Chapter 7 Introduction to Classifying Multispectral Images

In this section you will learn how to classify a scene based on the spectral properties of a pixel, a procedure that is analogous to classification using just the colors of objects. Thus, multispectral classification is quite different compared to our human vision system, which is mainly based on spatial patterns and context. Humans have no trouble identifying objects in black and white images, but the multispectral classification programs we are using do very poorly on such data.

Multispectral classification usually requires some knowledge of the scene. This differentiates multispectral classification from hyperspectral classification, where, at least in theory, it may be possible to identify classes entirely automatically, using generic spectral reflectance libraries. The information about the scene may come from personal knowledge of the area, field trips, and aerial photography. In addition, this information is usually supplemented by image interpretation by the analyst.

Classification is a grouping or generalization of the data. Thus it involves a simplification. Consider for a moment a hypothetical three-band, 8 bit data set. The potential number of unique combinations of DN values is 255^3, or 16.6 million. The number of unique combinations grows exponentially with the number of bands. Nevertheless, the number of useful classes that can be identified reliably in a typical multispectral image is usually quite small, perhaps ten or so. This is partly because usually only a small number of the potential DN combinations are actually found in real data, and partly because there is considerable variation within each class. Thus, the process of multispectral classification involves not just identifying the average DN values of each class, but also the variability of each class.

In classification it is also important to differentiate between **spectral classes** and **informational classes**. The spectral classes are the groups in the data; informational classes are the map classes, the groups the analyst would like to identify. There may be a 1:1 relationship between spectral and informational classes, but in general it is unlikely to be so. For example, an analyst may wish to identify the class Water. However, this class might consist of two relatively distinct spectral classes such as deep, clear water, and shallow, muddy water.

7.1 Introduction to Multispectral Classification Methods

There are many classification methods. To characterize the differences between these many methods, a number of terms are defined:

- Supervised versus unsupervised classification
- Soft versus hard classification
- Relative versus absolute classification

Understanding these terms helps illuminate some of the important characteristics of classifiers that are dealt with in this section.

7.1.1 Supervised Versus Unsupervised Classification

The difference between supervised and unsupervised classification relates to when the analyst uses knowledge of the scene to guide the classification. Unsupervised classification uses an algorithm to identify the spectral classes, and the analyst subsequently assigns informational class names to the algorithm-identified spectral classes. With supervised classification, the analyst identifies regions in the image, known as training areas, to represent the typical spectral classes that make up the informational classes. The classification algorithm then classifies each pixel in the rest of the image based on comparisons with training data, or more commonly, summary properties of the training data.

In the abstract, unsupervised classification sounds like a more reliable and less subjective process. In reality, both supervised and unsupervised classification require considerable subjective judgment and skill.

7.1.2 Soft Versus Hard Classification

The cartographic tradition is that of maps comprising discrete areas, with sharp boundaries, and distinct, contrasting characteristics. This tradition has been transferred to remote sensing classification, where the aim is usually to assign each pixel to only one of a number of classes. The real world is not necessarily so simple: classes are likely to grade into one another, and a location may have characteristics of two or more classes. For example, the classes Clean Water and Muddy Water may represent a continuum, and Muddy Water in turn may grade through Wetlands into Dry Land. In addition, a pixel that falls on a boundary between two or more classes would be expected to have attributes of both classes.

In fuzzy classification, a type of soft classification, a degree of membership in each class is generated for each pixel location, rather than just a value representing the class number, as is the case with hard classifiers. (Note that the IDRISI documentation makes the argument that soft classification is preferable to fuzzy classification as a generic term.)

7.1.3 Relative Versus Absolute Classifiers

It is relatively difficult to determine if two objects are the same, since then one is forced to define how much variation is acceptable in the quality of "sameness." It is generally much easier to invert the process and find differences. Thus, most classifiers are relative classifiers, assigning an unknown pixel to a class only after comparing the unknown with each class, and choosing the one to which it is most similar (or, the least different). In contrast, an absolute classifier usually stops comparing an unknown pixel to the training classes once a match has been met. Relative classifiers require the user to identify training data for all the spectral classes, whereas absolute classifiers only need training data for the class or classes of interest. However, one disadvantage with absolute classifiers is that they are poor generalizers, and often leave many pixels unclassified.

7.2 Copy Data for This Chapter

In this chapter we will work with different image sets for each section. Therefore, you should now copy the *Chap7* folder from the CD, and paste it as a new subfolder within the *\ID Man* folder on your computer.

After you have copied the folder, you should remove the Read-Only attribute from this new folder on your computer. This is done by right-clicking on the *Chap7* folder name, selecting *Properties* from the pop-up menu. A dialog box will open, labeled *Chap7 Properties* (if you apply this procedure to the entire *ID Man* directory, then the dialog box will be labeled *ID Man Properties*). Now clear the check mark from the *Read Only* check box, by clicking in the box. You should then click on the button for *Apply*, and in the subsequent *Confirm Attribute Changes* dialog box, accept the default *Apply changes to this folder, subfolder and files*, and click on *OK*. You will need to also click on *OK* in the *Chap7 Properties* dialog box.

Note: Section 1.3.1 provides detailed instructions on how to copy the data from the CD, and also on how to remove the *Read-Only* attribute from the data. Also, the procedure for setting up the *ID Man* folder on your computer is described.

7.3 Unsupervised classification

7.3.1 Overview

The sequence of operations in unsupervised classification is summarized in Figure 7.3.1.a.

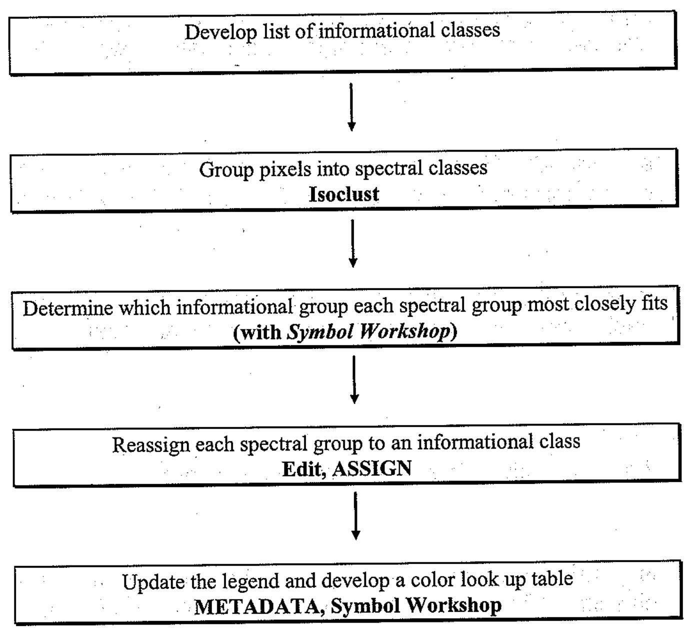


Figure 7.3.1.a Overview of unsupervised classification.

The first step is to identify the list of informational classes based on knowledge of the area and usually an examination of the image to determine the likely classes that might be discriminated.

The next step is to cluster the image to produce the spectral classes, typically many more than the expected number of final informational classes. The analyst then views each spectral class, and develops a list of the original spectral class numbers and the informational class number to which each spectral class is assigned. Developing this list can be difficult, because often the spectral class consists of more than one informational class. In other words, when you try to decide on the informational class to assign the spectral class to, you find that there are two or even more informational classes that seem appropriate. There are four options when this happens:

1. Label the pixel according to the dominant informational class.

2. Create informational classes that are mixtures.
3. Start again from the beginning choosing clustering parameters that will give you even more classes.
4. Follow a "cluster-buster" procedure, where mixed classes are subjected to a second round of clustering, in the hope that this will split these classes into classes that are more pure.

In this exercise, we will follow option (1) from above, and try to identify the dominant class for each cluster.

After the relationship between each spectral and informational class is established, the image classes are recoded to produce a new image with only informational classes.

7.3.2 Preparation

In Section 7.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for this section.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap7* subfolder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap7* will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

For this exercise we will investigate multispectral classification using Landsat Thematic Mapper data of the area around Morgantown, West Virginia, USA. Begin by creating a false color composite, in which TM bands 3, 4, and 5 are assigned blue, green and red, as described below.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* ***tm3***. Click on *OK* to close the *Pick list.*
3. Specify the *Green image band as* ***tm4***.
4. Specify the *Red image band* as ***tm5***.

5. Enter the *Output image* filename in the text box provided: **tm345fcc**.
6. Accept all other defaults, and click *OK* to create and display the false color composite.

Figure 7.3.2.a shows the results of the image, which will be displayed automatically. The image has been annotated with the major land use types.

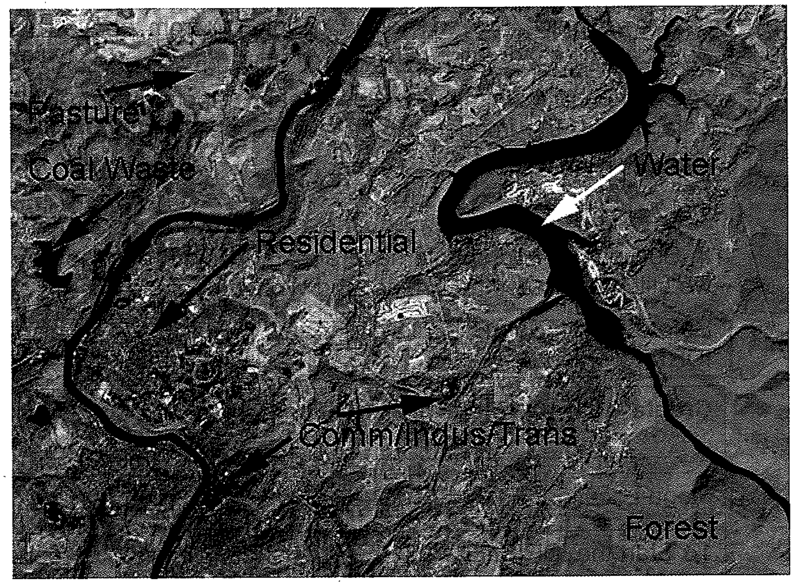


Figure 7.3.2.a False color composite of Morgantown, WV (Bands 3, 4, 5 as B, G, R). Major land use types are indicated.

The false color composite image we have just created (Figure 7.3.2.a) will be used for interpretation of the land cover types.

Before we go on to run the ISOCLUST unsupervised classification program, we need to generate a *Raster Group File* for the input data. This format is useful, as it means we can specify just one file name (the group), instead of the multitude of individual bands. The procedure to create a raster group file is described below briefly. If you want additional discussion on creating *Raster Group Files*, you may wish to review the material in Section 1.3.7.

Creating a file collection with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Open the *IDRISI EXPLORER* window from the menu or the main icon toolbar.
2. Click on the tab for *Files*. If the files in the directory are not listed, double click on the directory name (e.g. *C:\ID Man\Chap7*), as listed in the *Files* pane.
3. Click on ***tm1.rst***. The file name will then be highlighted.
4. Press, and holding the *CTRL* key down, click on the ***tm2.rst, tm3.rst, tm4.rst, tm5.rst, and tm7.tst.***
5. You should now have 6 TM files highlighted. Remove your finger from the *CTRL* button. Press the right mouse button.
6. A pop-up menu will appear. Within this menu, scroll down to *Create*, and then select *Raster Group File*.

7. A new file should be listed in the Files pane, ***Raster Group.rgf***. Select that file by clicking on it.
8. In the *Metadata* pane of the *IDRISI EXPLORER*, delete the text in the *Name* text box (***Raster Group***), and type: **Tm_all**.
9. Press *Enter* on the computer keyboard, and then click on the *Save* icon in the bottom left hand corner of the *Metadata* pane.

7.3.3 Develop the List of Land Cover Types

Table 7.3.3.a lists five major land cover types, which will form the basis of the informational classes for the unsupervised classification. The information in the table should be compared against the false color composite you have generated to see if you can identify all the classes present (Figure 7.3.2.a). The numbers given in the left hand column will be used to represent the classes in the final classification. Note that the table **does not include the Coal Waste class** shown in Figure 7.3.2.a. The reason for this is that this class is difficult to differentiate with unsupervised classification, and for the moment we will not try to separate it. Instead, for this exercise, you should include the Coal Waste as part of the Commercial/Industrial/Transportation class. For the supervised classification, we will separate out this class.

Table 7.3.3.a. Table of land cover classes for unsupervised classification.

Class Number	**Name**	**Color in 345 false color composite**	**Texture**
1	Water	Black	Smooth
2	Forest	Green	Moderate
3	Pasture/Grass	Pink to light green/yellow	Moderate
4	Commercial / Industrial / Transportation	Blue/Grey	Rough
5	Residential	Bright blue	Rough

7.3.4 Group Pixels into Spectral Classes: ISOCLUST

The ISOCLUST program has a number of parameters that you, as the analyst, have to specify. These parameters all affect the classification output. While the range of options can be daunting, IDRISI does have excellent help documentation, as already described earlier (Section 1.3.3). You should get into the habit of checking the on-line help to find out more about how programs work, or to understand the implications of each of the options offered, when you are faced with options or parameters that you are unsure how to deal with.

Clustering an image with ISOCLUST

Menu location: **Image processing – Hard classifiers - ISOCLUST**

1. Start the ISOCLUST program from the menu.
2. In the *ISOCLUST* dialog box, click on the *Insert layer group* button.
3. A *Pick list* window will open. Double click on ***Tm_all***.

4. The six tm bands (***tm1, tm2,....tm5, tm7***) should all be listed now in the *ISOCLUST* dialog box, in the *Bands to processed- Filename* text box (Figure 7.3.4.a).
5. Click on *Next.*

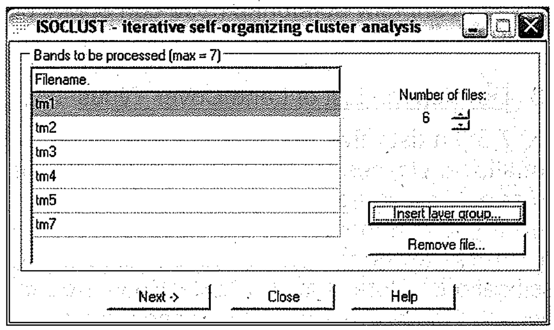


Figure 7.3.4.a *ISOCLUST* dialog box with the raster group file bands specified.

The program will then generate an analysis of the potential classes and the comparative number of pixels that fall into these classes. This information is reported in a *HISTOGRAM* window (Figure 7.3.4.b). A new *ISOCLUST* window (with a new set of control parameters) will also open.

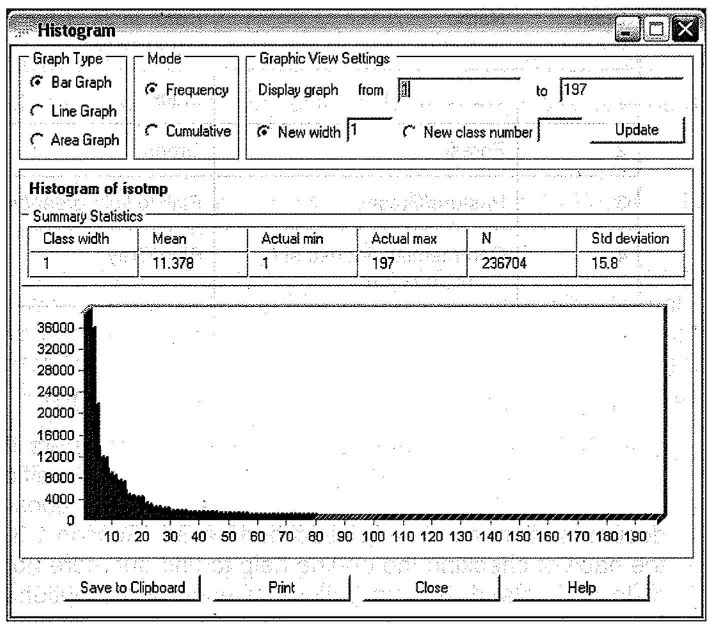


Figure 7.3.4.b Histogram of potential classes.

The purpose of the histogram is to assist in the process of deciding on the number of spectral classes to generate through the ISOCLUST program. In examining Figure 7.3.4.b, it is apparent that most of the data fall in a small number of classes, each with many pixels. The remainder of the pixels falls in a large number of classes, each with very few pixels. Thus there is a diminishing return as higher numbers of classes are selected. The IDRISI on-line help suggests looking for a break in the histogram curve to decide on a logical value. The number of spectral classes we choose should be much larger than the number of informational classes. Since we are interested in 5 classes, and the histogram seems to flatten out around 20, we shall select 20 spectral classes. This choice of 20 is somewhat arbitrary, however, and the reader might like to experiment with different values, after completing the initial guided exercise.

Clustering an image with ISOCLUST (cont.)

6. In the *ISOCLUST* dialog box, specify the *Number of clusters desired* as **20**.
7. Specify the *Output image* filename as **Isoclust20**
8. Figure 7.3.4.c shows the dialog box with the parameters specified.
9. Click on *OK*.

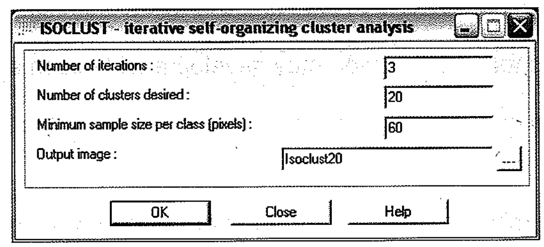


Figure 7.3.4.c *ISOCLUST* dialog box with clustering parameters.

The classification will take a while to process the image. You can watch the Status bar and progress indicators in the outer IDRISI frame for messages on progress. When the program is finished it will automatically display the classification (Figure 7.3.4.d).

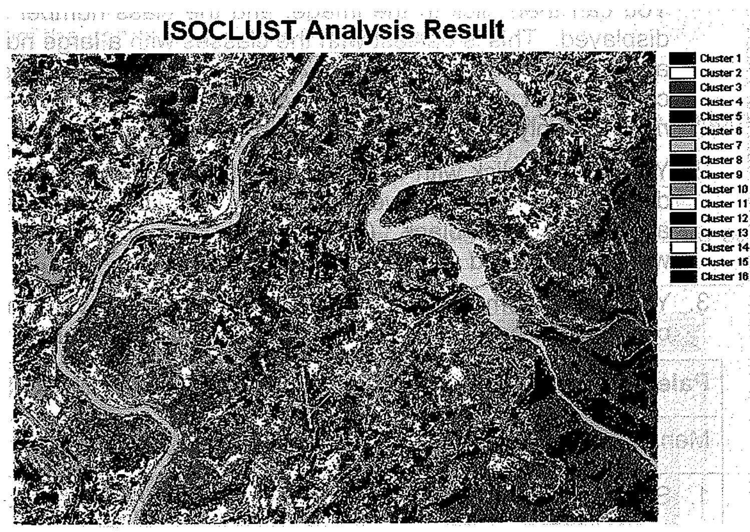


Figure 7.3.4.d Results of ISOCLUST program, with 20 classes.

Note that, if necessary, you can always redisplay the image you have just created, if you need to stop temporarily at this stage and close IDRISI. However, if you redisplay the image, bear in mind that this is no longer a raw image of radiance values, but a classified image. Therefore, you should use the IDRISI Default Qualitative palette, and also display the legend.

7.3.5 Determine the Informational Class

Even though we now have a classification, we unfortunately have only just begun our work. The next stage is to build a table of values listing the spectral classes from 1-20 (the number of spectral classes we specified in the ISOCLUST program), and the associated informational class number for each of those spectral classes. We will use a visual interpretation of the false color composite of Bands 3, 4, and 5 (***tm345fcc***, Figure 7.3.2.a) to determine the appropriate informational class. This part of the exercise is a somewhat tedious process!

Note that you should expect at least some informational class to have many informational classes. Unfortunately the reverse relationship is not allowed, and you cannot assign one spectral class to two informational classes.

Your final list of classes will have two columns, one each for the spectral class (ISOCLUST output), and associated informational class (final class number). Thus for example, you may develop a table such as:

1 2

2 2

3 2

4 4

...

20 3

There are three ways to decide on the informational class for a spectral class. You may wish to use a combination of the methods.

1. You can click on the main IDRISI toolbar icon to select *Curser inquiry mode.* You can then click in the image, and the class number for that pixel will be displayed. This is easiest with the classes with a large number of pixels, such as sinuous tan cluster (Cluster 7). (This cluster can be identified as Water, by comparing it to the false color composite.) To turn off the *Curser inquiry mode,* simply click again on the icon.
2. You can left-click with the mouse on the color chip in the legend for the map display, and switch between a display with just that class, shown in red, and all other pixels in black. (Unfortunately, this option does not always seem to work reliably, and so we do not recommend it.)
3. You can systematically work through the classes by setting them to distinctive colors. This procedure is described in more detail below.

Palette file interactive modification with SYMBOL WORKSHOP

Menu location: **Display – SYMBOL WORKSHOP**

1. Start the SYMBOL WORKSHOP from the main icon bar, or the main menu.
2. In the *SYMBOL WORKSHOP* window, select the menu option for *File – New.*
3. In the resulting *New Symbol File* dialog box, select *Palette* as the choice for *Symbol File Type.*
4. Enter the *File name* in the text box provided: **iso20**.
5. Click on *OK* to close the *New Symbol File* dialog box.
6. The *SYMBOL WORKSHOP* window will immediately change from a grid of circles, to a uniform red grid (Figure 7.3.5.a).

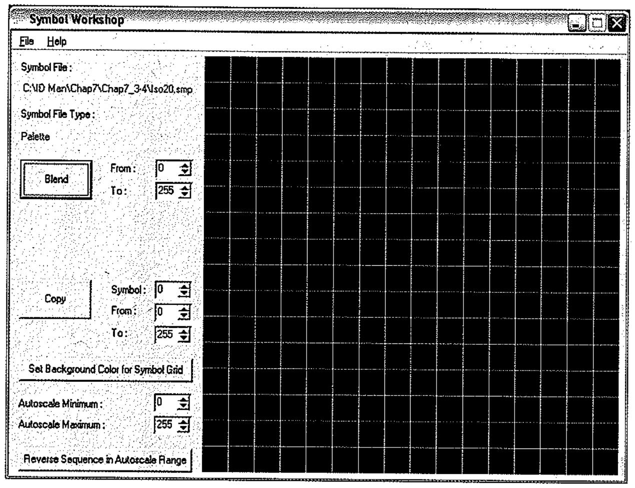


Figure 7.3.5.a *SYMBOL WORKSHOP* window, after specifying a new palette file.

We will now set up a gray scale range from 0 to 20, the maximum class number. We will specify 0 as black, and 20 as white. The values between 0 and 20 will be progressive shades of gray between those two extremes.

Palette file interactive modification with SYMBOL WORKSHOP (cont.)
7. Run your cursor over the red cells. Note how a small yellow rectangle appears next to the cursor. The number in this rectangle indicates the image DN number associated with that cell. 8. Select the upper left cell, cell 0, by clicking on it. 9. A *Color* dialog box will appear. 10. In the *Color* dialog box, click on the color chip for black (the bottom left color chip in the *Basic colors* section) (Figure 7.3.5.b). 11. Click on *OK*. 12. The *SYMBOL WORKSHOP* window should now have cell zero set to black (Figure 7.3.5.c).

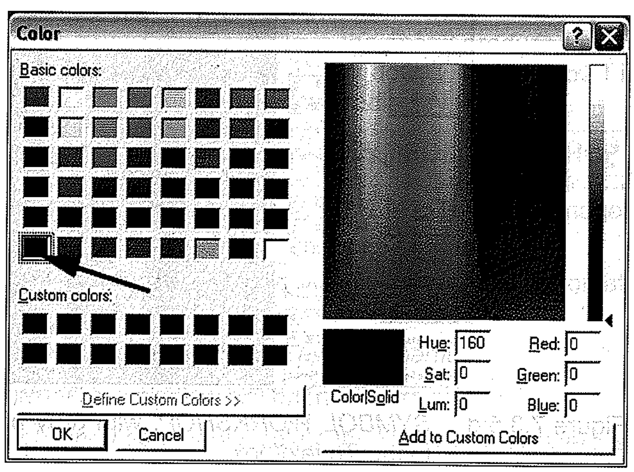


Figure 7.3.5.b *COLOR* dialog box, with Black chip indicated by the arrow.

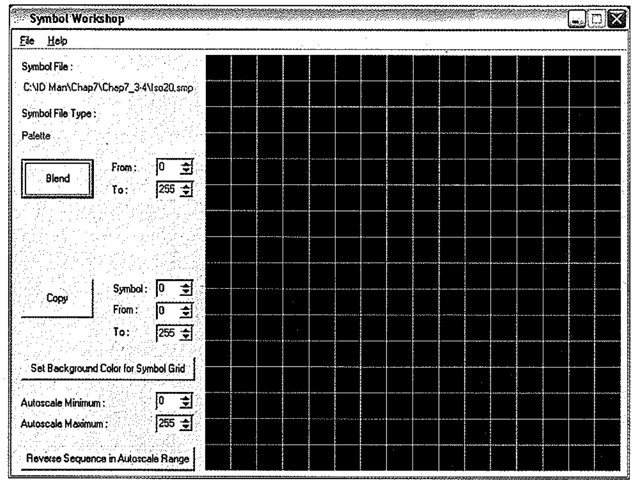


Figure 7.3.5.c *SYMBOL WORKSHOP* with cell 0 set to black.

Palette file interactive modification with SYMBOL WORKSHOP (cont.)

13. Now select cell *20* (run the cursor over the cells, to identify which cell is 20).
14. The *COLOR* dialog box will open. Select the chip for white (bottom right color chip, in the *Basic colors* section).
15. Click *OK* to close the *COLOR* dialog box, and return to the *SYMBOL WORKSHOP* window.
16. There should now be two cells that are not red: cell 0, which is black, and cell 20, which is white.
17. In the text box labeled *To*, which is situated next to the *Blend* button, enter **20**.
18. Click on the *Blend* button.
19. The result should be a gray scale color ramp from black to white for the first 20 cells (Figure 7.3.5.d).

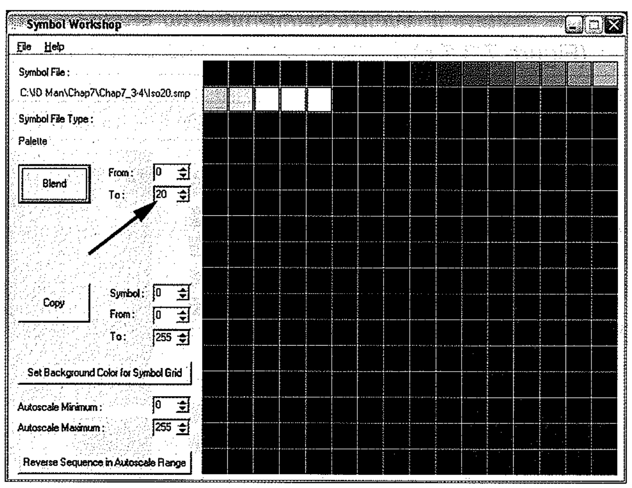


Figure 7.3.5.d *SYMBOL WORKSHOP*, with gray blend applied. Arrow points to the *To* text box.

Having now established a palette file that goes from black to white for image values that go from 0 to 20, we can now modify a few select values to other colors. In this way, when we apply this palette file to the ISOCLUST image, we will be able to see the general pattern of the classes in gray tones, but just focus on a few classes at a time in the distinctive colors. Note that we start at cell 1, and not 0, since IDRISI has assigned the first class to 1, not 0.

Palette file interactive modification with SYMBOL WORKSHOP (cont.)
20. In the *SYMBOL WORKSHOP* window, select cell 1, and this time set this cell to blue. (The specific blue color chip is not important; we simply want any bright and distinctive color.)
21. Select cell 2, and set it to green.
22. Select cell 3, and set it to red.
23. Use the menu in the *SYMBOL WORKSHOP* window, to save the palette file: *File – Save*.

Figure 7.3.5.e shows the SYMBOL WORKSHOP window, with the gray scale ramp, and three cells set to distinctive colors.

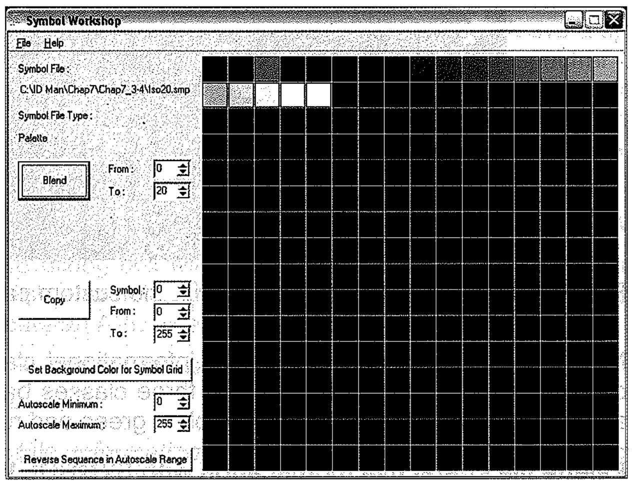


Figure 7.3.5.e *SYMBOL WORKSHOP* with 3 cells set to distinctive colors.

The next step is to apply the palette file to the image produced by the ISOCLUST program. Therefore, find the *DISPLAY* window, with the ***Iso20*** image already displayed. If you have closed the window, redisplay the image.

Palette file interactive modification with SYMBOL WORKSHOP (cont.)
24. Click on window that displays ***Iso20***. This is to bring the image to the front of your screen.
25. Now find the *Composer* window. This window is automatically opened whenever a *DISPLAY* window is opened.
26. In the *Composer* window, click on *Layer Properties*.
27. The *Layer properties* window will open.
28. In the *Layer Properties* window, select the *Display parameters* tab.

29. Click on the file selection icon (…) next to the *Palette file* text box, and in the *Pick list* that will open, double click on the name of the palette file you have just created: ***Iso20***.
30. The image should now be displayed in black and white, except for the selected classes we have set to blue, green and red, respectively (Figure 7.3.5.f).
31. Compare the patterns in the classified image to the false color composite (***tm345fcc***), which should be redisplayed if necessary.
32. Note the informational class numbers for each spectral class. (Hint: Classes 1, 2 and 3 all appear to be Forest. Forest is new class number 2 – see Table 7.3.3.a).

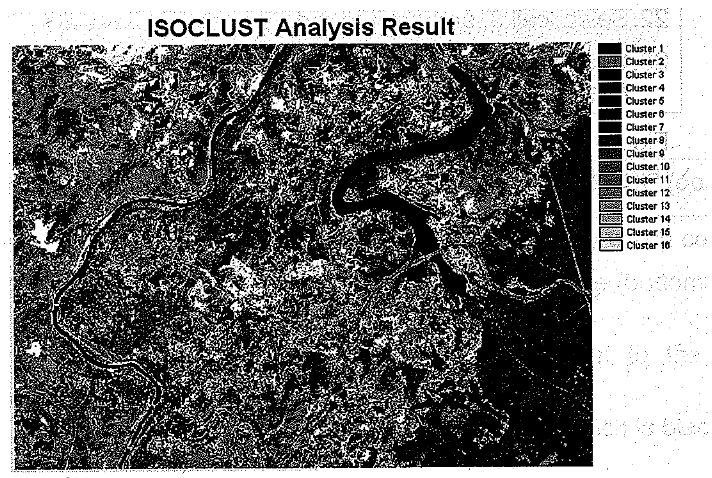


Figure 7.3.5.f ISOCLUST image with the custom palette applied.

Now that you have decided on the informational class numbers for the first 3 classes, we will now modify the first three classes back to the gray scale ramp, and assign DN values 4, 5, and 6 to blue, green and red, respectively.

Palette file interactive modification with SYMBOL WORKSHOP (cont.)

33. Find the *SYMBOL WORKSHOP* window.
34. Click on the button for *Blend*. This should remove the colors that were applied to cells 1, 2 and 3, and the color ramp should once again be from black to white without additional colors in between.
35. Click on cell 4, and select the blue color chip.
36. Click on cell 5, and select the green color chip.
37. Click on cell 6, and select the red color chip.
38. Save the file, by using the *SYMBOL WORKSHOP* window menu for *File - Save*.
39. Find the *DISPLAY* window, with the ***Iso20*** image. Click in that window.
40. In the *Composer* window, click on *Layer properties*.
41. In the Layer properties window, click on *Apply* to update the palette file used for displaying the image.

42. Determine which informational class each spectral cluster belongs to.

At this stage you should have a list of the spectral class numbers and the associated informational class numbers for the first 6 of the 20 classes. Repeat this procedure for the remaining 14 classes, so that you have a complete table of values.

7.3.6 Reassign Each Spectral Class to an Informational Class

This part of the procedure has two steps. First we use the IDRISI program EDIT to enter the list of spectral and informational classes in a table, then we use that table in the program ASSIGN. The advantage of developing a table is that we have a record of the assignment we made, and it is easy to reapply the recoding operation if we want to change a few values.

Enter the recode values table with EDIT

Menu location: **Data Entry – EDIT**.

1. Open the program EDIT from the main menu or the main icon bar.
2. The *IDRISI TEXT EDITOR* window will open.
3. In the blank window enter the spectral class number, leave a space, and then enter the informational class number. Enter each spectral class and the associated informational class on a new line. Start with spectral class 1 and end with 20. (For example, if you want to assign spectral class 1 to informational class 3, your first line would be: 1 3). See Figure 7.3.6.a for an example of how the completed list might look.
4. Use the *IDRISI TEXT EDITOR* menu to save the file: **File – Save As.**
5. A *SAVE AS* dialog box will open. In the Save as type text field, click on the pull-down list, and select *Attribute Values File*. This automatically gives the file you create an AVL extension.
6. Enter the file name **reclass1**.
7. Click *SAVE*.
8. A *Values File Information* dialog box will open. Take the default *Integer* option, and click on *OK*.

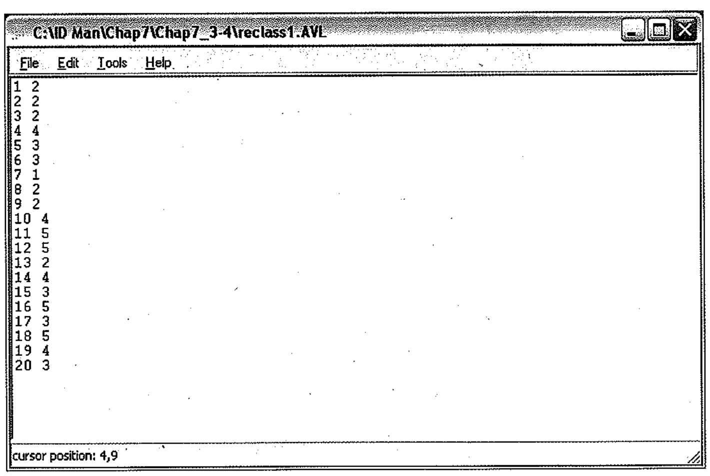


Figure 7.3.6.a *IDRISI TEXT EDITOR* window, with reclass data.

Now, use the *Attribute Values* file you have just created to create a new image, with DN values recoded according to the scheme specified in the text file.

Create a new image with informational class numbers, using ASSIGN

Menu location: **Data Entry – ASSIGN**

1. Use the IDRISI main menu to start the ASSIGN program.
2. In the *ASSIGN* window, use the pick list button (…) to specify the *Feature definition image* as the output of the ISOCLUST program, ***Isoclust20***.
3. The *Output image* is the new classified map with informational classes. Therefore type the new file name: **Isoclus20_reclass**.
4. The *Attribute values file* is the text file ***reclass1***.
5. Enter an Output title, such as: **Unsupervised ISOCLUSTER classification**.
6. Figure 7.3.6.b shows the dialog box with the parameters specified.
7. Click on *OK*.

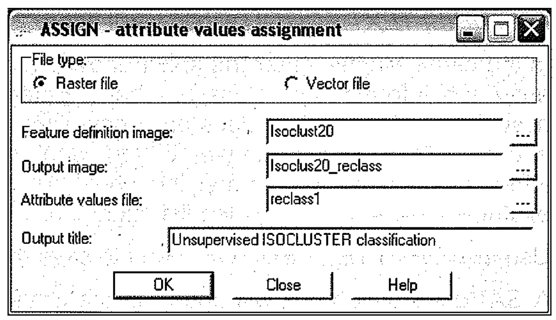


Figure 7.3.6.b *ASSIGN* dialog box with parameters specified.

The program will automatically display the reclassed image when processing is complete (Figure 7.3.6.c.).

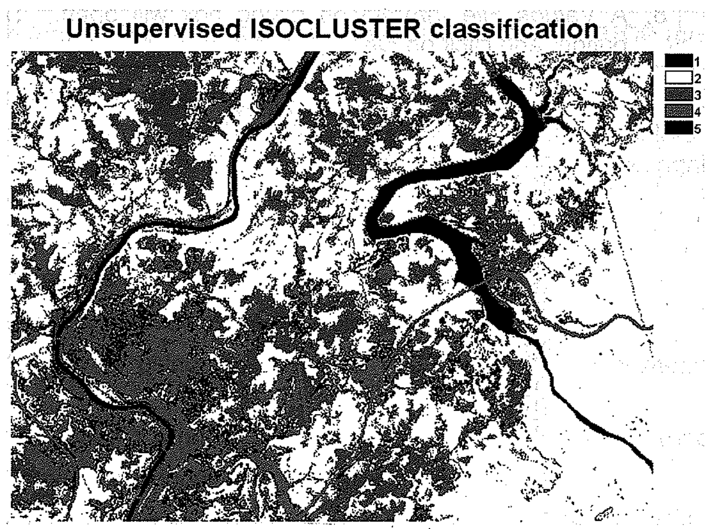


Figure 7.3.6.c The reclassed classification.

If you are satisfied with the output, you are ready to proceed to the next section (7.3.7). However, if you decide that you'd prefer to change one or more class assignments, it is very easy to do so, especially if all the dialog boxes are still open. Simply edit the values you want to change in the *IDRISI TEXT EDITOR* window, and click on Save. Then find the ASSIGN window, and click on OK. You will be asked if you want to over-write the original file. Click on Yes. A new image will automatically be displayed.

7.3.7 Update the Legend and Create a Custom Image Palette File

The final output is almost created. However, we need to enter the informational class names and choose colors for each class.

Update the classified image with the IDRISI EXPLORER

Menu location: **File – IDRISI EXPLORER**

1\. Start the IDRISI EXPLORER from the main menu, or the main icon bar.

10\. In the *IDRISI EXPLORER* window, click on the tab for *Files*.

11\. If the files are not listed in the *Files* pane, double click on the directory name to display the files.

2\. In the *Files* pane, click on the ***Isoclus20_reclass.rst*** classified image file.

3\. In the Metadata pane below the Files pane, scroll down, and find the blank cell next to the label *Categories* (Figure 7.3.7.a).

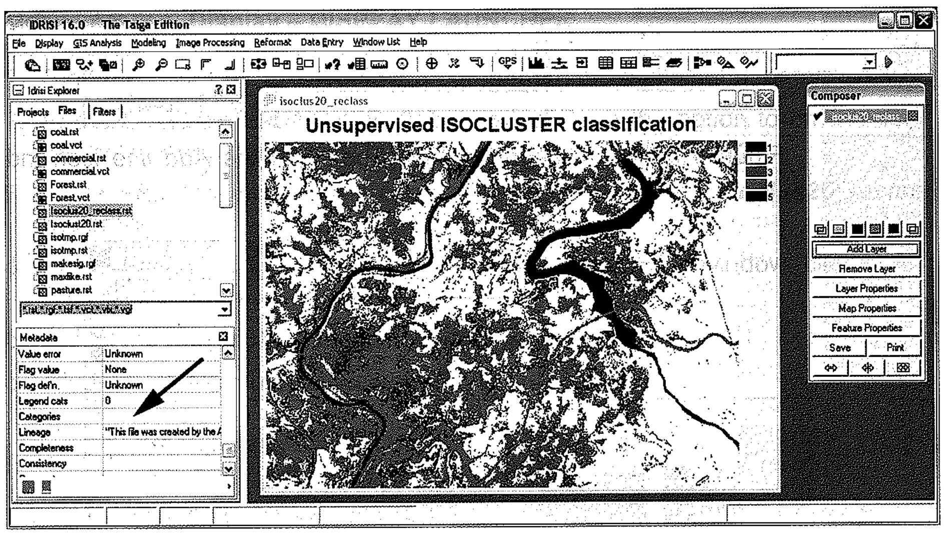


Figure 7.3.7.a *Categories* cell in the *Metadata* pane of the *IDRISI EXPLORER*

Update the classified image with the IDRISI EXPLORER (cont.)

4\. Click in the blank *Categories* cell. The cell will turn white, and a *Pick list* button (…) will appear. Click on that button.

5\. A *Categories* dialog box will open.

6\. In the first cell below *Code*, enter **1**.

7\. In the cell below *Category*, enter **Water**.

8. Find the *Add line* icon on the right of the *Categories* dialog box (Figure 7.3.7.b). Click on this icon.
9. In the new line enter the *Code* **2** and the *Category* **Forest**.
10. Repeat the previous two steps in order to enter the remaining classes on three additional rows:
    3 Pasture
    4 Comm/Ind/Trans
    5 Residential
11. Figure 7.3.7.c shows the *Categories* dialog box with the legend specified.
12. Click on *OK* to close the *Categories* dialog box.
13. The *IDRISI EXPLORER Metadata* pane should now have the number **5** in the cell next to *Legend cats*, indicating we have specified category names for 5 classes.

14. Click on the icon for *Save*, in the bottom left corner of the *Metadata* pane. After the file is saved, the icon will go blank.

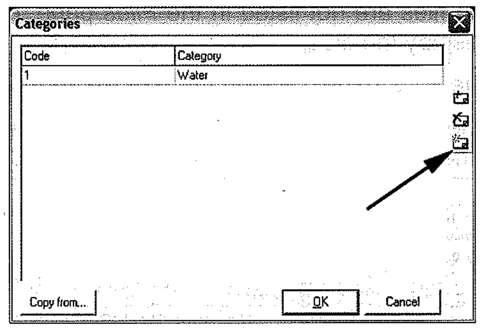


Figure 7.3.7.b *Categories* dialog box with the *Add line* icon indicated by the arrow.

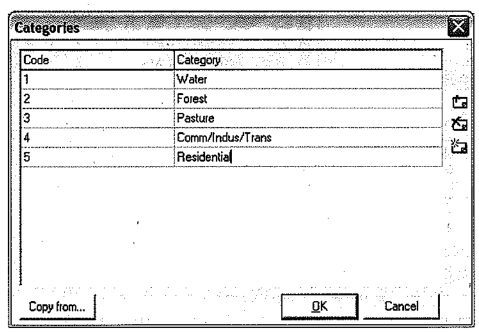


Figure 7.3.7.c *Categories* dialog box with the 5 legend categories specified.

The final step is to update the classified image palette file (color scheme) with the *SYMBOL WORKSHOP*. You can refer back to earlier in this exercise (Section 7.3.5) for more details, if the instructions below are too brief.

Create a color look up table for the final map with SYMBOL WORKSHOP

Menu location: **Display – SYMBOL WORKSHOP**.

1. Start the SYMBOL WORKSHOP from the main menu or the main icon bar.

2. Once the *SYMBOL WORKSHOP* dialog box and window has opened, use the window menu for *File – New*.
3. In the *New Symbol File* dialog box, click in the radio button for *Palette*.
4. Enter a file name: **Iso_lookup**.
5. Click on *OK* to close the *New Symbol File* dialog box.
6. The *SYMBOL WORKSHOP* window will now change to red squares.
7. Place the cursor over the second cell from the top left. Confirm from the label that will be shown that this is cell 1. Click in this cell.
8. Since class 1 is Water, click on a dark blue color chip in the *Color* dialog box that will open.
9. Click on *OK* to close the *Color* dialog box.
10. Repeat steps 8 and 9 above to specify 2 (Forest) as a dark green, 3 (Pasture) as light green, 4 (Com/Indus/Trans) as light blue, and 5 (Residential) as pink.
11. When you have completed specifying the five colors, save the palette file through the *SYMBOL WORKSHOP* window menu *File – Save*.

Finally, redisplay your image, as described below. The displayed image should now have the updated palette file and legend applied.

Displaying an image with a custom palette file using the DISPLAY LAUNCHER

Menu Location: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER program from the main menu, or the tool bar.
2. In the *DISPLAY LAUNCHER* dialog box, click on the option to browse for a file by selecting the *Pick list* button (…) in the center left column.
3. A file *Pick List* window will open. Double click on the ***Isoclus20_reclass*** raster file.
4. In the *Palette File* section of the DISPLAY LAUNCHER window, click on the *Pick list* button (…).
5. Select the ***Iso_lookup*** file by double clicking on it.
6. Click on *OK* to display the image (Figure 7.3.7.d).

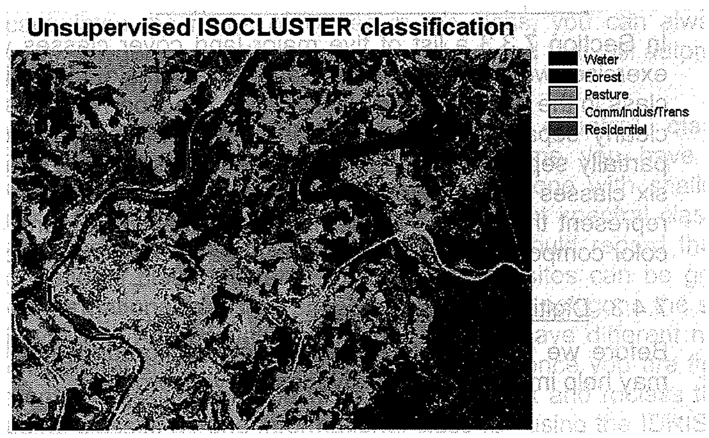


Figure 7.3.7.d Final ISOCLUST classification map.

7.4 Supervised Classification

Figure 7.4.a illustrates the steps involved in supervised classification. First we identify small areas for which we know the land cover. These areas are called *training sites*. The image DN values within the training sites are generalized to represent the typical spectral properties of the training classes. Finally, the rest of the image is compared on a pixel by pixel basis to the generalized data of the training classes, to determine which class each pixel belongs to.

The first step is to define the training sites. Each known land cover type will be assigned an integer identifier, and one or more training sites will be identified for each integer.

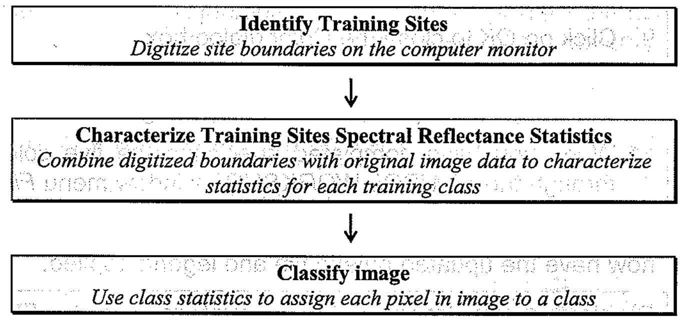


Figure 7.4.a Overview of the Supervised Classification Process.

7.4.1 Preparatory

It is recommended that you do this exercise only after completing the unsupervised classification of Section 7.3. If you choose to do this section first, or have not saved your results from Section 7.3, you will need to complete Section 7.2 (copy the data from the CD) and 7.3.2 (set project space, create a false color composite, and a raster group file) before continuing with this exercise.

Open the IDRISI EXPLORER from the main menu or the main icon bar, click on the *Projects* tab, and check that the radio button for the ***Chap7*** has been selected.

7.4.2 Develop the List of Land Cover Types

In Section 7.3.3 a list of five major land cover classes was developed. In this exercise, we will add a sixth class, Coal Waste. We did not separate out this class in the unsupervised classification (Section 7.3) because coal waste was not clearly separable in that exercise. You will see, however, that it is at least partially separable through supervised classification. Table 7.4.2.a lists the full six classes for this exercise. The numbers in the table will be the DN used to represent the classes in the final classification. Figure 7.3.2.a shows the false color composite with the examples of each class indicated.

7.4.3 Digitize Training Classes

Before we begin digitizing, a general background and tips regarding digitizing may help improve the effectiveness of your work.

Table 7.4.2.a Supervised classification classes.

Class Number	Name	Color in 345 false color composite	Texture
1	Water	Black	Smooth
2	Forest	Green	Moderate
3	Pasture/Grass	Pink to light green/yellow	Moderate
4	Commercial / Industrial / Transportation	Blue/Grey	Rough
5	Residential	Bright blue	Rough
6	Coal Waste	Dark purple/Black	Smooth

- **Select typical areas**. The training polygons are supposed to represent the typical properties of the class. Thus it is important that your training sites should be as *homogeneous* as possible (i.e. they should contain only that land cover type, and typically only one dominant color on the monitor). However, the training sites should also cover the *range of typical values* for that cover-type.
- **Digitize efficiently**. Do not spend hours digitizing each class - it is important to be able to outline a "typical" area rapidly. You probably should zoom in (i.e. expand the image on the screen), to make digitizing easier. However, it is not worthwhile to zoom in so much that you are digitizing individual pixels. In most cases you should be able to digitize a polygon quite rapidly.
- **Digitize a reasonable number of pixels.** Your training sites should contain an adequate sample of pixels for statistical characterization. A general rule of thumb is that the number of pixels in each training set (i.e. the total over all sites for a single land cover class) should not be less that 10 times the number of bands. Therefore, since we will use 6 bands of TM data, we should aim to have no less than 60 pixels per signature. It is not necessary to count the number of pixels when you are digitizing the polygon, as you will be warned later if the polygons are too small. However, if you think a polygon is too small, or you don't think the polygon encapsulates the range of values in the class, you can always digitize several polygons, all with the same number, and that will automatically be combined later into one large spectral class.
- **Bear in mind the difference between spectral classes and informational classes**. For example, assume you have two water bodies, one with clean and deep water, and one with shallow, muddy water. This might give rise to two very different spectral classes (*Clean Water and Muddy Water*), even though we would regard them as one informational class (*Water*). Multiple training sites can be grouped into one informational class by simply assigning the polygons the same value (DN value). Alternatively, you might want to have different numbers for each training sites. With this latter approach, once you are finished with the entire classification you would then go back and reclass the different spectral classes as one informational class (by using the IDRISI programs

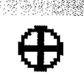
RECLASS or ASSIGN). In this exercise, however, we will take the simpler approach of assigning multiple spectral classes to one DN value.

- **Keep careful track of the class name you are digitizing**. *The most common problem in this exercise is losing track of the class you are digitizing*. Always make a conscious effort to keep track of which class you are digitizing. This will help avoid confusion.

We now need to display an image, to digitize on. Therefore, as described below, open the false color composite, created earlier, in Section 7.3.2.

Displaying a previously created false color composite using the DISPLAY LAUNCHER
Menu Location: **Display – DISPLAY LAUNCHER**
1. Start the DISPLAY LAUNCHER program from the main menu, or the tool bar. 2. In the *DISPLAY LAUNCHER* dialog box, click on the option to browse for a file by selecting the *Pick list* button (…) in the center left column. 3. A *Pick List* window will open. Double click on the ***tm345fcc*** raster file to insert this file name into the *DISPLAY LAUNCHER* dialog box. 4. In the *DISPLAY LAUNCHER* dialog box, click on *OK* to display the image.

The next step is to digitize the training polygons, at least one for each informational class, on the image we have just we have just opened.



Digitizing polygons
Menu location: Main tool bar icons only (Note that the icons are grayed out if an image is not yet displayed.)
1. An image should already be open in the IDRISI workspace. 2. Click on the *Full extent maximized* icon from the main tool bar to enlarge the image display to the maximum possible within the constraints of your monitor. 3. Zoom in to a region with a large area of water. To do this, first select the *Zoom Window* icon from the main tool bar. 4. Now, use the left mouse button to click in the image, and, with your left finger still depressed, stretch the screen box to delineate the area you want to zoom into. Release the left mouse button, and the display should only show the zoomed area, much enlarged. 5. Click on the *Digitize* icon. A dialog box labeled *Digitize* will open. 6. Enter the file name **Water** in the text box labeled *Name of layer to be created*. Leave all other values at their defaults. 7. Click on *OK* to close the *Digitize* window. 8. Move the cursor over the image. Note how when the cursor is over the image, it takes on a form similar to the *Digitize* icon, instead of the normal arrow. 9. Move the cursor over the water feature. Digitize the first vertex of the polygon that will represent Water, by pressing the *left* mouse button. Continue clicking in the image to specify the outer boundaries of the polygon you wish to digitize.

10. Close the polygon by pressing the *right* mouse button. Note that the program automatically closes the polygon by duplicating the first point; so you do not need to attempt to close the polygon by digitizing the first point again.
11. Figure 7.4.3.a shows an example of what the Water digitized polygon might look like.

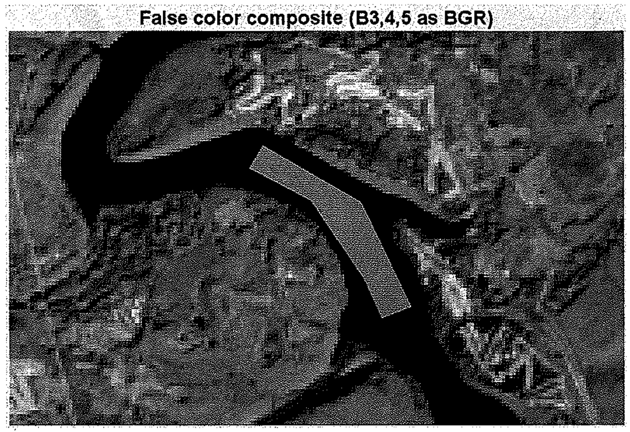
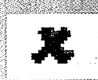


Figure 7.4.3.a Digitized Water training polygon.

Correcting a mistake is relatively easy. You can delete an entire polygon, after it has been closed, by following the procedure below. The first step, perhaps somewhat counter-intuitively, is to save the polygon.

Digitizing polygons (cont.): Deleting a polygon



12. Click on the *Save digitized data* icon in the main IDRISI toolbar.
13. In the *Save Prompt* window, click on *Yes*.
14. Click on the *Delete Feature* icon in the main IDRISI toolbar.
15. After clicking on the icon, the cursor becomes a pointing hand.
16. Click on the polygon you wish to delete, and it will be highlighted.
17. Now press the delete key on the computer keyboard.
18. A *Delete feature* dialog box will open.
19. Select *Yes*, if you wish to confirm deleting the polygon, otherwise click *No*.

The polygon we have just digitized is in an area of deep water. To the south (i.e. bottom of the image), that same body of water is quite shallow, and the spectral properties differ from the area we have just digitized. Additionally, the river to the east (left) is also a little different spectrally. Therefore, we should add two more polygons to this vector layer. However, because they are just part of the same water class, and are not separate spectral classes, we will use the same number to represent all three polygons.

For this additional digitizing for this class, and for the subsequent digitizing of additional classes, it will be helpful to get a general idea of the size and distribution of the training classes from Figure 7.4.3.b. Note that each class has been coded a different color in this figure for ease of interpretation, unlike on your screen, where the classes should all have the same color.

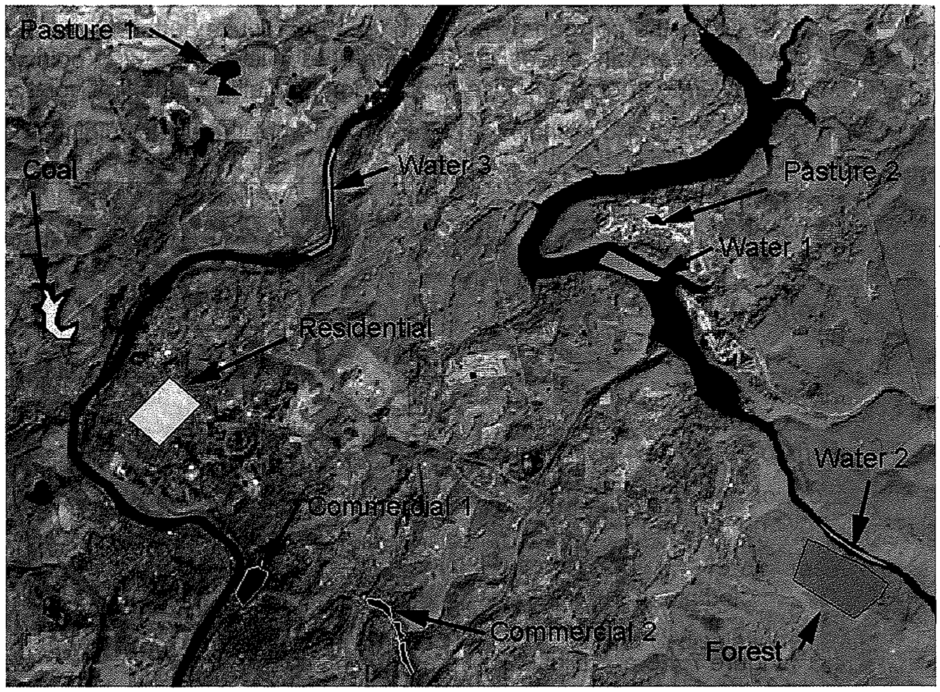


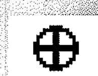
Figure 7.4.3.b Training classes for supervised classification.

Digitizing polygons (cont.): Adding additional polygons to a class

20. Return the view to the original full image, by clicking on the *Full extent normal* icon in the main IDRISI tool bar.

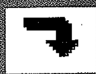
21. Then click on the *Full extent maximized* icon.

22. Use the *Zoom window* icon to zoom in on the bottom right hand corner of the image, where the river channel is very narrow. As the river is narrow, and it will be harder to digitize here, you should zoom in a great deal. If necessary, you can repeat the zoom function to zoom in multiple times.



23. Click on the *Digitize* icon.
24. A dialog box labeled *Digitize* will open.
25. Accept the default to *Add features to the currently active vector layer*, and click on *OK*.
26. The *Digitize* dialog box will now show the digitizing parameters. It is very important that we change the number in the *ID or Value* text box to the value of the previous polygon, since we want to add it to that class, and not have a new class. Therefore, *ID or Value* text box which currently should show the number *2*, should be changed to **1**.
27. Click on *OK*.
28. Now digitize the river channel. Be sure not to include any pixels from the forested river banks.
29. Close the polygon by clicking with the right mouse button. If you feel the polygon is not quite what you want, review the material above for deleting a polygon, and try again.

30. Now digitize a third polygon for the Water class, this time for the river on the west (left) side of the image. Remember to set the *ID or Value* to **1** in the *Digitize* dialog box.



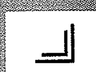
31. If you are satisfied with this second polygon, save the polygon file by clicking on the *Save digitized data* icon.

32. A *Save prompt* dialog box will open. Click on *Yes*.

We will now add the Forest class. In order to make our work simpler, each time we add a new class, we will digitize it in a separate file. An alternative approach is to digitize all the classes in the same file. However, digitizing in one file can get confusing.

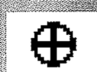
Digitizing polygons (cont.): Digitizing a second class

33. Return the view to the original full image, by first clicking on the *Full extent normal icon* in the main IDRISI tool bar.



34. Then click on the *Full extent maximized* icon.

35. Use the *Zoom window* icon to zoom in on the bottom right hand corner of the image, which is dominated by Forest. Include both the poorly illuminated (darker color) steep canyon slopes and brightly illuminated (brighter color) ridge top.



36. Click on the *Digitize* icon.

37. A dialog box labeled *Digitize* will open.

38. Click on the radio button to *Create a new layer for the features to be digitized.*

39. Click on *OK*.

40. The *Digitize* dialog box will now provide a text box for the *Name of the layer to be created*. Enter the new class name: **Forest**.

41. Digitize a polygon that includes both poorly illuminated forest areas and brightly illuminated areas. Close with a right click.

42. Save the file by clicking on the on the *Save digitized data* icon.

43. A *Save prompt* dialog box will open. Click on *Yes*.

44. Repeat the steps 30 to 39 for the next class, **Pasture**. Note that the pasture and grass class comprises mostly agricultural pasture, which has a distinctive pink to brown color (Pasture 1 in Figure 7.4.3.b). However, the class also includes golf courses, which are irrigated, and therefore have a different color, yellow (Pasture 2 in Figure 7.4.3.b). Therefore, it will be necessary to digitize two polygons for this class, as we did for Water. Follow the procedure outlined in 18 to 29, being sure to remember to set the *ID or Value* text box to **1** when you digitize the second polygon in the *Pasture* file.

45. Repeat steps 30 to 38 for **Residential**. The Residential class is a difficult class because it is characterized more by a rough texture, than a distinct color.

46. Now digitize the class **Commercial**. The Commercial class has a distinctive dark blue color, and also has a rough texture.

47. Because the area of the region digitized for the first Commercial polygon is quite small (indicated by the polygon labeled Commercial 1 in Figure 7.4.3.b), we will need to add a second polygon for this class (indicated by Commercial 2 in Figure 7.4.3.b). Follow the procedure outlined in 18 to 29, being sure to remember to set the *ID or Value* text box to **1**.

48. Now digitize the class **Coal**. The region shown in Figure 7.4.3.b for the class Coal consists of a large settling pond, where coal is cleaned to remove waste.
49. Close the image before proceeding to the next step. If there are any unsaved polygons, you will be prompted whether you wish to save them. Click on *Yes* in the *Save Prompt* dialog box to save the polygons.

7.4.4 Generate Class Signatures with MAKESIG

Once you are satisfied that your training sites were digitized satisfactorily, you can create signature files for each cover class. These files have statistical information about the reflectance values for each band for each site, derived from the polygons we have just digitized.

Create signature files using MAKESIG

Menu location: **Image Processing - Signature development – MAKESIG**

1. Start the MAKESIG program from the main menu.
2. In the *MAKESIG* dialog box, click on the Pick list button (…) to the right of the text box of *Vector file defining training sites.*
3. In the Pick list window, double click on the ***Water*** file.
4. In the *MAKESIG* dialog box, click on the button *Enter signature filenames*.
5. An *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **Water**.
6. Uncheck the box labeled *Create signature group file* (Figure 7.4.4.a).
7. Click on *OK* to close the *Enter signature filenames* dialog box.
8. In the *MAKESIG* dialog box, click on the button for *Insert layer group*.
9. From the *Pick list,* double click on ***Tm_all***.
10. The *MAKESIG* dialog box should now show the six bands of the TM data (Figure 7.4.4.b).
11. Note in *MAKESIG* dialog box the text box for the minimum sample size has been set automatically to 60 (10 pixels x the number of bands).
12. Click *OK*.

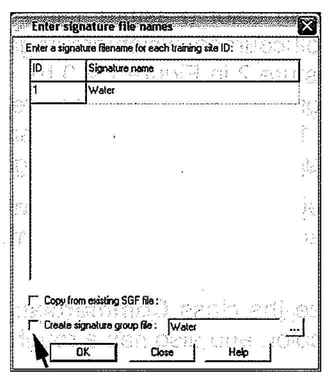


Figure 7.4.4.a *Enter Signature file names* dialog box.

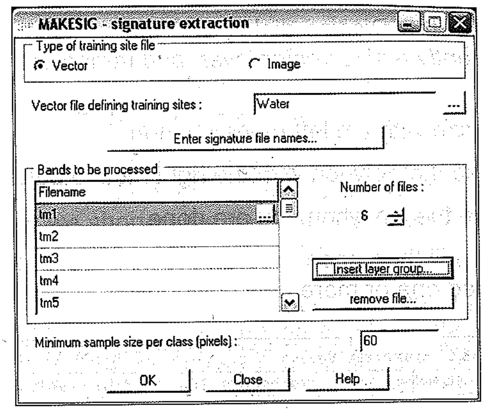


Figure 7.4.4.b *MAKESIG* dialog box with parameters set.

After the program has completed, the *MAKESIG* dialog box will remain open, because of IDRISI's persistent windows.

If you have sufficient pixels in each class, the program should execute normally, and you will see a brief indication that the program is running in the status bar of the IDRISI workspace.

However, if you do not have enough pixels, you will receive a warning message. You will then need to either (a) increase the number of pixels in the class, or (b) reduce the threshold of number of pixels required. Adding additional pixels is relatively straightforward, and is described below. However, if the program did end normally, then you can skip these instructions below.

Digitizing additional polygons in an existing vector file

Menu location: Main tool bar icons only

1. An image should already be open in the IDRISI workspace, with the training polygons overlaid. If not, first display the image **tm345fcc**. Then add the vector file you wish to add to by clicking on the *Composer window* button for *Add layer*. Add the vector layer you wish to work on, and then select the radio button for a **Qualitative** *Symbol file*.
2. If the image is still open from the Digitizing exercise, find the *Composer window*, and click on the name of the class you wish to add to. This will highlight the name of the class in *Composer window*. Figure 7.4.4.b shows the Commercial class selected.
3. You can now follow the procedures you are already familiar with to add an additional polygon, as summarized below.
4. Maximize the viewer by clicking on the *Full extent normal* icon in the main IDRISI tool bar.
5. Click on the *Full extent maximized* icon. This enlarges the display window to the largest size possible with the IDRISI window.
6. Zoom in to the area of interest by clicking on the *Zoom window* icon. Draw a rectangle around the area of interest.
7. Click on the *Digitize* icon.

8. When the *Digitize* dialog box opens, take the option to *Add features to the currently active vector layer*, and remember to change the *ID or Value* back to **1**.
9. Digitize with the left mouse button.
10. Close the polygon with the right mouse button.
11. Save the file when you are done.
12. You will then need to rerun the *MAKESIG* program for the class for which you added one or more new polygons.

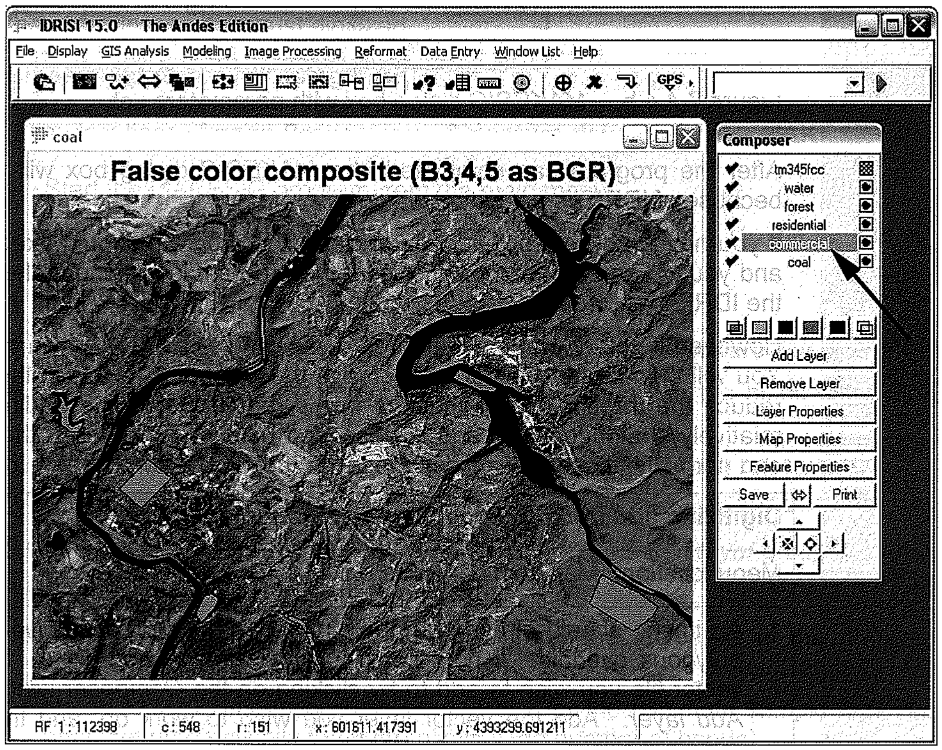


Figure 7.4.4.c Selecting a vector layer prior to adding additional polygons.

So far we have created only one signature file, for Water. We now need to create the signature files for the remaining classes. Each signature will be in its own separate file.

Create signature files using MAKESIG (cont.): Remaining signatures

1. The *MAKESIG* dialog box should still be open from creating the Water signature. The *Bands to processed* should still list the tm bands 1 through 5 and 7.
2. In the *MAKESIG* dialog box, click on the Pick list button (...) for *Vector file defining training site.*
3. In the *Pick list* window, double click on the ***Forest*** file.
4. In the *MAKESIG* dialog box, click on the button *Enter signature filenames.*
5. An *Enter signature filenames* dialog box will open. In the cell to the right of 1, type **Forest**.

6. Ensure the check box for *Create signature group file* is not checked.
7. Click on *OK* to close the *Enter signature filenames* dialog box.
8. Click on *OK* in the *MAKESIG* dialog box, to create the Forest signature file.
9. Repeat steps 2 through 8 above to create the signature files for the remaining vector files: ***Pasture***, ***Commercial*** (this class also includes Industrial and Transportation, but we shorten the name to Commercial for simplicity's sake), **Residential** and **Coal** (the Coal Waste class).

If you need to recreate any signature (maybe you are unhappy with the signature, or something didn't work, or maybe at a later stage you decide you did not collect all the cover classes needed) re-display the image using **DISPLAY,** digitize the boundaries of the new polygon, save the file (either with a new name, or use the old name, and thus over-write the file) and then run **MAKESIG** again on the new vector file.

7.4.5 <u>Group the Class Signatures into a Single Signature Collection</u>

We have now created the six signatures, each of which is in a separate file. Although we could now proceed to the classification step, it is convenient to group the signature files into a single collection. This will make repeat handling of the files simpler, in that we will then only need to specify the collection, instead of each file individually. Section 1.3.7 discusses working with collections in some detail, and you may wish to review that section if the instructions below are not sufficient. In addition, in Section 6.3.4, we worked with a raster collection to streamline the PCA decorrelation stretch. In this exercise we work with a signature collection, but the principle is the same.

Creating a signature file collection with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Open the IDRISI EXPLORER.
2. In the *IDRISI EXPLORER* window, click on the tab for *Filters*.
3. Uncheck all the boxes that are checked (these are the default files that will be displayed in the *IDRISI EXPLORER* window).
4. Now click on the box to check the option to display *Signature (*.sig, *.spf)* files, and uncheck the boxes for *Raster Group (*.rgf)* and *Raster image (*.rst)* files (Figure 7.4.5.a).
5. Click on the tab for *Files*.
6. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
7. The *Files* pane should list the six signature files you have created. Each signature will be listed twice: once as a *.sig file, and once as a *.spf file. In addition, the vector files (*.vct) files will be listed. We will only work with the *.sig files.
8. Highlight the signature files for the six signatures ***<u>in this order</u>***: ***Water.sig, , Forest.sig, Pasture.sig, Commerical.sig, Residential.sig,*** and ***Coal.sig.*** Select multiple bands by clicking on each file sequentially, while simultaneously pressing the *Ctrl* key on the computer keyboard.
9. Right click in the *Files* pane. Select the menu option for *Create – Signature Group* (Figure 7.4.5.b).

10. Check the *Metadata* pane to see that the six signatures are listed in the same order as in step 7 above, i.e. *Water.sig* as *Group item (1)*, *Forest.sig* as *Group item (2)* etc. If the order is not the same, you should redo steps 7 and 8.

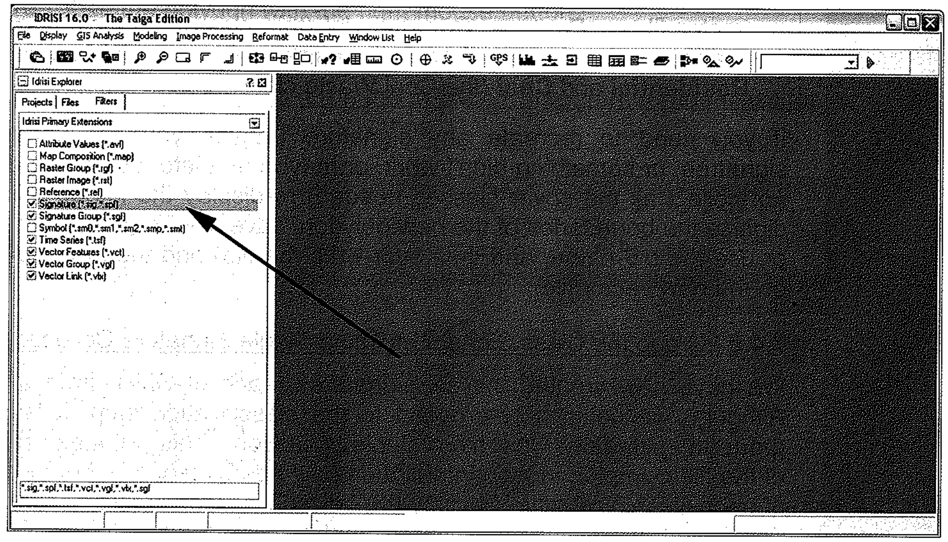


Figure 7.4.5.a *IDRISI EXPLORER Filters* pane, with *Signature* filter checked.

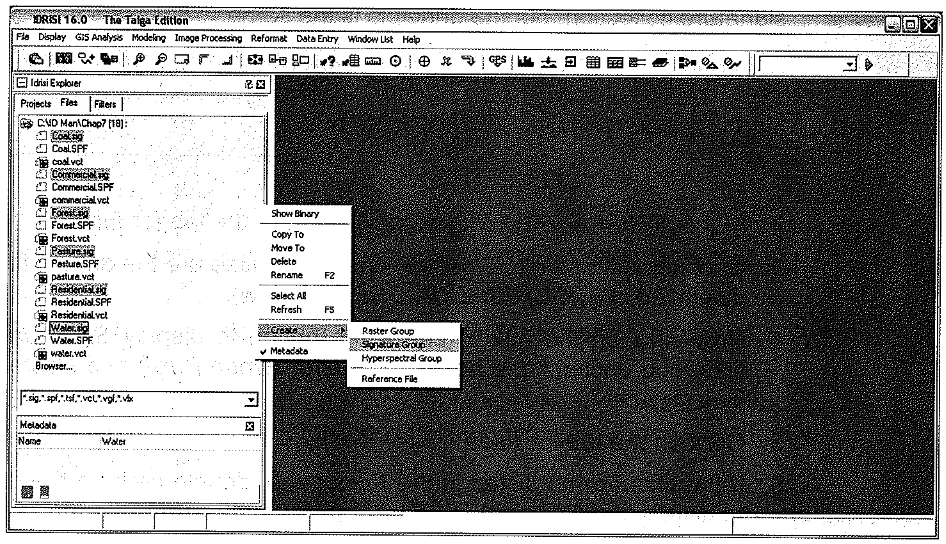


Figure 7.4.5.b *IDRISI EXPLORER Files* pane, with signatures selected, and pop-up menu for creating a signature group (collection) file.

Creating a signature file dollection with the IDRISI EXPLORER (cont.)

11. Click on the new signature group collection file name (***Signature Group.sgf***), to highlight the file in the *Files* pane.

12. In the *Metadata* pane, enter a new name for the file in the right hand cell of the first row, typing over the default name of ***Signature Group***. Since this is the collection of classification training signatures, we will enter **Train**.

13. Press the *Enter* key on your computer keyboard.
14. Click on the save (floppy disk) icon, at the bottom left hand corner of the *Metadata* pane. The name ***Train.sgf*** will immediately be updated in the *Files* window.

7.4.6 Comparing and Summarizing Signatures with SIGCOMP

It can be useful to visualize the statistics of your training signatures both as a check for gross errors, and also to help understand which classes are spectrally similar, and thus potentially poorly classified.

Compare the statistics of the training data with SIGCOMP

Menu location: **Image Processing - Signature development - SIGCOMP**

1. Use the main menu bar to start the SIGCOMP program.
2. In the *SIGCOMP* window, click on the button to *Insert signature group.*
3. A *Pick list* will open. Double click on the ***Train*** file.
4. In the *SIGCOMP* window, select the radio button to compare all signatures based on their *means* (Figure 7.4.6.a).

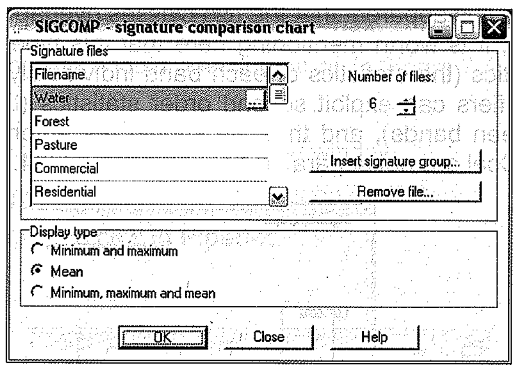


Figure 7.4.6.a SIGCOMP window.

A graph of the signature means will open automatically in a new window (Figure 7.4.6.b). (Note that your graph should look somewhat similar, but will not be exactly the same, as it is unlikely you have digitized precisely the same pixels.)

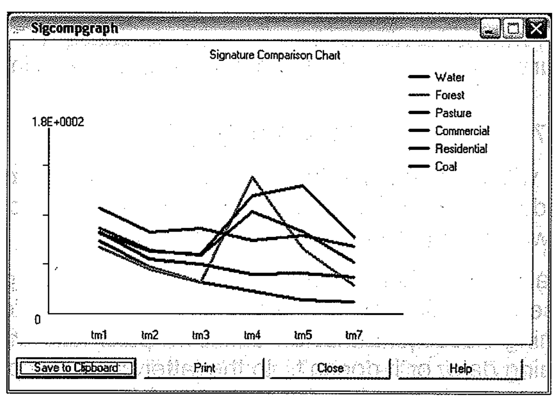


Figure 7.4.6.b Signature means for the six classes.

The graph in Figure 7.4.6.b tells us a lot about the classes we have identified, especially if we mentally associate the band numbers with their respective wavelengths (Table 5.5.3.a). For example, we note that *Forest* and *Pasture* both have a very distinct pattern of high near infrared (TM4) and low visible (especially TM3) values. This is typical of vegetation and this spectral pattern is exploited in vegetation ratios (Section 5.3.4). We can also see that Residential is somewhat similar to the Forest class, a result of the many trees in residential areas in this city. It is apparent that Coal and Water are similar, with the latter being just slightly darker at all wavelengths. It is this similarity of spectral shape that makes water and coal waste difficult to separate, especially in unsupervised classification (Section 7.3).

You may also want to experiment with the other options in the *SIGCOMP* dialog box. For example, you can select radio buttons to compare the signatures based on their maxima and minima, and then click on the button for *OK* to generate the new graph. A graph of maxima and minima is useful for understanding signature overlap. However, since the maximum and minimum graphs get very confusing with many signatures displayed simultaneously, it is best to select a subset of the signatures – for example, just the Coal and Water signatures. Simply highlight in the *SIGCOM* window a file you would like to exclude, and click on the button for *Remove file*.

Figure 7.4.6.c shows a comparison of the minima and maxima of Water and Coal. It is apparent that the two classes overlap substantially in all bands. As an aside, it is worth mentioning here that this type of graph shows only first order statistics (the statistics of each band individually). Some remote sensing image classifiers can exploit second order statistics (the statistics of the relationships between bands), and thus we should not automatically assume that the Water and Coal are not separable based on Figure 7.4.6.c.

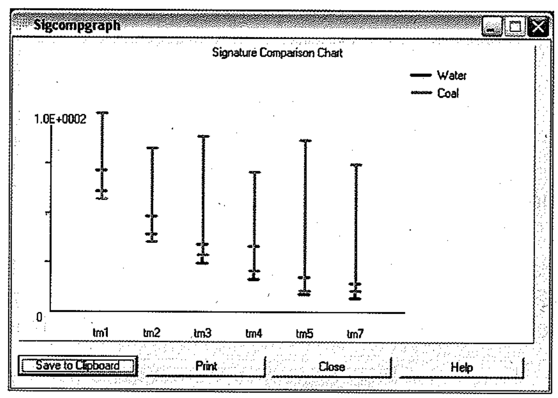


Figure 7.4.6.c Comparison of minima and maxima of *Water* and *Coal*.

7.4.7 Parallelepiped Classification

We will now run the first of two classifiers which we will use to classify the Landsat data. In this section we do parallelepiped classification, in Section 7.4.8 we will do a maximum likelihood classification.

Parallelepiped is an absolute classifier, which simply checks each unknown pixel to see if it falls within the range of DN values for each band, for each of the training classes. Either an unknown pixel falls within the ranges defined by the training data, or it doesn't. In the latter case, the pixel would remain unclassified. Note that it is possible for a pixel to fall into more than one class. In this case, usually an arbitrary decision is made, for example, based on the order the classes were entered into the classifier. More details on parallelepiped classification can be found in most basic remote sensing texts.

We will run the parallelepiped classification *twice*. Parallelepiped is a relatively simple classifier (and therefore a very quick classifier), and is susceptible to outliers (noise, slight variations) in the training data. The second time we run the classification we will see how using a more conservative definition of the class extents will help the classification. The Z-score option defines the parallelepipeds based on the number of standard deviations for each class. This approach, which assumes each class has a Gaussian distribution, allows the analyst to exclude outliers in a systematic fashion. However, note that by making the class boundaries narrower, a greater percentage of pixels fall outside the range of the training classes.

Classify an image with PIPED

Menu location: **Image processing - Hard classifiers – PIPED**

1. Start the PIPED program from the menu.
2. In the *PIPED* dialog box click on the *Insert signature group* button.
3. In the *Pick list* that opens, double click on ***Train*** to select that signature group file.
4. For the *Output file name*, enter **Piped-min-max**.
5. The PIPED dialog box should now appear as in Figure 7.4.7.a.
6. Click on *OK*.
7. The classification should appear in a new window.
8. In the PIPED window, select the radio button for *Z-Score.*
9. Change the Output file new to **Piped-Z**.
10. Click on *OK*.

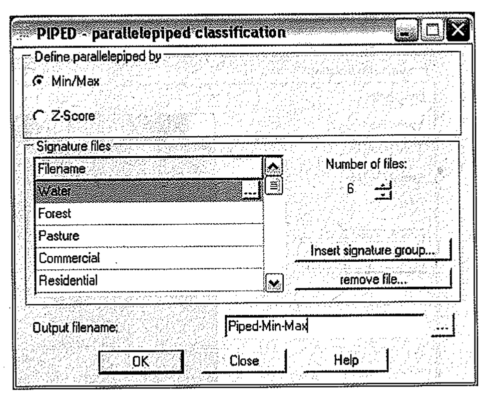


Figure 7.4.7.a PIPED dialog box.

At this stage you should have produced two classifications. In order to compare this classification to our previous unsupervised classification (Section 7.3) and our future maximum likelihood classification, it will be useful to apply our earlier ***Iso_lookup*** palette file so that the colors in the map are the same as those we used before. However, we will need to add a color for the *Coal* class. Therefore, before we proceed, we will modify our previous palette file, created in Section 7.3.7.

(Note: If you did not do Section 7.3, or you did not save those files, you will need to follow the instructions in Section 7.3.7 to create a new palette file, and assign colors for DN values 1-5, before following the instructions below.)

Modify an existing look up table with SYMBOL WORKSHOP

Menu location: **Display – SYMBOL WORKSHOP**.

1. Start the SYMBOL WORKSHOP from the main menu or the main icon bar.
2. Once the *SYMBOL WORKSHOP* dialog box and window has opened, use the window menu for *File – Open*.
3. In the *Open Symbol File* dialog box, click in the radio button for *Palette*.
4. Click on the *File name* pick list button (…).
5. In the *Pick list* window, double click on **iso_lookup**.
6. Click on *OK*.
7. The *SYMBOL WORKSHOP* window should now display the palette file that you developed for the unsupervised classification. Specifically, it should have different colors assigned to DN values 1-5, and the remaining values should all be red.
8. Place the cursor over the cell for a DN value of 6 (this should be the first red cell to the right of the cells previously assigned colors). Confirm that the label shown that this is cell 6. Click in this cell.
9. Since class 6 is *Coal*, click on a black color chip in the *Color* dialog box that opens automatically.
10. Click on *OK* to close the *Color* dialog box.
11. Repeat steps 8 and 9 above to specify white for a DN value of 0 (the first cell in the grid).
12. Save the palette file through the *SYMBOL WORKSHOP* window menu *File – Save* as.

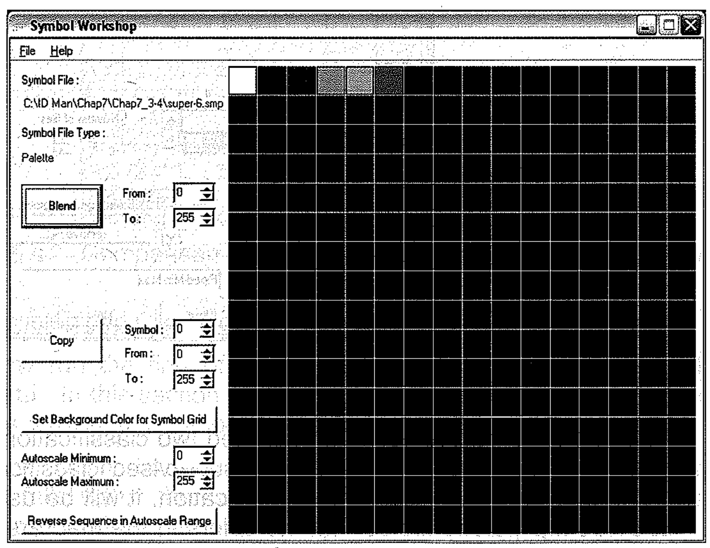


Figure 7.4.7.b SYMBOL WORKSHOP with the new palette file specified.

13. In the *Save symbol file as* dialog box, enter the new file name: **Super-6**.
14. Click *OK* to close the *Save symbol file as* dialog box.
15. Figure 7.4.7.b shows the SYMBOL WORKSHOP with the two new colors specified.

Now that we have created the modified palette file, we can apply it to each of the two classified images.

Apply a custom palette file to a previously displayed image

1. Click in the display window for the *Piped-min-max* classification to give it focus (bring this window to the front).
2. Find the *Composer* window, which is always opened when an image is displayed. Click on this window to give it focus.
3. In the Composer window, click on the *Layer Properties* button.
4. Click on the tab for *Display parameters*.
5. Click on the *Pick list* button (…) next to the *Palette file* text box.
6. In the Pick list window that will open automatically, double click on the **Super-6** Palette file.
7. In the Layer properties window, click on *Apply*.
8. This should update the color scheme for the Piped-min-max classification. (Figure 7.4.7.c shows the results. Keep in mind that your training classes will be slightly different from those used to produce the figure, therefore your results will not be identical.)
9. Repeat steps 1-8 for the Piped-Z image. (See Figure 7.4.7.d, but bear in mind that your results will also be slightly different for this figure, too.)

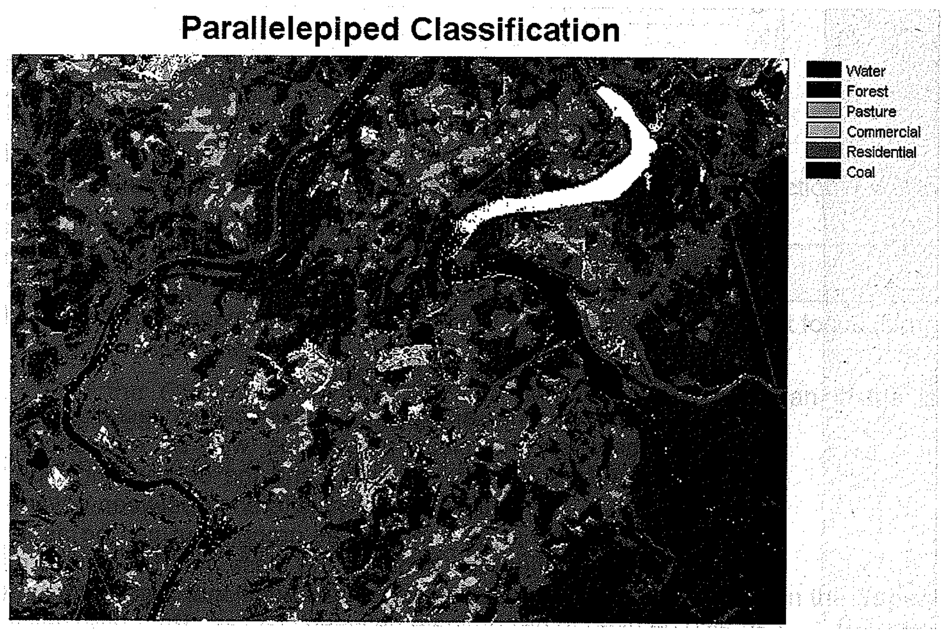


Figure 7.4.7.c Piped-min-max classification.

It is important to note that the legends besides each classification do not include an important class: 0. The 0 class is the Unclassified. The Unclassified class is a typical characteristic of an absolute classifier, such as the parallelepiped classifier. Since we set a DN of 0 to white, any pixel that is white is unclassified. It is immediately apparent that that the z-scores approach (Figure 7.4.7.c) produces far more unclassified pixels than the min-max approach (Figure 7.4.7.d). Although the latter might seem a better product, close inspection of the original Landsat image suggests that the min-max image has a very low overall

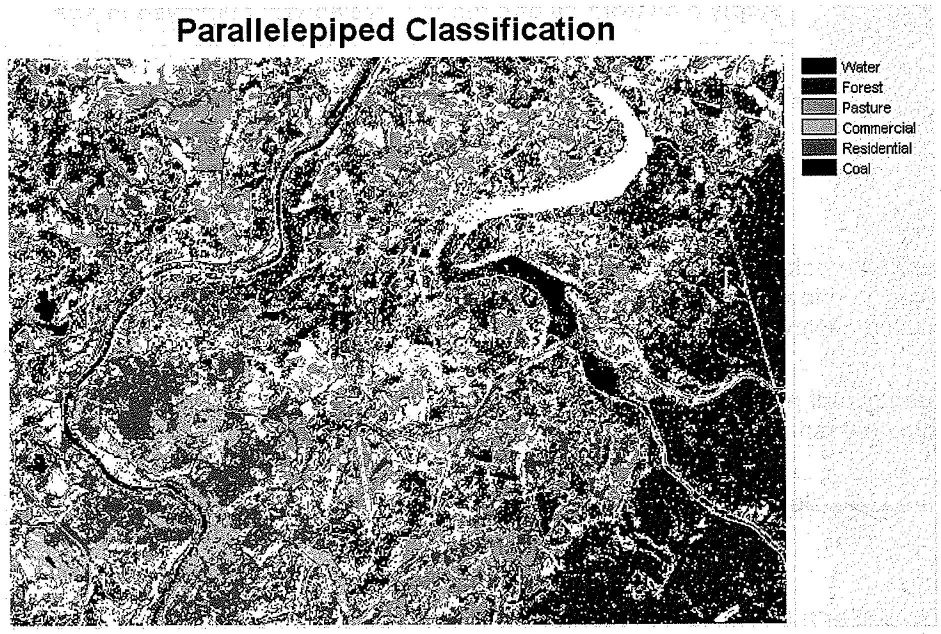


Figure 7.4.7.d Piped-Z classification.

accuracy. In particular, an excessive number of pixels appear to be classified as Residential. In comparison, though the z-scores image has many unclassified pixels, those that are classified appear to be relatively accurate. The z-scores image appears to have a more reasonable distribution of the Residential class, and the confusion between Water and Coal appears to be much more limited.

The z-score approach defines the class extents based on a statistical distribution. Try running the classification again with a large (e.g. 3), and then with a small number (e.g. 1) to see the tradeoffs associated with changing this parameter. Remember to apply the new palette file to the image after the classification.

7.4.8 Maximum Likelihood Classification

Maximum Likelihood is a powerful classification technique. It draws on differences between the class means, as well as differences between the covariance matrices (i.e. the variability and the degree and type of correlation between bands). The latter parameter, difference between covariance matrices, is difficult to visualize in an image or as graphs, but can be as important, if not more so, than the difference between the class means. This is particularly true as the number of bands increases. An additional parameter, prior probability, can also be used to discriminate between classes. Prior probability is the chance a certain class is like to occur before you even run the classification. For example, assume that based on prior knowledge of an area, you were able to estimate that your scene is likely to be approximately 20% Water, 50% Forest and 30% Pasture. You could then enter values of 0.2, 0.5 and 0.3 as the prior probabilities for those classes. (The values sum to 1.0 by convention). In practice, however, this is difficult to do, and most of the time we just set the prior probabilities as equal values, which is the default in IDRISI. Additional information on maximum likelihood can be found in most introductory remote sensing texts.

Classify an image with MAXLIKE

Menu location: **Image processing - Hard classifiers – MAXLIKE**

1. Start the MAXLIKE program from the menu.
2. In the *MAXLIKE* dialog box, click on the *Insert signature group* button.
3. In the *Pick list*, double click on the *Train* signature group file.
4. In the MAXLIKE dialog box, specify the *Output image* as **maxlike**.
5. Leave the option for prior probabilities as the default (*Use equal prior probabilities for each signature*), as well as the *Proportion to exclude* at the default of *0%*.
6. Figure 7.4.8.a shows the dialog box completed.
7. Click on *OK* to run the classification.

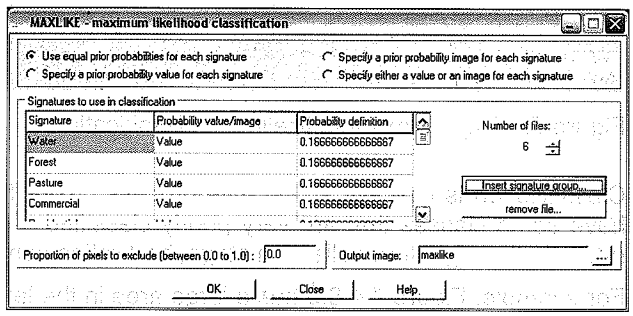


Figure 7.4.8.a MAXLIKE dialog box.

As a final step, we will now apply the palette file developed in Section 7.4.7 to this image, to aid comparison with the parallelepiped classification.

Apply a custom palette file to a previously displayed image

1. Click in the display window for the *Maxlike* classification to give it focus (bring this window to the front).
2. Find the *Composer* window, which is always opened when an image is displayed. Click on this window to give it focus.
3. In the Composer window, click on the *Layer Properties* button.
4. Click on the tab for *Display parameters*.
5. Click on the *Pick list* button (…) next to the *Palette file* text box.
6. In the Pick list window that will open automatically, double click on the **Super-6** Palette file.
7. In the Layer properties window, click on *Apply*.

Chapter 8 Advanced Classification Issues

8.1 Introduction

The previous chapter provided an introduction to basic classification methods. It is assumed that you have completed that chapter before you start this chapter.

In this chapter, we focus on two issues related to classification. The first is error analysis. There is a strong tradition in remote sensing classification of always conducting an error analysis. The error analysis provides a statement regarding the reliability of the classification, and is therefore essential information for the map user.

The error should be estimated using an independent source of information to provide a check of selected points. Ideally the independent data source would be based on a field visit. Oftentimes, limited access, expense, or changes in land cover over time, make a field visit impossible. Therefore, a visual interpretation of aerial photography or some other high resolution imagery is often a more practical alternative.

The second major focus of this chapter is on linear pixel unmixing, or fuzzy classification. This is a particularly interesting topic in remote sensing, and is an area of intensive current research. It is notable that IDRISI is very strong in classification techniques in general, including in the area of sophisticated classification approaches, such as fuzzy classification. Even if you never use fuzzy classification in your own work, the theoretical issues associated with this topic are well worth considering, and have ramifications in more traditional methods.

8.2 Copy Data for This Chapter

In this chapter we will work with two different image sets, one for the error analysis (Section 8.3) and one for the fuzzy classification (Section 8.4). Therefore, you should now copy the *Chap8* folder from the CD, and paste it as a new subfolder within the *\ID Man* folder on your computer.

You may wish to use your own classification for the error analysis exercise, rather than the one provided on the CD. If so, you should copy the raster file and associated metadata from your best maximum likelihood classification, e.g. maxlike2.rst and maxlike2.rdc, (note the extensions) from your working directory (e.g. *\ID Man\Chap7*) to the new location *(\ID Man\Chap8\Chap8_3*).

After you have copied the *Chap8* folder, you should remove the *Read-Only* attribute from this new folder on your computer. This is done by right-clicking on the *Chap8* folder name, selecting *Properties* from the pop-up menu. A dialog box will open, labeled *Chap8 Properties.* Now clear the check mark from the *Read Only* check box, by clicking in the box. You should then click on the button for *Apply*, and in the subsequent *Confirm Attribute Changes* dialog box, accept the default *Apply changes to this folder, subfolder and files*, and click on *OK*. You will need to also click on *OK* in the *Chap8 Properties* dialog box.

Note: Section 1.3.1 provides detailed instructions on how to copy the data from the CD, and also on how to remove the *Read-Only* attribute from the data. Also, the procedure for setting up the *ID Man* folder on your computer is described.

8.3 Classification error analysis

8.3.1 Overview

Figure 8.3.1.a provides an overview of the error analysis procedure: sample points are selected, the correct land cover class for those points is determined independently, and then those points are used to estimate the overall classification error. The figure also shows the main IDRISI programs we will use to conduct the error analysis.

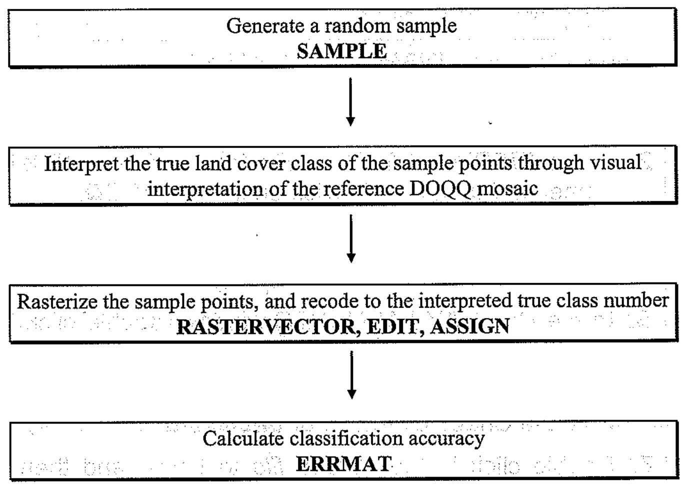


Figure 8.3.1.a Overview of the classification error analysis procedure.

8.3.2 Preparatory

In Section 8.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for this section.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap8,* and then the *Chap8_3* subfolder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap8_3* will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.

7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

Check that the project directory has been set correctly, by displaying the images, as described below. (If IDRISI is not able to find the image, then you have not set the directory correctly.) The ***DOQQ.rst*** is a false color composite mosaic of USGS digital orthophoto quarter quadrangles (DOQQs) with 1 meter pixels. The ***tmclassfd.rst*** image is a maximum likelihood classification, produced in Section 7.4.

Initial display of images

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***DOQQ***.
3. Click on *OK* to display the image (Figure 8.3.2.a).

4. Start the DISPLAY LAUNCHER again.
5. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name
6. From the pick list that will open, double click on either the file you have copied from the Chap7 directory, or ***tmclassfd***.
7. Double click in the *Palette file* text box, and then in the resulting pick list, double click on ***super-6.***
8. Click on *OK* to display the image (Figure 7.4.8.c).

Figure 8.3.2.a False color DOQQ mosaic of Morgantown, WV.

Compare the two images you have just displayed. The DOQQ is a false color image. IDRISI automatically scales an image so that the entire image can be displayed on your monitor. Therefore, even if you have a very large monitor, you are probably not seeing the full resolution of the data. However, it is easy to zoom in to see more detail in selected areas.

In standard false color images, red typically represents green vegetation. The DOQQ photographs were acquired in the very early spring (April), before the deciduous trees had leafed out. Therefore the deciduous trees are a rather dark red or even magenta to blue, and evergreen vegetation has a very strong red color. Grass typically has a light red color, trending to pink or even white where the grass is sparse.

An interesting feature of Figure 8.3.2.a is the small patches of white, and occasionally red, in the water. The white areas are sun-glint, and not rapids or other features in the water. The red features are related to the sun glint and the mosaicking process, and are therefore also artifacts.

8.3.3 Generate the Random Sample

Generate a random sample of test points with SAMPLE
Menu Location: **Image Processing – Accuracy Assessment – SAMPLE.**
1. Start the SAMPLE program from the main menu. 2. In the *SAMPLE* dialog box, double click in the text box labeled *Reference image*. 3. Double click on the name of the image which will be evaluated for its accuracy (***tmclassfd***, if you are using the image provided on the CD). 4. From the list under the heading *Sampling scheme,* select the option for *Stratified random.*

As you can see from the SAMPLE dialog box, IDRISI provides three sample selection strategies:

1. Random: the points are distributed randomly in no clear pattern throughout the entire image. Some will randomly be close together, some farther away from each other.

2. Systematic: the points are distributed an equal distance apart from each other across the entire image. This is a dangerous option to select if there is any structure to your data. For example, in an agricultural landscape, if the fields are a typical size, systematic sampling may result in over-sampling or under-sampling some cover types.

3. Stratified random: the points are distributed randomly, but an equal number in each strata, or class. IDRISI seems to be rather limited in that the user is not allowed to determine what is used for strata. The on-line help seems to suggest that the strata used are created simply by applying a matrix or grid to the image. Each grid cell is then sampled randomly.

It is important to be aware that classes that are relatively rare (in our classified image, this would include the Water, Commercial and Coal classes) will have fewer samples than classes that are more common. Therefore, other image processing packages have the option for the user to specify the strata using an image.

Generate a random sample of test points with SAMPLE (cont.)

4. Enter the number of points as **30**.
5. Enter the output vector file name: **sample**.
6. Figure 8.3.3.a shows the dialog box with the parameters completed.
7. Click on *OK*. A blank image with 30 points (the random sample) indicated by small black dots will be generated.

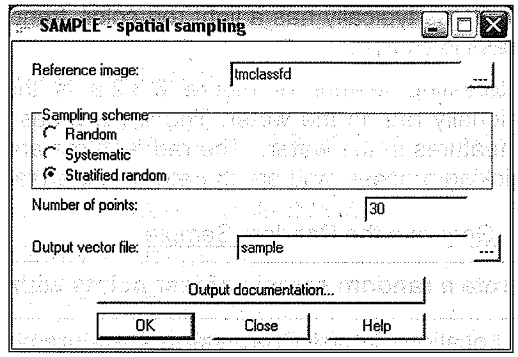


Figure 8.3.3.a The *SAMPLE* dialog box.

A total of just 30 points is probably much too low for a reliable estimate of the accuracy of the classification. At least 100 points would be a recommended minimum, with a number closer to 300 preferred. However, this exercise with 30 points should at least illustrate the procedures involved, and give an approximate idea of the overall map accuracy. We should be particularly cautious about interpreting the accuracy of the individual classes, however, as some classes will have very few, if any, test samples. This is a consequence of our not being able to stratify by class.

8.3.4 Interpret the True Land Cover Class for Each Sample Point

The next step involves careful image interpretation. You will examine the DOQQ to determine the "true" land cover for each of the 30 random points. Because each random image generation is unique, your selection of 30 points will not be the same as the one used to illustrate this manual. Therefore, in the next section, only the general procedure is described. You will have to use your best judgment in interpreting the DOQQ.

We will record the true land cover class (coded by the DN values of each class) in a simple text file, using the program EDIT. The values will be stored in an Attribute Values File (AVL extension).

The final AVL text file we have the point number (from 1 to 30), followed by the class number. For example, if point 1 was associated with class 3, and point 2 with class 5, then the first two lines of your table will be

1 3

2 5

Note that each point is on a new line and there is a single space between the point number, and the associated class. Since you have 30 points, your file will have 30 lines. At this initial stage we will only list the point numbers; we will add the interpreted class numbers subsequently.

Build the initial values for the recode values table with EDIT

Menu location: **Data Entry – EDIT**.

1. Start the EDIT program from the main menu or the main icon tool bar.
2. The *IDRISI TEXT EDITOR* window will open.
3. In the *IDRISI TEXT EDITOR*, sequentially enter the sample point number, followed by a carriage return ("Enter" on your keyboard), starting with 1, and ending with 30. Thus each point will be on a new line. Start with point 1, and end with point 30.
4. Use the menu in the *IDRISI TEXT EDITOR* window to initiate saving the file: *File – Save As.*
5. In the *Save file* window, select from the *Save as type* pull-down list *Attribute values file*.
6. In the *File name* text box, enter **landcover**. The file will automatically be given an AVL extension.
7. Click on *Save*.
8. A *Values File Information* window will open. In this new window, select the radio button for *Integer*, and click on *OK*.
9. Figure 8.3.4.a shows the ***landcover.AVL*** file in the *EDIT* window.
10. Do not close the *IDRISI TEXT EDITOR* window, as we will enter our land use interpretations directly in the file.

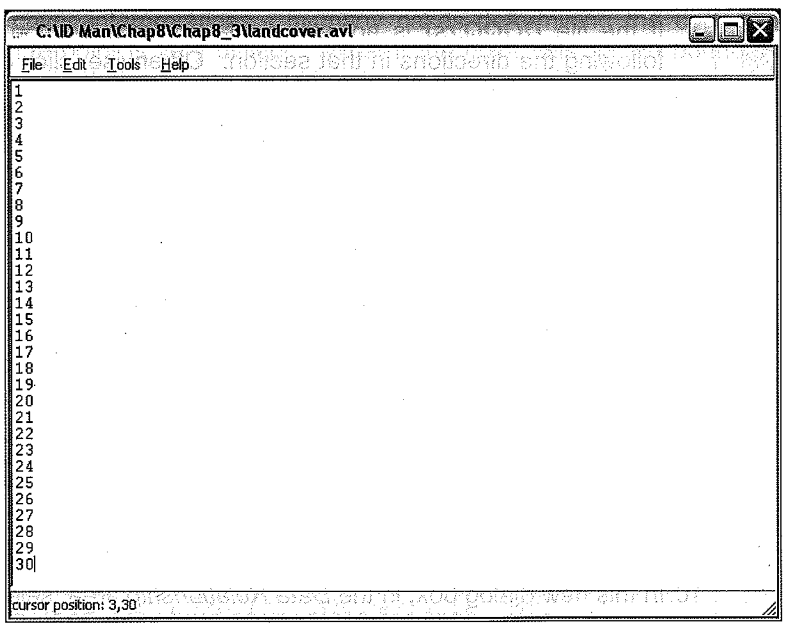


Figure 8.3.4.a *IDRISI TEXT EDITOR* window with the ***Landcover.AVL*** file.

We are now ready to start the interpretation. Table 8.3.4.a gives a short description of each class, as well as the associated code (DN value). The DN for each class is the same as the scheme used in the classifications produced in Section 7.4 and thus for the ***tmclassfd.rst*** image.

Table 8.3.4.a Maxlike class numbers, to be used in coding the random points generated by the **SAMPLE** program

Class Number	Class Name	Appearance on false color DOQQ
1	Water	Black (also white sun glint and associated red artifacts); smooth texture, sinuous water bodies
2	Forest	Red, magenta, blue in places, characteristically rough texture.
3	Pasture	Red, to pale pink, occasionally white, characteristically smooth texture
4	Commercial / Industrial / Transportation	Blue to black, characteristically geometric shapes of buildings and sinuous and straight linear features for roads
5	Residential	Mixture of colors, red dominates, blue common. Characteristically very rough texture from roads, houses and gardens
6	Coal Waste	Black to dark blue, smooth to rough texture. Found in dammed valleys, and adjacent to river, where it is associated with barge loading.

Display vector file as overlay on DOQQ

1. If the file ***DOQQ.rst*** is not still displayed from Section 8.3.2, open it now, following the directions in that section. Otherwise, click on DOQQ display, to give it focus (bring it to the front).
2. Find the *Composer* dialog box, which is automatically opened when an image is displayed.
3. In the Composer dialog box, click on the button to *Add Layer.*
4. In the *Add Layer* dialog box, double click in the left hand text box.
5. A pick list will open; double click on the file **sample**.
6. Click on *OK* to close the dialog box, and add the points as an overlay to the DOQQ image. However, at this stage the points are too small to be visible. We will therefore make them clearer by making them much larger.
7. In the *Composer* dialog box, click on *the Layer Properties* button.
8. The *Layer Properties* dialog box will open. In this new dialog box, click on the button for *Advanced Palette/Symbol Selection.*
9. The *Advanced Palette/Symbol Selection* dialog box will open.
10. In this new dialog box, in the *Data Relationship* area, select *Qualitative.*
11. In the area labeled *Symbol Size*, select the radio button for *16*
12. Click on *OK*.
13. The vector points should now be displayed on the DOQQ as very large circles. Figure 8.3.4.b. shows an example of what your display should look like. Note, however, that the specific locations of your sample points will be different, since the selection of locations is supposed to be random.

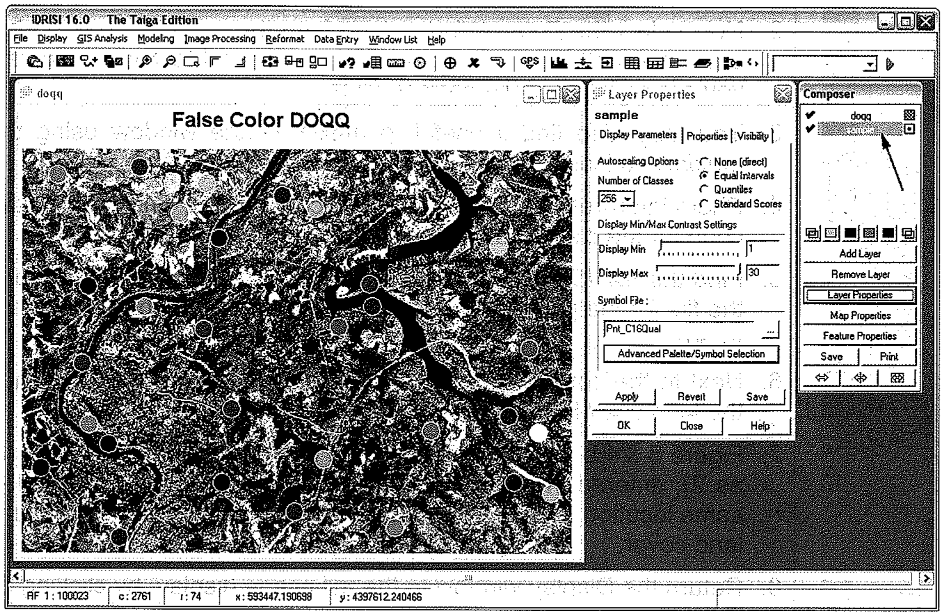


Figure 8.3.4.b False color DOQQ showing the 30 sample points overlaid. Note the *Composer* and *Layer Properties* dialog boxes. In the *Composer* dialog box, the ***sample*** layer is highlighted.

Now that we have set up the *IDRISI TEXT EDITOR* window and the display of the DOQQ with the SAMPLE overlay, we are ready to compile the list of land use / land cover interpretations. In many cases determining the correct value to assign the point is very difficult. What if the point falls on the boundary of two classes? Technically, you should estimate the dominant land use class over the 30 meter Landsat pixel centered on the point. Since the DOQQ has 3 meter pixels, this would be a 10 by 10 pixel window. This is actually rather difficult to do, so we usually just take the land use class directly at the point itself.

Though making a decision of the spectral class for each sample point is really hard, it illustrates well why the classification is so complex. For example, you may find a point that falls in a large patch of trees in a residential area. The land use is clearly residential (and this is how you should code the point). Nevertheless, the land cover, which is what is observed by the remote imaging device, is Forest.

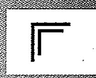
If you truly don't know how to label a pixel, you could label it 0, which will effectively delete that point. Use this approach with caution, though, as it will reduce your number of sample points, and potentially bias your results.

Note: If you get RGB values instead of the point number when you try to query a point as described in the next section, make sure that the ***sample*** vector layer is highlighted in the *Composer* window (Figure 8.3.4.b).

Interpret land use / land cover class for each point
1. In the DOQQ image display, select each sample point in turn. For example, start in the bottom left corner. Query the value of the sample point by clicking on the icon for *Cursor Inquiry Mode* in the main tool bar, and then clicking on the circle representing the sample in the image display. Note the value that will be indicated for this point. (It should be a value between 1 and 30.)

2. Now select the *Zoom Window* icon form the main tool bar, and zoom in to an area around the sample point. You may need to zoom in several times until you are satisfied of the correct value.

3. You may also find it useful to maximize the window using the *Full extent maximized* icon.
4. Photo-interpret the land use / land cover class, and identify the correct DN code for the class (Table 8.3.4.a).
5. Find the *IDRISI TEXT EDITOR* window, and scroll down to the correct line in the file for the point you have just worked with (i.e. the sample number, from 1 to 30).
6. Next to the correct sample number, enter a space and then the DN code for the land use / land cover.
7. Figure 8.3.4.b shows sample 1, with the interpreted land cover (Forest, coded as 2), entered in the AVL file. (Note that your sample #1 will not be in the same location, and therefore will not necessarily have the same the land use / land cover.



8. Return the Display window to the full image display, by clicking on the icon for *Full extent normal* from the main IDRISI tool bar.
9. Iterate through the process for interpreting each point (steps 1 through 8 above) until you have developed a complete table of the "true" land cover class for each of the 30 samples.
10. Figure 8.3.4.d shows the completed table. (Note that your table will have a different set of land use / land cover classes, because your sample will be different.)
11. Save the text file by using the *IDRISI TEXT EDITOR* main menu: *File – Save.*
12. A *Values File Information* window will open. In this new window, select the radio button for *Integer*, and click on *OK*.

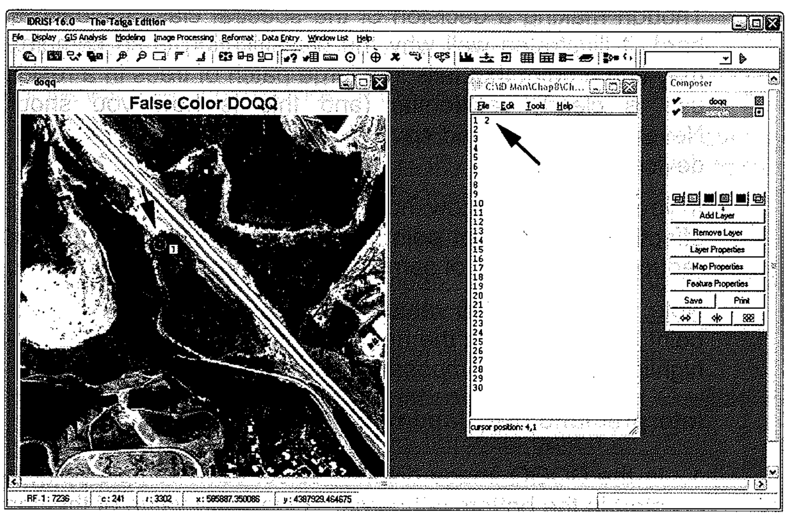


Figure 8.3.4.c A zoomed in window around a sample, and the associated value for Forest entered in the ***landcover.AVL*** file. (Note that your sample 1 will not be in the same location as shown.)

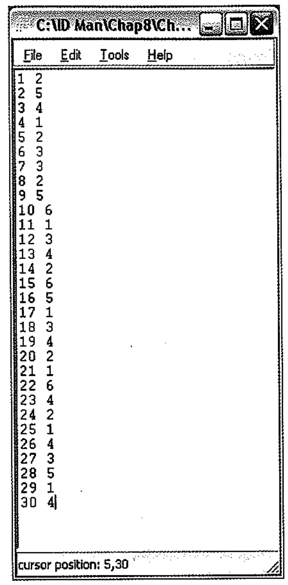


Figure 8.3.4.d Example of completed ***landcover.AVL*** file. Your list will have different land cover class numbers in the second column.

8.3.5 Rasterize the Recode of the Sample Points

Now that we have interpreted what each sample represents, we need to convert our vector file to a raster file. This raster file will have zeros everywhere, except where the samples are located. For the samples, the DN value will initially bee equal to the sample number. We will then use the text ***landcover.AVL*** file to recode the values in this image to the "true" values.

Rasterize the sample vector file with RASTERVECTOR
Menu Location: **Reformat - RASTERVECTOR**
1. Open the RASTERVECTOR program from the main menu. 2. In the *RASTERVECTOR* dialog box, select the radio button for *Vector to Raster.* 3. Select the radio button for *Point to Raster*. 4. Select the radio button for *Change cells to record the identifiers of points*. 5. Click on the file pick list button (…) next to the *Vector point file* text box. 6. In the pick list window that will open, double click on the ***sample*** vector file. 7. In the *Image file to be updated* text box enter **point_locations**. 8. Figure 8.3.5.a shows the *RASTERVECTOR* dialog box completed. 9. Click on *OK*. 10. A dialog box will open with the following message: *Image to be updated (point_location.rst) does not exist. Bring up* ***INITIAL*** *to create this image?* 11. Click on *Yes*. 12. The window for the program INITIAL will open. This program creates a blank file, into which the rasterized vector points are subsequently inserted.

13. In the *INITIAL* window, find and double click in the text box for *Image to copy parameters from*.
14. In the *Pick list* that will open, double click on ***tmclassfd***.
15. Figure 8.3.5.b shows the *INITIAL* window with the parameters selected.
16. Accept all other defaults, and click on *OK*.
17. The rasterized sample image will open in a new *DISPLAY* viewer (the points themselves are very small, and may be hard to see, and thus the image may appear to be almost entirely black (DN = 0).)

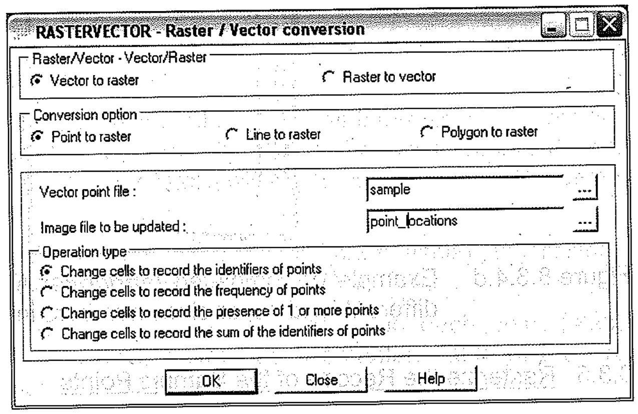


Figure 8.3.5.a *RASTERVECTOR* window.

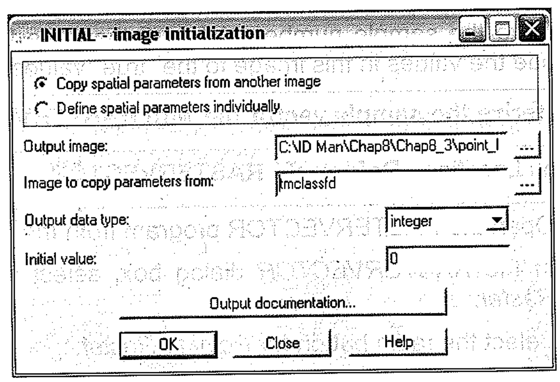


Figure 8.3.5.b *INITIAL* window.

The rasterized image that you have created will have a DN value equal to the sample number, or zero if there is no sample at that location. For our accuracy assessment we need the DN value the "true" land use / land cover. Therefore, we will now use the *Attribute Values file* to create a new image of the sample points, with values according to the true classes of those points.

Create new image with land cover class values using ASSIGN
Menu location: **Data Entry – ASSIGN**
1. Use the main IDRISI menu to start the ASSIGN program. 2. In the *ASSIGN* window, select the radio button for *Raster file*.

3. Double click in the *Feature definition image* text box, and in the subsequent pick list, double click on ***point_locations***.
4. In the textbox for Output image, enter **truth_sample**.
5. Double click in *The Attribute values* file text box, and in the subsequent pick list, double click on ***landcover***.
6. In the *Output title* text box, enter **Photo-interpreted land use / land cover**.
7. Figure 8.3.5.c shows the *ASSIGN* text box with parameters selected.
8. Click on *OK*, and the new image of sample points will be displayed automatically. Again, the image may appear to be entirely black, with the points hardly visible.

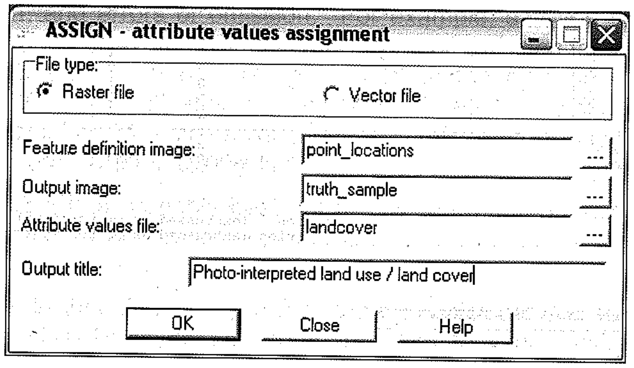


Figure 8.3.5.c *ASSIGN* window.

8.3.6 <u>Calculate the classification Accuracy using ERRMAT</u>

In the previous steps we created an image that is blank everywhere, except for the 30 pixels for which we determined the "true" land cover from the visual interpretation of the DOQQ mosaic. We can now overlay this image with the classification to determine the overall accuracy of that latter image.

Calculate classification accuracy using ERRMAT
Menu Location: **Image Processing – Accuracy Assessment – ERRMAT.**

1. Use the main IDRISI menu to start the ERRMAT program.
2. In the *ERRMAT* window, double click in the text box next to *Ground truth image*.
3. In the pick list that will open, double click on ***truth_sample***.
4. Double click in the *Categorical map image* text box.
5. In the *Pick list* that will open, double click on the name of the file you would like to evaluate the accuracy of. If you are using the classified image from the CD, this will be ***tmclassfd***.
6. Figure 8.3.6.a shows the *ERRMAT* window with the files specified.
7. Click on *OK*.
8. The accuracy assessment results will open in a new text window, labeled *Module Results.* Note that you can save the results to a file, or to the clipboard, thus facilitating pasting the results in a text editor.

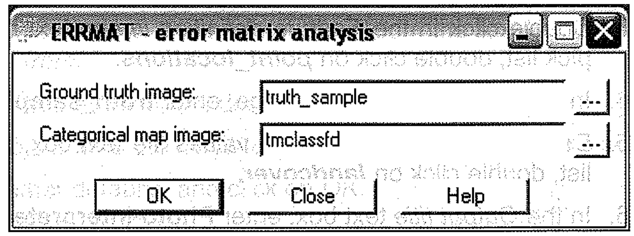


Figure 8.3.6.a *ERRMAT* window.

Table 8.3.6.a Example of *ERRMAT* output

Error Matrix Analysis of TRUTH_SAMPLE (columns : truth) against TMCLASSFD (rows : mapped)

	1	2	3	4	5	Total	ErrorC
1	1	0	0	0	0	1	0.0000
2	0	13	0	0	1	14	0.0714
3	0	0	2	0	0	2	0.0000
4	0	0	0	0	1	1	1.0000
5	0	2	3	1	5	11	0.5455
6	0	0	0	1	0	1	1.0000
Total	1	15	5	2	7	30	
ErrorO	0.0000	0.1333	0.6000	1.0000	0.2857		0.3000

ErrorO = Errors of Omission (expressed as proportions)
ErrorC = Errors of Commission (expressed as proportions)

KAPPA INDEX OF AGREEMENT (KIA)

Using TMCLASSFD as the reference image ...

Category	KIA
1	1.0000
2	0.8571
3	1.0000
4	-0.0714
5	0.2885
6	0.0000

TRUTH_SAMPLE

Category	KIA
1	1.0000
2	0.7500
3	0.3571
4	-0.0345
5	0.5489

Overall Kappa = 0.5500

The ERRMAT accuracy assessment shows a detailed breakdown of how each of your sample pixels in the "truth" file compares to its assignment in the classified file. Table 8.3.6.a shows an example data set. Remember your results will be different, as your random sample will be different.

If the table is too wide, IDRISI breaks the accuracy table up into pieces to make it fit in a standard format on a piece of paper. If this is the case, you may wish to create a version of the table that is not broken across the page, using a text editor. Table 8.3.6.a is not broken up, however, because no samples were identified in the photo interpretation as the Coal class (DN = 6). Thus, the last column of the table is absent.

In the error matrix, correctly classified pixels are listed down the diagonal. In Table 8.3.6.a the diagonal is a bit difficult to identify because of the missing column 6. An error matrix that indicated a 100% accurate classification would have zeros everywhere, except the diagonal. Errors are the non-zero values that are not on the diagonal.

The error of the overall classification is the proportion of incorrectly classified test pixels. In table 8.3.6.a, the overall error is reported as 0.30 (i.e. 30%) in the bottom right cell in the main table. A 30% error rate is higher than that normally desired for a remote sensing classification.

The Overall Kappa statistic is an attempt to adjust the accuracy for the anticipated chance agreement if you just randomly assigned classes to the image. The Kappa value is thus lower than the overall accuracy. For Table 8.3.6.a, the accuracy would be 0.70 (i.e. 1.0 minus the error, or 1.0 – 0.3 = 0.7). The reported Kappa is only 0.55, 0.15 lower than the accuracy.

When it comes to the pixels off the diagonal, there are two types of errors - errors of commission, and errors of omission. For example, say you classified ***all*** of Morgantown image as Water. Clearly your *errors of omission* for Water would be *low*, since you would *not omit* a single pixel that should have been Water, because the whole classification is assigned to Water! However, the *errors of commission* would be *high*, since you would *commit* an error in calling the rest of Morgantown Water, when it clearly is not.

For Table 8.3.6.a it is probably best not to pay too much attention to the class errors of commission and omission, since the number of pixels for each class is so small.

As a final step in this exercise, you may want to calculate the accuracy of your parallelepiped classifications, and compare them to your maximum likelihood classifications. Carrying out such a task is quite straightforward, since after copying the *.rst and *.rdc files to your *\ID Man\Chap8\Chap8_3* directory, you can immediately run the ERRMAT program (this Section, 8.3.6), as you do not need to replicate the preparatory steps of generating the random sample, rasterizing it, and recoding it to the correct land use / land cover classes.

8.4 Linear Pixel Unmixing

8.4.1 Overview

As discussed in the Introduction to this chapter, soft classification is an alternative to the relatively simple hard classification methods discussed so far, where each pixel is assigned to one class only. In soft classification methods, a pixel can potentially be associated with more than one class.

There are three main applications for soft classification:

1. **Classification of mixed pixels that arise from integrating discrete areas of different classes.** For example, an individual pixel along a river bank may include both water and land areas. Mixed pixels are a direct result of the spatial integration across the instantaneous field of view (IFOV) of the sensor. The standard way to analyze mixed pixels is linear pixel unmixing, however soft classifiers can also be used to investigate class mixing.
2. **Classification of conceptually fuzzy classes that arise from variability in the underlying classes.** Where classes have transitional, rather than discrete boundaries, pixels from the transitional areas will typically have a spectral radiance that is intermediate between those of the pure classes. For example, river water may vary from deep and clear to shallow and muddy. Thus, the deep and clear water is simply one end of a continuum of classes, and the variability is inherent in the land cover, not the mechanics of imaging the site.

3. **Investigation of the confidence the user has in the classification of each pixel.** For example, how do we know that we haven't ignored an important spectral class in defining our class training areas?

In this exercise we will investigate the use of soft classification for unmixing pixels. In forest cover mapping, the IFOV of the Landsat ETM+ sensor, at approximately 30 meters, is much larger than the typical size of the canopy of a single tree. Thus, we can consider forest spectral radiance as a mixture of the trees within each pixel. Foresters traditionally recognize forest communities as groups of trees. However, the boundaries of those communities may be gradational, and the same species may occur in more than one community. Thus, it would seem that forest applications are ideally suited to a fuzzy approach.

Our study site for this exercise is Chestnut Ridge, West Virginia, a subset of the area on the extreme eastern edge of the area we were examining in the supervised and unsupervised classification exercises in this chapter. (More background on this area can be found in Nellis et al. 2000).

8.4.2 Preparatory

In Section 8.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for this section.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap8,* and then the *Chap8_4* subfolder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap8_4* will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

The data for this section consists of Enhanced Thematic Mapper Plus imagery from October 30, 2000. The bands are labeled ***tm30oct1*** to ***tm30oct7***, where the last digit is the band number. (Note that the sixth band is not provided, as this is the thermal band, and is not needed for this exercise).

It is always useful to become familiar with the data at the start of the project. Therefore, we will now create a simulated natural color composite. By now you should be familiar with the process of creating color composites. To create a simulated natural color composite you need to match the colors that a band is displayed to the approximate wavelengths of the sensor (Table 5.5.3.a). Thus, for a simulated natural color image, the blue image display band should be TM band 1, and the green band should be TM band 2 and the red band TM band 3.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, double click in the *Blue image band* text box, and then double click on the file ***tm30oct1*** in the subsequent *Pick list.*
3. Double click in the *Green image band* text box, and then double click on ***tm30oct2***.
4. Double click in the *Red image band* text box, and then double click on ***tm30oct3***.
5. Enter the *Output image* filename in the text box provided: **tm123**.
6. In the *Title* text box enter **Simulated natural color composite**.
7. Accept all other defaults, and click *OK* to create and display the false color composite.
8. Once the image has been displayed, you can close the *COMPOSITE* window.

Figure 8.4.2.a shows the results of the image, which will be displayed automatically. The sinuous band of blue in the lower left of the image is a river (the Cheat River), and the sinuous band of white is a major highway (Interstate 68). A faint diagonal linear feature can be observed; this indicates the zone of cleared vegetation associated with an electricity power line.

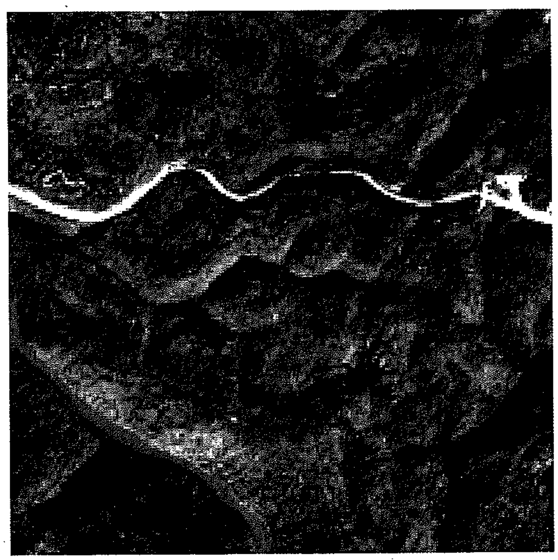


Figure 8.4.2.a Simulated natural color ETM+ image of Chestnut Ridge.

It is apparent from Figure 8.4.2.a that this is a very rugged area. The average elevation of the upland areas is over 700 meters; in the river below, it is approximately 270 meters. Note the presence of steep slopes in the image, and the associated shadows. Since this is a northern hemisphere image, and the image was acquired in the morning at approximately 10 a.m., the shadows are on the northwest facing slopes.

The forest here is dominantly deciduous. Since this is an autumn image, the colors in the image are much more varied than would be found with, for example, a summer image. Unlike in the September image we were classifying earlier, in this autumn image, two main forest communities are evident. Oaks (*Quercus spp.*) tend to have a red to brown color in this image, and yellow poplar (which we will refer to as "poplar") (*Liriodendron tuliperifera*) have a yellow to green color.

8.4.3 Digitize Training Class Data

Linear pixel unmixing is a type of supervised classification. Therefore, we will begin by digitizing training areas. Because of the variation inherent in the autumn forest colors, we will need to digitize multiple training areas for each of the two forest classes. We will also digitize a third class, shade, to account for some forest areas that are shaded by the steep topography (Figure 8.4.3.a). Figure 8.4.3.a gives an overview of the recommended number and distribution of training polygons that should be digitized. Note that when you digitize your polygons, they will all have the same color, unlike in Figure 8.4.3.a.

Table 8.4.3.a Training classes for linear pixel unmixing.

#	Class	Color in simulated natural color image
1	Oaks	Red to brown
2	Poplar	Yellow to green
3	Shadow	Black

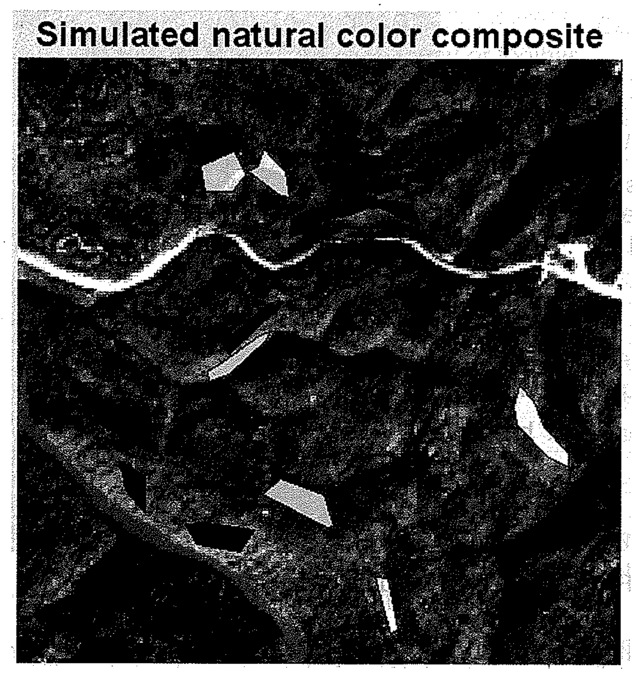


Figure 8.4.3.a Training classes for the linear pixel unmixing. (Red = Oak, Yellow = Poplar, and Blue = shadow.)

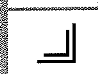
Since you should be familiar with digitizing from Section 7.4.3, a relatively brief description of digitization will be provided below. If this description is not sufficiently clear, please review Section 7.4.3 before proceeding. Note that Section 7.4.3 also includes a description of how to correct mistakes by deleting polygons.

Digitizing training polygons

Menu location: Main tool bar icons only (Note that the icons are grayed out if an image is not yet displayed.)

1. The simulated natural color image ***tm123*** should already be displayed in a Viewer.

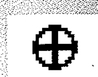
2. Click on the *Full extent normal* icon from the main tool bar, to display the entire image, if not already at the default zoom.



3. Click on *Full extent maximized*, to maximize the size of the display window.

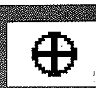
4. If necessary, click on the *Zoom window* icon, to zoom in on area of oak trees (Table 8.4.3.a and Figure 8.4.3.a). (If you have a large monitor, the full extent maximized display may be at a sufficiently high resolution not to require additional zooming in.)

5. Click on the *Digitize* icon. A dialog box labeled *DIGITIZE* will open.
6. Enter the file name **Oaks** in the text box labeled *Name of layer to be created.* Leave all other values at their defaults.
7. Click on *OK* to close the *DIGITIZE* window.
8. Move the cursor over the image. Note how when the cursor is over the image, it takes on a form similar to the *Digitize* icon, instead of the normal arrow.
9. Digitize the first vertex of the first oak polygon by pressing the *left* mouse button. Continue clicking in the image to specify the outer boundaries of the polygon you wish to digitize.
10. Close the polygon by pressing the *right* mouse button. Note that the program automatically closes the polygon by duplicating the first point; so you do not need to attempt to close the polygon by digitizing the first point again.



11. If you have zoomed in on the image, repeat the process to return the image to full extent, and zoom in on another oak area.
12. Now start digitizing the second polygon by clicking on the *Digitize* icon again.
13. The *DIGITIZE* dialog box will open again.
14. Confirm that the radio button for *Add features to the currently active vector layer* is selected.
15. Click *OK*.
16. The ID for the polygon will be incremented automatically. *Be sure to set it back to 1, as all the oak polygons should be digitized as part of the general Oak class.*
17. Digitize the next polygon.
18. Repeat the process of adding polygons to the Oak class until you have created all five oak training areas.

19. Save the polygon file by clicking on the *Save digitized data icon.*



20. A *Save prompt* dialog box will open. Click on *Yes*.
21. Now start digitizing the second class by clicking on the *Digitize* icon again.
22. The *DIGITIZE* dialog box will open again.
23. Select the radio button for *Create a new layer for the features to be digitized.*
24. Click *OK.*
25. In the text box labeled *Name of layer to be created*, enter **Poplar**.
26. Leave all other values at their defaults, and click on *OK.*
27. Digitize the poplar polygons. *Remember always to set the ID value back to 1 each time you start the process of adding a new polygon to the file.*

28. Save the polygon file by clicking on the *Save digitized data icon.*
29. A *Save prompt* dialog box will open. Click on *Yes*.
30. Repeat steps 21 to 29 for the **shade** class. Remember always to set the ID value back to 1 each time you start the process of adding a new polygon to the file, and remember to save the file.
31. When you are finished digitizing all the training areas, close the viewer. If you have any unsaved vector files you will be given an opportunity to save them.

8.4.4 Create Signature Files of Training Data

The process of creating signature files is described in detail in Section 7.4.4. Here we provide a brief overview of the process.

Create signature files using MAKESIG

Menu location: **Image Processing - Signature development – MAKESIG**

1. Start the MAKESIG program from the main menu.
2. In the *MAKESIG* dialog box, click on the Pick list button (...) to the right of the text box of *Vector file defining training sites.*
3. In the Pick list window, double click on the ***Oak*** file.
4. In the *MAKESIG* dialog box, click on the button *Enter signature filenames*.
5. An *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **Oak**.
6. Uncheck the box labeled *Create signature group file*.
7. Click on *OK* to close the *Enter signature filenames* dialog box.
8. In the *MAKESIG* dialog box, click on the button for *Insert layer group*.
9. From the *Pick list,* double click on ***tm30oct_all***.
10. The *MAKESIG* dialog box should now show the six bands of the TM data.
11. Click *OK*.
12. When the program has finished running (it should be very quick), double click in the *Vector file defining training sites* text box and in the subsequent pick list double click on ***Poplar***.
13. Click on the button *Enter signature filenames*.
14. An *Enter signature filenames* dialog box will open. In the cell to the right of 1, type **Poplar**.

15. Click on *OK* to close the *Enter signature filenames* dialog box.
16. Click *OK*.
17. Repeat steps 12 to 16 for the class **Shadow**.

8.4.5 Group the Signature Files into a Signature Group File

Now that we have the signatures, we need to group them into a collection of signatures, or a *signature group file*. This procedure was also explained in more detail in Section 7.4.5.

Creating a signature file collection with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Open the IDRISI EXPLORER.
2. In the *IDRISI EXPLORER* window, click on the tab for *Filters*.
3. Uncheck all the boxes that are checked (these are the default files that will be displayed in the *IDRISI EXPLORER* window).
4. Now click on the box to check the option to display *Signature (*.sig, *.spf)* files.
5. Click on the tab for *Files*.
6. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
7. The *Files* pane should list the three signature files you have created. Each signature will be listed twice: once as a *.sig file, and once as a *.spf file. We will only work with the *.sig files.
8. Highlight the signature files for the three signatures *in this order*: ***Oak.sig, Poplar.sig,*** and ***Shadow.sig.*** Select multiple bands by clicking on each file sequentially, while simultaneously pressing the *Ctrl* key on the computer keyboard.
9. Right click in the *Files* pane. Select the menu option for *Create – Signature Group.*
10. Check the *Metadata* pane, to see that the six signatures are listed in the same order as in step 7 above, i.e. *Water.sig* as *Group item (1)*, *Forest.sig* as *Group item (2)* etc. If the order is not the same, you should redo steps 7 and 8.
11. Make sure the ***Signature Group.sgf*** file name is highlighted in the *Files* pane.
12. In the *Metadata* pane, enter a new name in the right hand cell of the first row, typing over the default name of *Signature Group:* **Sig_all**.
13. Press the *Enter* key on your computer keyboard.
14. Click on the save (floppy disk) icon, at the bottom left hand corner of the *Metadata* pane. The name ***Sig_all.sgf*** will immediately be updated in the *Files* window.

8.4.6 Use UNMIX to Perform Linear Unmixing

Linear spectral unmixing assumes that each pixel can be modeled as a linear function of the input classes. Thus, this approach assumes that the spectral value of a pixel that comprises 50% of each of two different classes should lie half way between the two classes in the feature space (the spectral dimension of the data). Pixels that lie outside the bounding envelope of the training classes in the feature space would have to be modeled as having negative proportions of the training classes, which has no physical meaning, and is normally not allowed.

Unmix an image
Menu location: **Image Processing - Soft Classifiers - UNMIX**
1. Start the UNMIX program from the main IDRISI menu. 2. In the *UNMIX* dialog box, select the option for *Linear spectral unmixing*. 3. Double click in the text box labeled *Signature group file*. 4. In the subsequent pick list, double click on ***Sig_all***. 5. In the *Output prefix* text box, type **Unmixed**. 6. Figure 8.4.6.a shows the UNMIX dialog box, with files specified. 7. Click on *OK*.

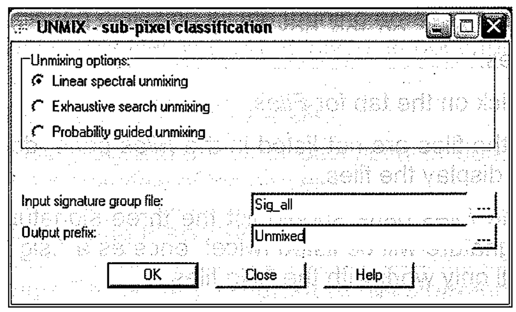


Figure 8.4.6.a The *UMIX* dialog box.

IDRISI automatically displays the unmixing residual image, with a Quantitative look up table (Figure 8.4.6.b). (Note that your image will be slightly different from that in the figure, because your training classes will not be identical. However, the overall pattern should be similar.)

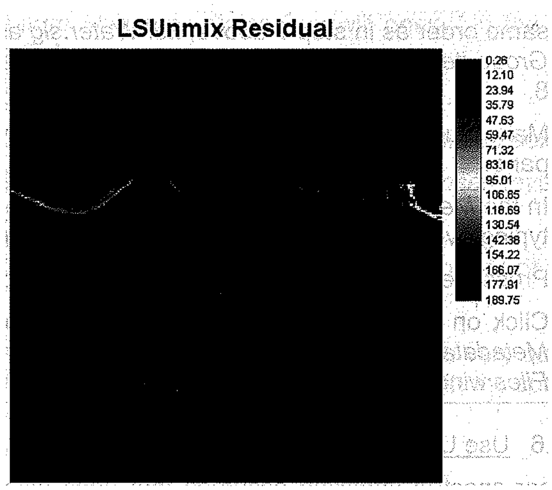


Figure 8.4.6.b Linear spectral unmixing residuals.

The unmixing residual gives an estimate of how well the training data can produce the original pixels: yellow and red indicate a poor match; black and dark purple indicate a good match. In our case, since we did not collect training data for the water or road classes, these areas have high residuals. It is also interesting to note that the hillside on the northeast side of the river does not appear to be well represented by the training classes, suggesting that perhaps this area is covered by a third forest community.

Now examine the three images that represent the proportion of each class for each pixel. These images have the prefix ***Unmixed***, and the rest of the name is the original class signature name. For example, ***UnmixedOak*** is the proportion of Oak in each pixel (Figure 8.4.6.c). You will need to use the IDRISI DISPLAY module to display each of the images, as they are not automatically shown. When you display the images, use all default options.

The three images showing the proportions of each class in each pixel show that although there are some areas that are very likely one forest class or the other, most areas are a combination of proportions of the two forest classes.

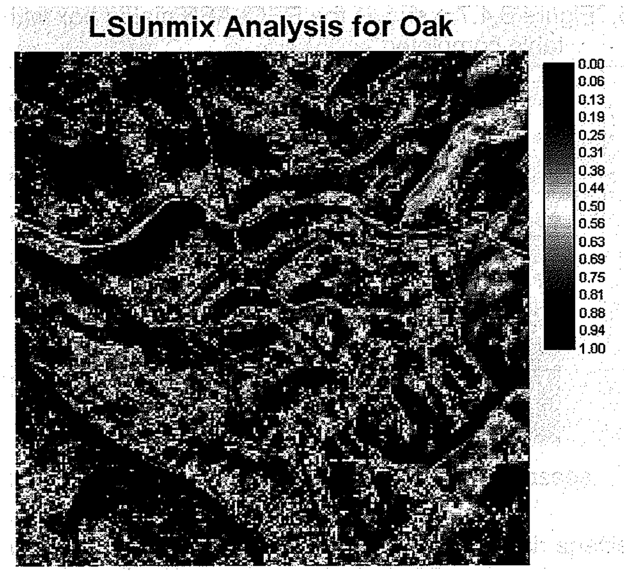


Figure 8.4.6.c Proportion of oaks in each pixel.

8.4.7 <u>Summarize the Output of the Forest Classification</u>

The images of the proportion of the Oak and Poplar communities might be regarded as an endpoint to the analysis. However, these data are difficult to visualize in their entirety, because the information is present in multiple images, and due to the complexity of the output. Therefore, many soft classification exercises end by returning to a modified version of the traditional approach, where each pixel is summarized by the class with the highest mixture proportion. IDRISI includes the module HARDEN to produce hard classifications from the soft classifiers in an automated fashion.

In this exercise, we will take a slightly different approach in order to preserve the fuzzy information in the forest communities, despite simplifying the classification. We will do this by manually recoding the image to an output that includes mixture classes.

Recode linear unmixing images with RECLASS

Menu Location: **GIS Analysis – Database Query – RECLASS**

1. Open the RECLASS program from the main icon bar or the main menu.
2. In the *RECLASS* window, enter the *Input file* name by double clicking in the text box, and selecting ***UnmixedOak***.
3. Enter the *Output file* as **Reclass_UnmixedOak**.
4. In the *Reclass Parameters* sections of the *RECLASS* window, enter the values to compete the table as indicated below:

Assign a new value of	*To all values from*	*To just less than*
1	**0.0**	**0.25**
2	**0.25**	**0.75**
3	**0.75**	**1.1**

5. Figure 8.4.7.a shows the RECLASS dialog box with the files specified and the table completed.

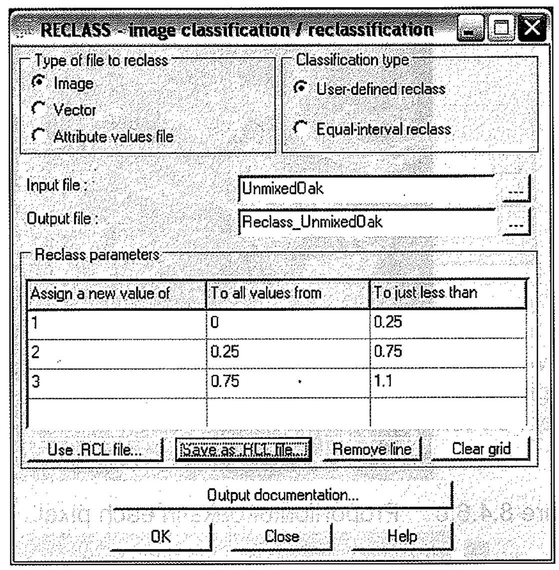


Figure 8.4.7.a RECLASS dialog box.

Note that the maximum value of **1.1** in the table is well above the limit of 1.0, which is the maximum proportion theoretically possible. We use 1.1, rather than 1.0, because the test is "*to just* ***less*** *than*" and not "*to* ***all values*** *of*."

In the table, 1 represents a low proportion of oak in the pixel, 2 a moderate proportion, and 3 a dominant proportion.

Recode linear unmixing images with RECLASS (cont.)

5. Click on *Save as .RCL file* button.
6. In the *Recode as* window, enter the Filename as **Recode_table**.
7. Click on *Save* to close the *Recode as* window.
8. In the *RECLASS* window, click on the *OK* button.

9. A dialog box will open with the question: *Warning: The input data contains real values. Would you like to change the output file to integer?* This question is prompted by IDRISI having recognized that you are converting the image from a continuous variable (numbers with decimals) to an integer (whole numbers). Accept the default, and click on *Yes*.
10. The reclassed image will be displayed automatically.
11. We will now reclass the second file. In the *RECLASS* window text box for Input file, double click in the *Input file* text box. In the pick list, double click on ***UnmixedPoplar***.
12. Change the Output file name to **Reclass_UnmixedPoplar**.
13. Click on *OK*.

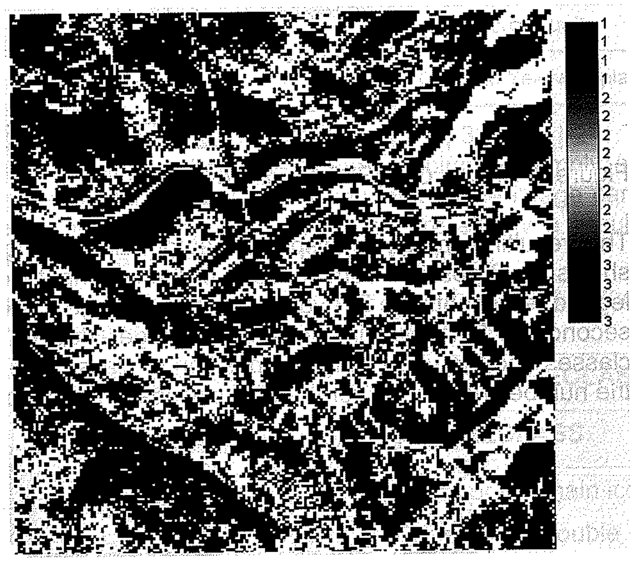


Figure 8.4.7.b Unmixed Oak image reclassed in the 3 classes.

So far we have produced two 3-class images, one for each species. In the next steps we will combine the two reclassed images into a single image. This will be done in two steps. First we will run the program CROSSTAB, to combine the two images. Finally we will run yet another RECLASS to produce a single summary image.

Combine the two 3-class images with CROSSTAB

Menu Location: **GIS Analysis – Database Query – CROSSTAB**

1. Start the CROSSTAB program from the main menu.
2. In the *CROSSTAB* window, double click in the *First image (column)* text box, and in the subsequent pick list, double click on **Reclass_UnmixedOak**.
3. Double click in the *Second image (row)* text box, and in the subsequent pick list, double click on **Reclass_UnmixedPoplar**.
4. Enter the *Output image* file name as: **Crosstab_oak_poplar**.
5. Accept the default for the *Type of analysis* (*Hard classification*) and *Output type* (*Cross-classification image*).

6. Figure 8.4.7.c shows the *CROSSTAB* window with the files specified.
7. Click on *OK*.

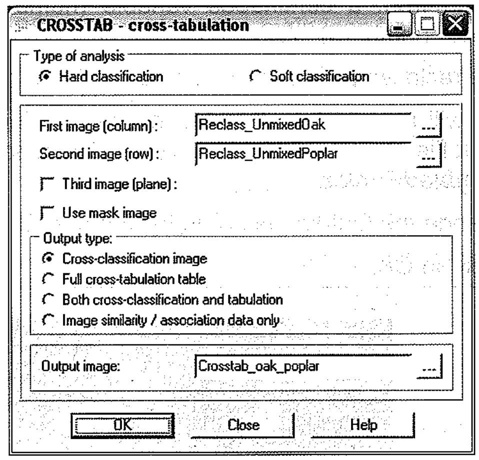


Figure 8.4.7.c *CROSSTAB* window.

The resulting image is displayed automatically (Figure 8.4.7.d). The image shows the 6 possible combinations of the two input files. The first number in the legend represents the DN value in the first image (Oaks, in our exercise), and the second the DN value in the second image (Poplar). Table 8.4.7.a lists these classes and the underlying composition of class. The final column in the table is the number we will use for the final classes in the second RECLASS operation.

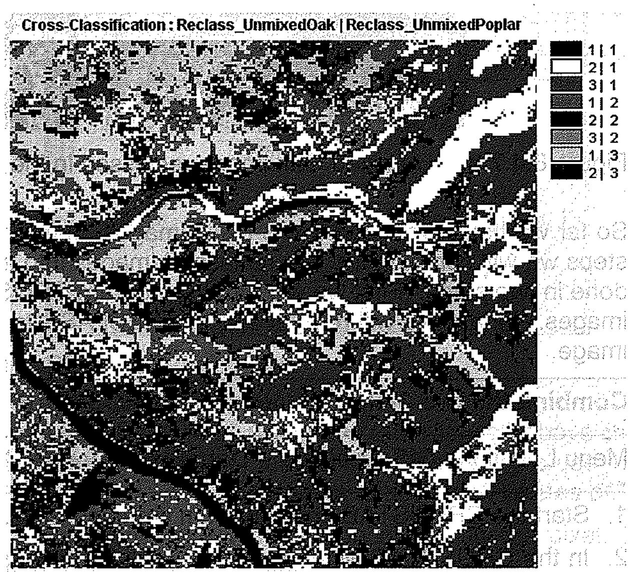


Figure 8.4.7.d Cross tabulation image of forest classes.

Table 8.4.7.a CROSSTAB output classes.

DN Value	Class	Oaks	Poplar	Interpretation	Reclass to
1	1 | 1	Low	Low	Non-veg, or shade	1
2	2 | 1	Middle	Low	Oak community	2
3	3 | 1	High	Low	Oak community	2
4	1 | 2	Low	Middle	Yellow poplar community	3
5.	2 | 2	Middle	Middle	Mixed Oak and Yellow poplar	4
6.	3 | 2	High	Middle	Mixed Oak and Yellow poplar	4
7	1 | 3	Low	High	Yellow poplar community	3
8	2 | 3	Middle	High	Mixed Oak and Yellow poplar	4

An interesting case is where we have the class "2 | 3" or "3 | 2". These are not really supposed to happen, because these combinations imply a greater than 100% total for the mixture. However, if you look at the image carefully you will see these pixels are actually quite rare, and are simply a result of rounding errors. They are likely also members of the mixed class.

As a final step in our analysis, we will now reclass the output of the CROSSTAB program to just 4 classes, using the program RECLASS.

Recode the results of the cross tabulation output with RECLASS

Menu Location: **GIS Analysis – Database Query – RECLASS**.

1. Start the RECLASS program from the main menu or the main icon tool bar.
2. In the *RECLASS* window, enter the *Input file* name by double clicking in the text box, and selecting ***Crosstab_Oak_Poplar***.
3. Enter the *Output file* as **Reclass_Crosstab_Oak_Poplar**.
4. In the *Reclass Parameters* sections of the *RECLASS* window, enter the values to compete the table as indicated below:

Assign a new value of	*To all values from*	*To just less than*
1	**1**	**2**
2	**2**	**4**
3	**4**	**5**
4	**5**	**7**
3	**7**	**8**
4	**8**	**9**

   Make sure you understand why these values were chosen by comparing each of these classes to Table 8.4.7.a. Also, double check that you have entered the values correctly in the table.
5. Click on *Save as .RCL file* button.
6. In the *Recode as* window, enter the Filename as **Recode_table2**.
7. Click on *Save* to close the *Recode as* window.

8. In the *RECLASS* window, click on the *OK* button.
9. The reclassed image will be displayed automatically (Figure 8.4.7.e).

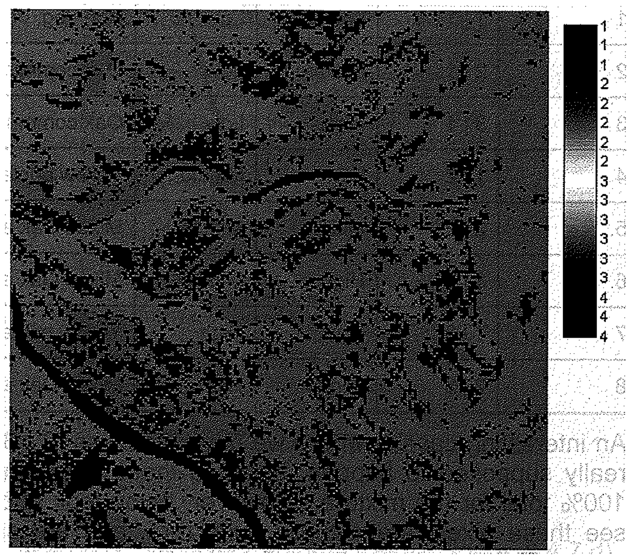
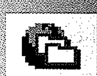


Figure 8.4.7.e Automatic display of the RECLASS program.

Finally, add a descriptive legend using IDRISI explorer. Additional details of this procedure are described in Section 7.3.7.

Update the classified image with the IDRISI EXPLORER

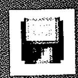


Menu location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu, or the main icon bar.
2. In the *IDRISI EXPLORER* window, click on the tab for *Files*.
3. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
4. In the *Files* pane, click on the ***Reclass_Crosstab_Oak_Poplar*** file.
5. In the *Metadata* pane below the *Files* pane, scroll down, and find the blank cell next to the label *Categories*.
6. Double click in the blank *Categories* cell.
7. A *Categories* dialog box will open.
8. In the first cell below *Code*, enter **1**.
9. In the cell below *Category*, enter **Non-vegetation or shade**.
10. Find the *Add line* icon on the right of the *Categories* dialog box (it is the third icon on the right side of the dialog box). Click on this icon.
11. In the new line enter the *Code* **2** and the *Category* **Oaks**.
12. Repeat the previous two steps in order to enter the remaining classes on two additional rows:

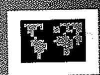
    3 Yellow Poplar

    4 Mixed Oak and Yellow Poplar



13. Click on *OK* to close the *Categories* dialog box.
14. The *IDRISI EXPLORER Metadata* pane should now have the number *4* in the cell next to *Legend cats*, indicating we have specified category names for 4 classes.
15. Click on the icon for *Save*, in the bottom left corner of the *Metadata* pane. After the file is saved, the icon will go blank.

Finally, redisplay the classification, to show the new legend.



Displaying a previously created false color composite using the DISPLAY LAUNCHER

Menu Location: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER program from the main menu, or the tool bar.
2. In the *DISPLAY LAUNCHER* dialog box, double click in the text box in the left side of the window.
3. A *Pick List* window will open. Double click on ***Reclass_Crosstab_Oak_Poplar***.
4. Click on *OK* to display the image (Figure 8.4.7.f).

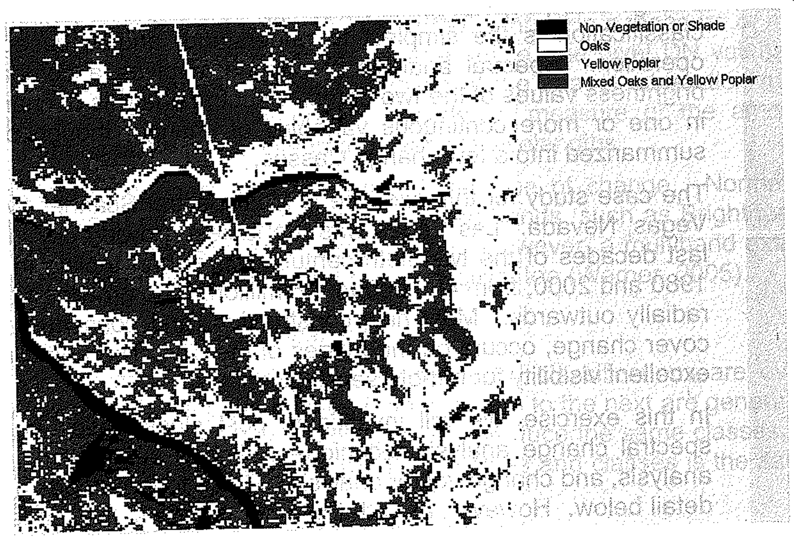


Figure 8.4.7.f Final mixture image, with updated legend.

The final image (Figure 8.4.7.f) lends strong support for the notion that the forest communities are mixtures. Although some areas are relatively pure, almost one quarter of the scene appears to be a mixture of Oak and Yellow Poplar. It is noteworthy that in Figure 8.4.7.f we have produced a map that shows the relatively pure and mixed classes, although our training areas were exclusively based on pure classes. It is only through the linear unmixing that the mixed classes were identified.

Chapter 9 Image Change Analysis

Change detection is one of the principal applications of remote sensing. Reasons for this include:

- Archived images are often the only available record of past conditions.
- Remote sensing can be very effective and accurate for identifying change.
- There is growing interest in monitoring change from local to global scales.

In principal, change detection is very simple: changes in image brightness values are assumed to represent change in ground conditions.

Broadly speaking, there are two types of change: change in degree, and change in class. Change in degree is a change in some continuous variable, such as biomass, whereas change in class implies a change from one material to another, such as from a forest to a road.

Change Detection methods can be grouped in two classes: spectral analysis of change and post-classification comparison of previously classified data. Post-classification is the simplest to understand, and is based on a GIS overlay operation. Spectral analysis of change involves a comparison of the image brightness values of the two dates. Spectral analysis of change generally results in one or more continuous variables of change, though often the results are summarized into a few change classes.

The case study for this exercise is Multispectral Scanner (MSS) imagery of Las Vegas, Nevada. Las Vegas was the fastest growing city in the U.S. during the last decades of the twentieth century, more than tripling in population between 1980 and 2000, from 460,000 to 1.6 million. The growth of the city is dominantly radially outwards. Most new construction, and consequently most of the land cover change, occurs on the fringes of the city. The arid climate also makes for excellent visibility for remote sensing.

In this exercise, we will investigate post classification comparison and three spectral change analysis techniques: image subtraction, principal component analysis, and change vector analysis. These four methods are described in more detail below. However, as with the other chapters, the reader is urged to consult a remote sensing text (Table 1.1.2.a) or Warner *et al.* 2009b for additional information, as the material below is only a very brief summary of these topics.

9.1 Introduction

9.1.1 <u>Change Detection Methods</u>

9.1.1.1 Image Subtraction

Image subtraction involves the direct comparison of the DN values of the two images. IDRISI offers four different outputs:

1. The raw differenced values
2. The differenced values as a percentage of the original value of the pixel
3. Change values expressed as z-scores, where the change value is expressed in terms of the number of standard deviations it is from the mean.

4. Change value z-scores grouped into 6 classes of change.

9.1.1.2 Principal Component Analysis (PCA)

Principal component analysis (PCA) was originally introduced in Section 6.3.3 as a spectral enhancement technique. As explained in that section, PCA is a rotation and translation of the band axes. The new bands are orthogonal and uncorrelated. The first band is oriented to capture the maximum variance. Subsequent bands are oriented to capture the maximum remaining variance. PCA produces as many new bands as there were old bands, although it is usually assumed that most of the information is present in the first few new bands, which have most of the variance.

PCA can also be used for change detection. Instead of applying the PCA technique to the image of one date, as is done for regular image enhancement, the method is applied to two or more images simultaneously. For change detection, it is assumed that the first PCA band of the multi-date set is likely to be an average image, and therefore is likely to be of less interest. Change is usually isolated in the second and subsequent bands.

9.1.1.3 Change Vector Analysis

Change vector analysis separates change into two components: magnitude and direction.

The magnitude component is the simpler component: it is a measure of how far in the spectral space (also known as feature space) the pixel DN values have changed. It is thus a multiple-band variation of the image subtraction method. Therefore, the magnitude component provides a measure of the amount of change that has taken place, integrated over all wavelengths.

The direction component is a measure of the type of change. Normally the direction is based on just two bands, or derived bands, such as Brightness and Greenness in a Tasseled Cap Transformation. However, a multiband extension to direction changes has been found to be effective, too (Warner, 2005).

9.1.1.4 Post Classification Comparison

In post classification, two independently produced classifications are overlaid, and new classes showing the change from one date to the next are generated. It is important that the two dates are classified to produce the same classes, in the same order (i.e. the relationship between DN values and classes is the same for both images).

9.1.2 <u>Required Preprocessing.</u>

9.1.2.1 Geometric Co-Registration

It is obvious that the quality of co-registration in all change analysis studies must be excellent (less than 1 pixel); otherwise artifacts will be introduced into the analysis. With nadir-viewing satellite imagery such as Landsat, high quality co-registration can usually be achieved. In rugged terrain, orthorectification is usually required for imagery from off-nadir viewing sensors such as SPOT. For aerial imagery, high quality orthorectification is essential.

9.1.2.2 Radiometric Normalization

Radiometric normalization is a process by which the image DN values are adjusted so that the specific values of each date can be compared directly.

Radiometric normalization is an attempt to reduce the effect of variations in illumination and variations in atmospheric transmission and scattering properties.

Unlike co-registration, radiometric normalization is not always needed. Post classification comparison does not require that the images be radiometrically normalized, but doing so can be useful, because then the same class signatures can be applied to both images. Radiometric normalization is also not required for PCA. Radiometric normalization is required for image subtraction and CVA.

Before discussing normalization methods, it is useful to first briefly review some terminology and background. The concentration of the sun's energy is dependent on the angle of incidence of the energy, in other words on the sun's elevation in the sky. Furthermore, sun's energy has to travel through the atmosphere, which absorbs and scatters the energy. At the molecular level, atmospheric gases cause Rayleigh scattering that progressively affects shorter wavelengths (causing, for example, the sky to appear blue). Also, specific atmospheric components, such as ozone and water vapor, cause absorption of energy at selected wavelengths. Furthermore, aerosol particulates, the primary determinant of haze, create Mie scattering, a largely non-selective (i.e., affecting all wavelength equally) effect. In visible wavelengths, moisture vapor has a major effect on atmospheric properties.

The problem of atmospheric normalization has received considerable attention from researchers in remote sensing, and two broad classes of image radiometric normalization have been developed. The first method is to convert image DN values to exoatmospheric radiance, which is in turn, usually converted to estimated reflectance, using physical or empirical models of radiative transfer. Radiance refers to the flux of energy per solid angle in a given direction. While radiance corresponds to brightness in a given direction, it is sometimes confused with reflectance, which is the ratio of reflected and irradiant energy (illumination). Radiance is the energy measured at the sensor and is dependent on the reflectance of the surface being observed, the irradiant energy, and the interaction of the energy with the atmospheric.

Conversion to radiance or reflectance is the best approach in theory, but is often impossible to implement because of a lack of information about atmospheric transmissivity and scattering, or lack of knowledge of the conversion factors from DN values to radiance.

The second class of image radiometric normalization is an empirical regression of one date on the other. This approach is relatively easy to implement, but does require clearly identifiable regions where the image is assumed not to have changed. In some environments, change may be so pervasive, or so complex, that it may not be possible to use this method.

Because radiometric normalization is so important for some change detection methods, and can also be so difficult to implement, both methods will be illustrated. We will first convert the red band from the 1972 and 1992 images to radiance. The next step would be to convert these images to apparent reflectance, but because they were acquired on near anniversary dates (September 10 1972 and September 13 1992), the difference in solar illumination should be small. Furthermore, the IDRISI reflectance conversion program, ATMOSC, is quite complex, and requires data that is often difficult to obtain.

9.2 Copy Data for this Chapter

In this chapter we will work with different image sets for each section. Therefore, you should now copy the *Chap9* folder from the CD, and paste it as a new subfolder within the *\ID Man* folder on your computer.

After you have copied the folder, you should remove the Read-Only attribute from this new folder on your computer. This is done by right-clicking on the *Chap9* folder name, selecting *Properties* from the pop-up menu. A dialog box will open, labeled *Chap9 Properties* (if you apply this procedure to the entire *ID Man* directory, then the dialog box will be labeled *ID Man Properties*). Now clear the check mark from the *Read Only* check box, by clicking in the box. You should then click on the button for *Apply*, and in the subsequent *Confirm Attribute Changes* dialog box, accept the default *Apply changes to this folder, subfolder and files*, and click on *OK*. You will need to also click on *OK* in the *Chap9 Properties* dialog box.

Note: Section 1.3.1 provides detailed instructions on how to copy the data from the CD, and also on how to remove the *Read-Only* attribute from the data. Also, the procedure for setting up the *ID Man* folder on your computer is described.

9.3 Preparatory

In the previous section (Section 9.2) you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for this section.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap9.*
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap9* will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

You will find two sets of MSS images in this directory (Table 9.3.a), acquired by Landsat 1, on September 13 1972, and by Landsat 5, on September 10 1992. Note that the band number designation of MSS data changed after 1982, but for convenience the 1972 and 1992 images have been labeled with consistent band numbers, and these are the numbers that will be used in this exercise. Thus, for example the green bands of the two images have been labeled ***mss72_1.rst*** and ***mss92_1.rst***, respectively, and in both cases, will be referred to as *band 1*. Nevertheless, as you will see, there are times when you will need to refer back to the old band numbers for the 1972 images.

Table 9.3.a MSS imagery of Las Vegas

1972 imagery file names	**Original band designation**	**1992 imagery file names**	**Original band designation**	**Wavelength interval (µm)**	**Wavelength region**
mss72_1.rst	4	mss92_1.rst	1	0.5-0.6	green
mss72_2.rst	5	mss92_2.rst	2	0.6-0.7	red
mss72_3.rst	6	mss92_3.rst	3	0.7-0.8	infrared
mss72_4.rst	7	mss92_4.rst	4	0.8-1.1	infrared

The MSS images used in this section are from the National American Landscape Characterization (NALC) Project. These images have been resampled to a 60 meter UTM grid, although the original instantaneous field of view (IFOV) of the MSS sensor was approximately 56 by 80 meters. You can find out more about the NALC project, as well as the preprocessing used to produce the images at: http://eros.usgs.gov/products/satellite/nalc.php

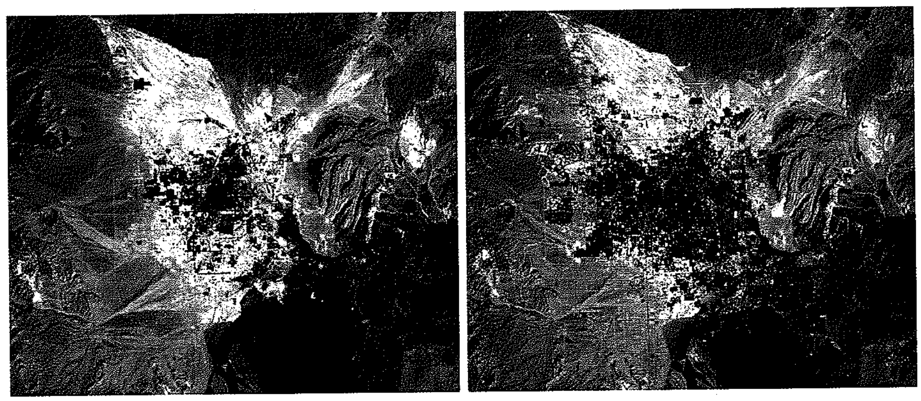
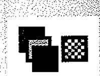


Figure 9.3.a MSS false color composites of Las Vegas, Nevada. Left: September 13 1972. Right: September 10 1992.



Create a color composite image
Menu Location: **Display - COMPOSITE**
1. Start the COMPOSITE program using the main menu or tool bar. 2. In the *COMPOSITE* dialog box, double click in the *Blue image band* text box. The *Pick list* window will open. 3. In the *Pick list* window, double click on the file ***mss72_1***. If necessary, click on the plus symbol to display the files. 4. Double click in the *Green image band* text box, and then double click on ***mss72_2***. 5. Double click in the *Red image band* text box, and then double click on ***mss72_4***. 6. Enter the *Output image* filename in the text box provided: **mss72_fcc**. 7. Click *OK* to create and display the false color composite.

8. Repeat steps 2-7, using ***mss92_1***, ***mss92_2, and mss92_4*** to create the image **mss92_fcc**.
9. Once the images have been displayed, you can close the *COMPOSITE* window.

The two false color composite images provide a dramatic demonstration of how rapidly the city of Las Vegas has grown over 20 years (Figure 9.3.a).

For this study, we will use data that have already been co-registered. Co-registration and georeferencing is dealt with in more detail in Chapter 3, especially Section 3.2.

9.4 Change Detection Pre-Processing: Radiometric Normalization through Conversion to Radiance

Note that this section is an alternative method to the regression normalization method discussed in the next section. Of the change detection methods presented in this manual, radiometric normalization is only required as a preprocessing step for ***image differencing*** and ***change vector analysis.***

9.4.1 Convert Raw Image DN Values to Radiance Values

The program RADIANCE converts Landsat 1-5 MSS and 4-5 TM raw satellite DN values calibrated radiance values, using published conversion factors. The program has optional input for specifying the conversion factors manually, so that data from other satellites may also be converted with this program.

Conversion of Landsat image DN values to radiance

Menu Location: **Image Processing - Restoration – RADIANCE**

1. Start the RADIANCE program from the main menu.
2. First, we will convert the 1972 data to radiance. In the *RADIANCE* window, use the pull-down menu to select *Landsat -1 MSS*.
3. Double click in the *Input image* text box. In the subsequent pick list window, double click on ***mss72_2***.
4. Enter the *Output image* name: **mss72_2_rad**.
5. In the *Band number* text box, enter **5**.

   (Note that the program will give you an error if you specify the band number according to the new numbering system, i.e. 2. Refer to Table 7.2.1.a for the original band designations for Landsat 1 MSS.)
6. Figure 9.4.1.a shows the *RADIANCE* window, with the parameters specified.
7. Click on *OK*.
8. Once the program has completed processing the first image, it will be displayed automatically (9.4.1.b).
9. Now convert the 1992 data to radiance. Use the pull-down menu to select *Landsat - 5 MSS (On or after Nov 9, 1984).*
10. Change the *Input image* to ***mss92_2***.
11. Enter the new *Output image* name as **mss92_2_rad**.
12. Change the *Band number* to **2**.

(Note that the 1992 image is a Landsat 5 image, and therefore ***mss92_2*** has a different band designation from the Landsat 1 data, even though it has the same approximate wavelength sensitivity as the ***mss72_2*** image.)

13. Click on *OK*.

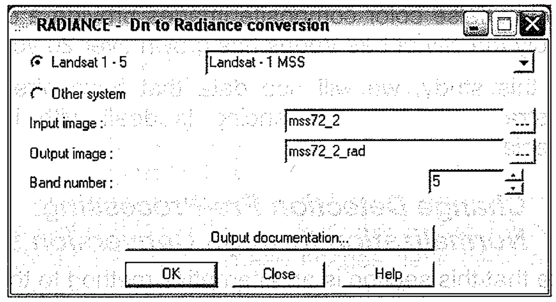


Figure 9.4.1.a *RADIANCE* window.

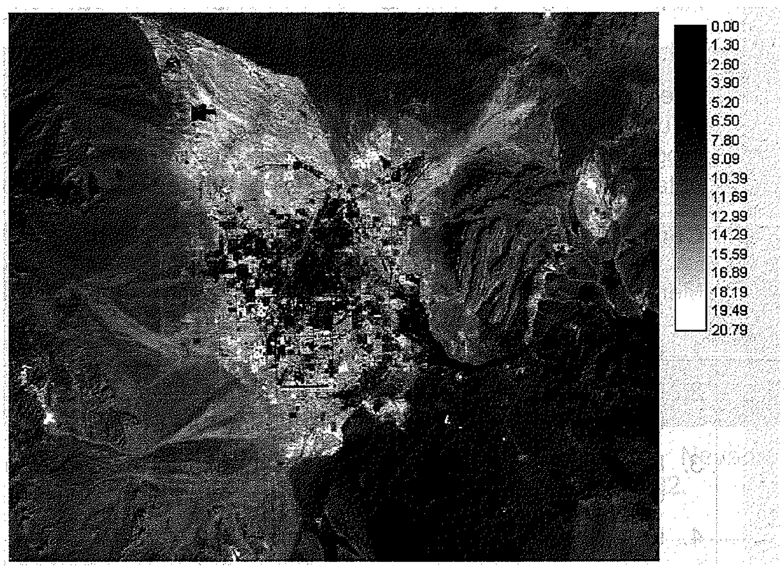


Figure 9.4.1.b Las Vegas 1972 data converted to radiance.

Figure 9.4.1.b shows the 1972 data converted to radiance. Because the image has an automated contrast stretch applied, it looks no different to the same single-band image prior to radiance conversion. However, in this case, the scale indicated on the right side of the image is in physical units of radiance, mW cm^{-1} sr^{-1} μm^{-1}.

Before continuing on to the next step, we will also radiometrically normalize the near infrared bands of the two dates, as described below.

Conversion of Landsat image DN values to radiance (cont.)

14. In the *RADIANCE* window, use the pull-down menu to select *Landsat -1 MSS*.

15. Double click in the *Input image* text box. In the subsequent pick list window, double click on ***mss72_4***.

16. Enter the *Output image* name: **mss72_4_rad**.

17. In the Band number text box, enter **7**.

    (Reminder – 7 was the original band number of the fourth band on the MSS instrument.)

18. Click on *OK*.
19. Once the program has completed processing the image, start the process to convert the 1992 data to radiance. Use the pull-down menu to select *Landsat - 5 MSS (On or after Nov 9, 1984)*.
20. Change the *Input image* to ***mss92_4***.
21. Enter the new *Output image* name as **mss92_4_rad**.
22. Change the band number to **4**.
23. Click on *OK*.

9.4.2 Preliminary Image Differencing

The two images have now been converted to radiance values, instead of arbitrary image DN values. The simplest way to test the success of this operation, and to illustrate the application to conversion to radiance, is to run a preliminary image differencing operation. The topic of image differencing will be dealt with in more detail later in this chapter.

Preliminary image differencing as a test for image normalization

Menu Location: **GIS Analysis – Mathematical Operators – OVERLAY**

1. Open the OVERLAY program through the main menu or the main toolbar.
2. In the *OVERLAY* window, double click in the text box for *First image*. In the resulting pick list, double click on ***mss92_2_rad***.
3. Double click in the text box for *Second image*. In the resulting pick list, double click on ***mss72_2_rad***.
4. In the text box for *Output image*, enter **mss92-72_b2_rad**.
5. Select from the list of *Overlay options* the radio button for *First – Second*.
6. Figure 9.4.2.a shows the OVERLAY window with processing parameters specified.
7. Click on *OK*.

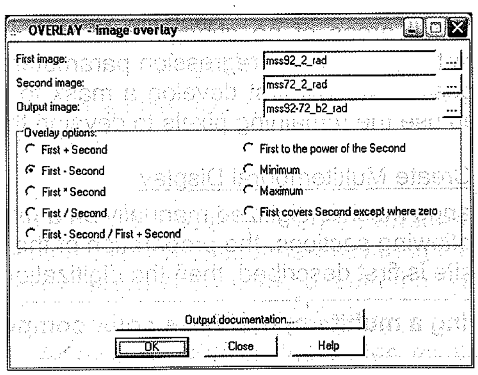


Figure 9.4.2.a OVERLAY window.

The difference image should have been displayed automatically (Figure 9.4.2.b). From the legend, note the color associated with a value closest to 0. These should be areas of no change. Although the city shows extensive change (principally a reduction in red brightness values, as shown by the green colors in the image), most of the surrounding desert shows little change, as would be expected.

To end this section, close all open windows.

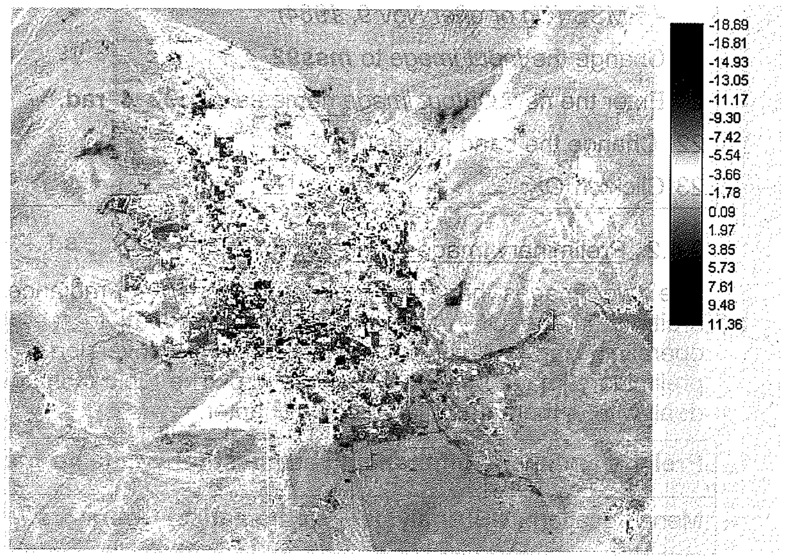


Figure 9.4.2.b Preliminary change detection of Las Vegas, Nevada, MSS red bands, 1992-1972.

9.5 *Change Detection Pre-Processing: Image Normalization through Regression*

Sections 9.4 and 9.5 (this section) provide alternative radiometric normalization methods. In the last section, we used the packaged conversion to radiance method provided by IDRISI. In this section, we investigate an alternative method, based on developing a regression relationship between the two images.

The procedure for regression-based radiometric normalization requires the identification of areas of no change, and developing empirical models to convert the one date to have values equivalent to those of the second date. One can select small areas of no change, and use a spreadsheet, or other statistical package to calculate the regression parameters. Our approach, however, will be the opposite: we will first develop a mask to indicate broad regions of change, and then use the remaining pixels to develop the regression.

9.5.1 Create Multitemporal Display

The change mask is digitized manually on a multitemporal false color composite. In the following sections, the preparation of the multitemporal false color composite is first described, then the digitization of the mask.

Preparing a multitemporal false color composite
Menu location: **Display – DISPLAY LAUNCHER**
1. Start the DISPLAY LAUNCHER from the main menu or icon bar.

2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***mss72_2***.
3. Click on *OK* to display the image, accepting all the other defaults.
4. Find the *Composer* dialog box, which is automatically opened when an image is displayed.
5. In the *Composer* dialog box, click on the ***red*** button (see arrowed button in Figure 9.5.1.a). (If you place your cursor over the red button the screen tip will show: *Set selected layer as red component of RGB composite or anaglyph.*)
6. The image should now be displayed in tones of red (Figure 9.5.1.a).

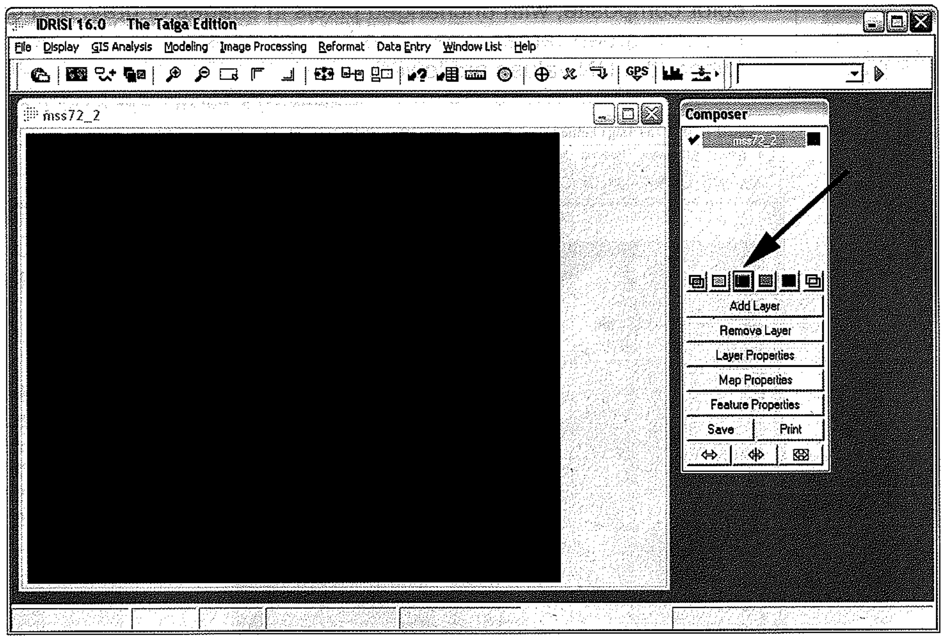


Figure 9.5.1.a 1972 Las Vegas image after clicking on red button.

Preparing a multitemporal false color composite (cont.)

7. In the *Composer* dialog box, click on *Add Layer*.
8. The *Add Layer* dialog box will open.
9. Click on the radio button to change the *File Type* to *Raster Layer*.
10. Double click in the (unlabeled) file name window. In the resulting pick list, double click on ***mss92_2***.
11. Click on *OK*.
12. The image will now be displayed in the same viewer as the ***mss72_2*** image, with the second image, ***mss92_2,*** opaquely covering the first. The *Composer* dialog box will therefore now show name of both the ***mss72_2*** and ***mss92_2*** images.
13. In the *Composer* dialog box, click on the button for the **green** layer. The image should now be dominated by yellow colors, with some red and minor areas of green. Yellow indicates areas that are bright in both dates, because

the two different dates are displayed in red and green, and red and green makes yellow.

14. For a second time, click on *Add Layer* in the *Composer* dialog box.
15. In the *Add Layer* dialog box, change the *File Type* to *Raster Layer.*
16. Double click in the (unlabeled) file name window. In the resulting pick list, double click on ***mss72_2*** once again (we have already used this image for the red band.)
17. Again the new image will opaquely cover the previously displayed images.
18. In the *Composer* dialog box, click on the button for the **blue** layer.
19. The result is displayed in Figure 9.5.1.b, and shows a multitemporal false color composite, with unchanged pixels in shades of gray, and changed pixels in either green (areas where the DN values are higher in 1992) or magenta (where the DN values are lower).

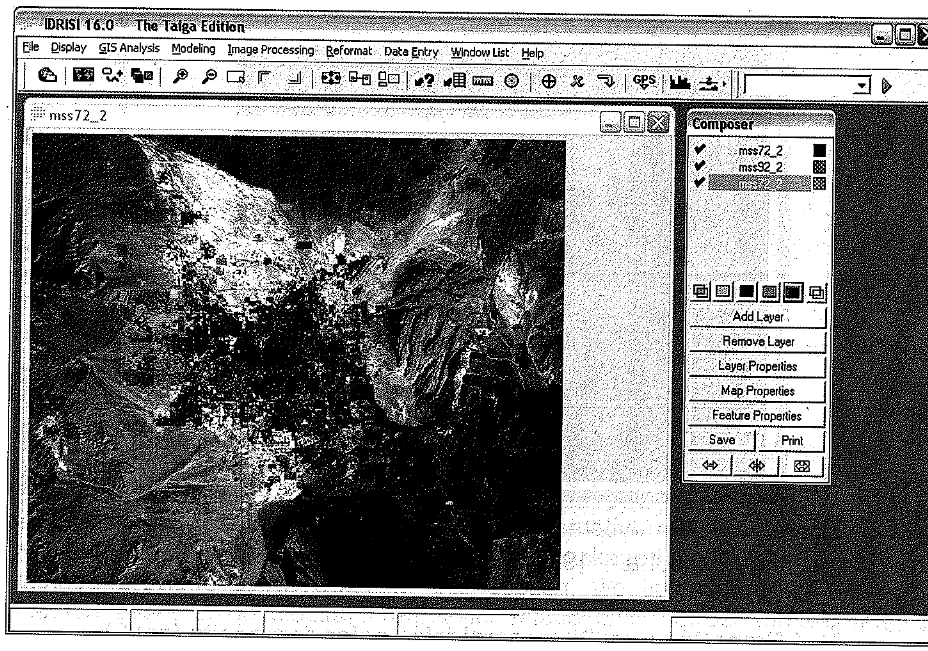


Figure 9.5.1.b Las Vegas multitemporal false color composite: 1972 as magenta, 1992 as green.

9.5.2 Digitize Change Mask

The next step is to digitize change areas with a value of 0, to mask them out from the analysis. By now you should be familiar with digitizing. However, if you feel the instructions below are too brief, please review Section 7.4.3 for more details.

Digitizing change areas on the multitemporal composite

1. The multi-temporal composite, as described above and shown in Figure 9.5.1.b, should be displayed in the *DISPLAY* window.
2. From the main icon toolbar, select the icon for *Full extent normal.*
3. Click on the icon for *Full extent maximized.*
4. Select the *Digitize* icon.

5. The *Digitize* dialog box will open. In the textbox for *Name of layer to be created*, enter **Mask**.
6. In the text box for *ID or Value* enter **0**.
7. Click on *OK*.
8. Digitize a large, single polygon that encloses the majority of the changed (i.e. pixels with magenta and green colors) pixels (Figure 9.5.2.a). The unchanged areas, left outside the polygon, should have a wide range of brightness levels (gray tones), to give the most reliable regression. Note that it is not necessary to digitize in very fine detail, because a few changed pixels will not affect the overall regression, as the sample will have many thousands of pixels.
9. Right-click to close the polygon.
10. Click on the icon *Save digitized data*.
11. Close the *DISPLAY* window.

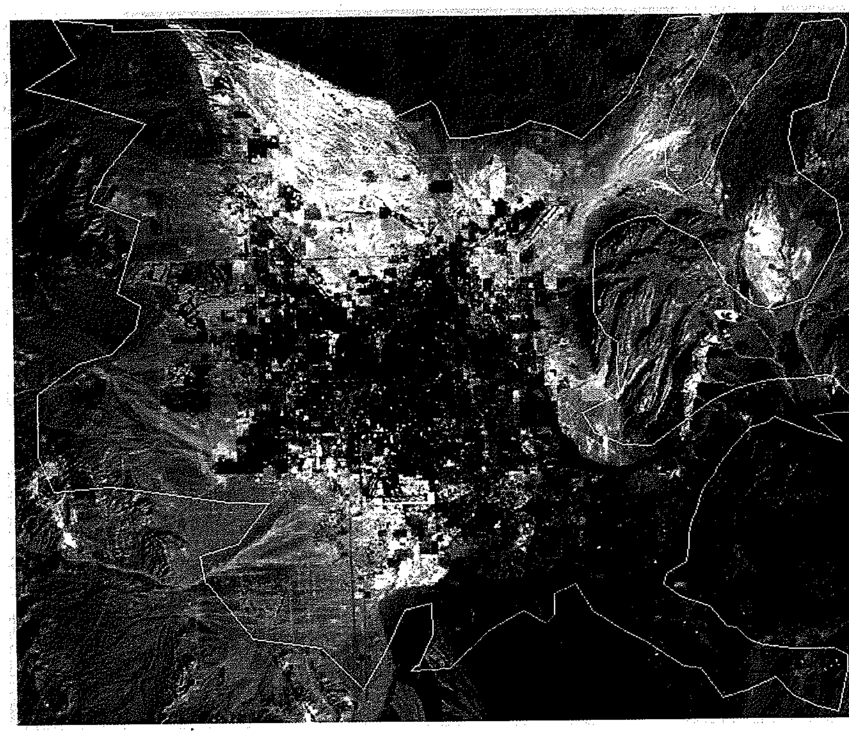


Figure 9.5.2.a Digitizing the changed areas. Note that the polygon outline is somewhat rough, as the selection of change pixels is very broad.

9.5.3 Rasterize the Vector Mask

The mask we have created is a vector file. In order to apply the mask, it must be rasterized. The rasterization process has two parts. First, a blank file, with a value of 1 in every pixel location, is created. This file will have the dimensions of the MSS images. In the second step, the vector file is used to over-write 0 in each pixel within the polygon just created.

Create a new file prior to rasterization

Menu location: **Data entry – INITIAL**

1. Start the INITIAL program from the main menu.
2. In the INITIAL window, confirm that the radio button has been selected for *Copy spatial parameters from another image.*
3. Also confirm that the *Output data type* has been set to *byte*.
4. Enter the *Output image* file name: **Mask**.
5. Double click in the text box next to *Image to copy parameters from*. In the resulting pick list, double click on ***mss72_1***.
6. Change the *Initial value* from the default 0 to **1**.
7. Figure 9.5.3.a shows the *INITIAL* window with the processing parameters specified.
8. Click on *OK*.
9. Because the image is uniform, with every pixel having a value of 1, the image is not displayed. Therefore, once you have confirmed from the progress meter that the program has completed, close the *INITIAL* window.

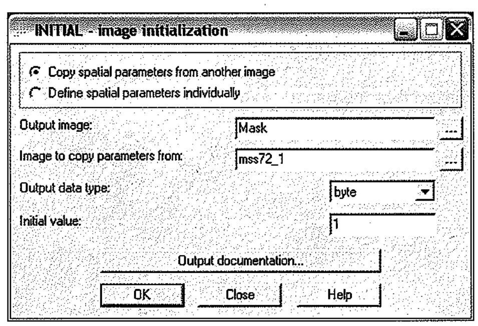


Figure 9.5.3.a The *INITIAL* window.

In the second step, the vector file is used to over-write 0 in each pixel within the polygon just created.

Rasterize the vector file with the polygon of change areas

Menu location: **Reformat - RASTERVECTOR**

1. Start the RASTERVECTOR program from the main menu.
2. In the *RASTERVECTOR* window, select the radio button for *Polygon to Raster*.
3. Double click in the *Vector polygon file* text box, and in the resulting pick list double click on ***Mask***.
4. Double click in the *Image file to be updated* text box, and in the resulting pick list, double click on ***Mask***.
5. Click on *OK*.
6. The mask will be displayed automatically (Figure 9.5.3.c).

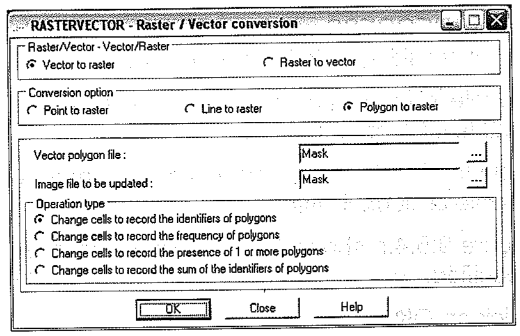


Figure 9.5.3.b *RASTERVECTOR* window.

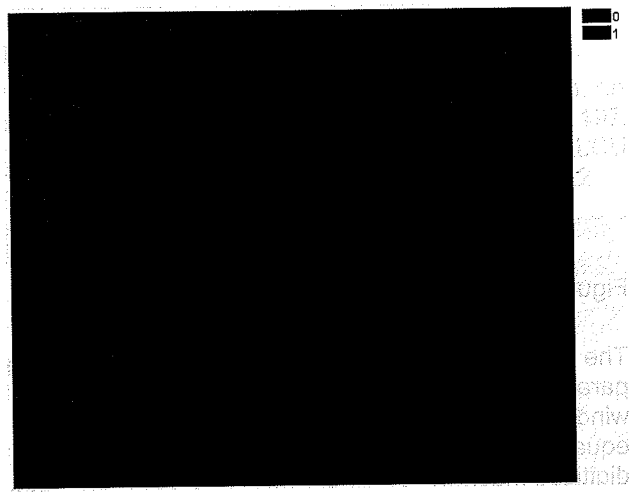


Figure 9.5.3.c Rasterized mask of change areas.

You should now confirm in your rasterized mask (Figure 9.5.3.c), by checking the legend, that the central area, corresponding to the region of the city, has a value of 0, and the surrounding areas have a value of 1.

9.5.4 Regression of the Masked Imagery

In the regression analysis, we would like to find an equation that converts the 1972 DN values so that in areas did not change in the twenty year interval, the DN values will be similar to those of the 1992 image. The formula we are looking for has the form:

1992 DN = a + b * 1972 DN

where a and b are the regression parameters. Therefore, we will specify the 1992 image as the *dependent* variable, and 1972 as the *independent* variable in the regression, even though it is actually the 1972 data that will be modified in the application of the formula for the image normalization.

Regression estimation
Menu location: **GIS analysis – Statistics - REGRESS**
1. Start the REGRESS program from the main menu.

2. In the *REGRESS* window, double click in the *Independent variable* text box. In the resulting pick list, double click on ***mss72_2***.
3. Double click in the *Dependent variable* text box. In the resulting pick list, double click on ***mss92_2***.
4. Double click in the *Mask name (optional)* text box. In the resulting pick list, double click on ***Mask***.
5. Figure 9.5.4.a shows the *REGRESS* window, with the processing parameters specified.
6. Click on *OK*.

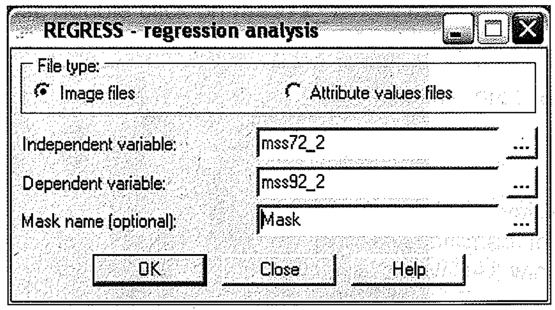


Figure 9.5.4.a The *REGRESS* window.

The program output is a scatter plot, along with a listing of the regression parameters (Figure 9.5.4.b). Note the regression at the top left of the output window (Y = 4.989321 + 0.844283 X for the mask used in the example; your equation should be similar, but will not be precisely the same because your digitized mask will be different). Write down the equation from the regression for later use.

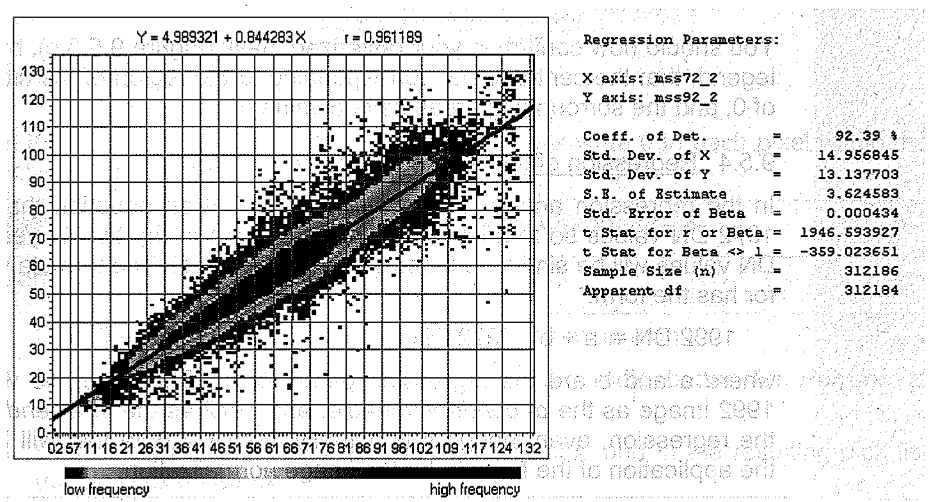


Figure 9.5.4.b Regression of 1992 and 1972 band 2 images.

We will now repeat the regression calculation using the same dates, and mask, but changing the bands from 2, to 4 (i.e. use ***mss72_4*** and ***mss92_4***).

Regression estimation (cont.)
7. The *REGRESS* window should still be open from the first regression. 8. In the *REGRESS* window, double click in the *Independent variable* text box. In the resulting pick list, double click on ***mss72_4***. 9. Double click in the *Dependent variable* text box. In the resulting pick list, double click on ***mss92_4***. 10. Confirm that the *Mask name (optional)* text box still contains the file name ***Mask***. 11. Click on *OK*.

Write down this second regression equation.

9.5.5 Normalize the 1972 data using the regression equation

We have now gathered the data we need for the normalization, and are ready to apply the correction from the regression equations to the 1972 images. A convenient tool for applying the equations is the IMAGE CALCULATOR. The IMAGE CALCULATOR program was introduced in Section 6.4.2.

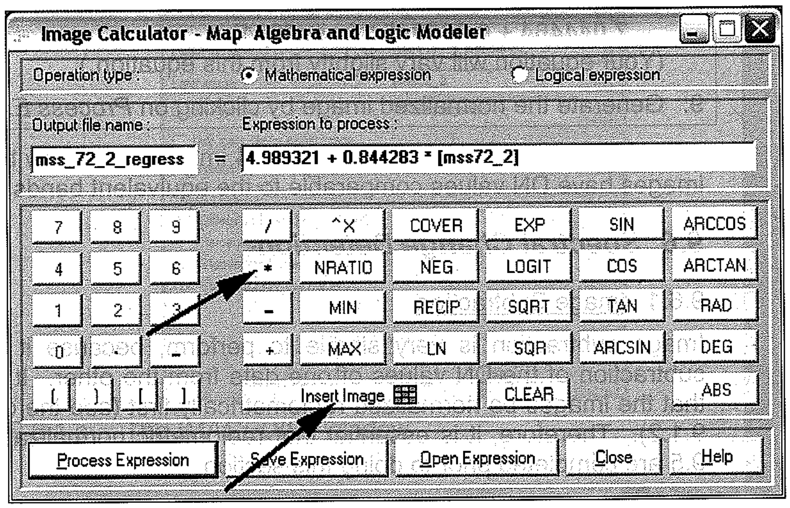


Figure 9.5.5.a The IMAGE CALCULATOR window. The multiply (*) and *Insert Image* buttons are arrowed.

Apply normalization equation
Menu location: **Modeling – Model Deployment Tools - IMAGE CALCULATOR**
1. Open the IMAGE CALCULATOR program from the main menu or toolbar. 2. In the *IMAGE CALCULATOR* window, enter in the *Output file name* text box **mss_72_2_regress**. 3. Enter the equation you wrote down for the band 2 regression (i.e. the first regression), in the *Expression to process* text box. Use * to represent multiply. Instead of entering X, click on the button for *Insert Image*. In the resulting pick list, double click on ***mss72_2***. This will place the file name in

parentheses in the equation.
Thus, for example, in the example in this text, the equation becomes:
4.989321 + 0.844283 * [mss72_2]
(Note that your values of your equation will vary slightly, but should be in the same range.)

4. Figure 9.5.5.a shows the equation entered in the *IMAGE CALCULATOR* window.
5. Click on *Process Expression*.
6. The output image will be displayed automatically.

We will now repeat the development of the equation for the 1972 band 4 data.

Apply normalization equation (cont.)

7. In the *IMAGE CALCULATOR* window, change the *Output file name* text box to **mss_72_4_regress**.
8. Enter the equation you wrote down for the band 4 regression (i.e. the *second* regression), in the *Expression to process* text box. Be sure to change the file that is processed from **[mss72_2]** to **[mss72_4]**. Thus, for the data in the example in this text, the equation becomes:
   7.044464 + 0.965945 * [mss72_4]
   (Your equation will vary slightly from this equation.)
9. Generate the normalized image by clicking on *Process Expression*.

The 1972 normalized band 2 and band 4 images have now been created. These images have DN values comparable to the equivalent bands in the 1992 images.

9.6 Spectral Change Detection

9.6.1 Image Subtraction

Image subtraction is very simple to perform, because it simply requires the subtraction of the DN values of one date from the other. It is essential, though, that the images be normalized radiometrically first (see the discussion in Section 9.1.2). Therefore, it is essential that radiometric normalization exercises 9.4 or 9.5 are completed prior to doing this section.

In the exercise below we will use the results from Section 9.5, the normalization using regression. However, if you prefer to use the results from Section 9.4, the normalization using the IDRISI routine that converts DNs to radiance, simply substitute the images ***mss72_2_rad*** for ***mss_72_2_regress*** and ***mss_92_2_rad*** for ***mss92_2*** in the instructions below.

Image subtraction can be performed using the *IMAGE CALCULATOR*, or alternatively, with the dedicated change detection program, *IMAGEDIFF*. We will use the latter program, which gives you 4 choices for the type of output, as discussed in the introduction to this chapter. We will first select a type of classification in which the differenced image output is grouped into 6 classes. The classes are calculated by converting the raw differenced DN values to z-scores. Z-scores are simply a type of transformation, where the values are expressed as a distance from the mean of the change DN values, in units of the standard deviation of the distribution. Standard deviation units are often used as a way of grouping the otherwise continuous change values.

Image differencing
Menu location: **GIS Analysis – Change/Time Series – IMAGEDIFF**
1. Start the IMAGEDIFF program from the main IDRISI menu. 2. In the *IMAGEDIFF* window, double click in the text box for *Earlier image*. In the resulting pick list, double click on ***MSS_72_2_REGRESS***. 3. Double click in the text box for the *Later image*, and in the resulting pick list, double click on ***mss92_2***. 4. In the text box for *Output filename*, enter **72-92-imagediff**. 5. For the *Output option*, select the radio button for the *Standardized class image*. 6. Figure 9.6.1.a shows the IMAGEDIFF window with the processing parameters specified. 7. Click on *OK*. 8. IDRISI will automatically display the resulting image (Figure 9.6.1.b).

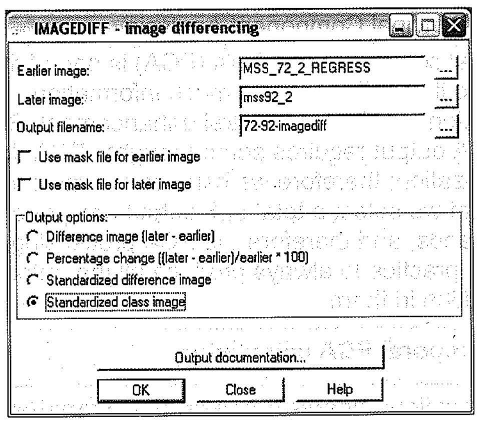


Figure 9.6.1.a The *IMAGEDIFF* window.

Figure 9.6.1.b Results of image differencing using MSS band 2 (red) for 1972 and 1992.

The image differencing image (Figure 9.6.1.b) shows a very interesting and distinct pattern of land use change. To understand this pattern we need to think about how vegetation affects red reflectance. Desert soil will be brightest, especially where salts have accumulated. The chlorophyll in vegetation absorbs red radiance, and thus vegetated areas will be darker. Desert vegetation is relatively sparse, and not very green. Thus, natural desert vegetation will be darker than exposed soil, but not as dark as irrigated green vegetation, especially residential lawns and golf courses. With that background, we can now interpret the image.

The center of the city has not changed appreciably. It is therefore shown in the change classification in the pastel colors of yellow and pale green, representing respectively a small drop, or small rise, in radiance. Surrounding this unchanged core, is a "U" of change, shown in red and orange, and representing growth to the east, south and west. The new urban land cover, especially residential development with lawns, is much darker in the red band than the relatively sparsely vegetated desert. On the edge of the city is a ring of higher red radiance, shown in shades of green. These areas of higher reflectance represent new construction, and general disturbance of desert vegetation, for example by off-road vehicle traffic.

9.6.2 Principal Component Analysis

Principal component analysis (PCA) is one of the easiest analysis methods to run, and it usually captures much information. However, as we saw in the discussion of PCA for spectral enhancement, Section 6.3.3, the interpretation of the PCA output requires some thought. PCA does not require image normalization; therefore we can use the raw images. In the instructions below, note that we select a total of 8 output components. This is because we have 8 input bands, and therefore the PCA processing produces up to 8 output bands. It is good practice to always produce all the output bands, in order to evaluate the information in them.

Multitemporal PCA calculation

Menu location: **Image Processing – Transformation - PCA**

1. Start the PCA program from the main menu.
2. In the PCA window, click on the button to *Insert layer group…* In the resulting pick list, double click on ***mss72***
3. For a second time, click on the *Insert layer group…* button. In the resulting pick list, double click on ***mss92***.
4. In the *Number of components to be extracted:* text box, enter **8**.
5. In the *Prefix for output files (can include path):* text box, enter **PCA**.
6. Select the radio button for *Complete output.*
7. Figure 9.6.2.a shows the PCA window with the processing parameters specified.
8. Click on *OK*.
9. The text results are displayed in a new window, *Module Results*. The images are not displayed automatically.

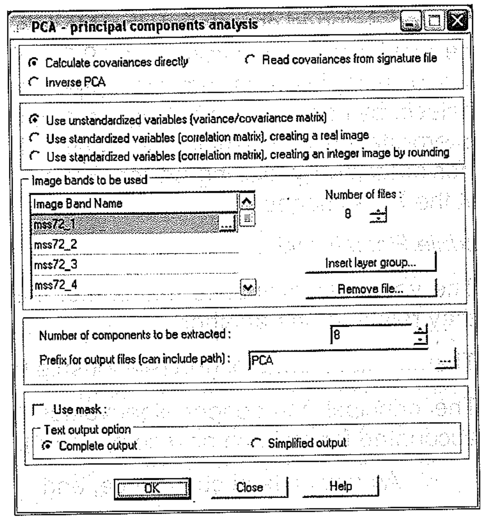


Figure 9.6.2.a The *PCA* Window.

Table 9.6.2.a The PCA *Module Results* output.

VAR/COVAR	mss72_1	mss72_2	mss72_3	mss72_4	mss92_1	mss92_2	mss92_3	mss92_4
mss72_1	165.28	221.90	199.75	174.17	94.82	138.59	144.11	123.94
mss72_2	221.90	316.40	282.57	245.96	128.84	197.40	205.44	176.99
mss72_3	199.75	282.57	268.40	239.72	115.38	175.90	193.42	171.59
mss72_4	174.17	245.96	239.72	222.11	101.24	154.19	175.49	159.48
mss92_1	94.82	128.84	115.38	101.24	91.29	137.83	133.59	111.34
mss92_2	138.59	197.40	175.90	154.19	137.83	223.15	214.03	179.02
mss92_3	144.11	205.44	193.42	175.49	133.59	214.03	228.25	200.06
mss92_4	123.94	176.99	171.59	159.48	111.34	179.02	200.06	183.95

COR MATRX	mss72_1	mss72_2	mss72_3	mss72_4	mss92_1	mss92_2	mss92_3	mss92_4
mss72_1	1.00000	0.97037	0.94839	0.90906	0.77193	0.72164	0.74197	0.71082
mss72_2	0.97037	1.00000	0.96964	0.92780	0.75806	0.74291	0.76446	0.73366
mss72_3	0.94839	0.96964	1.00000	0.98181	0.73712	0.71876	0.78146	0.77225
mss72_4	0.90906	0.92780	0.98181	1.00000	0.71096	0.69259	0.77941	0.78900
mss92_1	0.77193	0.75806	0.73712	0.71096	1.00000	0.96572	0.92546	0.85919
mss92_2	0.72164	0.74291	0.71876	0.69259	0.96572	1.00000	0.94837	0.88359
mss92_3	0.74197	0.76446	0.78146	0.77941	0.92546	0.94837	1.00000	0.97638
mss92_4	0.71082	0.73366	0.77225	0.78900	0.85919	0.88359	0.97638	1.00000

COMPONENT	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8
% var.	85.67	10.34	2.53	0.62	0.49	0.13	0.12	0.09
eigenval.	1455.45	175.69	43.04	10.45	8.37	2.27	2.03	1.51
eigvec.1	0.3139	-0.2684	-0.3138	-0.3349	0.6354	0.3319	0.3157	-0.0731
eigvec.2	0.4423	-0.3627	-0.3273	-0.3676	-0.5034	-0.0835	-0.3922	-0.1276
eigvec.3	0.4104	-0.3392	0.1674	0.2419	-0.1025	-0.3908	0.4607	0.5046
eigvec.4	0.3668	-0.2875	0.4381	0.5182	0.1398	0.2971	-0.2994	-0.3535
eigvec.5	0.2221	0.2554	-0.3241	0.2316	0.4760	-0.4963	-0.4836	0.1414
eigvec.6	0.3451	0.4738	-0.4216	0.3809	-0.2832	0.4545	0.1682	0.1361
eigvec.7	0.3644	0.4266	0.1937	-0.1724	-0.0415	-0.3705	0.3440	-0.6006
eigvec.8	0.3189	0.3565	0.5041	-0.4441	0.0664	0.2274	-0.2533	0.4467

LOADING	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8
mss72_1	0.9314	-0.2767	-0.1601	-0.0842	0.1430	0.0389	0.0350	-0.0070
mss72_2	0.9487	-0.2703	-0.1207	-0.0668	-0.0819	-0.0071	-0.0315	-0.0088
mss72_3	0.9556	-0.2744	0.0670	0.0477	-0.0181	-0.0360	0.0401	0.0378
mss72_4	0.9389	-0.2557	0.1929	0.1124	0.0271	0.0301	-0.0287	-0.0291
mss92_1	0.8868	0.3542	-0.2225	0.0784	0.1441	-0.0783	-0.0722	0.0182
mss92_2	0.8813	0.4204	-0.1852	0.0824	-0.0548	0.0459	0.0161	0.0112
mss92_3	0.9202	0.3742	0.0841	-0.0369	-0.0080	-0.0370	0.0325	-0.0488
mss92_4	0.8971	0.3484	0.2438	-0.1059	0.0142	0.0253	-0.0266	0.0404

After the processing is completed, the *Module Results* window will display a text file of the results of the analysis (Table 9.6.2.a). As mentioned above, one of the difficulties of using PCA is that the output images can be difficult to interpret. Nevertheless, by carefully examining the output as shown in the *Module Results*, some interpretation can usually be made. Therefore, these results should be saved, for example by clicking on the *Save to File* button, because they help to interpret the PCA images.

The *Module Results* includes information on:

- The variance/covariance matrix (i.e. the variability of the bands, and how they relate to one another),
- The correlation matrix (the relationship between the bands)
- The principal component eigenvalues (amount of variance explained, or accounted for by each new component), expressed in two forms:
  - As raw units of covariance, and
  - As a proportion of the total variance ("% var.") in the output.
- The eigenvectors, which give the equation to convert the input data to get the output data.
- The Loadings, which provide information on the correlation between the original bands and the new components.

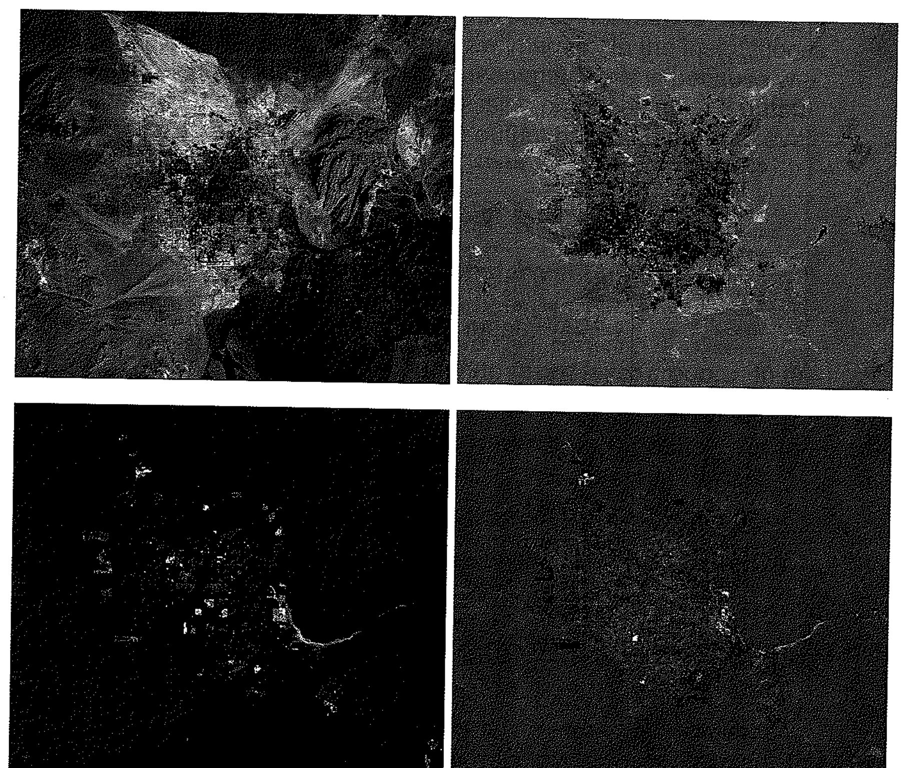


Figure 9.6.2.b Upper left: ***pcacmp1***. Upper right: ***pcacmp2***. Lower left: ***pcacmp3***. Lower right: ***pcacmp4***.

In order to interpret the text output, it will be useful to have the PCA images displayed. Therefore, use the IDRISI Display launcher to display the 8 output files, each time using a GreyScale Palette file (Figure 9.6.2.b shows the first four PCA images). For the discussion below, you should refer to the relevant images, Table 9.6.2.a, as well as the two original false color composites of 1972 (***mss72_fcc***) and 1992 (***mss92_fcc***), to see if you can verify the interpretations suggested.

In interpreting the values for the Las Vegas change data (Table 9.6.2.a), we see that the first four components (C1, C2, C3 and C4) comprise a total of over 99% of the original variance (i.e. 85.67% + 10.34% + 2.53% +0.62%= 99.16%) This suggests that the majority of the information has been captured in these first four components. Note how the images appear to get progressively more noisy with higher numbers. For example, notice how ***pcacmp1*** shows the pattern of land use clearly, but ***pcacmp8*** is dominated by the image striping.

The eigenvectors help us understand what the output bands mean. For example, we find that the eigenvectors for C1 are all positive, and similar (0.22 to 0.44). This suggests that C1 (the image ***pcacmp1***) represents an average of all the bands, of both dates. Indeed, the loadings show that C1 is highly correlated with all the input bands (the values are approximately 0.9 or greater).

C2, on the other hand, has negative eigenvectors for the bands for date 1, and positive values for the bands for date 2. This implies that C2 (the image ***pcacmp2***), is a difference image of 1992-1972, and is thus somewhat similar to the results of the image differencing exercise we completed earlier.

C3 is notable for having negative values for the visible bands (original image bands 1 and 2) for the 1972 and 1992 data, but positive values for the near infrared bands (original image bands 3 and 4). Since the difference between the visible and near infrared bands is a measure of vegetation presence, this suggests C3 (***pcacmp3***) is an average of the vegetation for the two dates.

C4 is similar to C3, in that it has negative values for the visible bands for 1972, and positive values for the near infrared bands for the same year. However, C4 has the opposite pattern for the 1992 bands, thus suggesting this component is a vegetation difference image, of 1972-1992. Note that this means that new vegetation in 1992 will show as dark, not bright, in the image ***pcacmp4***.

AS a final step, the PCA components can be visualized as a false color composite, using components 1, 2, and 4. (Since component 3 is an average vegetation image, it is not so useful, and therefore is not used.) Based on the discussion above, however, before using component 4, we should first reverse this image. This will make new vegetation bright in the image, instead of dark, and thus make interpretation of the false color composite easier. This reversal will make no other difference to the outcome.

Create inverse image with SCALAR
Menu location: **GIS Analysis – Mathematical operators - SCALAR**
1. Start the SCALAR program from the main IDRISI menu. 2. In the *SCALAR* window, double click in the Input image text box. In the resulting pick list, double click on ***PCAcmp4***. 3. In the *Output image* text box, enter **pcacmp4a**. 4. In the *Scalar value* text box, enter **-1**. 5. Select the radio button for *Multiply*.

6. Figure 9.6.2.c shows the *SCALAR* window with the processing parameters selected.
7. Click on *OK*.
8. The image is automatically displayed.

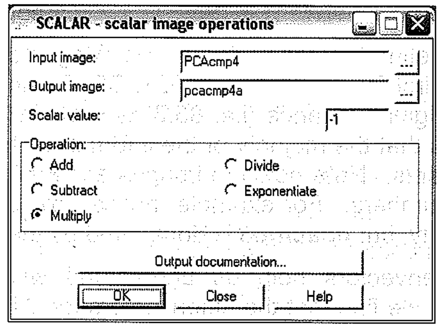


Figure 9.6.2.c The SCALAR window.

You are now ready to create the false color composite, as described below.

Create a color composite image
Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, double click in the *Blue image band* text box, and then double click on the file ***pcacmp1*** in the subsequent *Pick list.*
3. Double click in the *Green image band* text box, and then double click on ***pcacmp2***.
4. Double click in the *Red image band* text box, and then double click on ***pcacmp4a***.
5. Enter the *Output image* filename in the text box provided: **pca124fcc**.
6. Click *OK* to create and display the false color composite.

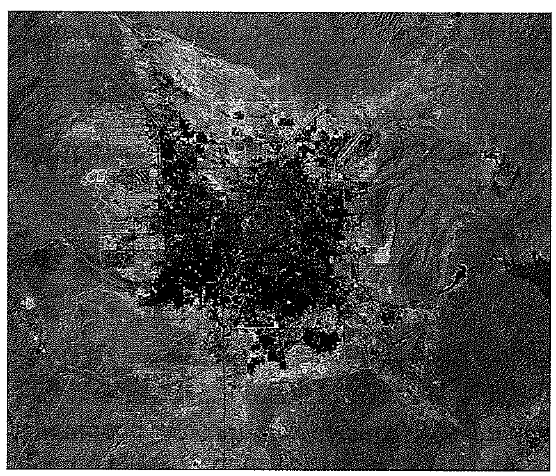


Figure 9.6.2.d Multitemporal PCA false color composite.

In the resulting image (Figure 9.6.2.d), see if you can relate the colors to your knowledge of the original bands. For example, red should be new vegetation in 1992, and green to cyan should represent areas where the albedo (average brightness) increased. Note, however, that the image presents an interesting overview of the pattern of change in Las Vegas – with most growth occurring in a ring to the east, south and west, and comparatively little growth to the north.

9.6.3 Change Vector Analysis

Change vector analysis, like image differencing, requires radiometrically normalized data. It is therefore essential to complete sections 9.4 and 9.5 prior to working through this exercise. We will use the regression-normalized data (i.e. from Section 9.5) for this exercise. However, if you wanted to use the radiance-based data, you would use the images **mss72_2_rad**, **mss72_4_rad**, **mss92_2_rad** and **mss92_4_rad.**

Although some users of change vector analysis use spectrally transformed data as input into change vector analysis, we will use the radiometrically normalized MSS bands. Using the MSS bands will make it easier to compare the results to other methods.

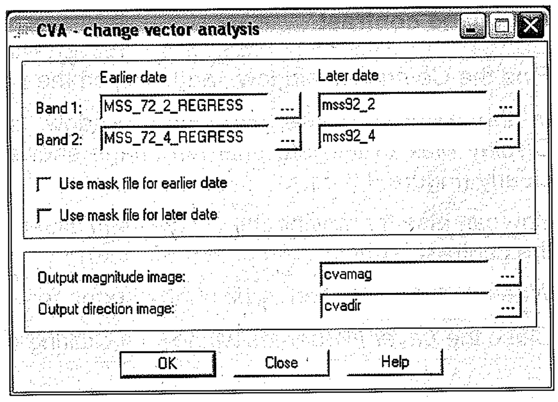


Figure 9.6.3.a The *CVA* window.

Change vector analysis
Menu location: **GIS Analysis – Change/Time Series – CVA**
1. Start the CVA program from the main IDRISI menu. 2. In the *CVA* window, double click in the text box for the *Earlier date* and *Band 1*. In the resulting pick list, double click on ***MSS_72_2_REGRESS***. 3. Double click in the text box for the *Earlier date* and *Band 2*. In the resulting pick list, double click on ***MSS_72_4_REGRESS***. 4. Now chose the files for the *Later date*. Start by double clicking in the *Band 1* text box. In the resulting pick list, double click on the raw 1992 band 2 data ***mss92_2***. 5. Double click in the *Later date* and *Band 2* text box. In the resulting pick list double click on ***mss92_4***. 6. In the Output magnitude image text box, enter **cvamag**. 7. In the Output direction image text box, enter **cvadir**.

8. Figure 9.6.3.a shows the CVA window with the processing parameters specified.
9. Click on *OK*.

Unlike other IDRISI programs, CVA does not open the output images. Start by opening the change magnitude image.

Display image

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***cvamag***.
3. Select the radio button for the *GreyScale* palette file.
4. Click on *OK* to display the image.

After the image has opened, adjust the contrast of the image.

Adjust image contrast

1. Find the *Composer* window., and click on the *Layer properties* button.
2. In the resulting *Layer Properties* window, slide the *Contrast Setting* for *Display Max* to the left, until the image shows the patterns of change more clearly (Figure 9.6.3.b).
3. You can also try moving the *Display Min* slider to the right, in order to improve the contrast farther.
4. When you are satisfied, click on the button for *Apply*
5. Close the *Layer Properties* window by clicking on *OK*.

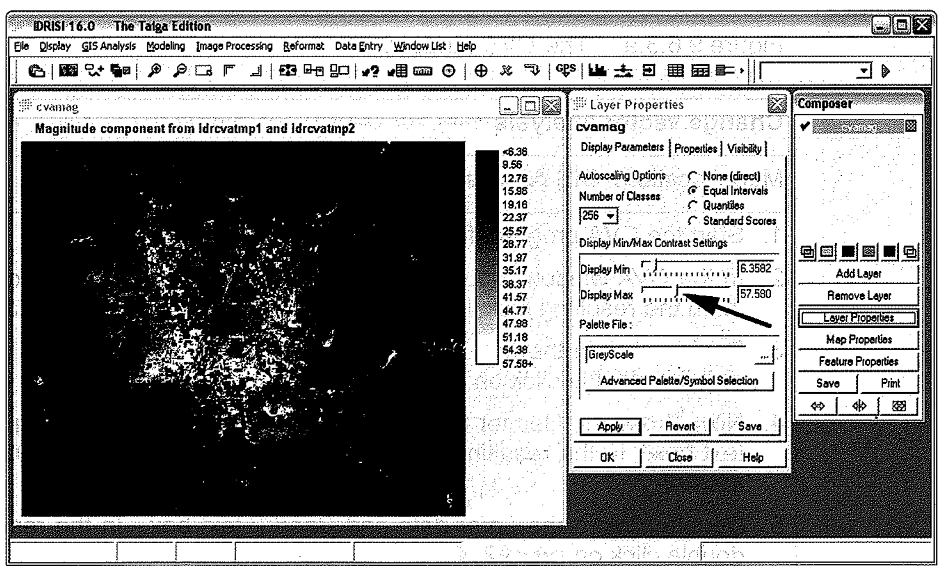


Figure 9.6.3.b Setting the sliders for *Display Min* and *Display Max* to enhance the magnitude of the spectral change.

Figure 9.6.3.b displays the areas of change very clearly. The center of the city has not changed appreciably. On the other hand, change is concentrated across the south of the city, and to a slightly lesser extent to the east and west. Only isolated areas of change are indicated in the desert, associated with local changes such as landslides, changes in the Las Vegas Wash (the river running through Las Vegas), water levels in Lake Mead, and mining.

Now display the change direction image using the *IDRISI Default Quantitative* palette.

Display image
Menu: **Display – DISPLAY LAUNCHER**
1. Start the DISPLAY LAUNCHER from the main menu or icon bar. 2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***cvadir***. 3. Click on *OK* to display the image (Figure 9.6.3.c).

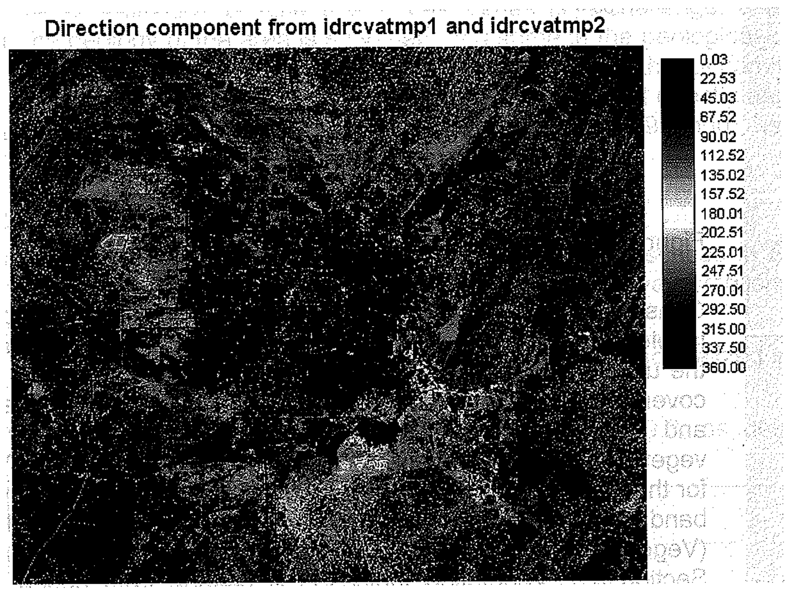


Figure 9.6.3.c Change direction image.

Interpreting the change direction image is more difficult than the magnitude image. However, with a little background information, the meaning of this image becomes much clearer.

Use the cursor inquiry tool from the main menu to query the pixel values in this image. The DN values are in units of degrees, and can be interpreted with reference to the legend and also Figure 9.6.3.d, as will be explained in more detail below. (Note that the IDRISI help for this program appears to be incorrect in specifying that the angles are those from date 1, though the figure in the help file correctly shows the angles as being calculated from date 2.)

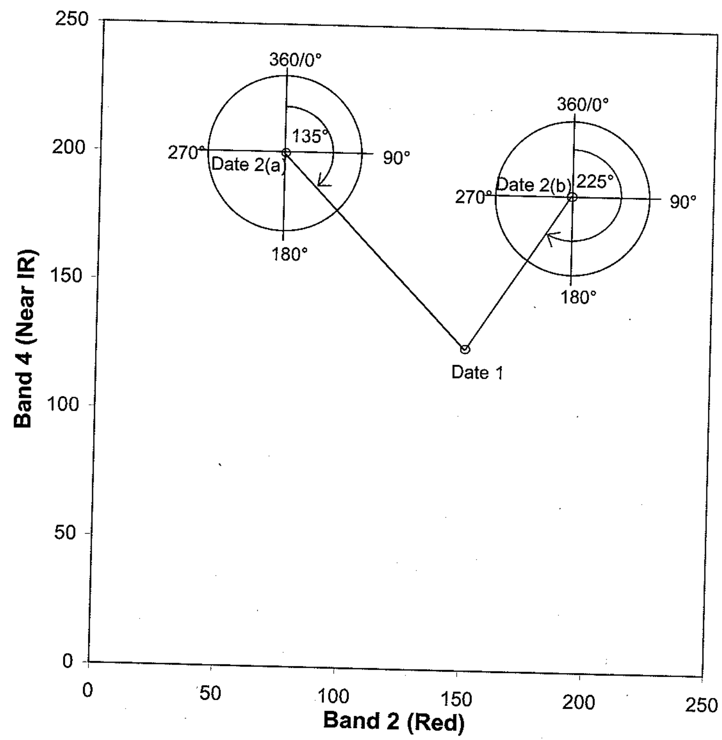


Figure 9.6.3.d Interpreting the CVA direction angles.

Consider a pixel, which has a combination of DN values associated with the point labeled *Date 1* in Figure 9.6.3.d. Hypothetically, this point might be a pixel from the undisturbed desert, with only sparse vegetation cover. This type of ground cover is likely to have moderate to high reflectance in DN values in both the red and near infrared bands. If this pixel is subsequently converted to lush vegetation, for example one of the many golf courses in Las Vegas, the DN value for the red band will decrease due to chlorophyll absorption, whereas the infrared band will increase due to scattering off the spongy mesophyll of the grass leaves. (Vegetation is characteristically bright in the near infra-red, as was discussed in Section 5.3, Vegetation Indices.) A change from desert to green grass will therefore result in the movement of the point up and to the left in the graph (see the point labeled Date 2(a) in Figure 9.6.3.d). This direction of movement, *measured from the second point's location*, is an angle of 135°. With reference to the legend of the change direction image for Las Vegas (Figure 9.6.3.c), we see that change of approximately 135° is represented in shades of green.

It is important to realize that CVA separates change magnitude from direction. Changes associated with the greening of previously built suburbs will also have the same change direction as new vegetation due to the construction of a new golf course in what was previously desert. However, the greening of a suburb will, at least over the short term, have a much smaller magnitude of change compared to the new golf course. Thus, not all the green in change direction image represents change between land cover classes, but instead may represent subtle changes within a relatively consistent land cover class.

An alternative change scenario to the one just described is presented by the pixel labeled *Date 2(b)* in Figure 9.6.3.d. This pixel could represent a desert area that is disturbed, for example, due to construction activities or even recreational off-road vehicle use. In this circumstance, the loss of the sparse vegetation and erosion of surface material will result in both red and near-infrared DN values increasing. This direction of change is associated with a 225° change, and is shown in the change direction image legend as an orange color. It is clear from Figure 9.6.3.c that this degradation of land cover is extensive on the periphery of Las Vegas.

9.7 Post Classification Change Detection

Post-classification change detection is the GIS overlay operation of two previously classified images. Therefore, the major part of applying post-classification change detection is classification.

Chapter 7 describes classification in detail, and the section on supervised classification (7.3) should be completed prior to doing this section. Therefore, the instructions for classification will be rather brief in this section. If it is some time since you completed the classification section, or you find the instructions below to brief, you may wish to refresh your memory by rereading through that material.

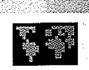
Note: The classification of land use in Las Vegas is a challenge, especially because the geology of the area is so varied, and some of the geological classes are spectrally similar to the urban land use classes, especially that of commercial activities. Readers wishing to skip over the classifications, and directly apply the GIS overlay operation may go directly to Section 9.7.9, and use the classifications provided with this chapter's data.

9.7.1 Preparatory

You should have already copied the data from the CD, as described in Section 9.2. In addition, as described in Section 9.3, you should have established the ***Chap9*** project file within the *IDRISI EXPLORER*.

For this section, we will use the original raw data, and not the normalized images created in the previous sections.

Display the two false color composites created in Section 9.3, as described below.



Initial display of images
Menu: **Display – DISPLAY LAUNCHER**
1. Start the DISPLAY LAUNCHER from the main menu or icon bar. 2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***ms72_fcc***. 3. Click on *OK* to display the image. 4. Start the DISPLAY LAUNCHER again. 5. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***ms92_fcc***. 6. Click on *OK* to display the image.

9.7.2 Develop a List of Spectral Classes

The first step is to develop the list of spectral classes. Examine the 1972 false color composite (***mss72_fcc***). Five informational classes can be identified, as listed in Table 9.7.2.a. The Desert class is very variable, and consists of at least

8 or 10 different spectral classes. We will therefore need to collect training signatures for each of the various spectral desert classes. We will leave this to last in the digitizing order.

Table 9.7.2.a Supervised classification classes for Las Vegas.

Class Number	Name	Color in false color composite	Texture
1	Water	Black	Smooth
2	Vegetation	Bright red	Moderate
3	Commercial / Industrial / Transportation	Blue to gray; black	Rough
4	Residential	Dark red to magenta	Rough
5	Desert	Highly variable: brown, black, gray, white	Moderate

9.7.3 Digitize Training Polygons for the 1972 Image

Our overall aim is to classify each of the two images using maximum likelihood classification in separate classifications. This means that we will need to collect a set of class signatures for each image independently.

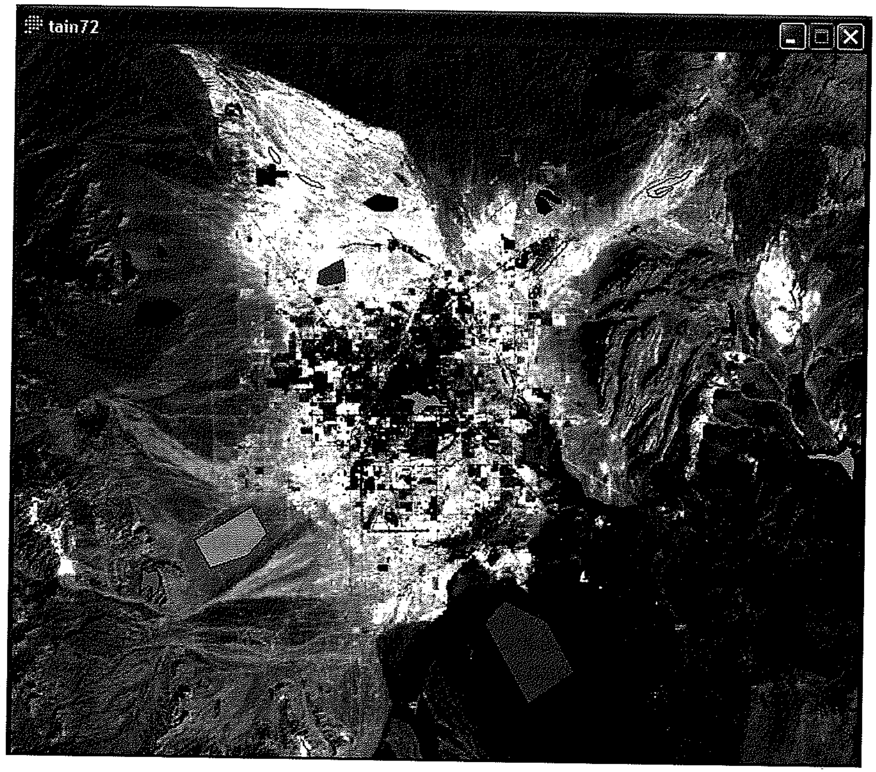


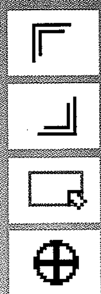
Figure 9.7.3.a False color composite of 1972 MSS data with training polygons overlaid. Note the more than 10 training polygons (each comprising a separate spectral class in the classification, and thus having a unique associated number) for the Desert class.

After you have developed the list of spectral classes, digitize the polygons over the 1972 image. Figure 9.7.3.a shows a recommended number and extent of the polygons required. The instructions below describe the procedures for digitizing the polygons for the training areas. Those who feel the instructions are too brief might review Section 7.4.3.

Digitizing training polygons

Menu location: Main tool bar icons only (Note that the icons are grayed out if an image is not yet displayed.)

1. The false color image ***ms72_fcc*** should already be displayed in a Viewer.



2. Click on the *Full extent normal* icon from the main tool bar, to return the image to the default zoom if you have zoomed in on part of the image.
3. *Full extent maximized* icon from the main tool bar, to enlarge the image display.
4. Click on the *Zoom window* icon. Draw a zoom box around the lake on the right side of the image (this is a corner of Lake Mead, created by the Hoover Dam, on the Colorado River.)
5. Click on the *Digitize* icon. A dialog box labeled *DIGITIZE* will open.
6. Enter the file name **Water** in the text box labeled *Name of layer to be created*. Leave all other values at their defaults.
7. Click on *OK* to close the *DIGITIZE* window.
8. Move the cursor over the image, and the cursor will become a *Digitize* icon, instead of the normal arrow.
9. Digitize the first vertex of the water polygon by pressing the *left* mouse button. Continue clicking in the image to specify the outer boundaries of the polygon you wish to digitize. <u>Note</u>: Try to avoid the small islands in the lake.
10. Close the polygon by pressing the *right* mouse button. Note that the program automatically closes the polygon by duplicating the first point; so you do not need to attempt to close the polygon by digitizing the first point again.

11. Save the polygon file by clicking on the *Save digitized data icon.*
12. A *Save prompt* dialog box will open. Click on *Yes.*

13. Click on the *Full extent normal* icon from the main tool bar, to return the image to the default zoom.
14. Click on the *Full extent maximized* icon from the main tool bar.
15. Click on the *Zoom window* icon. Draw a zoom box around the bright red vegetation in the irrigated fields to the right (east) of the city.
16. Now start digitizing the polygon for vegetation by clicking on the *Digitize* icon.
17. The *DIGITIZE* dialog box will open again.
18. Select the radio button for *Create a new layer for the features to be digitized.*
19. Click *OK.*
20. Another dialog box labeled *DIGITIZE* will open.
21. Enter the file name **Vegetation** in the text box labeled *Name of layer to be created*. Leave all other values at their defaults.
22. Click on *OK* to close the *DIGITIZE* window.

23. Digitize the vegetation polygon with left mouse clicks. Close the polygon with a right mouse click. Note: Digitize the bright red region only.

24. Save the polygon file by clicking on the *Save digitized data icon*.
25. A *Save prompt* dialog box will open. Click on *Yes*.
26. Repeat the sequence of restoring, maximizing and zooming, (steps 13-15 above), only this time zoom in on the dark downtown region, representing the commercial core of the city. Name the file **commercial**.
27. Add to the commercial class by digitizing a second polygon, this time over the airport runway, south of the city. (The runway is a good example of the transportation part of this class.) Follow steps 13-15 to zoom in on the runway.

28. Click on the Digitize icon.
29. This time, when the *DIGITIZE* dialog box opens, accept the default radio button for *Add features to the currently active vector layer.*
30. Click *OK*.
31. Another *DIGITIZE* dialog box will open.
32. The ID for the polygon will be incremented automatically. Be sure to set it back to 1, as both commercial polygons should be digitized as part of the same class.
33. Digitize the polygon.

34. Save the polygon file by clicking on the *Save digitized data icon*.
35. A *Save prompt* dialog box will open. Click on *Yes*.
36. Now digitize the residential class. Follow steps 13-15 to zoom in on a dark red area of the more mature suburbs.

37. Click on the *Digitize* icon.
38. The *DIGITIZE* dialog box will open again.
39. Select the radio button for *Create a new layer for the features to be digitized.*
40. Click *OK*.
41. In the text box labeled *Name of layer to be created*, enter **Residential**.
42. Click on *OK*.
43. Digitize the residential polygon.

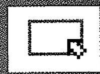
44. Save the polygon file by clicking on the *Save digitized data icon*.
45. A *Save prompt* dialog box will open. Click on *Yes*.

So far we have created the polygons for all the training areas, except the desert. Because the desert is so complex, we will now digitize multiple spectral classes for this area. These will be classified separately, and then only after the classification will they be grouped to a single desert class. Figure 9.7.3.a gives the approximate distribution of training areas. Be sure to include the very bright playas and very dark rocks, too.

Digitizing training polygons (cont.)

46. Click on the *Full extent normal* icon from the main tool bar, to return the image to the default zoom.

47. Click on the *Full extent maximized* icon from the main tool bar, to enlarge the image display.



48. Click on the *Zoom window* icon. Draw a zoom box around the first desert area.

49. Click on the *Digitize* icon.
50. A dialog box labeled *DIGITIZE* will open.
51. Select the radio button for *Create a new layer for the features to be digitized.*
52. Click *OK*.
53. Another dialog box labeled *DIGITIZE* will open.
54. Enter the file name **Desert1** in the text box labeled *Name of layer to be created*. Leave all other values at their defaults.
55. Click on *OK* to close the *DIGITIZE* window.
56. Digitize the first desert polygon.

57. Save the polygon file by clicking on the *Save digitized data icon.*
58. A *Save prompt* dialog box will open. Click on *Yes.*
59. Digitize additional desert polygons, by following steps 48 to 57 as many times as necessary. Each time give the file a new name, e.g. **Desert2, Desert3,** etc.
60. Once you have completed all 5 desert classes, close the displayed image. IDRISI will prompt you to save any unsaved polygons.

9.7.4 Create Signatures with MAKESIG

We are now ready to run the MAKESIG program to generate the signature files. (See also Section 7.4.4).

Create signature files using MAKESIG

Menu location: **Image Processing - Signature development – MAKESIG**

1. Start the MAKESIG program from the main menu.
2. In the *MAKESIG* dialog box, click on the Pick list button (…) to the right of the text box of *Vector file defining training sites.*
3. In the Pick list window, double click on the ***Water*** file.
4. In the *MAKESIG* dialog box, click on the button *Enter signature filenames.*
5. The *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **Water**.
6. Uncheck the box labeled *Create signature group file.*
7. Click on *OK* to close the *Enter signature filenames* dialog box.
8. In the *MAKESIG* dialog box, click on the button for *Insert layer group.*
9. From the *Pick list,* double click on ***ms_72***.
10. The *MAKESIG* dialog box should now show the four bands of the MSS data.
11. Click *OK* to create the signature file.
12. Now create the next signature file, for vegetation. Start by double clicking in the *MAKESIG* dialog box text box for *Vector file defining training sites .*

13. In the resulting pick list, double click on ***Vegetation***.
14. In the *MAKESIG* dialog box, click on the button *Enter signature filenames*.
15. The *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **Vegetation**.
16. Click on *OK* to close the *Enter signature filenames* dialog box.
17. In the MAKESIG dialog box, click *OK* to create the signature file.
18. Repeat steps 12-17 for each of the remaining vector files: ***commercial, residential, desert1, desert2, desert3, desert4, and desert5.*** Remember each time to click on the Enter signature filenames button, and change the right cell to the appropriate file name.

Now create a signature group file with the combined list of signatures. In Section 7.4.5, we used the IDRISI EXPLORER. In this section we will use the IDRISI COLLECTION EDITOR.

Create signature group file with the COLLECTION EDITOR

Menu location: **File – COLLECTION EDITOR**

1. Open the COLLECTION EDITOR from the main menu.
2. In the *COLLECTION EDITOR* window, use the menu for *File – New.*
3. In the resulting *New file…* window, click on the pull-down menu next to the text box for *Files of type*. Select *Signature group files (*.sgf)*.
4. In the *File name* text box, type **mss72**.
5. Click on *Open*.
6. The *COLLECTION EDITOR* window will now show the list of potential signatures in the left column. The right column, currently blank, is where signatures will be entered (Figure 9.7.4.a).
7. In the left column click on ***Water***.

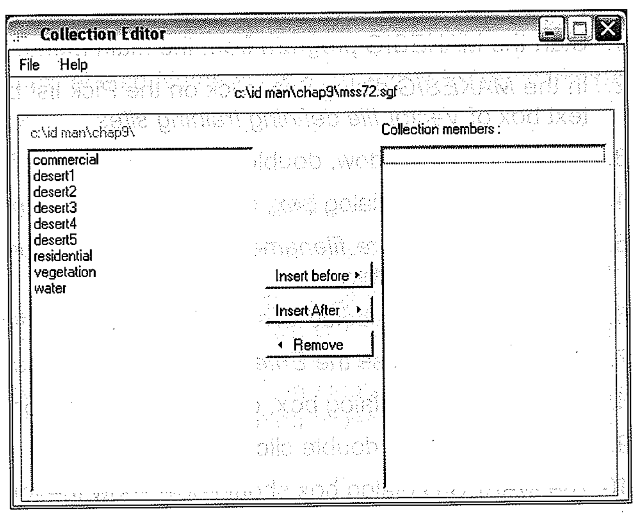


Figure 9.7.4.a The *COLLECTION EDITOR* window after specifying the new signature group file name.

8. Click on the button *Insert after >*
9. The Water signature should now be listed in the right column.
10. Repeat steps 7 and 8, to insert, in the following order, ***vegetation, commercial, residential, desert1, desert2, desert3, desert4,*** and ***desert5*** (Figure 9.7.4.b).
11. In the *COLLECTION EDITOR* window, use the menu to select *File – Save.*
12. Close the *COLLECTION EDITOR* window. (It is important to close the window, even though we will use the program again later.)

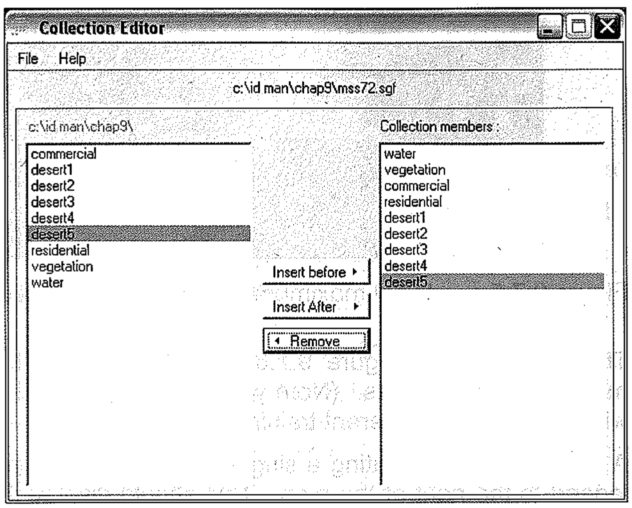


Figure 9.7.4.b The COLLECTION EDITOR window with signatures specified in order.

9.7.5 <u>Classify the 1972 Image</u>

Classify the 1972 MSS raster group file using maximum likelihood program, as described below.

Classify an image with MAXLIKE

Menu location: **Image processing - Hard classifiers – MAXLIKE**

1. Start the MAXLIKE program from the menu.
2. In the *MAXLIKE* dialog box, click on the *Insert signature group* button.
3. In the *Pick List*, double click on the ***MSS72*** signature group file.
4. In the MAXLIKE dialog box, specify the *Output file name* as **Max72a**.
5. Click on *OK* to run the classification.
6. The classification is displayed automatically (Figure 9.7.5.a).
7. Close the *MAXLIKE* dialog box, even though we will use this program again later.

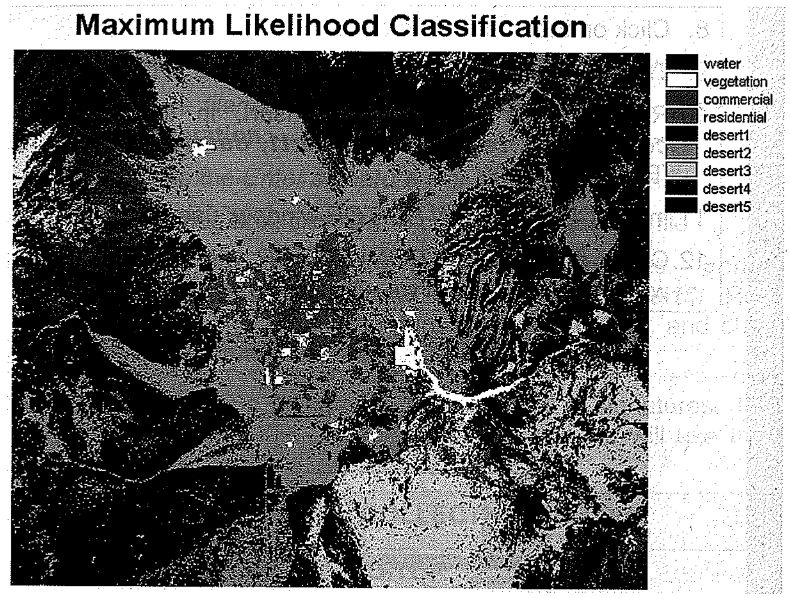


Figure 9.7.5.a Initial maximum likelihood classification

The classification (Figure 9.7.5.a) is a little hard to interpret because of the multiple desert classes. (Note your classification will look different, because you will have selected different training areas.)

A good way of evaluating a single class is to click on the class color chip in the legend to the right of the map. This should display that class in red, and all the other classes in black (Figure 9.7.5.b). (Warning: we have noticed some anomalous behavior where this option does not always work correctly.)

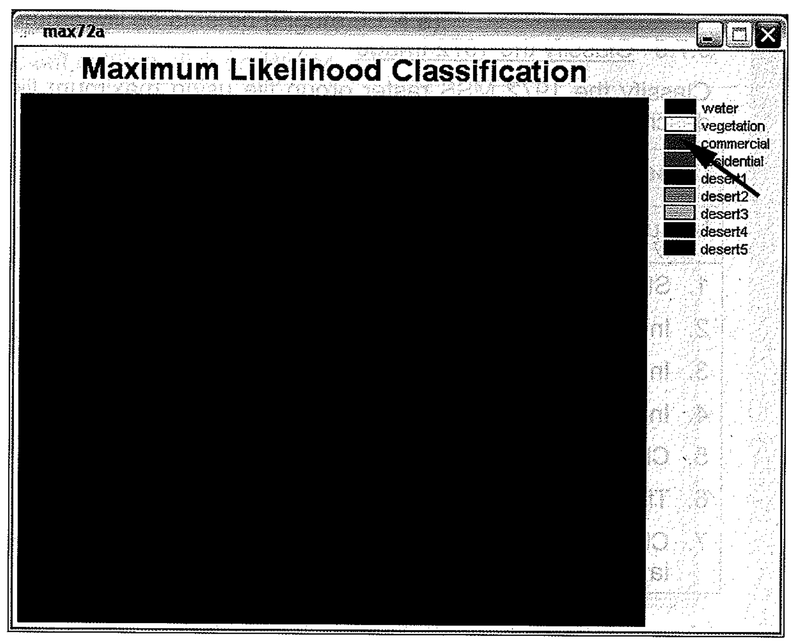


Figure 9.7.5.b Map display when cursor (not shown) is clicked on the *Commercial* class color chip (see arrow).

Figure 9.7.5.b indicates that large areas of the desert are being confused with the commercial class. Therefore, we need to collect additional desert training areas, focused on the areas where *the confusion is most common*.

9.7.6 Add Additional Desert Spectra to the Classification

To collect the addition spectra we need to do the following: display the false composite, digitize additional desert training areas (in the regions of common errors), run MAKESIG on these areas, add these additional spectra to the signature group file, and run the classification again. These steps are described briefly below.

9.7.6.1 Display the False Color Image

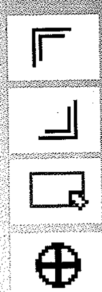
Initial display of images

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***ms72_fcc***.
3. Click on *OK* to display the image.

9.7.6.2 Digitize Additional Desert Training Areas

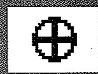
Carefully examine the areas where desert is incorrectly classified as commercial. Identify about 5 such areas.



Digitize additional training areas

1. The false color image ***ms72_fcc*** should already be displayed in a Viewer.
2. Click on the *Full extent normal* icon from the main tool bar, to return the image display to the default zoom.
3. Click on the *Full extent maximized* icon from the main tool bar, to enlarge the image display.
4. Click on the *Zoom window* icon. Draw a zoom box around the first new desert location.
5. Click on the *Digitize* icon. A dialog box labeled *DIGITIZE* will open.
6. Enter the file name **Desert6** in the text box labeled *Name of layer to be created* (adjust the name of this class if necessary, so that it is the next number in your list of desert classes.)
7. Click on *OK* to close the *DIGITIZE* window.
8. Digitize the desert polygon with left mouse clicks. End the polygon with a right mouse click.
9. Save the polygon file by clicking on the *Save digitized data icon*.
10. A *Save prompt* dialog box will open. Click on *Yes*.
11. Click on the *Full extent normal* icon from the main tool bar, to return the image display to the default zoom.
12. Click on the *Full extent maximized* icon to return the display of the image to the entire image.
13. Click on the *Zoom window* icon.

14. Draw a zoom box around the next desert polygon.



15. Click on the *Digitize* icon.
16. The *DIGITIZE* dialog box will open again.
17. Select the radio button for *Create a new layer for the features to be digitized.*
18. Click *OK*.
19. Another dialog box labeled *DIGITIZE* will open.
20. Enter the file name **Desert7** in the text box labeled *Name of layer to be created.*
21. Click on *OK* to close the *DIGITIZE* window.
22. Digitize the next polygon.

23. Save the polygon file by clicking on the *Save digitized data icon.*
24. A *Save prompt* dialog box will open. Click on *Yes.*
25. Repeat steps 11-24 to create 5 more desert polygons.
26. When you are done digitizing, close the DISPLAY. You will be prompted to save any unsaved polygons.

9.7.6.3 Run MAKESIG on the New Signatures

Create additional signature files using MAKESIG

Menu location: **Image Processing - Signature development – MAKESIG**

1. Start the MAKESIG program from the main menu.
2. In the *MAKESIG* dialog box, click on the Pick list button (…) to the right of the text box of *Vector file defining training sites.*
3. In the Pick list window, double click on the ***desert6*** file.
4. In the *MAKESIG* dialog box, click on the button *Enter signature filenames.*
5. The *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **desert6**.
6. Uncheck the box labeled *Create signature group file.*
7. Click on *OK* to close the *Enter signature filenames* dialog box.
8. In the *MAKESIG* dialog box, click on the button for *Insert layer group.*
9. From the *Pick list,* double click on ***ms_72***.
10. Click *OK* to create the signature file.
11. Now create the next signature file, for *Desert7*. Start by double clicking in the *MAKESIG* dialog box text box for *Vector file defining training sites.*
12. In the resulting pick list, double click on ***desert7***.
13. In the *MAKESIG* dialog box, click on the button *Enter signature filenames.*
14. The *Enter signature filenames* dialog box will open. In the blank cell to the right of 1, type **desert7**.
15. Click on *OK* to close the *Enter signature filenames* dialog box.
16. In the MAKESIG dialog box, click *OK* to create the signature file.

17. Repeat steps 12-17 for each of the remaining vector files: ***desert8, desert9, desert10.*** Remember each time to click on the Enter signature filenames button, and change the right cell to the appropriate file name.

9.7.6.4 Add Signatures to the Signature Group File

Add signatures to a signature group file with the COLLECTION EDITOR
Menu location: **File – COLLECTION EDITOR**

1. Open the COLLECTION EDITOR from the main menu.
2. In the *COLLECTION EDITOR* window, use the menu for *File – Open.*
3. In the resulting *Open file…* window, click on the pull-down menu next to the text box for *Files of type.* Select *Signature group files (*.sgf).*
4. Double click in the *File name* text box, and in the resulting pick list, select ***mss72***.
5. Click on *Open*.
6. The *COLLECTION EDITOR* window will now show the list of potential signatures in the left column, and the list of current signatures in the right column.
7. Click on the last signature in the right column (e.g. ***desert5***).
8. In the left column click on ***desert6***.
9. Click on the button *Insert after* >.
10. The desert6 signature should now be listed at the bottom of the right column.
11. Repeat steps 8 and 9, to insert, in the following order the remaining desert signatures: ***desert7, desert8, desert9***, and ***desert10***.
12. Figure 9.7.6.4.a shows the *COLLECTION EDITOR* window with the additional signature files specified.
13. In the *COLLECTION EDITOR* window, use the menu to select *File – Save.*
14. Close the *COLLECTION EDITOR* window.

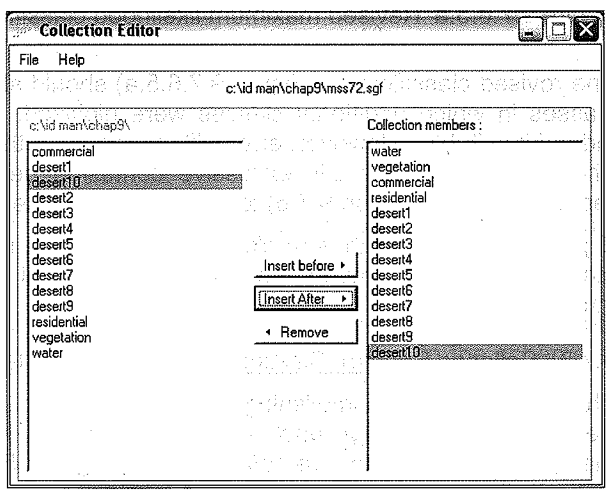


Figure 9.7.6.4.a The *COLLECTION EDITOR* window with additional desert signatures.

9.7.6.5 Reclassify the Image with Maximum Likelihood

Classify an image with MAXLIKE
Menu location: **Image processing - Hard classifiers – MAXLIKE**
1. Start the MAXLIKE program from the menu. 2. In the *MAXLIKE* dialog box, click on the *Insert signature group* button. 3. In the *Pick List*, double click on the ***MSS72*** signature group file. 4. In the MAXLIKE dialog box, specify the *Output image* as **Max72b**. 5. Click on *OK* to run the classification. 6. The classification is displayed automatically (Figure 9.7.6.5.a). 7. Close the *MAXLIKE* dialog box.

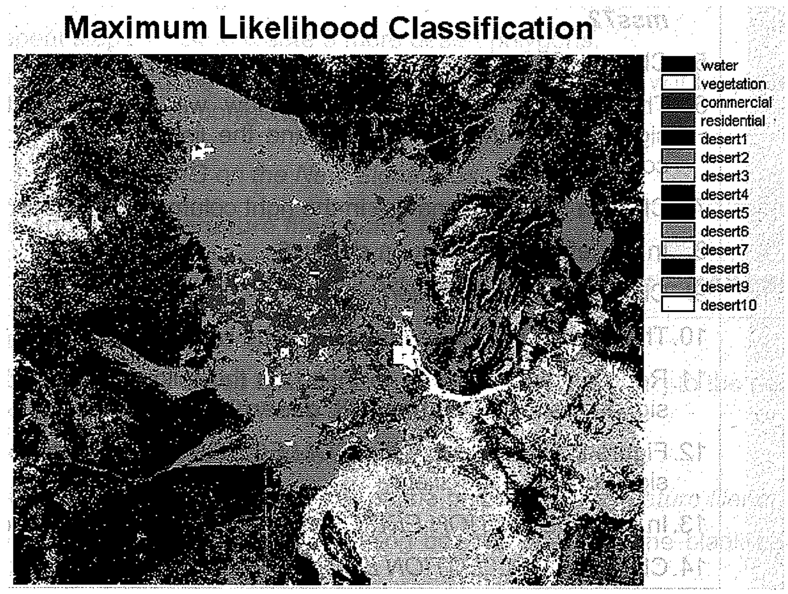


Figure 9.7.6.5.a Revised maximum likelihood classification.

The revised classification (Figure 9.7.6.5.a) should show an improvement for the classes in which additional classes were digitized. Some error is acceptable, indeed inevitable. However, error will propagate to the change detection product. Therefore, if there is still excessive confusion between classes, you should repeat this step (section 9.7.6) to create a second set of additional classes.

If you are satisfied with your classification, you are ready to proceed to the next step, which is to convert the 10 desert spectral classes to a single desert informational class.

9.7.7 Collapse Spectral Classes to Informational Classes

The method for accomplishing the reassignment of classes is described in Section 7.3.6, *Reassign each spectral class to an informational class.* As with that previous exercise, we will use the program EDIT to create an *Attribute Values File*, which specifies the old and new numbers for each class. The *Attribute Values File* is then one of the inputs for the program *ASSIGN*, which creates a new file with the final informational classes generated by combining the spectral classes.

In this case, the Water, Vegetation, Commercial and Residential classes will not change. Only the multiple Desert classes will be collapsed into one class. Therefore, spectral classes 1-5 will stay the same, and the desert classes (10, or the number you have chosen) will all be assigned to the new class 5.

Enter the recode values table with EDIT
Menu location: **Data Entry – EDIT**.
1. Open the program EDIT from the main menu or the main icon bar. 2. The *IDRISI TEXT EDITOR* window will open. 3. In the blank window enter the spectral class number, leave a space then enter the associated informational class number, with each spectral class on a new line. Thus each line has just two numbers: the old and new DN value for that class. Start with spectral class 1 and end with the last spectral class number. See Figure 9.7.7.a for an example of how the completed list might look. 4. Use the *IDRISI TEXT EDITOR* menu to save the file: **File – Save As.** 5. A *SAVE AS* dialog box will open. In the Save as type text field, click on the pull-down list, and select *Attribute Values File*. 6. Enter the file name **reclass72**. 7. Click *SAVE*. 8. A *Values File Information* dialog box will open. Take the default *Integer* option, and click on *OK*.

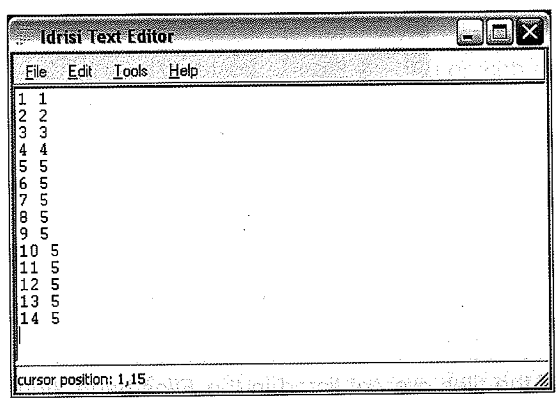


Figure 9.7.7.a The *IDRISI TEXT EDITOR* window with the assignment values specified.

The next step is to use the *Attribute Values* file you have just created to generate a new image, with DN values recoded according to the scheme specified in the text file.

Create a new image with informational class numbers using ASSIGN
Menu location: **Data Entry – ASSIGN**
1. Use the IDRISI main menu to start the ASSIGN program.

2. In the *ASIGN* window, double click in the *Feature definition image* text box. In the resulting pick list, double click on the image you wish to reclass: ***max72b***.
3. In the *Output image* text box type: **max72final**.
4. Double click in the text box next to *Attribute values file.* In the resulting pick list double click on ***reclass72***.
5. Enter an Output title, such as: **1972 Classification**.
6. Click on *OK*.

The ASSIGN program will automatically display the resulting image (Figure 9.7.7.b). This new file will have just numbers for classes. We therefore need to add class names using the IDRISI EXPLORER.

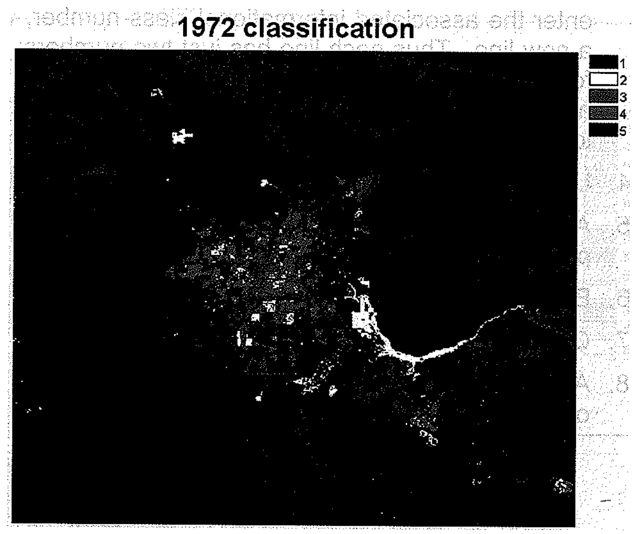


Figure 9.7.7.b Result of the ASSIGN program.

Modifying image metadata with IDRISI EXPLORER

Menu Location: **File - IDRISI EXPLORER**

1. Open the *IDRISI EXPLORER* from the main menu or the main toolbar.
2. In the IDRISI EXPLORER, click on the tab for *Files*.
3. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
4. If the *Metadata* pane is not shown below the *Files* pane, right click on ***max72final.rst***. In the pop-up menu, select *Metadata*.
5. If the Metadata pane is already shown, click on ***max72final.rst***.
6. In the *Metadata* pane, scroll down to *Categories.*
7. Double click in the blank cell next to *Categories*.
8. The *CATEGORIES* window will open.
9. Click four times on the *Add Line* icon on the right of the *CATEGORIES* window, so that five blank lines are shown.

10. In the first blank line, under *Code*, enter **1**.
11. In the next cell, under Category, enter **Water**.
12. In the subsequent blank line, enter **2** and **Vegetation**, and in the following lines **3** and **Commercial**, **4** and **Residential** and **5** and **Desert**.
13. Figure 9.7.7.c shows the CATEGORIES window with the classes specified.
14. Click on *OK*.
15. In the bottom left corner of the *Metadata* pane of the *IDRISI EXPLORER*, click on the *File save* icon.

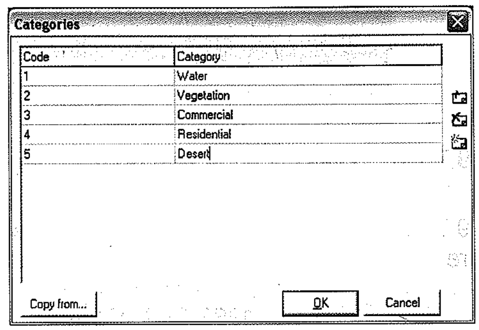


Figure 9.7.7.c The *CATEGORIES* window.

Now redisplay the max72final image using the DISPLAY LAUNCHER, as described below.

Display image
Menu: **Display – DISPLAY LAUNCHER**
1. Start the DISPLAY LAUNCHER from the main menu or icon bar. 2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and then double click on the file ***max72final***. 3. Click on *OK* to display the image.

9.7.8 Classification of the 1992 Image

Once you have completed the classification for the 1972 data, you should repeat the classification exercise, except this time using the 1992 MSS data (***mss92_fcc***). You will need to collect a new set of signatures. It is essential, however, that you should end up with the same specific informational classes, which associated with the same DN values. For example, since 1 represents Water for the 1972 data, 1 should also represent Water for the 1992 data.

Note that IDRISI places each signature in its own file, as well as linking them through the group file. Therefore, for the 1992 signatures, it is very important that you specify a name that differs from those of the 1972 signatures. One way to ensure all the signature names are different is to add the numerals 92 in front of each name, thus Water becomes 92Water.

The final image, after running the ASSIGN program, should be called ***max92final***.

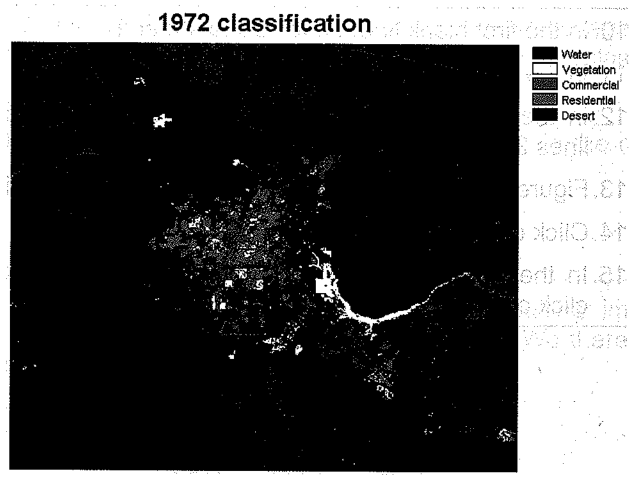


Figure 9.7.7.d Classification with updated legend.

Figure 9.7.7.e shows the final 1992 image classification, with an updated legend. Compare with 9.7.7.d to see how the city of Las Vegas has grown.

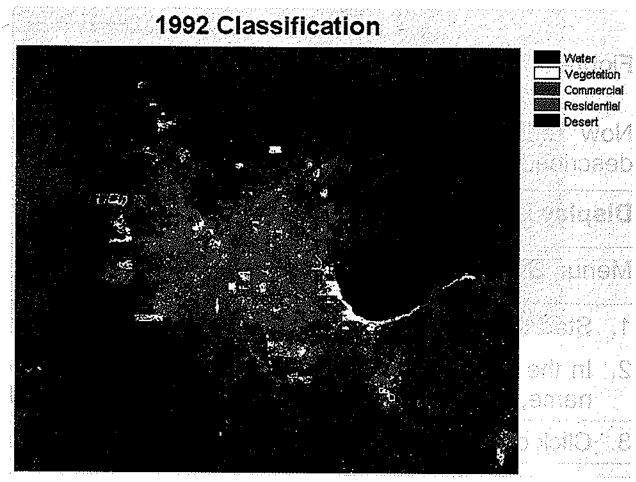


Figure 9.7.7.e Classification of the 1992 MSS image of Las Vegas.

9.7.9 Overlay of Two Independent Classifications using CROSSTAB

After you have classified the 1992 MSS image, you are ready for the final step, which is the overlay of the two separate classifications, to obtain a single change map.

Note: If you have skipped the previous classification steps, Section 9.7.1 through 9.7.8, and wish to use the classifications provided with the data for this exercise, simply use the following files in the CROSSTAB program: ***max72final_cd*** and ***max92final_cd*** instead of ***max72final*** and ***max92final.***

Overlay operation with CROSSTAB
Menu location: **GIS Analysis – Database Query – CROSSTAB**
1. Open the CROSSTAB program from the main IDRISI menu.

2. In the *CROSSTAB* window, double click in the text box next to *First image (column)*. In the resulting pick list, double click on ***max72final***.
3. Double click in the text box next to *Second image (row)*. In the resulting pick list, double click on ***max92final***.
4. In the region marked *Output type*, select the radio button for *Both cross-classification and tabulation*.
5. In the Output file name text box, enter **72-92-Crosstab**.
6. Figure 9.7.9.a shows the *CROSSTAB* window, with parameters specified.
7. Click on *OK*.

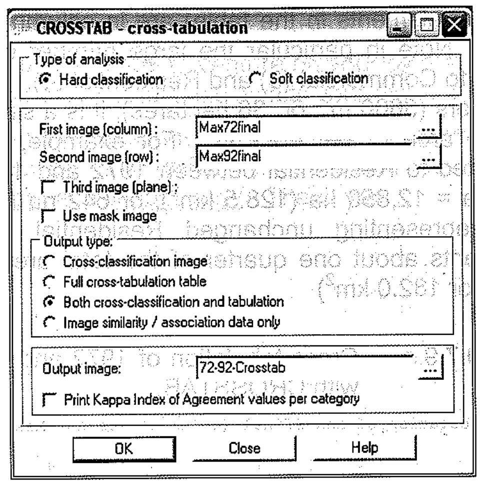


Figure 9.7.9.a *CROSSTAB* window.

The output of the CROSSTAB program is a post-classification change map (Figure 9.7.9.b) and a table (Table 9.7.9.a). (Note, since your classifications will be different, unless you are using the classifications provided on the CD, the change map and table will be slightly different, however the overall patterns should be the same.)

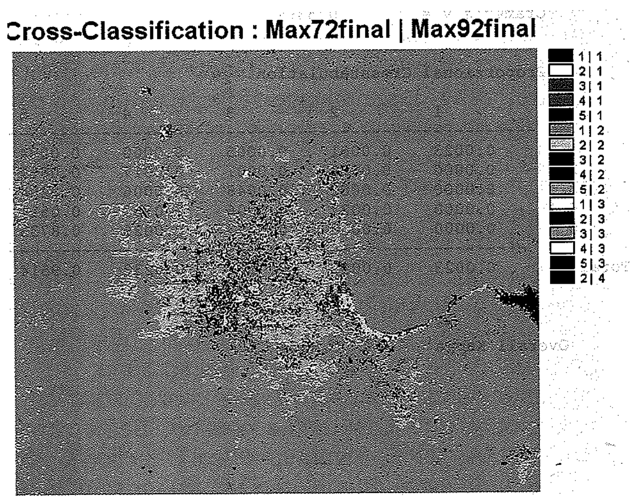


Figure 9.7.9.b Crosstabulation of the 1972 and 1992 classifications.

The change map has a separate category for each possible transition. Thus the legend is indicated as a series of pairs of numbers, each pair with a separating vertical bar. Thus, the first legend category, **1|1** represents the combination (or change transition) of class 1 in 1972 and class 1 in 1992 (i.e. pixels that remained as Water in both years.) This class is dominated by the small area of Lake Mead in the right side of the image, displayed in red. Likewise, **1|2** represents the transition from Water in 1972 to Vegetation in 1992.

Since each classification had 5 classes, there are 5*5 = 25 possible transitions. However, only a small number of transitions dominate the map, as can be observed by just a few dominant colors in the image. This dominance of just a few classes is confirmed in the table of transitions (Table 9.7.9.a). It is notable from the table that in Las Vegas, most of the largest change classes (i.e. off-diagonal elements in the table) are in column 5 (i.e. pixels that were Desert in 1972). Note in particular the large number of pixels that have changed from Desert to Commercial (3) and Residential (4). Since each pixel represents 60 by 60 meters (3600 m^2, or .36 hectares), it is a simple matter to convert the change data to area or percentages. For example, the area of the Desert that was converted to Residential between 1972 and 1992 is 35,695 pixels, or 35,695 x 0.36 ha = 12,850 ha (128.5 km^2), or 642 ha (6.4 km^2) per year. Note that the area representing unchanged Residential (12,582 pixels, or 45.29 km^2), represents about one quarter of the total area in Residential by 1992 (50,552 pixels, or 182.0 km^2)

Table 9.7.9.a. Cross-tabulation of 1972 and 1992 classifications as calculated with CROSSTAB.

Cross-tabulation of Max72final (columns) against Max92final (rows)

	1	2	3	4	5	Total
1	1578	44	318	28	297	2265
2	3	3650	38	1167	4266	9124
3	13	116	3327	430	14230	18116
4	0	1865	410	12582	35695	50552
5	4	1268	5087	1997	609557	617913
Total	1598	6943	9180	16204	664045	697970

Chi Square = 804105.18750
df = 16
P-Level = 0.0000
Cramer's V = 0.5367

Proportional Crosstabulation

	1	2	3	4	5	Total
1	0.0023	0.0001	0.0005	0.0000	0.0004	0.0032
2	0.0000	0.0052	0.0001	0.0017	0.0061	0.0131
3	0.0000	0.0002	0.0048	0.0006	0.0204	0.0260
4	0.0000	0.0027	0.0006	0.0180	0.0511	0.0724
5	0.0000	0.0018	0.0073	0.0029	0.8733	0.8853
Total	0.0023	0.0099	0.0132	0.0232	0.9514	1.0000

Overall Kappa 0.3804