Digital Image Processing of Satellite Data with ILWIS

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CONTENTS

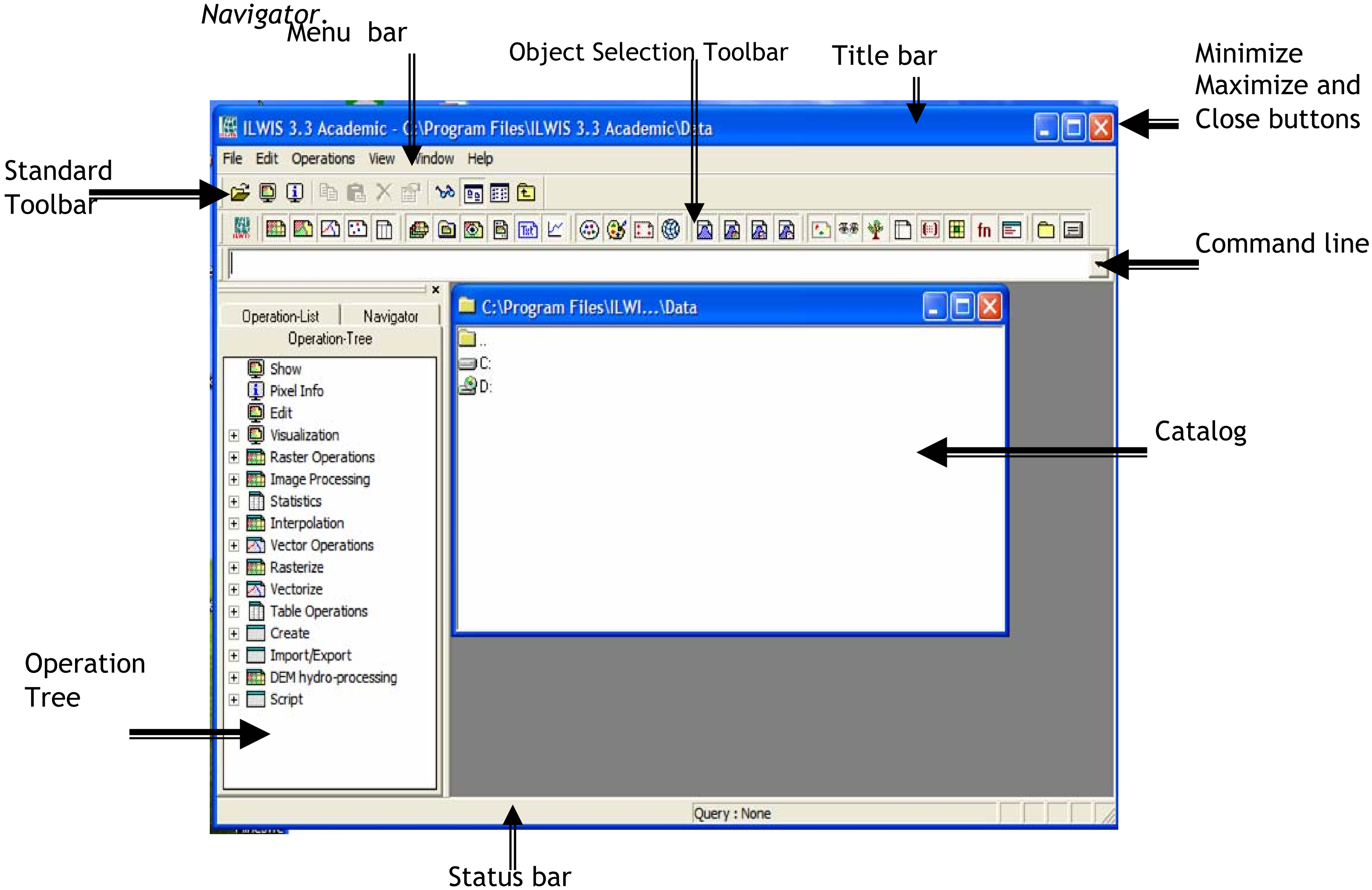
Exercise 1 : Familiarization with ILWIS software

ILWIS is an acronym for the Integrated Land and Water Information System. It is a Geographic Information System (GIS) with Image Processing capabilities. ILWIS has been developed by the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands.

As of July, 1 2007, ILWIS is a freeware.

Starting ILWIS
To start ILWIS, double-click the ILWIS icon on the desktop. After the opening screen you see the ILWIS *Main window* (see Figure 1.1). From this window you can manage your data and start all operations.

The ILWIS Main window consists (by default) of a *Title bar*, a *Menu bar*, a *Standard toolbar*, an *Object selection toolbar*, a *Command line*, a *Catalog*, a *Status bar* and an *Operations/Navigator* pane with an *Operation-tree*, an *Operation-list* and a *Navigator*.



The Navigator

You can use the *Navigator* to change the current drive and working directory.

Click the word Navigator in the Operations/Navigator pane
The Navigator lists all drives and directories (i.e. folders) in a tree structure. The Navigator also has a History to easily return to previously visited drives and directories.
Click on the drives and folders in the Navigator until you are in the directory where the data for these exercises has been stored. Keep the data in C:\Exercise data\I

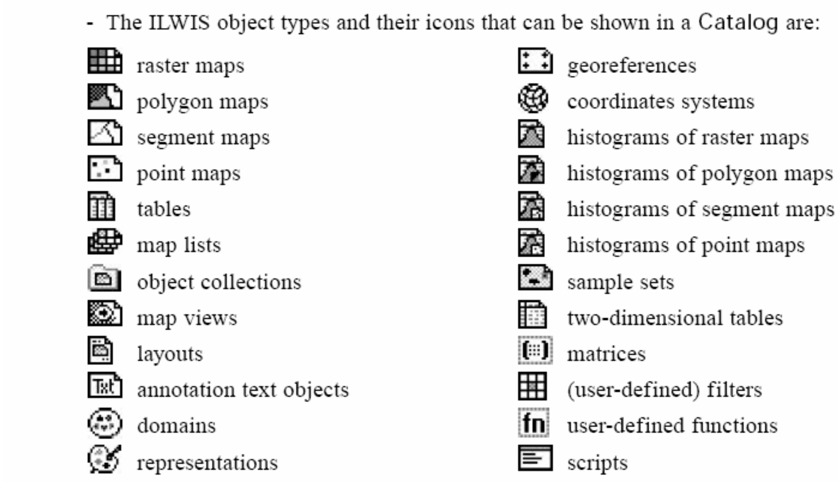
Catalog

This part of the Main window, in which maps, tables and other ILWIS objects in the working directory are displayed each with its own type of icon, is called the *Catalog*. When you double-click an object in the Catalog, it will be displayed

The Operation-tree and Operation-list
The *Operation-tree* and the *Operation-list* are located on the first two tabs in the Operations/Navigator pane, by default along the left-hand side of the Main window.

- The *Operation-tree* provides a tree structure for all ILWIS operations, similar to the Operations menu.
- The *Operation-list* contains an alphabetic list of all ILWIS operations. Each operation is preceded by an icon; the icon indicates the output data type of the operation.
- The *Navigator* provides a tree structure for all drives and directories and has a history of recently visited drives and directories.
- The *Title bar* is always located at the top of the window. It shows the name of the window and can be used to move the window on the screen.
- The *Menu bar* can be used to start an operation, to create or edit objects, to view the properties of an object, etc.
- The *Standard toolbar* provides shortcuts for regularly used menu commands such as Customize Catalog, List/Details View, etc.
- The *Object selection toolbar* can be used to select the object types that should be visible in the currently active Catalog.
- The *Command line* is mainly used to type calculations (MapCalc) and expressions (i.e. perform operations).
- The *Status bar* gives short information on the item on which the mouse pointer is located: a menu command, a button in the Toolbar, an object in the Catalog, an operation in the Operation-list or the Operation-tree, etc.
- The *ILWIS Help* allows you to obtain help information from any point within the program. The ILWIS Help viewer has a Topic pane, a Navigation pane and a Toolbar.

Object types in ILWIS

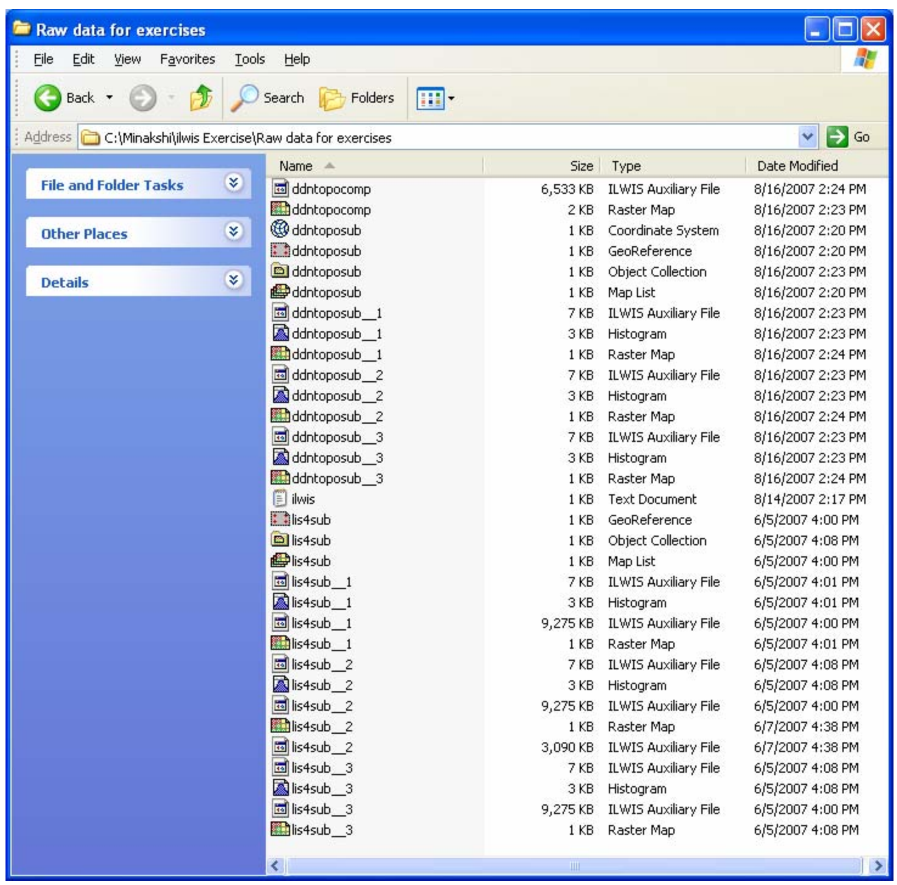


- The ILWIS object types and their icons that can be shown in a Catalog are:

raster maps	georeferences
polygon maps	coordinates systems
segment maps	histograms of raster maps
point maps	histograms of polygon maps
tables	histograms of segment maps
map lists	histograms of point maps
object collections	sample sets
map views	two-dimensional tables
layouts	matrices
annotation text objects	(user-defined) filters
domains	user-defined functions
representations	scripts

Data set for the exercises

The data used for the exercises is subset of Dehradun Area (Uttarakhand) LISS III and LISS IV data of IRS P6 (Resourcesat) in the folder Raw data for exercises. Please make a copy of the dataset and use it for practice.

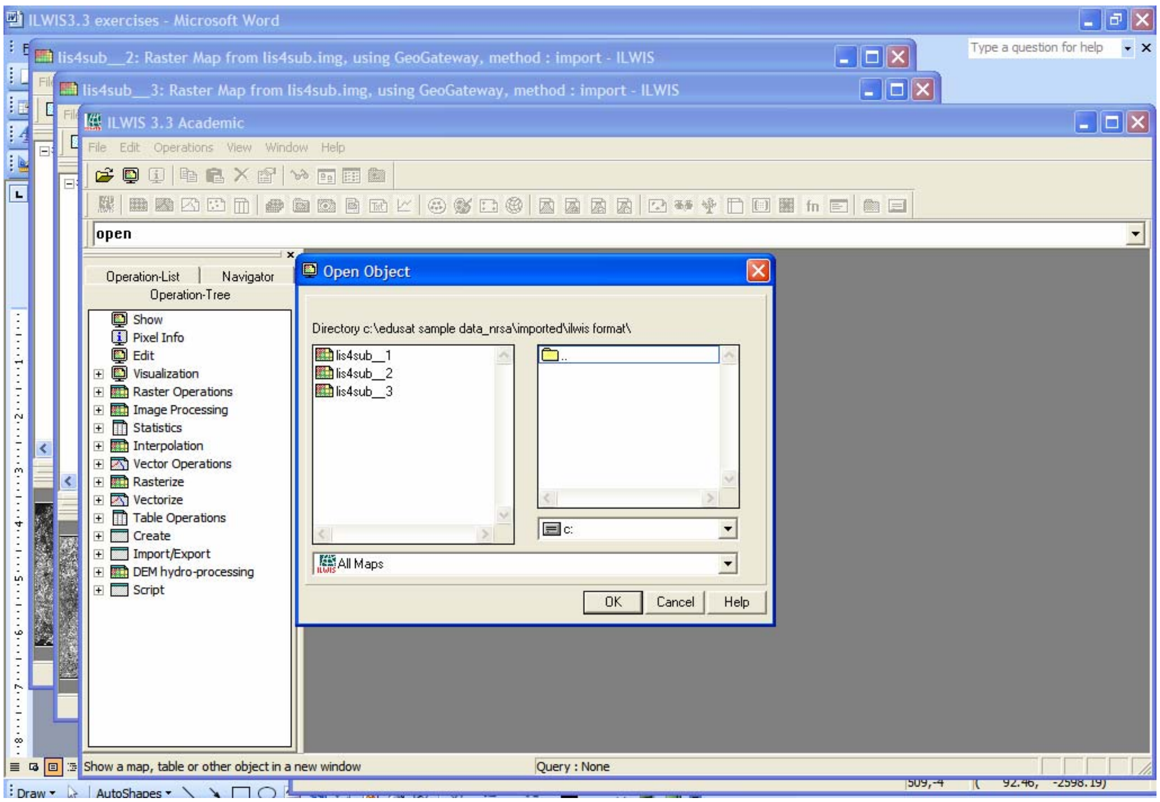


Exercise 2 Image Visualisation

Visualization of single band images

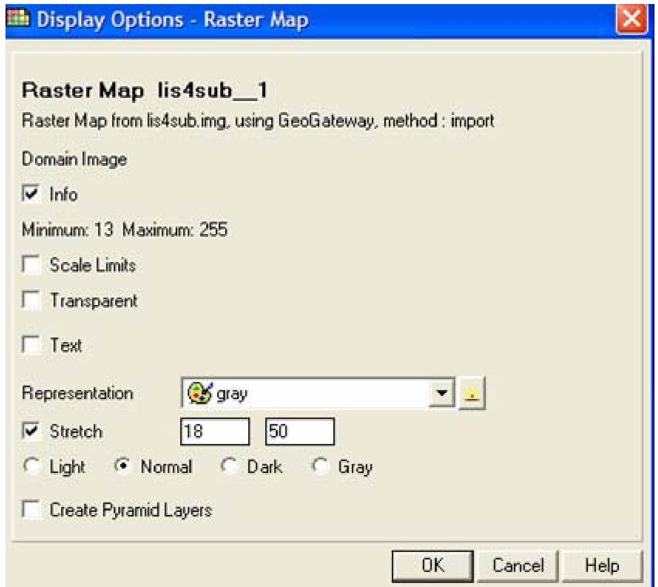
For satellite images and scanned black and white aerial photographs the *image domain* is used. Pixels in a satellite image or scanned aerial photograph usually have values ranging from 0-255. The values of the pixels represent the reflectance of the surface object. The image domain is in fact a special case of a *value domain*. Raster maps using the image domain are stored using the '1 byte' per pixel storage format. A single band image can be visualized in terms of its gray shades, ranging from black (0) to white (255).

You can open an object collection by double-clicking it in a Catalog; you can subsequently open the imported objects also by double-clicking.

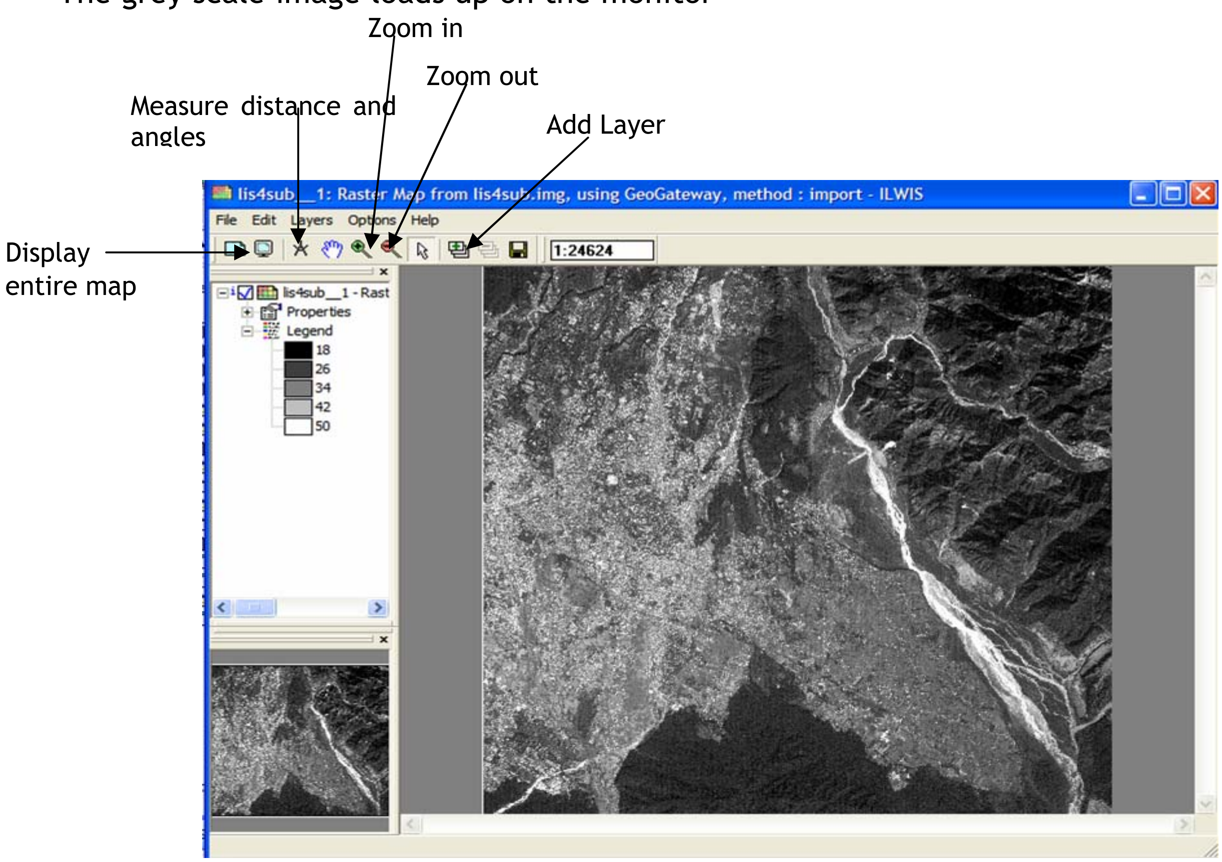


- ❖ click show from the Operations tree. An open object dialog box opens up. Select the filename lis4sub_1 and click OK.

A Display Options – Raster Map opens up.



The grey scale image loads up on the monitor

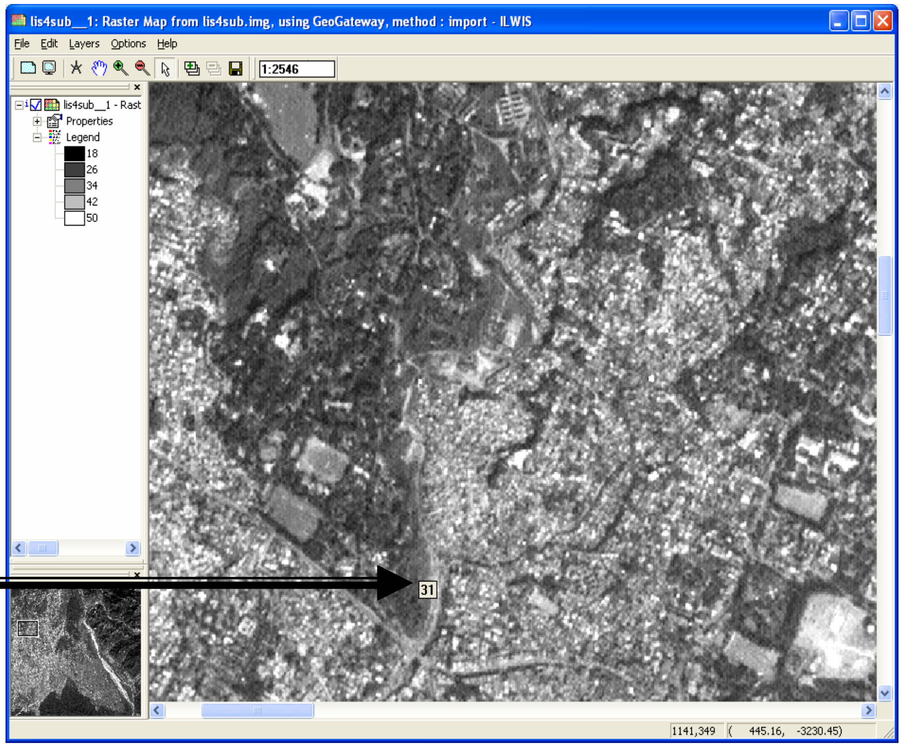


Alternatively you can load an image by double clicking the lis4sub_1 from the catalog .

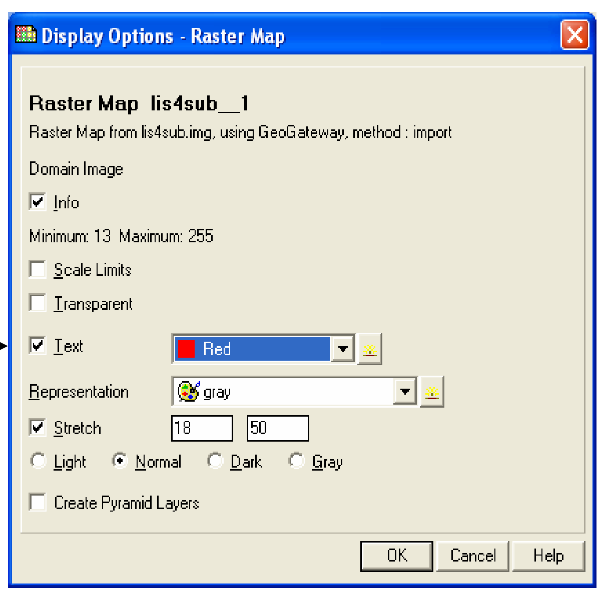
Displaying Individual Pixel Values

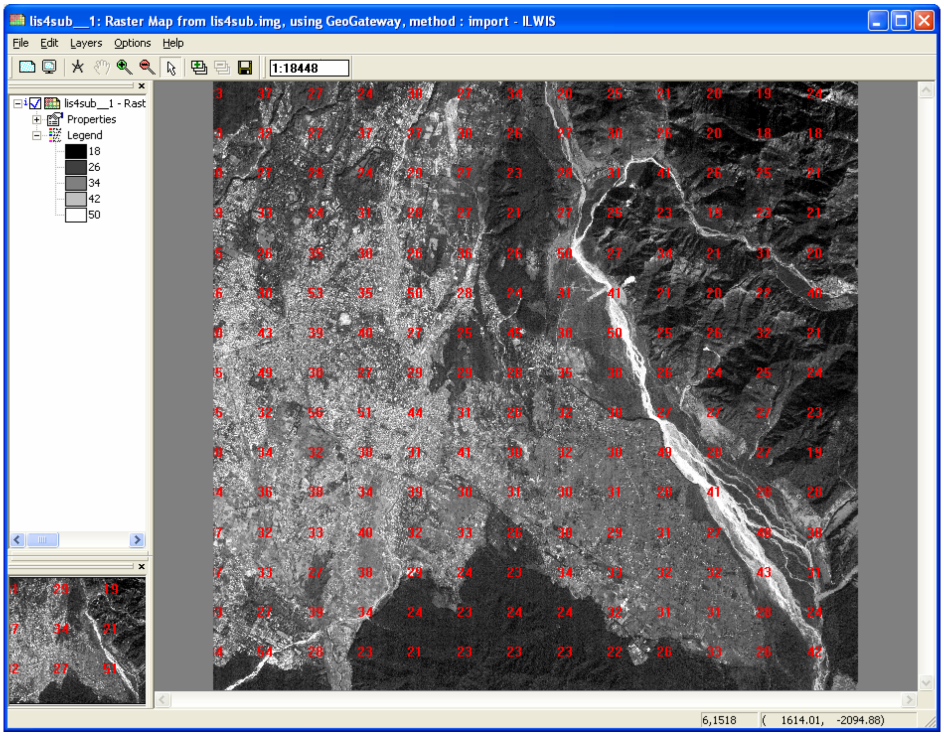
When a raster map is displayed the pixel value at any location is obtained by holding the left mouse button over the desired location.

Pixel
Value



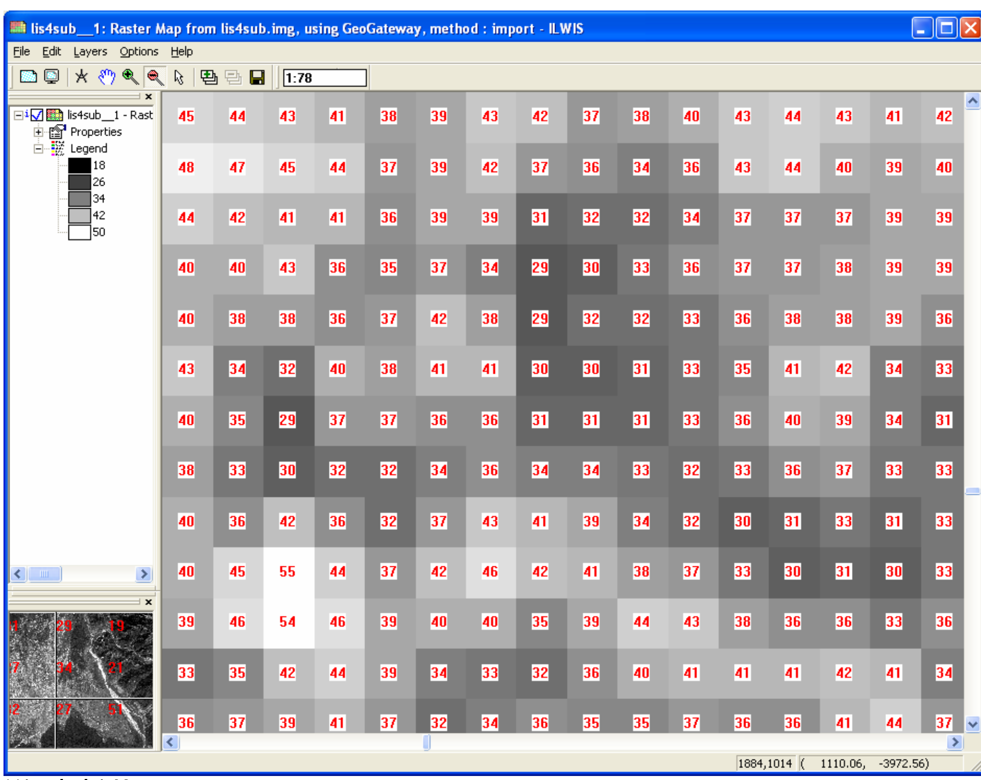
❖ Double click the raster map lis4sub_1 . The Display options for lis4sub_1 opens up. Check the Text button on and change the colour from Black to any other by drop down list





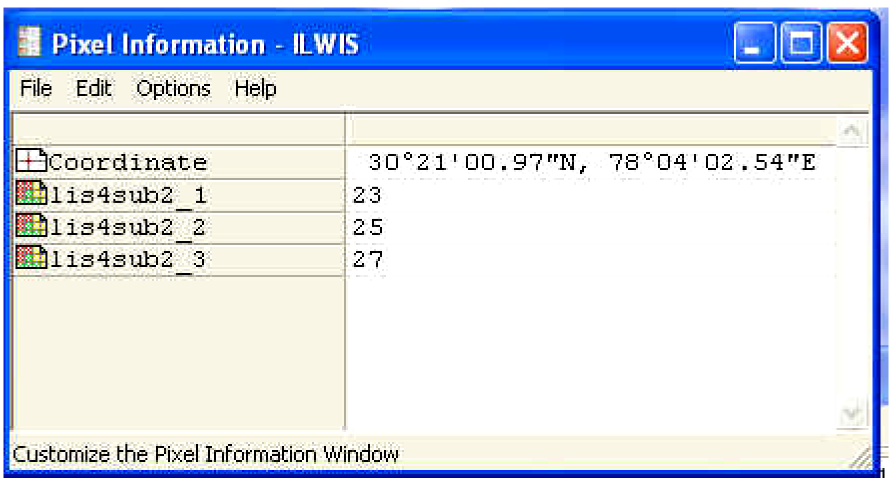
The image is displayed with DN values in the red colour

Zoom on an area till you see individual pixels along with their DN values



Displaying pixel values of more than one band

- ❖ Display map lis4sub_1 in a map window.
- ❖ From the File menu in the map window, select Open Pixel Information. The pixel information window appears.
- ❖ Make sure that the pixel information window can be seen on the screen.
- ❖ Select lis4sub_2 and lis4sub_3 in the Catalog and drag these maps to the pixel information window: hold the left mouse button down; move the mouse pointer to the pixel information window; and release the left mouse button; The images are dropped in the pixel information window.
- ❖ In the pixel information window the DNs of all three selected bands will be displayed. Zoom in if necessary.

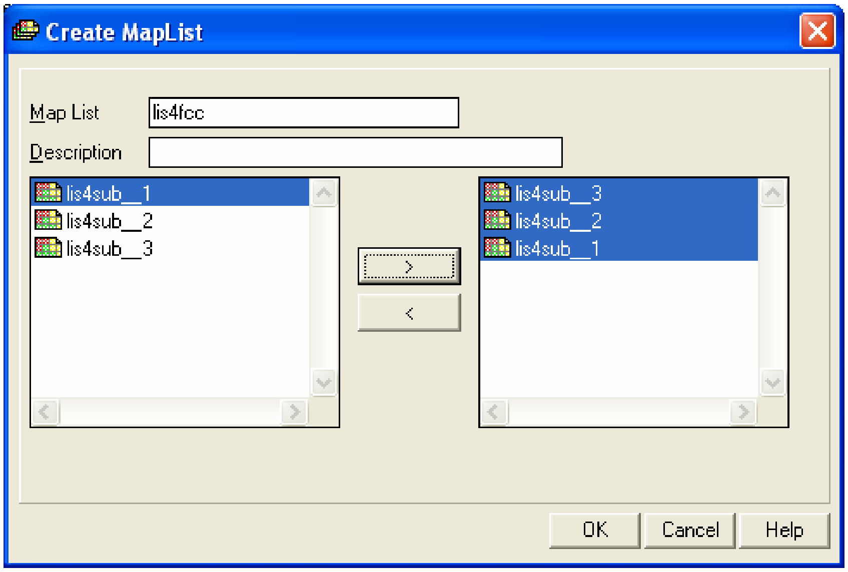


Displaying Colour Composites

A specific combination of bands used to create a color composite image called *False Color Composite* (*FCC*). In a FCC, the red color is assigned to the near infrared band, the green color to the red visible band and the blue color to the green visible band. The green vegetation will appear reddish, the water bluish and the (bare) soil in shades of brown and gray. For LISS IV multi-spectral imagery, the bands 1, 2 and 3 are displayed respectively in blue, green and red.

- ❖ In the Operation-tree expand the Create item and double-click New Map List. The Create Map List dialog box is opened.

- ❖ Write a new map list name . select the individual bands and insert them by pressing the > button and click Ok



A map list lis4fcc gets created.

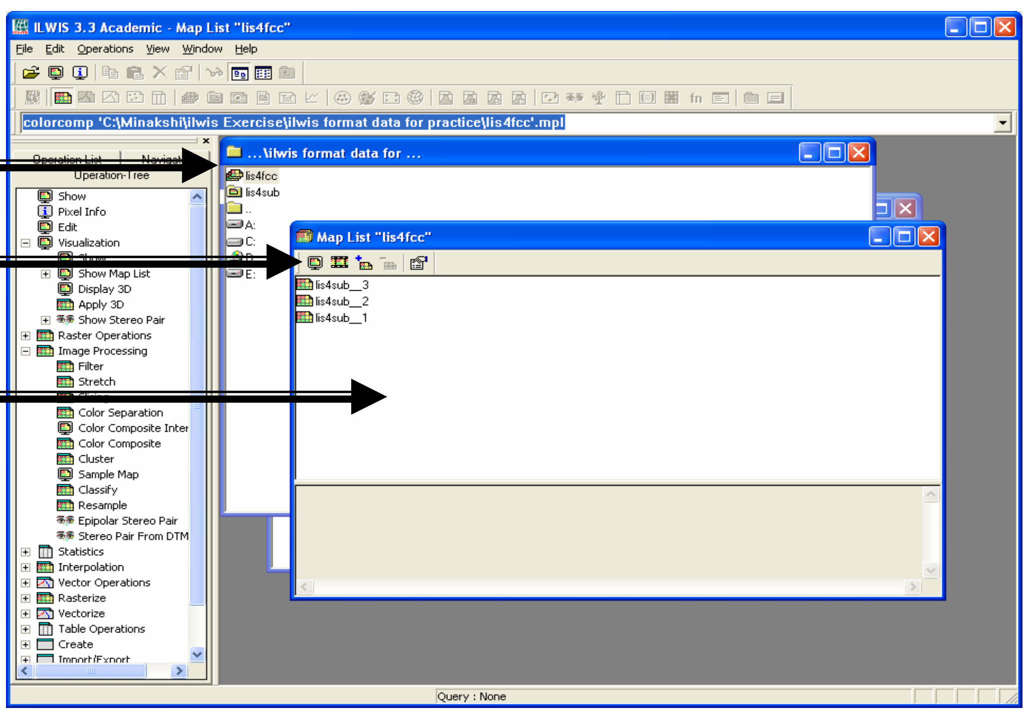
To display the map list as a color composite:

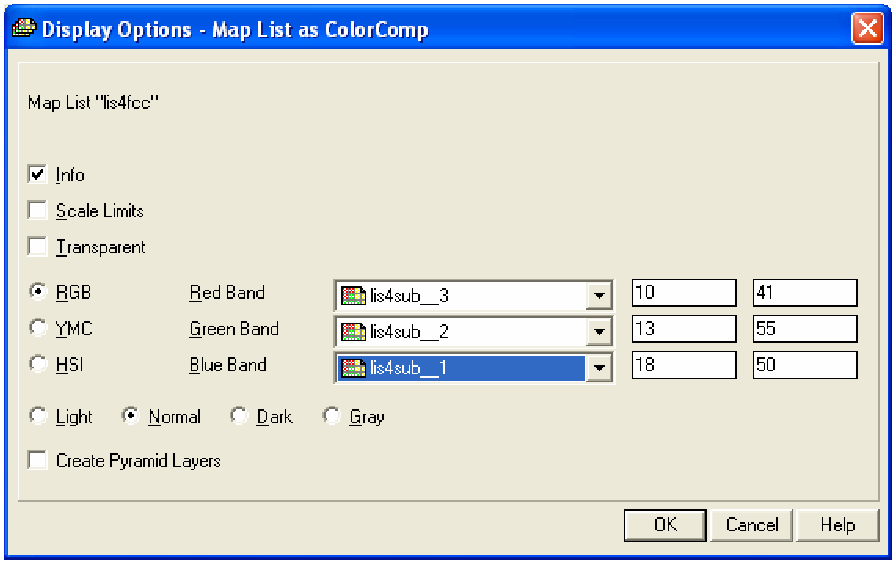
- ❖ Double-click map list lis4fcc in the Catalog. The map list is opened as a Catalog.
- ❖ Press the Open As Color Composite button in the toolbar of the opened map list. The Display Options - Map List as ColorComp dialog box appears.
- ❖ Select image lis4sub_3 for the Red Band, lis4sub_2 for the Green Band and lis4sub_1 for the Blue Band.
- ❖ Accept all other defaults and click OK. The interactive color composite is shown in a map window.

Map List

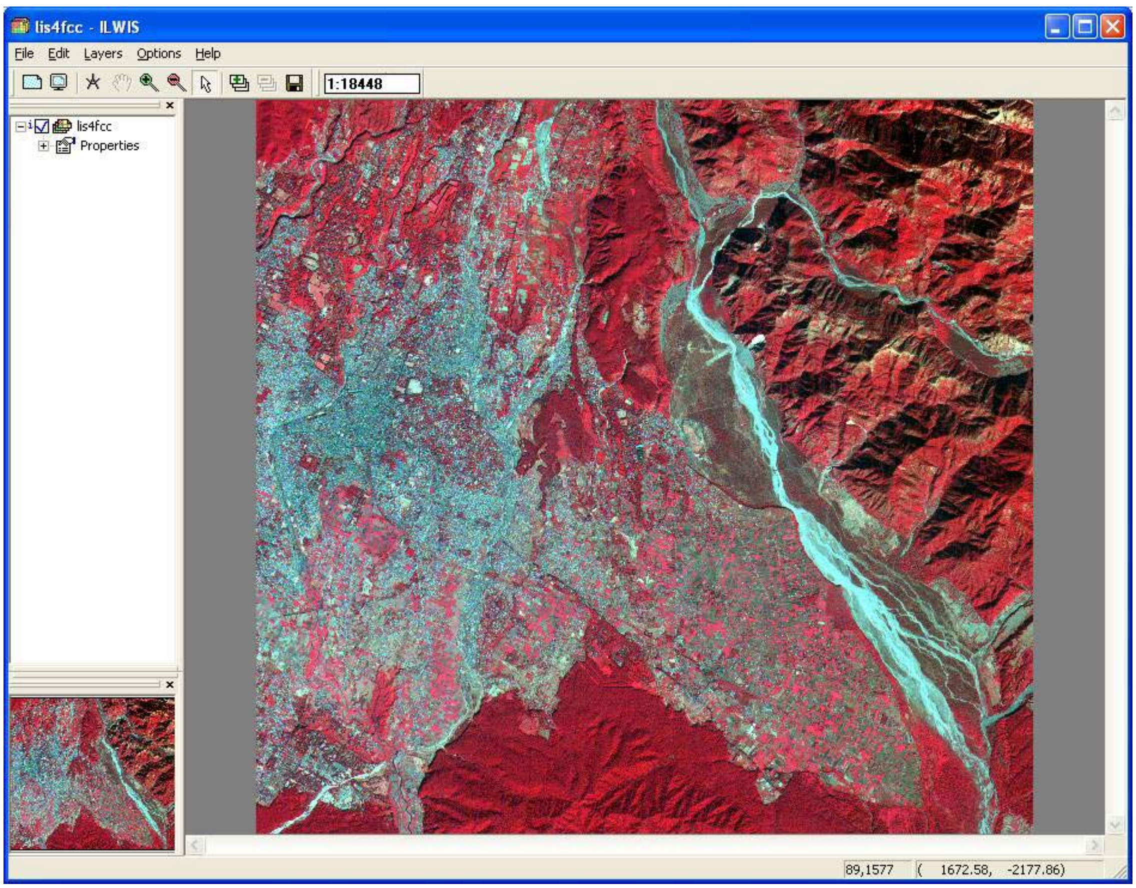
Button to display color composite

Map list opened after double clicking





The fcc image loads up on the monitor



Exercise 3 : Image enhancement

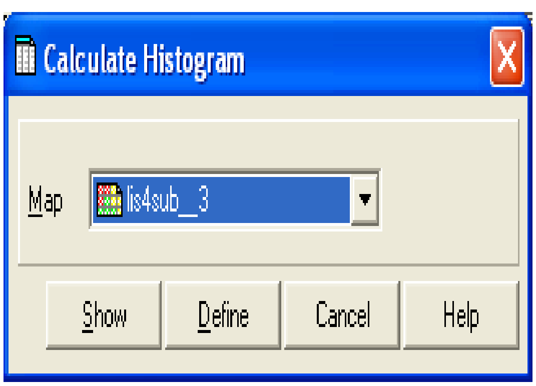
Image enhancement techniques can be classified in many ways. *Contrast enhancement*, also called *global enhancement*, transforms the raw data using the statistics computed over the whole data set. Examples are: *linear contrast stretch*, *histogram equalized stretch* and *piece-wise contrast stretch*. Contrary to this, spatial or local enhancement only take local conditions into consideration and these can vary considerably over an image. Examples are *image smoothing and sharpening*.

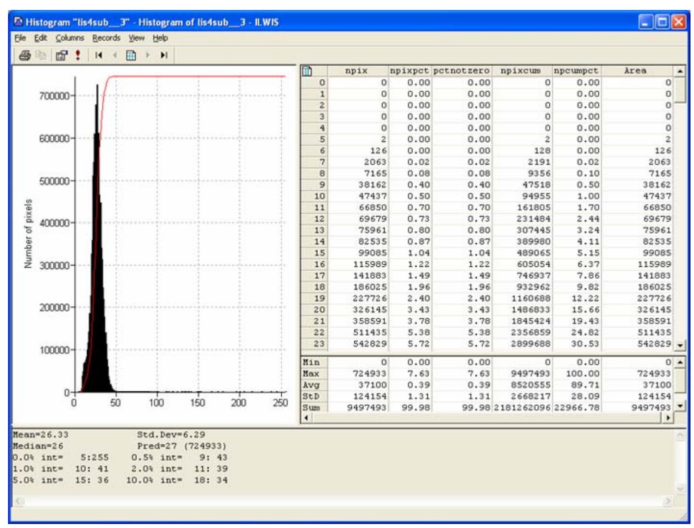
Contrast Enhancement

Before stretching can be performed, a histogram of the image has to be calculated.

- ❖ In the Operation-tree, expand Statistics and double-click the Histogram operation. The Calculate Histogram dialog box is opened.
- ❖ Select the raster map lis4sub__3 and click the Show button.
- ❖ The histogram window appears showing a graphical display of the histogram as well as a numerical display of the histogram in a number of columns:

Npix (= number of pixels with a certain pixel value),
Npixpct (= the percentage of pixels compared to the total number of pixels),
Pctnotzero (= the percentage of pixels compared to the total number of pixels with non zero values),
Npixcum (= cumulative frequency distribution),
Npcumpct (= cumulative frequency distribution in percentages) and, if pixel size is known,
Area (= area of pixels with a certain DN).

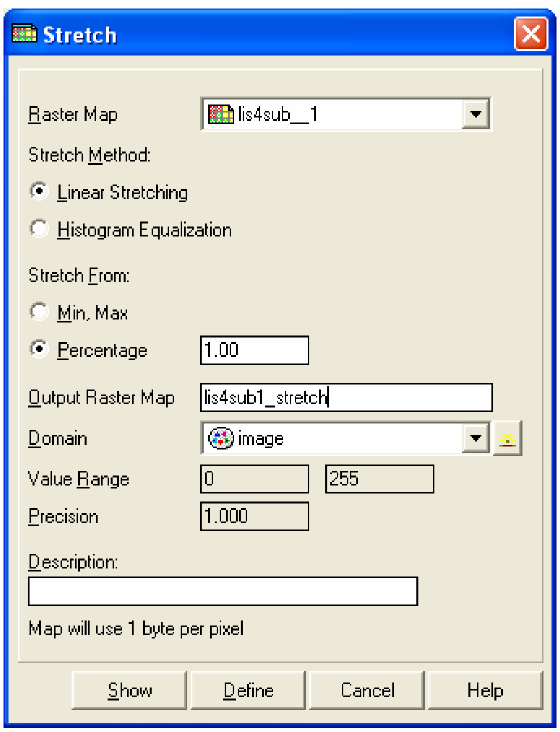


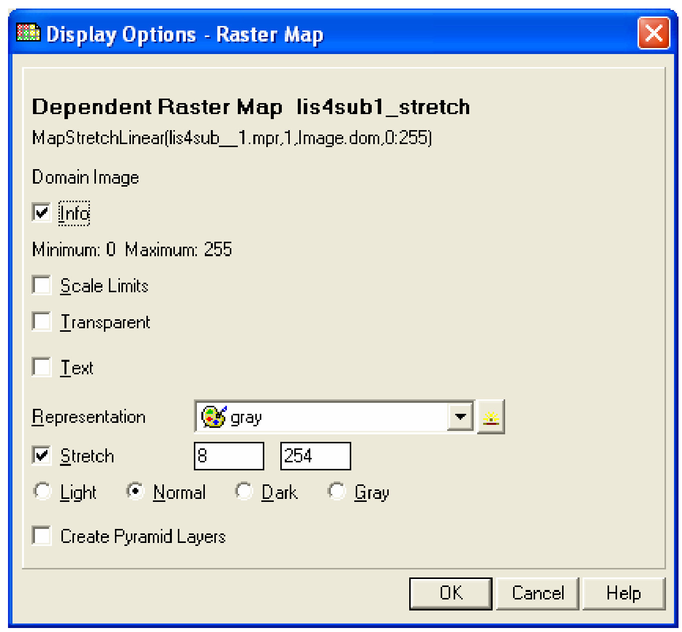


Linear stretching

After a histogram has been calculated for a certain image, the image can be stretched.
A linear stretch is used here. Only the pixel values in the 1 to 99% interval will be used as input; pixel values below the 1% boundary and above the 99% boundary will not be taken into account.

- ❖ In the Main window, open the Operations menu and select Image Processing, Stretch. The Stretch dialog box is opened.
- ❖ Select lis4sub_1 as Raster Map, accept Linear stretching as stretching method with a Percentage equal to 1.00 and type lis4sub1_stretch as Output Raster Map.
- ❖ Accept all other defaults and click the Show button. The raster map lis4sub1_stretch is calculated after which the Display Options – Raster Map dialog box appears.
- ❖ Click OK to display the map.





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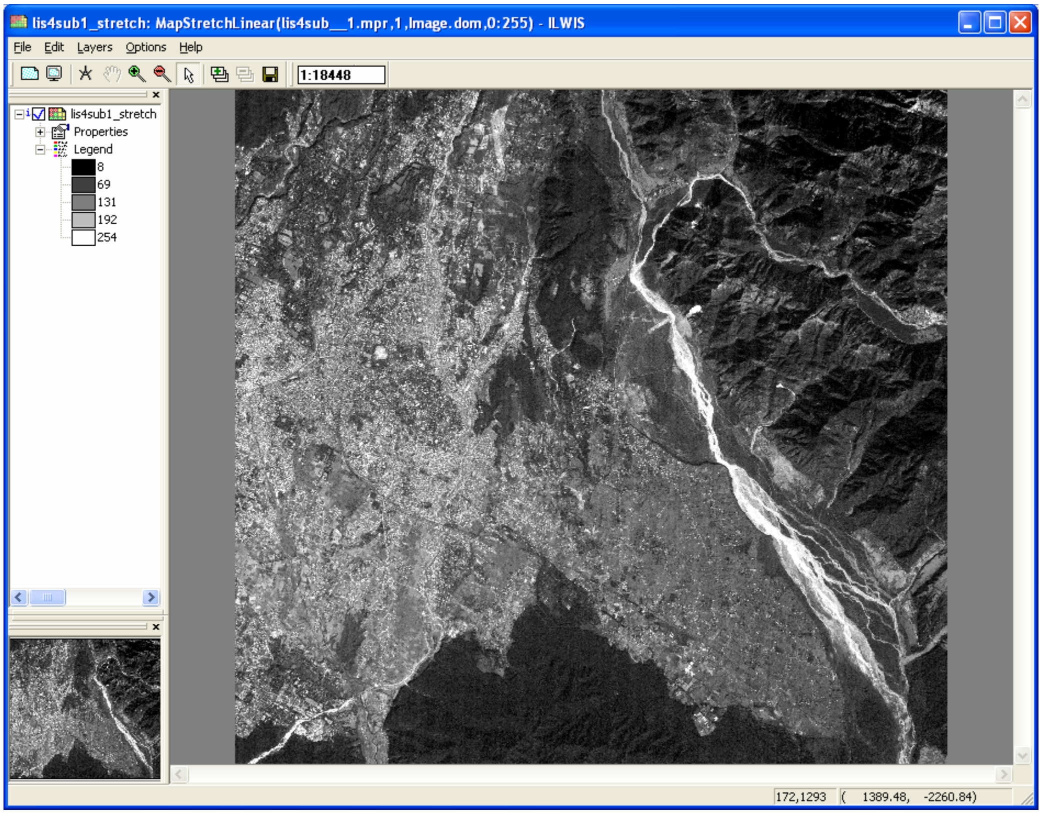
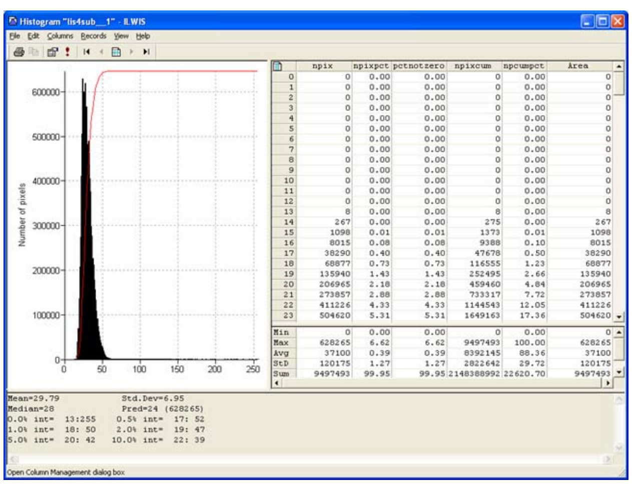
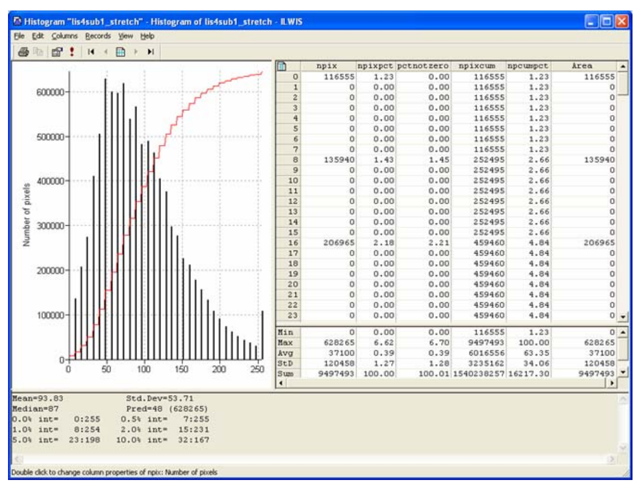


Compare the original and stretched image and histograms of lis4sub_1 and lis4sub1_stretch.





Similarly stretch the lis4sub_1 using Histogram equalization and compare the original image, its histogram and histogram equalized image and its histogram.

Exercise 4 Spatial enhancement

The objective is to understand the concept of spatial enhancement using filters and to be able to apply different types of filters.

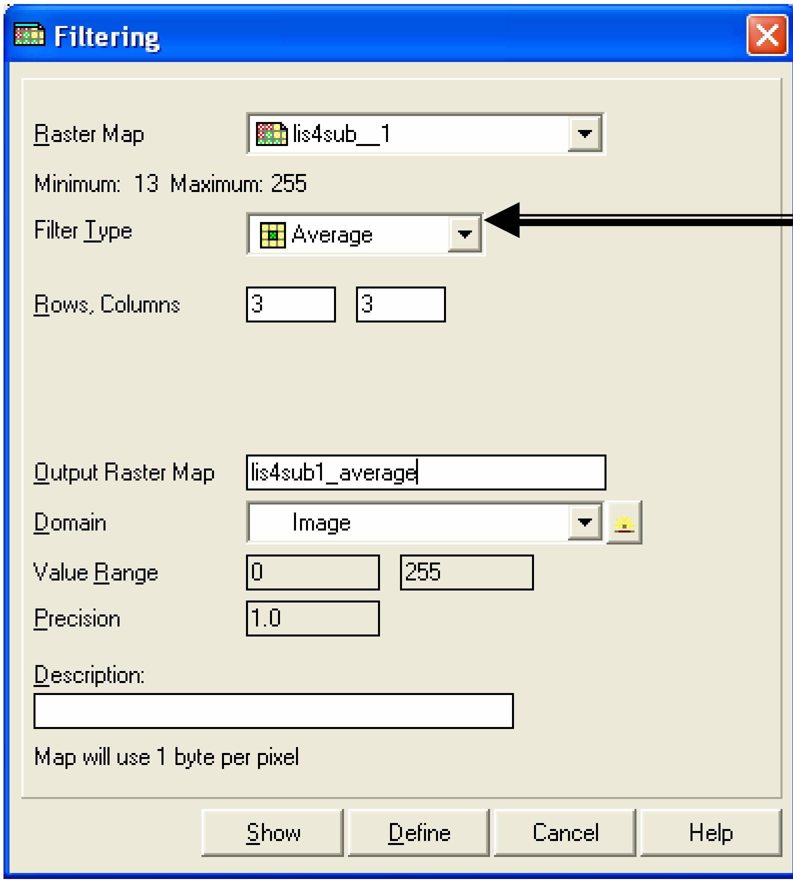
Spatial enhancement procedures result in modification of an image pixel value, based on the pixel values in its immediate vicinity (*local enhancement*).

Spatial frequency filters, also often simply called *spatial filters*, may emphasize or suppress image data of various spatial frequencies. Spatial frequency refers to the roughness of the variations in DN values occurring in an image. In high spatial frequency areas, the DN values may change abruptly over a relatively small number of pixels (e.g. across roads, field boundaries, shorelines). Smooth image areas are characterized by a low spatial frequency, where DN values only change gradually over a large number of pixels (e.g. large homogeneous agricultural fields, water bodies). Low pass filters are designed to emphasize low frequency features and to suppress the high frequency component of an image. High pass filters do just the reverse.

Low pass filters. Applying a low pass filter has the effect of filtering out the high and medium frequencies and the result is an image, which has a smooth appearance. Hence, this procedure is sometimes called *image smoothing* and the low pass filter is called a *smoothing filter*. It is easy to smooth an image. The basic problem is to do this without losing interesting features. For this reason much emphasis in smoothing is on edge-preserving smoothing.

A filter usually consists of a 3x3 array (sometimes called *kernel*) of coefficients or weighting factors. It is also possible to use a 5x5, a 7x7 or even a larger odd numbered array. The filter can be considered as a window that moves across an image and that looks at all DN values falling within the window. Each pixel value is multiplied by the corresponding coefficient in the filter. For a 3x3 filter, the 9 resulting values are summed and the resulting value replaces the original value of the central pixel. This operation is called *convolution*.

- ❖ In the Operation-tree, expand Image Processing and double-click the Filter operation. The Filtering dialog box appears.
- ❖ Select Raster Map lis4sub_1, use the Linear Filter Type and the standard low pass filter Avg3x3. Enter lis4sub1_average as Output Raster Map and click the Show button.
- ❖ Display the filtered and the unfiltered image next to each other and make a visual comparison.

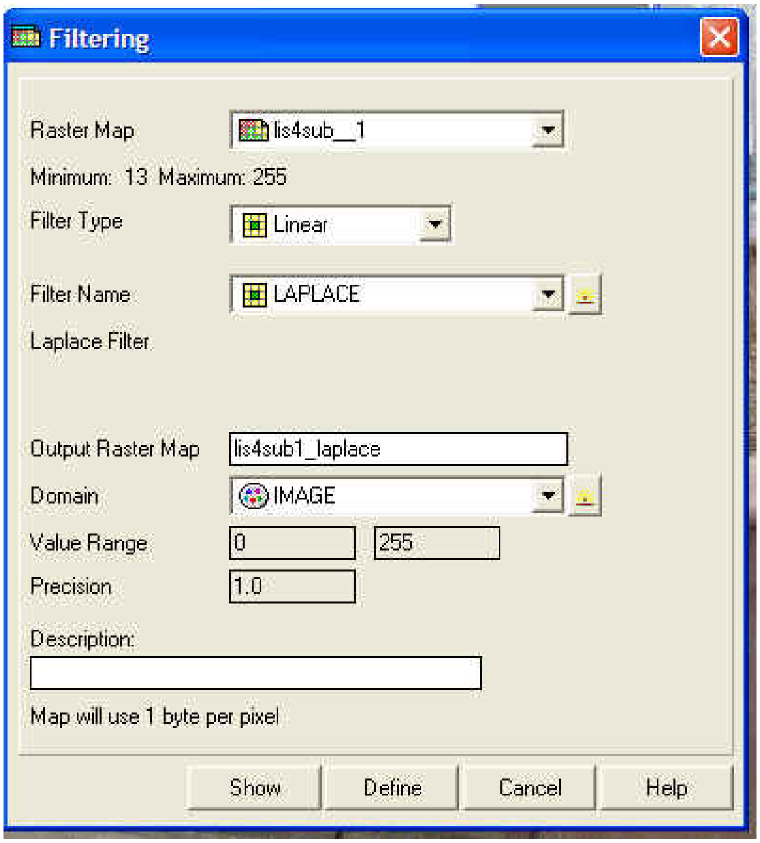


Select different filter types from this drop down list

High Pass Filtering

High pass filters. Sometimes abrupt changes from an area of uniform DNs to an area with other DNs can be observed. This is represented by a steep gradient in DN values. Boundaries of this kind are known as edges. They occupy only a small area and are thus high-frequency features. High pass filters are designed to emphasize high frequencies and to suppress low-frequencies. Applying a high pass filter has the effect of enhancing edges. Hence, the high pass filter is also called an *edge-enhancement filter*.

Two classes of high-pass filters can be distinguished: *gradient (or directional) filters* and *Laplacian (or non-directional) filters*. Gradient filters are directional filters and are used to enhance specific linear trends. They are designed in such a way that edges running in a certain direction (e.g. horizontal, vertical or diagonal) are enhanced. In their simplest form, they look at the difference between the DN of a pixel to its neighbor and they can be seen as the result of taking the first derivative (i.e. the gradient). Laplacian filters are non-directional filters because they enhance linear features in any direction in an image. They do not look at the gradient itself, but at the changes in gradient. In their simplest form, they can be seen as the result of taking the second derivative.

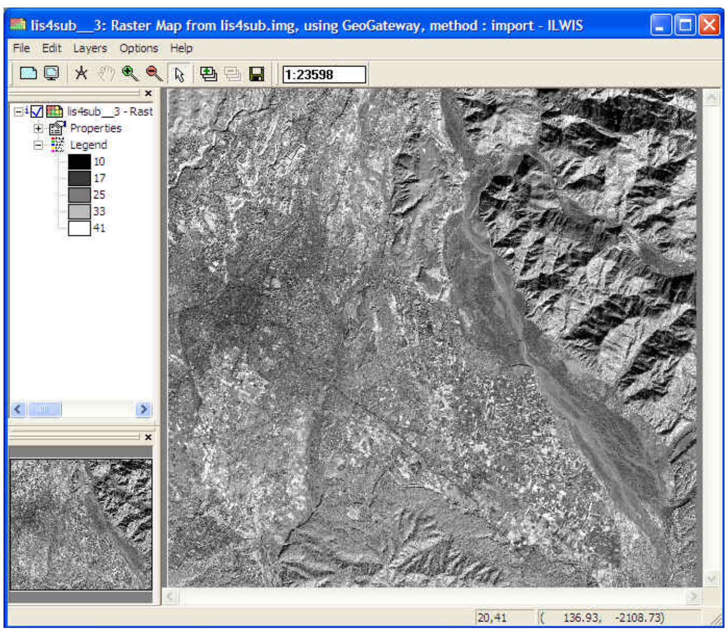


Similarly explore the other filter types and interpret the edges extracted.

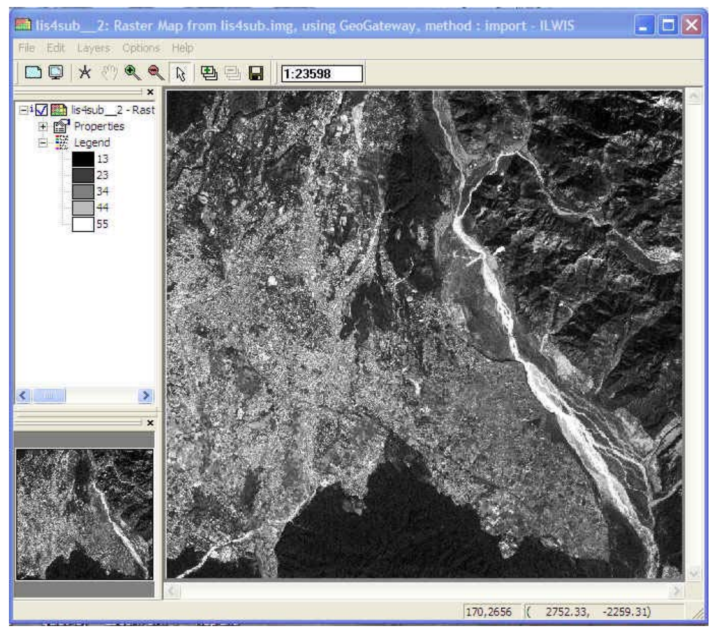
Exercise 5 : Band Ratioing

Ratioed images are created in order to minimize the effects of differences in illumination. Various mathematical combinations of satellite bands, have been found to be sensitive indicators of the presence and condition of green vegetation. These band combinations are thus referred to as vegetation indices. Two such indices are the simple *Vegetation Index* (*VI*) and the *Normalized Difference Vegetation Index* (*NDVI*). Both are based on the reflectance properties of vegetated areas as compared to clouds, water and snow on the one hand, and rocks and bare soil on the other. Vegetated areas have a relatively high reflection in the near-infrared and a low reflection in the visible range of the spectrum. Clouds, water and snow have larger visual than near-infrared reflectance. Rock and bare soil have similar reflectance in both spectral regions.

To show the effect of band ratios for suppressing topographic effects on illumination, LISS IV Infrared and Red bands are used



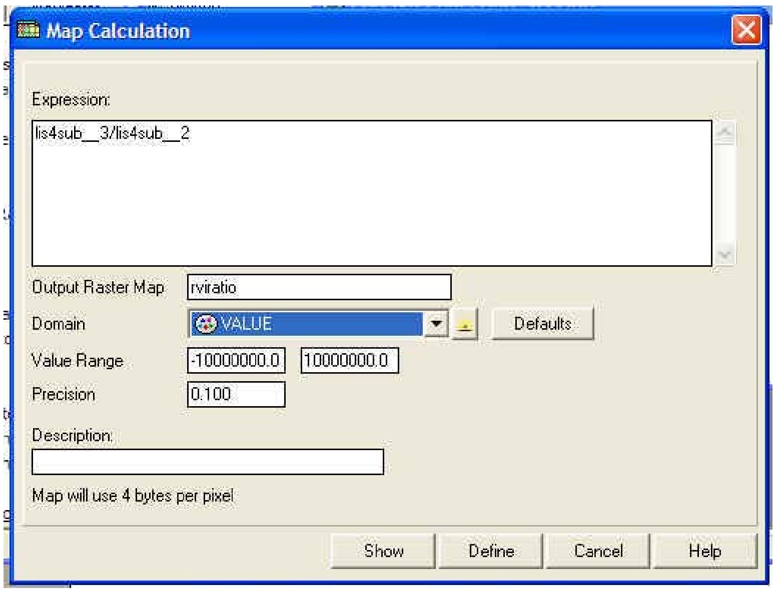
Infrared Band



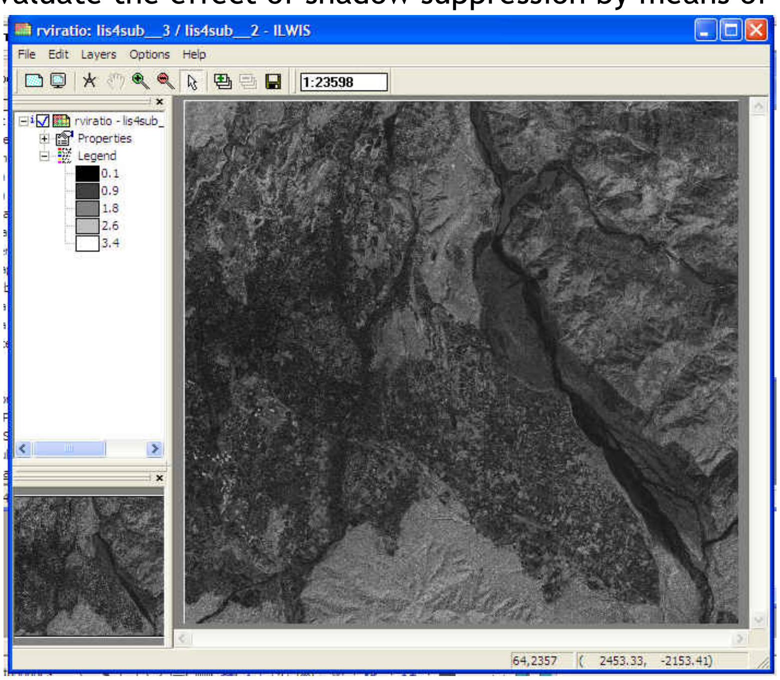
Red Band

- Display the images lis4sub__2 and lis4sub__3 using a Gray Representation.
- Visually inspect the two displayed bands on the effect of illumination conditions.
- Use the mouse to view the DNs in the mountain areas.
- Ratio Vegetation Index (RVI or VI) = Infrared band / Red Band

- ❖ Double-click the Map Calculation item in the Operation-list or Map calculations from Rater Operations in operation tree. The MapCalculation dialog box is opened.
- ❖ In the Expression text box type the following map calculation formula: lis4sub__3/lis4sub__2
- ❖ Enter rviratio for Output Raster map, select as system Domain Value, click on the Defaults button and click Show.



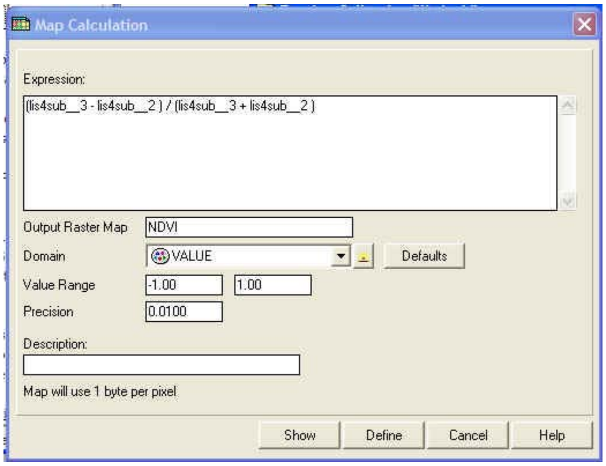
- ❖ The map rviratio is calculated and the Display Options - Raster Map dialog box is opened.
- ❖ chose **gray representation,** Accept the other defaults and click OK.
- ❖ Zoom in on a sunlit-shaded part of the image.
- ❖ Open the pixel information window and drag-and-drop raster maps lis4sub_2,lis4sub_3 and rviratio.
- ❖ Evaluate the effect of shadow suppression by means of this band ratio.



Ratio vegetation Index

Normalized Diferential Vegetaion Index (NDVI)

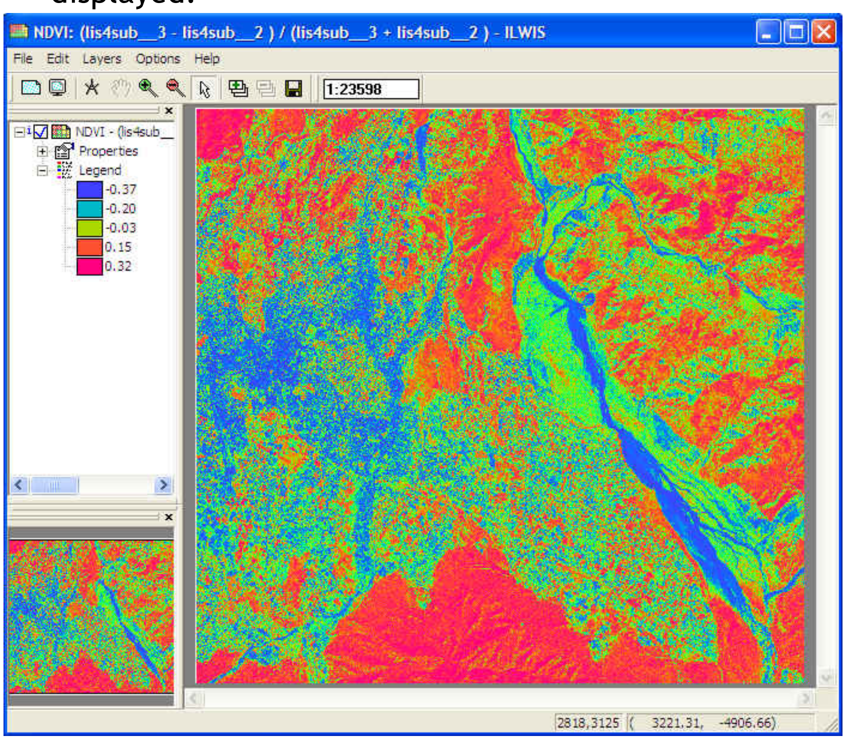
NDVI = (Infrared band – Red Band) / (Infrared band + Red Band)



- ❖ Double-click the Map Calculation operation in the Operation-list. The Map Calculation dialog box is opened.
- ❖ In the Expression text box type the following map calculation formula: (lis4sub__3-lis4sub__2)/(lis4sub__3 + lis4sub__2)
- ❖ Enter NDVI for Output Raster map, select system Domain Value, change
- ❖ the Value Range to -1 and +1, and the Precision to 0.01. Click Show.

The map NDVI is calculated and the Display Options - Raster Map dialog box is opened.

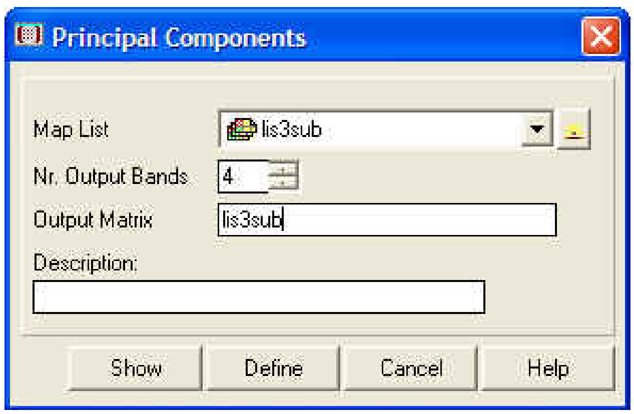
- ❖ In the Display Options - Raster Map dialog box select Pseudo as Representation. In this representation the colors range from blue (for the low DNs) through green (for the medium DNs) to red (for the high DNs). Click OK. The map NDVI is displayed.

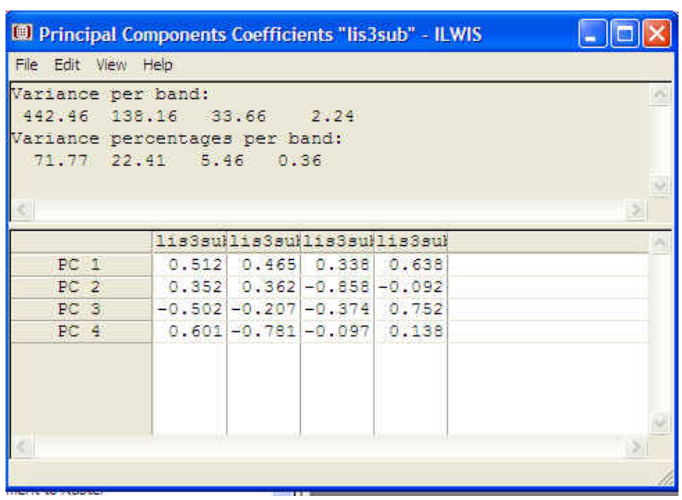


Exercise 6 : Principal Component Analysis

Principal Components Analysis (*PCA*), can be applied to compact the redundant data into fewer layers. Principal component analysis can be used to transform a set of image bands, as that the new layers (also called components) are not correlated with one another. Because of this, each component carries new information.

- ❖ Double-click the Principal Components operation in the Operation-list.
- ❖ Select Map List lis3sub.
- ❖ Accept the Number of Output Bands, type Tm in the Output Matrix text box and click Show. The Matrix viewer is opened.

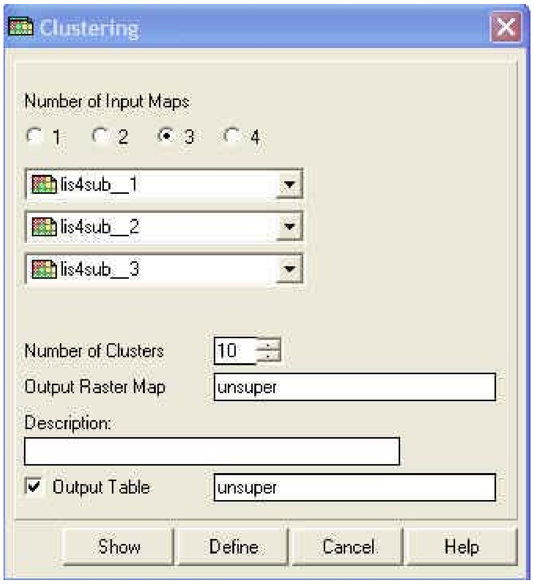




Display the PCA images individual components as well as FCC as demonstrated in exercise 2 .

Exercise 7 : Unsupervised Classification

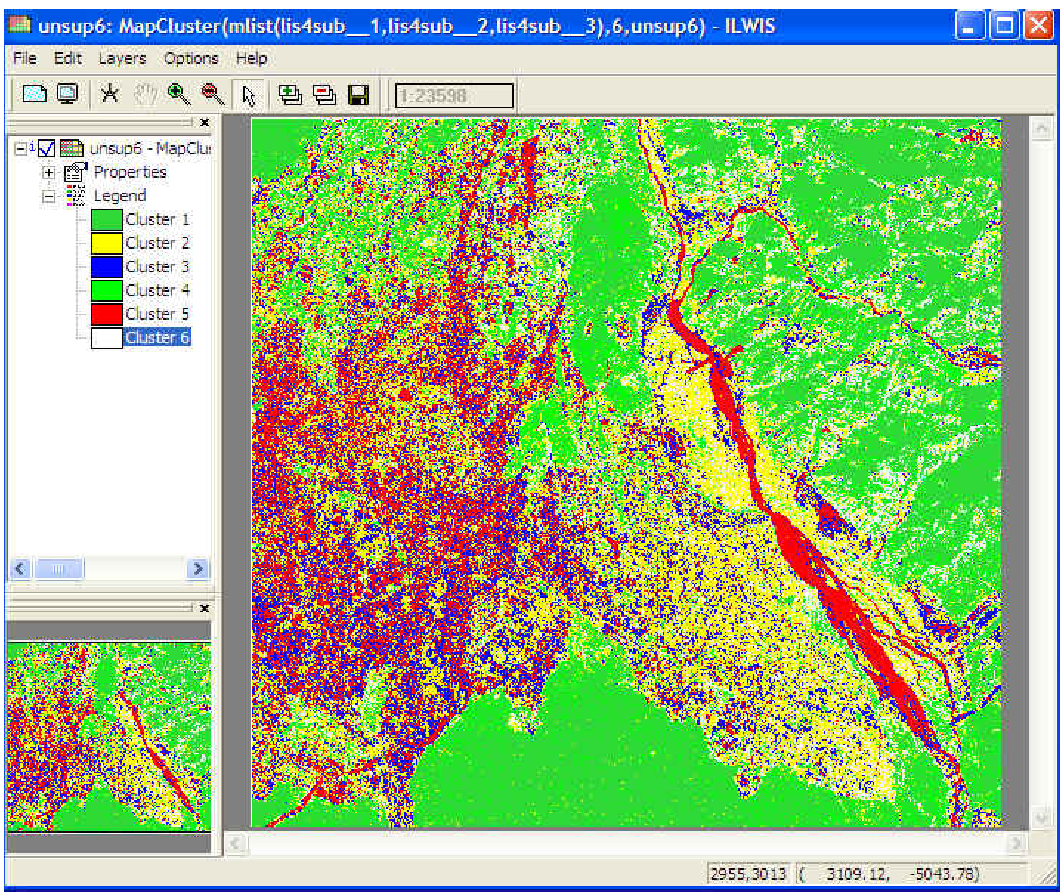
❖ Double-click the Cluster operation in the Operation-list. The Clustering dialog box is opened.



❖ Select lis4sub_1, lis4sub_2 and lis4sub_3. Use the number of classes by comparing the as when performing the supervised classification or visual interpretation.

❖ Type Unsuper for the Output Raster Map name, clear the check box Output Table and click Show. The unsuper map is calculated and after the calculation the Display Options - Raster Map dialog box is opened.

❖ Accept the defaults in the Display Options - Raster Map dialog box by clicking OK. The map is displayed.

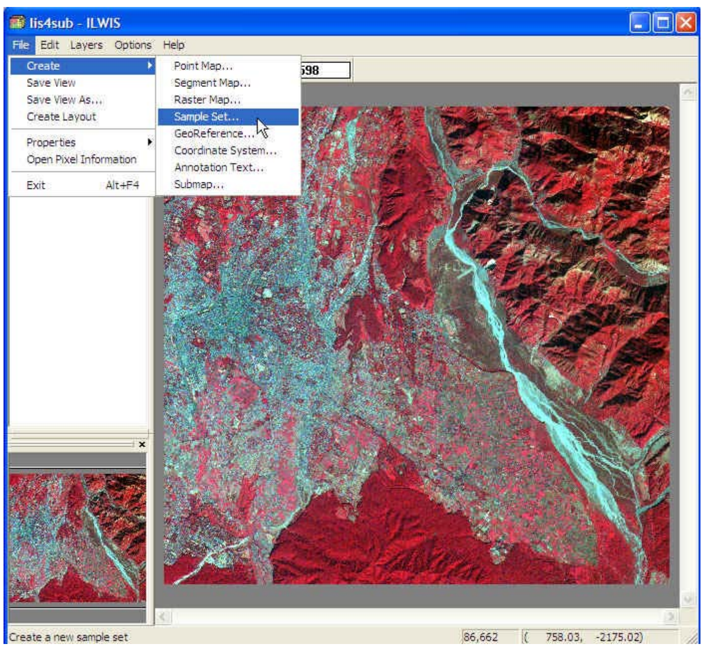


Exercise 8 : Supervised Classification

Supervised classification methods are is divided into two phases: a training phase, where the user 'trains' the computer, by assigning for a limited number of pixels to what classes they belong in this particular image, followed by the decision making phase, where the computer assigns a class label to all (other) image pixels, by looking for each pixel to which of the trained classes this pixel is most similar.

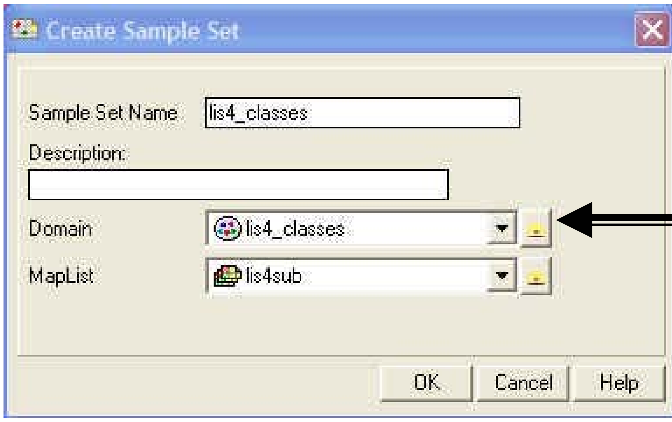
A *sample set* has to be created in which the relevant data regarding input bands (map list), cover classes (domain codes) and background image for selecting the training areas is stored.

❖ Display the color composite lis4fcc as demonstrated in exercise 2
❖ In the map window, choose Create Sample Set from the File menu.

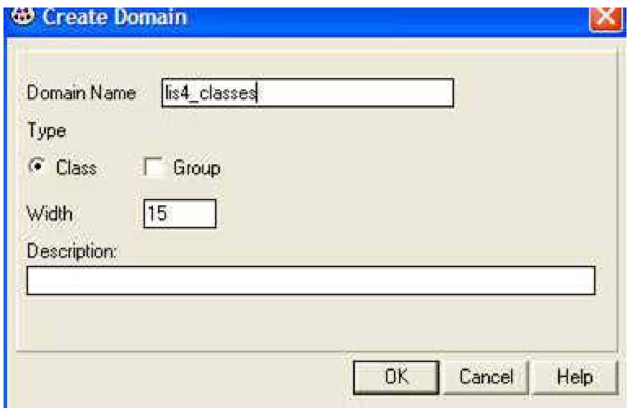


❖ In the Sampling dialog box enter Lis4_classes for the Sample Set Name.

❖ Create a domain for the classes to be sampled by selecting the Create Domain button. The Create Domain dialog box is opened.

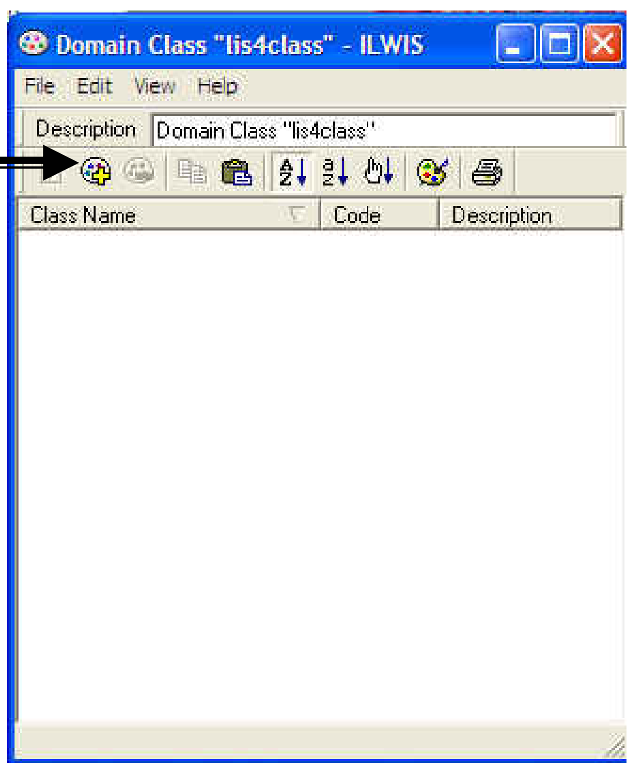


Create button to create domain



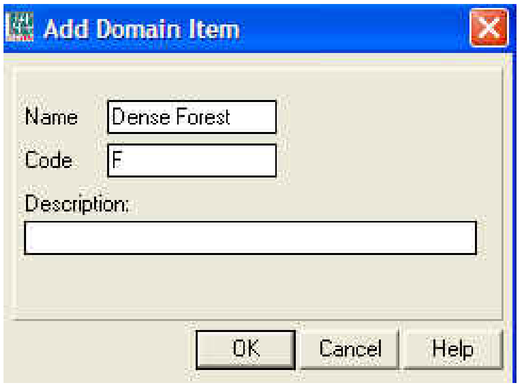
❖ Enter lis4_classes for the Domain Name and click OK. The Domain Class editor appears.

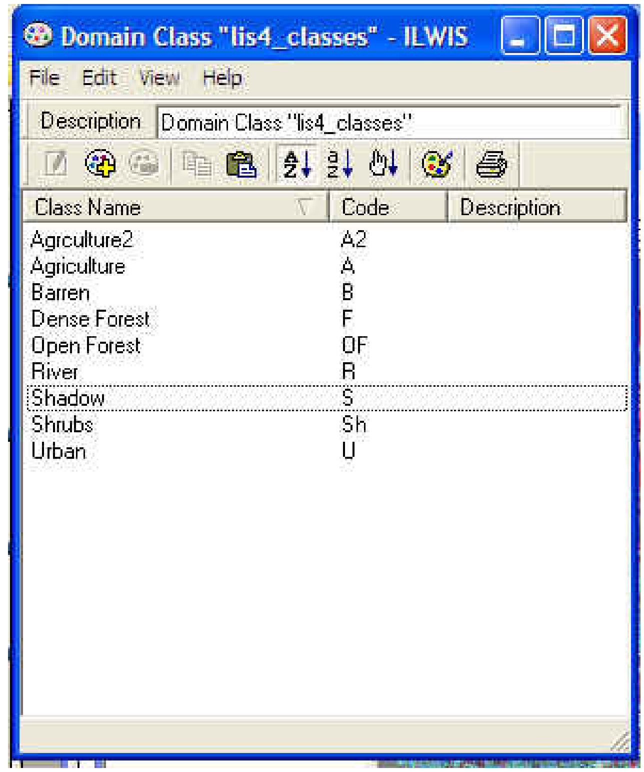
Icon to add classes



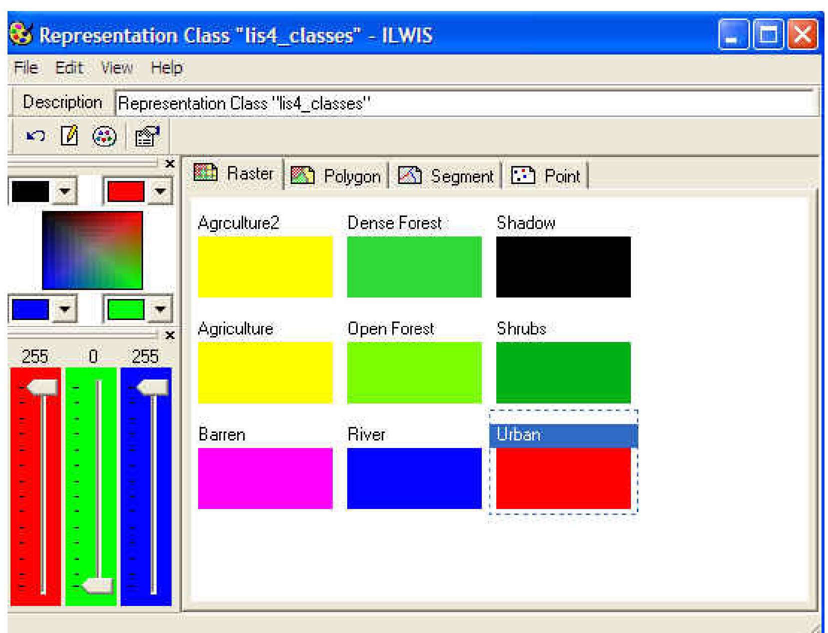
❖ In the Domain Class editor, click the Add Item button. The Add Domain Item dialog box is displayed.

Enter the Name: Dense Forest, and the Code: F. Click OK. Repeat this for all classes as given



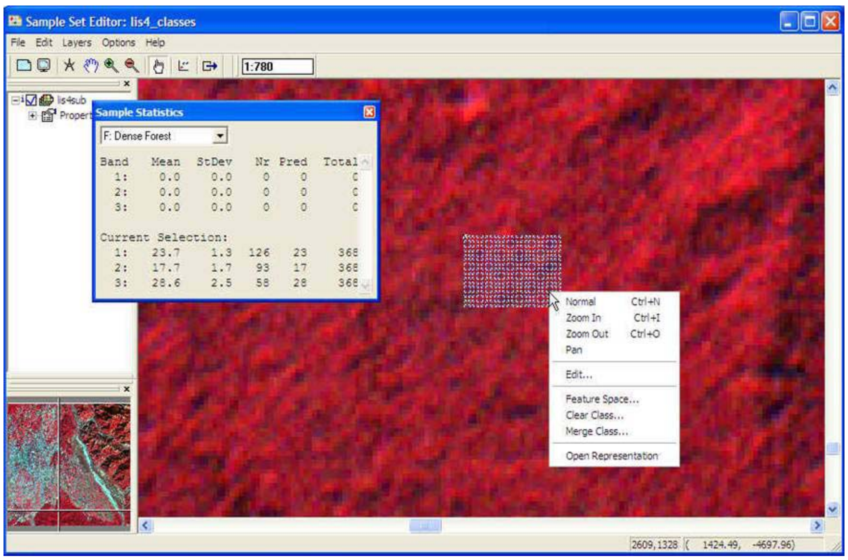


❖ After having entered all classes, open the Representation Class editor by pressing the Open Representation button in the toolbar of the Domain Class editor. Select each class by double-clicking it and choose a color from the color list or define your own color.

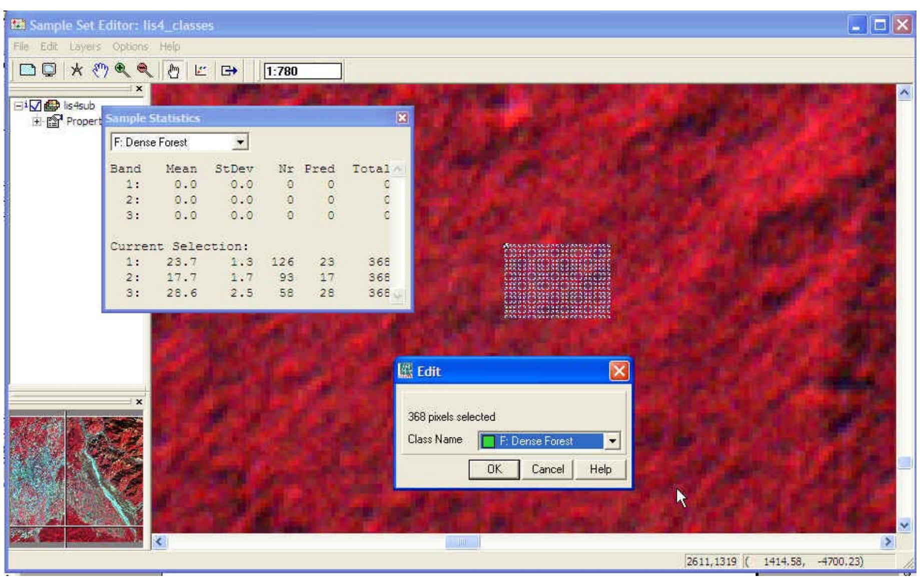


❖ Close the Representation Class editor and close the Domain Class editor to return to the Create Sample Set dialog box.
❖ The MapList created before is already filled out.
❖ Click OK in the Create Sample Set dialog box.

The Sample Set editor will be started. Two windows are displayed: A map window showing the false color composite and a window showing the sample set statistics.



Zoom in on an area with dense forest and press the Normal button in the toolbar to return to the normal mode.
To select pixels press the left mouse button and drag the cursor. When the mouse button is released, the statistics of the current selection of pixels are shown in the Sample Statistics window, Current Selection .

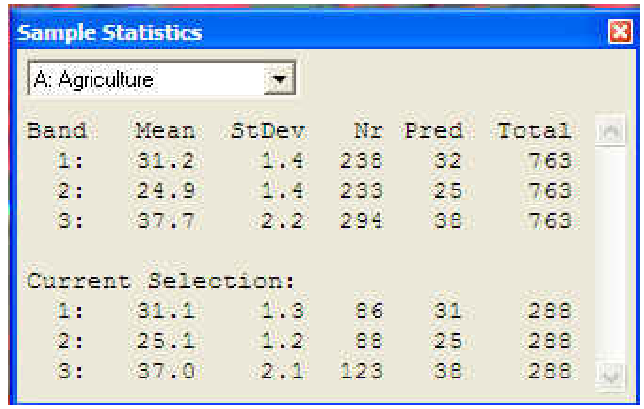


Click the right mouse button to reveal the context-sensitive menu and select Edit.
Select the appropriate class from the class list (F: Dense Forest).
Once this selection is added to the class, the total class statistics are shown in the upper part of the table.

One can always compare the statistics of a sample with the statistics of a class, by selecting the class in the class list.

Repeat the sampling procedure for a number of forest samples and then continue with sampling the other land cover classes.
If a land cover class has not yet been defined and, therefore, does not appear in the class list, a new class can be created by selecting <new>.

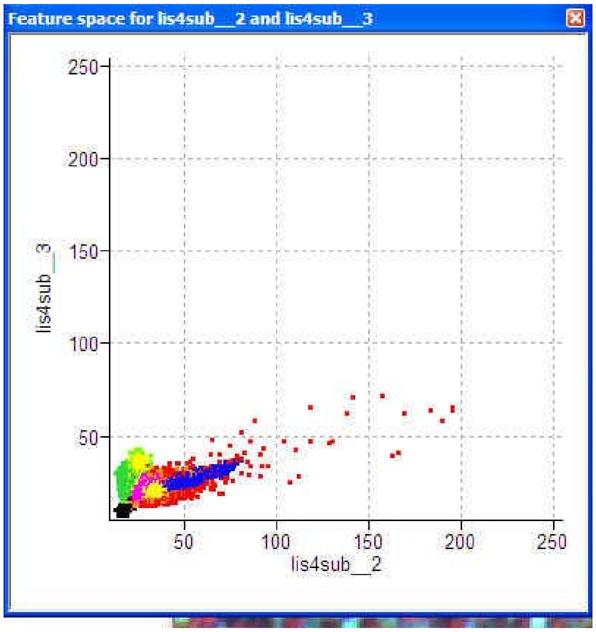
The Sample Statistics window contains the code and name of the selected class as well as the number of bands. The following statistics are shown for a selected class :
- Mean value of pixels (Mean).
- Standard deviation of pixels (StDev).
- The number of pixels having the predominant value (Nr).
- The predominant pixel value (Pred.).
- The total number of the selected pixels (Total).

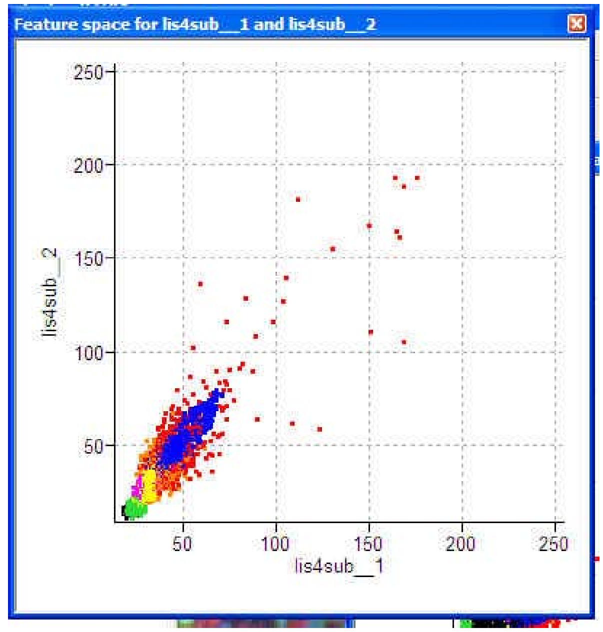


Displaying Feature Spaces

The classes can be plotted in distinct colors in the *feature space*, which enables a judgment of whether the classes can really be spectrally distinguished and whether each class corresponds to only one spectral cluster (if not, it is advisable to create sub-classes, which must be joined after the classification is finished).

Click the Feature Space button in the toolbar of the Sample Set editor. The Feature Space dialog box is opened.
Select two bands for which a feature space should be created. Select lis4sub1 for the horizontal axis (band 1) and lis4sub_2 for the vertical axis (band 2).
Click OK. The feature space is displayed.
Try also the other band combinations for the feature space display.

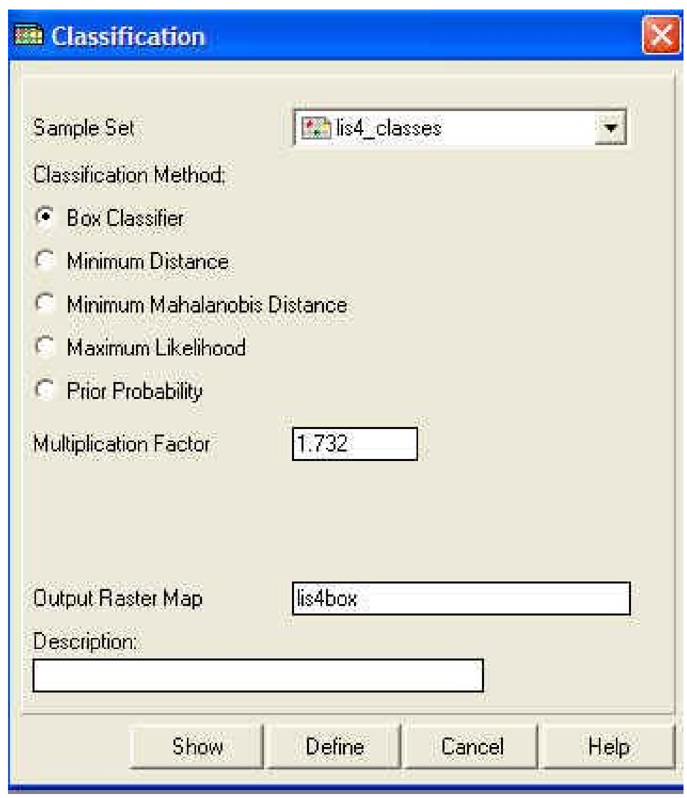




Classification

Select Classify in the operation tree of Image Processing. The Classification dialog box appears.
Select lis4_classes as sample set
Select Box Classifier as Classification Method. Accept the default Multiplication Factor. Type lis4_Box for the Output Raster Map name and click Show. The classification will take place and the Display Options Raster Map dialog box appears.

Click OK to display the result.

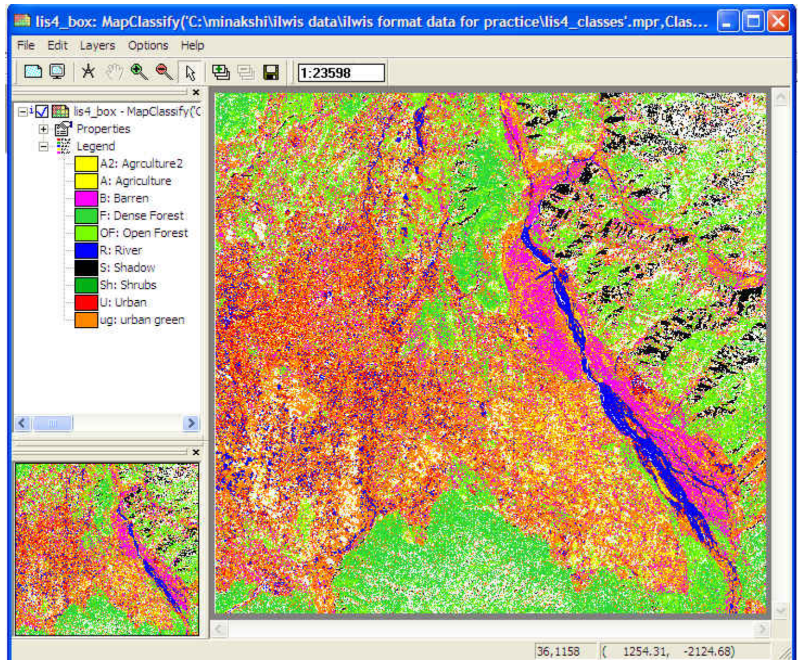


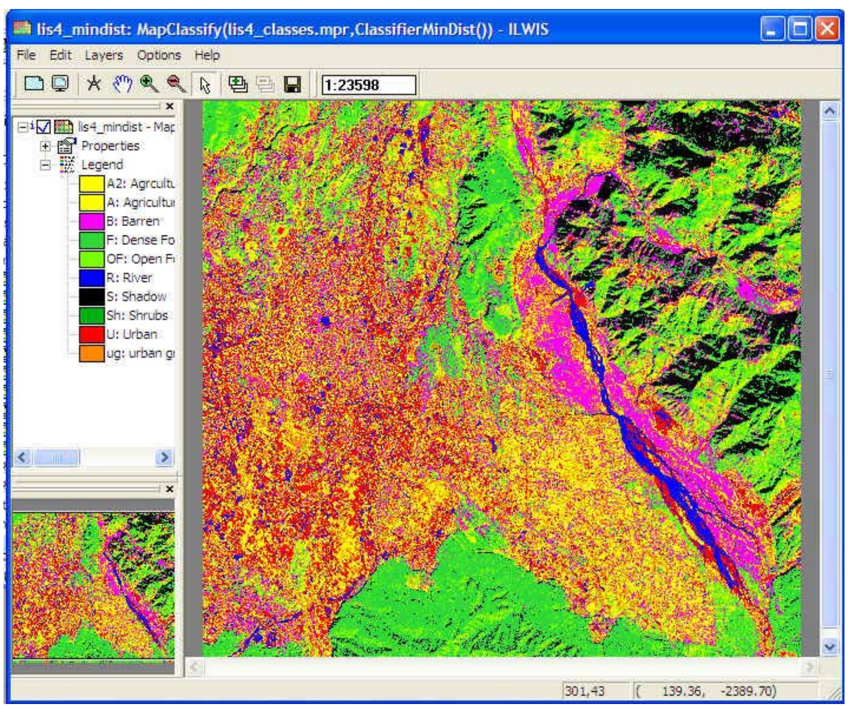
Repeat the procedure using a larger Multiplication Factor.

Visually compare the results with the classified map using the default multiplication factor.

Perform other classifications using the Minimum Distance, Minimum Mahalanobis Distance and Maximum Likelihood method. Classify once without using a Threshold Distance and once with a Threshold Distance of around 15. Name the output images for instance lis4_MinDist, lis4_MinMahaDist and lis4_MaxLikehd.

Compare the results with the box classified maps.





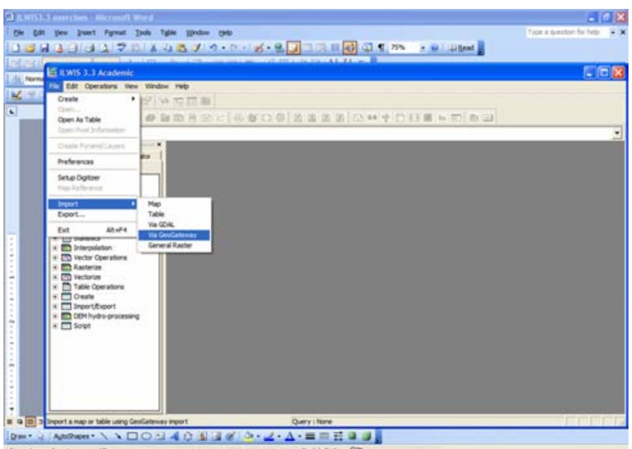
Exercise 9 : Importing Data into ILWIS Format

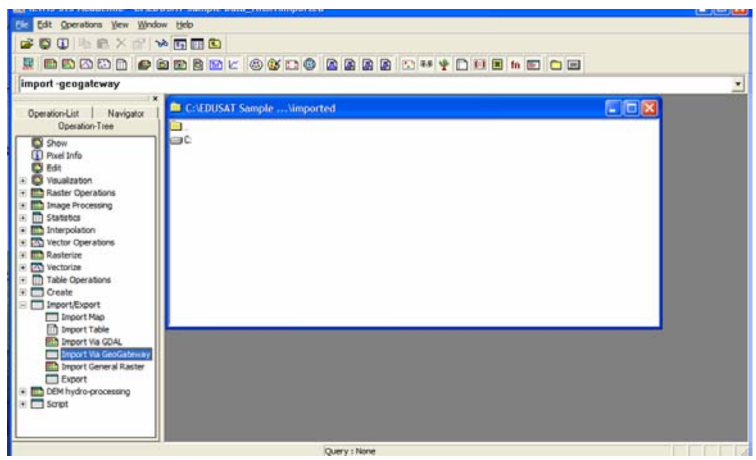
Converting data in another software format to ILWIS format

In order to use the digital data in ILWIS, the files need to be imported to the ILWIS file formats that are required. Importing can be done with the Import module, in which you can select the import method and format.

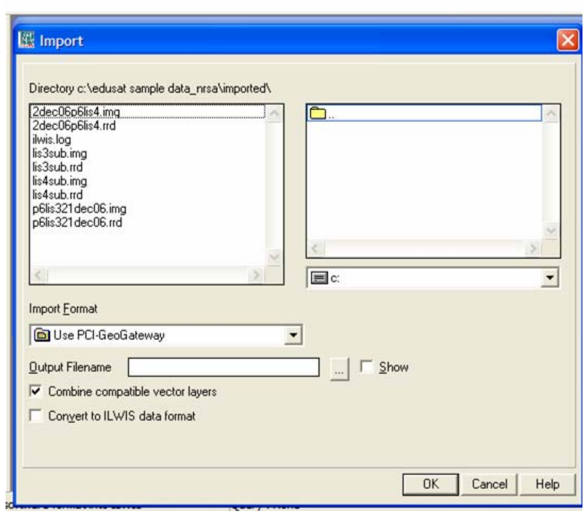
Within ILWIS, you can use the normal ILWIS import, but you can also import external files via GeoGateway.
GeoGateway is a product of PCI Geomatics (http://www.pcigeomatics.com) which allows programs to access data in many geomatics file formats, in a uniform manner,without having to translate them before use in applications. GeoGateway includes access to imagery, vectors, attributes, projections and other auxiliary information of interest to users of geomatics applications.

✓ From the File menu of ILWIS click on Import and select via Geogateway
or select alternatively from the tree list (as shown below)

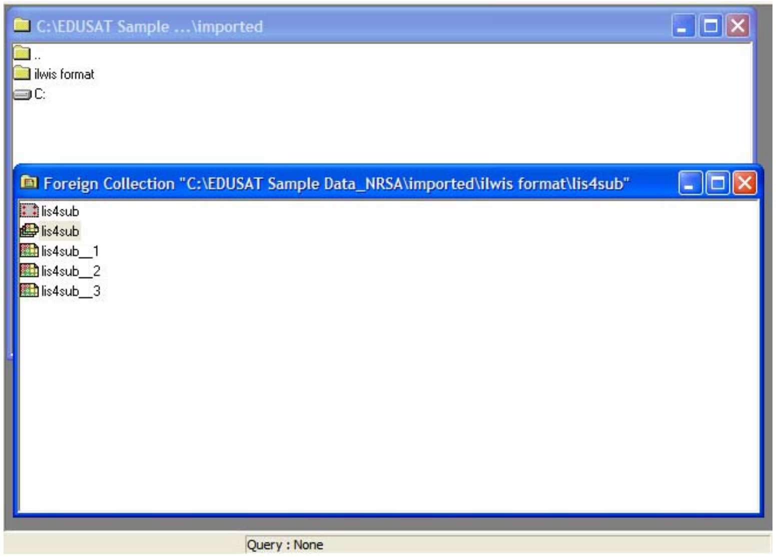




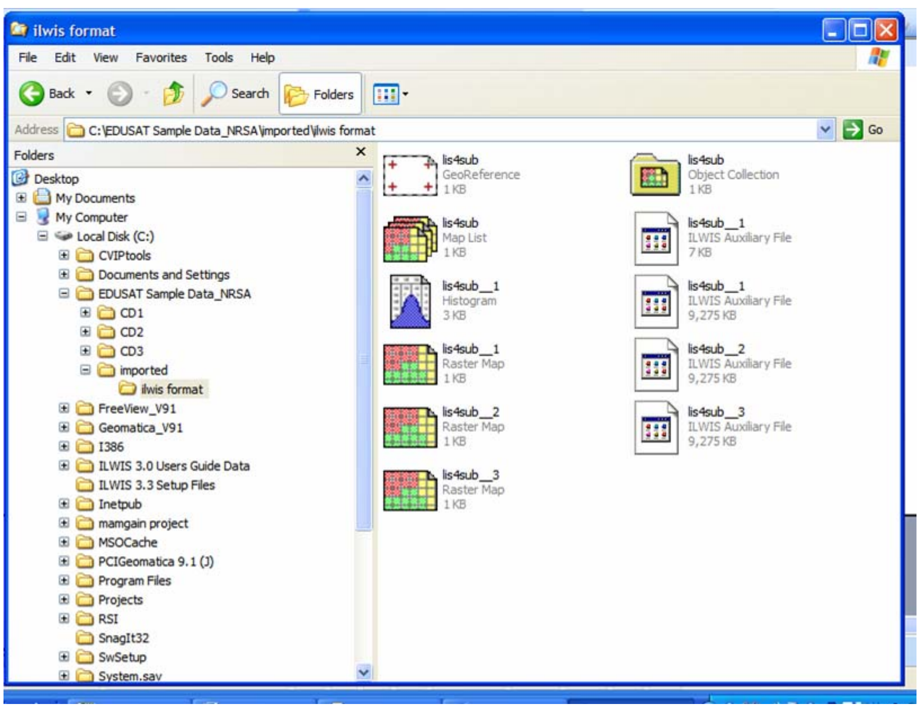
In both the cases the following window opens up



After you used Import via GeoGateway, you will obtain an ILWIS *object collection* . The object collection contains the ILWIS objects that are the result of the import.



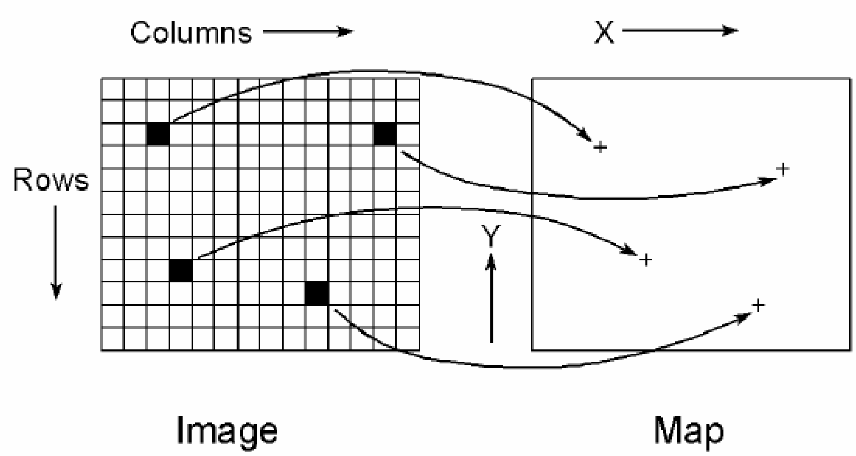
Navigate to your output directory path and note down the ILWIS objects created



Exercise 10: Geometric corrections and image referencing

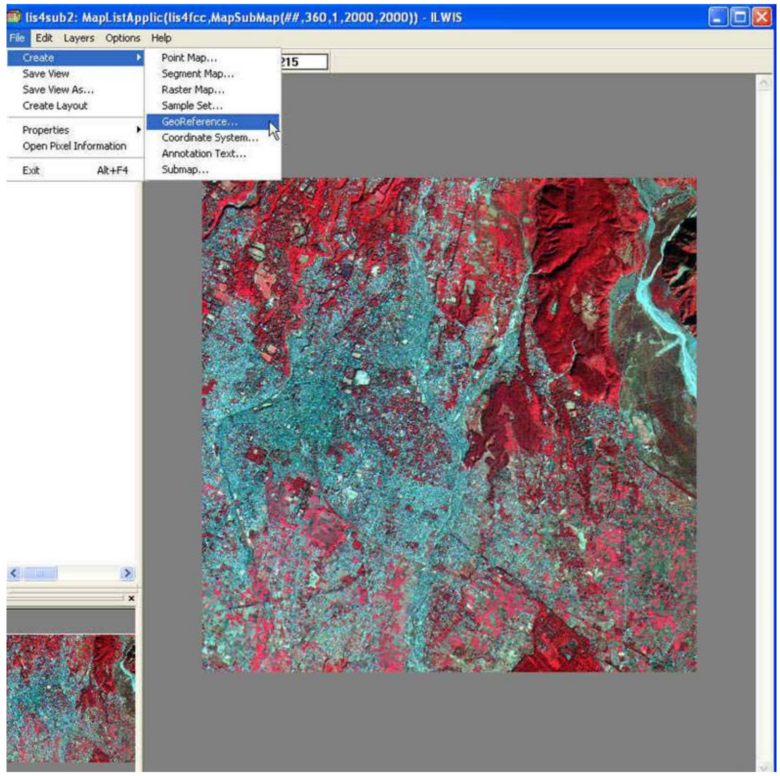
Remote sensing data is affected by geometric distortions due to sensor geometry, scanner and platform instabilities, earth rotation, earth curvature, etc. Some of these distortions are corrected by the image supplier and others can be corrected referencing the images to existing maps.
When an image (raster map) is created, either by a satellite, airborne scanner or by an office scanner, the image is stored in row and column geometry in raster format.
There is no relationship between the rows/columns and real world coordinates (UTM, geographic coordinates, or any other reference map projection). In a process called *geo-referencing* the relation between row and column numbers and real world coordinates are established.

Georeference Tiepoints Specifying reference points in an image so that specific row/column numbers obtain a correct X, Y coordinate. All other rows and columns then obtain an X, Y coordinate by an affine, second order or projective transformation as specified by the georeference tiepoints. A georeference tiepoints can be used to add coordinates to a satellite image or to a scanned photograph and when you do not have a DTM. This type of georeference can be used to resample (satellite) images to another georeference (e.g. to a georeference corners) or for screen digitizing.



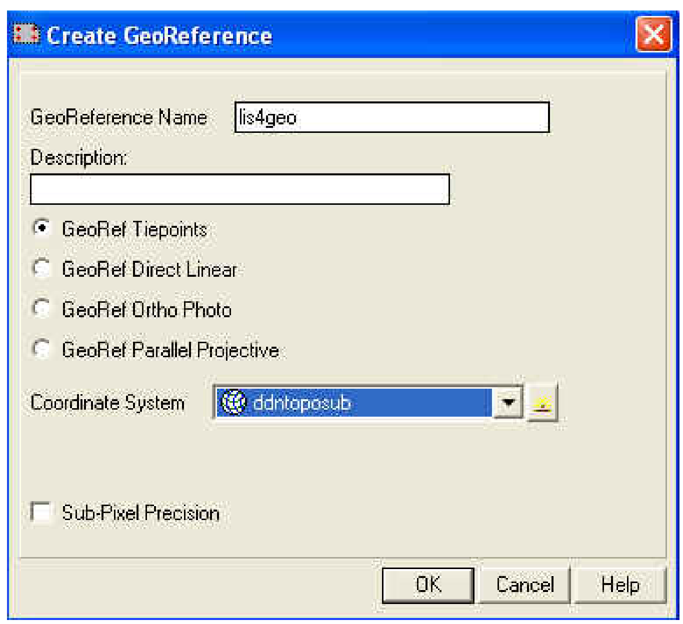
Display the scanned topographic map ddntoposub as a color composite. You will notice that this map (an image) is already rectified (Note down the coordinates in the status bar as you move the cursor over this image).

Display the lis4sub2 as a color composite . Move the mouse pointer over the image and note that on the Status bar of the window, the row and column location of the mouse pointer is shown and the message "No Coordinates". This means that the image is not geo-referenced yet.



In the map window, open the File menu and select Create, GeoReference.

The Create Georeference dialog box is opened.



Enter lis4geo for the GeoReference Name.

Check if the option Georef Tiepoints is selected.
Select Coordinate System ddntoposub and click OK. This is the georeference of the scanned topomap.

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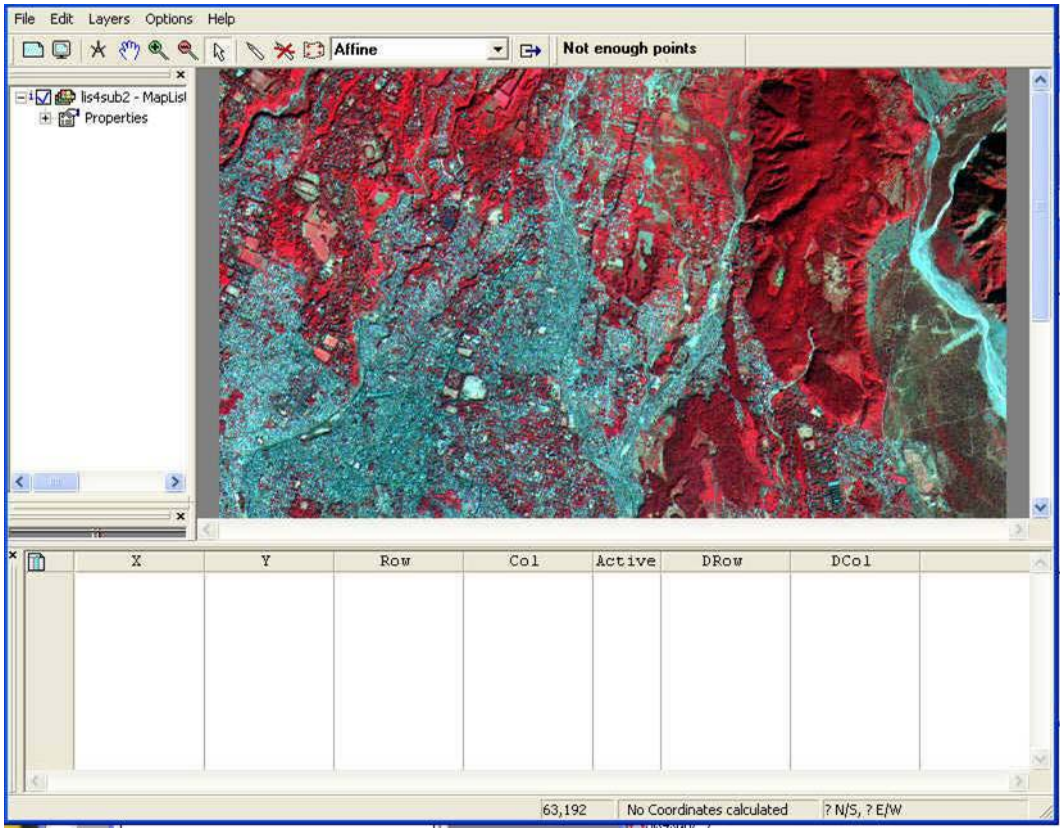
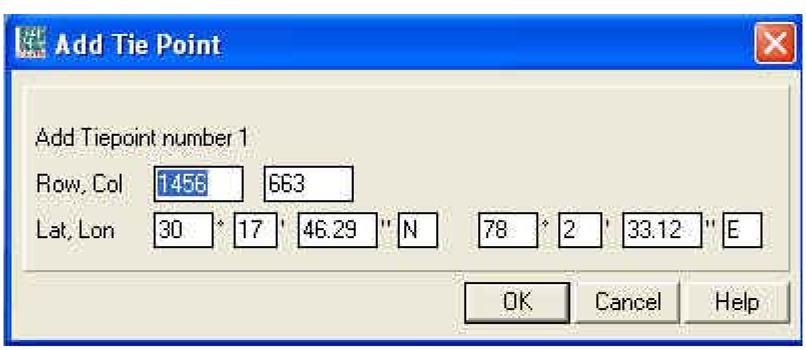
Photogrammetry And Remote Sensing Division
Indian Institute Of Remote Sensing, Dehradun

The GeoReference TiePoints editor is opened.
It consists of the map window, in which you will see the mouse pointer as a large square, and a table with the columns X, Y, Row, Column, Active, DRow, Dcol.

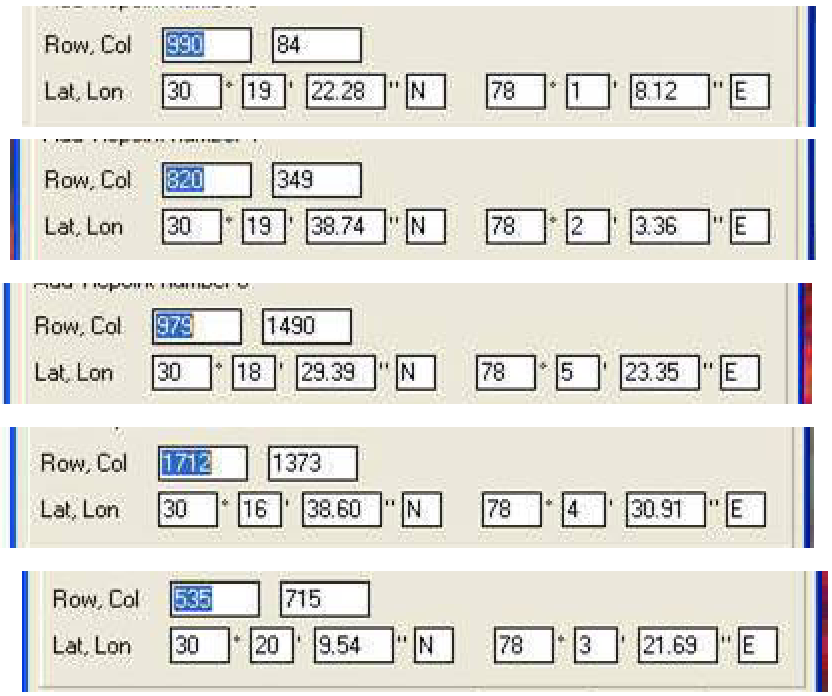


Zoom in on the map to a point where you wish to mark the first ground control point Locate the mouse pointer exactly at the point and click. The Add Tie Point dialog box appears. The row and column number of the selected pixel are already filled out.
Now click at the exactly same point on the ddntoposub which is opened in another display window. Once you click the reference coordinates are filled in the add tie point dialog box. Click OK to accept this GCP. The first reference point (tiepoint) will appear in the tiepoints table and The point number appear in the map window.



Repeat the procedure to mark at least three more Ground control points.

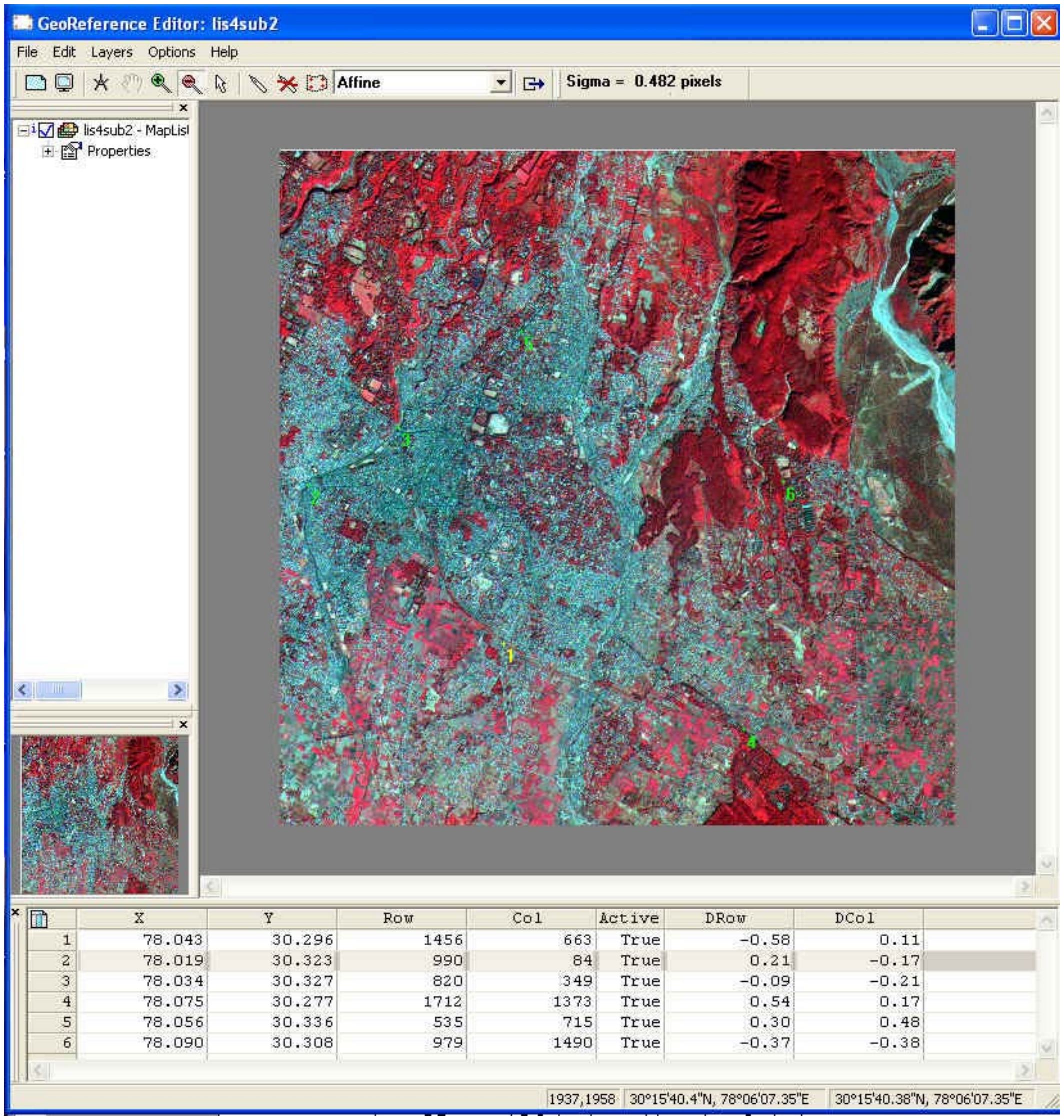
You can use for instance the following points:



When three control points are entered, a Sigma and residuals (DRow and DCol) are calculated. Columns DRow and DCol show the difference between calculated row and column values and actual row and column values in pixels. Very good control points have DRow and DCol values of less than 2 pixels.
The Sigma is calculated from the Drow and DCol values and the degrees of free-dom, and gives a measure for the overall accountability or credibility of the active tiepoints.
The overall sigma value indicates the accuracy of the transformation.
Based on the expected geometric distortions in the background image a transformation method can be selected. By default, an Affine transformation is used. You can choose another transformation method in the Transformation dialog box (Edit menu, or context-sensitive menu) as well as in the drop-down list box in the toolbar of the GeoReference Tiepoints editor.

A tiepoint can be selected or excluded from the transformation computation by putting True or False respectively in the column Active. By excluding tiepoints, you can for instance evaluate the performance of the transformation; assuming that the excluded tiepoints are correctly chosen. Furthermore, in the Georeference Tiepoints editor, good tiepoints are shown in green, medium good tiepoints are shown in yellow, 'bad' tiepoints are shown in red, and passive tiepoints are shown in blue. You can set these colors in the Customize Georeference Tiepoints editor dialog box.
Inspect the DRow and DCol values and inspect the Sigma.

Accept the default Affine Transformation method and close the Georeference Tiepoints editor by pressing the Exit Editor button in the toolbar when the Sigma value is less than 1 pixel.
With the above points sigma obtained is 0.482.



Close the GeoReference Tiepoints editor when finished.

You will return to the map window. See that the image lis4sub2 now has coordinates. Move the mouse pointer around in the image and determine for some easy identifiable pixels the accuracy of the transformation. Use the zoom in option if necessary.

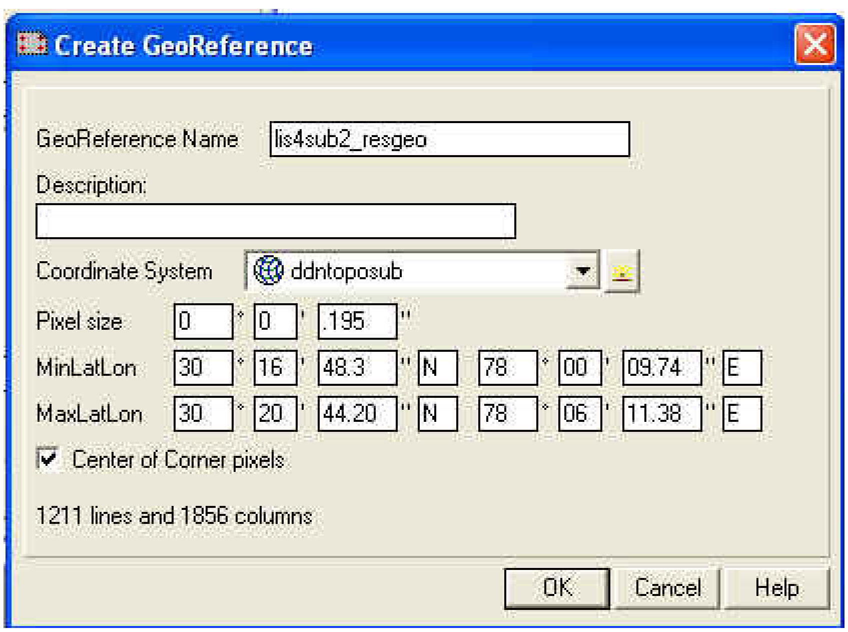
RESAMPLING

The radiometric values or pixel values of the new image are found by resampling the original image using a chosen interpolation method. This process, geocoding, results in a new image in which the pixels are arranged in the geometry of the master image or map, and the resolution is equal to the resolution of the master image or chosen in case the master is a topographic map.

There are three different interpolation methods:
- Nearest Neighbour. In the nearest neighbor method, the value for a pixel in the output image is determined by the value of the nearest pixel in the input image .
- Bilinear. The bilinear interpolation technique is based on a distance dependent weighted average, of the values of the four nearest pixels in the input image.
- Bicubic. The cubic or bicubic convolution uses the sixteen surrounding pixels in the input image. This method is also called cubic spline interpolation.

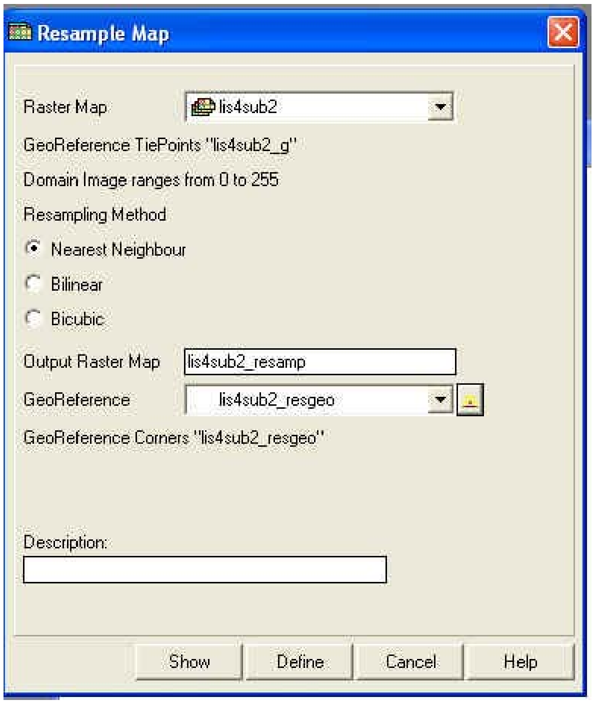
Double-click the Resample operation in the Operation-list in order to display the Resample Map dialog box.
Enter lis4sub2 for the Raster Map and accept the Resampling Method Nearest Neighbour.
Type lis4_resamp for the Output Raster Map,

In the GeoReference click on create new georeference box.
A create georeference dialog box appears. Fill in the details as in the figure here and and click Ok



The georeference name appears in the resampling dialog box

Now click Show.



The resampling starts and after the resampling process the Display Options - Raster Map dialog box is opened.
Click OK to display the map.

Display the color composite and you will observe the image comes tilted and the rectified coordinates are displayed in the status bar.