26.3	14		On
11	19	464	26.6	14		Off
-3	11	481	27.6	15		Off
-171	-3	468	26.9	14		On

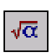
Summary of Yield_00difference map



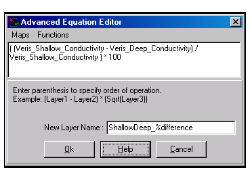
Descriptive Statistics



Histogram

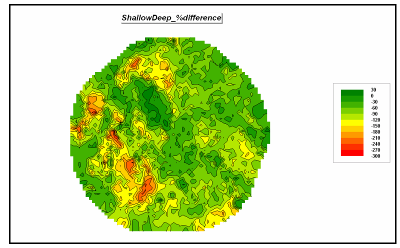


Press the **Map Analysis** button to access the analytical operations and select **Overlay→ Calculate**. Complete the following dialog box to calculate a percent difference between the *Veris_Shallow_Conductivity* and *Veris_Deep_Conductivity* maps.

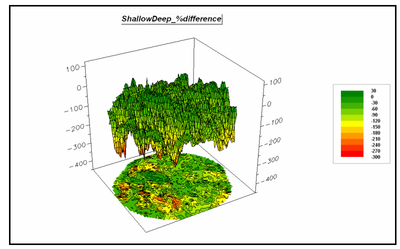


*Calculate ((Veris_Shallow_Conductivity - Veris_Deep_Conductivity) / Veris_Shallow_Conductivity) * 100 For ShallowDeep_%difference*

Using the Shading Manager display the result as a 2D continuous grid map with eleven user-defined 30-unit contour intervals from -300 to 30 and color ramped from green to red with yellow color inflection for the -120 to -150 range.



2D continuous lattice display of %Difference



3D continuous lattice display of %Difference

Which contour range occurs most frequently?

What percent of the field has a positive percent difference? Where does this condition occur in the field (NE, SE, NW or NW sector—"pie slice" from the center of the field)?

Which sector contains most of the large negative percent differences?

What are the basic descriptive statistics for the ShallowDeep_%difference map (Min, Max, Range, etc.)?

You can exit the program by selecting **File → Exit** or by clicking on the "X" in the upper-right corner of the MapCalc program window. If you want to save your work, specify a new file name, such as ***AgData_Topic3_exercises.rgs***. Each exercise set assumes you will start with the basic *AgData.rgs* data set and this database will become cluttered with exercise maps if you save your results to it each time.